

UNIT-I
PROBABILITY AND RANDOM VARIABLES
PART-A

- 1. Find the probability of a card drawn at random from an ordinary pack, is a diamond.**

(AU-A/M-2005)

Total number of ways of getting 1 card = 52

Number of ways of getting 1 diamond card is 13

$$\text{Probability} = \frac{\text{Number of favourable events}}{\text{Number of exhaustive events}} = \frac{13}{52} = \frac{1}{4}$$

- 2. A bag contains 8 white and 4 black balls. If 5 balls are drawn at random, what is the probability that 3 are white and 2 are black?**

(AU-N/D-2019)

Total no. of balls = 12

$$P[3 \text{ white balls and } 2 \text{ black balls}] = \frac{8C_3 \cdot 4C_2}{12C_5} = \frac{56 * 6}{792} = 0.4242$$

- 3. Let A and B be two events such that $P(A) = \frac{1}{3}$, $P(B) = \frac{3}{4}$, and $P(A \cap B) = \frac{1}{4}$. Compute**

$P(A/B)$ and $P(\bar{A} \cap \bar{B})$ (AU-A/M-2019)

$$P(A/B) = \frac{P(A \cap B)}{P(B)} = \frac{\cancel{\frac{1}{4}}}{\cancel{\frac{3}{4}}} = \frac{1}{3}$$

$$\begin{aligned} P(\bar{A} \cap \bar{B}) &= P(\overline{A \cup B}) = 1 - P(A \cup B) \\ &= 1 - (P(A) + P(B) - P(A \cap B)) \\ &= 1 - \left(\frac{1}{3} + \frac{3}{4} - \frac{1}{4} \right) = \frac{1}{6} \end{aligned}$$

- 4. State Baye's theorem.**

Let $A_1, A_2, A_3, \dots, A_n$ be 'n' mutually exclusive and exhaustive events with $P(A_i) \neq 0$ for $i = 1, 2, \dots, n$.

Let B be an event such that $B \subset \bigcup_{i=1}^n A_i$, $P(B) \neq 0$.

$$\text{Then } P(A_i/B) = \frac{P(A_i) \cdot P(B/A_i)}{\sum_{i=1}^n P(A_i) \cdot P(B/A_i)}$$

- 5. A bag contains 3 red and 4 white balls. Two draws are made without replacement. What is the probability that both the balls are red.** (AU-A/M-2007)

$$P(\text{drawing a red ball in the first draw}) = \frac{3}{7}$$

$$P(A) = \frac{3}{7}$$

$$P(\text{drawing a red ball in the second draw given that first ball drawn is red}) = \frac{2}{6}$$

$$P(B/A) = \frac{2}{6}$$

(Since only six balls are left and only two out of them are red)

$$P(AB) = P(A) \cdot P(B/A) = \frac{3}{7} \cdot \frac{2}{6} = \frac{1}{7}$$

- 6. If X is a discrete random variable with probability distribution $P(X=x) = kx$, $x = 1, 2, 3, 4$ find $P(2 < X < 4)$.** (AU-A/M-2013)

We know that $\sum p(x_i) = 1$

$$k+2k+3k+4k = 1$$

$$k = 1/10; \quad P(2 < X < 4) = P(x=3) = 3/10$$

7. A random variable X has the following probability function $P(X = x) = \frac{x}{10}$, $x = 1, 2, 3, 4$. Find the cumulative distribution function F(x) of X. (AU-A/M-2019)

X = x	F(x)
x = 1	1/10
x = 2	3/10
x = 3	6/10
x = 4	10/10 = 1

8. If X and Y are two independent random variables with variances 2 and 3, find the Variance of $3X+4Y$. (AU-A/M-2013)

Given: $\text{Var}(X) = 2$ and $\text{Var}(Y) = 3$

$$\text{Var}(3X+4Y) = 3^2 \text{Var}(X) + 4^2 \text{Var}(Y) = 9(2) + 16(3) = 18 + 48 = 66.$$

9. Test whether $f(x) = |x|$, $-1 \leq x \leq 1$ can be the probability density function of a continuous random variable. (AU-N/D-2015)

$$\int_{-\infty}^{\infty} f(x)dx = \int_{-1}^1 |x| dx = 2 \int_0^1 x dx = 2 \left[\frac{x^2}{2} \right]_0^1 = 1$$

$f(x)$ is a p.d.f.

10. A continuous random variable X has a probability density function $f(x) = 3x^2$, $0 \leq x \leq 1$. Find the value of "a" such that $P(X > a) = 0.05$. (AU-A/M-2011)-2

Given: $P(X > k) = P(X \leq k) = 0.05$

$$\int_0^k f(x)dx = 0.05 \Rightarrow 3 \int_0^k x^2 dx = 0.05 \Rightarrow \left[x^3 \right]_0^k = 0.05 \Rightarrow k^3 = 0.05 \Rightarrow k = 0.7937$$

11. A continuous random variable X can assume only any value between $x = 2$ and $x = 5$ and has the p.d.f $f(x) = k(1+x)$. Find $P(X < 4)$. (AU-N/D-2011)-2

$$\text{WKT } \int_{-\infty}^{\infty} f(x)dx = 1 \Rightarrow \int_2^5 k(1+x)dx = 1 \\ k\left(x + \frac{x^2}{2}\right)_2^5 = 1 \Rightarrow k\left(\left(5 + \frac{25}{2}\right) - \left(2 + \frac{4}{2}\right)\right) = 1 \Rightarrow k\left(\frac{27}{2}\right) = 1 \Rightarrow k = \frac{2}{27}$$

$$\text{Now } P[X < 4] = P(2 < X < 4) = \int_2^4 k(1+x)dx \\ \int_2^4 \frac{2}{27}(1+x)dx = \frac{2}{27} \left[x + \frac{x^2}{2} \right]_2^4 = \frac{2}{27} \left(\left(4 + \frac{16}{2}\right) - \left(2 + \frac{4}{2}\right) \right) = \frac{2}{27}(12 - 4) = \frac{16}{27}$$

12. A continuous random variable X has the p.d.f $f(x)$ given by $f(x) = Ce^{-|x|}$, $-\infty < x < \infty$. Find the value of C. (AU-A/M-2017)

$$\text{We know that } \int_{-\infty}^{\infty} f(x)dx = 1$$

$$\int_{-\infty}^0 Ce^x dx + \int_0^{\infty} Ce^{-x} dx = 1$$

$$C[e^x]_0^{\infty} - C[e^{-x}]_{-\infty}^0 = 1 \Rightarrow C(1+1) = 1$$

$$\therefore C = \frac{1}{2}$$

13. A test engineer discovered that the cumulative distribution function of the lifetime of an equipment (in years) is given by $F_X(x) = 1 - e^{(-x/5)}$, $x \geq 0$. What is the expected lifetime of the equipment? (AU-N/D-2017)

PDF of the given CDF

$$f(x) = \frac{d}{dx} F_x(x) = \frac{d}{dx} [1 - e^{-\frac{x}{5}}] = \frac{e^{-\frac{x}{5}}}{5}, x > 0$$

$$E(x) = \int_0^{\infty} xf(x) dx = \frac{1}{5} \int_0^{\infty} xe^{-\frac{x}{5}} dx = \frac{1}{5} \left[x \left(\frac{e^{-\frac{x}{5}}}{-\frac{1}{5}} \right) - (1) \left(\frac{e^{-\frac{x}{5}}}{-\frac{1}{5}} \right) \right]_0^{\infty} = \frac{1}{5} \left[(0 - 0) - (0 - \frac{1}{25}) \right] = 5$$

- 14. If a random variable has the moment generating function given by $M_X(t) = \frac{2}{2-t}$. Determine the variance of X.** (AU-A/M-2016)

$$\begin{aligned} \text{Given } M_X(t) &= \frac{2}{2-t} = \frac{2}{2\left(1 - \frac{t}{2}\right)} = \left(1 - \frac{t}{2}\right)^{-1} = 1 + \frac{t}{2} + \left(\frac{t}{2}\right)^2 + \dots \infty \\ &= 1 + \frac{t}{1!} \left(\frac{1}{2}\right) + \frac{t^2}{2!} \left(\frac{1}{2}\right) + \dots \end{aligned}$$

The coefficient of $\frac{t}{1!}$ is $\frac{1}{2}$ that is $E(X) = \frac{1}{2}$

The coefficient of $\frac{t^2}{2!}$ is $\frac{1}{2}$ that is $E(X^2) = \frac{1}{2}$

$$\text{Var}(X) = E(X^2) - [E(X)]^2 = \frac{1}{2} - \frac{1}{4} = \frac{1}{4}$$

- 15. Find the moment generating function of the p.d.f $f(x) = \frac{1}{2}$, $-1 < x < 1$.** (AU-A/M-2013)

$$M_x(t) = E(e^{tx}) = \int_{-1}^1 \frac{1}{2} e^{tx} dx = \frac{1}{2} \left[\frac{e^{tx}}{t} \right]_{-1}^1 = \frac{1}{2t} [e^t - e^{-t}] = \frac{\sinh t}{t}$$

- 16. Let $M_x(t) = \frac{1}{1-t}$, $|t| < 1$, be the Moment Generating function of a Random variable X. Find $E(X)$ and $E(X^2)$** (AU-N/D-2019)

$$M_x(t) = \frac{1}{1-t} = (1-t)^{-1} = 1 + t + t^2 + t^3 + \dots$$

$$E(X) = \text{coefficien } t \frac{t^1}{1!} = 1$$

$$E(X^2) = \text{coefficien } t \frac{t^2}{2!} = 2$$

- 17. If $M_x(t) = \frac{pe^t}{1-qe^t}$ is the Moment Generating function of X then find their mean and variance of X.** (AU-A/M-2018)

$M_x(t) = \frac{pe^t}{1-qe^t}$ is a MGF of Binomial distribution.

Mean = np ; Variance = npq

- 18. The mean of Binomial distribution is 20 and standard deviation is 4. Find the parameters of this distribution.** (AU-A/M-2018)

mean = 20, standard deviation = 4

$$np = 20, \sqrt{npq} = 4 \Rightarrow npq = 16$$

$$\frac{npq}{np} = \frac{16}{20} = \frac{4}{5}; \quad q = \frac{4}{5}; \quad p = 1-q = 1-4/5 = 1/5; \quad n(1/5) = 20; \quad n = 100$$

19. The mean and variance of a binomial variate X are 4 and 4/3 respectively. Find P(X ≥ 1).

mean = 4, variance = 4/3

(AU-N/D-2014)

$$np = 4, npq = 4/3$$

$$\frac{npq}{np} = \frac{4}{3} \times \frac{1}{4} = \frac{1}{3}$$

$$\therefore q = \frac{1}{3}$$

$$p = 1-q = 1-1/3 = 2/3$$

$$\therefore n = 4 \times \frac{3}{2} = 6$$

$$P(X \geq 1) = 1 - P(X < 1) = 1 - P(X = 0) = 1 - 6C_0 \left(\frac{2}{3}\right)^0 \left(\frac{1}{3}\right)^{6-0} = 1 - \frac{1}{3^6} = 1 - \frac{1}{729} = \frac{728}{729}$$

20. Obtain the binomial distribution whose mean is 6 and variance is 4.

(AU-A/M-2016)

Mean = 6 and variance = 4

Therefore np = 6 and npq = 4

$$q = 2/3 \Rightarrow p = 1-2/3 = 1/3$$

$$\therefore np = 6 \Rightarrow n(1/3) = 6 \Rightarrow n = 18$$

$$p(x) = nC_x p^x q^{n-x} = 18C_x \left(\frac{1}{3}\right)^x \left(\frac{2}{3}\right)^{18-x}$$

21. For a binomial distribution with mean 6 and standard deviation $\sqrt{2}$, find the first two terms of the distribution.

(AU-A/M-2014)

Mean = np = 6

$$\text{Var} = (\text{S.D})^2 = (\sqrt{2})^2 = 2$$

p = 1/3 and q = 2/3 and n = 18

The binomial distribution is $P(X = x) = nc_x p^x q^{n-x}$

$$\text{The first term is } P(X = 0) = 18C_0 \left(\frac{1}{3}\right)^0 \left(\frac{2}{3}\right)^{18-0}$$

$$\text{The second term is } P(X = 1) = 18C_1 \left(\frac{1}{3}\right)^1 \left(\frac{2}{3}\right)^{18-1}$$

22. If 3% of the electric bulbs manufactured by a company are defective, find the Probability that in a sample of 100 bulbs exactly 5 bulbs is defective. ($e^{-3} = 0.0498$)

(AU-N/D-2017)

Let P denote the probability that a bulb is defective = 0.03

$$n = 100$$

$$\lambda = np = 0.03(100) = 3$$

$$\text{The probability distribution is } P(X = x) = \frac{e^{-\lambda} \lambda^x}{x!}, x = 0, 1, 2, \dots$$

$$P(\text{exactly 5 bulbs are defective}) = P(x = 5) = \frac{e^{-3} 3^5}{5!} = \frac{0.0498 \times 243}{120} = 0.1008$$

23. If the probability of a target is destroyed on any one shot is 0.5, find the probability that it would be destroyed on 6th attempt.

(AU-A/M-2013)

Let X be the R.V denoting the number of attempts required for the first success.

Given p = 0.5 and also q = 1-p = 0.5

$$P(X=x) = p \cdot q^{x-1}; x = 1, 2, \dots$$

$$P(X=6) = (0.5)(0.5)^5 = 0.0156$$

24. State the memory less property of Geometric distribution.

(AU-A/M-2010)

If X has a geometric distribution then for any two positive integers 'm' and 'n',

$$P[X > m+n / X > m] = P[X > n].$$

25. State memory less property of exponential distribution.

(AU-N/D-2013)

If X is exponentially distributed, then $P(X > S+t / X > S) = P(X > t)$, for any S, t > 0.

26. If X is a normal random variable with mean 3 and variance 9, find the probability that X lies between 2 and 5. (AU-N/D-2018)

Given $\mu = 3$

$$\sigma^2 = 9 \Rightarrow \sigma = 3$$

$$z = \frac{X - \mu}{\sigma} = \frac{X - 3}{3}$$

When $X = 2$, $z = \frac{2-3}{3} = \frac{-1}{3}$ and When $X = 5$, $z = \frac{2}{3}$

$$P(2 \leq X \leq 5) = P\left(\frac{-1}{3} \leq Z \leq \frac{2}{3}\right) = 0.3779 \text{ (Use normal table)}$$

27. State any four properties of normal distribution. (AU-A/M-2011)-2

- (i) The value of $f(x)$ approaches zero as x tends to $-\infty$ and x tends to ∞ that is x -axis is an asymptote to the normal curve.
- (ii) The p.d.f. is symmetric about μ .
- (iii) The maximum of the p.d.f. occurs at $x = \mu$.
- (iv) Mean, Median, Mode coincide.

28. Define normal distribution. (AU-N/D-2013)-2

A continuous random variable X , assuming all real values in $-\infty < x < \infty$ has a normal distribution

if its p.d.f. is of the form $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$, here μ and σ^2 are the parameters of this

distribution. Hence it is also written as $N(\mu, \sigma^2)$. The area under the normal curve is unity.

29. If A and B are mutually exclusive events, $P(A) = 0.29$ and $P(B) = 0.43$ then find $P(\bar{A})$ and $P(A \cup B)$. (AU-N/D-2019)

Given $P(A) = 0.29$ and $P(B) = 0.43$

Then $P(\bar{A}) = 1 - P(A) = 1 - 0.29 = 0.71$ and

$$P(A \cup B) = P(A) + P(B) = 0.29 + 0.43 = 0.72$$

30. Derive the moment generating function of uniform distribution. (AU-N/D-2019)

$$M_X(t) = 1 + [(b-a)/2][t/!] + [(b^2+ba+a^2)/3][t^2/2!] + \dots$$

31. The probability density function of the random variable X is given by

$$\begin{aligned} f(x) &= k(1-x^2) \text{ for } 0 < x < 1 \\ &= 0 \quad \text{elsewhere.} \end{aligned}$$

Find the value of k.

$$\int_{-\infty}^{\infty} f(x) dx = 1$$

$$\int_0^1 k(1-x^2) dx = 1$$

$$k\left(x - \frac{x^3}{3}\right)_0^1 = 1 \Rightarrow k\left(\left(1 - \frac{1}{3}\right) - \left(0 - \frac{0}{3}\right)\right) = 1 \Rightarrow k\left(\frac{2}{3}\right) = 1 \Rightarrow k = \frac{3}{2}$$

32. For a binomial distribution mean is 2 and variance is 4/3, find the first term of the distribution. (AU-A/M-2019)

$$\text{Mean} = np = 2$$

$$\text{Var} = (S.D)^2 = 4/3$$

$$p = 1/3 \text{ and } q = 2/3 \text{ and } n = 6$$

The binomial distribution is $P(X = x) = nc_x p^x q^{n-x}$

$$\text{The first term is } P(X = 0) = 6c_0 \left(\frac{1}{3}\right) \left(\frac{2}{3}\right)^6$$

33. Find the mean of a Normal distribution. (AU-N/D-2018)

$$\text{Mean} = E(X) = \mu$$

PART-B

1. (a) A bag contains 10 white, 6 red, 4 black and 7 blue balls. 5 balls are drawn at random. What is the probability that 2 of them are red and one is black? **(AU-A/M-2005)(8)**
 (b) A bag contains 3 black and 4 white balls. Two balls are drawn at random one at a time without replacement. (i) What is the probability that the second ball drawn is white? (ii) What is the conditional probability that the first ball drawn is white if the second ball is known to be white? **(AU-A/M-2019)(8)**
- 2.(a) There are 3 boxes containing respectively, 1 white, 2 red, 3 black balls, 2 white, 3 red, 1 black balls; 3 white, 1 red, 2 black balls. A box is chosen at random and from it two balls are drawn at random. The two balls are 1 red and 1 white. What is the probability that they came from second box? **(AU-N/D-2019)(8)**
- (b) In a bolt factory machines A, B, C manufacture respectively 25 %, 35 % and 40 % of the total of their output 5 %, 4 % & 2 % are defective bolts. A bolt is drawn at random from the product and is found to be defective. What are the probabilities that it was manufactured by machine A, B & C. **(AU-A/M-2004)(8)**
3. (a) The first bag contains 3 white balls, 2 red balls and 4 black balls. Second bag contains 2 white balls, 3 red and 5 black balls and third bag contains 3 white, 4 red and 2 black balls . One bag is chosen at random and from it 3 balls are drawn. Out of 3 balls, 2 balls are white and one is red. What are the probabilities that they were taken from first bag, second bag third bag. **(8)**
- (b) A consulting firm rents cars from three rental agencies in the following manner. 20 % from agency D, 20 % from agency E and 60 % from agency F. If 10 % cars from D, 12 % of the cars from E and 4% of the cars from F have bad tyres, what is the probability that the firm will get a car with bad tyres is rented from agency F. **(AU-A/M-2019)(8)**
4. (a) The probability mass function of a discrete R.V X is given in the following table:

X :	-2	-1	0	1	2	3
P(x) :	0.1	k	0.2	2k	0.3	k

 (i) Find the value of k
 (ii) Find $P(X < 1)$, $P(-1 < X \leq 2)$ and (iii) $E(X)$ **(AU-A/M-2016)(8)**
- (b) A random variable X takes the values -2, -1, 0 and 1 with probabilities $\frac{1}{8}$, $\frac{1}{8}$, $\frac{1}{4}$ and $\frac{1}{2}$ respectively. Find the draw the probability distribution function. **(AU-N/D-2014)(8)**
5. (a) The distribution function of a random variable X is given by $F(x) = 1-(1+x)e^{-x}$, $x \geq 0$.
 Find the density function, mean and variance. **(AU-A/M-2014)(8)**
- (b) If the density function of a continuous R.V X is given by $f(x) = \begin{cases} ax, & 0 \leq x \leq 1 \\ a, & 1 \leq x \leq 2 \\ 3a - ax, & 2 \leq x \leq 3 \\ 0, & \text{elsewhere} \end{cases}$
 (i) Find the value of 'a' (ii) Find the CDF of X and (iii) $P(X > 1.5)$ **(AU-A/M-2017)(8)**
6. (a) If a random variable X has the probability density function $f(x) = \begin{cases} xe^{-x}, & x > 0 \\ 0, & x \leq 0 \end{cases}$ find (i) Moment generating function, $M_X(t)$ of X and hence obtain $E(X)$ and $\text{Var}(X)$ (ii) Cumulative distribution function of X (iii) $P(X \leq 2)$. **(AU-A/M-2019)(8)**
- (b) The p.d.f of a continuous R.V. X is given by $f(x) = \begin{cases} \frac{x}{2} e^{-\frac{x}{2}}, & x > 0 \\ 0, & x \leq 0 \end{cases}$ Obtain (i) C.D.F of X, $F(x)$ (ii) $P(X > 1)$ (iii) $P(1 < x < 2)$ (iv) $E(X^2)$. **(AU-N/D-2019)(8)**

7. (a) The distribution function of a random variable X is given by $F(x) = \begin{cases} 0, & x < 0 \\ \frac{x^2}{2}, & 0 \leq x < 1 \\ K(4x - x^2), & 1 \leq x < 2 \\ 1, & x \geq 2 \end{cases}$ (AU-N/D-2007)(8)
- (i) Find the density function (ii) Find the value of K
- (b) Find the MGF of the random variable X having the probability density function
 $f(x) = \begin{cases} \frac{x}{4} e^{-\frac{x}{2}}, & x > 0 \\ 0, & \text{Otherwise} \end{cases}$. Also find the first four moments about the origin. (AU-A/M-2017)(8)
8. (a) Let X be a continuous random variable with the probability density function $f(x) = 1/4$, $2 \leq x \leq 6$. Find the expected value and variance of X. (AU-N/D-2017)(8)
- (b) The probability distribution function of a random variable X is given by $f(x) = \frac{4x(9-x^2)}{81}$, $0 \leq x \leq 3$. Find the mean, variance and third moment about origin. (AU-N/D-2016)(8)
9. (a) Suppose the random variable X has a geometric distribution $P(X = x) = \left(\frac{1}{3}\right)\left(\frac{2}{3}\right)^{x-1}$, $x = 1, 2, 3, \dots$
Determine (i) $P(X \leq 2)$ (ii) $P(X > 4 / X > 2)$ (iii) Moment generating function, $M_X(t)$ of X and hence obtain $E(X)$ and $\text{Var}(X)$ (AU-A/M-2019)(8)
- (b) Find the MGF of the random variable X having the p.d.f $f(x) = \begin{cases} x, & 0 < x < 1 \\ 2 - x, & 1 < x < 2 \\ 0, & \text{otherwise} \end{cases}$ (AU-N/D-2013)(8)
10. (a) Derive MGF of the binomial distribution and hence find its mean and variance.
(b) Let X be a binomial R.V with $E(x) = 4$ and $\text{Var}(X) = 3$. Find: (i) $P(X = 5)$, (ii) M.G.F of X, $M_X(t)$, (iii) $E(X^2 - 1)$, (iv) $\text{Var}\left(-\frac{1}{2}X + 4\right)$. (AU-N/D-2019)(8)
11. (a) In a large consignment of electric bulbs, 10 percent are defective. A random Sample of 20 are taken for inspection. Find the probability that (1) all are good bulbs (2) at most there are 3 defective bulbs (3) exactly there are 3 defective bulbs? (AU-A/M-2013)(8)
(b) Find the probability that in tossing a fair coin 5 times, there will appear (i) 3 heads (ii) 3 tails and 2 heads (iii) atleast 1 head (iv) not more than 1 tail. (AU-A/M-2007)(8)
12. (a) Messages arrive at a switch board in a Poisson manner at an average rate of six per hour.
Find the probability for each of the following events: (1) exactly two messages arrive within One hour. (2) No message arrives within one hour (3) at least three messages arrive within One hour. (AU-N/D-2017)(8)
(b) The number of monthly breakdown of a computer is a R.V having a poisson distribution with mean equal to 1.8. Find the probability that this computer will function for a month with only one breakdown. (AU-N/D- 2008) (8)
13. (a) Find the MGF of a Poisson random variable and hence find its mean and variance. (AU-A/M-2014)(8)
(b) The probability of a man hitting a target is $1/4$. If he fires 7 times, what is the probability of his hitting the target at least twice? And how many times must he fire so that the probability of his hitting the target at least once is greater than $2/3$? (AU-A/M-2017)(8)
14. (a) State and Prove memory less property of Geometric distribution. (AU-N/D-2010)(8)
(b) Suppose that a trainee soldier shoots a target in an independent fashion. If the probability that the target is shot on any one shot is 0.7, (i) what is the probability that the target would be hit on 10th attempt? (ii) What is the probability that it takes him less than 4 shots?
(iii) What is the probability that it takes him an even number of shots? (AU-A/M- 2013)(8)

15. (a) If the probability that an applicant for a driver's license will pass the road test on any given trial is 0.8, what is the probability that he will finally pass the test; (i) on the fourth trial
(ii) in fewer than 4 trials? (AU-N/D-2013)(8)
- (b) Find the moment generating function of Uniform distribution. Hence find its mean and variance. (AU-A/M-2013)(8)
16. (a) A R.V is uniformly distributed on (-5, 15). Determine: (i) C.D.F of X, $F(x)$ (ii) $P(X > 5 / X < 0)$
(iii) $P(|X-1|<5)$ (iv) $E\left(e^{\frac{-x}{5}}\right)$. (AU-N/D-2019)(8)
- (b) Let X be uniformly distributed random variable in the interval (a, 9) and $P[3 < X < 5] = 2/7$.
Find the constant 'a' and compute $P[|x-5| < 2]$. (AU-A/M-2018)(8)
17. (a) Trains arrive at a station at 15 minutes intervals starting at 4 a.m. If a passenger arrive at a Station at a time that is uniformly distributed between 9.00 and 9.30, find the probability that has to wait for the train for (i) less than 6 minutes (ii) more than 10 minutes. (AU-A/M-2014)(8)
- (b) State and prove memory less property of exponential distribution. (AU-A/M-2013)(8)
18. (a) Find the moment generating function of an exponential distribution and hence find its mean and variance. (AU-N/D-2015)(8)
- (b) State and prove forgetfulness property of exponential distribution. Using this property, solve the following problem:
The length of the shower on a tropical island during rainy season has an exponential distribution with parameter 2 time being measured in minutes. What is the probability that a shower will last more than 3 minutes? (AU-N/D-2016)(8)
19. (a) Find the moment generating function of a normal distribution and hence find its mean and variance. (AU-N/D-2017)(8)
- (b) In a distribution 30 % of the items are under 50 and 10% are over 86. Find the mean and standard deviation of the distribution. (8)
20. (a) The scores on an achievement test given to 1,00,000 students are normally distributed with mean 500 and standard deviation 100. What should the score of a student be to place him among the top 10% of all students? (AU-A/M-2018)(8)
- (b) In a normal population with mean 15 and standard deviation 3.5, it is found that 647 observation exceed 16.25. What is the total number of observations in the population? (AU-A/M-2017)(8)
21. (i) State and prove the additive property of Poisson distribution. (AU-N/D-2018)(4)
- (ii) A machine manufacturing bolts is known to produce 5 % defective. In a random sample of 15 bolts, what is the probability that there are (1) exactly 3 defective bolts, and (2) not more than 3 defective bolts ? (AU-N/D-2018)(6)
- (iii) Find the value of k and calculate mean and variance for the random variable X with the following probability function : (AU-N/D-2018)(6)
- | | | | | | | |
|----------|-----|----|-----|----|-----|---|
| X : | -2 | -1 | 0 | 1 | 2 | 3 |
| $P(x)$: | 0.1 | k | 0.2 | 2k | 0.3 | k |
22. (i) State and prove the memoryless property of an exponential distribution. (AU-N/D-2018)(4)
- (ii) A given lot of product contains 2 % defective products. Each product is tested before delivery. The probability that the product is good given that it is actually good is 0.95 and the probability that the product is defective given that it is actually defective is 0.94. If a tested product is defective, what is the probability that it is actually defective ? (AU-N/D-2018)(6)
- (iii) If X is uniformly distributed over (0, 5), find $P(X < 2)$, $P(X > 3)$ and $P(2 < X < 5)$. (AU-N/D-2018)(6)
23. (i) Find the moment generating function of a Poisson distribution. Hence find mean and variance. (AU-A/M-2019)(8)
- (ii) Four boxes A, B, C, D contain fuses. The boxes contain 5000, 3000, 2000 and 1000 respectively. The percentages of fuses in boxes which are defective are 3 %, 2 %, 1 % and 0.5 % respectively. One fuse is selected at random arbitrarily from one of the boxes. It is found to be defective fuse. Find the probability that it has come from box D. (AU-A/M-2019)(8)
24. (i) Find mean, variance and moment generating function of Exponential distribution. Also prove the lack of memory property of the Exponential distribution. (AU-A/M-2019)(10)

- (ii) The distribution function of a random variable X is given by $F(x) = 1 - (1+x)e^{-x}$; $x \geq 0$. Find the density function, mean, variance of X. (AU-A/M-2019)(6)

25. (i) When a die is thrown, X denotes the number that turns up. Find the values of $E[X]$, $E[X^2]$ and $\text{Var}[X]$. (AU-N/D-2019)(8)

- (ii) Assume that 10 coins are thrown simultaneously. Find the probability of getting atleast 7 heads. (AU-N/D-2019)(8)

26. (i) Derive the Moment Generating Function (MGF) of normal distribution. (AU-N/D-2019)(8)
(ii) Let X be a continuous random variable for the pdf

$$f(x) = \begin{cases} \frac{4x}{81}(9-x^2), & 0 \leq x \leq 3 \\ 0, & \text{Otherwise} \end{cases}$$

Find the first four moments about the origin. (AU-N/D-2019)(8)

UNIT-II
TWO DIMENSIONAL RANDOM VARIABLES
PART-A

1. If the joint probability density function of X and Y is $f(x, y) = e^{-(x+y)}$, $0 \leq x, 0 \leq y$. Are X and Y independent. (AU-N/D-2011)-3

Given $f(x, y) = e^{-(x+y)}$

$$f_x(x) = f(x) = \int_{-\infty}^{\infty} f(x, y) dy = e^{-x} \int_0^{\infty} e^{-y} dy = e^{-x} \left[-e^{-y} \right]_0^{\infty} = -e^{-x} [0 - 1] = e^{-x}$$

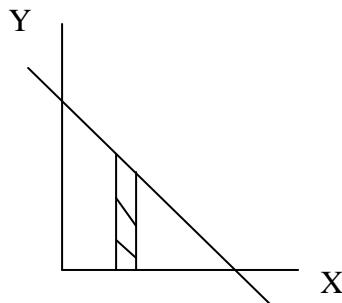
$$f_y(y) = f(y) = \int_{-\infty}^{\infty} f(x, y) dx = e^{-y} \int_0^{\infty} e^{-x} dx = e^{-y} \left[-e^{-x} \right]_0^{\infty} = -e^{-y} [0 - 1] = e^{-y}$$

$$f(x).f(y) = e^{-x} e^{-y} = e^{-(x+y)} = f(x,y)$$

Therefore X and Y are independent.

2. If the joint probability density function of X and Y is $f(x, y) = e^{-(x+y)}$, $x \geq 0, y \geq 0$. Find $P(X+Y \leq 1)$ (AU-N/D-2019)

$$\begin{aligned} P(X + Y < 1) &= \int_0^1 \int_0^{1-x} e^{-(x+y)} dy dx \\ &= \int_0^1 e^{-x} \left[\frac{e^{-y}}{-1} \right]_0^{1-x} dx \\ &= - \int_0^1 e^{-x} [e^{x-1} - e^0] dx \\ &= - \int_0^1 e^{-1} - e^{-x} dx \\ &= [e^{-1} + e^{-1} - 1] = 1 - 2e^{-1} \end{aligned}$$



3. The joint probability density function of the random variable (X, Y) is given by

$f(x, y) = Kxy e^{-(x^2+y^2)}$, $x > 0, y > 0$. Find the value of K. (AU-A/M- 2013)-4

By the property of the joint pdf,

$$\iint_{x>0, y>0} f(x, y) dxdy = 1$$

$$K \int_0^{\infty} \int_0^{\infty} xye^{-(x^2+y^2)} dxdy = 1$$

$$K \int_0^{\infty} xe^{-x^2} dx \int_0^{\infty} ye^{-y^2} dy = 1 \text{ put } x^2 = t; 2x dx = dt, y^2 = u; 2y dy = du$$

$$(K/2) \int_0^{\infty} e^{-t} dt (1/2) \int_0^{\infty} e^{-u} du = 1$$

$$(k/4)[(-e^{-t})_0^{\infty} (-e^{-u})_0^{\infty}] = 1$$

Therefore $k = 4$.

- 4. Find K if the joint p.d.f of (X, Y) is given by $f(x, y) = K(1-x)(1-y)$, $0 < x, y < 1$**
 $= 0$, otherwise (AU-A/M-2013)

$$\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x, y) dx dy = 1$$

$$K \int_0^1 \int_0^1 (1-x)(1-y) dx dy = 1$$

$$K \int_0^1 \int_0^1 [1-x-y+xy] dx dy = 1 \Rightarrow K \int_0^1 \left[1 - \frac{1}{2} - y + \frac{y}{2} \right] dy = 1 \Rightarrow K \int_0^1 \left[\frac{1}{2} - \frac{y}{2} \right] dy = 1$$

$$\frac{K}{2} \left[y - \frac{y^2}{2} \right]_0^1 = 1 \Rightarrow K = 4$$

- 5. The joint p.d.f of a two-dimensional random variables (x, y) is given by**

$$f(x, y) = kxe^{-y}, 0 \leq x \leq 2, y > 0$$
 $= 0$, otherwise. Find the value of k. (AU-A/M-2015)

$$k \left(\int_0^{\infty} e^{-y} dy \right) \left(\int_0^2 x dx \right) = 1 \Rightarrow k \left(-e^{-y} \right)_0^{\infty} \left(\frac{x^2}{2} \right)_0^2 = 1 \Rightarrow k(2) = 1 \Rightarrow k = \frac{1}{2}$$

- 6. If the joint pdf of (X, Y) is given by $f(x, y) = 2$ in $0 \leq x < y \leq 1$, find E[X].** (AU-N/D-2013)

$$f(x) = \int_{-\infty}^{\infty} f(x, y) dy = \int_x^1 2 dy = 2[y]_x^1 = 2[1-x]$$

$$E[X] = \int_{-\infty}^{\infty} xf(x) dx = 2 \int_0^1 (x - x^2) dx = 2 \left(\frac{x^2}{2} - \frac{x^3}{3} \right)_0^1 = 2 \left(\frac{1}{2} - \frac{1}{3} \right) = 2 \left(\frac{1}{6} \right) = \left(\frac{1}{3} \right)$$

- 7. Given that joint probability density function of (X, Y) as $f(x, y) = 1/6$, $0 < x < 2$, $0 < y < 3$, Determine the marginal density.** (AU-A/M-2014)

Marginal density of X if given by

$$f(x) = \int_0^3 f(x, y) dy = \int_0^3 \frac{1}{6} dy = \frac{3}{6} = \frac{1}{2}$$

Marginal density of Y if given by

$$f(y) = \int_0^2 f(x, y) dx = \int_0^2 \frac{1}{6} dx = \frac{2}{6} = \frac{1}{3}$$

- 8. The joint pdf of (X, Y) is $f(x, y) = 4xy$, $0 < x, y < 1$**
 $= 0$, otherwise . Examine X and Y are independent and find $E(XY)$. (AU-A/M-2019)-3

$$\text{Marginal density of } X, f(x) = \int_0^1 4xy dy = 2x$$

$$\text{Marginal density of } Y, f(y) = \int_0^1 4xy dx = 2y$$

$$f(x) \cdot f(y) = 4xy = f(x, y)$$

\therefore X and Y are independent.

$$E(XY) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} xy f(x, y) dx dy = \int_0^1 \int_0^1 xy 4xy dx dy = 4 \int_0^1 x^2 \left[\frac{y^3}{3} \right]_0^1 dx = \frac{4}{3} \left[\frac{x^3}{3} \right]_0^1 = \left(\frac{4}{3} \right) x \left(\frac{1}{3} \right) = \frac{4}{9}$$

9. If X and Y are random variables having the joint density function

$$f(x, y) = (6-x-y)/8, 0 < x < 2; 2 < y < 4, \text{ find } P(X+Y < 3).$$

(AU-N/D-2018)-3

$$\begin{aligned} P(X+Y < 3) &= \int_2^3 \int_0^{3-y} \frac{1}{8}(6-x-y) dx dy = \frac{1}{8} \int_2^3 \left(6x - \frac{x^2}{2} - xy \right)_{0}^{3-y} dy \\ &= \frac{1}{8} \int_2^3 \left(18 - 6y - \frac{9}{2} - \frac{y^2}{2} + 3y - 3y + y^2 \right) dy \\ &= \frac{1}{8} \int_2^3 \left(\frac{y^2}{2} - 6y + \frac{27}{2} \right) dy = \frac{1}{8} \left[\frac{y^3}{6} - 6\left(\frac{y^2}{2}\right) + \frac{27y}{2} \right]_2^3 = \frac{1}{8} \left[-9 + \frac{32}{3} \right] = \frac{5}{24} \end{aligned}$$

10. The joint probability density function of two random variables given by

$$f_{xy}(x, y) = x(x-y)/8, 0 < x < 2; -x < y < x \text{ and find } f_{y/x}(y/x)$$

(AU-N/D-2016)-2

$$f_{xy}(x, y) = \frac{1}{8} x(x-y)$$

$$f(y/x) = \frac{f(x, y)}{f(x)}$$

$$\begin{aligned} f_x(x) &= \int_{-\infty}^{\infty} f(x, y) dy = \frac{1}{8} \int_{-x}^x (x-xy) dy = \frac{1}{8} \left[x^2 y - \frac{xy^2}{2} \right] = \frac{1}{8} \left[\left(x^3 - \frac{x^2}{2} \right) - \left(-x^3 - \frac{x^2}{2} \right) \right] \\ &= \frac{1}{8} (2x^3) = \frac{1}{4} x^3 \\ f(y/x) &= \frac{f(x, y)}{f(x)} = \frac{1}{8} x(x-y) / \frac{1}{4} x^3 = \frac{1}{2x^2} (x-y). \end{aligned}$$

11. Let the joint probability density function of random variables X and Y be given by

$$f(x, y) = 8xy, 0 \leq y \leq x \leq 1. \text{ Calculate the marginal probability density function of X.}$$

(AU-N/D-2017)

$$\text{The marginal pdf of X is } f_X(x) = f(x) = \int_{-\infty}^{\infty} f(x, y) dy = \int_0^x 8xy dy = 8x \left(\frac{y^2}{2} \right)_0^x = 4x^3, 0 \leq x \leq 1.$$

12. Let X and Y be two independent R.Vs with Var(X) = 9 and Var(Y) = 3. Find Var (4X-2Y+6).

$$\text{Var}(X) = 9, \text{Var}(Y) = 3$$

(AU-N/D-2019)-2

$$\text{Var}(4X-2Y+6) = 4^2 \text{Var}(X) + (-2)^2 \text{Var}(Y) = 16(9)+4(3) = 156.$$

13. Write any two properties of joint cumulative distribution function.

(AU-N/D-2016)

$$1. F(-\infty, y) = 0 = F(x, -\infty) \text{ and } F(-\infty, \infty) = 1$$

$$2. P(a < X < b, Y \leq y) = F(b, y) - F(a, y)$$

$$3. P(X < x, c < Y \leq d) = F(x, d) - F(x, c)$$

$$4. P(a_1 < X < b_1, a_2 < X < b_2) = F(b_1, b_2) + F(a_1, a_2) - F(a_1, b_2) - F(b_1, a_2).$$

14. Define covariance and correlation between the random variables X and Y.

(AU-N/D-2012)

If X and Y are two random variables, then the covariance between X and Y is

$$\text{Cov}(X, Y) = E[(X - E(X))(Y - E(Y))] = E(XY) - E(X)E(Y)$$

If (X, Y) vary in such a way that change in one variable corresponds to the change in the other variable then the variables X and Y are correlated.

15. Prove that Cov(aX, bY) = ab.Cov(X, Y).

(AU-A/M-2016)

$$\begin{aligned} \text{Cov}(aX, bY) &= E[(aX)(bY)] - E(ax)E(bY) \\ &= ab E(XY) - abE(X)E(Y) = ab [E(XY) - E(X)E(Y)] \\ &= ab \text{Cov}(X, Y). \end{aligned}$$

16. Give a real life example each for positive correlation and negative correlation. (AU-A/M-2010)

Example for positive correlation

(a) the heights and weights of a group of persons and

(b) income and expenditure.

Example for Negative correlation

(a) price and demand of a commodity and

(b) the correlation between volume and pressure of a perfect gas.

17. Write the properties of correlation coefficient.

(AU-N/D-2013)

- (i) Correlation coefficient does not exceed unity.
- (ii) When $r = 1$ the correlation is perfect and positive.
- (iii) Two independent variables are uncorrelated.

18. Show that $\text{Cov}^2(X, Y) \leq \text{Var}(X).\text{Var}(Y)$.

(AU-N/D-2010)

Let X and Y be two random variables. For any real number "a"

$E([a(X - \bar{X}) - (Y - \bar{Y})]^2]$ must always be non-negative.

$$E(a^2(X - \bar{X})^2 - 2a(X - \bar{X})(Y - \bar{Y}) + (Y - \bar{Y})^2] \geq 0$$

$$[a^2 E(X - \bar{X})^2 - 2aE(X - \bar{X})(Y - \bar{Y}) + E(Y - \bar{Y})^2] \geq 0$$

$$a^2 \text{Var}(X) - 2a\text{Cov}(X, Y) + \text{Var}(Y) \geq 0.$$

This is a quadratic in 'a' and is always non-negative so the discriminant must be Non positive.

Therefore $\text{Cov}^2(X, Y) \leq \text{Var}(X).\text{Var}(Y)$

19. If there is no linear correlation between two random variables X and Y, then what can you say about the regression lines?

(AU-N/D-2012)

When there is no linear correlation between X and Y that is when $r_{XY} = 0$.

The equations of the regression lines become $y = \bar{y}$ and $x = \bar{x}$ which are at right angles.

20. State the equations of the two regression lines.

(AU-A/M-2013)

The equations of regression of y on x is given by $y - \bar{y} = r \frac{\sigma_y}{\sigma_x} (x - \bar{x})$

The equations of regression of x on y is given by $x - \bar{x} = r \frac{\sigma_x}{\sigma_y} (y - \bar{y})$

21. The regression equations of X on Y and Y on X are respectively $5x-y = 22$ and $64x-45y = 24$.

Find the means of X and Y.

(AU-A/M-2012)

Since \bar{x} and \bar{y} lies on the given two lines we get

$$5\bar{x} - \bar{y} = 22 \dots \dots \dots (1)$$

$$64\bar{x} - 45\bar{y} = 24 \dots \dots \dots (2)$$

Solving the two equations we get

$$\bar{x} = 6 \text{ and } \bar{y} = 8$$

Therefore Mean of X = 6 and Mean of Y = 8.

22. In a partially destroyed laboratory, record of an analysis of correlation data, the following results only are legible: Variance of X = 9 ; Regression equations are $8X-10Y+66 = 0$ and $40X-18Y = 214$. What are mean values of X and Y?

(AU-A/M-2015)

$$8\bar{x} - 10\bar{y} = -66 \dots \dots \dots (1)$$

$$40\bar{x} - 18\bar{y} = 214 \dots \dots \dots (2)$$

Solving equations (1) and (2),

$$(2) - (1) \times 5 \text{ implies that } \bar{y} = 17$$

$$(1) \text{ implies that, } \bar{x} = 13$$

24. The two equations of the variables X and Y are $x = 8 - 0.9y$ and $y = 10 - 0.4x$. Find the correlation co-efficient between X and Y.

(AU-A/M-2014)

The Regression Equation of X on Y is $x = 8 - 0.9y$; $b_{xy} = -0.9$

The Regression Equation of X on Y is $y = 10 - 0.4x$; $b_{yx} = -0.4$

The Correlation coefficient between X and Y is given by $r = \pm \sqrt{(b_{xy}b_{yx})} = -0.6$

25. Can $Y = 5 + 2.8X$ and $X = 3 - 0.5Y$ be the estimated regression equations of Y on X and X on Y respectively? Explain your answer.

(AU-N/D-2013)

Given $X = 3 - 0.5Y$ and $Y = 5 + 2.8X$

i.e., $b_{XY} = -0.5$ and $b_{YX} = 2.8$

$$r^2 = b_{XY} \times b_{YX} = -0.5 \times 2.8 = -1.4$$

$r = \sqrt{-1.4}$ which is imaginary quantity

r cannot be imaginary.

\therefore The given lines are not estimated as regression equations.

26. Find the acute angle between the two lines of regression.

(AU-A/M-2010)

$$\text{Angle between the lines is given by } \tan\theta = \frac{1-r^2}{r} \left(\frac{\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \right)$$

27. State Central limit theorem.

(AU-A/M-2019)-3

Liapounoff's form:

If X_i ($i = 1, 2, 3, \dots, n$) be "n" independent random variables such that $E(X_i) = \mu$ and $\text{Var}(X_i) = \sigma^2$ then under certain general condition, the random variable $S_n = X_1 + X_2 + \dots + X_n$ is asymptotically normal

with mean μ and standard deviation σ where $\mu = \sum_{i=1}^n \mu_i$ and $\sigma^2 = \sum_{i=1}^n \sigma_i^2$.

Lindberg-Levy's form:

If X_1, X_2, \dots, X_n be a sequence of independent identically distributed random variables with $E(X_i) = \mu$ and $\text{Var}(X_i) = \sigma^2$, $i = 1, 2, \dots$ and if $S_n = X_1 + X_2 + \dots + X_n$ then under certain general condition, S_n follows a normal distribution with mean $n\mu$ and variance $n\sigma^2$ as n tends to infinity.

**28. The joint probability mass function of (X, Y) is given by $P(x, y) = K(2x+3y)$, $x = 0, 1, 2$; $y = 1, 2$.
3. Find K and $P(X = 2)$.**

(AU-N/D-2018)

X \ Y	1	2	3	Total
0	3K	6K	9K	18K
1	5K	8K	11K	24K
2	7K	10K	13K	30K
Total	15K	24K	33K	72K

$$\text{Total Probability} = 1$$

$$72K = 1$$

$$K = 1/72$$

X \ Y	1	2	3	Total
0	3/72	6/72	9/72	$P(X = 0) = 18/72$
1	5/72	8/72	11/72	$P(X = 1) = 24/72$
2	7/72	10/72	13/72	$P(X = 2) = 30/72$
Total	$P(Y = 1) = 15/72$	$P(Y = 2) = 24/72$	$P(Y = 3) = 33/72$	1

$$P(X=2) = 30/72.$$

**29. Find the Marginal Density function of X if $f(x, y) = 8xy$, $0 < x < y < 1$
= 0, otherwise .**

(AU-A/M-2019)

$$\text{Marginal density of } X, f(x) = \int_0^1 8xy dy = 4x.$$

30. The two lines of regression are $3x+2y-26 = 0$, $6x+y-31 = 0$. Find the value of correlation coefficient between x and y.

(AU-A/M-2019)

$$\text{Given } 3x+2y = 26 \quad \dots \dots \dots (1)$$

$$6x+y = 31 \quad \dots \dots \dots (2)$$

Solving (1) and (2) we get

$$\bar{X} = 4, \bar{Y} = 7$$

From (1) is the regression line of Y on X

$$2y = 26-3x \Rightarrow y = (-3/2)x+13 \quad \dots \dots \dots (3)$$

From (2) is the regression line of X on Y

$$6x = -y+31 \Rightarrow x = (-1/6)y+(31/6) \quad \dots \dots \dots (4)$$

From (3), $b_{yx} = -3/2$, From (3), $b_{xy} = -1/6$,
 $r_{XY} = -1/2$.

31. Prove that $\text{Cov}(X, Y) = E[XY] - E[X]E[Y]$.

(AU-N/D-2019)

$$\begin{aligned}\text{Cov}(X, Y) &= E[(X-E(X))(Y-E(Y))] \\ &= E[XY-XE(Y)-YE(X)+E(X)E(Y)] \\ &= E[XY]-E[X]E[Y]-E[X]E[Y]+E[X]E[Y] \\ &= E[XY]-E[X]E[Y].\end{aligned}$$

PART-B

1. (a) The joint probability density function of a two-dimensional random variable (X, Y) is

$$f(x, y) = \frac{1}{8}(6-x-y), 0 < x < 2, 2 < y < 4$$

Find (i) $P[X < 1 \cap Y < 3]$ (ii) $P(X+Y < 3)$ (3) $P[X < 1 / Y < 3]$. (AU-A/M-2013)(8)

(b) The probability density function of X and Y is given by $f(x, y) = \frac{6}{7} \left(x^2 + \frac{xy}{2} \right), 0 < x < 1, 0 < y < 2$ (AU-A/M-2017)-2(8)

2. (a) The joint distribution of X and Y is given by, $f(x, y) = \frac{x+y}{21}, x = 1, 2, 3, y = 1, 2$. Find the marginal distributions. (AU-N/D-2015)(8)

(b) Assume that the random variables X and Y have the joint PDF $f(x, y) = \frac{1}{2}x^3y; 0 \leq x \leq 2, 0 \leq y \leq 1$.

Determine if X and Y are independent. (AU-A/M-2015)(8)

3. (a) The joint probability mass function of the random variables of X and Y is given by,

$$P(X = x, Y = y) = \begin{cases} \frac{x+y}{12}, & x=1,2, y=1,2 \\ 0, & \text{otherwise} \end{cases}$$

Find the (i) Marginal probability mass functions of X and Y (ii) $P(X+Y \leq 3)$ (iii) $P(X > Y)$

(iv) Are the R.Vs X and Y independent? (AU-A/M-2019)(8)

- (b) The joint probability density function of two random variables X and Y is given by

$$f(x, y) = k[(x+y)-(x^2+y^2)], 0 < (x, y) < 1 \\ = 0, \quad \text{otherwise}$$

Show that X and Y are uncorrelated but not independent. (AU-A/M-2014)(16)

4. The joint PDF of a two dimensional random variable (X, Y) is given by

$$f(x, y) = xy^2 + \frac{x^2}{8}, 0 \leq x \leq 2, 0 \leq y \leq 1. \text{ Compute (i) } P(x > 1) \text{ (ii) } P(y < \frac{1}{2}) \text{ (iii) } P(x > 1 / y < \frac{1}{2})$$

(iv) $P(y < \frac{1}{2} / x > 1)$ (v) $P(x < y)$ and (vi) $P(x+y \leq 1)$. (AU-A/M-2018)(16)

5. (a) If the joint distribution function of x and y is given by $F(x, y) = (1-e^{-x})(1-e^{-y})$ for $x > 0, y > 0$
 $= 0 \quad \text{otherwise}$

(1) Find the marginal densities of x and y.

(2) Are x and y independent

(3) Find $P(1 < x < 3, 1 < y < 2)$. (AU-A/M-2016)(8)

- (b) Two random variables X and Y have the following joint probability density function

$f(x, y) = xe^{-x(y+1)}$, $x \geq 0, y \geq 0$. Determine the conditional probability density function of X given Y and the conditional probability density function of Y given X. (AU-N/D-2017)(8)

6. (a) The probability density function of (X, Y) is given by $f(x, y) = \begin{cases} 8xy, & 0 < x < y < 1 \\ 0, & \text{Otherwise} \end{cases}$.

Find $P(X < \frac{1}{2} \cap y < \frac{1}{4})$. Are X and Y independent? Justify your answer. (AU-A/M-2017)(8)

- (b) The joint probability density function of the two dimensional random variable (X, Y) is given

by $f(x, y) = \frac{x}{4}(1+3y^2), 0 < x < 2, 0 < y < 1$. Find (i) Conditional probability density function of x given $Y = y$ and Y given $X = x$. (ii) $P[0.25 < X < 0.5 / Y = 0.33]$ (AU-A/M-2018)(8)

7. (a) The joint probability density function of (X, Y) is $f(x, y) = \begin{cases} \frac{1}{240}, & 8.5 \leq x \leq 10.5, 120 \leq y \leq 240 \\ 0, & \text{otherwise.} \end{cases}$

Determine (i) the marginal p.d.fs of X and Y (ii) E(X) and E(Y) (iii) E(XY) (iv) Are X and Y independent R.Vs? Justify. (AU-N/D-2019)(8)

(b) The joint probability density function of (X, Y) is $f(x, y) = \begin{cases} Ce^{-(2x+3y)}, & 0 \leq y \leq x < \infty \\ 0, & \text{otherwise.} \end{cases}$ Determine (i)

the Value of C (ii) Are X and Y independent R.Vs? (AU-N/D-2019)(8)

8.(a) The joint probability density function of (X, Y) is $f(x, y) = \begin{cases} Cxy^2, & 0 \leq x \leq y \leq 1 \\ 0, & \text{otherwise.} \end{cases}$

Determine (i) the value of 'C' (ii) the p.d.f conditional of X given that Y = y (iii) E(XY). (AU-A/M-2019)(8)

(b) The joint PDF of the random variables X and Y is defined as $f(x, y) = 25e^{-5y}; 0 < x < 0.2, y > 0$
 $= 0, \text{ otherwise}$

(i) Find the marginal PDFs and X and Y

(ii) What is the covariance of X and Y? (AU-N/D-2015)(16)

9. (a) Let X and Y be continuous random variables with joint p.d.f.

$f(x, y) = \begin{cases} \frac{1}{3}x^3 e^{-(1+y)x}, & x > 0, y > 0 \\ 0, & \text{otherwise} \end{cases}$. Find Cov(X, Y). (AU-N/D-2014)(8)

(b) The joint p.d.f. of two continuous random variables X and Y is given as

$f(x, y) = \begin{cases} x + y, & 0 \leq x \leq 1, 0 \leq y \leq 1 \\ 0, & \text{otherwise} \end{cases}$. Compute the correlation coefficient ρ_{xy} of the random variables X and Y. (AU-A/M-2016)(8)

10.(a) The joint probability mass function of the random variables of X and Y is given by,

$P(X = x, Y = y) = \begin{cases} \frac{x+y}{21}, & x=1,2, y=1,2 \\ 0, & \text{otherwise} \end{cases}$. Compute the correlation coefficient of X and Y. (AU-A/M-2019)(8)

11. (a) Calculate the correlation coefficient for the following data:

X : 65 66	67	67	68	69	70	72
Y : 67 68	65	68	72	72	69	71

(AU-N/D-2016)(8)

(b) Let X and Y be random variables having joint density function (AU-N/D-2014)(8)

$f(x, y) = \begin{cases} \frac{3}{2}(x^2 + y^2), & 0 \leq x \leq 1, 0 \leq y \leq 1 \\ 0, & \text{otherwise} \end{cases}$. Find the correlation coefficient r_{xy} .

12. (a) Let X and Y be random variables such that $E(X) = 1, E(Y) = 2, \text{Var}(X) = 6, \text{Var}(Y) = 9$ and the correlation coefficient is $-2/3$. Calculate (i) The covariance, Cov(X, Y) (ii) E(XY) (iii) $E(X^2)$ and $E(Y^2)$ (AU-N/D-2019)(8)

(b) If the independent random variables X and Y have the variances 36 and 16 respectively, find the correlation coefficient, r_{UV} where $U = X+Y$ and $V = X-Y$. (AU-A/M-2014)(8)

13. (a) Given that $X = 4Y+5$ and $Y = kX+4$ are regression lines of X on Y and Y on X respectively.

Show that $0 \leq k \leq 1/4$. If $k = 1/16$, find the means of X and Y and the correlation coefficient r_{XY} . (AU-A/M-2018)(8)

(c) Obtain the equations of the regression lines from the following data. Hence find the coefficient of correlation between X and Y. Also estimate the value of y when x = 38 and X when y = 18.

X: 22 26 29 30 31 31 34 35	Y: 20 20 21 29 27 24 27 31
----------------------------	----------------------------

(AU-A/M-2018)-2(16)

14. (a) Find the equation of the regression line Y on X from the following data: (AU-N/D-2015)(8)

$$\begin{array}{ccccccc} X: & 3 & 5 & 6 & 8 & 9 & 11 \\ Y: & 2 & 3 & 4 & 6 & 5 & 8 \end{array}$$

(b) If X and Y are two independent random variables each normally distributed with mean 0

and variance σ^2 , then find the joint probability density function of $R = \sqrt{x^2 + y^2}$ and

$$\theta = \tan^{-1}\left(\frac{y}{x}\right) \text{ and hence find the probability density function of } \theta. \quad (\text{AU-N/D-2017})(8)$$

15. (a) If X and Y each follow an exponential distribution with parameter 1 and are independent, find the p.d.f of $U = X - Y$. (AU-A/M-2017)(8)

(b) The joint p.d.f of X and Y is given by $f(x, y) = e^{-(x+y)}$, $x > 0, y > 0$, find the probability density function of $U = (X+Y)/2$. (AU-N/D-2016)(8)

16. (a) The joint p.d.f of X and Y is given by $f(x, y) = e^{-(x+y)}$, $x > 0, y > 0$, find the probability density function of $U = X/Y$. (AU-A/M-2019)(8)

$$(b) \text{ Let } X \text{ and } Y \text{ be two continuous R.Vs with joint p.d.f } f(x, y) = \begin{cases} 4xy, & 0 \leq x \leq 1, 0 \leq y \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

Determine the joint p.d.f of the R.Vs $U = X^2$ and $V = XY$ and hence obtain the marginal p.d.f of U (AU-N/D-2019)(8)

17. (a) If the joint pdf of (X, Y) is given by $f(x, y) = x+y$, $0 \leq x, y \leq 1$, find the pdf of the R.V $U = XY$. (AU-A/M-2018)(8)

(b) If X_1, X_2, \dots, X_n are Poisson variates with parameter $\lambda = 2$, use central limit theorem to estimate $P(120 < S_n < 160)$; where $S_n = X_1 + X_2 + \dots + X_n$ and $n = 75$. (AU-N/D-2017)(8)

18. (a) The life time of a certain brand of an electric bulb may be considered as a RV with mean 1200 h and SD 250 h. Using central limit theorem, find the probability that the average life time of 60 bulbs exceeds 1250 h. (AU-N/D-2013)(8)

(b) A distribution with unknown mean u has variance equal to 1.5 Use central limit theorem to find how large a sample should be taken from the distribution in order that the probability will be at least 0.95 that the sample mean will be within 0.5 of the population mean. (AU-A/M-2013)(8)

19. (i) If X and Y are independent random variables, with density function

$$f(x) = e^{-x}, x \geq 0, f(y) = e^{-y}, y \geq 0, \text{ show that } U = X / (X+Y) \text{ and } V = X+Y \text{ are independent.}$$

(AU-N/D-2018)(10)

(ii) The life time of a certain brand of an electric bulb may be considered as a RV with mean 1200 h and SD 250 h. Using central limit theorem, find the probability that the average life time of 60 bulbs exceeds 1250 h. (AU-N/D-2018)(6)

20. The joint probability density function of a two dimensional random variables is ,

$$f(x, y) = \begin{cases} \frac{x+y}{3}, & 0 \leq x \leq 1, 0 \leq y \leq 2 \\ 0, & \text{otherwise} \end{cases}, \text{ find the equations of the lines of regression.}$$

(AU-N/D-2018)(16)

21. (i) X and Y are two random variables having the joint probability mass function

$$f(x, y) = k(3x+5y), x = 1, 2, 3 : y = 0, 1, 2.$$

Find the marginal distributions and conditional distribution of X, $P(X = x_i | Y = 2)$, $P(X \leq 2 | Y \leq 1)$. (AU-A/M-2019)(8)

(ii) The joint density function of two random variables X and Y is given by

$$f(x, y) = \frac{1}{4} e^{-(x+y)/2}, x > 0, y > 0. \text{ Find the distribution of } (X-Y)/4. \quad (\text{AU-A/M-2019})(8)$$

22. The joint probability density function of a two dimensional random variables X and Y is given by

$$f(x, y) = k(xy + y^2), 0 \leq x \leq 1, 0 \leq y \leq 2. \text{ Find } P(Y > 1), P(X > \frac{1}{2} | Y < 1) \text{ and } P(X+Y \leq 1).$$

(AU-A/M-2019)(16)

23. (i) The random variables X and Y have joint probability density function

$$f_{XY}(x, y) = \begin{cases} x^2 + \frac{xy}{3}, & 0 < x < 1, 0 < y < 2 \\ 0, & \text{otherwise} \end{cases}$$

Find the marginal density functions of X and Y.

(AU-N/D-2019)(8)

- (ii) If X_1 and X_2 are two independent random variables with means 5 and 10 and standard deviations 2 and 3 respectively. Obtain correlation coefficient of (U, V) if $U = 3X_1 + 4X_2$ and $V = 3X_1 - X_2$.

(AU-N/D-2019)(8)

24. (i) The random variables X and Y have joint density function.

$f_{XY}(x, y) = K(x^3y + xy^3)$, $0 \leq x \leq 2$, $0 \leq y \leq 2$ find the value of K and the conditional densities of X given y and Y given x.

(AU-N/D-2019)(8)

- (ii) X is a continuous random variable uniformly distributed in the interval (0, 2). Let $Y = 4X + 3$. Then find $F_Y(y)$ and $f_Y(y)$, for $f_X(x) = \frac{1}{2}$ in (0, 2).

UNIT-III
TESTING OF HYPOTHESIS
PART-A

- 1. What is random sampling?** (AU-N/D-2015)

A sampling method in which all members of a group (population or universe) have an equal and independent chance of being selected.

- 2. Define Null hypothesis and Alternative hypothesis.** (AU-N/D-2012)

Null hypothesis:

For applying the tests of significance we first set up a hypothesis which is a definite statement about the population parameter. Usually, such a hypothesis is a hypothesis of no difference and it is denoted by H_0

Alternative Hypothesis:

Any hypothesis which is complementary to the Null hypothesis is called an Alternative Hypothesis, usually denoted by H_1 .

- (i.e.) $H_0 = \mu = \mu_0$, $H_1 = \mu \neq \mu_0$ (Two tailed Alternative)
- $H_1 = \mu > \mu_0$ (Right tailed Alternative hypothesis)
- $H_1 = \mu < \mu_0$ (Left tailed Alternative hypothesis)

- 3. Define the following terms: Statistic, Parameter and Standard Error.** (AU-A/M-2018)

To avoid verbal confusion with the statistical constants of the population, namely mean μ , variance σ^2 which are usually referred to as Parameters. Statistical measures computed from sample observations alone e.g mean, variance are usually referred to as statistic. The standard deviation of the sampling distribution is called the standard error.

- 4. For the following cases, specify which probability distribution to use in a hypothesis test**

- a) $H_0 : \mu = 27$, $H_1 : \mu \neq 27$, $\bar{X} = 20.1$, $\sigma = 5$, $n = 12$ (AU- A/M-2018)
- b) $H_0 : \mu = 98.6$, $H_1 : \mu > 98.6$, $\bar{X} = 65.1$, $s = 12$, $n = 42$

The probability distribution is Standard normal distribution

- 5. Define the term critical region in testing hypothesis?** (AU-N/D-2019)-3

A region in the sample space which amounts to rejection of H_0 is termed as critical region or region of rejection.

- 6. State level of significance.** (AU-N/D-2013)

The probability ' α ' that a random value of the statistic 't' belongs to the critical region is known as the level of significance. In other words, level of significance is the size of the Type-I error, the level of significance usually employed in testing of hypothesis are 5% and 1%.

- 7. Define Type-I error and Type-II errors in testing of hypothesis.** (AU- N/D-2019)-8

Type I error: Reject H_0 when it is true.

Type II error: Accept H_0 when it is wrong.

- 8. Mention the various steps involved in testing of hypothesis.** (AU-A/M-2010)

- (i) Set up the null hypothesis
- (ii) Choose the appropriate level of significance

(iii) Compute the test statistic $z = \frac{\bar{x} - E(t)}{sE(t)}$ under the null hypothesis

(iv) We compare the computed value of z in step (iii) with the significant value at given level of Significance.

If $|z| < 1.96$, H_0 may be accepted at 5% level of significance.

If $|z| > 1.96$, H_0 may be rejected at 5% level of significance.

If $|z| < 2.58$, H_0 may be accepted at 1% level of significance.

If $|z| > 2.58$, H_0 may be rejected at 1% level of significance.

9. Explain the terms sample size and sampling error in random sampling? (AU-N/D-2019)

The process of drawing a sample from a population is called sampling. The number of items selected in a sample is called the sample size and is denoted by n. If $n \geq 30$, the sample is called large sample and $n < 30$, it is called small sample.

10. A random sample of 25 cups from a certain coffee dispensing machine yields a mean $\bar{x} = 6.9$ occurs per cup. Use $\alpha = 0.05$ level of significance to test, on the average, the machine dispense

$\mu = 7.0$ ounces against the null hypothesis that, on the average, the machine dispenses $\mu < 7.0$ ounces. Assume that the distribution of ounces per cup is normal, and that the variance is the known quantity $\sigma^2 = 0.01$ ounces.

$$n = 25, \bar{x} = 6.9, \mu_0 = 7.0, \sigma^2 = 0.01, s = \sigma = 0.1$$

$$H_0 : \mu = 7 \text{ ounces } H_1 : \mu < 7$$

$$\text{The test statistic is } z = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} = \frac{6.9 - 7}{\frac{0.1}{\sqrt{25}}} = -5$$

Conclusion : $|z| = 5 > 1.645$. Hence H_0 is rejected.

11. Mention 3 tests of significance for large samples.

1. Test of significance for single mean.
2. Test of significance for difference of means
3. Test of significance for difference of standard deviations

12. A random sample of 200 tins of coconut oil gave an average weight of 4.95 kgs. With a standard deviation of 0.21 kg. Do we accept that the net weight is 5 kgs per tin at 5% level?

(AU-A/M-2017)-2

$$n = 200, \bar{x} = 4.95 \text{ kg}, \sigma = s = 0.21 \text{ kg}, \mu_0 = 5 \text{ kg}$$

$$H_0 : \mu = 5 \text{ kgs} ; H_1 : \mu \neq 5 \text{ kgs}$$

$$z = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} = \frac{4.95 - 5}{\frac{0.21}{\sqrt{200}}} = -3.36$$

$|z| = 3.36 > 1.96$ and $3.36 > 2.58$, $\therefore H_0 : \mu = 5$ is rejected.

Hence we cannot consider the net weight is 5 kgs at both the level of significance.

13. Write the application of t-test

(AU-A/M-2010)-2

- (i) The parent population from which the sample is drawn is normal
- (ii) The sample observations are independent. i.e. the sample is random
- (iii) The population standard deviation σ is unknown

14. Define student's t-test for single mean.

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n-1}}}$$

Where, \bar{x} = sample mean ; μ = population mean ; s = sample standard deviation n = no. of samples

15. State the important properties of 't' distribution.

- (i) The probability curve of the t-distribution is similar to the standard normal curve and is symmetric about $t=0$, bell-shaped and asymptotic to the t-axis
- (ii) For sufficiently large value of n, the t-distribution tends to the standard normal distribution
- (iii) The mean of the t-distribution is zero.

16. Write down the formula of test statistic 't' to test the significance of difference between the means of large samples.

(AU-N/D-2016)-2

$$t = \frac{\left| \bar{x}_1 - \bar{x}_2 \right|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \bar{x}_1, \bar{x}_2 \text{ sample means ; } s_1^2, s_2^2 \text{ are sample variances; } n_1, n_2 \text{ sample size.}$$

17. Write about 'F' test

(AU-N/D-2015)

- (i) 'F' test is test whether there is any significant difference between two estimates of population variance.
- (ii) 'F' test is test if the two samples have come from the same population

18. Define a 'F' variate.

$$F = \frac{S_1^2}{S_2^2}, S_1^2 > S_2^2 \text{ where } S_1^2 = \frac{\sum(x_1 - \bar{x}_1)^2}{n_1 - 1} \text{ and } S_2^2 = \frac{\sum(x_2 - \bar{x}_2)^2}{n_2 - 1}$$

Where, x_1 & x_2 = Given samples, n_1 & n_2 = No. of samples, \bar{x}_1 & \bar{x}_2 = sample mean

19. A sample of size 13 gave an estimated population variance of 3.0 while another sample of size 15 gave an estimate of 2.5. Could both samples be from populations with the same Variance?

(AU-N/D-2018)

$$n_1 = 13, \sigma_1^2 = 3, n_2 = 15, \sigma_2^2 = 2.5$$

$$v_1 = n_1 - 1 = 12, v_2 = n_2 - 1 = 14$$

$$H_0: \sigma_1^2 = \sigma_2^2; H_1: \sigma_1^2 \neq \sigma_2^2$$

$$\text{The test static is } F = \sigma_1^2 / \sigma_2^2 = 1.2 < 2.53$$

Hence H_0 is accepted.

20. Define χ^2 test of goodness of fit.

(AU-A/M-2010)

Chi square test of goodness of fit is a test to find if the deviation of the experiment from theory is just by chance or it is due to the inadequacy of the theory is just by chance or it is due to the inadequacy of the theory to fit the observed data. By this test, we test whether differences between observed and expected frequencies are significant or not.

21. State any two applications of χ^2 test.

(AU-A/M-2019)-6

- (i) To test the goodness of fit.
- (ii) To test the "independence of attributes"
- (iii) To test the significance discrepancy between experimental values and the theoretical values

22. Write the condition for the application of χ^2 test.

(AU-M/J-2014)

- (i) The sample observations should be independent.
- (ii) Constraints the cell frequencies, if any must be linear
- (iii) N, the total frequency, should be at least 50
- (iv) No theoretical cell frequency should be less than 5.

23. Write the formula for the chi-square test of goodness of fit of a random sample to hypothetical distribution.

(AU-A/M-2010)

$$\chi^2 = \sum \frac{(O - E)^2}{E}, \text{ where O--Observed frequency}$$

E-Expected frequency

24. Give the formula for the χ^2 test of independence for

a	b
c	d

(AU-M/J-2016)

$$\chi^2 = \frac{(a+b+c+d)(ad-bc)^2}{(a+b)(a+c)(c+d)(b+d)}$$

25. What are the expected frequencies of 2x2

The expected frequencies are given by

a	b
c	d

contingency table

(AU-A/M-2017)

$E(a) = \frac{(a+c)(a+b)}{N}$	$E(b) = \frac{(b+d)(a+b)}{N}$	a+b
$E(a) = \frac{(a+c)(c+d)}{N}$	$E(a) = \frac{(c+d)(b+d)}{N}$	c+d
a+c	b+d	N

26. Define one-tailed and two-tailed tests.

(AU-N/D-2018)

A test of any statistical hypothesis where the alternative hypothesis is one tailed (right tailed or left tailed) is called a one tailed test.

For example, in a test for testing the mean of a population in a single tailed we assume that the null hypothesis $H_0: \mu = \mu_0$ against the alternative hypothesis

$$H_1: \mu > \mu_0 \text{ (Right Tailed)}$$

$$\text{or } H_1: \mu < \mu_0 \text{ (Left Tailed)}$$

is called One Tailed Test.

in a test of statistical hypothesis where the alternative hypothesis is two tailed, we assume that the null hypothesis.

$$H_0: \mu = \mu_0$$

against the alternative hypothesis

$$H_1: \mu \neq \mu_0$$

is called Two Tailed Test.

PART-B

- 1.(a) A sample of 900 members has a mean 3.4 c.m and standard deviation 2.61 c.m. Is the Sample from a large population of mean 3.25 c.ms and standard deviation of 2.61c.ms? (Test at 5% L.O.S)

(AU-N/D-2016) -2(8)

- (b) The manufacturer of a medicine claimed that it was 90% effective in relieving an allergy for a period of 8 hours. In a sample of 200 people who had the allergy, the medicine provided relief for 160 people. Determine whether the manufacturer's claim is legitimate at 1% level of significance.

(AU-A/M-2019)(8)

2. (a) A test of the breaking strengths of 6 ropes manufactured by a company showed a mean breaking strength of 3515kg and a standard deviations of 60 kg, whereas the manufacturer claimed a mean breaking strength of 3630 kg. Can we support the manufacture's claim at a level of significance of 0.05.

(AU-A/M-2014)(8)

- (b) The independent samples from normal populations with equal variance gave the following:

Sample	Size	Mean	S.D
1	16	23.4	2.5
2	12	24.9	2.8

Is the difference between the means significant?

(AU-N/D-2019)(8)

3. (a) Examine whether the difference in the variability in yields is significant at 5% L.O.S, for the following.

(AU-M/J-2011)(8)

	Set of 40 Plots	Set of 60 Plots
Mean yield per Plot	1258	1243
S.D. per Plot	34	28

- (b) A certain medicine administered to each of the 10 patients resulted in the following increase in the B.P. 8, 8, 7, 5, 4, 1, 0, 0, -1, -1. Can it be conclude that the medicine was responsible for the increase in B.P at 5% level of significance.

(AU-N/D-2017)(8)

4. (a) A mathematics test was given to 50 girls and 75 boys. The girls made an average grade of 76 with a SD of 6, while boys made an average grade of 82 with SD of 2. Test whether there is any significant difference between the performance of boys and girls.

(AU-M/J-2016)-2(8)

- (b) A random sample of 100 bulbs from a company P shows a mean life 1300 hours and standard deviation of 82 hours. Another random sample of 100 bulbs from company Q showed a mean life 1248 hours and standard deviation of 93 hours. Are the bulbs of company superior to bulbs of a company Q at 5% level of significance?

(AU-N/D-2017)(8)

5. (a) The Mean height of 50 male students who showed above average participation in college athletics was 68.2 inches with a standard deviation of 2.5 inches ;while 50 male students who showed no interest in such participation had a mean height of 67.5 inches with a standard deviation of 2.8 inches

(1) Test the hypothesis that male students who participate in college athletics are taller than other male students.

(2) By how much should the sample size of each of the two groups be increase in order that the

observed difference of 0.7 inches in the mean height be significant at the 5% level of significance. (AU-N/D-2016)(8)

- (b) Given a sample mean of 83, a sample standard deviation of 12.5 and a sample size of 22, test the hypothesis that the value of the population mean is 70 against the alternative that it is more than 70. Use the 0.025 significance level. (AU-A/M-2018)(8)
6. (a) Two samples of sizes 9 and 8 give the sum of the squares of deviations from their respective means equal to 160 and 91 respectively. Can they be regarded as drawn from the same normal population? (AU-N/D-2019)(8)
- (b) A sample of 10 boys had the IQ's : 70, 83, 88, 95, 98, 100, 101, 107, 110 and 120. Do these data support the assumption of a population mean IQ of 100 at 5% level of significance? (AU-A/M 2018)(8)
7. (a) A sample of heights of 6400 Englishmen has a mean of 67.85 inches and a S.D of 2.56 inches, while a sample of heights of 1600 Australians has a mean of 68.55 inches and a S.D of 2.52 inches. Do the data indicate that Australians are on the average taller than Englishmen. (AU-N/D-2019)(8)
- (b) In the past the standard deviation of weights of certain 1135 gm. Packages filled by a machine was 7.1 grams. A random sample of 20 packages showed a standard deviation of 9.1 grams. Is the apparent increase in variability significant at 0.05 level of significance? (AU-A/M-2019)(8)

8. (a) Two independent samples of 9 and 7 from a normal population had the following values of the variable .
- | | | | | | | | | | |
|------------|----|----|----|----|----|----|----|----|----|
| Sample I : | 18 | 13 | 12 | 15 | 12 | 14 | 16 | 14 | 15 |
| Sample II: | 16 | 19 | 13 | 16 | 18 | 13 | 15 | | |
- Use 0.05 level of significance to test whether it is reasonable to assume that the variances of the two population's sample are equal. (AU-A/M-2017)(8)
- (b) A group of 10 rats fed on diet A and another group of 8 rats fed on diet B, recorded the following increase in weight.(gms)
- | | | | | | | | | | | |
|--------|---|---|---|---|----|---|---|---|---|----|
| Diet A | 5 | 6 | 8 | 1 | 12 | 4 | 3 | 9 | 6 | 10 |
| Diet B | 2 | 3 | 6 | 8 | 10 | 1 | 2 | 8 | - | - |
- Show that the estimates of the population variance from the sample are not significantly different. (AU-N/D-2016)-2(8)

9. (a) Time taken by workers in performing a job is given below:

Method 1	20	16	26	17	33	22
Method 2	27	33	42	35	34	38

Test whether there is any significant difference between the variances of the time distribution at 5% level of significance. (AU- N/D-2017)(8)

- (b) Two random samples gave the following results:

	Size	Sample mean	Sum of squares of deviation from the mean
1	10	15	90
2	12	14	108

Test whether the samples have come from the same normal population. (AU-N/D-2016)(8)

10. (a) The nicotine content in milligram of 2 samples of tobacco were found to be as follows:

Sample A	24	27	26	21	25	
Sample B	27	30	28	31	22	36

Can it be said that these samples were from normal population with the same mean

(AU- A/M-2018)(8)

- (b) A survey of 320 families with 5 children each revealed the following distribution:

Number of boys : 5 4 3 2 1 0

Number of girls : 0 1 2 3 4 5

Number of Families : 14 55 110 88 40 12

Is this result consistent with the hypothesis that male and female births are equally probable? (AU-M/J-2014)-3(8)

11. (a) Using the data given in the following table to test at 1% level of significance whether the person's ability in Mathematics is independent of his/her interest in Statistics.

Interest in Statistics	Ability in Mathematics		
	Low	Average	High
Low	63	42	15
Average	58	61	31
High	14	47	39

(AU-N/D-2017)(8)

- (b) The following data gives the number of aircraft accidents that occurred during the various days of a week. Find whether the accidents are uniformly distributed over the week.
(AU-N/D-2010)(8)

Days	Sun	Mon	Tues	Wed	Thu	Fri	Sat
No. of accidents	14	16	8	12	11	9	14

12. (a) Five coins are tossed 320 times . The number of heads observed is given below:

Number of heads	0	1	2	3	4	5
Frequency	15	45	85	95	60	20

Examine whether the coin is unbiased. Use 5% level of significance. (AU-A/M-2018)(8)

- (b) In a big city 325 men out of 600 men were found to be smokers. Does this information support the conclusion that the majority of men in this city are smokers? (AU-N/D-2010)-2(8)
13. (a) Theory predicts that the proportion of beans in four groups A, B, C, D should be 9:3:3:1. In an experiment among 1600 beans, the numbers in the four groups were 882, 313, 287 and 118. Does the experiment support the theory? (AU-M/J-2016)-2(8)

- (b) A sample analysis of examination results of 1000 students were made and it was found that 260 failed, 110 first class, 420 second class and rest obtained third class. Do these data support the general examination result in the ration 2:1:4:3. (AU-N/D-2019)(8)

14. (a) 1000 students at college level were graded according to their I.Q and their economic conditions. What conclusion can you draw from the following data:

Economic conditions	IQ Level	
	High	Low
Rich	460	140
Poor	240	160

(AU-M/J-2013)(8)

- (b) The sales manager of a large company conducted a sample survey in states A and B taking 200 samples in each case. The results were in the following table. Test whether the average sales in the same in the 2 states at 1% level

Average sales	State A	State B
	Rs. 2500	Rs. 2200
	S.D	Rs. 400
		Rs. 550

(AU-A/M-2017)(8)

15. (a) Find if there is any association between extravagance in fathers and extravagance in sons from the following data. Determine the coefficient of association also

	Extravagance father	Miserly father
Extravagance son	327	741
Miserly son	545	234

(AU-M/J-2013)(8)

- (b) Mechanical engineers testing a new arc welding technique, classified welds both with respect to appearance and an X-ray inspection

X-ray	Appearance			
		Bad	Normal	
	Bad	20	7	3
	Normal	13	51	16
	Good	7	12	21

Test for independence using 0.05 level of significance.

(AU-A/M-2018)(10)

16. (a) The average breaking strength of steel rods is specified to be 17.5 (in units of 1000 kg). To test this, a sample of 15 rods were tested and gave the following results: 15, 18, 16, 21, 19, 21, 17, 17, 15, 17, 20, 19, 17 and 18. Is the result of the experiments significant ? (AU-N/D-2018)(8)

- (b) A sample of size of 600 persons selected at random from a large city shows that the percentage of males in the sample is 53. It is believed that the ratio of males to the total population in the city is 1/2. Test whether the belief is confirmed by the observation. **(AU-N/D-2018)(8)**

17. (a) Two independent samples of sizes 9 and 7 from a normal population had the following values of the variables.

Sample I	18	13	12	15	12	14	16	14	15
Sample II	16	19	13	16	18	13	15	-	-

Do the estimates of the population variance differ significantly at 5 % level? **(AU-N/D-2018)(8)**

- (b) In an investigation into the health and nutrition of two groups of children of different social status, the following results are got. **(AU-N/D-2018)(8)**

Health	Social Status		Poor	Rich	Total
	Below Normal	Normal			
Below Normal	130	20	150		
Normal	102	108	210		
Above Normal	24	96	120		
Total	256	224	480		

Discuss the relation between the Health and their social status.

18. Two random samples are drawn from normal populations are given below: **(AU-A/M-2019)(16)**

Sample 1	17	27	18	25	27	29	13	17
Sample 2	16	16	20	27	26	25	21	

Can we conclude that the two samples are drawn. Test at 5 % level of significance?

19. (a) Fit a Poisson's distribution to the following data and test the goodness of fit. Test at 5 % level of significance. **(AU-A/M-2019)(8)**

x :	0	1	2	3	4	5
f :	142	156	69	27	5	1

- (c) A drug manufacturer claims that the proportion of patients exhibiting side effects to their new arthritis drug is at least 8 % lower than for the standard brand X. In a controlled experiment, 31 out of 100 patients receiving the new drug exhibited the side effects, as did 74 out of 150 patients receiving brand X. Test the manufacturer's claim at 5 % level of significance? **(AU-A/M-2019)(8)**

20. (a) The average income of persons was Rs. 210 and with Rs. 10 for S.D. in a sample of 100 people of a city. For another sample of 150 people the average income was Rs. 220 with S.D. of Rs. 12. Test whether there is any significant difference between the average income of the locality. **(AU-N/D-2019)(8)**

- (b) In one sample of 10 observations, the sum of squares of deviations of sample values from the sample mean was 120 and in another sample of 12 observations it was 314. Test whether this difference is significant at 5 % level of significance? **(AU-N/D-2019)(8)**

21. (a) A sample of 20 items has mean 42 units and S.D. 5 units. Test the hypothesis that it is a random sample from a normal population with mean 45 units. **(AU-N/D-2019)(8)**

- (b) In 120 throws of a single die, the following distribution of faces was observed.

Face	1	2	3	4	5	6
Frequency	30	25	18	10	22	15

Can you say that the die is biased? **(AU-N/D-2019)(8)**

UNIT – IV
DESIGN OF EXPERIMENTS
PART-A

- 1. What do you understand by the design of experiments?** (AU-N/D-2015)
 The design of experiment may be defined as the logical construction of the experiment in which the degree of uncertainty with which the inference is drawn may be well defined.
- 2. Define experimental error** (AU-N/D-2016)
 Experimental error is the difference between a measurement and the true value or between two measured values. Experimental error itself is measured by its accuracy and precision.
- 3. What are the Basic principles of an Experimental design?** (AU-N/D-2019)
 There are three basic designs of experiments
 - (i) Randomization
 - (ii) Replication
 - (iii) Local control (error control)
- 4. Define Randomization.**
 As it is not possible to eliminate completely the contribution of extraneous variables to the value of the response variable, we try to control it by randomization. The group of experimental units in which the manure is used is called the experimental group and the other group is called the control group.
- 5. Define Replication.**
 Replication means the repetition of the treatments under investigation. An experimenter resorts to replication in order to average out the influence of the chance factors on different experimental units. Thus, the repetition of treatments results in more reliable estimate than is possible with a single observation. Thus the precision of the experiment is inversely proportional to the square root of the replications consequently replication has an important but limited role in increasing the efficiency of the design.
- 6. What is the aim of the design of experiments?** (AU-N/D-2018)
 The main aim of the design of experiment is to control the extraneous variables and to minimize the error so that the results of the experiments could be attributed to the experimental values only.
- 7. State the advantages of a factorial experiment over a simple experiment.** (AU-N/D-2014)
 - (i) Factorial experiment is the procedure of varying all factors simultaneously.
 - (ii) An assessment of each individual factor effect is based on the whole set of measurements so that a more efficient utilization of experimental resources is achieved.
- 8. Define ANOVA** (AU-N/D-2016)-2
 Analysis of variance (ANOVA) is a technique that will enable us to test for the significance of the difference among more than two sample means.
- 9. Define Local Control.**
 The process of reducing the experimental error by dividing relatively the heterogeneous experimental area into homogeneous blocks is known as the local control. It increases the efficiency of the design by reducing the experimental error.
- 10. What are the uses of ANOVA?** (AU-A/M-2017)
 Analysis of variance is useful, for example, for determining (i) which of various training methods produces the fastest learning record, (ii) whether the effects of some fertilizers on the yields are significantly different, (iii) whether the mean qualities of outputs of various machines differ significantly etc. In fact this technique finds application in nearly every type of experimental design in natural sciences as well in social sciences.
- 11. What are the advantages of a Completely Randomized Experimental Design?** (AU-N/D-2016)-2
 The advantages of a Completely Randomized Experimental Design are as follows.
 - (a) Easy to lay out.
 - (b) Allows flexibility.
 - (c) Simple statistical analysis.
 - (d) The loss of information due to missing data is smaller than with any other design.
- 12. What are the assumptions you make in analysis of variance?** (AU-N/D-2018)
 (i) Each of the samples is drawn from a normal population.

- (ii) The variances for the population from which samples have been drawn are equal.
- (iii) The variation of each value around its own grand mean should be independent for each value.

13. Discuss the advantages and disadvantages of Randomized block design. (AU-A/M-2010)

Advantages:

- (i) It has a simple layout but it is more efficient than CRD because of reduction of experimental error.
- (ii) Analysis is possible even if some observations are missing.
- (iii) It is flexible and so any number of treatments and any number of replication may be used.

Disadvantages:

- (i) If the number of treatments is large, then the size of the blocks will increase this may cause heterogeneity within blocks.
- (ii) If the interactions are large, the experiment may yield misleading results.
- (iii) The shape of the experimental material should be rectangular.

14. Explain the situations in which randomized block design is considered an improvement over a completely randomized design. (AU-N/D-2014)

In RBD there are no restrictions on number of treatments on the number of replicates.

15. What are the advantages of a Latin square design? (AU-N/D-2019)

- (i) Statement should clearly mention the hypothesis to be tested.
- (ii) Description should include the type of experimental material, size of the experiment and the number of replication
- (iii) The outline of method consists of analysis of variance.

16. Write the advantages of the Latin square design over the other design. (AU-M/J-2012)

- (i) With a two-way stratification, the Latin square controls more of the variation than the completely randomized design or the randomized completely block design. The two way elimination of variation often results in small error mean square.
- (ii) The analysis is simple; it is only slightly more complicated than that for the randomized complete block design.
- (iii) The analysis remains relatively simple even with missing data.

17. What is main advantage of LSD over RBD? (AU-M/J-2011)

LSD is superior to the RBD because, Experimental error is reduced to a large extent, because variation is controlled in two directions.

18. What is the Latin square design? (AU-A/M-2019)

The term Latin square takes its name from a figure of mathematical puzzle that was studied many years before, its use as a plan of experiment. Latin squares are very extensively used in agricultural trial in order to eliminate fertility trends in two directions simultaneously. The data are classified according to the different criteria, according to columns, rows and varieties and are arranged in a square known as Latin Square

19. Is 2x2 Latin square Design possible? Why? (AU-A/M-2015)

In Latin square, the formula for degrees of freedom for residual is $= (n-1)(n-2)$.

Substituting $n = 2$, d.f = 0.

$MSE = \infty$

Therefore 2x2 Latin square is not possible.

20. Compare one-way classification model with two-way classification model. (AU-N/D-2010)

In a two-way classification method, we can test two sets of hypothesis with the same data at the same time but in one-way classification method, we cannot test two sets of hypothesis. In a one-way classification method of analysis of variance the treatments constitute different levels of a single factor which is controlled in the experiment. There are however, many situations in which the response variable of interest may be affected by more than one factor. That it is solved by two way classification method of a time.

21. Write down the format the ANOVA table for one factor of classification. (AU-A/M-2018)

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	Ratio of F
Between classes	Q_1	$h-1$	$Q_1 / (h-1)$	$\left[\frac{Q_1 / (h-1)}{Q_2 / (N-h)} \right]^{\pm 1}$
Within classes	Q_2	$N-h$	$Q_2 / (N-h)$	-
Total	Q	$N-1$	-	-

22. Write down the format the ANOVA table for two factors of classification.

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	Ratio of F
Between rows	Q_1	$h-1$	$Q_1 / (h-1)$	$\left[\frac{Q_1 / (h-1)}{Q_3 / (h-1)(k-1)} \right]^{\pm 1}$
Between Columns	Q_2	$k-1$	$Q_2 / (k-1)$	$\left[\frac{Q_2 / (k-1)}{Q_3 / (h-1)(k-1)} \right]^{\pm 1}$
Residual of error	Q_3	$(h-1)(k-1)$	$Q_3 / (h-1)(k-1)$	-
Total	Q	$hk-1$	-	-

23. Write down the ANOVA table for Latin square. (or) Write down the format the ANOVA table for three factors of classification.

Source of variation	Sum of squares	Degrees of freedom	Mean sum of squares	Ratio of F
Between rows	Q_1	$n-1$	$Q_1 / (n-1)=M_1$	$\left[\frac{M_1}{M_4} \right]^{\pm 1}$
Between Columns	Q_2	$n-1$	$Q_2 / (n-1)=M_2$	$\left[\frac{M_2}{M_4} \right]^{\pm 1}$
Between letters	Q_3	$n-1$	$Q_3 / (n-1)=M_3$	$\left[\frac{M_3}{M_4} \right]^{\pm 1}$
Residual of error	Q_4	$(n-1)(n-2)$	$Q_4 / (n-1)(n-2)=M_4$	-
Total	Q	n^2-1	-	-

24. Define 2^2 factorial experiment

(AU-N/D-2013)

A factorial design with 2 factors, each at two levels is called a 2^2 factorial design.

25. State the advantage of a factorial experiment over a simple experiment? (AU-A/M-2010)

Experiments dealing with only one factor are known as simple experiments but in Factorial experiment involving several factors where it is necessary to the joint effect of the factors on a response.

26. State the identity for sum of squares for one – way of analysis of variance. (AU-A/M-2019)

Then, 'between column' sum of squares : SSC =

'Within column' sum of squares : SSE =

Total sum of squares : TSS =

PART – B

1. The following table shows the lives in hours of four brands of electric lamps.

Brand

(AU-N/D-2015)(16)

- A: 1610, 1610, 1650, 1680, 1700, 1720, 1800
 B: 1580, 1640, 1640, 1700, 1750
 C: 1460, 1550, 1600, 1620, 1640, 1660, 1740, 1820
 D: 1510, 1520, 1530, 1570, 1600, 1680

- Perform an analysis of variance and test the homogeneity of the mean lives of the four brands of lamps
 2. The result of an RBD experiment on 3 blocks with 4 treatments is tabulated below. Carry out an analysis of variance. **(AU-M/J-2016)(16)**

Blocks	Treatment effects			
	A36	D35	C21	B36
I	A36	D35	C21	B36
II	D32	B29	A28	C31
III	B28	C29	D29	A26

3. Given

Detergent	Engine		
	1	2	3
A	45	43	51
B	47	46	52
C	48	50	55
D	42	37	49

Perform ANOVA and test at 0.05 level of significance whether there are differences in the detergents or in the engines. **(AU-N/D-2015)(16)**

4. Three varieties of coal were analyzed by 4 chemists and the ash content is tabulated here. Perform an analysis of variance. **(AU-M/J-2016)(16)**

	Chemists			
	A	B	C	D
Coal	8	5	5	7
	7	6	4	4
	3	6	5	4

5. The following table gives the yields of 15 samples of plot under three varieties of seed.

A	20	21	23	16	20
B	18	20	17	15	25
C	25	28	22	28	32

Test using analysis of variance whether there is any significant difference in the average of yield of seeds. **(AU-N/D-2016)(16)**

6. The following data represent a certain person to work from Monday to Friday by four different routes. Test at 5% level of significance whether the differences among the means obtained for the different routes are significant and also whether the differences among the means obtained for the different days of the week are significant. **(AU-N/D-2017)(16)**

Routes	Days				
		Mon	Tue	Wed	Thu
1	22	26	25	25	31
2	25	27	28	26	29
3	26	29	33	30	33
4	26	28	27	30	30

7. (a) A set of data involving A,B,C,D tried on 20 chicks 20 chicks are treated the feeding treatments and each feeding treatment is given to 5 chicks. Analyze the data:

A	55	49	42	21	52
B	61	112	30	89	63
C	42	97	81	95	92
D	169	137	169	85	154

(b) Perform a 2-way ANOVA on the data given below:

4 tropical food stuffs is given below. All the alike in all respects except

(AU-A/M-2017)(8)

		Treatment 1		
		1	2	3
Treatment 2	1	30	26	38
	2	24	29	28
	3	33	24	35
	4	36	31	30
	5	27	35	33

9. The table shows the yield of paddy in arbitrary units obtained from four different varieties planted in five blocks where each block is divided into four plots. Test at 5% level whether the yields vary significantly with (i) soil differences (ii) differences in the type of paddy.

Blocks	Types of Paddy			
	I	II	III	IV
A	12	15	10	14
B	15	19	12	11
C	14	18	15	12
D	11	16	12	16
E	16	17	11	14

Carry out an analysis of variances.

(AU-N/D-2019)(16)

10. A chemist wishes to test the effect of four chemical agents on the strength of a particular type of cloth. Because there might be variability from one bolt to another, the chemist decides to use a randomized block design, with the bolts of cloth consider as blocks, she selects five bolts and applies all four chemicals in random order to each bolt. .The resulting tensile strengths follows:

Chemical	Bolt				
	1	2	3	4	5
1	73	68	74	71	67
2	73	67	75	72	60
3	75	68	78	73	68
4	73	71	75	75	69

Does the tensile strength depend on chemical? Test at $\alpha = 0.10$

(AU-A/M-2018)(16)

11. A farmer wishes to test the effects of four different fertilizers A, B, C, D on the yield of wheat. In order to eliminate sources of error due to variability in soil fertility, he uses the fertilizers, in a Latin square arrangement as indicated in the following table, where the numbers indicate yields in bushels per unit area.

A 18	C 21	D 25	B 11
D 22	B 12	A 15	C 19
B 15	A 20	C 23	D 24
C 22	D 21	B 10	A 17

Perform an analysis of variance to determine if there is a significant difference between the fertilizers at $\alpha = 0.05$ levels of significance.

(AU-A/M-2019)(16)

12. A variable trial was conducted on wheat with 4 varieties in a Latin square design. The plan of the experiment and the per plot yield are given below.

C	25	B	23	A	20	D	20
A	19	D	19	C	21	B	18
B	1	A	14	D	17	C	20
D	17	C	20	B	21	A	15

Analyze data and interpret the result.

(AU-N/D-2016)(16)

13. Analyze the variance in the Latin square of yields (in kgs) of paddy where P, Q, R, S denote the

different methods of cultivation.

Examine whether the different methods of cultivation have given significantly different yields

(AU-N/D-2019)-4(16)

14. A Latin square design was used to compare the bond strengths of gold semi conductor lead wires bounded to the lead terminal by 5 different methods, A, B, C, D and E. The bonds were made by 5 different operators and the devices were encapsulated using 5 different plastics, with the following results, expressed as pounds of force required to break the bond.

Plastics	Operator				
	1	2	3	4	5
1	A 3	B 2.4	C 1.9	D 2.2	E 1.7
2	B 2.1	C 2.7	D 2.3	E 2.5	A 3.1
3	C 2.1	D 2.6	E 2.5	A 2.9	B 2.1
4	D 2.0	E 2.5	B 3.2	B 2.5	C 2.2
5	E 2.1	A 3.6	B 2.4	C 2.4	D 2.1

Analyze these results and test with 0.01 level of significance.

(AU- A/M-2018)(16)

15. Four air-conditioning compressor designs were tested in four different regions of India. The test was repeated by installing additional air conditioners in a second cooling season. The following are the times to failure of each compressor tested.

Design	Replicate 1				Replicate 2			
	A	B	C	D	A	B	C	D
Northeast	58	35	72	61	49	24	60	64
Southeast	40	18	54	38	38	22	64	50
Northwest	63	44	81	52	59	16	60	48
southwest	36	09	47	30	29	13	52	41

Test at the 0.05 level of significance whether the differences among the means determined for designs, for regions, and are significant and for significance of the interaction between compressor designs and regions.

(AU-N/D-2017)(16)

16. Find out the main effects and interactions in the following 2^2 – factorial experiment and write down the ANOVA table

	I	a	b	ab
Block	00	10	01	11
I	64	25	30	6
II	75	14	50	33
III	76	12	41	17
IV	75	33	25	10

17. The following data resulted from an experiment from an experiment to compare three burners B1, B2 and B3. A Latin square design was used as the tests were made on 3 engines and were spread over 3 days.

	Engine 1	Engine 2	Engine 3
Day 1	B1-16	B2-17	B3-20
Day 2	B2-16	B3-21	B1-15
Day 3	B3-15	B1-12	B2-13

Test the hypothesis that there is no difference between the burners.

(AU-N/D-2018)(16)

18. An experiment was performed to judge the effect of four different fuels and three different types of launchers on the range of a certain rocket. Test, on the basis of following ranges in miles, whether there is a significant effect due to differences in fules and, whether there is a significant effect due to differences in launchers. Use the 0.01 level of significance. **(AU-A/M-2019)(16)**

	Fuel 1	Fuel 2	Fuel 3	Fuel 4
Launcher X	45	47	48	42
Launcher Y	43	46	50	37
Launcher Z	51	52	55	49

19. As part of the investigation of the collapse of the roof of a building, a testing laboratory is given all the available bolts that connected the steel structure at 3 different positions on the roof. The forces required to shear each of these bolts (coded values) are as follows :

Position 1	90	82	79	98	83	91	
Position 2	105	89	93	104	89	95	86
Position 3	83	89	90	94			

Perform an analysis of variance to test at the 0.05 level of significance whether the differences among the sample means at the 3 positions are significant. **(AU-A/M-2019)(16)**

20. The table shown below gives the samples got from the normal population with equal variances. Test the hypothesis that the sample mean is equal at 5 % level of significance. **(AU-N/D-2019)(16)**

A	8	10	12	8	7
B	12	11	14	9	4
C	18	16	12	8	6
D	16	15	13	12	9

21. Four varieties A, B, C, D of a fertilizer are tested in a randomized block design with 4 replications. The plot yields, in pounds are as follows. Analyse the experimental yield.

Column Row	1	2	3	4
1	A12	D20	C16	B10
2	D18	A14	B11	C14
3	B12	C15	D19	A13
4	C16	B11	A15	D20

UNIT-V**STATISTICAL QUALITY CONTROL****PART-A****1. Write the formula for control chart value of a C-Chart.**

The formula for control value of a c-chart is $\bar{c} = \frac{1}{N}(c_1 + c_2 + c_3 + \dots + c_N)$, where c_i is the number of defects in the i th unit.

2. What is the purpose of using control channel?

The Control charts help us to decide whether the process of production is in control or not.

3. How many control charts are there?

There are two types of control charts. They are,

- (i) Control charts for variables.
- (ii) Control charts for attributes.

4. Write down the formula for Mean chart.

For drawing the mean chart, we draw the three lines $y = \bar{X}$, $y = \bar{X} - A_2 \bar{R}$ and $y = \bar{X} + A_2 \bar{R}$ which represent respectively the central line, LCL line and UCL line.

5. What are the charts we can use when the quality of a product is measurable quantitatively?

The quality of a product is measurable quantitatively, we use control charts namely

- (i) \bar{X} - chart
- (ii) R - chart

6. What are the three horizontal lines in control charts?

The three horizontal lines in control charts are Center line, UCL and LCL.

7. What is Statistical quality control?

When the variability present in a production process is due to chance variations alone the process is said to be in a state of Statistical quality control.

8. Write down advantage of SQC.

- 1) It provides a means of detecting error at inspection.
- 2) It leads to more uniform quality of production.
- 3) It improves the relationship with the customer.

9. Define chance variation and assignable variation?

(AU-N/D-2018)

This is the variations, which may occur due to many minor causes but which behave in a random manner.

This is the variations due to special non-random causes such as fatigue of technicians, a change in the raw material used, a new operation, improper machine testing, mechanical faults in the plant etc.,

10. Define Process control.

Statistical quality control may be applied to any repetitive process and control charts constructed by using statistical techniques helps us to find out whether the manufacturing process, for example, is under

control or it has a tendency to go out of control soon.

11. Define Product control.

This is the inspection of materials to determine their acceptability i.e., whether the lots contain too many defective items than expected. It is also called as lot control.

12. What is Control Chart?

A Control chart is essentially a diagrammatic presentation of data designed to reveal the frequency and extent of variations from established specifications or standards or goals

13. Write down types of Acceptance sampling plan.

The theory of acceptance sampling plan is categorized into four types and they are listed below:

- Lot by lot sampling with attributes inspection
- Lot by lot sampling with measurements on variables
- Continuous sampling flows of units with inspection of attributes
- Special purpose plans like, chain sampling; skip lot sampling, reliability sampling, etc.

14. Define OC Curve.

There are different types of sampling plans and an excellent graphical representation to judge various acceptance sampling plans and compare their performance over a range of quality levels of a product by a curve called operating characteristic curve (OC curve).

15. Write the formula for np-chart.

Central line: \bar{p} = Average no. of defectives

$$\bar{p} = \frac{\text{No. of defective item}}{\text{No. of samples X sample size}}$$

$$UCL = \bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$$

$$LCL = \bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$$

16. What is meant by AQL and LTPD.

AQL is typically considered to be the worst **quality level** that is still considered satisfactory. The LTPD of a sampling plan is a level of quality routinely rejected by the sampling plan.

17. What is the formula for c chart and p chart?

The formula for c chart is, $\bar{c} = \frac{\text{Total number of defects}}{\text{No. of samples}}$

$$UCL = \bar{c} + 3\sqrt{\bar{c}}, LCL = \bar{c} - 3\sqrt{\bar{c}}$$

$$\text{The formula for p chart is, } UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}, LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

18. Define Acceptance Sampling.

The specified number of defectives that a lot can have at the most is called acceptance sampling.

19. Explain producers Risk and Consumer Risk.

Producer's risk is that risk a producer takes in a situation where a lot is rejected by a sampling plan when infact it confirms to the quality standards. This is called Type I error and it is denoted by α .

Consumer's risk is that risk a customer takes in a situation where a lot is accepted when it is infact of bad quality. This is called Type II error and it is denoted by β .

20. Define Tolerance limits.

(AU-A/M-2019)

Tolerance limits are limits that include a specific proportion of the population at a given confidence level. It is proposed to obtain long-term and short-term estimates of the process tolerances and to use them

in capability analysis as an alternative method to the use of capability ratios.

21. Determine UCL for the number of defects from the following data which give the number of defects in 15 pieces of cloth of equal length when inspected in a textile mill.

Number of defects : 3, 4, 2, 7, 9, 6, 5, 4, 8, 10, 5, 8, 7, 7, 5. (AU-N/D-2018)

22. A garment was sample on 10 consecutive hours of production. The number of defects found per garment is given below :

Defects : 5, 1, 7, 0, 2, 3, 4, 0, 3, 2. Compute upper and lower control limits of monitoring number of

defects.

(AU-A/M-2019)

23. Explain upper control limit and lower control limits in quality control.

(AU-N/D-2019)

$$UCL = \bar{X} + A_2 \bar{R}, LCL = \bar{X} - A_2 \bar{R}$$

$$UCL = D_3 \bar{R}, UCL = D_4 \bar{R}$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}}, LCL = \bar{c} - 3\sqrt{\bar{c}}$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}, LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$UCL = \bar{p} + 3\sqrt{\bar{p}(1-\bar{p})}, LCL = \bar{p} - 3\sqrt{\bar{p}(1-\bar{p})}$$

PART-B

1. Construct a control chart for the proportion of defectives for the following data:

Sample No	: 1	2	3	4	5	6	7	8	9	10
No. of. inspected	: 90		65	85	70	80	80	70	95	90
No. of. defective	: 9	7	3	2	9	5	3	9	6	7

Comment the nature of the process.

2. Define (i) Acceptance Quality Level (ii) Lot Tolerance proportion Defective (iii) Single Sample Plan.

3. A machine fills boxes with dry cereal. 15 samples of 4 boxes are drawn randomly. The weights of the sampled boxes are shown as follows. Draw the control charts for the sample mean and sample range and determine whether the process is in a state of control.

Sample No.	1	2	3	4	5	6	7	8
Weights of Boxes (X)	10.0	10.3	11.5	11.0	11.3	10.7	11.3	12.3
	10.2	10.9	10.7	11.1	11.6	11.4	11.4	12.1
	11.3	10.7	11.4	10.7	11.9	10.7	11.1	12.1
	12.4	11.7	12.4	11.4	12.1	11.0	10.3	10.7
Sample No.	9	10	11	12	13	14	15	
Weights of Boxes (X)	11.0	11.3	12.5	11.9	12.1	11.9	10.6	
	13.1	12.1	11.9	12.1	11.1	12.1	11.9	
	13.1	10.7	11.8	11.6	12.1	13.1	11.7	
	12.4	11.5	11.3	11.4	11.7	12.0	12.1	

4. The following data give the average life in hours and range in hours of 12 sample each of 15 lamps.

Construct the control charts for \bar{X} and R and comment on the state of control.

(AU-A/M-2019)(16)

\bar{X}	12	12	15	15	16	13	13	12	14	14	12	12
0	7	2	7	0	4	7	3	0	4	0	7	7
R	30	44	60	34	38	35	45	62	39	50	35	41

5. On inspection of 10 samples, each of size 400, the number of defective articles was

19 4 9 12 9 15 26 14 15 17

Draw the np chart and p chart and comment on the state of control.

6. The following data relate to the number of defects in each of 15 units drawn randomly from a production process. Draw the control or the number of defects and comment on the state of control.

6 4 9 10 11 12 20 10 9 10 15 10 20 15 10

7. The specification for a certain quality characteristic are 15.0 ± 6.0 . 15 samples of 4 readings each gave the following values of \bar{X} and R.

Sam ple No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
\bar{X}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
R	3	2	5	2	4	2	2	3	5	2	1	1	4	5	2
0	.0	.1	.6	.4	.1	.7	.3	.8	.0	.9	.3	.8	.9	.6	.2

Compute the control limits for \bar{X} and R charts using the above data for all the samples. If not, remove the doubtful samples and re-compute the revised s for \bar{X} control limit. After testing the state of control, estimate the tolerance limits and find if the process will meet the required specification.

8. Explain the charts that are used for attributes.

9. What do you understand by SQC. Discuss its utility and limitations?

10. The following data give the weight of an automobile part. Five samples of four items each were taken on a random sample basis (at an interval of 1 hour each). Draw the mean Control Chart and find out if the production process is in control.

Sample	Weight of the parts in ounces			
1		12	10	12
2		12	13	13

3	10	10	9	11
4	10	10	9	14
5	10	12	12	12

11. Write the role and advantages of SQC.

12. You are given the value of sample means \bar{X} and Range for 10 samples of size 5 each. Draw mean chart and comment on the state of control of the process.

Sample No	1	2	3	4	5	6	7	8	9	10
X	4	49	37	44	45	37	51	46	43	47
R	5	6	5	7	7	4	8	6	4	6

13. The following data relate to the life (in hours) of 10 samples of 6 electric bulbs each drawn at an interval of one hour from a production process. Draw the control chart for \bar{X} and R comment.

Sample No.	Life time (in hours)					
1	620	687	666	689	738	686
2	501	585	524	585	653	668
3	673	701	686	567	619	660
4	646	626	572	628	631	743
5	494	984	659	643	660	640
6	634	755	625	582	683	555
7	619	710	664	693	770	534
8	630	723	614	535	550	570
9	482	791	533	612	497	499
10	706	524	626	503	661	754

(Given for n = 6, $A_2 = 0.483$, $D_3 = 0$, $D_4 = 2.004$)

14. For a sampling plan $N = 1,200$, $n = 64$ and $c = 1$, determine the probability of acceptance of the following lots; (i) 0.5% defective (ii) 0.8% defective (iii) 1% defective (iv) 2% defective (v) 4% defective (vi) 10% defective. Also draw and OC curve.

15. 10 samples each of size 50 were inspected and the number of defectives in the inspection were : 2, 1, 1, 2, 3, 5, 5, 1, 2, 3. Draw the appropriate control chart for defectives.

16. A machine is set to deliver packets of a given weight, 10 samples of size 5 each were recorded. Below are given the relevant data:

Sample No	1	2	3	4	5	6	7	8	9	10
X	1	17	15	1	17	1	18	15	17	16
R	5	8	4	9	8	4	12	4	11	5

Calculate the values of the Central Line and the control limits for the mean chart and the range chart and then comment on the state of control. (Conversion factors for n = 5 are $A_2 = 0.58$, $D_3 = 0$, $D_4 = 2.115$).

17. Explain in detail the R-Chart clearly?

18. The following data show the values of sample mean \bar{X} and the range R for the samples of size 5 each. Calculate the values for central line and control limits for mean-chart and range chart and determine whether the process is in control.

Sample No	1	2	3	4	5	6	7	8	9	10
\bar{X}	11	11	10	11	11	9.	10	9.6	10	1

.2	.8	.8	.6		6	.4		.6	0
----	----	----	----	--	---	----	--	----	---

R	7	4	8	5	7	4	8	4	7	9
---	---	---	---	---	---	---	---	---	---	---

(Conversion factors for $n = 5$ are $A_2 = 0.577$ $D_3 = 0$, $D_4 = 2.115$)

19. Explain in detail the \bar{X} Chart clearly?

20. The following table gives the inspection data relating to 10 samples of 100 items each, concerning the production of bottle corks.

Sample Number	Size of Sample	Number of Defectives	Fraction Defective
1	100	5	.05
2	100	3	.03
3	100	3	.03
4	100	6	.06
5	100	5	.05
6	100	6	.06
7	100	8	.08
8	100	10	.10
9	100	10	.10
10	100	4	.04

Construct a p- chart.

21. 15 tape-recorders were examined for quality control test. The number of defects in each tape-recorder is recorded below. Draw the appropriate control chart and comment on the state of control.

Unit No (i)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
15														
No of defects (c)	2	4	3	1	1	2	5	3	6	7	3	1	4	2

22. Construct chart for following data

Sample No	1	2	3	4	5	6	7	8
	32	28	39	50	42	50	44	22
Observation	36	32	52	42	45	29	52	35
	42	40	28	31	34	21	35	44

Also determine whether the process is in control.

23. The following data gives the number of defectives in 10 samples each of size 100. Construct a np chart for these data and also determine whether the process is in control **(AU-A/M-2019)(8)**

Sample No.	1	2	3	4	5	6	7	8	9	10
No. of defectives	24	3	6	3	2	3	38	5	33	44

24. The data given below are the number of defectives in 10 samples of 100 items each. Construct a p-chart and np-chart and comment on the results **(AU-N/D-2019)(16)**

Sample No.	1	2	3	4	5	6	7	8	9	10
No. of defectives	6	1	7	3	8	1	7	1	1	4

State your conclusions. Write all the steps in the construction of the above chart including formula for UCL and LCL.

25. Write the Procedure for acceptance sampling.

26. Construct a Control Chart for fraction defectives (p-Chart) for following data. **(AU-A/M-2019)(8)**

Sample No.	1	2	3	4	5	6	7	8	9	10
Sample Size	90	65	85	70	80	80	70	95	90	75
No of defectives	9	7	3	2	9	5	3	9	6	7

27. Explain Control Limits for the sample mean \bar{X} and sample range R.

28. An inspection of 10 samples of size 400 each from 10 lots revealed the following number of defective units 17, 15, 14, 26, 9, 4, 19, 12, 9, 6.

29. Write the Procedure to draw the X-chart and R-chart.

30. Construct R chart for following data

Sample No.	Observation					Comment on State of Control.
1	1.7	2.2	1.9	1.2		
2	0.8	1.5	2.1	0.9		
3	1	1.4	1	1.3		
4	0.4	0.6	0.7	0.2		
5	1.4	2.3	2.8	2.7		
6	1.8	2	1.1	0.1		
7	1.6	1.	1.5	2		
8	2.5	1.6	1.8	1.2		
9	2.9	2	0.5	2.2		

31. A machine fills boxes with dry cereal. 15 samples of 4 boxes are drawn randomly. The weights of the sampled boxes are shown as follows.

Draw the control charts for the sample mean and sample range and determine whether the process is in a state of control.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight of Boxes (X)	10.3	10.5	11.1	11.3	11.7	10.3	11.3	12.3	11.3	11.5	12.9	11.1	12.9	11.6	10.
	10.9	10.7	10.1	11.6	11.4	11.4	11.1	12.1	13.1	12.1	11.9	12.1	11.1	12.1	11.
	11.7	10.4	11.4	10.9	11.7	10.1	11.7	12.1	13.1	10.7	11.8	11.6	12.1	13.1	11.
	12.4	11.7	12.4	11.1	12.1	11.3	10.7	10.4	12.5	11.3	11.4	11.7	11.1	12.7	12.

32. The following are the \bar{X} and R values for 20 samples of readings. Draw \bar{X} chart and R chart and write your conclusion.

Samples	1	2	3	4	5	6	7	8	9	10	Comment on State of Control.
\bar{X}	34	31.6	30.8	33	35	33.2	33	32.6	33.8	37.8	
R	4	4	2	3	5	2	5	13	19	6	
Samples	11	12	13	14	15	16	17	18	19	20	

\bar{X}	3 5.8	38 .4	34	35	38 .8	3 1. 6	33	28 .2	31 .8	35 .6	
R	4	4	14	4	7	5	5	3	9	6	
(Given for n = 5 are $A_2 = 0.58$ $D_3 = 0$, $D_4 = 2.12$)											

33. The following table gives the sample means and ranges for 10 samples, each of size 6, in the production of certain component. Construct the control charts for mean and range and comment on the nature of control. **(AU-N/D-2019)(16)**

Sample s	1	2	3	4	5	6	7	8	9	10
\bar{X}	37. 3	49 .8	51 .5	59. 2	54. 7	34 .7	5 1.4	61 .4	70 .7	75 .3
R	9.5	12 .8	10 .0	9.1	7.8	5. 8	1 4.5	2. 8	3. 7	8. 0

34. The following are the figures for the number of defectives of 10 samples each containing 100 items : 8, 10, 9, 8, 10, 11, 7, 9, 6, and 12. Draw control chart for fraction defective and comment on the state of control of the process. **(AU-N/D-2018)(8)**

35. 20 pieces of cloth out of different rolls contained respectively 1, 4, 3, 2, 4, 5, 6, 7, 2, 3, 2, 5, 7, 6, 4, 5, 2, 1, 3 and 8 imperfections. ascertain whether the process is in a state of statistical control. **(AU-N/D-18)(8)**

TWO MARK QUESTIONS AND ANSWERS

1. Define fluid and fluid mechanics.

Fluid may be defined as a substance which is capable of flowing and deforms continuously under the application of constant application of shear force. It has no definite shape of its own, but confirms to the shape of the containing vessel.

It is the branch of science, which deals with the behavior of the fluids (liquids or gases) at rest as well as in motion.

2. Define Mass Density.

Mass Density or Density is defined as ratio of mass of the fluid to its volume (V) or mass per unit volume. Density of water = 1 gm/cm³ or 1000 kg / m³.

$$\rho = \frac{\text{Mass of fluid}}{\text{Volume of fluid}}$$

3. Define Specific Weight.

It is the ratio between weight of a fluid to its volume.

$$w = \frac{\text{Weight of fluid}}{\text{Volume of fluid}} = \left(\frac{\text{Mass of fluid}}{\text{Volume of fluid}} \right) \times g = \rho \times g$$

$$w = \rho \times g$$

Unit: N / m³

4. Define Viscosity.

Viscosity is defined as the property of fluid, which offers resistance to the movement of one layer of fluid over another adjacent layer of fluid. When two layers move one over the other at different velocities, say u and u+ du, the viscosity together with relative velocity causes a shear stress acting between the fluid layers. The top layer causes a shear stress on the adjacent lower layer while the lower layer causes a shear stress on the adjacent top layer. This shear stress is proportional to the rate of change of velocity.

$$\tau = \mu \frac{du}{dy}$$

$\mu \Rightarrow$ Coefficient of dynamic viscosity (or) only viscosity
 du / dy = rate of shear strain

5. Define Specific Volume.

Volume per unit mass of a fluid is called specific volume.

$$\text{sp.vol.} = \frac{\text{volume of fluid}}{\text{mass of fluid}} .$$

Unit: m^3 / kg

6. Define Specific Gravity.

Specific gravity is the ratio of the weight density or density of a fluid to the weight density or density of standard fluid. It is also called as relative density.

Unit : Dimension less. Denoted as 'S'

$$S(\text{for liquid}) = \frac{\text{Weight density of liquid}}{\text{Weight density of water}}$$

7. Calculate the specific weight, density and specific gravity of 1 litre of liquid which weighs 7 N.

Solution:

$$\text{Given } V = 1 \text{ litre} = \frac{1}{1000} m^3$$

$$W = 7 \text{ N}$$

i. Sp. Weight (w) = $\frac{\text{weight}}{\text{volume}} = \frac{7 \text{ N}}{\frac{1}{1000} m^3} = 7000 \text{ N/m}^3$

ii Density (p) = $\frac{w}{g} = \frac{7000 \text{ N}}{9.81 \text{ m}^3} \text{ kg/m}^3 = 713.5 \text{ Kg/m}^3$

iii. Sp. Gravity (S) = $\frac{\text{Density of liquid}}{\text{Density of water}} = \frac{713.5}{1000}$ (Density of water = 1000 kg / m³)

$$S = 0.7135$$

8. State Newton's Law of Viscosity. (Nov-Dec 2018)

It states that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain. The constant of proportionality is called the co-efficient of viscosity

$$\boxed{\tau = \mu \frac{du}{dy}}$$

9. Name the Types of fluids.

1. Ideal fluid
2. Real fluid
3. Newtonian fluid
4. Non-Newtonian fluid.
5. Ideal plastic fluid

10. Define Kinematic Viscosity.

It is defined as the ratio between the dynamic viscosity and density of fluid.

Represented as γ ; $\nu = \frac{\text{Viscosity}}{\text{Density}} = \frac{\mu}{\rho}$

Unit: m² / sec.

$$1 \text{ Stoke} = \frac{Cm^2}{S} = \left(\frac{1}{100} \right)^2 \frac{m^2}{S} = 10^{-4} m^2 / s.$$

$$\text{Centistoke means } = \frac{1}{100} \text{ stoke}$$

11. Find the Kinematic viscosity of an oil having density 981 kg/m. The shear stress at a point in oil is 0.2452 N/m² and velocity gradient at that point is 0.2 /sec.

Mass density $p = 981 \text{ kg/m}^3$, Shear stress $\tau = 0.2452 \text{ N/m}^2$

$$\text{Velocity gradient } \frac{du}{dy} = 0.2$$

$$\tau = \mu \frac{du}{dy}$$

$$0.2452 = \mu \times 0.2 \Rightarrow \mu = \frac{0.2452}{0.2} = 1.226 \text{ Ns/m}^2$$

$$\text{kinematic viscosity}(\nu) = \frac{\mu}{p} = \frac{1.226}{981}$$

$$= 0.125 \times 10^{-2} \text{ m}^2/\text{s}$$

$$= 0.125 \times 10^{-2} \times 10^4 \text{ cm}^2/\text{s}$$

$$= 12.5 \text{ stoke.}$$

12. Determine the specific gravity of a fluid having viscosity 0.05 poise and Kinematic viscosity 0.035 stokes.

Given: Viscosity, $\eta = 0.05 \text{ poise} = (0.05 / 10) \text{ Ns/m}^2$.

$$\begin{aligned} \text{Kinematic viscosity } \dot{\nu} &= 0.035 \text{ stokes} = 0.035 \text{ cm}^2/\text{s} \\ &= 0.035 \times 10^{-4} \text{ m}^2/\text{s} \end{aligned}$$

$$\boxed{\nu = \frac{\mu}{P}}$$

$$0.035 \times 10^{-4} = \frac{0.05}{10} \times \frac{1}{p} \Rightarrow p = 1428.5 \text{ kg/m}^3$$

$$\text{Specific gravity of liquid} = \frac{\text{Density of liquid}}{\text{Density of water}} = \frac{1428.5}{1000} = 1.428 = 1.43$$

13. Define Compressibility.

Compressibility is the reciprocal of the bulk modulus of elasticity, K which is defined as the ratio of compressive stress to volumetric strain.

$$\begin{array}{ll} V & \rightarrow \text{Volume of gas enclosed in the cylinder} \\ P & \rightarrow \text{Pressure of gas when volume is } \nabla \end{array}$$

$$\text{Increase in pressure} = dp \text{ kgf / m}^2$$

$$\text{Decrease of volume} = d\nabla$$

$$\therefore \text{Volumetric strain} = \frac{-d\nabla}{\nabla}$$

- Ve sign → Volume decreases with increase in pressure

$$\therefore \text{Bulk modulus } K = \frac{\text{Increase of Pressure}}{\text{Volumetric strain}} = \frac{d_p}{-\frac{d\nabla}{\nabla}} = -\frac{d_p}{d\nabla} \nabla$$

$$\boxed{\text{Compressibility} = \frac{1}{K}}$$

14. Define Surface Tension.

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

Unit: N / m.

15. Define Capillarity:

Capillary is defined as a phenomenon of rise of a liquid surface in a small tube relative to adjacent general level of liquid when the tube is held vertically in the liquid. The resistance of liquid surface is known as capillary rise while the fall of the liquid surface is known as capillary depression. It is expressed in terms of cm or mm of liquid.

16. The Capillary rise in the glass tube is not to exceed 0.2 mm of water. Determine its minimum size, given that surface tension of water in contact with air = 0.0725 N/m

Solution:

$$\text{Capillary rise, } h = 0.2 \text{ mm} = 0.2 \times 10^{-3} \text{ m}$$

$$\text{Surface tension } \sigma = 0.0725 \text{ N/m}$$

Let, Diameter of tube = d

Angle θ for water = 0

Density for water = 1000 kg / m³

$$h = \frac{4\sigma}{\rho \times g \times d} \Rightarrow 0.2 \times 10^{-3} = \frac{4 \times 0.0725}{1000 \times 9.81 \times d}$$

$$d = \frac{4 \times 0.0725}{1000 \times 9.81 \times 0.2 \times 10^{-3}} = 0.148 \text{ m} = 14.8 \text{ cm}$$

Minimum ϕ of the tube = 14.8 cm.

17. Find out the minimum size of glass tube that can be used to measure water level if the capillary rise in the tube is to be restricted to 2mm. Consider surface tension of water in contact with air as 0.073575 N/m.

Solution:

$$\text{Capillary rise } h = 2.0 \text{ mm} = 2.0 \times 10^{-3} \text{ m}$$

Let, diameter = d

Density of water = 1000 kg / m³

$$\sigma = 0.073575 \text{ N/m}$$

Angle for water $\theta = 0$

$$h = \frac{4\sigma}{\rho g d}$$

$$\Rightarrow 2.0 \times 10^{-3} = \frac{4 \times 0.073575}{1000 \times 9.81 \times d}$$

$$d = 0.015 \text{ m} = 1.5 \text{ cm.}$$

Thus the minimum diameter of the tube should be 1.5 cm.

18. Define Real fluid and Ideal fluid.

Real Fluid:

A fluid, which possesses viscosity, is known as real fluid. All fluids, in actual practice, are real fluids.

Ideal Fluid:

A fluid, which is incompressible and is having no viscosity, is known as an ideal fluid. Ideal fluid is only an imaginary fluid as all the fluids, which exist, have some viscosity.

19. Write down the expression for capillary fall.

$$\text{Height of depression in tube } h = \frac{4\sigma \cos \theta}{\rho \times g \times d}$$

Where,

h = height of depression in tube.

d = diameter of the

σ = surface tension

ρ = density of the liquid.

θ = Angle of contact between liquid and gas.

20. Two horizontal plates are placed 1.25 cm apart. The space between them being filled with oil of viscosity 14 poises. Calculate the shear stress in oil if upper plate is moved with a velocity of 2.5 m/s.

Solution:

Given:

Distance between the plates, $dy = 1.25 \text{ cm} = 0.0125 \text{ m.}$

Viscosity $\eta = 14 \text{ poise} = 14 / 10 \text{ Ns / m}^2$

Velocity of upper plate, $u = 2.5 \text{ m/Sec.}$

Shear stress is given by equation as $\tau = \eta (du / dy).$

Where $du = \text{change of velocity between the plates} = u - 0 = u = 2.5 \text{ m/sec.}$

$$dy = 0.0125m.$$

$$IJ = (14 / 10) \times (2.5 / 0.0125) = 280 \text{ N/m}^2.$$

21. What is cohesion and adhesion in fluids?

Cohesion is due to the force of attraction between the molecules of the same liquid.

Adhesion is due to the force of attraction between the molecules of two different liquids or between the molecules of the liquid and molecules of the solid boundary surface.

22. What is momentum equation/ the law of conservation of momentum

It is based on the law of conservation of momentum or on the momentum principle. It states that, the net force acting on a fluid mass is equal to the change in momentum of flow per unit time in that direction.

23. What are the properties of ideal fluid?

Ideal fluids have following properties

- i) intermolecular collisions are perfectly elastic
- ii) It has zero viscosity
- iii) Shear force is zero
- iv) It is incompressible

24. What are the properties of real fluid?

Real fluids have following properties

- i) It is compressible
- ii) They are viscous in nature
- iii) Shear force exists always in such fluids.

25. What are the different approaches for analysis of fluid mechanics?

Lagrangian approach and Eulerian approach

26. What are the differences in Lagrangian approach and Eulerian approach?

Lagrangian approach

Considers fluid as a particle

Ordinary differential is performed

Eulerian approach

Considers fluid as control volume

Partial differential is involved

27. What are the features of Control mass system or closed system?

- a) System of fixed mass or identity
- b) No mass transfer across Boundary
- c) Energy transfer may happen in or out of the system.
eg: A nuclear reactor.

28. What are the features of Control Volume System or open system?

- a) System of fixed volume.
- b) No transfer/change in volume but transfer of mass and energy may occur across control boundary.
- c) Most of the engineering devices use this concept.
eg: Heat exchanger & pumps.

29. What are the features of an Isolated System?

- a) System with fixed mass or fixed identity.
- b) No interaction of mass or energy across the system boundary with the surroundings.
eg: Thermoflask.

30. What is called steady flow or stationary flow?

A flow in which the velocity and pressure of the fluid may vary from point to point but constant at a particular fixed point i.e. does not change with time.

31. What is called unsteady flow?

A flow in which the velocity and pressure of the fluid vary at a particular fixed point i.e. changes with time is called unsteady flow.

32. Write the types of steady flow and unsteady flow?

- (a) steady uniform flow: velocity of fluid is same at each cross section and lives constant
- (b) steady non-uniform flow: velocity and cross section may vary at positions but does not vary with time
- (c) unsteady uniform flow: at a given instant of time velocity at every point is same but changes with time
- (d) unsteady non-uniform flow: cross section and velocity vary from point to point and also changes with time while flowing through the channel.

UNIT – II

1. Define the term static fluid (Nov-Dec 2018)

When the fluid of consideration is static, or stationary or non-moving is called static fluid. We can calculate for example, fluid pressure at different depths (in the ocean) or altitudes (in the atmosphere) or the force (on a dam) due to the fluid.

2. Assumptions made in the derivation of Bernoulli's equation:

- (i). The fluid is ideal, i.e., Viscosity is zero. (ii). The flow is steady
- (iii). The flow is incompressible. (iv). The flow is irrotational.

3. Bernoulli's theorem for steady flow of an incompressible fluid./ State Bernoulli's equation. Write dimensions of each term involved. (Nov-Dec 2018)

It states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant. The total energy consists of pressure energy, kinetic energy and potential energy or datum energy. These energies per unit weight of the fluid are:

$$\text{Pressure Energy} = p / \rho g \quad \text{Dimension: } \frac{P}{\rho g} = \frac{\frac{MLT^{-2}}{L^2}}{\frac{M}{L^3} \cdot \frac{L}{T^2}} = L$$

$$\text{Kinetic energy} = v^2 / 2g \quad \text{Dimension: } [L^2 T^2 / LT^2] = L$$

$$\text{Datum Energy} = z \quad \text{Dimension: } L$$

Bernoulli's theorem is written as $(p/w) + (v^2 / 2g) + z = \text{Constant}$.

4. Water is flowing through a pipe of 5 cm diameter under a pressure of 29.43 N/cm² (gauge) and with mean velocity of 2.0 m/s. find the total head or total energy per unit weight of the water at cross – section, which is 5 cm above the datum line.

Given:

$$\text{Diameter of the pipe} \quad 5 \text{ cm} = 0.5 \text{ m.}$$

$$\text{Pressure} \quad p = 29.43 \text{ N/cm}^2 = 29.23 \text{ N/m}^2$$

$$\text{velocity,} \quad v = 2.0 \text{ m/s.}$$

$$\text{datum head} \quad z = 5 \text{ m}$$

$$\text{total head} \quad = \text{Pressure head} + \text{Velocity head} + \text{Datum head}$$

$$\text{pressure head} \quad = (p / \rho g) = (29.43 \times 10^4 / (2 \times 9.81)) = 30 \text{ m}$$

$$\text{kinetic head} \quad = (v^2 / 2g) = (2 \times 2 / (2 \times 9.81)) = 0.204 \text{ m}$$

$$\text{Total head} \quad = (p / (\rho g)) + (v^2 / 2g) + z$$

$$= 30 + 0.204 + 5 = 35.204 \text{ m}$$

5. Water is flowing through two different pipes, to which an inverted differential manometer having an oil of sp. Gr 0.8 is connected the pressure head in the pipe A is 2 m of water, find the pressure in the pipe B for the manometer readings.

$$\text{Pr head at } A = \frac{P_A}{pg} = 2 \text{ m of water.}$$

$$p_A = p \times g \times 2 = 1000 \times 9.81 \times 2 \\ = 19620 \text{ N/m}^2$$

$$\text{Pr below X-X in left limb} = P_A - p_1 gh_1 = 19620 - 1000 \times 781 \times 0.3 = \\ 16677 \text{ N/m}^2$$

P_r below X-X in right limb

$$p_B - 1000 \times 9.81 \times 0.1 - 800 \times 9.81 \times 0.12 = P_B - 1922.76$$

Equating two pressures, we get,

$$P_B = 16677 + 1922.76 = 18599.76 \text{ N/m}^2 = 1.8599 \text{ N/cm}^2$$

6. The diameters of a pipe at the sections 1 and 2 are 10 cm and 15 cm respectively. Find the discharge through the pipe if the velocity of water flowing through the pipe section 1 is 5 m/s. determine also the velocity at section 2.

Solution. Given:

At section 1. D₁ = 10 cm = 0.1 m.

$$A_1 = (\pi / 4) \times D_1^2 = (\pi / 4) \times (0.1)^2 = 0.007854 \text{ m}^2.$$

$$V_1 = 5 \text{ m/s.}$$

At section 2. D₂ = 15 cm = 0.15 m.

$$A_2 = (\pi / 4) \times (0.15)^2 = 0.01767 \text{ m}^2.$$

1. Discharge through pipe is given by equation

$$Q = A_1 \times V_1 \\ = 0.007544 \times 5 = 0.03927 \text{ m}^3/\text{s.}$$

Using equation, We have A₁V₁ = A₂V₂.

$$V_2 = (A_1 V_1 / A_2) = (0.007854 / 0.01767) \times 5 = 2.22 \text{ m/s.}$$

7. What do you mean by hydrostatic law? / Pascal's Law (Nov-Dec 2018)

Pressure at any point inside a static fluid is equal towards all directions in the plane. The pressure at any point inside a fluid is a magnitude of compressive force or the normal compressive force acting per unit area over that point.

P = hρg, where P is applied pressure, h is height, ρ is density of fluid and g is gravitational acceleration.

8. A pitot – static tube is used to measure the velocity of water in a pipe. The stagnation pressure head is 6mm and static pressure head is 5m. Calculate the velocity of flow assuming the co-efficient of tube equal to 0.98.

Given:

$$\text{Stagnation Pressure head, } h_s = 6\text{mm.}$$

$$\text{Static pressure } h_t = 5 \text{ mm.}$$

$$h = 6 - 5 = 1 \text{ m}$$

$$\text{Velocity of flow } V = C_v \sqrt{2gh} = 0.98 \sqrt{2 \times 9.81 \times 1} = 4.34 \text{ m/s.}$$

9. A sub-marine moves horizontally in a sea and has its axis 15 m below the surface of water. A pitot tube properly placed just in front of the sub-marine and along its axis connected to the two limbs of a U – tube containing mercury. The difference of mercury level is found to be 170 mm. find the speed of the sub-marine knowing that the sp.gr. of mercury is 13.6 and that of sea-water is 1.026 with respect fresh water.

Given :

$$\text{Diff. of mercury level } x = 170 \text{ mm} = 0.17 \text{ m}$$

$$\text{Sp. gr. Of mercury } S_g = 13.6$$

$$\text{Sp. gr. Of sea-water } S_o = 1.026$$

$$\therefore h = x [S_g / S_o - 1] = 0.17 [(13.6 / 1.026) - 1] = 2.0834 \text{ m}$$

$$V = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.0834} = 6.393 \text{ m/s.}$$

$$= (6.393 \times 60 \times 60 / 1000) \text{ km/hr} = 23.01 \text{ km/hr.}$$

10. Write the equations of motion.

$$F_x = (F_g)_x + (F_p)_x + (F_v)_x + (F_t)_x + (F_c)_x$$

If the force due to compressibility, F_c is negligible, the resulting net force.

$$F_x = (F_g)_x + (F_p)_x + (F_v)_x + (F_t)_x$$

Where F_g = gravity force

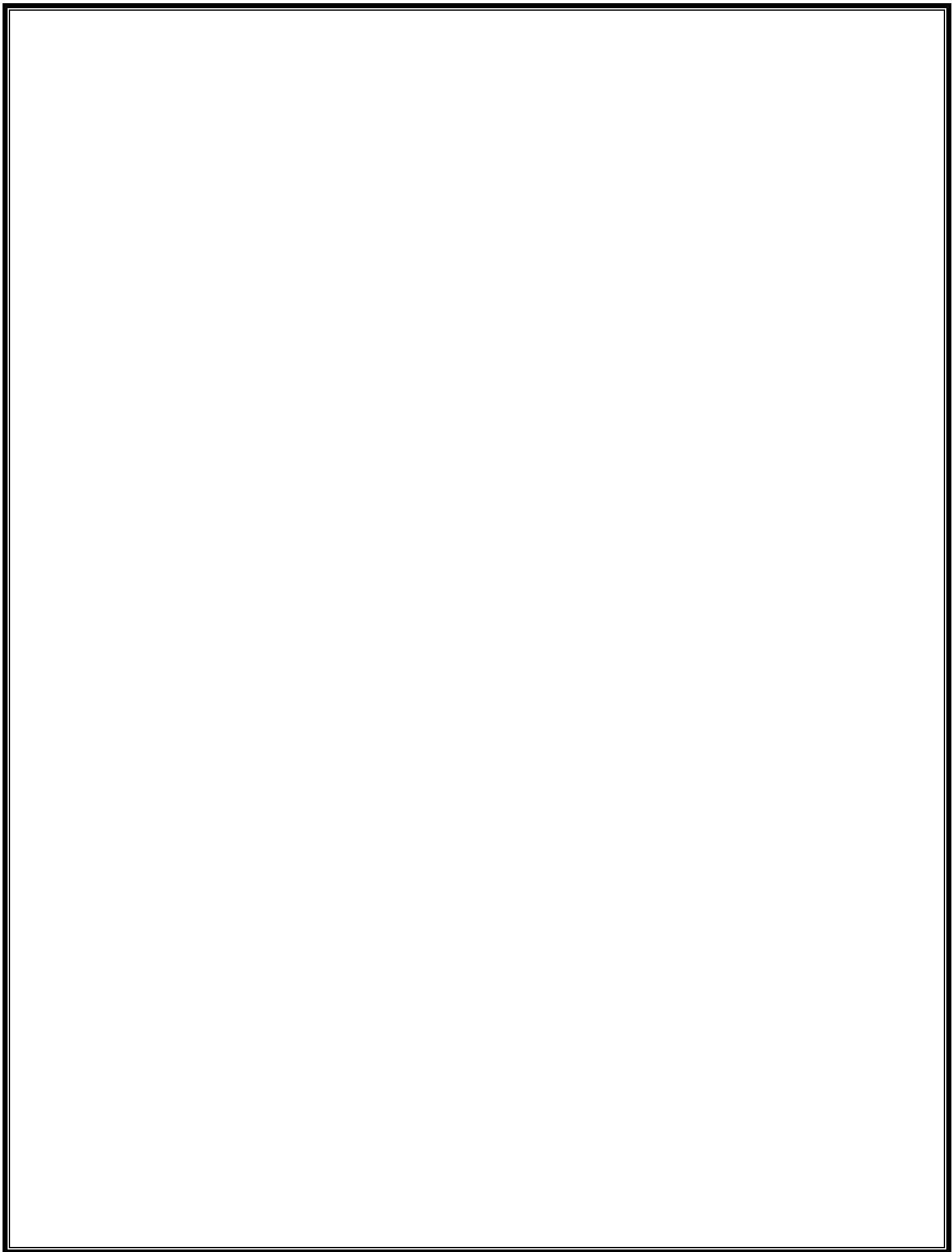
F_p = Pressure force

F_v = force due to viscosity

F_t = force due to turbulence

F_c = force due to compressibility

11. State Euler's Equation of motion.



Venturi meter.

Venturimeter is a device used for measuring the rate of flow of a fluid flowing through a pipe. It consists of three parts (i). A short converging part (ii) Throat and (iii) Diverging part.

Pitot-tube.

Pitot tube is a device used for measuring the velocity of flow at any point in a pipe or channel. It is based on the principle that if the velocity of flow at a point becomes zero.

Free liquid jet

Free liquid jet is defined as the jet of water coming out from the nozzle in atmosphere. The path traveled by the free jet is parabolic.

Write down the formulae for finding the discharge in Venturimeter.

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

Where a_1 = area of the inlet Venturi meter.

a_2 = area at the throat

C_d = co-efficient of venturi meter.

h = difference of pressure head in terms of fluid head flowing through venture meter

Dynamics of fluid flow

The study of fluid motion with the forces causing flow is called dynamics of fluid flow. The dynamic behavior of the fluid flow is analyzed by the Newton's second law of motion, which relates the acceleration with the forces.

Formula to find the maximum height attained by the jet

$$S = \frac{U^2 \sin^2 \theta}{2g}$$

Where, S = maximum vertical height attained by the particle.

U = velocity of jet of water.

g = acceleration due to gravity.

θ = angle with horizontal direction.

Euler's Equation of motion.

This is equation of motion in which the forces due to gravity and pressure are taken into consideration. This is derived by considering the motion of a fluid element along a streamline in which flow is taking place in s-direction as shown in fig. Consider a cylindrical element of cross-section dA and length ds . The forces acting on the cylindrical element are:

- a. Pressure force pdA In the direction of flow.
- b. Pressure force $\left(p + \frac{\partial p}{\partial s} ds \right) dA$ opposite to the direction of flow.
- c. Weight of element $\rho g dA ds$

Let θ is the angle between the direction of flow and the line of action of the weight of element.

The resultant force on the fluid element of 's' must be equal to the mass on the fluid element X acceleration in the direction 's'.

$$\begin{aligned} & pdA - \left(p + \frac{\partial p}{\partial s} \right) dA - \rho g dA ds \cos \theta \\ & = \rho dA ds X a_s \dots \dots \dots \quad (1) \end{aligned}$$

Where a_s is the acceleration in the direction of 's'

$$\begin{aligned} \text{Now, } a_s &= \frac{dv}{dt}, \text{ where } v \text{ is a function of 's' and 't'.} \\ &= \frac{\partial v}{\partial s} \frac{dv}{dt} + \frac{\partial v}{\partial t} = \frac{v \partial v}{\partial s} + \frac{\partial v}{\partial t} \left\{ \frac{ds}{dt} = v \right\} \end{aligned}$$

if the flow is steady, $\frac{dv}{dt} = 0$

$$a_s = \frac{v \partial v}{\partial s}$$

Substituting the value of ' a_s ' in equation (1) and simplifying the equation, we get

$$-\frac{\partial p}{\partial s} dsdA - \rho g dA d\theta \cos \theta = \rho dA d\theta X \frac{v \partial v}{\partial s}$$

$$\text{Dividing by } \rho dA d\theta, -\frac{\partial p}{\rho \partial s} - g \cos \theta = \frac{v \partial v}{\partial s}$$

$$\text{or } \frac{\partial p}{\rho \partial s} + g \cos \theta + v \frac{v \partial v}{\partial s} = 0$$

But from fig, we have $\cos \theta = \frac{dz}{ds}$

$$\frac{1}{\rho} \frac{\partial p}{\partial s} + g \frac{dz}{ds} + \frac{v \partial v}{\partial s} = 0$$

$$(\text{or }) \frac{\partial p}{\rho} + gdz + vdv = 0 \dots\dots\dots\dots\dots(2).$$

Equation 2 is known as Euler's equation of motion

The water is flowing through a pipe having diameters 20 cm and 10 cm at sections 1 and 2 respectively. The rate of flow through pipe is 35 lit/sec. the section 1 is 6m above datum. If the pressure at section 2 is 4m above the datum. If the pressure at section 1 is 39.24 N/cm², find the intensity of pressure at section 2.

Given:

At section 1, $D_1 = 20 \text{ cm} = 0.2 \text{ m}$

$$A_1 = \frac{\pi}{4} (0.2)^2 = 0.314 \text{ m}^2.$$

$$P_1 = 39.24 \text{ N/cm}^2 = 39.24 \times 10^4 \text{ N/m}^2.$$

$$Z_1 = 6.0 \text{ m}$$

At section 2, $D_2 = 0.10 \text{ m}$

$$A_2 = \frac{\pi}{4} (0.1)^2 = 0.0785 \text{ m}^2.$$

$$P_2 =$$

$$Z_2 = 4.0 \text{ m}$$

Rate of flow $Q = 35 \text{ lit/sec} = 35/1000 = 0.035 \text{ m}^3/\text{s}$

$$Q = A_1 V_1 = A_2 V_2$$

$$V_1 = Q / A_1 = 0.035 / 0.0314 = 1.114 \text{ m/s}$$

$$V_2 = Q / A_2 = 0.035 / 0.0785 = 4.456 \text{ m/s.}$$

Applying Bernoulli's Equations at sections at 1 and 2, we get

$$\frac{p_1}{\rho g} + \frac{V^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V^2}{2g} + z_2$$

$$\begin{aligned} \text{Or } & (39.24 \times 10^4 / 1000 \times 9.81) + ((1.114)^2 / 2 \times 9.81) + 6.0 \\ & = (p_2 / 1000 \times 9.81) + ((4.456)^2 / 2 \times 9.81) + 4.0 \\ & 40 + 0.063 + 6.0 = (p_2 / 9810) + 1.012 + 4.0 \\ & 46.063 = (p_2 / 9810) + 5.012 \\ & (p_2 / 9810) = 46.063 - 5.012 = 41.051 \\ & p_2 = (41.051 \times 9810 / 10^4) = 40.27 \text{ N/cm}^2 \end{aligned}$$

In a vertical pipe conveying oil of specific gravity 0.8, two pressure gauges have been installed at A and B where the diameters are 16 cm and 8 cm respectively. A is 2 m above B. the pressure gauge readings have shown that the pressure at B is greater than at A by 0.981 N/cm². Neglecting all losses, calculate the flow rate. If the gauges at A and B are replaced by tubes filled with the same liquid and connected to a U – tube containing mercury, calculate the difference of level of mercury in the two limbs of the U-tube.

Given:

Sp.gr.. of oil,

$$S_o = 0.8$$

Density,

$$\rho = 0.8 \times 1000 = 800 \text{ kg/m}^3.$$

Dia at A,

$$D_A = 16 \text{ cm} = 0.16 \text{ m}$$

Area at A,

$$A_A = \frac{\pi}{4} \times (0.16)^2 = 0.0201 \text{ m}^2.$$

Dia. At B

$$D_B = 8 \text{ cm} = 0.08 \text{ m}$$

Area at B,

$$A_B = \frac{\pi}{4} \times (0.08)^2 = 0.005026 \text{ m}^2$$

(i). Difference of pressures, $p_B - p_A = 0.981 \text{ N/cm}^2$.

$$= 0.981 \times 10^4 \text{ N/m}^2 = 9810 \text{ N/m}^2.$$

Difference of pressure head $(p_B - p_A) / \rho g = (9810 / (800 \times 9.81)) = 1.25$

Applying Bernoulli's theorem at A and B and taking reference line passing through section B, we get

$$\frac{p_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{p_B}{\rho g} + \frac{V_B^2}{2g} + Z_B$$

$$\frac{p_A - p_B}{\rho g} + Z_A - Z_B = \frac{V_B^2}{2g} - \frac{V_A^2}{2g}$$

$$\frac{p_A - p_B}{\rho g} + 2.0 - 0.0 = \frac{V_B^2}{2g} - \frac{V_A^2}{2g}$$

$$-1.25 + 2.0 = \frac{V_B^2}{2g} - \frac{V_A^2}{2g} \quad \frac{p_B - p_A}{\rho g} = 1.25$$

$$0.75 = \frac{V_B^2}{2g} - \frac{V_A^2}{2g} \quad \text{----- (i)}$$

Now applying continuity equation at A and B, we get

$$V_A X A_1 = V_B X A_2$$

$$V_B = \frac{V_A X A_1}{A_2^2} = \frac{V_A X \frac{\pi}{4} (.16)^2}{\frac{\pi}{4} (.08)^2} = 4V_A$$

Substituting the Value of V_B in equation (i), we get

$$0.75 = \frac{16V_A^2}{2g} - \frac{V_A^2}{2g} = \frac{15V_A^2}{2g}$$

$$V_A = \sqrt{\frac{0.75 \times 2 \times 9.81}{15}} = 0.99 \text{ m/s.}$$

$$\begin{aligned} \text{Rate of flow, } Q &= V_A X A_1 \\ &= 0.99 \times 0.0201 = 0.01989 \text{ m}^3/\text{s.} \end{aligned}$$

(ii). Difference of mercury in the U-tube.

Let h = difference of mercury level.

$$\begin{aligned} \text{Then } h &= x \left(\frac{S_g}{S_o} - 1 \right) \\ &= -1.25 + 2.0 - 0 = 0.75. \\ \therefore 0.75 &= x \left[\frac{13.6}{0.8} - 1 \right] = x \times 16 \\ x &= (0.75 / 16) = \\ &0.04687 \text{ cm.} \end{aligned}$$

Expression for loss of head due to friction in pipes or Darcy – Weisbach Equation.

Consider a uniform horizontal pipe, having steady flow as shown figure. Let 1 -1 and 2-2 is two sections of pipe.

Let P_1 = pressure intensity at section 1-1.

Let P_2 = Velocity of flow at section 1-1.

L = length of the pipe between the section 1-1 and 2-2

d = diameter off pipe.

f^l = Frictional resistance per unit wetted area per unit velocity.

h_f = loss of head due to friction.

And P_2, V_2 = are the values of pressure intensity and velocity at section 2-2.

Applying Bernoulli's equation between sections 1-1 & 2-2

Total head 1-1 = total head at 2-2 + loss of head due to friction between 1-1&2-2

$$(P_1/\rho g) + (V_1^2 / 2g) + Z_1 = (P_2/\rho g) + (V_2^2 / 2g) + Z_2 + h_f \quad \dots\dots\dots(1)$$

but $Z_1 = Z_2$ [pipe is horizontal]

$V_1 = V_2$ [diameter of pipe is same at 1-1 & 2-2]

(1) becomes,

$$(P_1/\rho g) = (P_2/\rho g) + h_f$$

$$h_f = (P_1/\rho g) - (P_2/\rho g)$$

Frictional resistance = frictional resistance per unit wetted area per unit velocity X
wetted area X velocity².

$$F = f^l \times \pi d L \times V^2 \quad [\text{Wetted area} = \pi d L, \text{ and Velocity } V = V_1 = V_2]$$

$$F_1 = f^l \times P \times L \times V^2 \quad \dots\dots\dots(2). \quad [\pi d = \text{wetted perimeter} = p]$$

The forces acting on the fluid between section 1-1 and 2-2 are,

1) Pressure force at section 1-1 = $P_1 A$

2) Pressure force at section 2-2 = $P_2 A$

3). Frictional force F_1

Resolving all forces in the horizontal direction.,

$$P_1 A - P_2 A - F_1 = 0$$

$$(P_1 - P_2)A = F_1 = f^l \times P \times L \times V^2$$

$$(P_1 - P_2) = (f^l \times P \times L \times V^2 / A).$$

But from (1) we get

$$P_1 - P_2 = \rho g h_f$$

Equating the values of $(P_1 - P_2)$ we get

$$\rho g h_f = (f^1 x P x L x V^2 / A).$$

$$h_f = (f^1 / \rho g) X (P/A) X L X V^2$$

$$(P/A) = (\pi d / (\pi d^2/4)) = (4/d)$$

$$\text{Hence, } h_f = (f^1 / \rho g) x (4/d) x L x V^2.$$

Putting $(f^1 / \rho) = (f / 2)$, where f is the co-efficient of friction

$$h_f = \frac{4 f L V^2}{2 g d}$$

This equation is known as Darcy – Weisbach equation. This equation is commonly used to find loss of head due to friction in pipes.

Expression for rate of flow through Venturimeter.

Venturi meter is a device used for measuring the rate of flow of a fluid flowing through a pipe. It consists of three parts (i). A short converging part (ii) Throat and (iii). Diverging part

Let d_1 = diameter at inlet or at section 1

Let P_1 = pressure at section 1

Let V_1 = velocity of fluid at section 1

$$\text{Let } a_1 = \text{area of section 1} = \frac{\pi}{4} d^2$$

And d_2, P_2, V_2, a_2 are the corresponding values at section 2

Applying the Bernoulli's equation at section 1 & 2

$$(P_1/\rho g) + (V_1^2 / 2g) + Z_1 = (P_2/\rho g) + (V_2^2 / 2g) + Z_2$$

since the pipe is horizontal $Z_1 = Z_2$

$$(P_1/\rho g) + (V_1^2 / 2g) = (P_2/\rho g) + (V_2^2 / 2g)$$

$$\frac{P_1 - P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

We know that $\frac{P_1 - P_2}{\rho g}$ is the difference or pressure head and is equal to h .

$$h = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \quad \dots \dots \dots (1).$$

Now applying, continuity equation at 1 & 2

$$a_1 V_1 = a_2 V_2 \text{ or } V_1 = (a_2 V_2 / a_1) \quad \dots \dots \dots (2).$$

Sub (2) in equation (1) we get

$$h = \frac{V_2^2}{2g} - \frac{\left(\frac{a_2 V_2}{a_1}\right)^2}{2g} = \frac{V_2^2}{2g} \left[1 - \frac{a_2^2}{a_1^2} \right]$$

$$V_2^2 = 2gh (a_1^2 / (a_1^2 - a_2^2))$$

$$V_2 = \sqrt{2gh} \cdot \frac{a_1}{\sqrt{a_1^2 - a_2^2}}$$

Discharge, $Q = a_2 V_2$

$$Q = \frac{a_2 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}} \text{ theoretical discharge}$$

Actual discharge

$$Q_{act} = C_d \times \frac{a_2 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$$

Where C_d = co - efficient of venturi meter.

Water flows through a pipe AB 1.2m diameter at 3 m/s and then passes through a pipe BC 1.5 m diameter at C, the pipe branches. Branch CD is 0.8m in diameter and carries one third of the flow in AB. The flow velocity in branch CE is 2.5 m/s. Find the volume rate of flow in AB, the velocity in BC, the velocity in CD and the diameter of CE.

Solution. Given:

$$\text{Diameter of Pipe AB, } D_{AB} = 1.2 \text{ m.}$$

$$\text{Velocity of flow through AB } V_{AB} = 3.0 \text{ m/s.}$$

$$\text{Dia. of Pipe BC, } D_{BC} = 1.5 \text{ m.}$$

$$\text{Dia. of Branched pipe CD, } D_{CD} = 0.8 \text{ m.}$$

$$\text{Velocity of flow in pipe CE, } V_{CE} = 2.5 \text{ m/s.}$$

$$\text{Let the rate of flow in pipe } AB = Q \text{ m}^3/\text{s.}$$

$$\text{Velocity of flow in pipe } BC = V_{BC} \text{ m}^3/\text{s.}$$

$$\text{Velocity of flow in pipe } CD = V_{CD} \text{ m}^3/\text{s.}$$

Diameter of pipe	$CE = D_{CE}$
Then flow rate through	$CD = Q / 3$
And flow rate through	$CE = Q - Q/3 = 2Q/3$
(i). Now the flow rate through AB = $Q = V_{AB} \times \text{Area of AB}$	$= 3 \times (\pi / 4) \times (D_{AB})^2 = 3 \times (\pi / 4) \times (1.2)^2$
	$= 3.393 \text{ m}^3/\text{s.}$

(ii). Applying the continuity equation to pipe AB and pipe BC,

$$\begin{aligned} V_{AB} \times \text{Area of pipe AB} &= V_{BC} \times \text{Area of Pipe BC} \\ 3 \times (\pi / 4) \times (D_{AB})^2 &= V_{BC} \times (\pi / 4) \times (D_{BC})^2 \\ 3 \times (1.2)^2 &= V_{BC} \times (1.5)^2 \\ V_{BC} &= (3 \times 1.2^2) / 1.5^2 = 1.92 \text{ m/s.} \end{aligned}$$

(iii). The flow rate through pipe

$$\begin{aligned} CD &= Q_1 = Q/3 = 3.393 / 3 = 1.131 \text{ m}^3/\text{s.} \\ Q_1 &= V_{CD} \times \text{Area of pipe } CD \times (\pi / 4) (C_{CD})^2 \\ 1.131 &= V_{CD} \times (\pi / 4) \times (0.8)^2 \\ V_{CD} &= 1.131 / 0.5026 = 2.25 \text{ m/s.} \end{aligned}$$

(iv). Flow through CE,

$$\begin{aligned} Q_2 &= Q - Q_1 = 3.393 - 1.131 = 2.262 \text{ m}^3/\text{s.} \\ Q_2 &= V_{CE} \times \text{Area of pipe CE} = V_{CE} \times (\pi / 4) (D_{CE})^2 \\ 2.263 &= 2.5 \times (\pi / 4) (D_{CE})^2 \\ D_{CE} &= \sqrt{(2.263 \times 4) / (2.5 \times \pi)} = 1.0735 \text{ m} \end{aligned}$$

Diameter of pipe CE = 1.0735m.

A horizontal Venturimeter with inlet and throat diameters 30 cm and 15 cm respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is 20 cm of mercury. Determine the rate of flow. Take $C_d = 0.98$.

Given:

$$d_1 = 30 \text{ cm}$$

$$a_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} (30)^2 \\ = 706.85 \text{ cm}^2$$

$$d_2 = 15 \text{ cm}$$

$$a_2 = \frac{\pi}{4} d_2^2 = \frac{\pi}{4} (15)^2 \\ = 176.7 \text{ cm}^2$$

$$C_d = 0.98$$

Reading of differential manometer = x = 20 cm of mercury.

$$\text{Difference of pressure head, } h = x \left(\frac{S}{S_o} - 1 \right) \\ = 20 [(13.6 / 1) - 1] = 252.0 \text{ cm of mercury.}$$

$$Q_{\text{act}} = C_d x \frac{a_2 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}} \\ = 0.98 \times \frac{706.85 \times 176.7 \sqrt{2} \times 9.81 \times 252}{\sqrt{706.85^2 - 176.7^2}} \\ = 125756 \text{ cm}^3 / \text{s} \\ = \mathbf{125.756 \text{ lit / s.}}$$

UNIT – IV

BOUNDARY LAYER AND FLOW THROUGH PIPES

Definition of boundary layer – Thickness and classification – Displacement and momentum thickness – Development of laminar and turbulent flows in circular pipes – Major and minor losses of flow in pipes – Pipes in series and in parallel – Pipe network

Hydraulic gradient line.

It is defined as the line which gives the sum of pressure head ($P/\rho g$) and datum head (z) of a flowing fluid in a pipe with respect to some reference line or is the line which is obtained by joining the top of all vertical ordinates, showing the pressure head ($P/\rho g$) of a pipe from the center of the pipe. It is briefly written as H.G.L

Major energy loss and minor energy loss in pipe

The loss of head or energy due to friction in pipe is known as major loss while the loss of energy due to change of velocity of the flowing fluid in magnitude or direction is called minor loss of energy.

Total Energy line

It is defined as the line, which gives sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line.

Equivalent pipeline

An Equivalent pipe is defined as the pipe of uniform diameter having loss of head and discharge of a compound pipe consisting of several pipes of different lengths and diameters.

Water Hammer in pipes.

In a long pipe, when the flowing water is suddenly brought to rest by closing the valve or by any similar cause, there will be a sudden rise in pressure due to the momentum of water being destroyed. A pressure wave is transmitted along the pipe. A sudden rise in pressure has the effect of hammering action on the walls of the pipe. This phenomenon of rise in pressure is known as water hammer or hammer blow.

Pipes in series:

Pipes in series or compound pipes is defined as the pipes of different lengths and different diameters connected end to end (in series) to form a pipe line.

Pipes in parallel:

The pipes are said to be parallel, when a main pipe divides into two or more parallel pipes, which again join together downstream and continues as a mainline. The pipes are connected in parallel in order to increase the discharge passing through the main.

Boundary layer.

When a solid body is immersed in a flowing fluid, there is a narrow region of the fluid in neighbourhood of the solid body, where the velocity of fluid varies from zero to free stream velocity. This narrow region of fluid is called boundary layer.

laminar sub layer

In turbulent boundary layer region, adjacent to the solid boundary velocity for a small thickness variation is influenced by various effect. This layer is called as laminar sub layer.

Boundary layer thickness.

It is defined as the distance from the boundary of the solid body measured in the y – direction to the point where the velocity of the fluid is approximately equal to 0.99 times the free stream (v) velocity of the fluid.

momentum thickness.

It is defined as the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid of boundary

$$\theta = \int_0^{\delta} u / v (1 - u / v) dy$$

Incompressible flow.

It is define as the type of flow in which the density is constant for the fluid flow. Mathematically $\rho = \text{constant}$. Examples: Subsonic, aerodynamics.

Different methods of preventing the separation of boundary layers

1. Suction of slow moving fluid by suction slot
2. Supplying additional energy from a blower
3. Providing a bypass in the slotted wring
4. Rotating boundary in the direction of flow.
5. Providing small divergence in diffuser
6. Providing guide – blades in a bend.

Examples laminar flow / viscous flow

- (i) Flow past tiny bodies,
- (ii) Underground flow
- (iii) Movement of blood in the arteries of human body,
- (iv) Flow of oil in measuring instruments,
- (v) Rise of water in plants through their roots etc.,

Characteristics of laminar flow

- (i) No slip at the boundary
- (ii) Due to viscosity, there is a shear between fluid layers, which is given by

$$\tau = \mu(du/dy)$$
 for flow in x- direction
- (iii) The flow is rotational.
- (iv) Due to viscous shear, there is continuous dissipation of energy and for maintaining the flow must be supplied externally.
- (v) Loss of energy is proportional to first power of velocity and first power of viscosity.
- (vi) No mixing between different fluid layers (except by molecular motion, which is very small)

Differentiate between laminar boundary layer and turbulent boundary layer

The boundary layer is called laminar, if the Reynolds number of the flow is defined as $R_e = U \times X / v$ is less than 3×10^5

If the Reynolds number is more than 5×10^5 , the boundary layer is called turbulent boundary.

Where, U = Free stream velocity of flow

X = Distance from leading edge

v = Kinematic viscosity of fluid

Chezy's formula.

Chezy's formula is generally used for the flow through open channel.

$$V = C \sqrt{mi}$$

Where, C = Chezy's constant, m = hydraulic mean depth and $i = h_f / L$.

A crude oil of kinematic viscosity of 0.4 stoke is flowing through a pipe of diameter 300mm at the rate of 300 litres/sec. find the head lost due to friction for a length of 50m of the pipe.

Given :

Kinematic viscosity $v = 0.4$ stoke $= 0.4 \text{ cm}^2/\text{s} = 0.4 \times 10^{-4} \text{ m}^2/\text{s}$

Dia. Of pipe $d = 300\text{mm} = 0.3\text{m}$

Discharge $Q = 300 \text{ Lit/S} = 0.3 \text{ m}^3/\text{s}$

Length of pipe $L = 50\text{m}$

Velocity $V = Q / \text{Area} = 0.3 / (\frac{\pi}{4} (0.3)^2) = 4.24 \text{ m/s}$

Renold number $R_e = (V \times d) / v = (4.24 \times 0.30) / 0.4 \times 10^{-4} = 3.18 \times 10^4$

As R_e lies between 4000 and 100,000, the value of "f" is given by

$$f = \frac{0.079}{(R_e)^{1/4}} = \frac{0.079}{(3.18 \times 10^4)^{1/4}} = 0.00591$$

Head lost due to friction $h_f = 4 f L V^2 / 2 g d$

$$\begin{aligned} &= (4 \times 0.00591 \times 50 \times 4.24^2) / (0.3 \times 2 \times 9.81) \\ &= 3.61 \text{ m} \end{aligned}$$

Find the type of flow of an oil of relative density 0.9 and dynamic viscosity 20 poise, flowing through a pipe of diameter 20 cm and giving a discharge of 10 lps.

Solution :

$s = \text{relative density} = \text{Specific gravity} = 0.9$

$\mu = \text{Dynamic viscosity} = 20 \text{ poise} = 2 \text{ Ns/m}^2$.

Dia of pipe D = 0.2 m; Discharge Q = 10 lps = $(10 / 1000) \text{ m}^3/\text{s}$; $Q = AV$.

$$\text{So } V = Q / A = [10 / (1000 \times (\frac{\pi}{4} \times (0.2)^2))] = 0.3183 \text{ m/s.}$$

Kinematic viscosity $v = \mu / \rho = [2 / (0.9 \times 1000)] = 2.222 \times 10^{-3} \text{ m}^2/\text{s}$.

Reynolds number $Re = VD / v$

$$Re = [0.3183 \times 0.2 / 2.222 \times 10^{-3}] = 28.647;$$

Since $Re (28.647) < 2000$,

It is **Laminar flow**.

Formula for finding the loss of head due to entrance of pipe h_i

$$h_i = 0.5 (V^2 / 2g)$$

Formula to find the Efficiency of power transmission through pipes

$$n = (H - h_f) / H$$

where, H = total head at inlet of pipe.

h_f = head lost due to friction

Hydro dynamically smooth pipe carries water at the rate of 300 lit/s at 20°C

($\rho = 1000 \text{ kg/m}^3$, $v = 10^{-6} \text{ m}^2/\text{s}$) with a head loss of 3m in 100m length of pipe.

Determine the pipe diameter. Use $f = 0.0032 + (0.221) / (Re)^{0.237}$ equation for f

where $h_f = (fXLV^2) / 2gd$ and $Re = (\rho VD / \mu)$

Given:

Discharge, $Q = 300 \text{ lit/sec} = 0.3 \text{ m}^3/\text{s}$

Density $\rho = 1000 \text{ kg/m}^3$

Kinematic viscosity $v = 10^{-6} \text{ m}^2/\text{s}$

Head loss $h_f = 3 \text{ m}$

Length of pipe, $L = 100 \text{ m}$

Value of friction factor, $f = 0.0032 + 0.221 / (Re)^{0.237}$

Renolds number $Re = (\rho VD / \mu) = (VXD) / v$ $(\mu / \rho = v)$

$$VXD / 10^{-6} = VXDX10^6$$

Find diameter of pipe.

Let D = diameter of pipe

Head loss in terms of friction factor is given as

$$h_f = (f \cdot X \cdot L \cdot V^2) / (2g \cdot X \cdot D)$$

$$3 = (f \cdot X \cdot 100 \cdot V^2) / (2 \cdot 9.81 \cdot X \cdot D)$$

$$f = (3 \cdot X \cdot D \cdot 2 \cdot 9.81) / 100 \cdot V^2$$

$$f = 0.5886 \cdot D / V^2 \quad \text{(i)}$$

$$\text{now } Q = A \cdot X \cdot V$$

$$0.3 = \frac{\pi}{4} (D)^2 \cdot X \cdot V \quad \text{or } D^2 \cdot X \cdot V = (4 \cdot 0.3 / \pi) = 0.382$$

$$V^2 = 0.382 / D^2 \quad \text{(ii)}$$

$$f = 0.0032 + (0.221) / (R_e)^{0.237}$$

$$0.5886 / D^2 = 0.0032 + (0.221) / (V \cdot X \cdot D \cdot 10^6)^{0.237}$$

{ from equation (i), $f = 0.5886 \cdot D / V^2$ and $R_e = V \cdot X \cdot D \cdot 10^6$ }

$$0.5886 \cdot D / (0.382 / D^2)^2 = 0.0032 + \left(\frac{0.221}{\left(\frac{0.382}{D^2} \cdot X \cdot D \cdot 10^6 \right)^{0.237}} \right)$$

{ from Equation (ii), $V = 0.382 / D^2$ }

$$0.5886 \cdot D^5 / 0.382^2 = 0.0032 + \left(\frac{0.221}{\left(\frac{(0.382 \cdot 10^6)^{0.237}}{D^{0.237}} \right)} \right)$$

$$4.0333 \cdot D^5 = 0.0032 + 0.0015 \cdot D^{0.237}$$

$$4.0333 \cdot D^5 - 0.0105 \cdot D^{0.237} - 0.0032 = 0 \quad \text{(iii)}$$

the above equation (iii) will be solved hit trial method

(i). Assume $D = 1\text{m}$, then L.H.S of the equation (iii), becomes as

$$\begin{aligned} \text{L.H.S} &= 4.033 \cdot 1^5 - 0.0105 \cdot 1^{0.237} - 0.0032 \\ &= 4.033 - 0.0105 - 0.0032 = 4.0193 \end{aligned}$$

by increasing the value of D more than 1m , the L.H.S. will go on increasing.

Hence decrease the value of D.

(ii) Assume $D = 0.3$ than L.H.S of equation (iii)

$$\text{becomes as L.H.S} = 4.033 \cdot 0.3^{0.237} - 0.0032$$

$$= 0.0098 - 0.00789 - 0.0032 = -0.00129$$

as this value of negative, the values of D will be slightly more than 0.3

(iii) Assume $D = 0.306$ then L.H.S of equation (iii) becomes as

$$\begin{aligned} \text{L.H.S} &= 4.033 \times 0.306^{0.237} - 0.0105 \times 0.306^{0.237} - 0.0032 \\ &= 0.0108 - 0.00793 - 0.0032 = -0.00033 \end{aligned}$$

This value of L.H.S is approximately equal to equal to zero. Actually the value of D will be slightly more than 0.306m say **0.308m**.

Expression for loss of head due to friction in pipes.

Or

Darcy – Weisbach Equation.

Consider a uniform horizontal pipe, having steady flow as shown figure. Let 1 -1 and 2-2 are two sections of pipe.

Let P_1 = pressure intensity at section 1-1.

Let P_2 = Velocity of flow at section 1-1.

L = length of the pipe between the section 1-1 and 2-2

d = diameter off pipe.

f^l = Frictional resistance per unit wetted area per unit velocity.

h_f = loss of head due to friction.

And P_2, V_2 = are the values of pressure intensity and velocity at section 2-2.

Applying Bernoulli's equation between sections 1-1 & 2-2

Total head 1-1 = total head at 2-2 + loss of head due to friction between 1-1&2-2

$$(P_1/\rho g) + (V_1^2 / 2g) + Z_1 = (P_2/\rho g) + (V_2^2 / 2g) + Z_2 + h_f \quad \dots\dots\dots(1)$$

but $Z_1 = Z_2$ [pipe is horizontal]

$V_1 = V_2$ [diameter of pipe is same at 1-1 & 2-2]

(1) becomes,

$$(P_1/\rho g) = (P_2/\rho g) + h_f$$

$$h_f = (P_1/\rho g) - (P_2/\rho g)$$

frictional resistance = frictional resistance per unit wetted area per unit velocity X
wetted area X velocity².

$$F = f^l \times \pi d l \times V^2 \quad [\text{Wetted area} = \pi d \times L, \text{and Velocity } V = V_1 = V_2]$$

$$F_1 = f^l X P X L X V^2 \quad \dots \quad (2). [\pi d = \text{wetted perimeter} = p]$$

The forces acting on the fluid between section 1-1 and 2-2 are,

- 1) Pressure force at section 1-1 = $P_1 A$
- 2) Pressure force at section 2-2 = $P_2 A$
- 3). Frictional force F_1

Resolving all forces in the horizontal direction.,

$$P_1 A - P_2 A - F_1 = 0$$

$$(P_1 - P_2)A = F_1 = f^l X P X L X V^2$$

$$(P_1 - P_2) = (f^l X P X L X V^2 / A).$$

But from (1) we get

$$P_1 - P_2 = \rho g h_f$$

Equating the values of $(P_1 - P_2)$ we get

$$\rho g h_f = (f^l X P X L X V^2 / A).$$

$$h_f = (f^l / \rho g) X (P/A) X L X V^2$$

$$(P/A) = (\pi d / (\pi d^2/4)) = (4/d)$$

$$\text{hence, } h_f = (f^l / \rho g) X (4/d) X L X V^2.$$

Putting $(f^l / \rho) = (f / 2)$, where f is the co-efficient of friction

$$h_f = \frac{4 f L V^2}{2 g d}$$

This equation is known as Darcy – Weisbach equation. This equation is commonly used to find loss of head due to friction in pipes

The rate of flow through a horizontal pipe is $0.25 \text{ m}^3/\text{s}$. the diameter of the pipe which is 200mm is suddenly enlarged to 400mm. the pressure intensity in the smaller pipe is 11.772 N/cm^2 . Determine (i). Loss of head due to sudden enlargement (ii). Pressure intensity in large pipe. (iii). Power lost due to enlargement.

Given:

$$\text{Discharge} \qquad \qquad Q = 0.25 \text{ m}^3/\text{s.}$$

Dia. Of smaller pipe	$D_1 = 200\text{mm} = 0.2\text{m}$
Area	$A_1 = \frac{\pi}{4} (0.2)^2 = 0.03141 \text{ m}^2.$
Dia of large pipe	$D_2 = 400\text{mm} = 0.4\text{m}$
Area	$A_2 = \frac{\pi}{4} (0.4)^2 = 0.12566 \text{ m}^2.$
Pressure in smaller pipe	$p_1 = 11.772 \text{ N/cm}^2 = 11.772 \times 10^4 \text{ N/m}^2.$
Now velocity	$V_1 = Q / A_1 = 0.25 / 0.03141 = 7.96 \text{ m/s.}$
Velocity	$V_2 = Q / A_2 = 0.25 / 0.12566 = 1.99 \text{ m/s.}$

(i). Loss of head due to sudden enlargement,

$$h_e = (V_1 - V_2)^2 / 2g = (7.96 - 1.99)^2 / 2 \times 9.81 = 1.816 \text{ m.}$$

(ii). Let the pressure intensity in large pipe = p_2 .

Then applying Bernoulli's equation before and after the sudden enlargement,

$$(P_1/\rho g) + (V_1^2 / 2g) + Z_1 = (P_2/\rho g) + (V_2^2 / 2g) + Z_2 + h_e$$

$$\text{But } Z_1 = Z_2$$

$$(P_1/\rho g) + (V_1^2 / 2g) = (P_2/\rho g) + (V_2^2 / 2g) + h_e$$

$$\text{Or } (P_1/\rho g) + (V_1^2 / 2g) = (P_2/\rho g) + (V_2^2 / 2g) + Z_2 + h_f$$

$$(P_2/\rho g) = (P_1/\rho g) + (V_1^2 / 2g) - (V_2^2 / 2g) - h_e$$

$$= \frac{11.772 \times 10^4}{1000 \times 9.81} + \frac{-7.96^2}{2 \times 9.81} - \frac{-1.99^2}{2 \times 9.81} - 1.816$$

$$= 12.0 + 3.229 - 0.2018 - 1.816$$

$$= 15.229 - 20.178 = 13.21 \text{ m of water}$$

$$p_2 = 13.21 \times \rho g = 13.21 \times 1000 \times 9.81 \text{ N/m}^2$$

$$= 13.21 \times 1000 \times 9.81 \times 10^4 \text{ N/cm}^2 = 12.96 \text{ N/cm}^2.$$

(iii). Power lost due to sudden enlargement,

$$P = (\rho g Q h_e) / 1000 = (1000 \times 9.81 \times 0.25 \times 1.816) / 1000 = 4.453 \text{ kW.}$$

A horizontal pipeline 40m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end. For the first 25m of its length from the tank, the pipe is 150mm diameter is suddenly enlarged to 300mm. the height of water level in the tank is 8m above the centre of the pipe. Considering all losses of head, which occur. Determine the rate of flow. Take $f = 0.01$ for both sections of the pipe.

Given:

Total length of pipe, $L = 40\text{m}$

Length of 1st pipe, $L_1 = 25\text{m}$

Dia of 1st pipe $d_1 = 150\text{mm} = 0.15\text{m}$

Length of 2nd pipe $L_2 = 40 - 25 = 15\text{m}$

Dia of 2nd pipe $d_2 = 300\text{mm} = 0.3\text{m}$

Height of water $H = 8\text{m}$

Co-effi. Of friction $f = 0.01$

Applying the Bernoulli's theorem to the surface of water in the tank and outlet of pipe as shown in fig. and taking reference line passing through the center of the pipe.

$$0+0+8 = (P_2/\rho g) + (V_2^2 / 2g) + 0 + \text{all losses}$$

$$8.0 = 0 + (V_2^2 / 2g) + h_i + h_{fl} + h_e + h_{f2}$$

Where, h_i = loss of head at entrance = $0.5 V_1^2 / 2g$

$$h_{f1} = \text{head lost due to friction in pipe 1} = \frac{4XfXL_1XV_1^2}{d_1X2g}$$

h_e = loss of head due to sudden enlargement = $(V_1 - V_2)^2 / 2g$

$$h_{f2} = \text{head lost due to friction in pipe 2} = \frac{4XfXL_2XV_2^2}{d_2X2g}$$

But from continuity equation, we have

$$A_1V_1 = A_2V_2$$

$$V_1 = (A_2V_2/A_1) = \frac{\frac{\pi}{4} d_2^2 X V_2}{\frac{\pi}{4} d_1^2} = \left(\frac{d_2}{d_1} \right)^2 X V_2 = \left(\frac{0.3}{0.15} \right)_2 X V_2 = 4V_2$$

Substituting the value of V_1 in different head losses, we have

$$h_i = 0.5 V_1^2 / 2g = (0.5 \times (4V_2)^2) / 2g = 8V_2^2 / 2g$$

$$h_{f1} = \frac{4X0.01X25X(4V_2^2)}{0.15X2g} = \frac{4X0.01X25X16}{0.15} \times \frac{V_2^2}{2g} = 106.67 \frac{V_2^2}{2g}$$

$$h_e = (V_1 - V_2)^2 / 2g = (4V_2 - V_2)^2 / 2g = 9V_2^2 / 2g$$

$$h_{f2} = \frac{4X0.01X15X(V_2^2)}{0.3X2g} = \frac{4X0.01X15}{0.3} \times \frac{V_2^2}{2g} = 2.0 \frac{V_2^2}{2g}$$

Substituting the values of these losses in equation (i), we get

$$8.0 = \frac{V_2^2}{2g} + \frac{8V_2^2}{2g} + 106.67 \frac{V_2^2}{2g} + \frac{9V_2^2}{2g} + 2X \frac{V_2^2}{2g}$$

$$= \frac{V_2^2}{2g} [1+8+106.67+9+2] = 126.67 \frac{V_2^2}{2g}$$

$$V_2 = \sqrt{\frac{8.0 \times 2 \times g}{126.67}} = \sqrt{\frac{8.0 \times 2 \times 9.81}{126.67}} = 1.113 \text{ m/s}$$

$$\text{Rate of flow } Q = A_2 X V_2 = \frac{\pi}{4} (0.3)^2 \times 1.113 = 0.07867 \text{ m}^3/\text{s} = 78.67 \text{ litres/sec.}$$

A pipe line, 300mm in diameter and 3200m long is used to pump up 50kg per second of an oil whose density is 950 kg/m³.and whose Kinematic viscosity is 2.1 stokes. The center of the pipe at upper end is 40m above than at the lower end. The discharge at the upper end is atmospheric. Find the pressure at the lower end and draw the hydraulic gradient and the total energy line.

Given:

$$\text{Dia of pipe} \quad d = 300\text{mm} = 0.3\text{m}$$

$$\text{Length of pipe} \quad L = 3200\text{m}$$

$$\text{Mass} \quad M = 50\text{kg/s} = \rho \cdot Q$$

$$\text{Discharge} \quad Q = 50 / \rho = 50 / 950 = 0.0526 \text{ m}^3/\text{s}$$

$$\text{Density} \quad \rho = 950 \text{ kg/m}^3$$

$$\text{Kinematic viscosity } v = 2.1 \text{ stokes} = 2.1 \text{ cm}^2/\text{s} = 2.1 \times 10^{-4} \text{ m}^2/\text{s}$$

$$\text{Height of upper end} = 40\text{m}$$

$$\text{Pressure at upper end} = \text{atmospheric} = 0$$

$$\text{Renolds number, } R_e = V \times D / v, \text{ where } V = \text{Discharge / Area}$$

$$= 0.0526 / (\frac{\pi}{4} (0.3)^2) = 0.744 \text{ m/s}$$

$$R_e = (0.744 \times 0.30) / (2.1 \times 10^{-4}) = 1062.8$$

$$\text{Co - efficient of friction, } f = 16 / R_e = 16 / 1062.8 = 0.015$$

Head lost due to friction,h_f

$$= \frac{4 \times f \times L \times V^2}{d \times 2g} = \frac{4 \times 0.015 \times 3200 \times (0.744)^2}{0.3 \times 2 \times 9.81} = 18.05 \text{ m of oil.}$$

Applying the Bernoulli's equation at the lower and upper end of the pipe and taking datum line passing through the lower end, we have

$$(P_1/\rho g) + (V_1^2 / 2g) + Z_1 = (P_2/\rho g) + (V_2^2 / 2g) + Z_2 + h_f$$

but $Z_1 = 0$, $Z_2 = 40\text{m}$, $V_1 = V_2$ as diameter is same.

$$P_2 = 0, h_f = 18.05\text{m}$$

Substituting these values, we have

$$= 5400997 \text{ N/m}^2 = 54.099 \text{ N/cm}^2.$$

H.G.L. AND T.E.L.

$$V^2/2g = (0.744)^2/2 \times 9.81 = 0.0282 \text{ m}$$

$$p_1/\rho g = 58.05 \text{ m of oil}$$

$$p_2/\rho g = 0$$

Draw a horizontal line AX as shown in fig. From A draw the centerline of the pipe in such way that point C is a distance of 40m above the horizontal line. Draw a vertical line AB through A such that $AB = 58.05\text{m}$. Join B with C. then BC is the hydraulic gradient line.

Draw a line DE parallel to BC at a height of 0.0282m above the hydraulic gradient line. Then DE is the total energy line.

A main pipe divides into two parallel pipes, which again forms one pipe as shown. The length and diameter for the first parallel pipe are 2000m and 1.0m respectively, while the length and diameter of 2nd parallel pipe are 2000m and 0.8m. Find the rate of flow in each parallel pipe, if total flow in main is 3.0 m³/s. the co-efficient of friction for each parallel pipe is same and equal to 0.005.

Given:

Length of Pipe 1 $L_1 = 2000\text{m}$

Dia of pipe1 $d_1 = 1.0\text{m}$

Length of pipe 2 $L_2 = 2000\text{m}$

Dia of pipe 2 $d_2 = 0.8\text{m}$

Total flow $Q = 3.0\text{m}^3/\text{s}$

$$f_1 = f_2 = f = 0.005$$

let Q_1 = discharge in pipe 1

let Q_2 = discharge in pipe 2

from equation, $Q = Q_1 + Q_2 = 3.0 \dots \text{(i)}$

using the equation we have

$$\frac{\frac{4Xf}{d_1} \frac{XL}{2g} \frac{XV^2}{2}}{= \frac{\frac{4Xf}{d_2} \frac{XL}{2g} \frac{XV^2}{2}}{}}$$

$$\frac{4X0.005X2000XV^2}{1.0X2X9.81} = \frac{4X0.005X2000XV^2}{0.8X2X9.81}$$

$$\frac{V_1^2}{1.0} = \frac{V_2^2}{0.8} \text{ or } V_1^2 = \frac{V_2^2}{0.8}$$

$$V_1 = \frac{V_2}{\sqrt{0.8}} = \frac{V_2}{0.894}$$

$$\text{Now, } Q_1 = \frac{\pi}{4} d_1^2 X V_1 = \frac{\pi}{4} (1)^2 X (V_2 / 0.894)$$

$$\text{And } Q_2 = \frac{\pi}{4} d_2^2 X V_2 = \frac{\pi}{4} (0.8)^2 X (V_2) = \frac{\pi}{4} (0.64) X (V_2)$$

Substituting the value of Q_1 and Q_2 in equation (i) we get

$$\frac{\pi}{4} (1)^2 X (V_2 / 0.894) + \frac{\pi}{4} (0.64) X (V_2) = 3.0 \text{ or } 0.8785 V_2 + 0.5026 V_2 = 3.0$$

$$V_2 [0.8785 + 0.5026] = 3.0 \text{ or } V_2 = 3.0 / 1.3811 = 2.17 \text{ m/s.}$$

Substituting this value in equation (ii),

$$V_1 = V_2 / 0.894 = 2.17 / 0.894 \text{ m/s}$$

$$\text{Hence } Q_1 = \frac{\pi}{4} d_1^2 X V_1 = \frac{\pi}{4} 1^2 X 2.427 = \mathbf{1.096 \text{ m}^3/\text{s}}$$

$$Q_2 = Q - Q_1 = 3.0 - 1.906 = \mathbf{1.904 \text{ m}^3/\text{s}.}$$

Three reservoirs A, B, C are connected by a pipe system shown in fig. Find the discharge into or from the reservoirs B and C if the rate of flow from reservoirs A is 60 litres / s. find the height of water level in the reservoir C. take f = 0.006 for all pipes.

Given:

$$\text{Length of pipe AD, } L_1 = 1200\text{m}$$

$$\text{Dia of pipe AD, } d_1 = 30\text{cm} = 0.3\text{m}$$

$$\text{Discharge through AD, } Q_1 = 60\text{lit/s} = 0.06 \text{ m}^3/\text{s}$$

$$\text{Height of water level in A from reference line , } Z_A = 40\text{m}$$

$$\text{For pipe DB, length } L_2 = 600\text{mm, Dia., } d_2 = 20\text{cm} = 0.20\text{m, } Z_B = 38.0$$

$$\text{For pipe DC, length } L_3 = 800\text{mm, Dia., } d_3 = 30\text{cm} = 0.30\text{m,}$$

$$\text{Applying the Bernoulli's equations to point E and, } Z_A = Z_D + \frac{p_D}{\rho g} + h_f$$

$$\text{Where } h_f = \frac{4Xf}{d_1} \frac{XL}{2g} \frac{XV^2}{2g}, \text{ where } V_1 = Q_1 / \text{Area} = 0.006 / (\frac{\pi}{4} (0.3)^2) = 0.848 \text{ m/s.}$$

$$h_f = \frac{4 \times 0.006 \times 1200 \times 0.848^2}{0.3 \times 2 \times 9.81} = 3.518 \text{ m.}$$

$$\{Z_D + \frac{p_1}{\rho g}\} = 40.0 - 3.518 = 36.482 \text{ m}$$

Hence piezometric head at D = 36.482m. Hence water flows from B to D.

Applying Bernoulli's equation to point B and D

$$Z_B = \{Z_D + \frac{p_D}{\rho g}\} + h_f \text{ or } 38 = 36.482 + h_f$$

$$h_f = 38 - 36.482 = 1.518 \text{ m}$$

$$\text{But } h_f = \frac{4XfXL_2XV_2^2}{d_2X2g} = \frac{4X0.006X600XV_2^2}{0.2X2X9.81}$$

$$1.518 = \frac{4X0.006X600XV_2^2}{0.2X2X9.81}$$

$$V_2 = \sqrt{\frac{1.518X0.2X2X9.81}{4X0.006X600}} = 0.643 \text{ m/s}$$

$$\text{Discharge } Q_2 = V_2 X \frac{\pi}{4} (d_2)^2 = 0.643 X \frac{\pi}{2} X (0.2)^2 = 0.0202 \text{ m}^3/\text{s} = 20.2 \text{ lit/s.}$$

Applying Bernoulli's equation to D and C

$$\{Z_D + \frac{p_D}{\rho g}\} = Z_C + h_f$$

$$36.482 = Z_C + \frac{4XfXL_3XV_3^2}{d_3X2g} \text{ where, } V_3 = \frac{Q_3}{\frac{\pi}{4} d_3^2}$$

but from continuity $Q_1 + Q_2 = Q_3$

$$Q_3 = Q_1 + Q_2 = 0.006 + 0.0202 = 0.0802 \text{ m}^3/\text{s}$$

$$V_3 = \frac{Q_3}{\frac{\pi}{4} d_3^2} = \frac{Q_3}{\frac{\pi}{4} (0.9)^2} = 1.134 \text{ m/s}$$

$$36.482 = Z_C + \frac{4X0.006X800X1.134^2}{0.2X2X9.81} = Z_C + 4.194$$

$$Z_C = 36.482 - 4.194 = 32.288 \text{ m}$$

A Pipe line of length 2000 m is used for power transmission. If 110.365 kW power is to be transmitted through the pipe in which water having pressure of 490.5 N/cm² at inlet is flowing. Find the diameter of the pipe and efficiency

of transmission if the pressure drop over the length of pipe is 98.1 N/cm².

Take f = 0.0065.

Given:

$$\text{Length of pipe} \quad L = 2000\text{m.}$$

$$\text{H.P transmitted} \quad = 150$$

$$\text{Pressure at inlet,} \quad p = 490.5 \text{ N/cm}^2 = 490.5 \times 10^4 \text{ N/m}^2.$$

$$\text{Pressure head at inlet, } H = p / \rho g$$

$$\text{Pressure drop} \quad = 98.1 \text{ N/cm}^2 = 98.1 \times 10^4 / \text{m}^2$$

$$\text{Loss of head} \quad h_f = 98.1 \times 10^4 / \rho g = 98.1 \times 10^4 / (1000 \times 9.81) = 100\text{m}$$

$$\text{Co-efficient of friction } f = 0.0065$$

$$\text{Head available at the end of the pipe} = H - h_f = 500 - 100 = 400\text{m}$$

$$\text{Let the diameter of the pipe} = d$$

Now power transmitted is given by,

$$P = [\rho g \times Q \times (H - h_f)] / 1000 \text{ kW.}$$

$$110.3625 = [1000 \times 9.81 \times Q \times 400] / 1000$$

$$Q = [110.3625 \times 1000 / (1000 \times 9.81 \times 400)] = 0.02812 \text{ m}^3/\text{s}$$

$$\text{But discharge } Q = A \times V = \frac{\pi}{4} d^2 \times V$$

$$\frac{\pi}{4} d^2 \times V = 0.02812$$

$$V = (0.02812 \times 4) / (3.14 \times d^2) = 0.0358 / d^2 \quad \dots \dots \dots (1)$$

Total head lost due to friction,

$$h_f = \frac{4fXLV^2}{dX2g}$$

$$\text{but,} \quad h_f = 100\text{m}$$

$$100 = h_f = \frac{4XfXL \times V^2}{d \times X2g} = \frac{4 \times 0.0065 \times 2000 \times V^2}{d \times 2 \times 9.81} = \frac{2.65 \times V^2}{d}$$

$$= (2.65 / d) \times (0.358/d^2)^2 = 0.003396 / d^5$$

from equation (1),

$$V = 0.0358 / d^2$$

$$100 = 0.003396 / d^5$$

$$d = (0.003396 / 100)^{1/5} = 0.1277\text{m} = 127.7\text{mm.}$$

Efficiency of power transmission is given by equation

$$\eta = \frac{H - h_f}{H} = \frac{500 - 100}{500} = 0.80 = 80\%$$

UNIT – V

SIMILITUDE AND MODEL STUDY

Dimensional Analysis – Rayleigh's method, Buckingham's Pi-theorem – Similitude and models – Scale effect and distorted models

Dimensional analysis.

Dimensional analysis is defined as a mathematical technique used in research work for design and conducting model tests.

Fundamental dimensions

The fundamental units quantities such as length (L), mass (M), and time (T) are fixed dimensions known as fundamental dimensions.

Units.

Unit is defined as a yardstick to measure physical quantities like distance, area, volume, mass etc.

Derive the dimensions for velocity.

Velocity is the distance (L) travelled per unit time (T)

$$\text{Velocity} = \text{Distance/ Time} = [L/T] = LT^{-1}.$$

Model

Model is nothing but small-scale repetition of the actual structure or machine.

List out the advantages of model analysis.

The advantages of model analysis are:

1. The performance of hydraulic structure or machine can be easily predicted in advance from its model.
2. The merits of alternative design can be predicted with the help of model testing and the most economical and safe design may be finally adopted.

Fluid mechanics and Heat Transfer

**Unit 3 to
Unit 5**

UNIT: I - CONDUCTION**PART A - 2 Marks (Questions and Answers)****1. State Fourier's Law of conduction. (April/May 2011, Nov/Dec 14, Nov/Dec 16)**

The rate of heat conduction is proportional to the area measured – normal to the direction of heat flow and to the temperature gradient in that direction.

$$Q \propto -A \frac{dt}{dx}$$

$$Q = -KA \frac{dt}{dx}$$

Where, A are in m²

$\frac{dt}{dx}$ is temperature gradient in K/m

K is Thermal Conductivity W/mk

2. State Newton's law of cooling or convection law. (May/June 2009)

Heat transfer by convection is given by Newton's law of cooling

$$Q = hA (T_s - T_\infty)$$

Where

A – Area exposed to heat transfer in m², h - heat transfer coefficient in W/m²K

T_s – Temperature of the surface in K, T_∞ - Temperature of the fluid in K.

3. Define overall heat transfer co-efficient. (May/June 2007)

The overall heat transfer by combined modes is usually expressed in terms of an overall conductance or overall heat transfer co-efficient 'U'.

$$\text{Heat transfer } Q = UA \Delta T.$$

4. Write down the equation for heat transfer through composite pipes or cylinder. (April/May 2008)

$$\text{Heat transfer } Q = \frac{\Delta T_{overall}}{R} \text{ where } \Delta T = T_a - T_b$$

$$R = \frac{1}{2\pi L} \cdot \frac{1}{h_a r_1} + \frac{\ln\left[\frac{r_2}{r_1}\right]}{K_1} + \frac{\ln\left[\frac{r_3}{r_2}\right]}{K_1} L_2 + \frac{1}{h_a r_{13}}$$

5. What is critical radius of insulation (or) critical thickness? (May/June 2014) (Nov/Dec 2008)

$$\text{Critical radius} = r_c \quad \text{Critical thickness} = r_c - r_1$$

Addition of insulating material on a surface does not reduce the amount of heat transfer rate always. In fact under certain circumstances it actually increases the heat loss up to certain thickness of insulation. The radius of insulation for which the heat transfer is maximum is called critical radius of insulation, and the corresponding thickness is called critical thickness.

6. Define Fin efficiency and Fin effectiveness. (Nov/Dec 2015& Nov/Dec 2010)

The efficiency of a fin is defined as the ratio of actual heat transfer by the fin to the maximum possible heat transferred by the fin.

$$\eta = \frac{Q_{fin}}{Q_{max}}$$

Fin effectiveness is the ratio of heat transfer with fin to that without fin

$$\text{fin effectiveness} = \frac{Q_{withfin}}{Q_{withoutfin}}$$

7. Define critical thickness of insulation with its significance. [MAY-JUN 14]

Addition of insulating material on a surface does not reduce the amount of heat transfer rate always. In fact under certain circumstances it actually increases the heat loss up to certain thickness of insulation. The radius of insulation for which the heat transfer is maximum is called critical radius of insulation, and the corresponding thickness is called critical thickness. For cylinder, Critical radius = $r_c = k/h$, Where k- Thermal conductivity of insulating material, h- heat transfer coefficient of surrounding fluid. Significance: electric wire insulation may be smaller than critical radius. Therefore the plastic insulation may actually enhance the heat transfer from wires and thus keep their steady operating temperature at safer levels.

8. What is lumped system analysis? When is it applicable? [Nov/Dec 14 & April/May 2010]

In heat transfer analysis, some bodies are observed to behave like a "lump" whose entire body temperature remains essentially uniform at all times during a heat transfer process. The temperature of such bodies can be taken to be a function of time only. Heat transfer analysis which utilizes this idealization is known as the lumped system analysis. It is applicable when the Biot number (the ratio of conduction resistance within the body to convection resistance at the surface of the body) is less than or equal to 0.1.

9. Write the three dimensional heat transfer poisson and laplace equation in Cartesian co-ordinates(May/June 2012)(April/May 2010)

Poisson equation:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{g}{k} = 0$$

Laplace equation:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = 0$$

10. A 3 mm wire of thermal conductivity 19 W/mK at a steady heat generation of 500 MW/m³ .Determine the center temperature if the outside temperature is maintained at 25°C (May 2012)

$$\text{Critical temperature } T_c = T_\infty + \frac{qr^2}{4k}$$

$$= 298 + \left[\frac{500 \times 10^6 \times 0.0015^2}{4 \times 19} \right]$$

$$T_c = 312.8K$$

11. List down the three types of boundary conditions. (Nov/Dec 2005)

1. Prescribed temperature
2. Prescribed heat flux
3. Convection Boundary Conditions.

12. Define fins (or) extended surfaces.

It is possible to increase the heat transfer rate by increasing the surface of heat transfer. The surfaces used for increasing heat transfer are called extended surfaces or sometimes known as fins.

13. How thermodynamics differ from heat transfer?

- Thermodynamics doesn't deals with rate of heat transfer
- Thermodynamics doesn't tell how long it will occur
- Thermodynamics doesn't tell about the method of heat transfer

PART B - 13 Marks (Questions and Answers)

1. Derive the General Differential Equation of Heat Conduction in Cartesian coordinates.(NOV/DEC 2014)

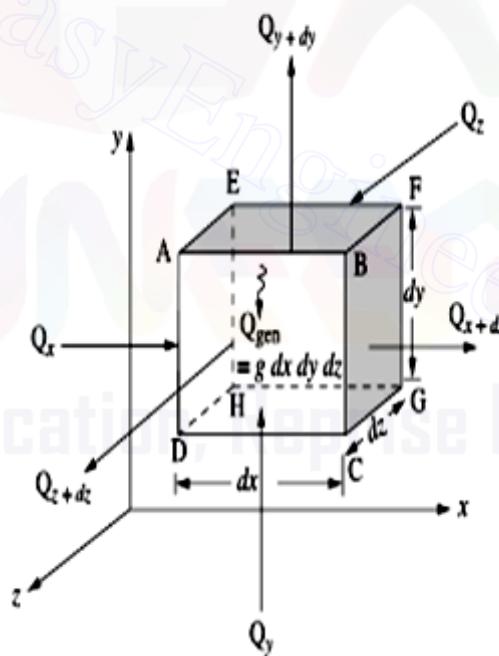


Fig 2.1

Consider a small volume element in Cartesian coordinates having sides dx , dy and dz as shown in Fig. 2.1 the energy balance for this little element is obtained from the first law of thermodynamics as:

$$\left\{ \begin{array}{l} \text{Net heat conducted into element} \\ \text{per unit time} \end{array} \right\}_{(I)} + \left\{ \begin{array}{l} \text{Internal heat generated} \\ \text{per unit time} \end{array} \right\}_{(II)}$$

$$= \left\{ \begin{array}{l} \text{Increase in internal} \\ \text{per unit time} \\ (\text{III}) \end{array} \right\} + \left\{ \begin{array}{l} \text{Work done by element} \\ \text{per unit time} \\ (\text{IV}) \end{array} \right\} \quad (2.2)$$

The last term of Eqn. (2.2) is very small because the flow work done by solids due to temperature changes is negligible.

The three terms, I, II and III of this equation are evaluated as follows:

Let q_x be the heat flux in x-direction at x , face ABCD and q_{x+dx} the heat flux at $x + dx$, face A'B'C'D'. Then rate of heat flow into the element in x-direction through face ABCD is:

$$Q_x = q_x dy dz = -k_x \frac{\partial T}{\partial x} dy dz \quad (2.3)$$

Where k_x is the thermal conductivity of material in x-direction and $\frac{\partial T}{\partial x}$ is the temperature gradient in

x-direction. The rate of heat flow out of the element in x-direction through the face at $x+dx$, A'B'C'D' is:

$$Q_x = -k_x \frac{\partial T}{\partial x} dy dz - \frac{\partial}{\partial x} \left(k_x \frac{\partial T}{\partial x} \right) dx dy dz \quad (2.4)$$

Then, the net rate of heat entering the element in x-direction is the difference between the entering and leaving heat flow rates, and is given by:

$$Q_x - Q_{x+dx} = \frac{\partial}{\partial x} \left(k_x \frac{\partial T}{\partial x} \right) dx dy dz \quad (2.5)$$

$$Q_y - Q_{y+dy} = \frac{\partial}{\partial y} \left(k_y \frac{\partial T}{\partial y} \right) dx dy dz$$

$$Q_z - Q_{z+dz} = \frac{\partial}{\partial z} \left(k_z \frac{\partial T}{\partial z} \right) dx dy dz$$

The net heat conducted into the element $dx dy dz$ per unit time, term I in Eqn. (2.2) is:

$$I = \left[\frac{\partial}{\partial x} \left(k_x \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(k_y \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left(k_z \frac{\partial T}{\partial z} \right) \right] dx dy dz \quad (2.6)$$

Let q be the internal heat generation per unit time and per unit volume (W/m^3), the rate of energy generation in the element, term II in Eqn. (2.2), is

$$II = q dx dy dz \quad (2.7)$$

The change in internal energy for the element over a period of time dt is:
(mass of element) (specific heat) (change in temperature of the element in time dt)

$$(\rho dx dy dz) (c_p) dT = (\rho c_p dT) dx dy dz \quad (2.8)$$

Where ρ and c_p are the density and specific heat of the material of the element.

Then, the change in internal energy per unit time, term III of Eqn. (2.2) is:

$$\text{III} = \rho c_p \frac{\partial T}{\partial t} dx dy dz \quad (2.9)$$

Substitution of Eqns. (2.6),(2.7) and (2.9) into Eqn. (2.2) leads to the general three-dimensional equation for heat conduction:

$$\frac{\partial}{\partial x} \left(k_x \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(k_y \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left(k_z \frac{\partial T}{\partial z} \right) + q = \rho c_p \frac{\partial T}{\partial t} \quad (2.10)$$

Since for most engineering problems the materials can be considered isotropic for which $K_x = K_y = K_z = k = \text{Constant}$, the general three-dimensional heat conduction equation becomes:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q}{k} = \frac{\rho c_p}{k} \frac{\partial T}{\partial t} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

The quantity $\frac{k}{\rho c_p}$ is known as the thermal diffusivity, α of the material. It has got the units m^2/s .

2. Derive the Heat conduction equation in cylindrical coordinates.

The heat conduction equation derived in the previous section can be used for solids with rectangular boundaries like slabs, cubes, etc. but then there are bodies like cylinders, tubes, cones, spheres to which Cartesian coordinates system is not applicable.

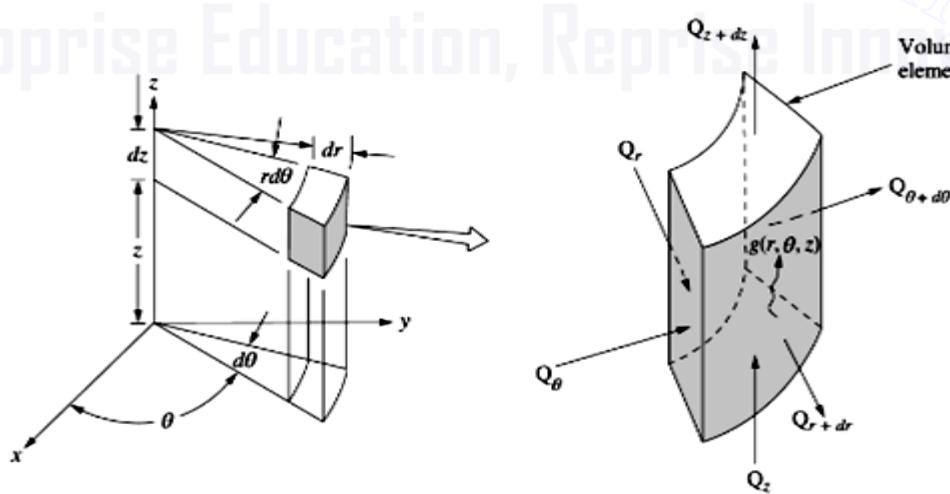


Fig 2.2

A more suitable system will be one in which the coordinate surfaces coincide with the boundary surfaces of the region. For cylindrical bodies, a cylindrical

coordinate system should be used. The heat conduction equation in cylindrical coordinates can be obtained by an energy balance over a differential element, a procedure similar to that described previously. The equation could also be obtained by doing a coordinate transformation from Fig. 2.2.

Consider a small volume element having sides dr , dz and $r d\theta$ as shown in Fig. 2.2. Assuming the material to be isotropic, the rate of heat flow into the element in r -direction is:

$$Q_r = -k \frac{\partial T}{\partial r} r d\theta dz$$

The rate of heat flow out of the element in r -direction at $r+dr$ is:

$$Q_{r+dr} = Q_r + \frac{\partial Q_r}{\partial r} dr$$

Then, the net rate of heat entering the element in r -direction is given by

$$\begin{aligned} Q_r - Q_{r+dr} &= k \frac{\partial}{\partial r} \left(r \frac{\partial T}{\partial r} \right) dr d\theta dz \\ &= k \left(\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right) dr d\theta dz \end{aligned}$$

Similarly,

$$\begin{aligned} Q_\theta - Q_{\theta+d\theta} &= -k \frac{\partial T}{\partial \theta} dr dz - \left[-k \frac{\partial T}{\partial d\theta} dr dz - \frac{k \partial}{\partial d\theta} \left(\frac{\partial T}{\partial \theta} \right) . r d\theta dr dz \right] \\ &= k \left(\frac{1}{r^2} \frac{\partial^2 T}{\partial \theta^2} \right) r dr d\theta dz \\ Q_z - Q_{z+dz} &= -k \frac{\partial T}{\partial z} . r d\theta dz - \left[-k \frac{\partial T}{\partial z} r d\theta dr - k \frac{\partial}{\partial z} \left(\frac{\partial T}{\partial z} \right) . r d\theta dr dz \right] \\ &= -k \left(\frac{\partial^2 T}{\partial z^2} \right) r dr d\theta dz \end{aligned}$$

The net heat conducted into the element $dr.r d\theta dz$ per unit time, term I of Eqn. (2.2)

$$I = k \left(\frac{\partial^2 T}{\partial z^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right) r dr d\theta dz$$

Taking q as the internal heat generation per unit time and per unit volume, term II of Eqn (2.2) is

$$II = q r dr d\theta dz$$

The change in internal energy per unit time, term III of Eqn. (2.2) is:

$$III = \rho c_p \frac{\partial T}{\partial t} r dr d\theta dz$$

Substitution of terms I, II and III into the energy balance Eqn. (2.2) leads to three-dimensional equation for an isentropic material in cylindrical coordinate system as

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \left(\frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial z^2} + \frac{q}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$$

3. A furnace wall is made up of three layer of thickness 25 cm, 10 cm and 15 cm with thermal conductivities of 1.65 W/mK and 9.2 W/mK respectively. The inside is exposed to gases at 1250°C with a convection coefficient of 25 W/m² K and the inside surface is at 1100°C , the outside surface is exposed to air at 25°C with convection coefficient of 12 W/m²K .Determine (i) the unknown thermal conductivity (ii)the overall heat transfer coefficient (iii) All the surface temperature.(May/June 2012)

Given:

$$\text{Thickness } L_1 = 25 \text{ cm} = 0.25 \text{ m}$$

$$L_2 = 10 \text{ cm} = 0.1 \text{ m}$$

$$L_3 = 15 \text{ cm} = 0.15 \text{ m}$$

$$\begin{aligned} \text{Thermal conductivity, } & k_1 = 1.65 \text{ W/mK}, \\ & k_2 = 9.2 \text{ W/mK} \end{aligned}$$

$$\text{Inside Gas Temperature, } T_a = 1250^{\circ}\text{C} = 1523 \text{ K}$$

$$T_b = 25^{\circ}\text{C} = 298 \text{ K}$$

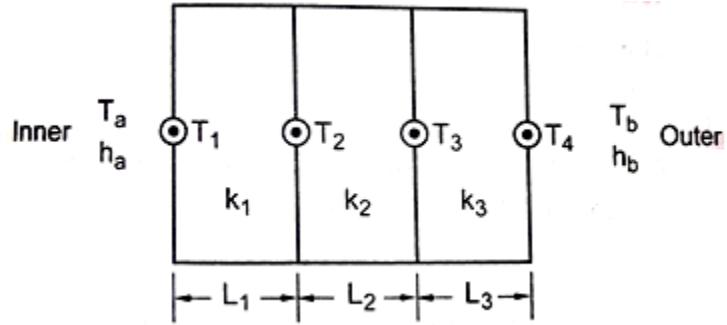
$$\text{Inner surface temperature, } T_1 = 1100^{\circ}\text{C} = 1373 \text{ K}$$

$$\text{Inside heat transfer coefficient, } h_a = 25 \text{ W/m}^2\text{K}$$

$$\text{Outside Heat Transfer Coefficient, } h_b = 12 \text{ W/m}^2\text{K}$$

To find:

- i) The Unknown Thermal Conductivity ,
- ii) The Overall Heat Transfer Coefficient
- iii) All The Surface Temperature

**Solution:****STEP-1**

Heat transfer $Q = h_a A (T_a - T_1)$
 $= 25(1523 - 1373) = 3750 \text{ W/m}^2$

From HMT data book P.No 45

Heat Flow, $Q = \Delta T_{\text{overall}} / R$

$$R = \frac{1}{H_a A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{L_3}{k_3 A} + \frac{1}{H_b A}$$

$$Q = \frac{T_a - T_b}{\frac{1}{H_a A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{L_3}{k_3 A} + \frac{1}{H_b A}}$$

$$\frac{Q}{A} = \frac{1523 - 298}{\frac{1}{25} + \frac{0.25}{1.65} + \frac{0.10}{k_2} + \frac{0.15}{9.2} + \frac{1}{12}}$$

$k_2 = 2.816 \text{ W/mK}$

STEP-2

From HMT data book P.No 45

Overall Thermal resistance (R)

$$R = \frac{1}{H_a A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{L_3}{k_3 A} + \frac{1}{H_b A}$$

[Take A=1 m²]

$R_{\text{total}} = 0.3267 \text{ W/m}^2$

$U = 1/R_{\text{total}} = 1/0.3267 = 3.06 \text{ W/m}^2 \text{K}$

STEP-3

$$Q = \frac{T_a - T_1}{R_a} = \frac{T_1 - T_2}{R_1} = \frac{T_2 - T_3}{R_2} = \frac{T_3 - T_4}{R_3} = \frac{T_4 - T_b}{R_b}$$

$$Q = \frac{T_a - T_1}{R_a},$$

$$Q = \frac{T_1 - T_2}{R_1},$$

$$R_1 = \frac{L_1}{K_1} = 0.1515$$

$$3750 = \frac{1373 - T_2}{0.1515}$$

$T_2 = 804.8\text{K}$

$$Q = \frac{T_2 - T_3}{R_2} \left[\because R_2 = \frac{L_2}{K_2} \right]$$

$$3750 = \frac{804.8 - T_3}{\frac{0.10}{2.816}}$$

$T_3 = 671.45\text{K}$

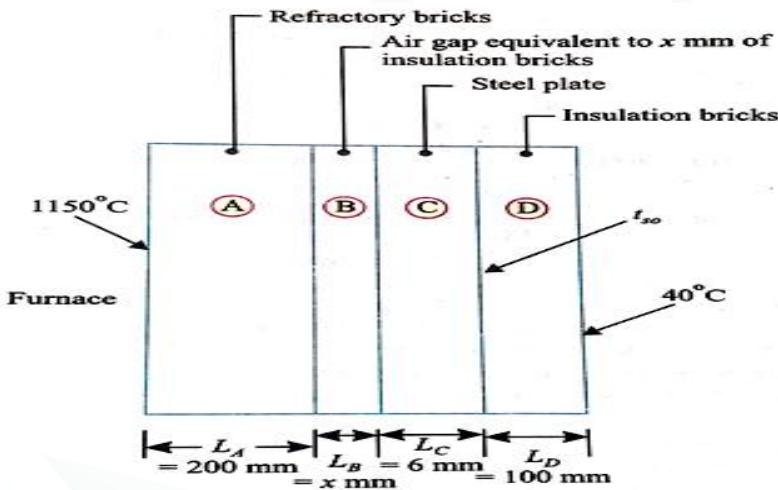
$$Q = \frac{T_3 - T_4}{R_3} \left[\because R_3 = \frac{L_3}{K_3} \right]$$

$$3750 = \frac{671.45 - T_4}{\frac{0.15}{9.2}}$$

$T_4 = 610.30\text{K}$

4. A furnace wall consists of 200mm layer of refractory bricks, 6 mm layer of steel plate and a 100mm layer of insulation bricks. The maximum temperature of the wall is 1150°C on the furnace side and the minimum temperature is 40°C on the outermost side of the wall. An accurate energy balance over the furnace shows that the heat loss from the wall is 400W/m^2 . It is known that there is a thin layer of air between the layers of refractory bricks and steel plate. Thermal conductivities for the three layers are 1.52, 45 and $0.138\text{ W/m}^\circ\text{C}$ respectively. Find

- i) To how many millimeters of insulation bricks is the air layer equivalent?
ii) What is the temperature of the outer surface of the steel plate? (Nov/Dec 2014)



Given

Thickness of refractory bricks, $L_A = 200\text{mm} = 0.2\text{m}$

Thickness of steel plate, $L_C = 6\text{mm} = 0.006\text{m}$

Thickness of insulation bricks, $L_D = 100\text{mm} = 0.1\text{m}$

Difference of temperature between the innermost and outermost sides of the wall,

$$\Delta t = 1150 - 40 = 1110^\circ\text{C}$$

$$K_A = 1.52 \text{ W/m}^\circ\text{C}$$

$$K_B = K_D = 0.138 \text{ W/m}^\circ\text{C}$$

$$K_C = 45 \text{ W/m}^\circ\text{C}$$

$$\text{Heat loss from the wall, } q = 400 \text{ W/m}^2$$

- i) The value of $x (=L_c)$

From HMT data book P.No 45

$$\text{Heat Flow, } Q = \Delta T_{\text{overall}} / R$$

$$R = \frac{1}{H_a A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{L_3}{k_3 A} + \frac{1}{H_b A}$$

$$400 = \frac{1110}{\frac{L_A}{K_A} + \frac{L_B}{K_B} + \frac{L_C}{K_C} + \frac{L_D}{K_D}}$$

$$400 = \frac{1110}{\frac{0.2}{1.52} + \frac{(x/1000)}{0.138} + \frac{0.006}{45} + \frac{0.1}{0.138}}$$

$$= \frac{1110}{0.1316+0.0072x+0.00013+0.7246}$$

$$= \frac{1110}{0.8563+0.0072x}$$

$$0.8563 + 0.0072x = \frac{1110}{400} = 2.775$$

$$x = \frac{2.775 - 0.8563}{0.0072} = 266.5 \text{ mm}$$

$$x = 266.5 \text{ mm}$$

ii) Temperature of the outer surface of the steel plate t_{so} :

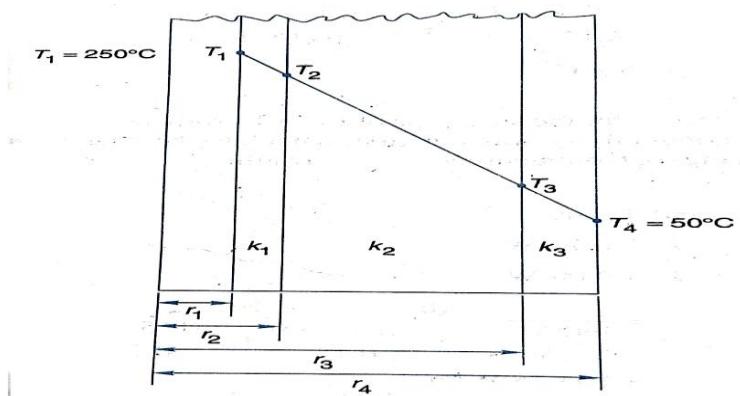
$$q = 400 = \frac{(t_{so} - 40)}{L_D/K_D}$$

$$400 = \frac{(t_{so} - 40)}{0.1/0.138}$$

$$t_{so} = \frac{400}{1.38} + 40 = 329.8^\circ\text{C}$$

$$t_{so} = 329.8^\circ\text{C}$$

5. A steel pipe line($K=50\text{W/mk}$) of I.D 110mm is to be covered with two layers of insulation each having a thickness of 50mm. The thermal conductivity of the first insulation material is 0.06W/mk and that of the second is 0.12W/mk . Calculate the loss of heat per metre length of pipe and the interface temperature between the two layers of insulation when the temperature of the inside tube surface is 250°C and that of the outside surface of the insulation is 50°C . (April/ may 2015)



Given :

$$r_1 = 50\text{mm}$$

$$r_2 = 55\text{mm}$$

$$r_3 = 105\text{mm}$$

$$r_4 = 155\text{mm}$$

$$K_1 = 50 \frac{W}{mk}$$

$$K_2 = 0.06 \frac{W}{mk}$$

$$K_3 = 0.12 \frac{W}{mk}$$

$$T_1 = 250^\circ C$$

$$T_4 = 50^\circ C$$

To find

$$T_3 = ?$$

Solution:**step-1**

From HMT data book P.No 46

Heat Flow , $Q = \Delta T_{\text{overall}} / R$

$$R = \frac{1}{2\pi L} \left[\frac{1}{k_1 r_1} + \frac{1}{k_2} \ln \left(\frac{r_2}{r_1} \right) + \frac{1}{k_3} \ln \left(\frac{r_3}{r_2} \right) + \frac{1}{k_4} \ln \left(\frac{r_4}{r_3} \right) + \frac{1}{k_5 r_4} \right]$$

$$\frac{Q}{L} = \frac{2\pi (T_1 - T_4)}{\frac{\ln(r_2/r_1)}{K_1} + \frac{\ln(r_3/r_2)}{K_2} + \frac{\ln(r_4/r_3)}{K_3}}$$

$$\frac{Q}{L} = \frac{2 \times 3.14 (250 - 50)}{\frac{\ln(55/50)}{0.06} + \frac{\ln(105/55)}{0.12}}$$

$$\frac{Q}{L} = 89.6 \text{ W/m}$$

step-2The interface temperature, T_3 is obtained from the equation

$$\frac{Q}{L} = \frac{2\pi(T_3 - T_4)}{\ln\left(\frac{r_4}{r_3}\right) / K_3}$$

$$T_3 = \frac{\frac{Q}{L} \times \ln\left(\frac{r_4}{r_3}\right)}{2\pi K_3} + T_4$$

$$= \frac{89.6 \times \ln\left(\frac{155}{105}\right)}{0.12 \times 6.28} + 50$$

$$T_3 = 96.3^{\circ}\text{C}$$

6. A plane wall 10cm thick generates heat at a rate of $4 \times 10^4 \text{ W/m}^3$ when an electric current is passed through it. The convective heat transfer coefficient between each face of the wall and the ambient air is $50 \text{ W/m}^2\text{K}$. Determine a) the surface temperature b) the maximum air temperature on the wall, Assume the ambient air temperature to be 20°C and the thermal conductivity of the wall material to be 15 W/mK . (May/June 2016)

Given:

Thickness $L = 10\text{cm} = 0.10\text{m}$

Heat generation $\dot{q} = 4 \times 10^4 \text{ W/m}^3$

Convective heat transfer co-efficient = $50 \text{ W/m}^2\text{K}$.

Ambient air temperature $T_{\infty} = 20^{\circ}\text{C} + 273 = 293\text{K}$

Thermal conductivity $k = 15 \text{ W/mK}$.

Solution:

Step 1

From HMT data book P.No 48

$$\begin{aligned} \text{Surface temperature } T_W &= T_{\infty} + \frac{\dot{q}L}{2h} \\ &= 293 + \frac{4 \times 10^4 \times 0.10}{2 \times 50} \end{aligned}$$

$$T_w = 333\text{K}$$

Step2

$$\text{Maximum temperature } T_{max} = T_w + \frac{\dot{q}L^2}{8k}$$

$$= 333 + \frac{4 \times 10^4 \times (0.10)^2}{8 \times 15}$$

$$T_{\max} = 336.3 \text{ K}$$

7. A cylinder 1m long and 5 cm in diameter is placed in an atmosphere at 45°C . It is provided with 10 longitudinal straight fins of material having $k=120 \text{ W/mK}$. The height of 0.76mm thick fins is 1.27cm from the cylinder surface. The heat transfer co-efficient between cylinder and the atmospheric air is $17 \text{ W/m}^2\text{K}$. Calculate the rate of heat transfer and the temperature at the end of fins if the surface temperature of cylinder is 150°C . (Nov/Dec 2015)

Given:

Length of cylinder $W = 1 \text{ m}$

Length of the fin $L = 1.27 \text{ cm} = 1.27 \times 10^{-2} \text{ m}$.

Thickness of the fin $t = 0.76 \text{ mm} = 0.76 \times 10^{-3} \text{ m}$.

Thermal conductivity $k = 120 \text{ W/mK}$

heat transfer co-efficient $h = 17 \text{ W/m}^2\text{K}$

Base temperature of the cylinder $T_b = 150^\circ\text{C} + 273 = 423 \text{ K}$

Ambient temperature $T_\infty = 45^\circ\text{C} + 273 = 318 \text{ K}$

Diameter of the cylinder $d = 5 \text{ cm} = 5 \times 10^{-2} \text{ m}$.

To find

- i) Heat transfer rate, Q_{total}
- ii) Temperature at the end of the fin, T

Solution:

Step-1

Perimeter = $2W = 2 \times 1 = 2 \text{ m}$

Area = $Wt = 1 \times 0.76 \times 10^{-3} = 0.76 \times 10^{-3} \text{ m}^2$

From HMT data book P.No 50

$$m = \sqrt{\frac{hp}{kA}}$$

$$= \sqrt{\frac{17 \times 2}{120 \times 0.76 \times 10^{-3}}}$$

$$m = 19.31$$

Step-2

$$\tan h(mL) = \tanh(19.81 \times 1.27 \times 10^{-2}) = 0.241$$

$$\frac{h}{mk} = \frac{17}{19.31 \times 120} = 0.00734$$

From HMT data book P.No 50

$$Q_{fin} = \sqrt{hpkA} (T_b - T_\infty) \left[\frac{\tanh(ml) + \left(\frac{h}{mk}\right)}{1 + \left(\frac{h}{mk}\right) \tanh(ml)} \right]$$

$$= \sqrt{17 \times 2 \times 120 \times 0.76 \times 10^{-3}} (423 - 318) \left[\frac{0.241 + (0.00734)}{1 + (0.00734) \cdot 0.241} \right]$$

$$Q_{fin} = 45.65 \text{ KW per fin}$$

From HMT data book P.No 44

$$Q_b = h[\pi D - [10 \times 0.76 \times 10^{-3}]L(T_b - T_\infty)]$$

$$= 17[\pi \times 0.05 - [10 \times 0.76 \times 10^{-3}]1(423 - 318)]$$

$$Q_b = 266.82W$$

Step-3

$$Q_{total} = 10Q_{fin} + Q_b$$

$$= (10 \times 45.7) + 266.82$$

$$Q_{total} = 723.82W$$

Step-4

From HMT data book P.No 50

The temperature at the end of the fin

$$T - T_\infty = \frac{T_b - T_\infty}{\cosh(ml) + \left(\frac{h}{mk}\right) \sinh(ml)}$$

$$T - 318 = \frac{423 - 318}{\cosh(19.81 \times 1.27 \times 10^{-2}) + (0.00734) \sinh(19.81 \times 1.27 \times 10^{-2})}$$

$$T = 419.74K$$

8. A circumferential rectangular fins of 140mm wide and 5mm thick are fitted on a 200mm diameter tube. The fin base temperature is 170°C and the ambient temperature is 25°C . Estimate fin Efficiency and heat loss per fin. Take Thermal conductivity $K = 220\text{W/mk}$ Heat transfer co-efficient $h=140\text{W/m}^2\text{k}$.

Given:

Wide $L = 140\text{mm}=0.140\text{m}$

Thickness $t = 5\text{mm} = 0.005\text{m}$

Diameter $d = 200\text{mm} \Rightarrow r = 100\text{mm} = 0.100\text{m}$

Fin base temperature $T_b = 170^{\circ}\text{C} + 273 = 443K$

Ambient temperature $T_{\infty} = 25^{\circ}\text{C} + 273 = 298K$

Thermal conductivity $k= 220\text{W/mk}$

Heat transfer co-efficient $h= 140\text{W/m}^2\text{k}$

To find:

Fin Efficiency, η

Heat loss Q

Solution:

A rectangular fin is long and wide. So heat loss is calculated by fin efficiency curves

From HMT data book P.No 52

Step1

$$\text{Corrected length } L_c = L + \frac{t}{2}$$

$$= 0.140 + \frac{0.005}{2}$$

$$L_c = 0.1425 \text{ m}$$

Step2

$$\begin{aligned} r_{2c} &= r_1 + L_c \\ &= 0.100 + 0.1425 \end{aligned}$$

$$r_{2c} = 0.2425 \text{ m}$$

Step 3

$$A_s = 2\pi [r_{2c}^2 - r_1^2]$$

$$= 2\pi[(0.2425)^2 - (0.100)^2]$$

$$A_s = 0.30650 m^2$$

Step4

$$A_m = t[r_{2c} - r_1]$$

$$A_m = 0.005[0.2425 - 0.100]$$

$$A_m = 7.125 \times 10^{-4} m^2$$

From the graph, we know that, [HMT data book page no.51]

$$X_{axis} = (L_c)^{1.5} \left[\frac{h}{KA_m} \right]^{0.5}$$

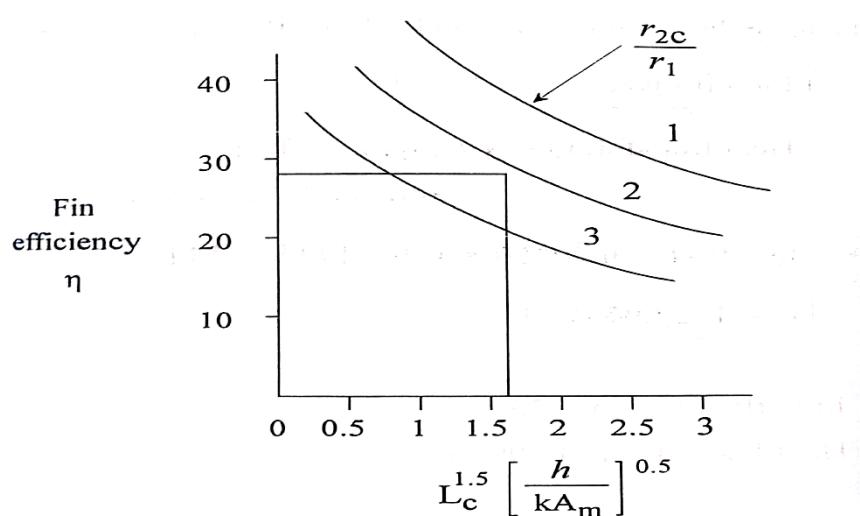
$$= (0.1425)^{1.5} \left[\frac{140}{220 \times 7.125 \times 10^{-4}} \right]^{0.5}$$

$$X_{axis} = 1.60$$

$$\text{Curve } \rightarrow \frac{r_{2c}}{r_1} = \frac{0.2425}{0.1} = 2.425$$

X_{axis} value is 1.60

Curve value is 2.425



By using these values we can find fin efficiency, η from graph

Fin Efficiency $\eta = 28 \%$

$$\text{Heat transfer} = \eta A_s h (T_b - T_\infty) \quad \text{from HMT data book P.No 50}$$

$$= 0.28 \times 0.30650 \times 140 \times [443 - 298]$$

$Q = 1742.99 \text{W}$

9. A metallic sphere of radius 10mm is initially at a uniform temperature of 400°C . It is heat treated by first cooling it in air ($h=10 \text{ W/m}^2\text{k}$) at 20°C until its central temperature reaches 335°C . It is then quenched in a water bath at 20°C with $h=6000 \text{ W/m}^2\text{K}$ until the centre of the sphere cools from 335°C to 50°C . compute the time required for cooling in air and water for the following physical properties of the sphere.

$$\text{Density}, \rho = 3000 \text{ kg/m}^3$$

$$c = 1000 \text{ J/kgK}$$

$$K = 20 \text{ W/mK}$$

$$\alpha = 6.66 \times 10^{-6} \text{ m}^2/\text{s}$$

Given

$$\text{Density}, \rho = 3000 \text{ kg/m}^3$$

$$c = 1000 \text{ J/kgK} \quad K = 20 \text{ W/mK}$$

$$\alpha = 6.66 \times 10^{-6} \text{ m}^2/\text{s}$$

To find

Surface temperature at end of cooling in water.

Solution

Step-1

- i) Cooling in air .

Let us check whether lumped capacity method can be used here

$$B_i = \frac{hr_0}{3k} = \frac{10 \times 0.01}{3 \times 20} = 16.66 \times 10^{-4} \ll 0.1$$

From HMT data book P.No 58

$$\therefore \frac{T - T_\infty}{T_0 - T_\infty} = \exp \left[- \left\{ \frac{hA}{\rho c V} \right\} \cdot t \right]$$

$$t = \frac{\rho c V}{hA} \ln \frac{T_0 - T_\infty}{T - T_\infty} = \frac{\rho r_0 c}{3h} \ln \frac{T_0 - T_\infty}{T - T_\infty}$$

$t = 188\text{s}$

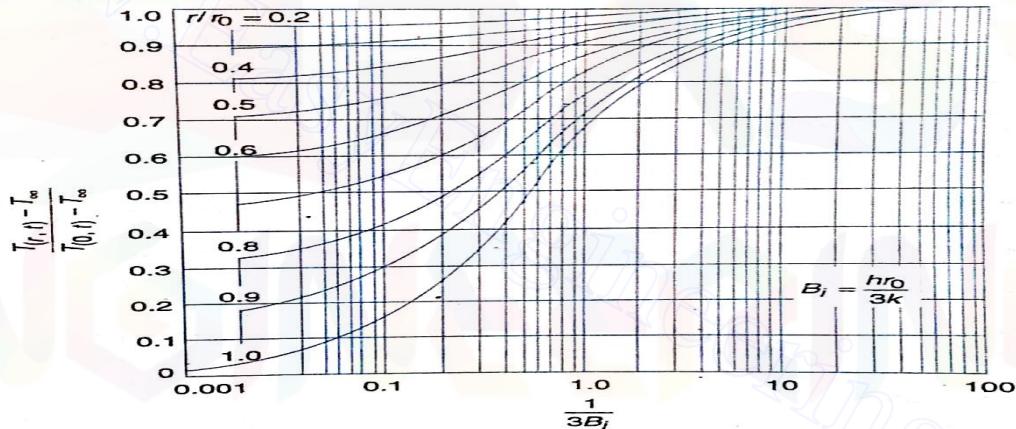
$$= \frac{3000 \times 0.01 \times 1000}{3 \times 10} \ln \frac{400 - 20}{335 - 20}$$

Step-2

ii) Cooling in water

$$B_i (\text{for lumped capacity method}) = \frac{hr_0}{3k} = \frac{6000 \times 0.01}{3 \times 20} = 1.0 > 0.1$$

So the lumped capacity method cannot be employed, but heisler charts can be used



$$\frac{1}{B_i} = \frac{k}{hr_0} = \frac{20}{6000 \times 0.01} = 0.33$$

$$\frac{T_{(0,t)} - T_\infty}{T_0 - T_\infty} = \frac{50 - 20}{335 - 20} = 0.095$$

$$F_o = \frac{\alpha t}{r_0^2} = 0.5$$

$$t = \frac{F_o r_0^2}{\alpha} = \frac{0.5 \times 0.01^2}{6.66 \times 10^{-6}} = 7.5\text{s}$$

The surface temperature at the end of quenching in water may be obtained from fig with

$$\frac{1}{3B_i} = 0.33$$

$$\frac{r}{r_0} = 1$$

$$\frac{T(r_0) - T_\infty}{T(0,t) - T_\infty} = 0.33$$

$$T(r_0) = [0.33 \times (50 - 20)] + 20 = 30^\circ\text{C}$$

$$T(r_0) = 30^\circ\text{C}$$

10. A thermocouple junction is in the form of 8 mm diameter sphere. Properties of material are $c=420 \text{ J/kg}^\circ\text{C}$, $\rho=8000 \text{ kg/m}^3$, $k=40 \text{ W/m}^\circ\text{C}$ and $h=40 \text{ W/m}^2\text{C}$. The junction is initially at 40°C and inserted in a stream of hot air at 300°C . Find

i) Time constant of the thermocouple

ii) The thermocouple is taken out from the hot air after 10 seconds and kept in still air at 30°C . Assuming the heat transfer coefficient in air $10\text{W/m}^2\text{C}$, find the temperature attained by the junction 20 seconds after removing from hot air.(Nov/Dec 2008)

Given

$$R=4 \text{ mm} = 0.004 \text{ m}$$

$$C= 420 \text{ J/kg}^\circ\text{C}$$

$$\rho=8000 \text{ kg/m}^3$$

$$k=40 \text{ W/m}^\circ\text{C}$$

$$h=40 \text{ W/m}^2\text{C} \text{ (gas stream)}$$

$$h=10 \text{ W/m}^2\text{C} \text{ (gas air)}$$

To Find

i) Time constant of the thermocouple τ^*

ii) The temperature attained by the junction (t)

Solution

Step-1

$$\tau^* = \frac{\rho V C}{h A_s} = \frac{\rho \times \left[\frac{4}{3} \pi R^3 \right] \times c}{h \times 4\pi R^2} = \frac{\rho R c}{3h}$$

$$\tau^* = \frac{8000 \times 0.004 \times 420}{3 \times 40} = 112 \text{ s}$$

$$\boxed{\tau^* = 112 \text{ s}}$$

Step-2

$$t_i = 40^\circ\text{C}, t_a = 300^\circ\text{C}, \tau = 10\text{s}$$

The temperature variation with respect to time during heating (when dipped in gas stream) is given by

From HMT data book P.No 58

$$\frac{t - t_a}{t_i - T_a} = \exp \left[- \left\{ \frac{hA}{\rho c V} \right\} \cdot t \right]$$

$$\frac{t - 300}{40 - 300} = \exp \left[- \left\{ \frac{\tau}{\tau^*} \right\} \right] = e^{(10/112)}$$

$$\frac{1}{e^{(10/112)}} = 0.9146$$

$$t = 300 + 0.9146(40 - 300) = 62.2^\circ\text{C}$$

$t = 62.2^\circ\text{C}$

The temperature variation with respect to time during cooling (when exposed to air) is given by

$$\frac{t - t_a}{t_i - T_a} = e^{-\frac{\tau}{\tau^*}}$$

Where

$$\tau^* = \frac{\rho R c}{3h} = \frac{8000 \times 0.004 \times 420}{3 \times 10} = 448\text{s}$$

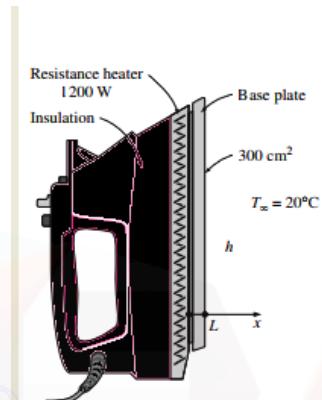
$$\frac{t - 30}{62.2 - 30} = e^{-\left(\frac{20}{448}\right)}$$

$$t = 30 + 0.9563(62.2 - 30) = 60.79^\circ\text{C}$$

$t = 60.79^\circ\text{C}$

PART C - 15 Marks (Questions and Answers)

1. Heat Conduction in the Base Plate of an Iron Consider the base plate of a 1200-W household iron that has a thickness of $L = 0.5$ cm, base area of $A = 300$ cm 2 , and thermal conductivity of $k = 15$ W/m · °C. The inner surface of the base plate is subjected to uniform heat flux generated by the resistance heaters inside, and the outer surface loses heat to the surroundings at $T = 20^\circ\text{C}$ by convection, as shown in Figure



Taking the convection heat transfer coefficient to be $h = 80$ W/m 2 · °C and disregarding heat loss by radiation, obtain an expression for the variation of temperature in the base plate, and evaluate the temperatures at the inner and the outer surfaces.

SOLUTION

The base plate of an iron is considered. The variation of temperature in the plate and the surface temperatures are to be determined.

Assumptions

- 1 Heat transfer is steady since there is no change with time.
- 2 Heat transfer is one-dimensional since the surface area of the base plate is large relative to its thickness, and the thermal conditions on both sides are uniform.
- 3 Thermal conductivity is constant.
- 4 There is no heat generation in the medium.
- 5 Heat transfer by radiation is negligible.
- 6 The upper part of the iron is well insulated so that the entire heat generated in the resistance wires is transferred to the base plate through its inner surface.

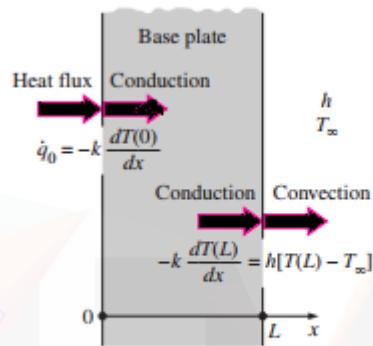
Properties

The thermal conductivity is given to be $k = 15 \text{ W/m} \cdot ^\circ\text{C}$.

Analysis The inner surface of the base plate is subjected to uniform heat flux at a rate of

$$q_0 = \frac{Q_0}{A_{base}} = \frac{1200}{0.03} = 40,000 \text{ W/m}^2$$

The outer side of the plate is subjected to the convection condition. Taking the direction normal to the surface of the wall as the x-direction with its origin on the inner surface, the differential equation for this problem can be expressed as fig



$$\frac{d^2 T}{dx^2} = 0$$

With the boundary conditions

$$-k \frac{dT(0)}{dx} = q_0 = 40000 \text{ W/m}^2$$

$$-k \frac{dT(L)}{dx} = h[T(L) - T_\infty]$$

The general solution of the differential equation is again obtained by two successive integrations to be

$$\frac{dT}{dx} = C_1$$

And

$$T(x) = C_1 x + C_2 \quad \dots \dots (1)$$

Where C_1 and C_2 are arbitrary constants. Applying the first boundary condition,

$$-k \frac{dT(0)}{dx} = q_0 \rightarrow -KC_1 = q_0 \rightarrow C_1 = -\frac{q_0}{k}$$

$$-k \frac{dT(L)}{dx} = h[T(L) - T_\infty] \rightarrow -KC_1 = h[(C_1 L + C_2) - T_\infty]$$

Substituting $C_1 = -\frac{q_0}{k}$ and solving for C_2 We obtain

$$C_2 = T_{\infty} + \frac{q_0}{h} + \frac{q_0}{k} L$$

Now substituting C_1 and C_2 into the general solution (1) gives

$$T(x) = T_{\infty} + q_0 \left(\frac{\frac{L-x}{k}}{h} + \frac{1}{h} \right) \quad \dots\dots(2)$$

Which is the solution for the variation of the temperature in the plate. The temperatures at the inner and outer surfaces of the plate are determined by substituting $x=0$ and $x=L$, respectively, into the relation (2)

$$\begin{aligned} T(0) &= T_{\infty} + q_0 \left(\frac{\frac{L}{k}}{h} + \frac{1}{h} \right) \\ &= 20^{\circ}\text{C} + (40000 \text{ W/m}^2) \left(\frac{0.005 \text{ m}}{15} + \frac{1}{80} \right) = 533^{\circ}\text{C} \end{aligned}$$

And

$$T(L) = T_{\infty} + q_0 \left(0 + \frac{1}{h} \right) = 20^{\circ}\text{C} + \frac{40000}{80} = 520^{\circ}\text{C}$$

Discussion Note that the temperature of the inner surface of the base plate will be 13°C higher than the temperature of the outer surface when steady operating conditions are reached. Also note that this heat transfer analysis enables us to calculate the temperatures of surfaces that we cannot even reach. This example demonstrates how the heat flux and convection boundary conditions are applied to heat transfer problems.

2. A person is found dead at 5 PM in a room whose temperature is 20°C . The temperature of the body is measured to be 25°C when found, and the heat transfer coefficient is estimated to be $h = 8 \text{ W/m}^2 \cdot ^{\circ}\text{C}$. Modeling the body as a 30-cm-diameter, 1.70-m-long cylinder, estimate the time of death of that person

SOLUTION A body is found while still warm. The time of death is to be estimated.

Assumptions 1 The body can be modeled as a 30-cm-diameter, 1.70-m-long cylinder. 2 The thermal properties of the body and the heat transfer coefficient are constant. 3 The radiation effects are negligible. 4 The person was healthy(!) when he or she died with a body temperature of 37°C .

Properties The average human body is 72 percent water by mass, and thus we can assume the body to have the properties of water at the average temperature of $(37 + 25)/2 = 31^{\circ}\text{C}$; $k = 0.617 \text{ W/m} \cdot ^{\circ}\text{C}$, $\rho = 996 \text{ kg/m}^3$, and $C_p = 4178 \text{ J/kg} \cdot ^{\circ}\text{C}$

Analysis The characteristic length of the body is

$$L_c = \frac{V}{A_s} = \frac{\pi r_0^2 L}{2\pi r_0 L + 2\pi r_0^2} = \frac{\pi (0.15)^2 (1.7)}{2\pi(0.15)(1.7) + 2\pi(0.15)^2} = 0.0689$$

Then the biot number becomes

$$Bi = \frac{hL_c}{k} = \frac{8 \times 0.0689}{0.617} = 0.89 > 0.1$$

Therefore lumped system analysis is not applicable. However, we can still use it to get a rough estimate of the time of death.

$$\frac{T(t) - T_{\infty}}{T_i - T_{\infty}} = e^{-bt} \quad \dots \dots (1)$$

The exponent b in this case is

$$b = \frac{hA_s}{\rho C_p V} = \frac{h}{\rho C_p L_c} = \frac{8}{996 \times 4178 \times 0.0689} = 2.79 \times 10^{-5}$$

now substitute these values into equation (1)

$$\frac{25 - 20}{37 - 20} = e^{-2.79 \times 10^{-5} t}$$

$$t = 43860 \text{ s} = 12.2 \text{ h}$$

The person died about 12 h before the body was found and thus the time of death is 5 AM.

UNIT: II - CONVECTION
PART A - 2 Marks (Questions and Answers)

1. Define critical Reynolds number. What is its typical value for flow over a flat plate and flow through a pipe? (May 2013, Nov/Dec 16)

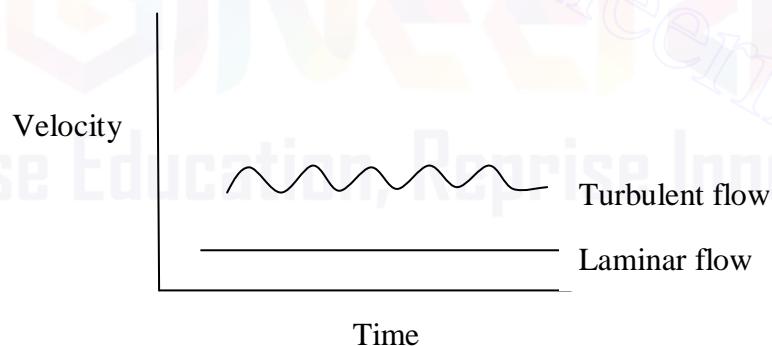
The critical Reynolds number refers to the transition from laminar to turbulent flow.

The critical Reynolds number for flow over a flat plate is 5×10^5 ; the critical Reynolds number for flow through a pipe is 4000.

2. How does or Distinguish laminar flow differ from turbulent flow? (May 2013 & May 2015)

Laminar flow: Laminar flow is sometimes called stream line flow. In this type of flow, the fluid moves in layers and each fluid particle follows a smooth continuous path. The fluid particles in each layer remain in an orderly sequence without mixing with each other.

Turbulent flow: In addition to the laminar type of flow, a distinct irregular flow is frequently observed in nature. This type of flow is called turbulent flow. The path of any individual particle is zig-zag and irregular.



3. Differentiate viscous sub layer and buffer layer. (May 2014)

In the turbulent boundary layer, a very thin layer next to the wall where viscous effect is dominant called the viscous sub layer. The velocity profile in this layer is very nearly linear and the flow is streamlined.

In the turbulent boundary layer, next to viscous sub layer, a layer called **buffer layer** in which turbulent effects are becoming significant, but the flow is still dominated by viscous effects.

4. Define grashoff number and prandtl number. Write its significance. (May 2014 & Nov 2014 & Nov 2015-Reg 2008)(Nov 2015) (APR/MAY 2017)

Grashoff number is defined as the ratio of product of inertia force and buoyancy force to the square of viscous force.

$$\text{Gr} = \frac{\text{Inertia Force} * \text{Buoyancy Force}}{(\text{Viscous Force})^2} \quad [\text{HMT Data Book, P.No 112}]$$

Significance: Grashoff number has a role in free convection similar to that played by Reynolds number in forced convection.

Prandtl number is the ratio of the momentum diffusivity of the thermal diffusivity.

$$\text{Pr} = \frac{\text{Momentum Diffusivity}}{\text{Thermal Diffusivity}} \quad [\text{HMT Data Book, P.No. 112}]$$

Significance: Prandtl number provides a measure of the relative effectiveness of the momentum and energy transport by diffusion.

5. Define velocity boundary layer thickness. (May 2015)

The region of the flow in which the effects of the viscous shearing forces caused by fluid viscosity are felt is called velocity boundary layer. The velocity boundary layer thickness, δ , is defined as the distance from the surface at which velocity, $u = 0.99V$

6. Air at 27°C and 1 atmospheric flow over a flat plate at a speed of 2m/s. Calculate boundary layer thickness at a distance 40 cm from leading edge of plate. At 27°C viscosity (air) = $1.85 * 10^{-5}$ kg/ms. (Nov 2012)

Given Data:

$$T = 27^\circ\text{C} = 27 + 273 = 300\text{K}$$

$$P = 1 \text{ atm} = 1 \text{ bar} = 1.01325 * 10^5 \text{ N/m}^2$$

$$U = 2 \text{ m/s}$$

$$\mu = 1.85 * 10^{-5} \text{ kg/ms. (At } 27^\circ\text{C)}$$

$$R = 287 \text{ (Gas constant)}$$

To Find: δ at $X = 40 \text{ cm} = 0.4 \text{ m}$

Solution:

$$\begin{aligned} \text{Step: 1 Density } \rho &= P/RT \\ &= \frac{1.01325 * 10^5}{(287 * 300)} \end{aligned}$$

$$= 1.177 \text{ Kg/m}^3$$

(Note: If Surface temperature (T_w) is given, then properties to be taken for T_f Value.)

Step: 2 Reynolds Number $Re = \rho UX / \mu$ [HMT Data Book, P.No. 112]

$$\begin{aligned} &= 1.177 * 2 * 0.4 \\ &\quad \overline{1.85 * 10^{-5}} \\ &= 55160. \text{ (Re} < 5 * 10^5, \text{ flow is laminar)} \end{aligned}$$

Step: 3 Boundary layer thickness $\delta = 5 * X * (Re)^{-0.5}$

[HMT Data Book, P.No.113]

$$\begin{aligned} &= 5 * 0.4 * (55160)^{-0.5} \\ &= 0.0085 \text{ m} \end{aligned}$$

Boundary layer thickness δ at X (0.4m) = 0.0085 m

7. A square plate 40*40 cm maintained at 400K is suspended vertically in atmospheric air at 300 K. Determine the boundary layer thickness at trailing edge of the plate. (Nov 2012)

Given Data:

Length of horizontal plate $X = 40 \text{ cm} = 0.4 \text{ m}$

Wide $W = 40 \text{ cm} = 0.40 \text{ m}$

Plate temperature $T_w = 400\text{K} = 127^\circ\text{C}$

Fluid temperature $T_\alpha = 300\text{K} = 27^\circ\text{C}$

$$\Delta T = (T_w - T_\alpha) = 400 - 300 = 100$$

To Find: δ at $X = 40 \text{ cm} = 0.4 \text{ m}$

Solution:

Step: 1 Film Temperature (T_f) $= \frac{T_w + T_\alpha}{2}$

$$\begin{aligned} &= \frac{127 + 27}{2} = 77^\circ\text{C} = 350\text{K} \\ &\quad 2 \end{aligned}$$

Step: 2 Properties of air at 77°C (apprx 75°C)

[HMT Data Book, P.No.34]

$$v = 20.56 * 10^{-6} \text{ m}^2/\text{s}$$

$$\text{Pr} = 0.693$$

Step: 3 Find $\beta = 1 / T_f$ in K

$$= 1 / 350$$

$$= 2.857 * 10^{-3} \text{ K}^{-1}$$

Step: 4 For free Convection (Note: As Velocity not given)

$$\frac{\text{Gr} = g^* \beta X^3 \Delta T}{v^2} \quad [\text{HMT Data Book, P.No.135}]$$

$$= \frac{9.81 * 2.857 * 10^{-3} * (0.4)^3 * (400-300)}{(20.56 * 10^{-6})^2}$$

$$= 4.24 * 10^8$$

Step: 5 Boundary layer thickness $\delta = 3.93 * X * (\text{Pr})^{-0.5} * (0.952+\text{Pr})^{0.25} * \text{Gr}^{-0.25}$

$$[\text{HMT Data Book, P.No.135}]$$

$$= 3.93 * 0.4 * (0.693)^{-0.5} * (0.952+0.693)^{0.25} * (4.24*10^8)^{-0.25}$$

$$= 0.0155 \text{ m}$$

Boundary layer thickness δ at X (0.4m) = 0.0155 m

8. Define the term thermal boundary layer thickness. (Nov 2013)

The thickness of the thermal boundary layer δ_t at any location along the surface is defined as the distance from the surface at which the temperature difference equals to $0.99(T_\alpha - T_s)$, in general $T = 0.99T_\alpha$

9. Why heat transfer coefficient for natural convection is much lesser than that for forced convection? (Nov 2013 & May 2016)

Heat transfer coefficient depends on the fluid velocity.

In natural convection, the fluid motion occurs by natural means such as buoyancy. Since the fluid velocity associated with natural convection is relatively low, the heat transfer coefficient encountered in natural convection is low.

The reason for higher heat transfer rates in forced convection is because the hot air surrounding the hot body is immediately removed by the flow of air around it. This is why forced convection heat transfer coefficient is greater than natural convection heat transfer coefficient.

10. Name four dimensions used for dimensional analysis. (Nov 2014)

1. Velocity
2. Density
3. Heat transfer coefficient
4. Thermal conductivity

11. Mention the significance of boundary layer. (Nov 2015)

Boundary layer is the layer of fluid in the immediate vicinity of a bounding surface where the effects of viscosity are significant.

12. What is Dittus Boelter equation? When does it apply? (Nov 2015)

Dittus-Boelter equation (for fully developed internal flow - turbulent flow) is an explicit function for calculating the Nusselt number. It is easy to solve but is less accurate when there is a large temperature difference across the fluid. It is tailored to smooth tubes, so use for rough tubes (most commercial applications) is cautioned.

The Dittus-Boelter equation is:

$$Nu_D = 0.023 Re_D^{0.8} Pr^n \quad [HMT Data Book, P.No.126]$$

13. What is the difference between friction factor and friction coefficient? (May 2016)

Friction factor, a dimensionless quantity used in the Darcy-Weisbach equation, for the description of friction losses in pipe flow as well as open-channel flow. Friction coefficient applied at the value of x ($x=x$ -Local friction coefficient, $x=L$ – Average friction coefficient)

14. Differentiate free and forced convection. (May 2016) (Nov/Dec 16)

Natural convection, or free convection, occurs due to temperature differences which affect the density, and thus relative buoyancy, of the fluid. Free convection is governed by Grashoff number and Prandtl number.

Example: Rise of smoke from a fire.

In forced convection, fluid movement results from external forces such as a fan or pump. Forced convection is typically used to increase the rate of heat exchange. It is governed by the value of the Reynolds number.

Example: Cooling of IC engines with fan in a radiator.

15. Differentiate hydrodynamic and thermal boundary layer. (May 2016)

The hydrodynamic boundary layer is a region of a fluid flow, near a solid surface, where the flow patterns (velocity) are directly influenced by viscous drag from the surface wall. The velocity of the fluid is less than 99% of free stream velocity.

The thermal boundary layer is a region of a fluid flow, near a solid surface, where the fluid temperatures are directly influenced by heating or cooling from the surface wall. The temperature of the fluid is less than 99% of free stream temperature.

16. What are the difference between natural convection and forced convection? (Nov/Dec 16)

Natural convection is a mechanism of heat transportation in which the fluid motion is not generated by an external source.

Forced convection is a mechanism, or type of heat transport in which fluid motion is generated by an external source (like a pump, fan, suction device, etc.)

PART B - 13 Marks (Questions and Answers)

1. Air at 25°C at the atmospheric pressure is flowing over a flat plat at 3m/s . If the plate is 1m wide and the temperature $T_w = 75^{\circ}\text{C}$. Calculate the following at a location of 1m from leading edge.

- a) Hydrodynamic boundary layer thickness,
- b) Local friction coefficient,
- c) Thermal heat transfer coefficient,
- d) Local heat transfer coefficient.

Given Data:

Fluid temperature, $T_{\alpha}=25^{\circ}\text{C}$

Velocity, $U=3\text{m/s}$

Wide, $W = 1\text{m}$

Plate surface temperature, $T_w=75^{\circ}\text{C}$

Distance, $x = 1\text{m}$

To Find: δ_{hx} , C_{fx} , δ_{Tx} , h_x ,

Solution:

[From HMT Data Book, P.No.113]

$$\text{Film temperature, } T_f = \frac{T_w + T_\alpha}{2}$$

$$= \frac{75+25}{2} = 323\text{K}$$

$$T_f = 50^\circ\text{C}$$

Properties of air at 50°C:

[From HMT Data Book, P.No.34]

Density, $\rho = 1.093\text{kg/m}^3$ Kinematic viscosity, $v = 17.95 \times 10^{-6}\text{ m}^2/\text{s}$ Prandtl number $Pr = 0.698$ Thermal conductivity, $k = 0.02826\text{ W/mk}$ Reynolds number, $Re = UL/v$

[From HMT Data Book, P.No.112]

$$[\because x=L=1\text{m}]$$

$$\frac{3*1}{17.95*10^{-6}} = 1.67*10^5$$

$$Re = 1.67*10^5 < 5*10^5$$

Since $Re < 5*10^5$ flow is laminar.

For the plate, laminar flow.

[From HMT Data Book, P.No.113]

- Hydrodynamic boundary layer thickness,

$$\begin{aligned} \delta_{hx} &= 5*x*Re^{-0.5} \\ &= 5*x*(1.67*10^5)^{-0.5} \end{aligned}$$

$$\delta_{hx} = 0.0122\text{m}$$

- Local friction coefficient,

[From HMT Data Book, P.No.113]

$$\begin{aligned} C_{fx} &= 0.664 Re^{-0.5} \\ &= 0.664 * (1.67*10^5)^{-0.5} \end{aligned}$$

$$C_{fx} = 1.62*10^{-3}$$

- Thermal heat transfer coefficient,

[From HMT Data Book, P.No.113]

$$\delta_{Tx} = \delta_{hx} * (Pr)^{-0.333}$$

$$= 0.0122 * (0.698)^{-0.333}$$

$$\boxed{\delta_{Tx} = 0.01375}$$

4. Local heat transfer coefficient, h_x

[From HMT Data Book, P.No.113]

$$\text{Local nusselt number } Nu_x = 0.332 Re^{0.5} (Pr)^{0.333}$$

$$= 0.332 (1.67 \times 10^5)^{0.5} (0.698)^{0.333}$$

$$Nu_x = 120.415$$

[From HMT Data Book, P.No.112]

$$Nu_x = \frac{h_x * L}{k}$$

$$120.415 = \frac{h_x * 1}{0.02826}$$

[::x=L=1m]

$$\boxed{\text{Local heat transfer coefficient, } h_x = 3.4 \text{ W/m}^2\text{K}}$$

Result:

- a) $\delta_{hx} = 0.0122 \text{ m}$
- b) $C_{fx} = 1.62 \times 10^{-3}$
- c) $\delta_{Tx} = 0.01375$
- d) $h_x = 3.4 \text{ W/m}^2\text{K}$

2. Air at 290°C flows over a flat plate at a velocity of 6 m/s . The plate is 1 m long and 0.5 m wide. The pressure of the air is 6 KN/m^2 . If the plate is maintained at a temperature of 70°C , estimate the rate of heat removed from the plate.

Given:

Fluid temperature $T_\infty = 290^\circ\text{C}$

Velocity $U = 6 \text{ m/s}$.

Length $L = 1 \text{ m}$

Wide $W = 0.5 \text{ m}$

Pressure of air $P = 6 \text{ KN/m}^2 = 6 \times 10^3 \text{ N/m}^2$

Plate surface temperature $T_w = 70^\circ\text{C}$

To find:

Heat removed from the plate

Solution:

[From HMT Data Book, P.No.113]

$$\text{Film temperature } T_f = \frac{T_w + T_a}{2}$$

$$T_f = \frac{70 + 290}{2}$$

$$T_f = 180^\circ\text{C}$$

Properties of air at 180°C (At atmospheric pressure)

[From HMT Data Book, P.No.34]

$$\rho = 0.799 \text{ Kg/m}^3$$

$$\nu = 32.49 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\text{Pr} = 0.681$$

$$K = 37.80 \times 10^{-3} \text{ W/mK}$$

Note: Pressure other than atmospheric pressure is given, so kinematic viscosity will vary with pressure. Pr, K, C_p are same for all pressures.

$$\text{Kinematic viscosity } \nu = \nu_{\text{atm}} \frac{P_{\text{atm}}}{P_{\text{given}}}$$

$$[\because 1 \text{ bar} = 1 \times 10^5 \text{ N/m}^2]$$

$$\nu = 32.49 \times 10^{-6} \times \frac{1 \times 10^5}{6 \times 10^3}$$

$$\text{Kinematic viscosity } \nu = 5.145 \times 10^{-4} \text{ m}^2/\text{s}$$

[From HMT Data Book, P.No.112]

$$\begin{aligned} \text{Reynolds number} \quad \text{Re} &= \frac{UL}{\nu} \\ &= \frac{6 \times 1}{5.145 \times 10^{-4}} \end{aligned}$$

$$\text{Re} = 1.10 \times 10^4 - 5 \times 10^5$$

Since $\text{Re} < 5 \times 10^5$, flow is laminar

For plate, laminar flow, $UL \nu$

[From HMT Data Book, P.No.113]

$$\text{Local nusselt number } Nu_x = 0.332 Re^{0.5} (\text{Pr})^{0.333}$$

$$= 0.332 (1.10 \times 10^4)^{0.5} (0.681)^{0.333}$$

$$Nu_x = 30.63$$

[From HMT Data Book, P.No.112]

$$Nu_x = \frac{h_x L}{K}$$

$$30.63 = \frac{h_x \times 1}{37.80 \times 10^{-3}} \quad [\because L = 1 \text{ m}]$$

Local heat transfer coefficient $h_x = 1.15 \text{ W/m}^2\text{K}$

Average heat transfer coefficient $h = 2 \times h_x$

$$h = 2 \times 1.15$$

$$h = 2.31 \text{ W/m}^2\text{K}$$

Heat transferred $Q = h A (T_\alpha - T_w)$

$$= 2.13 \times (1 \times 0.5) \times (563 - 343)$$

$$Q = 254.1 \text{ W}$$

Heat transfer from both side of the plate = 2×254.1

$$= 508.2 \text{ W.}$$

Result: Heat transfer from both side of the plate = 508.2 W

3. A large vertical plate 4 m height is maintained at 606°C and exposed to atmospheric air at 106°C. Calculate the heat transfer if the plate is 10 m wide.

Given :

Vertical plate length (or) Height, $L = 4 \text{ m}$

Wall temperature, $T_w = 606^\circ\text{C}$

Air temperature, $T_\infty = 106^\circ\text{C}$

Wide, $W = 10 \text{ m}$

To find:

a) Heat transfer, (Q)

Solution:

[From HMT Data Book, P.No.113]

$$\begin{aligned} \text{Film temperature } T_f &= \frac{T_w + T_\infty}{2} \\ &= \frac{606 + 106}{2} \end{aligned}$$

$$T_f = 356^\circ\text{C}$$

[From HMT Data Book, P.No.34]

Properties of air at 356°C = 350°C

Density, $\rho = 0.566 \text{ kg/m}^3$ Kinematic viscosity, $v = 55.46 \times 10^{-6} \text{ m}^2/\text{s}$ Prandtl number $Pr = 0.698$ Thermal conductivity, $k = 49.08 \times 10^{-3} \text{ W/mK}$ Coefficient of thermal expansion $\beta = \frac{1}{T_f \text{ in K}}$

$$= \frac{1}{356 + 273} = \frac{1}{629}$$

$$\beta = 1.58 \times 10^{-3} \text{ K}^{-1}$$

$$\text{Grashof number } Gr = \frac{g \times \beta \times L^3 \times \Delta T}{v^2}$$

$$\Rightarrow Gr = \frac{9.81 \times 2.4 \times 10^{-3} \times (4)^3 (606 - 106)}{(55.46 \times 10^{-6})^2}$$

$$\Rightarrow Gr = 1.61 \times 10^{11}$$

$$Gr Pr = 1.61 \times 10^{11} \times 0.676$$

$$Gr Pr = 1.08 \times 10^{11}$$

Since $Gr Pr > 10^9$, flow is turbulent

For turbulent flow,

$$\text{Nusselt number } Nu = 0.10 [Gr Pr]^{0.333}$$

$$\Rightarrow Nu = 0.10 [1.08 \times 10^{11}]^{0.333}$$

$$Nu = 471.20$$

[From HMT Data Book, P.No.112]

$$\text{Nusselt number } Nu = \frac{hL}{K}$$

$$\Rightarrow 472.20 = \frac{h \times 4}{49.08 \times 10^{-3}}$$

$$\text{Heat transfer coefficient } h = 5.78 \text{ W/m}^2\text{K}$$

$$\text{Heat transfer } Q = h A \Delta T$$

$$= h \times W \times L \times (T_w - T_\infty)$$

$$= 5.78 \times 10 \times 4 \times (606 - 106)$$

$$Q = 115600 \text{ W}$$

$$Q = 115.6 \times 10^3 \text{ W}$$

Result:

Heat transfer $Q = 115.6 \times 10^3 \text{ W}$

4. A thin 100 cm long and 10 cm wide horizontal plate is maintained at a uniform temperature of 150°C in a large tank full of water at 75°C. Estimate the rate of heat to be supplied to the plate to maintain constant plate temperature as heat is dissipated from either side of plate.

Given :

Length of horizontal plate, $L = 100 \text{ cm} = 1 \text{ m}$

Wide, $W = 10 \text{ cm} = 0.10 \text{ m}$

Plate temperature, $T_w = 150^\circ\text{C}$

Fluid temperature, $T_\infty = 75^\circ\text{C}$

To find:

a) Heat loss (Q) from either side of plate

Solution:

$$\text{Film temperature, } T_f = \frac{T_w + T_\infty}{2} \quad [\text{From HMT Data Book, P.No.113}]$$

$$= \frac{150 + 75}{2} = 323 \text{ K}$$

$$T_f = 112.5^\circ\text{C}$$

Properties of water at 112.5°C

$$\rho = 951 \text{ kg/m}^3$$

$$V = 0.264 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\Pr = 1.55$$

$$K = 683 \times 10^{-3} \text{ W/mK}$$

$$\text{Coefficient of thermal expansion } \beta = \frac{1}{T_f \text{ in K}} = \frac{1}{112.5 + 273} = 2.59 \times 10^{-3} \text{ K}^{-1}$$

$$\text{Grashof Number } \text{Gr} = \frac{g \times \beta \times L^3 \times \Delta T}{v^2}$$

For horizontal plate,

$$\text{Characteristic length } L_c = \frac{W}{2} = \frac{0.10}{2}$$

$$L_c = 0.05 \text{ m}$$

$$\text{Gr} = \frac{9.81 \times 2.59 \times 10^{-3} \times (0.05)^3 \times (150 - 75)}{(0.264 \times 10^{-6})^2}$$

$$\text{Gr} = 3.41 \times 10^9$$

$$\text{Gr Pr} = 3.14 \times 10^9 \times 1.55$$

$$\text{Gr Pr} = 5.29 \times 10^9$$

Gr Pr value is in between 8×10^6 and 10^{11}

i.e., $8 \times 10^6 < \text{Gr Pr} < 10^{11}$

For horizontal plate, upper surface heated:

$$\text{Nusselt number } \text{Nu} = 0.15 (\text{Gr Pr})^{0.333}$$

[From HMT Data Book, P.No.114]

$$\text{Nu} = 0.15 (5.29 \times 10^9)^{0.333}$$

$$\text{Nu} = 259.41$$

$$\text{Nusselt number } \text{Nu} = \frac{h_u L_c}{K}$$

$$259.41 = \frac{h_u \times 0.05}{683 \times 10^{-3}}$$

$$h_u = 3543.6 \text{ W/m}^2\text{K}$$

Upper surface heated, heat transfer coefficient $h_u = 3543.6 \text{ W/m}^2\text{K}$

For horizontal plate, lower surface heated:

$$\text{Nusselt number } \text{Nu} = 0.27 [\text{Gr Pr}]^{0.25}$$

$$\text{Nu} = 0.27 [5.29 \times 10^9]^{0.25}$$

$$\text{Nu} = 72.8$$

[From HMT Data Book, P.No.113]

$$\text{Nusselt number } \text{Nu} = \frac{h_1 L_c}{K}$$

$$72.8 = \frac{h_1 L_c}{K}$$

$$72.8 = \frac{h_1 \times 0.05}{683 \times 10^{-3}}$$

$$h_1 = 994.6 \text{ W/m}^2\text{K}$$

Lower surface heated, heat transfer coefficient $h_1 = 994.6 \text{ W/m}^2\text{K}$

$$\begin{aligned}\text{Total heat transfer } Q &= (h_u + h_1) \times A \times \Delta T \\ &= (h_u + h_1) \times W \times L \times (T_w - T_\infty) \\ &= (3543.6 + 994.6) \times 0.10 \times (150 - 75) \\ Q &= 34036.5 \text{ W}\end{aligned}$$

Result:

Total heat transfer $Q = 34036.5 \text{ W}$

5. Explain in detail about the boundary layer concept.

The concept of a boundary layer as proposed by Prandtl forms the starting point for the simplification of the equation of motion and energy.

When a real i.e., viscous fluid, flows along a stationary solid boundary, a layer of fluid which comes in contact with boundary surface and undergoes retardation this retarded layer further causes retardation for the adjacent layer of the fluid. So small region is developed in the immediate vicinity of the boundary surface in which the velocity of the flowing fluid increases rapidly from zero at boundary surface and approaches the velocity of main stream.

Types of boundary layer

1. Velocity boundary layer (or) hydrodynamic boundary layer
2. Thermal boundary layer

Velocity boundary layer (or) hydrodynamic boundary layer

In the Velocity boundary layer, velocity of the fluid is less than 99% of free steam velocity.

The fluid approaches the plate in x direction with uniform velocity u_∞ . The fluid particles in the fluid layer adjacent to the surface get zero velocity. This motionless layer acts to retard the motion of particles in the adjoining fluid layer as a result of friction between the particles of these two adjoining fluid layers at two different velocities. This fluid layer then acts to retard the motion of particles of next fluid layer and so on, until a distance $y = d$ from the surface reaches, where

these effects become negligible and the fluid velocity u reaches the free stream velocity u_∞ as a result of frictional effects between the fluid layers.

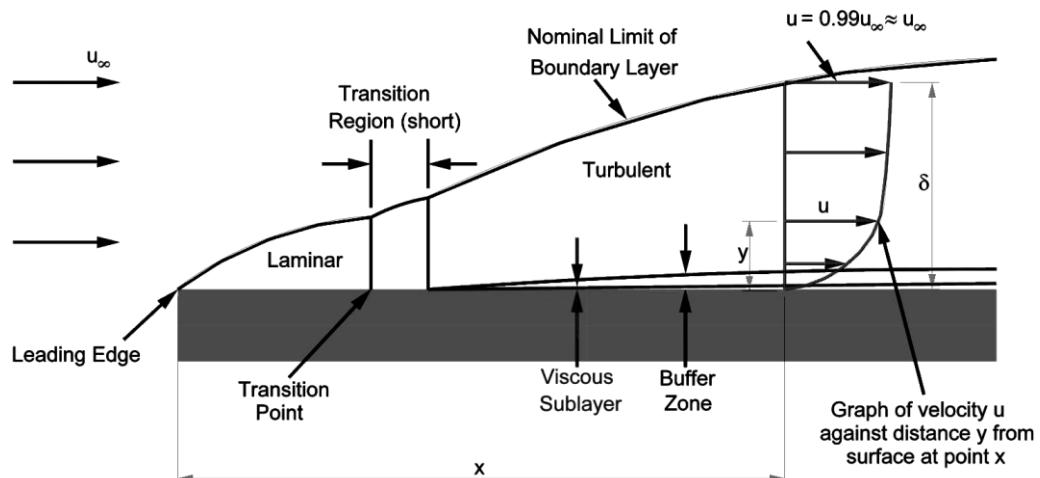
Thermal boundary Layer:

In the Thermal boundary layer, temperature of the fluid is less than 99% of free steam temperature.

If the fluid flowing on a surface has a different temperature than the surface, the thermal boundary layer developed is similar to the velocity boundary layer. Consider a fluid at a temperature T_∞ flows over a surface at a constant temperature T_s . The fluid particles in adjacent layer to the plate get the same temperature that of surface. The particles exchange heat energy with particles in adjoining fluid layers and so on. As a result, the temperature gradients are developed in the fluid layers and a temperature profile is developed in the fluid flow, which ranges from T_s at the surface to fluid temperature T_∞ sufficiently far from the surface in y direction.

Velocity boundary layer on a flat plate:

It is most essential to distinguish between laminar and turbulent boundary layers. Initially, the boundary layer development is laminar as shown in figure for the flow over a flat plate. Depending upon the flow field and fluid properties, at some critical distance from the leading edge small disturbances in the flow begin to get amplified, a transition process takes place and the flow becomes turbulent. In laminar boundary layer, the fluid motion is highly ordered whereas the motion in the turbulent boundary layer is highly irregular with the fluid moving to and from in all directions. Due to fluid mixing resulting from these macroscopic motions, the turbulent boundary layer is thicker and the velocity profile in turbulent boundary layer is flatter than that in laminar flow.



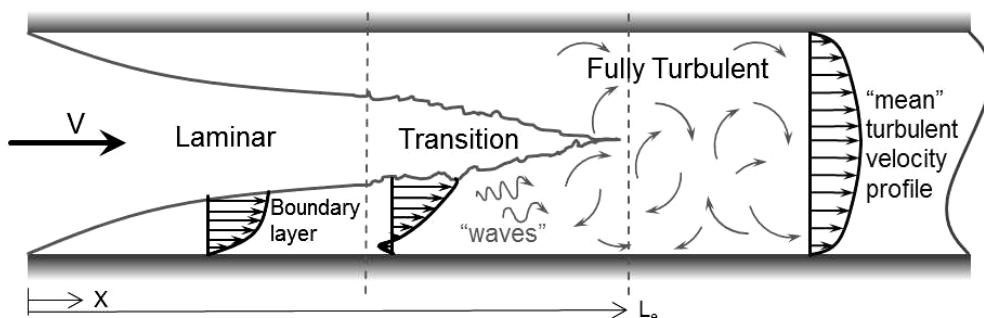
Velocity boundary layer on a tube:

Laminar Boundary Layer Flow

The laminar boundary is a very smooth flow, while the turbulent boundary layer contains swirls or "eddies." The laminar flow creates less skin friction drag than the turbulent flow, but is less stable. Boundary layer flow over a wing surface begins as a smooth laminar flow. As the flow continues back from the leading edge, the laminar boundary layer increases in thickness.

Turbulent Boundary Layer Flow

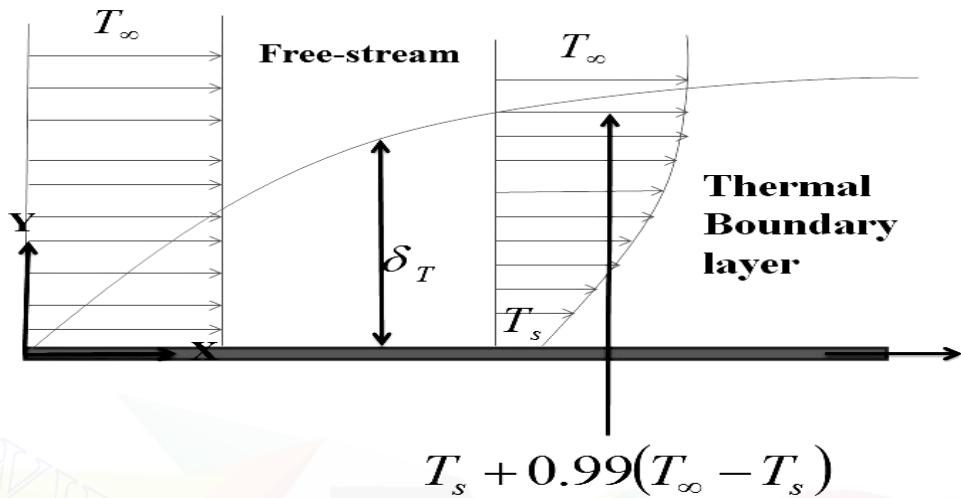
At some distance back from the leading edge, the smooth laminar flow breaks down and transitions to a turbulent flow. From a drag standpoint, it is advisable to have the transition from laminar to turbulent flow as far aft on the wing as possible, or have a large amount of the wing surface within the laminar portion of the boundary layer. The low energy laminar flow, however, tends to break down more suddenly than the turbulent layer.



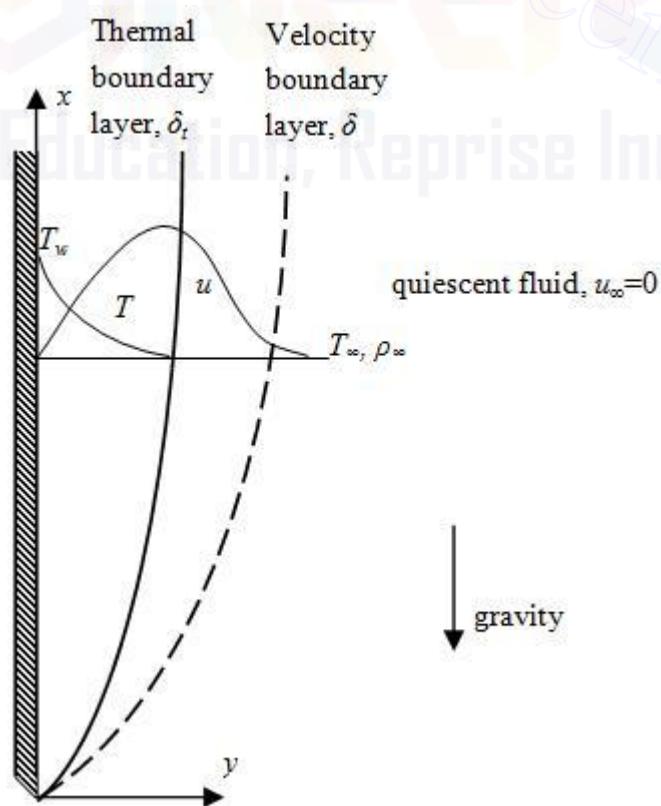
Thermal boundary Layer on a flat plate:

Consider a fluid of uniform temperature T_α approaching a flat plate of constant temperature T_s in the direction parallel to the plate. At the solid/liquid interface

the fluid temperature is T_s since the local fluid particles achieve thermal equilibrium at the interface. The fluid temperature T in the region near the plate is affected by the plate, varying from T_s at the surface to T_∞ in the main stream. This region is called the thermal boundary layer.



Velocity and Temperature boundary layer (Profile) for a vertical plate



6. In a long annulus (3.125 cm ID and 5 cm OD) the air is heated by maintaining the temperature of the outer surface of inner tube at 50°C. The air enters at 16°C and leaves at 32°C. Its flow rate is 30 m/s. Estimate the heat transfer coefficient between air and the inner tube.

Given : Inner diameter $D_i = 3.125 \text{ cm} = 0.03125 \text{ m}$

Outer diameter $D_o = 5 \text{ cm} = 0.05 \text{ m}$

Tube wall temperature $T_w = 50^\circ\text{C}$

Inner temperature of air $T_{mi} = 16^\circ\text{C}$

Outer temperature of air $t_{mo} = 32^\circ\text{C}$

Flow rate $U = 30 \text{ m/s}$

To find: Heat transfer coefficient (h)

Solution:

$$\begin{aligned}\text{Step 1. Mean temperature } T_m &= \frac{T_{mi} + T_{mo}}{2} \\ &= \frac{16 + 32}{2} \\ T_m &= 24^\circ\text{C}\end{aligned}$$

Properties of air at 24°C

[From HMT Data book page no. 34]

$$\rho = 1.185 \text{ Kg/m}^3$$

$$\nu = 15.53 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\Pr = 0.702$$

$$k = 0.02634 \text{ W/mK}$$

Step 2. Hydraulic or Equivalent diameter

$$\begin{aligned}D_h &= \frac{4A}{P} = \frac{\frac{4}{4} \pi [D_o^2 - D_i^2]}{\pi [D_o + D_i]} \\ &= \frac{[D_o + D_i][D_o - D_i]}{[D_o + D_i]} \\ &= D_o - D_i \\ &= 0.05 - 0.03125 \\ D_h &= 0.01875 \text{ m}\end{aligned}$$

$$\begin{aligned}\text{Step 3. Reynolds number, } Re &= \frac{UD_h}{\nu} \\ &= \frac{30 \times 0.01875}{15.53 \times 10^{-6}}\end{aligned}$$

$$Re = 36.2 \times 10^3$$

Since $Re > 2300$, flow is turbulent.

For turbulent flow, general equation is ($Re > 10000$).

$$Nu = 0.023 (Re)^{0.8} (Pr)^n$$

[From HMT Data book, Page No. 126]

This is heating process. So $n = 0.4$.

$$[T_{mo} > T_{mi}]$$

$$\text{Step 4. } Nu = 0.023 \times (36.2 \times 10^3)^{0.8} (0.702)^{0.4}$$

$$Nu = 88.59$$

$$\text{Step 5. } Nu = \frac{hD_h}{k}$$

$$88.59 = \frac{h \times 0.01875}{26.34 \times 10^{-3}}$$

$$h = 124.4 \text{ W/m}^2\text{K}$$

Heat transfer coefficient, $h = 124.4 \text{ W/m}^2\text{K}$

7. In a surface condenser, water flows through staggered tubes while the air is passed in cross flow over the tubes. The temperature and velocity of air are 30°C and 8 m/s respectively. The longitudinal and transverse pitches are 22 mm and 20 mm respectively. The tube outside diameter is 18 mm and tube surface temperature is 90°C. Calculate the heat transfer coefficient.

Given:

Fluid temperature, $T_\infty = 30^\circ\text{C}$

Velocity, $U = 8 \text{ m/s}$

Longitudinal pitch, $S_l = 22 \text{ mm} = 0.022 \text{ m}$

Transverse pitch, $S_t = 20 \text{ mm} = 0.020 \text{ m}$

Diameter, $D = 18 \text{ mm} = 0.018 \text{ m}$

Tube surface temperature, $T_w = 90^\circ\text{C}$

To find:

Step 1. Heat transfer coefficient.

Solution:

We know that,

$$\text{Film temperature, } T_f = \frac{T_w + T_\infty}{2}$$

$$= \frac{90+30}{2}$$

$$T_f = 60^\circ\text{C}$$

Properties of air at 60°C

[From HMT data book, Page No. 34]

$$\nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\text{Pr} = 0.696$$

$$K = 0.02896 \text{ W/mK}$$

$$\text{Step 2. Maximum velocity, } U_{\max} = U \times \frac{S_t}{S_t - D}$$

$$U_{\max} = 8 \times \frac{0.020}{0.020 - 0.018}$$

$$U_{\max} = 80 \text{ m/s}$$

$$\text{Step 3. Reynolds Number, } Re = \frac{U_{\max} XD}{\nu}$$

$$= \frac{80 \times 0.018}{18.97 \times 10^{-6}}$$

$$Re = 7.5 \times 10^4$$

$$\frac{S_t}{D} = \frac{0.020}{0.018} = 1.11$$

$$\boxed{\frac{S_t}{D} = 1.11}$$

$$\frac{S_l}{D} = \frac{0.022}{0.018} = 1.22$$

$$\boxed{\frac{S_l}{D} = 1.22}$$

$\frac{S_t}{D} = 1.11$, $\frac{S_l}{D} = 1.22$, corresponding C, n values are 0.518 and 0.556 respectively.

[From HMT data book, page No. 123]

$$C = 0.518$$

$$n = 0.556$$

Step 4. Nusselt Number, $Nu = 1.13 (\text{Pr})^{0.333} [C (\text{Re})^n]$

[From HMT data book, Page No. 123]

$$Nu = 1.13 \times (0.696)^{0.333} \times [0.518 \times (7.5 \times 10^4)^{0.556}]$$

$$Nu = 266.3$$

Step 5. Nusselt Number, $Nu = \frac{hD}{k}$

$$266.3 = \frac{h \times 0.018}{28.96 \times 10^{-3}}$$

$$\text{Heat transfer coefficient, } h = 428.6 \text{ W/m}^2\text{K}$$

8. A thin 100 cm long and 10 cm wide horizontal plate is maintained at a uniform temperature of 150°C in a large tank full of water at 75°C. Estimate the rate of heat to be supplied to the plate to maintain constant plate temperature as heat is dissipated from either side of plate.

Given:

Length of horizontal plate $L = 100 \text{ cm} = 1\text{m}$

Wide $W = 10 \text{ cm} = 0.10 \text{ m}$

Plate temperature $T_w = 150^\circ\text{C}$

Fluid temperature $T_\infty = 75^\circ\text{C}$

To find: Heat loss (Q) from either side of plate:

Solution:

$$\begin{aligned} \text{Step 1. Film temperature, } T_f &= \frac{T_w + T_\infty}{2} \\ &= \frac{150 + 75}{2} \end{aligned}$$

$$T_f = 112.5^\circ\text{C}$$

Properties of water at 112.5°C:

[From HMT data book, Page No. 22]

$$\rho = 951 \text{ Kg/m}^3$$

$$\nu = 0.264 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\Pr = 1.55$$

$$k = 0.683 \text{ W/mK}$$

$$\beta_{(\text{for water})} = 0.8225 \times 10^{-3} \text{ K}^{-1}$$

[From HMT data book, Page No. 30]

Step 2. Grashof Number, $\text{Gr} = \frac{g \times \beta \times L_c^3 \times \Delta T}{\nu^2}$

For horizontal plate,

$$\text{Characteristic length, } L_c = \frac{W}{2} = \frac{0.10}{2}$$

$$L_c = 0.05 \text{ m}$$

$$\text{Gr} = \frac{9.81 \times 0.8225 \times 10^{-3} \times (0.05)^3 \times (150-75)}{(0.264 \times 10^{-6})^2}$$

$$\text{Gr} = 1.0853 \times 10^9$$

$$\text{GrPr} = 1.0853 \times 10^9 \times 1.55$$

$$\text{GrPr} = 1.682 \times 10^9$$

GrPr value is in between 8×10^6 and 10^{11}

i.e., $8 \times 10^6 < \text{GrPr} < 10^{11}$

For horizontal plate, upper surface heated:

Step 3. Nusselt Number, $\text{Nu} = 0.15 (\text{GrPr})^{0.333}$

[From HMT data book, Page No. 136]

$$\text{Nu} = 0.15 [1.682 \times 10^9]^{0.333}$$

$$\text{Nu} = 177.13$$

Step 4. Nusselt Number, $\text{Nu} = \frac{h_u L_c}{k}$

$$177.13 = \frac{h_u \times 0.05}{0.683}$$

$$h_u = 2419.7 \text{ W/m}^2\text{K}$$

Upper surface heated, heat transfer coefficient

$$h_u = 2419.7 \text{ W/m}^2\text{K}$$

For horizontal plate, lower surface heated:

Step 5. Nusselt Number $\text{Nu} = 0.27 [\text{GrPr}]^{0.25}$

[From HMT data book, Page No. 136]

$$\text{Nu} = 0.27 [1.682 \times 10^9]^{0.25}$$

$$\text{Nu} = 54.68$$

Step 6. Nusselt Number, $\text{Nu} = \frac{h_l L_c}{k}$

$$54.68 = \frac{h_u \times 0.05}{0.683}$$

$$h_l = 746.94 \text{ W/m}^2\text{K}$$

Lower surface heated, heat transfer coefficient, $h_l = 746.94 \text{ W/m}^2\text{K}$

Step 7. Total heat transfer, $Q = (h_u + h_l) \times A \times \Delta T$

$$\begin{aligned} &= (h_u + h_l) \times W \times L \times (T_w - T_\infty) \\ &= (2419.7 + 746.94) \times 0.10 \times (150 - 75) \end{aligned}$$

Heat transfer, $Q = 23749.8 \text{ W}$

9. Atmospheric air at 275 K and a free stream velocity of 20 m/s flows over a flat plate 1.5 m long that is maintained at a uniform temperature of 325 K. Calculate the average heat transfer coefficient over the region where the boundary layer is laminar, the average heat transfer coefficient over the entire length of the plate and the total heat transfer rate from the plate to the air over the length 1.5 m and width 1 m. Assume transition occurs at $Re_c = 2 \times 10^5$.

Given: Fluid temperature, $T_\infty = 275 \text{ K} = 2^\circ\text{C}$

Velocity, $U = 20 \text{ m/s}$

Length, $L = 1.5 \text{ m}$

Plate surface temperature, $T_w = 325 \text{ K} = 52^\circ\text{C}$

Width, $W = 1 \text{ m}$

Critical Reynolds number, $Re_c = 2 \times 10^5$

To find: 1. Average heat transfer coefficient, h_l [Boundary layer is laminar]

2. Average heat transfer coefficient, h_t [Entire length of the plate]

3. Total heat transfer rate, Q .

Solution:

Step 1. Film temperature, $T_f = \frac{T_w + T_\infty}{2}$

$$= \frac{52 + 2}{2}$$

$$T_f = 27^\circ\text{C}$$

Properties of air at $27^\circ\text{C} \approx 25^\circ\text{C}$

[From HMT data book, Page No. 34]

$$\rho = 1.185 \text{ Kg/m}^3$$

$$v = 15.53 \times 10^{-6} \text{ m}^2/\text{s}$$

$$Pr = 0.702$$

$$k = 0.02634 \text{ W/mK}$$

Case (i): Reynolds number, $Re = \frac{UL}{v}$

Transition occurs at $Re_c = 2 \times 10^5$

ie., Flow is laminar upto Reynolds number value is 2×10^5 , after that flow is turbulent.

$$2 \times 10^5 = \frac{20 \times L}{15.53 \times 10^{-6}}$$

$$L = 0.155 \text{ m}$$

For flat plate, laminar flow,

Step 2. Local Nusselt number, $Nu_x = 0.332 (Re)^{0.5} (Pr)^{0.333}$

[From HMT data book, Page No. 113]

$$Nu_x = 0.332 (2 \times 10^5)^{0.5} (0.702)^{0.333}$$

$$Nu_x = 131.97$$

Step 3. Local Nusselt Number, $Nu_x = \frac{h_x L}{k}$

$$131.97 = \frac{h_x \times 0.155}{0.02634}$$

$$h_x = 22.42 \text{ W/m}^2\text{K}$$

Local heat transfer coefficient, $h_x = 22.42 \text{ W/m}^2\text{K}$

Step 4. Average heat transfer coefficient, $h = 2 \times h_x$

$$= 2 \times 22.42$$

$$= 44.84 \text{ W/m}^2\text{K}$$

Case (ii):

Step 5. Reynolds number, Re_L [For entire length] $= \frac{UL}{v}$

$$= \frac{20 \times 1.5}{15.53 \times 10^{-6}}$$

$$= 1.93 \times 10^6 > 5 \times 10^6$$

Since $Re_L > 5 \times 10^5$, flow is turbulent.

For flat plate, laminar-turbulent combined flow,

Step 6. Average Nusselt number, $Nu = (Pr)^{0.333} [0.037 (Re_L)^{0.8} - 871]$

$$Nu = (0.702)^{0.333} [0.037 (1.93 \times 10^6)^{0.8} - 871]$$

$$Nu = 2737.18$$

Step 7. Nusselt number, $Nu = \frac{hL}{k}$

$$2737.18 = \frac{h \times 1.5}{0.02634}$$

$$h = 48.06 \text{ W/m}^2\text{K}$$

Average heat transfer coefficient for turbulent flow, $h_t = 48.06 \text{ W/m}^2\text{K}$
$\text{W/m}^2\text{K}$

Step 8. Total heat transfer rate, $Q = h_t \times A \times \Delta T$

$$= h_t \times W \times L \times (T_w - T_\infty)$$

$$= 48.06 \times 1 \times 1.5 \times (52 - 2)$$

$$Q = 3604.5 \text{ W}$$

10. A steam pipe 10 cm outside diameter runs horizontally in a room at 23°C. Take the outside surface temperature of pipe as 165°C. Determine the heat loss per metre length of the pipe. [Dec 2004]

Given: Diameter of the pipe, $D = 10 \text{ cm} = 0.10 \text{ m}$

Ambient air temperature, $T_\infty = 23^\circ\text{C}$

Wall temperature, $T_w = 165^\circ\text{C}$

To find: Heat loss per metre length.

Solution:

Step 1. Film temperature, $T_f = \frac{T_w + T_\infty}{2}$

$$= \frac{165 + 23}{2}$$

$$T_f = 94^\circ\text{C}$$

Properties of air at $94^\circ\text{C} \approx 95^\circ\text{C}$

[From HMT data book, Page No. 34]

$$\rho = 0.959 \text{ Kg/m}^3$$

$$v = 22.615 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\text{Pr} = 0.689$$

$$k = 0.03169 \text{ W/mK}$$

Step 2. Coefficient of thermal expansion, $\beta = \frac{1}{T_f \text{ in } K}$

$$\begin{aligned} &= \frac{1}{94+273} \\ &= 2.72 \times 10^{-3} \text{ K}^{-1} \end{aligned}$$

$$\beta = 2.72 \times 10^{-3} \text{ K}^{-1}$$

Step 3. Grashof Number, $Gr = \frac{g \times \beta \times D^3 \times \Delta T}{\nu^2}$

[From HMT data book, Page No. 135]

$$Gr = \frac{9.81 \times 7.2 \times 10^{-3} \times (0.10)^3 \times (165-23)}{(22.615 \times 10^{-6})^2}$$

$$Gr = 7.40 \times 10^6$$

$$GrPr = 7.40 \times 10^6 \times 0.689$$

$$GrPr = 5.09 \times 10^6$$

For horizontal cylinder, Nusselt number, $Nu = C [GrPr]^m$

[From HMT data book, Page No. 138]

$GrPr = 5.09 \times 10^6$, corresponding $C = 0.48$, and $m = 0.25$

$$Nu = 0.48 [5.09 \times 10^6]^{0.25}$$

$$Nu = 22.79$$

Step 4. Nusselt number, $Nu = \frac{hD}{k}$

$$22.79 = \frac{h \times 0.10}{0.03169}$$

$$h = 7.22 \text{ W/m}^2\text{K}$$

Step 5. Heat loss, $Q = hA\Delta T$

$$= h \times \pi DL(T_w - T_\infty)$$

$$\frac{Q}{L} = h \times \pi \times D \times (T_w - T_\infty)$$

$$= 7.22 \times \pi \times 0.10 \times (165 - 23)$$

$$\frac{Q}{L} = 322.08 \text{ W/m}$$

$$\text{Heat loss per metre length, } \frac{Q}{L} = 322.08 \text{ W/m}$$

PART C – 15 Marks (Questions and Answers)

- 1. Consider the flow of oil at 20° C in a 30cm diameter pipeline at an average velocity of 2 m/s. a 200m long section of the pipeline passes through icy waters of a lake at 0° C. Measurements indicate that the surface temperature of the pipe is very nearly 0° C. Disregarding the thermal resistance of the pipe material determine (a) the temperature of the oil when the pipe leaves the lake, (b) the rate of heat transfer from the oil, and (c) the pumping power required to overcome the pressure losses and to maintain the flow of the oil in the pipe.**

Solution

Oil flows in a pipeline that passes through icy waters of a lake at 0° C. The exit temperature of the oil, the rate of heat loss, and the pumping power needed to overcome pressure losses are to be determined.

Assumptions

1. Steady operating conditions exist.
2. The surface temperature of the pipe is very nearly 0° C.
3. The thermal resistance of the pipe is negligible.
4. The inner surfaces of the pipeline are smooth.
5. The flow is hydrodynamically developed when the pipeline reaches the lake.

Properties

We do not know the exit temperature of the oil, and thus we cannot determine the bulk mean temperature, which is the temperature at which the properties of oil are to be evaluated. The mean temperature of the oil at the inlet is 20°C, and we expect this temperature to drop somewhat as a result of heat loss to the icy waters of the lake. We evaluate the properties of the oil at the inlet temperature, but we will repeat the calculations, if necessary, using properties at the evaluated bulk mean temperature. At 20° C from HMT data book

$$\rho = 888 \text{ kg/m}^3 \quad U = 901 \times 10^{-6} \text{ m}^2/\text{s}$$

$$k = 0.145 \text{ W/m } ^\circ\text{C} \quad Cp = 1880 \text{ J/kg } ^\circ\text{C}$$

$$Pr = 10,400$$

$$Re = \frac{UD}{v} = \frac{2 \times 0.3}{901 \times 10^{-6}} = 666$$

which is less than the critical Reynolds number of 2300. Therefore, the flow is

laminar, and we assume thermally developing flow and determine the nusselt number from

$$\begin{aligned} \text{Nu} &= \frac{hD}{k} = 3.66 + \frac{0.065 (D/L) R_e P_r}{1+0.04[(D/L) R_e P_r]^{2/3}} \\ &= 3.66 + \frac{0.065 (0.3/200) \times 666 \times 10400}{1+0.04[(0.3/200) 666 \times 10400]^{2/3}} = 37.3 \end{aligned}$$

This nusselt number is considerably higher than the fully developed value of 3.66 then

$$h = \frac{k}{D} \text{ Nu} = \frac{0.0145}{0.3} (37.3) = 18.0 \frac{W}{m^2} \text{ } ^\circ\text{C}$$

also we determine the exit temperature of air from

$$T_e = T_s - (T_s - T_i) \exp(-h A_s / m C_p)$$

here

$$A_s = PL = \pi D L = \pi (0.3 \text{ m})(200 \text{ m}) = 188.5 \text{ m}^2$$

$$m = \rho V = (1.009 \text{ kg/m}^3)(0.15 \text{ m}^3/\text{s}) = 0.151 \text{ kg/s}$$

Substitute A_s and m in T_e

$$T_e = 60 - (60 - 80) \exp(-13.5 \times 6.4 / 0.151 \times 1008) = 71.3 \text{ } ^\circ\text{C}$$

Then the logarithmic mean temperature difference and the rate of heat loss from the air become

$$\Delta T_{ln} = \frac{T_i - T_e}{\ln \frac{T_s - T_e}{T_s - T_i}} = -15.2 \text{ } ^\circ\text{C}$$

$$Q = h A_s \Delta T_{ln} = (13.5 \text{ W/m}^2 \text{ } ^\circ\text{C})(6.4 \text{ m}^2)(-15.2 \text{ } ^\circ\text{C}) = -1313 \text{ W}$$

Therefore, air will lose heat at a rate of 1313 W as it flows through the duct in the attic.

2. In condenser water flows through two hundred thin walled circular tubes having inner diameter 20mm and length 6 m. the mass flow rate of water is 160 kg/s. the water enters at 30° C and leaves at 50 ° C. Calculate the average heat transfer coefficient.

Given :

Inner diameter $D = 20\text{mm}$

Length $L = 6 \text{ m}$

Mass flow rate $m = 160 \text{ kg/s}$

Inlet water temperature $T_{mi} = 30^\circ C$

Outlet water temperature, $T_{mo} = 50^\circ C$

To find: Heat transfer coefficient (h)

Solution:

$$\text{Bulk mean temperature } T_m = \frac{T_{mi} + T_{mo}}{2} = \frac{30 + 50}{2} = 40^\circ C$$

Properties of water at $40^\circ C$ [from HMT data boo page no 21]

$$\rho = 995 \text{ kg/m}^3$$

$$v = 0.657 \times 10^{-6} \text{ m}^2/\text{s}$$

$$Pr = 4.340$$

$$k = 0.628 \text{ W/mK}$$

$$C_p = 4178 \text{ J/kg K}$$

$$\text{Reynolds Number } Re = UD / v$$

$$m = \rho A U$$

$$\text{Velocity } U = m / \rho A$$

$$= \frac{\left(\frac{160}{200}\right)}{995 \times \frac{\pi}{4} \times 0.020^2} = 2.55 \text{ m/s} \quad (\text{no of tubes} = 200)$$

$$Re = UD / v$$

$$= \frac{2.55 \times 0.020}{0.657 \times 10^{-6}} = 77625.57$$

Since $Re > 2300$, flow is turbulent

For turbulent flow, general equation is ($Re > 10000$)

$$Nu = 0.023 \times Re^{0.8} Pr^n \quad [\text{from HMT data boo page no 125}]$$

This is heating process so $n = 0.4$ ($T_{mo} > T_{mi}$)

$$Nu = 0.023 \times 77625.57^{0.8} 4.340^{0.4}$$

$$Nu = 337.8$$

$$Nu = \frac{hD}{k}$$

$$337.8 = \frac{h \times 0.020}{0.628}$$

$$\text{Heat transfer coefficient } h = 10606.9 \text{ w/m}^2\text{K}$$

UNIT: III PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGERS**PART A - 2 Marks (Questions and Answers)****1. What is burnout point in boiling heat transfer? Why is it called so? (May /June 2013)**

In the Nucleate boiling region, a point at which heat flow is maximum is known as burnout point. Once we cross this point, large temperature difference is required to get the same heat flux and most material may burn at this temperature. Most of the boiling heat transfer heaters are operated below the burnout heat flux to avoid that disastrous effect.

2. Define NTU and LMTD of a heat exchanger. (May/June 2013 & May/June 2016)**LMTD (Logarithmic Mean Temperature Difference)**

The temperature difference between the hot and cold fluids in the heat exchanger varies from point to point in addition various modes of heat transfer are involved. Therefore based on concept of appropriate mean temperature difference, also called logarithmic mean temperature difference, the total heat transfer rate in the heat exchanger is expressed as

$$Q = U A (\Delta T)_m$$

Where U – Overall heat transfer coefficient $\text{W}/\text{m}^2\text{K}$

A – Area m^2

$(\Delta T)_m$ – Logarithmic mean temperature difference.

NTU (No. of Transfer Units)

It is used to calculate the rate of heat transfer in heat exchangers, when there is insufficient information to calculate the Log-Mean Temperature Difference (LMTD). In heat exchanger analysis, if the fluid inlet and outlet temperatures are specified or can be determined, the LMTD method can be used; but when these temperatures are not available The NTU or The Effectiveness method is used.

3. What are the different regimes involved in pool boiling? (May/June 2014)

The different boiling regimes observed in pool boiling are

1. Interface evaporation
2. Nucleate boiling
3. Film boiling.

4. Write down the relation for overall heat transfer coefficient in heat exchanger with fouling factor. (May/June 2014)

Overall heat transfer coefficient in heat exchanger

$$\frac{1}{U_o} = \frac{1}{h_o} + R_{fo} + \frac{r_o}{k} \ln \frac{r_o}{r_i} + \frac{r_o}{r_i} R_{fi} + \frac{r_o}{r_i} \frac{1}{h_i}$$

Where R_{fi} and R_{fo} are the fouling factors at inner and outer surfaces.

[HMT Data Book, P.No.157]

5. How heat exchangers are classified? (May/June 2015)

The heat exchangers are classified as follows

1. Direct contact heat exchangers
2. Indirect contact heat exchangers
3. Surface heat exchangers
4. Parallel flow heat exchangers
5. Counter flow heat exchangers
6. Cross flow heat exchangers
7. Shell and tube heat exchangers
8. Compact heat exchangers.

6. What are the limitations of LMTD method? Discuss the advantage of NTU over the LMTD method. (May/June 2015 & Nov/Dec 2012 & Nov/Dec 2013)

The LMTD method cannot be used for the determination of heat transfer rate and outlet temperature of the hot and cold fluids for prescribed fluid mass flow rates and inlet temperatures when the type and size of heat exchanger are specified.

Effectiveness NTU is superior for the above case because LMTD requires tedious iterations for the same.

7. Differentiate between pool and forced convection boiling. (Nov/Dec 2012 & Nov/Dec 2013 & Nov/Dec 2015) (NOV/DEC 2016)

Boiling is called pool boiling in the absence of bulk fluid flow, and flow boiling (or forced convection boiling) in the presence of it.

In pool boiling, the fluid is stationary, and any motion of the fluid is due to natural convection currents and the motion of the bubbles due to the influence of buoyancy. Example: Boiling of water in a pan on top of a stove.

8. What is pool boiling? Give an example for it. (Nov/Dec 2014)

If heat is added to a liquid from a submerged solid surface, the boiling process referred to as pool boiling. In this case the liquid above the hot surface is essentially stagnant and its motion near the surface is due to free convection and mixing induced by bubble growth and detachment.

Example: Boiling of water in a pan on top of a stove.

9. What do you understand by fouling and effectiveness? (Nov/Dec 2014 & Nov/Dec 2015)

The surfaces of heat exchangers do not remain clean after it has been in use for some time. The surfaces become fouled with scaling or deposits. The effect of these deposits affecting the value of overall heat transfer coefficient. This effect is taken care of by introducing an additional thermal resistance called the fouling resistance or fouling factor.

10. Define effectiveness. (May/June 2016)

The heat exchanger effectiveness is defined as the ratio of actual heat transfer to the maximum possible heat transfer.

$$\text{Effectiveness } \varepsilon = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}}$$

11. What is meant by sub-cooled and saturated boiling? (Nov/Dec 2015)

The sub-cooled boiling or saturated boiling, depending on the bulk liquid temperature.

Sub-cooled boiling:

There is sharp increase in temperature near to the surface but through most of the liquid, temperature remains close to saturation temperature. ($T_\alpha < T_{sat}$)

Saturated boiling:

When the temperature of the liquid equals to the saturation temperature. ($T_\alpha = T_{sat}$)

12. What is a compact heat exchanger? Give applications. (May/June 2016)

Special purpose heat exchangers called compact heat exchangers. They are generally employed when convective heat transfer coefficient associated with one of the fluids is much smaller than that associated with the other fluid.

In variety of applications including,

- Compressed Gas / Water coolers
- Condensers and evaporators for chemical and technical processes of all kinds.
- Oil and water coolers for power machines
- Refrigeration and air-conditioning units

13. What are the assumptions made in Nusselt theory of condensation? (May/June 2016)

1. The plate is maintained at a uniform temperature which is less than the saturation temperature of vapour. ($T_w < T_{sat}$)
2. Fluid properties are constant.
3. The shear stress at the liquid vapour interface is negligible.
4. The heat transfer across the condensate layer is by pure conduction and the temperature distribution is linear.

14. How fouling affect the rate of heat transfer? (May/June 2016)

"Fouling" is any kind of deposit of extraneous material that appears upon the heat transfer surface during the life time of the heat exchanger.

This fouling will cause an additional resistance to heat transfer is introduced and the operational capability of the heat exchanger is correspondingly reduced. In many cases, the deposit is heavy enough to significantly interfere with fluid flow and increase the pressure drop required to maintain the flow rate through the exchanger.

PART B - 13 Marks (Questions and Answers)

1. Discuss briefly the pool boiling regimes of water at atmospheric pressure (May/June 2013, May/June 2014, Nov/Dec 2013)

Boiling is classified as pool boiling or flow boiling, depending on the presence of bulk fluid motion. Boiling is called pool boiling in the absence of bulk fluid flow and flow boiling in the presence of bulk fluid motion.

Boiling takes different forms, depending on the value of the excess temperature ΔT_{excess} . Four different boiling regimes are observed: natural convection boiling, nucleate boiling, transition boiling, and film boiling. These regimes are illustrated on the boiling curve in fig, which is a plot of boiling heat flux versus the excess temperature.

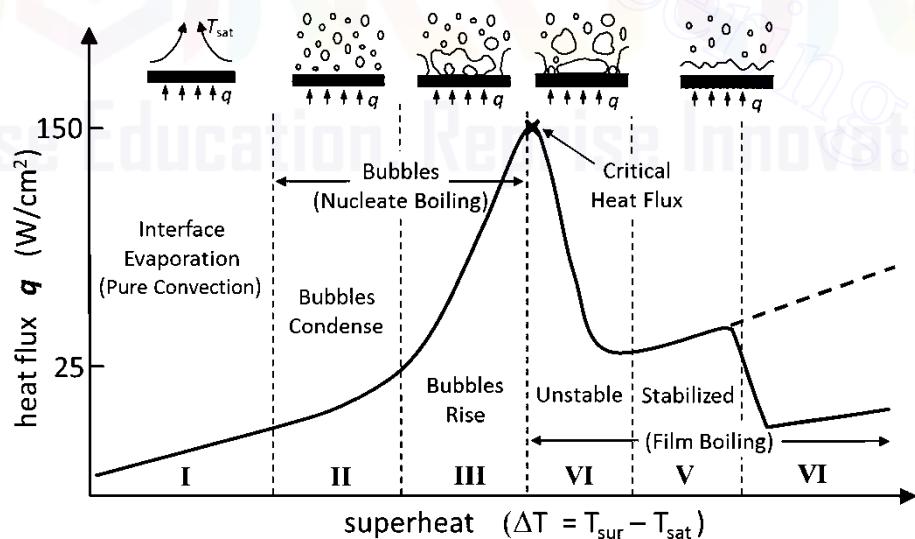


Fig: Typical boiling curve for water at 1 atmospheric pressure

NATURAL CONVECTION BOILING (to point A on the Boiling curve)

We know from thermodynamics that a pure substance at a specified pressure starts boiling when it reaches the saturation temperature at that

pressure. But in practice we do not see any bubbles forming on the heating surface until the liquid is heated a few degrees above the saturation temperature (about 2 to 6° C for water). Therefore, the liquid is slightly superheated in this case and evaporates when it rises to the free surface. The fluid motion in this mode of boiling is governed by natural convection currents, and heat transfer from the heating surface to the fluid is by natural convection. For the conditions of fig, natural convection boiling ends at excess temperature of about 5° C.

NUCLEATE BOILING (between points A and C)

The first bubbles start forming at point A of the boiling curve at various preferential sites on the heating surface. Point A is referred to as the onset of nucleate boiling (ONB). The bubbles form at an increasing rate at an increasing number of nucleation sites as we move along the boiling curve toward point C. From fig nucleate boiling exists in the range from about 5° C to about 30° C.

The nucleate boiling regime can be separated into two distinct regions. In regions A-B ($5^{\circ}\text{C} \leq \Delta T_{\text{excess}} \leq 10^{\circ}\text{C}$), isolated bubbles are formed at various preferential nucleation sites on the heated surface. But these bubbles are dissipated in the liquid shortly after they separate from the surface. The space vacated by the rising bubbles is filled by the liquid in the vicinity of the heater surface, and the process is repeated. The stirring and agitation caused by the entrainment of the liquid to the heater surface is primarily responsible for the increased heat transfer coefficient and heat flux in this region of nucleate boiling.

In region B-C ($10^{\circ}\text{C} \leq \Delta T_{\text{excess}} \leq 30^{\circ}\text{C}$), the heater temperature is further increased, and bubbles form at such great rates at such a large number of nucleation sites that they form numerous continuous columns of vapour in the liquid. These bubbles move all the way up to the free surface, where they break up and release their vapor content. The large heat fluxes obtainable in this region.

At large values of ΔT_{excess} , the rate of evaporation at the heater surface reaches such high values that a large fraction of the heater surface

is covered by bubbles, making it difficult for the liquid to reach the heater surface and wet it. Consequently, the heat flux increases at a lower rate with increasing ΔT_{excess} , and reaches a maximum at point C. the heat flux at this point is called the critical heat flux.

TRANSITION BOILING (between points C and D)

As the heater temperature and thus the ΔT_{excess} , is increased past point C, the heat flux decreases, as shown in fig. this is because a large fraction of the heater surface is covered by a vapour film, which acts as an insulation due to the low thermal conductivity of the vapour relative to that of the liquid. In the transition boiling regime, both nucleate and film boiling partially occur. Nucleate boiling at point C is completely replaced by film boiling at point D. for water, transition boiling occurs over the excess temperature range from about 30°C to about 120°C .

FILM BOILING (beyond point D)

In this region the heater surface is completely covered by a continuous stable vapour film. Point D, where the heat flux reaches a minimum, is called the Leidenforst point. The liquid droplets on a very hot surface jump around and slowly boil away. The presence of a vapour film between the heater surface and the liquid is responsible for the low heat transfer rates in the film boiling region. The heat transfer rate increases with increasing excess temperature as a result of heat transfer from the heated surface to the liquid through the vapour film by radiation, which becomes significant at high temperatures.

2. Water is to be boiled at atmospheric pressure in a polished copper pan by means of an electric heater. The diameter of the pan is 0.38 m and is kept at 115°C . calculate the following 1. Power required boiling the water 2. Rate of evaporation 3. Critical heat flux. (Nov/Dec 2012, Nov/Dec 2015)

Given:

Diameter, $d = 0.38 \text{ m}$;

Surface temperature, $T_w = 115^{\circ}\text{C}$.

To find:

1. Power required, (p)
2. Rate of evaporation, (m)
3. Critical heat flux, (Q/A)

Solution:**Step 1:**

Need to find the nucleate pool boiling or film pool boiling process.

ΔT = Excess Temperature = $T_w - T_{sat}$ = Answer, which is less than $50^\circ C$ then it is Nucleate pool boiling or greater than $50^\circ C$ then it is film pool boiling.

$$\boxed{\Delta T = T_w - T_{sat}}$$

We know that saturation temperature of water is $100^\circ C$. i.e. $T_{sat} = 100^\circ C$

$\Delta T = 115 - 100 = 15^\circ C$ so this is nucleate pool boiling process.

Step 2:

Need to find the properties of water at $100^\circ C$.

(From HMT data book page No. 21)

Density, $\rho_l = 961 \text{ kg/m}^3$

Kinematic viscosity, $\nu = 0.293 \times 10^{-6} \text{ m}^2/\text{s}$

Prandtl Number, $P_r = 1.740$

Specific heat, $C_{pl} = 4216 \text{ J/kg K}$

Dynamic viscosity, $\mu_l = \rho_l \times \nu = 961 \times 0.293 \times 10^{-6} = 281.57 \times 10^{-6} \text{ Ns/m}^2$

Enthalpy of evaporation, $h_{fg} = 2256.9 \text{ KJ/kg}$ (from steam table)

Specific volume of vapour, $v_g = 1.673 \text{ m}^3/\text{kg}$

Density of vapour, $\rho_v = (1/v_g) = 0.597 \text{ kg/m}^3$

Step 3:

Need to find the heat flux, power

$$\text{Heat flux, } \frac{Q}{A} = \mu_l \times h_{fg} \left[\frac{g \times (\rho_l - \rho_v)}{\sigma} \right]^{0.5} \times \left[\frac{C_{pl} \times \Delta T}{C_{sf} \times h_{fg} P_r^n} \right]^3 \quad \dots \dots 1 \quad (\text{from HMT data})$$

book page no. 142)

Where σ = surface tension for liquid vapour interface at $100^\circ C$.

$$\sigma = 0.0588 \text{ N/m} \quad (\text{from HMT data book page no. 144})$$

For water – copper $\rightarrow C_{sf}$ = surface fluid constant = 0.013 and n=1 for water (from HMT data book page no.143)

Substitute the μ_l , h_{fg} , ρ_l , ρ_v , C_{pl} , ΔT , C_{sf} , n and P_r values in equation 1

$$\frac{Q}{A} = 4.83 \times 10^5 \text{ W/m}^2$$

$$\text{Heat transfer } Q = 4.83 \times 10^5 \times A$$

$$\text{Area } A = \left(\frac{\pi}{4}\right)d^2 = 0.113 \text{ m}^2$$

$$\text{Power} = 54.7 \text{ kW}$$

Step 4:

Need to find Rate of evaporation, (\dot{m})

$$\text{Heat transferred } Q = \dot{m} \times h_{fg}$$

$$\text{Substitute } Q \text{ and } h_{fg}$$

$$\dot{m} = 0.024 \text{ kg/s}$$

Step 5:

Need to find the critical flux

For nucleate pool boiling, critical heat flux,

$$\frac{Q}{A} = 0.18 \times h_{fg} \times \rho_v \left[\frac{\sigma \times g \times (\rho_l - \rho_v)}{\rho_v^2} \right]^{0.25}$$

(from HMT data book page no. 142)

$$\text{Critical heat flux, } q = \frac{Q}{A} = 1.52 \times 10^6 \text{ W/m}^2$$

- 3. A wire of 1 mm diameter and 150mm length is submerged horizontally in water at 7 bar. The wire carries a current of 131.5 ampere with an applied voltage of 2.15 Volt. If the surface of the wire is maintained at 180° C, calculate the heat flux and the boiling heat transfer coefficient.(May/June 2014 Reg 2008)**

Given:

Diameter, D = 1 mm = 1×10^{-3} m;

Length, L = 150mm = 150×10^{-3} m;

Pressure, P = 7 bar

Voltage, V = 2.15 V

Current, I = 131.5 amps

T_w = 180° C

To find:

1. Heat flux, $\frac{Q}{A}$

2. Heat transfer coefficient, h

Solution:

Step 1:

Need to find heat flux

$$Q = V \times I = 2.15 \times 131.5 = 282.72 \text{ W}$$

$$A = \pi D L = \pi \times 1 \times 10^{-3} \times 150 \times 10^{-3} = 471.23 \times 10^{-6} \text{ m}^2$$

$$\text{Heat flux} = \frac{Q}{A} = 282.72 / 471.23 \times 10^{-6} = 599.950 \times 10^3 \text{ W/m}^2$$

$$\boxed{\frac{Q}{A} = 599.950 \times 10^3 \text{ W/m}^2}$$

Step 2:

Need to find the heat transfer co efficient h

At pressure P = 7 bar: ΔT = 180 - 100 = 80° C

Heat transfer co efficient, h = 5.56 (ΔT)³

(From HMT data book page no: 143)

$$h = 2846720 \text{ W/m}^2 \text{ K}$$

Heat transfer coefficient other than atmospheric pressure

$$h_p = h P^{0.4} = 2846720 \times 7^{0.4} = 6.19 \times 10^6 \text{ W/m}^2 \text{ K}$$

$$\boxed{h_p = 6.19 \times 10^6 \text{ W/m}^2 \text{ K}}$$

4. A vertical cooling fin approximating a flat plate 40 cm in height is exposed to saturated steam at atmospheric pressure. The fin is maintained at a temperature of 90° C. estimate the thickness of the film at the bottom of the fin, overall heat transfer coefficient and heat transfer rate after incorporating McAdam's correction, the rate of condensation of steam. (Nov/Dec 2015 Reg 2008)

Given:

Height (or) Length, $L = 40 \text{ cm} = 0.4\text{m}$

Surface temperature, $T_w = 90^\circ \text{C}$

To find:

1. The film thickness δ_x
2. Overall heat transfer coefficient h (McAdam's correction)
3. Heat transfer rate Q
4. Rate of condensation of steam \dot{m}

Solution:**Step 1:**

We know that, saturation temperature of water is 100°C , i.e. $T_{sat} = 100^\circ \text{C}$

$h_{fg} = 2256.9 \text{ KJ/kg}$ (from steam table)

We know that

Film temperature, $T_f = \frac{T_w + T_{sat}}{2} = 95^\circ \text{C}$

Properties of saturated water at 95°C (from HMT data book page no: 21)

Density, $\rho_l = 967.5 \text{ kg/m}^3$

Kinematic viscosity, $\nu = 0.328 \times 10^{-6} \text{ m}^2/\text{s}$

Specific heat, $C_{pl} = 4205.5 \text{ J/kg K}$

Thermal conductivity $K = 0.674 \text{ W/mk}$

Dynamic viscosity, $\mu_l = \rho_l \times \nu = 967.5 \times 0.328 \times 10^{-6} = 3.173 \times 10^{-4} \text{ Ns/m}^2$

Step 2:

We need to find the film thickness

$$\delta_x = \left[\frac{4 \mu K x (T_{sat} - T_w)}{g h_{fg} \rho_l^2} \right]^{0.25} \quad (\text{from HMT data book page no: 148})$$

substitute all appropriate property value in above formula

$$\delta_x = 1.13 \times 10^{-4} \text{ m}$$

Step 3:

We need to find the heat transfer coefficient h

For vertical surface laminar flow (assume) or find by Re-Reynolds number

$R_e = \frac{4 \dot{m}}{P \mu}$ here P = perimeter; $R_e > 1800$ then that flow is turbulent flow,

$R_e < 1800$ then that flow is laminar flow,

$$h = 0.943 \left[\frac{k^3 \times \rho^2 \times g h_{fg}}{\mu \times L \times (T_{sat} - T_w)} \right]^{0.25} \quad (\text{from HMT data book page no: 148})$$

The factor 0.943 may be replaced by 1.13 for more accurate result as suggested by Mc Adams

$$h = 1.13 \left[\frac{k^3 \times \rho^2 \times g h_{fg}}{\mu \times L \times (T_{sat} - T_w)} \right]^{0.25}$$

Substitute all the properties in above formula

$$h = 1495.3 \text{ W/m}^2 \text{ K}$$

Step 4:

We need to find the heat transfer rate Q

$$Q = h A (T_{sat} - T_w) = h L W (T_{sat} - T_w)$$

$$Q = 1495.3 \times 0.4 \times 1 \times 10 = 5981.26 \text{ W}$$

$$Q = 5981.26 \text{ W}$$

Step 5:

We need to find the rate of condensation of steam \dot{m}

$$Q = \dot{m} h_{fg}$$

$$\dot{m} = Q/h_{fg}$$

$$\dot{m} = 0.00265 \text{ kg/s}$$

5. A condenser is to be designed to condense 600 kg/h of dry saturated steam at a pressure of 0.12 bar. A square array of 400 tubes, each of 8 mm diameters is to be used. The tube surface is maintained at 30° C. Calculate the heat transfer coefficient and the length of each tube. (April/May 2015) (NOV/DEC 2013)

Given:

$$\dot{m} = 600 \text{ kg/h} = 0.166 \text{ kg/s}$$

$$\text{Pressure } P = 0.12 \text{ bar}$$

$$\text{No. of tubes} = 400$$

$$\text{Diameter, } D = 8 \text{ mm} = 8 \times 10^{-3} \text{ m}$$

$$\text{Surface temperature, } T_w = 30^\circ \text{ C.}$$

To find:

1. Heat transfer coefficient h
2. Length

Solution:**Step 1:**

We need find the properties of steam at 0.12 bar (from steam table)

$$T_{sat} = 49.45^\circ C.$$

$$h_{fg} = 2384.3 \times 10^3 \text{ J/kg}$$

$$\text{Film temperature, } T_f = \frac{T_w + T_{sat}}{2} = 39.72^\circ C = 40^\circ C$$

Properties of saturated water at 40°C (from HMT data book page no: 21)

$$\text{Density, } \rho_l = 995 \text{ kg/m}^3$$

$$\text{Kinematic viscosity, } v = 0.657 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\text{Thermal conductivity K} = 0.628 \text{ W/mk}$$

$$\text{Dynamic viscosity, } \mu_l = \rho_l \times v = 995 \times 0.657 \times 10^{-6} = 653.7 \times 10^{-6} \text{ Ns/m}^2$$

With 400 tubes, a 20 × 20 tube of square array could be formed

$$N = \sqrt{400} = 20$$

Step 2:

We need to find the heat transfer coefficient h

$$h = 0.728 \left[\frac{k^3 \times \rho^2 \times g \ h_{fg}}{\mu \times N \ D \times (T_{sat} - T_w)} \right]^{0.25} \quad (\text{from HMT data book page no: 148})$$

$$h = 5304.75 \text{ W/m}^2 \text{ K}$$

Step 3:

$$Q = h A (T_{sat} - T_w) = h D L (T_{sat} - T_w) = 1.05 \times 10^6 \text{ W} \quad \dots \dots 1$$

We know that

$$Q = \dot{m} h_{fg} = 0.3957 \times 10^6 \text{ W} \quad \dots \dots 2$$

Equating (1) and (2) We get,

$$\boxed{\frac{L}{m} = 0.37}$$

6. In a double pipe counter flow heat exchanger, 10000 kg/hr of an oil having a specific heat of 2095 J/kg-k is cooled from 80°C to 50°C by 800kg/hr of water entering at 25°C. Determine the heat exchanger area

for an overall heat transfer co-efficient of 300 W/m²k. Take C_P for water as 4180 J/kg-k.

Given:

Hot fluid – oil (T₁-T₂) Cold fluid - water (t₁-t₂)

The mass flow rate of oil (Hot fluid), m_h = 10000 kg/hr

$$= \frac{10000 \text{ kg}}{3600 \text{ s}}$$

$$m_h = 2.277 \text{ kg/s}$$

Specific heat of oil, C_{ph} = 2095 J/kg-k

Entry temperature of oil , T₁ = 80°C

Exit temperature of oil , T₂ = 50°C

Mass flow rate of water (Cold fluid), m_c = 8000 kg/hr

$$= \frac{8000 \text{ kg}}{3600 \text{ s}}$$

$$m_c = 2.22 \text{ kg/s}$$

Entry temperature of water, t₁ = 25°C

Overall heat transfer co-efficient, U = 300 W/m²k

Specific heat of water, C_{pc} = 4180 J/kg-k

To find:

Heat exchanger area, A

Solution:

Heat lost by oil (Hot fluid) = Heat gained by water (Cold fluid)

$$Q_h = Q_c$$

$$m_h C_{ph} (T_1 - T_2) = m_c C_{pc} (t_1 - t_2)$$

$$2.277 \times 2095 (80-50) = 2.22 \times 4180 \times (t_2 - 25)$$

$$174.53 \times 10^3 = 9.27 \times 10^3 t_2 - 231.99 \times 10^3$$

$$t_2 = 43.85^\circ\text{C}$$

$$\boxed{\text{Exit temperature of water, } t_2 = 43.85^\circ\text{C}}$$

Heat transfer,Q = m_h C_{ph} (T₁-T₂) or m_c C_{pc} (t₁-t₂)

$$Q = 2.22 \times 4180 \times (43.85 - 25)$$

We know that,

$$Q = 174.92 \times 10^3 \text{ W}$$

$$\text{Heat transfer, } Q = UA (\Delta T)_m \quad \dots\dots(1)$$

Where,

$(\Delta T)_m$ – Logarithmic Mean Temperature Difference.
(LMTD)

$$\begin{aligned} \text{For counter flow, } (\Delta T)_m &= \frac{[(T_1 - t_2) - (T_2 - t_1)]}{\ln \left[\frac{T_1 - t_2}{T_2 - t_1} \right]} \\ &= \frac{[(80 - 43.85) - (50 - 25)]}{\ln \left[\frac{80 - 43.85}{50 - 25} \right]} \end{aligned}$$

$$(\Delta T)_m = 30.23^\circ\text{C}$$

Substitute $(\Delta T)_m$, U and Q value in eqn (1)

$$Q = UA (\Delta T)_m$$

$$174.92 \times 10^3 = 300 \times A \times 30.23$$

$$\boxed{\text{Heat exchanger area } A = 19.287 \text{ m}^2}$$

7.In a cross flow heat exchangers, both fluids an mixed, hot fluid with a specific heat of 2300 j/kg k ,enters at 380^o and leaves at 300^oc. Cold fluids enter at 25^oc and leaves 210^oC. Calculate the required surface area of heat exchanger. Take overall heat transfer co-efficient is 750 w/m²k. Mass flow rate of hot fluid is 1Kg/s.

Given:

Specific heat of hot fluid $C_{ph} = 2300 \text{ J/Kg K}$

Entry temperature of hot fluid $T_1 = 380^\circ \text{C}$

Exit temperature of hot fluid $T_2 = 300^\circ \text{C}$

Entry temperature of Cold fluid $t_1 = 25^\circ \text{C}$

Exit temperature of Cold fluid $t_2 = 210^\circ \text{C}$

Overall heat transfer co-efficient, $U = 750 \text{ w/m}^2\text{k}$

The mass flow rate of hot fluid , $m_h = 1 \text{ kg/s}$

To find:

Heat exchanger area (A)

Solution:

This is Cross flow, both fluids unmixed type heat exchanger.

For cross flow heat exchanger,

$$Q = F \cdot U \cdot A \cdot (\Delta T)_m \quad (\text{counter flow}) \quad(1)$$

[From HMT Data book page No. 152]

Where,

$(\Delta T)_m$ – Logarithmic Mean Temperature Difference for counter flow.

$$\text{For counter flow, } (\Delta T)_m = \frac{\ln \left[\frac{T_1 - t_2}{T_2 - t_1} \right]}{\frac{(T_1 - t_2) - (T_2 - t_1)}{(T_1 - t_2) + (T_2 - t_1)}}$$

$$= \frac{[(380 - 210) - (300 - 25)]}{\ln \left[\frac{380 - 210}{300 - 25} \right]}$$

$$(\Delta T)_m = 218.3^{\circ}\text{C}$$

$$\text{Heat transfer, } Q = m_h \cdot C_{ph} \cdot (T_1 - T_2)$$

$$Q = 1 \times 2300 \times (380 - 300)$$

$$Q = 184 \times 10^3 \text{ W}$$

To find correction factor F, refer HMT data book page No 162

[Single pass cross flow heat exchanger – Both fluids unmixed]

From graph,

$$\text{Xaxis value } P = \left[\frac{t_2 - t_1}{T_1 - T_2} \right]$$

$$= \left[\frac{210 - 25}{380 - 25} \right] \quad \text{X axis Value is 0.52, Curve Value is 0.432,}$$

corresponding Yaxis Value is 0.97 i,e

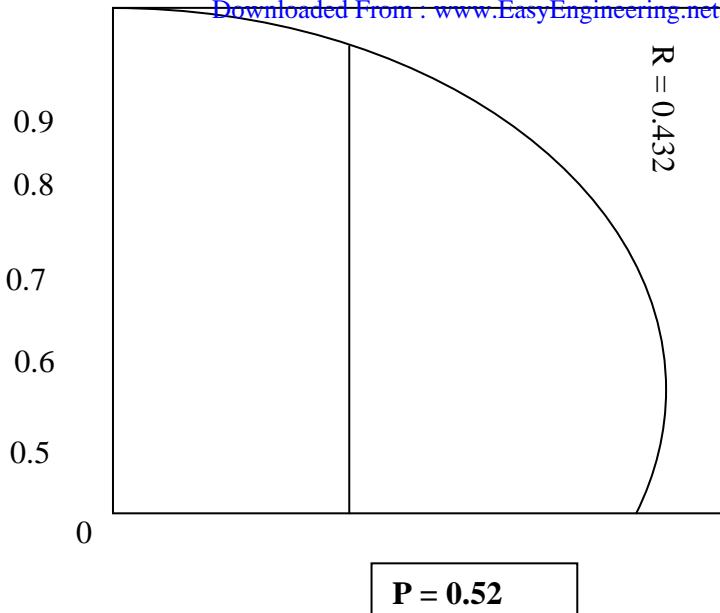
$$F = 0.97$$

$$P = 0.52$$

$$\text{Curve Value } R = \left[\frac{T_1 - T_2}{t_2 - t_1} \right]$$

$$= \left[\frac{380 - 300}{210 - 25} \right]$$

$$R = 0.432$$



Substitute, Q , F $(\Delta T)_m$, and U value in eqn (1)

$$Q = F UA (\Delta T)_m$$

$$184 \times 10^3 = 0.97 \times 750 \times A \times 218.3$$

$$\text{Surface Area } A = 1.15 \text{ m}^2$$

8. Classify the heat exchangers, draw the temperature distribution in a condenser and evaporator.

There are several types heat exchangers which may be classified on the basis of

- I. Nature of heat exchange process
- II. Relative direction of fluid motion
- III. Design and constructional features
- IV. Physical state of fluids.

I. Nature of heat exchange process

On the basis of the nature of heat exchange processes, heat exchangers are classified as

Direct contact heat exchangers or open heat exchangers

a) Indirect contact heat exchangers

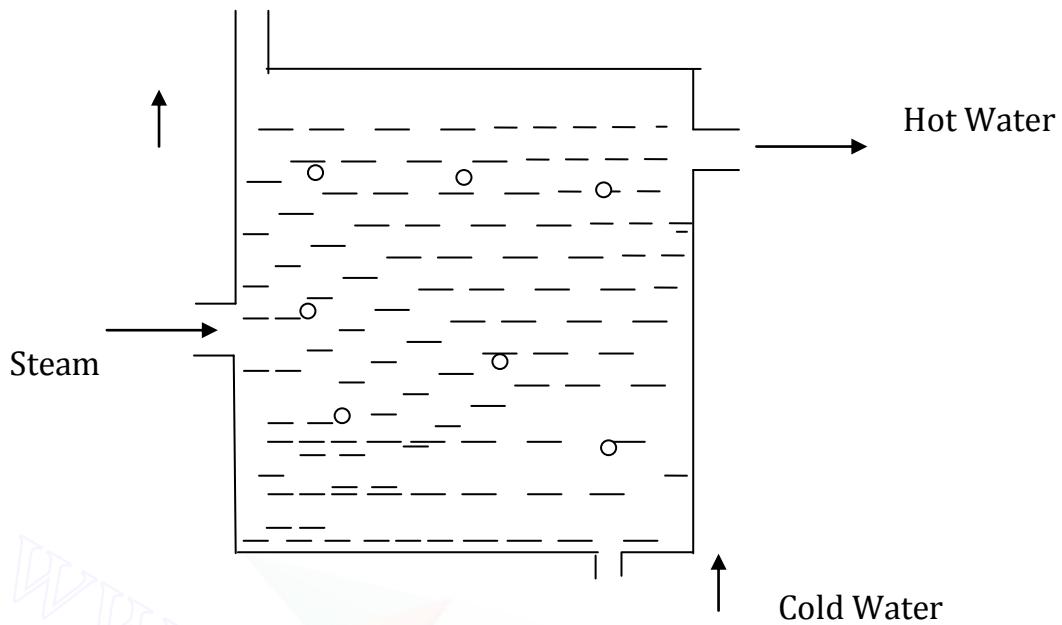
a. Direct contact heat exchangers

The heat exchange takes place by direct mixing of hot and cold fluids.

This heat transfer is usually accompanied by mass transfer.

Ex: cooling towers, direct contact feed heaters

Gas



b. Indirect contact heat exchangers could be carried out by transmission through a wall which separates the two fluids

It may be classified as

- i) Regenerators
- ii) Recuperators

Regenerators

Hot and cold fluids flow alternately through the same space

Ex: IC engines, gas turbines

Recuperators

This is most common type of heat exchanger in which the hot and cold fluid do not come into direct contact with each other but are separated by a tube wall or a surface.

Ex: Automobile radiators, Air pre heaters, Economisers

Advantages

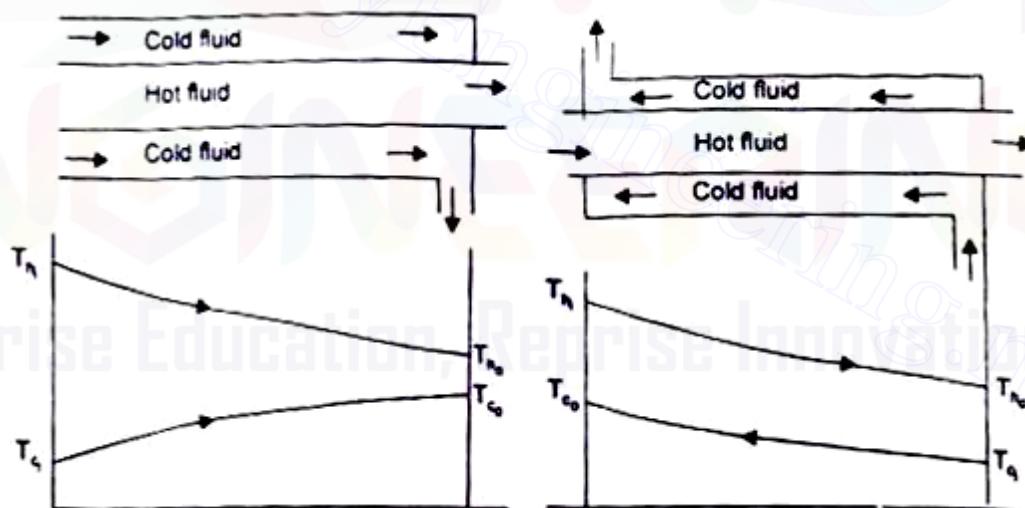
1. Easy construction
2. More economical
3. More surface area for heat transfer

Disadvantages

- 1.Less heat transfer co-efficient
 - 2.Less generating capacity
- II.Relative direction of fluid motion
- a.Parallel flow heat exchanger
 - b.Counter flow heat exchanger
 - c.Cross flow heat exchanger

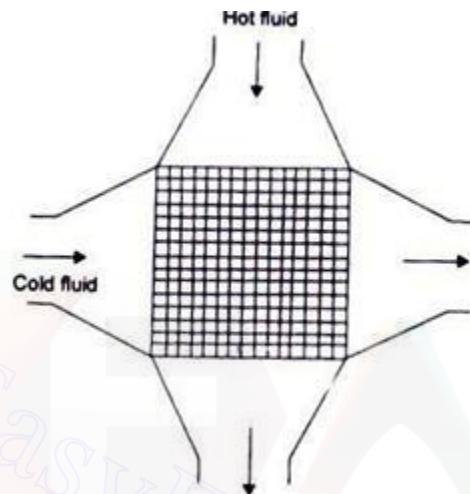
a)Parallel Flow – the hot and cold fluids flow in the same direction. Depicts such a heat exchanger where one fluid (say hot) flows through the pipe and the other fluid (cold) flows through the annulus.

(b) Counter Flow – the two fluids flow through the pipe but in opposite directions. A common type of such a heat exchanger. By comparing the temperature distribution of the two types of heat exchanger



We find that the temperature difference between the two fluids is more uniform in counter flow than in the parallel flow. Counter flow exchangers give the maximum heat transfer rate and are the most favoured devices for heating or cooling of fluids. When the two fluids flow through the heat exchanger only once, it is called one-shell-pass and one-tube-pass

(c) Cross-flow - A cross-flow heat exchanger has the two fluid streams flowing at right angles to each other. illustrates such an arrangement An automobile radiator is a good example of cross-flow exchanger. These exchangers are 'mixed' or 'unmixed' depending upon the mixing or not mixing of either fluid in the direction transverse to the direction of the flow stream and the analysis of this type of heat exchanger is extremely complex because of the variation in the temperature of the fluid in and normal to the direction of flow



III.Design and constructional features

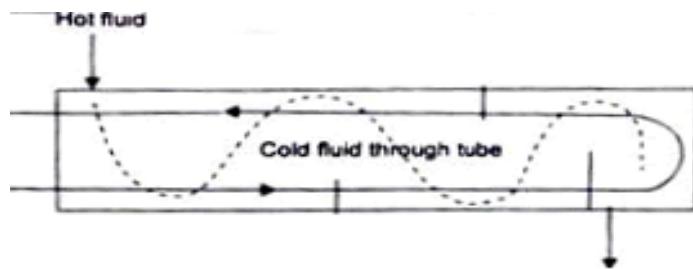
- a.Concentric tubes
- b.Shell and tube
- c.Mutible shell and tube passes
- d.Compact heat exchangers

a Concentric tubes

Two concentric pipes ,each carrying one of the fluids are used as a heat exchanger.The direction of flow may be parallel or counter.

b. Shell and tube

One of the fluids move through a bundle of tubes enclosed by a shell.The other fluid is forced through the shell and it moves over the outside surface of the tubes.

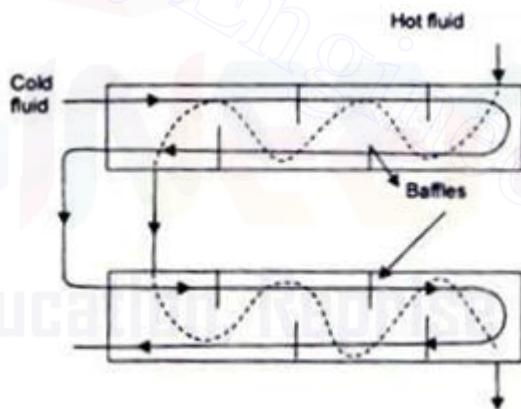


c. Multiple shell and tube passes

If the fluid flowing through the tube makes one pass through half of the tube, reverses its direction of flow, and makes a second pass through the remaining half of the tube, it is called 'one-shell-pass, two-tube-pass' heat exchanger. Many other possible flow arrangements exist and are being used. depicts a 'two-shell-pass, four-tube-pass' exchanger.

d. Compact heat exchangers

There are many special purpose heat exchangers called compact heat exchangers. They are generally employed when convective heat transfer coefficient associated with one of the fluids is much smaller than that associated with the other fluid.



IV. Physical state of fluids

a. Condensers

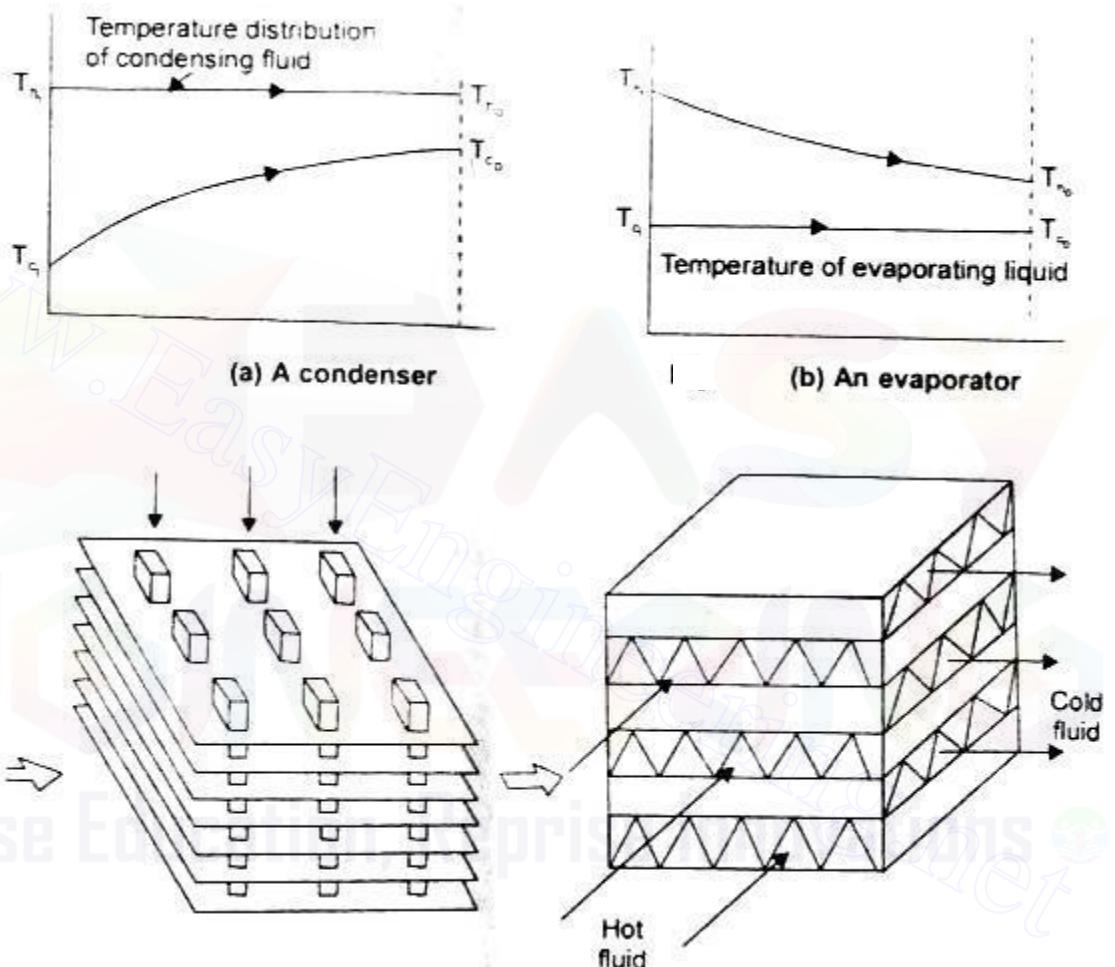
b. Evaporators

a) Condenser

In a condenser, the condensing fluid temperature remains almost constant throughout the exchanger and temperature of the colder fluid gradually increases from the inlet to the exit.

b)Evaporator

Temperature of the hot fluid gradually decreases from the inlet to the outlet whereas the temperature of the colder fluid remains the same during the evaporation process. Since the temperature of one of the fluids can be treated as constant, it is immaterial whether the exchanger is parallel flow or counter flow.



9. Water at the rate of 4 kg/s is heated from 38°C to 55°C in a shell -and-tube heat exchanger .The water is flow inside tube of 2 cm diameter with an average velocity 35 cm/s. How much water available at 95°C and at the rate of 2.0 kg/s is used as the heating medium on the shell side .If the length of tubes must not be more than 2m calculate the number of tube passes , the number of tubes per pass and the length of the tubes for one pass shell, assuming $U_0 = 1500 \text{ W/m}^2\text{k}$.

Given:

$$M_c = 4 \text{ kg/s}$$

$$T_{Cl} = 38^\circ C$$

$$T_{Co} = 55^\circ C$$

$$U = 35 \text{ m/s}$$

$$T_{hi} = 95^\circ C$$

$$C_h = 2 \text{ kg/s}$$

$$U_0 = 1500 \text{ W/m}^2\text{k}$$

To find:

- 1) Number of tubes per pass
- 2) Number of passes
- 3) Length of tube per pass

Solution:

The heat transfer rate for the cold fluid is

$$\begin{aligned} Q &= m_c c_c \Delta T_c \\ &= 4 \times 4186 (55 - 38) \\ Q &= 284.65 \text{ KW} \end{aligned}$$

The exit temperature of hot fluid can be calculated

$$\begin{aligned} Q &= m_h C_h \Delta T_h \\ &= 284.65 \text{ kw} \\ \Delta T_h &= \frac{284.65}{4186 \times 2} \\ &= 34^\circ C \end{aligned}$$

$$T_{ho} = 95 - 34 = 61^\circ C$$

Counter flow heat exchanger

$$\begin{aligned} \Delta T_{ln} &= \frac{(\Delta T_1 - \Delta T_2)}{\ln (\Delta T_1 / \Delta T_2)} \\ \Delta T_1 &= T_{h,i} - T_{c,o} \\ &= 95 - 55 = 40^\circ C \\ \Delta T_2 &= T_{h,o} - T_{c,i} \\ &= 61 - 38 = 23^\circ C \\ \Delta T_{ln} &= \frac{(40 - 23)}{\ln (40/23)} = 30.72^\circ C \end{aligned}$$

$$A = \frac{Q}{U_{\Delta T \ln}} = 284.65 \times 1000 / ((1500) \times 30.72)$$

$$= 6.177 \text{ m}^2$$

Using average velocity of water in the tubes and its flow rates

$$m_c = \rho A U$$

$$A = 4 / [(1000)(0.35)]$$

$$A = 0.011429 \text{ m}^2$$

This area can also be put as the number of tubes

$$0.011429 = n \pi \frac{d^2}{4}$$

$$n = 36.38$$

Taking $n = 36$, the total surface area of tubes for one shell pass exchanger in terms of L ,

$$A = 6.177 = n \pi d L$$

$$L = 6.177 / [(36) \pi (0.02)]$$

$$L = 2.731 \text{ m}$$

Since this length is greater than the permitted length of 2m,

$$P = \frac{t_o - t_i}{T_L - t_i}$$

$$= 0.3$$

$$R = \frac{T_L - T}{t_o - t_i}$$

$$R = 2$$

Thus the total area required for one shell, 2 tube pass exchanger is

$$A' = Q / [U F \Delta T_{\ln}]$$

$$A' = 6.863 \text{ m}^2$$

Due to velocity requirement let the number of tubes per pass still be 36

$$A' = 2n \pi d l$$

$$L = 6.863 / [2 \times 36 \times \pi \times 0.02]$$

$$L = 1.517 \text{ m}$$

PART C - 15 Marks (Questions and Answers)

1. A nickel wire carrying electric current of 1.5 mm diameter and 50 cm long, is submerged in a water bath which is open to atmospheric pressure. calculate the voltage at the burn out point, if at this point the wire carries a current of 200A.

Given:

$$D = 1.5 \text{ mm} = 1.5 * 10^{-3} \text{ m}$$

$$L = 50 \text{ cm} = 0.50 \text{ m}$$

$$\text{Current , } I = 200 \text{ A.}$$

To find:

Voltage (v)

Solution:

We know that, saturation temperature of water is 100° C .

$$\text{i.e., } T_{\text{sat}} = 100^\circ \text{ C.}$$

PROPERTIES OF WATER AT 100° C .

From HMT Data book page no 21

$$\rho_l = 961 \text{ Kg / m}^3$$

$$v = 0.293 * 10^{-6} \text{ m}^2/\text{s}$$

$$P_r = 1.740$$

$$C_{pl} = 4216 \text{ J / Kg k}$$

$$\begin{aligned}\mu_l &= \rho_l * v \\ &= 961 * 0.293 * 10^{-6} \\ &= 281.57 * 10^{-6} \text{ Ns / m}^2\end{aligned}$$

From steam table at 100° C .

$$h_{fg} = 2256.9 \text{ KJ/Kg}$$

$$h_{fg} = 2256.9 * 10^3 \text{ J/Kg}$$

$$v_g = 1.673 \text{ m}^3/\text{Kg}$$

$$\rho_v = 1 / v_g = 1 / 1.673$$

$$= 0.597 \text{ Kg / m}^3$$

σ = surface tension for liquid – vapour interface

At 100° C (From HMT databook page no 144)

$$\sigma = 0.0588 \text{ N/m}$$

For Nucleate pool boiling critical heat flux (at burn out)

$$Q/A = 0.18 * h_{fg} * \rho_v [((\sigma * g * (\rho_l - \rho_v)) / (\rho_v^2))]^{0.25}$$

From HMT databook page no 142

Substitute h_{fg} , ρ_l , σ , ρ_v

$$Q/A = 0.18 * 2256.9 * 10^3 * 0.5978 [((0.0588 * 9.81 * (961 - 0.597)) / (0.597)^2)]$$

$$Q/A = 1.52 * 10^6 \text{ W/m}^2.$$

Heat transferred , $Q = V * 1$

$$Q/A = (V*1) / A$$

$$1.52 * 10^6 = (V * 200) / (\pi dL)$$

$$1.52 * 10^6 = ((V * 200) / (\pi * 1.5 * 10^{-3} * 0.50))$$

- $V = 17.9 \text{ Volts}$

2. An oil cooler of the form of tubular heat exchanger cools oil from a temperature of 90° C to 35° C by a large pool of stagnant water assumed at constant temperature of 28° C .The tube length is 32 m and diameter is 28 mm. The specific heat and specific gravity of the oil are 2.45 KJ / Kg K and 0.8 respectively. The velocity of the oil is 62 cm / s. Calculate the overall heat transfer co – efficient.

Given:

Hot fluid – oil

(T1, T2)

Cold fluid - water

(t1 , t2)

Entry temperature of oil $T_1 = 90^\circ \text{ C}$

Exit temperature of oil $T_2 = 35^\circ \text{ C}$

Entry and Exit temperature of water , $t_1 = t_2 = 28^\circ \text{ C}$

Tube length $L = 32 \text{ m}$

Diameter $D = 28 \text{ mm} = 0.028 \text{ m}$

Specific heat of oil , $C_{ph} = 2.45 \text{ KJ/Kg k} = 2.45 * 10^3 \text{ J/Kg k}$

Specific gravity of oil = 0.8

Velocity of oil, $C = 62 \text{ cm / s} = 0.62 \text{ m/s.}$

To Find:

Overall heat transfer co- efficient U

Solution:

Specific gravity of oil = Density of oil / density of water

$$= \rho_0 / \rho_w$$

$$0.8 = \rho_0 / 1000$$

$$\rho_0 = 800 \text{ Kg} / \text{m}^3.$$

Mass flow rate of oil, $m_h = \rho_0 * A * C$

$$= 800 * ((\pi/4) * (D^2) * 0.62$$

$$= 800 * ((\pi/4) * (0.028^2) * 0.62$$

$$m_h = 0.305 \text{ Kg} / \text{s.}$$

Heat transfer , $Q = m_h * C_{ph} * (T_1 - T_2)$

$$= 0.305 * 2.45 * 10^3 * (90 - 35)$$

$$Q = 41 * 10^3 \text{ W.}$$

We know that

Heat transfer , $Q = UA (\Delta T)_m$

From HMT databook page no 151

$(\Delta T)_m$ = logarithmic mean temperature difference (LMTD)

For parallel flow

$$(\Delta T)_m = [((T_1 - t_1) - (T_2 - t_2))] / \ln [((T_1 - t_1) / (T_2 - t_2))]$$

$$= [((90 - 28) - (35 - 28))] / \ln [((90 - 28) / (35 - 28))]$$

$$(\Delta T)_m = 25.2^\circ \text{C.}$$

Substitute $(\Delta T)_m$ value in Q Equation

$$Q = UA (\Delta T)_m$$

$$41 * 10^3 = U * \pi * D * L * (\Delta T)_m$$

$$41 * 10^3 = U * \pi * 0.028 * 32 * 25.2$$

$$U = 577.9$$

Overall heat transfer co – efficient , $U = 577.9 \text{ W} / \text{m}^2 \text{ K}$

UNIT: IV RADIATION**PART A - 2 Marks (Questions and Answers)****1. State Planck's distribution law. (Nov/Dec 2013)**

The relationship between the monochromatic emissive power of a black body and wave length of a radiation at a particular temperature is given by the following expression, by Planck.

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\left(\frac{C_2}{\lambda T}\right)} - 1}$$

Where

$$c_1 = 0.374 \times 10^{-15} \text{ W m}^2$$

$$c_2 = 14.4 \times 10^{-3} \text{ mK}$$

2. State Wien's displacement law & Stefan – Boltzmann law. (Nov/Dec 2010)

The Wien's law gives the relationship between temperature and wave length corresponding to the maximum spectral emissive power of the black body at that temperature.

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ mK}$$

The emissive power of a black body is proportional to the fourth power of absolute temperature.

$$E_b = \sigma T^4$$

Where σ = Stefan – Boltzmann constant

$$= 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$$

$$\Rightarrow E_b = (5.67 \times 10^{-8}) (2773)^4$$

$$E_b = 3.35 \times 10^6 \text{ W/m}^2$$

3. State Kirchoff's law of radiation. (April/May 2015)

This law states that the ratio of total emissive power to the absorptivity is constant for all surfaces which are in thermal equilibrium with the surroundings. This can be written as

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2} = \frac{E_3}{\alpha_3} \dots\dots\dots$$

It also states that the emissivity of the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings.

$$\alpha_1 = E_1; \alpha_2 = E_2 \text{ and soon.}$$

4. What is the purpose of radiation shield? (Nov/Dec 2014)

Radiation shields constructed from low emissivity (high reflective) materials. It is used to reduce the net radiation transfer between two surfaces.

5. Define irradiation (G) and radiosity (J) (Nov/Dec 2015)

It is defined as the total radiation incident upon a surface per unit time per unit area. It is expressed in W/m^2 .

It is used to indicate the total radiation leaving a surface per unit time per unit area. It is expressed in W/m^2 .

6. What are the factors involved in radiation by a body. (Nov /Dec 2014)

- Wave length or frequency of radiation
- The temperature of surface
- The nature of the surface

7. What is meant by shape factor?

The shape factor is defined as the fraction of the radiative energy that is diffused from one surface element and strikes the other surface directly with no intervening reflections. It is represented by Fig. Other names for radiation shape factor are view factor, angle factor and configuration factor.

8. How radiation from gases differs from solids? (Nov/Dec 2013)

A participating medium emits and absorbs radiation throughout its entire volume thus gaseous radiation is a volumetric phenomenon, solid radiation is a surface phenomena. Gases emit and absorb radiation at a number of narrow wavelength bands. This is in contrast to solids, which emit and absorb radiation over the entire spectrum.

9. What is black body and gray body?

Black body is an ideal surface having the following properties. A black body absorbs all incident radiation, regardless of wave length and direction. For a prescribed temperature and wave length, no surface can emit more energy than black body. If a body absorbs a definite percentage of incident radiation irrespective of their wave length, the body is known as gray body. The emissive power of a gray body is always less than that of the black body.

10. Define emissive power [E] and monochromatic emissive power. [$E_{b\lambda}$]

The emissive power is defined as the total amount of radiation emitted by a body per unit time and unit area. It is expressed in W/m^2 .

The energy emitted by the surface at a given length per unit time per unit area in all directions is known as monochromatic emissive power.

11. Two parallel radiating Planes 10 x 50 cm are separated by a distance Of 50 cm .what is the radiation shape factor between the planes?(May/June 2012)

$L=100 \text{ cm}$ $B= 50 \text{ cm}$ $D= 50 \text{ cm}$ [From HMT data book ,Page no.92]

$$X=L/D=100/50=2 \quad Y=B/D = 50/50=1$$

From table,for $X=2$ and $Y=1$

$$F_{12}=F_{21}=0.28588$$

12. What does the view factor represent? When is the view factor from a surface to itself not zero?

The view factor F_{i-j} represents the fraction of the radiation leaving surface i that strikes surface j directly. The view factor from a surface to itself is non-zero for concave surfaces.

13. State Lambert's cosine law.

It states that the total emissive power E_b from a radiating plane surface in any direction proportional to the cosine of the angle of emission

$$E_b \propto \cos \theta$$

14. Find the temperature of the sun assuming as a Block Body, if the intensity of radiation is maximum at the wavelength of 0.5μ

According to Wien's displacement law:

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ mK}$$

$$0.5 \times 10^{-6} T = 2.9 \times 10^{-3}$$

$$T = 5800 \text{ K}$$

15. What is a radiation shield? Why is it used?

Radiation heat transfer between two surfaces can be reduced greatly by inserting a thin, high reflectivity (low emissivity) sheet of material between the two surfaces. Such highly reflective thin plates or shells are known as radiation shields. Multilayer radiation shields constructed of about 20 shields per cm. thickness separated by evacuated space are commonly used in cryogenic and space applications to minimize heat transfer. Radiation shields are also used in temperature measurements of fluids to reduce the error caused by the radiation effect.

16. State Lambert's cosine law for radiation (April/May 2017)

It states that the total emissive power E_b from a radiating plane surface in any direction proportional to the cosine of the angle of emission. $E_b \propto \cos \theta$

17. Define monochromatic emissive power (Nov/Dec 2016)

The monochromatic emissive power E_λ , is defined as the rate, per unit area, at which the surface emits thermal radiation at a particular wavelength λ . Thus the total and monochromatic hemispherical emissive power are related by

$$E = \int_0^{\infty} E_\lambda d\lambda$$

18. What is meant by infrared and ultra violet radiation (Nov/Dec 2016)

Infrared radiation, or simply infrared or IR, is electromagnetic radiation (EMR) with longer wavelengths than those of visible light, and is therefore invisible. Ultraviolet (UV) radiation is a type of radiation that is produced by the sun and some artificial sources, such as solariums

PART B - 13 Marks (Questions and Answers)

1. Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500°C

Monochromatic emissive power at 1.2 μm wave length.

- i) Wave length at which emission is maximum.
- ii) Maximum emissive power.
- iii) Total emissive power,
- iv) The total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.9. (Nov / Dec 2014) (Nov / Dec 2015)

Given: Surface temperature $T = 2500^\circ\text{C} = 2773\text{K}$

Monochromatic emissive power $\lambda = 1.2 \times 10^{-6} \text{ m}$

Emissivity = 0.9

Solution:

Step 1. Monochromatic Emissive Power:

From Planck's distribution law, we know

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\left(\frac{C_2}{\lambda T}\right)} - 1} \quad [\text{From HMT data book, Page No.82}]$$

Where

$$C_1 = 0.374 \times 10^{-15} \text{ W m}^2$$

$$C_2 = 14.4 \times 10^{-3} \text{ mK}$$

$$\lambda = 1.2 \times 10^{-6} \text{ m} \quad [\text{Given}]$$

$$E_{b\lambda} = 5.39 \times 10^{12}$$

Step 2. Maximum wave length (λ_{\max})

From Wien's law, we know

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ mK}$$

$$\lambda_{\max} \times 2773 = 2.9 \times 10^{-3} \text{ mK}$$

$$\lambda_{\max} = 5.37 \times 10^{-16}$$

Step 3. Maximum emissive power ($E_{b\lambda}$) max:

Maximum emissive power

$$\begin{aligned}(E_{b\lambda})_{\max} &= 1.307 \times 10^{-5} T^5 \\ &= 1.307 \times 10^{-5} \times (2773)^5 \\ (E_{b\lambda})_{\max} &= 2.14 \times 10^{12} \text{ W/m}^2\end{aligned}$$

Step 4. Total emissive power (E_b):

From Stefan – Boltzmann law, we know that

$$E_b = \sigma T^4 \quad [\text{From HMT data book Page No.72}]$$

Where σ = Stefan – Boltzmann constant

$$\begin{aligned}&= 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4 \\ \Rightarrow E_b &= (5.67 \times 10^{-8}) (2773)^4 \\ E_b &= 3.35 \times 10^6 \text{ W/m}^2\end{aligned}$$

Step 5. Total emissive power of a real surface:

$$(E_b)_{\text{real}} = \varepsilon \sigma T^4$$

Where ε = Emissivity = 0.9

$$\begin{aligned}(E_b)_{\text{real}} &= 0.9 \times 5.67 \times 10^{-8} (2773)^4 \\ (E_b)_{\text{real}} &= 3.011 \times 10^6 \text{ W/m}^2\end{aligned}$$

2.Two parallel plates of size 1.0 m x 1.0 m spaced 0.5 m apart are located in very large room , the walls are maintained at a temperature of 27°C .one plate is maintained at a temperature of 900°C and other at 400°C .their emissivities are 0.2 and 0.5 respectively .if the plate exchange heat themselves and surroundings , find the heat transfer to each plate and to them . consider only the plate surface facing each other.(May/June 2012&Nov/Dec 2014)

Given:

Size of the Plate = 1.0 m x 1.0 m

Distance between plates = 0.5 m

Room Temperature , $T_3 = 27^\circ\text{C} + 273 = 300 \text{ K}$

First plate temperature , $T_1 = 900^\circ\text{C} + 273 = 1173 \text{ K}$

Second plate temperature , $T_2=400^{\circ}\text{C} + 273 = 673 \text{ K}$

Emissivity of first plate, $\epsilon_1 = 0.2$

Emissivity of second plate, $\epsilon_2 = 0.5$

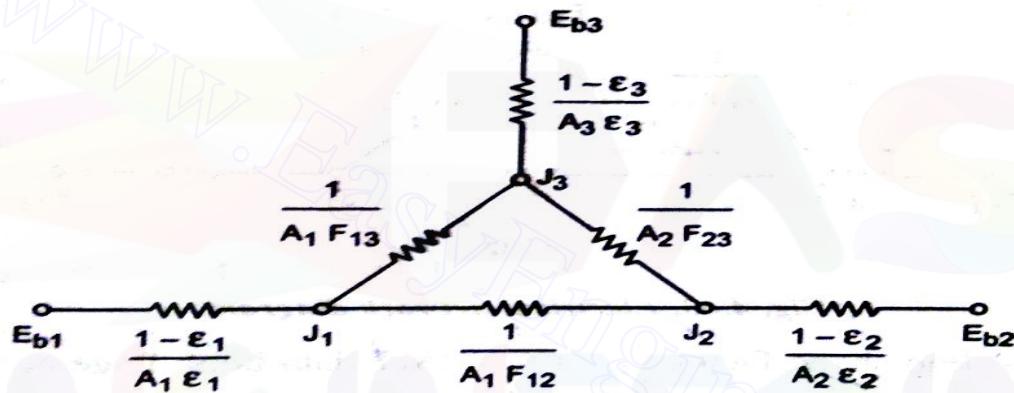
To Find:

1. Net Heat Transfer to each

2. Net heat transfer to room

Solution:

In this problem heat exchange take place between two plates and the room so, this is three surface problem and the corresponding radiation network is given below.



Electrical network diagram

Area , $A_1 = 1 \times 1 = 1 \text{ m}^2$

$$A_1 = A_2 = 1 \text{ m}^2$$

Since the room is large , $A_3 = \infty$

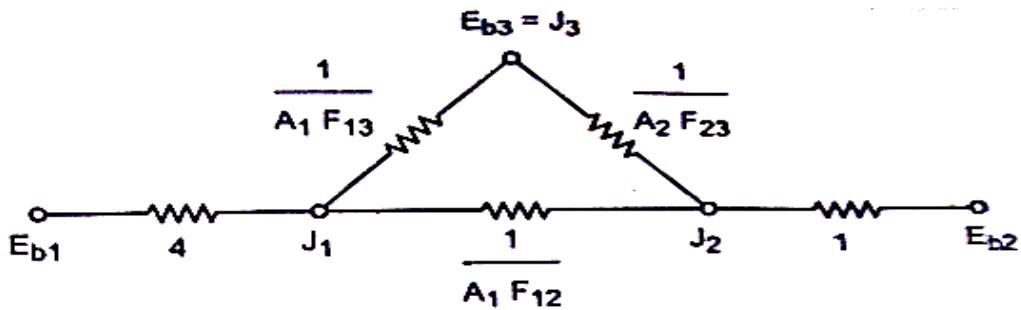
Step:1 From electrical network diagram,

$$\frac{1 - \epsilon_1}{A_1 \epsilon_1} = \frac{1 - 0.2}{1 \times 0.2} = 4$$

$$\frac{1 - \epsilon_2}{A_2 \epsilon_2} = \frac{1 - 0.5}{1 \times 0.5} = 1$$

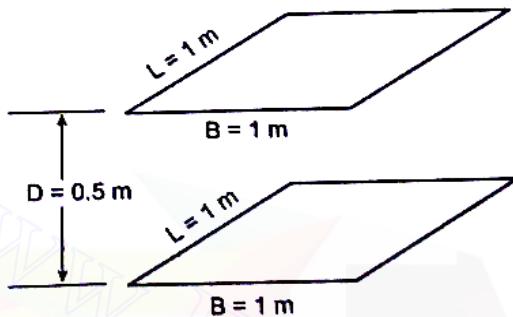
$$\frac{1 - \epsilon_3}{A_3 \epsilon_3} = 0 \quad [A_3 = \infty]$$

Apply $\frac{1 - \epsilon_1}{A_1 \epsilon_1} = 4$, $\frac{1 - \epsilon_2}{A_2 \epsilon_2} = 1$, $\frac{1 - \epsilon_3}{A_3 \epsilon_3} = 0$ values in electrical network diagram.



Electrical network diagram

Step:2 To find shape factor F_{12} , refer HMT data book page no.92 and 93



$$X = \frac{L}{D} = \frac{1}{0.5} = 2$$

$$Y = \frac{B}{D} = \frac{1}{0.5} = 2$$

X value is 2, Y value is 2. From that, we can find corresponding shape factor value is 0.41525 [From the table]

$$\text{i.e } F_{12} = 0.41525$$

we know that,

$$F_{11} + F_{12} + F_{13} = 1, \text{ we know that } F_{11} = 0$$

$$F_{13} = 1 - 0.41525$$

$$F_{13} = 0.5847$$

$$\text{Similarly, } F_{21} + F_{22} + F_{23} = 1 \quad \text{We Know that, } F_{22} = 0$$

$$\begin{aligned} F_{23} &= 1 - F_{21} \\ &= 1 - F_{12} = 1 - 0.41525 \\ &= 0.5847 \end{aligned}$$

From electrical network diagram,

$$\frac{1}{A_1 F_{13}} = \frac{1}{1 \times 0.5847} = 1.7102$$

$$\frac{1}{A_2 F_{23}} = \frac{1}{1 \times 0.5847} = 1.7102$$

$$\frac{1}{A_1 F_{12}} = \frac{1}{1 \times 0.41525} = 2.408$$

Step: 3 From stefan-Boltzmann Law,

$$E_b = \sigma T^4$$

$$E_{b1} = \sigma T_1^4$$

$$= 5.67 \times 10^{-8} [1173]^4$$

$$E_{b1} = 107.34 \times 10^3 \text{ W/m}^2$$

$$E_{b2} = \sigma T_2^4$$

$$= 5.67 \times 10^{-8} [673]^4$$

$$E_{b2} = 11.63 \times 10^3 \text{ W/m}^2$$

$$E_{b3} = \sigma T_3^4$$

$$= 5.67 \times 10^{-8} [300]^4$$

$$E_{b3} = 459.27 \text{ W/m}^2$$

From the electrical network diagram , we know that

$$E_{b3} = J_3 = 459.27 \text{ W/m}^2$$

Step: 4

The radiosities J_1 and J_2 can be calculated by using Krichoff's

The sum of current entering the node J_1 is zero.

At Node J_1 :

$$\frac{E_{b1} - J_1}{4} + \frac{J_2 - J_1}{\frac{1}{A_1 F_{12}}} + \frac{E_{b3} - J_1}{\frac{1}{A_1 F_{13}}} = 0 \quad [\text{From electrical network diagram}]$$

$$\frac{107.34 \times 10^3 - J_1}{4} + \frac{J_2 - J_1}{2.408} + \frac{459.27 - J_1}{1.7102} = 0$$

$$26835 - 0.25 J_1 + 0.415 J_2 - 0.415 J_1 + 268.54 - 0.5847 J_1 = 0$$

$$-1.2497 J_1 + 0.415 J_2 = -27.10 \times 10^3 \quad \dots \dots \dots (1)$$

At Node J_2 :

$$\frac{J_1 - J_2}{\frac{1}{A_1 F_{12}}} + \frac{E_{b3} - J_1}{\frac{1}{A_2 F_{23}}} + \frac{E_{b2} - J_2}{1} = 0$$

$$\frac{J_2 - J_1}{2.408} + \frac{459.27 - J_1}{1.7102} + \frac{11.63 \times 10^3}{1} = 0$$

$$0.415 J_1 - 1.4997 J_2 = -11.898 \times 10^3 \quad \dots \dots \dots (2)$$

Solving the equation (1) and (2)

$$-1.2497 J_1 + 0.415 J_2 = -27.10 \times 10^3$$

$$\begin{array}{r} -0.415 J_1 - 1.4997 J_2 = -11.898 \times 10^3 \\ \hline \end{array}$$

$$J_1 = 26.780 \times 10^3 \text{ W/m}^2$$

$$J_2 = 15.34 \times 10^3 \text{ W/m}^2$$

Step: 5

Heat lost by plate (1) $Q_1 = \frac{E_{b1} - J_1}{1 - \varepsilon_1} \quad [\text{From electrical network diagram}]$

$$A_1 \varepsilon_1$$

$$= \frac{107.34 \times 10^3 - 26.780 \times 10^3}{\frac{1-0.2}{1 \times 0.2}}$$

$$Q_1 = 20.140 \times 10^3 \text{ W}$$

$$\text{Heat lost by plate (1)} Q_2 = \frac{J_2 - E_{b2}}{1 - \varepsilon_2}$$

$$= \frac{15.34 \times 10^3 - 11.63 \times 10^3}{\frac{1-0.5}{1 \times 0.5}}$$

$$Q_2 = 3710 \text{ W}$$

Total heat lost by the plates(1) and(2)

$$Q = Q_1 + Q_2$$

$$Q = 20.140 \times 10^3 + 3710$$

$$Q = 23.850 \times 10^3 \text{ W}$$

Total heat received or absorbed by the room

$$Q = \frac{J_1 - J_3}{\frac{1}{A_1 F_{13}}} + \frac{J_2 - J_3}{\frac{1}{A_2 F_{23}}}$$

$$Q = \frac{26.780 \times 10^3 - 459.27}{1.7102} + \frac{11.06 \times 10^3 - 459.27}{1.7102}$$

$$Q = 24.09 \times 10^3 \text{ W}$$

Result:

1. Net heat lost by each plates

$$Q_1 = 20.140 \times 10^3 \text{ W}$$

$$Q_2 = 3710 \text{ W}$$

2. Net heat transfer to the room

$$Q = 24.09 \times 10^3 \text{ W}$$

3. Emissivities of two large parallel planes maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiant heat exchange per square meter of the plates. Find the percentage of reduction in heat transfer when a polished aluminium shield ($\epsilon = 0.05$) is placed between them. Also find the temperature of the shield (April/May 2015) (Nov/Dec 2015). (NOV/DEC 2013)

Given:

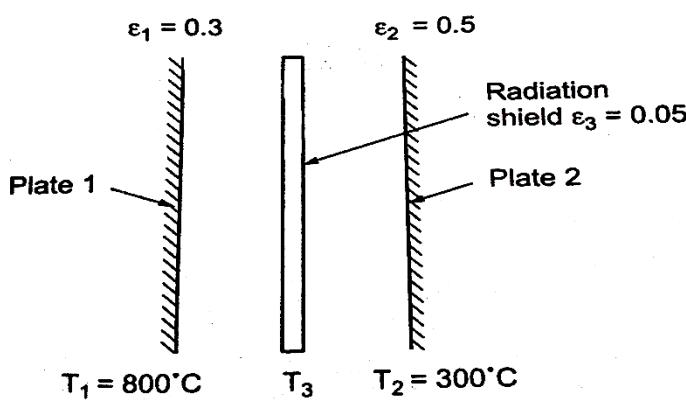
$$T_1 = 800^\circ\text{C} + 273 = 1073 \text{ K}$$

$$T_2 = 300^\circ\text{C} + 273 = 573 \text{ K}$$

$$\epsilon_1 = 0.3$$

$$\epsilon_2 = 0.3$$

Radiation shield emissivity $\epsilon_3 = 0.05$



To find:

- (i) Percentage of reduction in heat transfer due to radiation shield.
- (ii) Temperature of the shield (T_3)

Solution:

Case: 1 Heat transfer without radiation shield:

Heat exchange between two large parallel plates without radiation shield is given by

$$\text{Step: 1} \quad Q_{12} = \varepsilon^- \sigma A [T_1^4 - T_2^4]$$

$$\begin{aligned} \text{Where } \varepsilon^- &= \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \\ &= \frac{1}{\frac{1}{0.3} + \frac{1}{0.5} - 1} \end{aligned}$$

$$\varepsilon^- = 0.2307$$

$$Q_{12} = 0.2307 \times 5.67 \times 10^{-8} \times A \times [(1073)^4 - (573)^4]$$

Step: 2

$$\frac{Q_{12}}{A} = 15.9 \times 10^3 \text{ W/m}^2$$

$$\text{Heat transfer without radiation shield } \frac{Q_{12}}{A} = 15.9 \times 10^3 \text{ W/m}^2 \text{ ----- (1)}$$

Case : 2 Heat transfer with radition shield:

Heat exchange between radiation plate 1 and radiation shield 3 is given

Step: 3

$$Q_{13} = \varepsilon^- \sigma A [T_1^4 - T_3^4]$$

$$\text{Where } \varepsilon^- = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_3} - 1}$$

$$Q_{13} = \frac{\sigma A [T_1^4 - T_3^4]}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_3} - 1} \text{ ----- (2)}$$

Heat exchange between radiation shield 3 and plate 2 is given

Step: 4

$$Q_{32} = \varepsilon^- \sigma A [T_3^4 - T_2^4]$$

$$\text{Where } \varepsilon^- = \frac{1}{\frac{1}{\varepsilon_3} + \frac{1}{\varepsilon_2} - 1}$$

$$Q_{32} = \frac{\sigma A [T_3^4 - T_2^4]}{\frac{1}{\varepsilon_3} + \frac{1}{\varepsilon_2} - 1} \quad \dots \dots \dots (3)$$

Step: 5

We know that,

$$Q_{13} = Q_{32}$$

$$\frac{\sigma A [T_1^4 - T_3^4]}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_3} - 1} = \frac{\sigma A [T_3^4 - T_2^4]}{\frac{1}{\varepsilon_3} + \frac{1}{\varepsilon_2} - 1}$$

$$\frac{\sigma A [1073^4 - T_3^4]}{\frac{1}{0.3} + \frac{1}{0.05} - 1} = \frac{\sigma A [T_3^4 - 573^4]}{\frac{1}{0.05} + \frac{1}{0.5} - 1}$$

$$3.02 \times 10^{13} = 43.3 T_3^4$$

$$T_3 = 913.8 \text{ K}$$

Temperature of the shield $T_3 = 913.8 \text{ K}$

Substitute T_3 value in equation (2) or (3),

$$\text{Heat transfer with radiation shield } Q_{13} = \frac{\sigma A [1073^4 - 913.8^4]}{\frac{1}{0.3} + \frac{1}{0.05} - 1}$$

$$\frac{Q_{13}}{A} = 159.46 \text{ W/m}^2$$

Step: 6

Percentage of reduction in heat transfer due to radiation shield

$$= \frac{Q_{\text{without shield}} - Q_{\text{with shield}}}{Q_{\text{with shield}}}$$

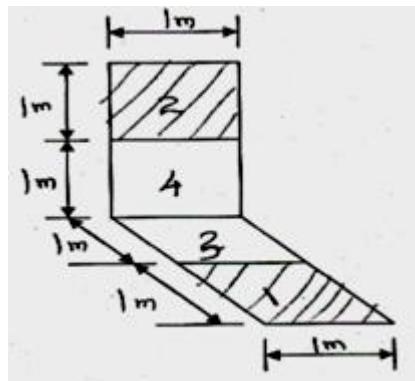
$$= \frac{Q_{12} - Q_{13}}{Q_{12}}$$

$$= \frac{15.8 \times 10^3 - 1594.6}{15.8 \times 10^3} \times 100$$

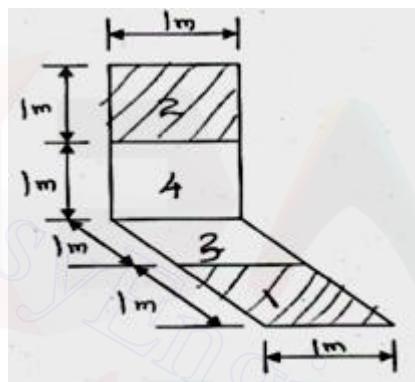
$$= 0.899 \times 100 \% = 89.9\%$$

Percentage of reduction in heat transfer due to radiation shield = 89.9%

4. The area A_1 and A_2 are perpendicular but do not share the common edge. find the shape factor F_{1-2} for the arrangement. (Nov/Dec 2015).

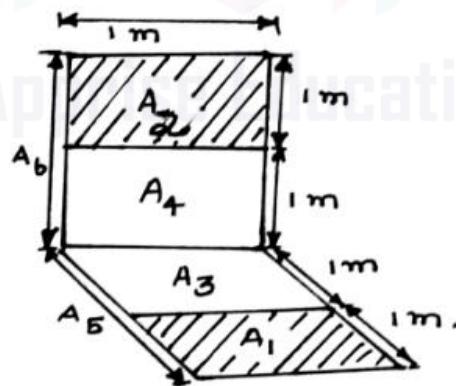


Given:



To find : Shape Factor of F_{1-2}

Solution:



From the figure we know that

Step: 1

$$A_5 = A_1 + A_3$$

$$A_6 = A_2 + A_4$$

Further Step: 2

$$A_5 F_{5-6} = A_1 F_{1-6} + A_3 F_{3-6}$$

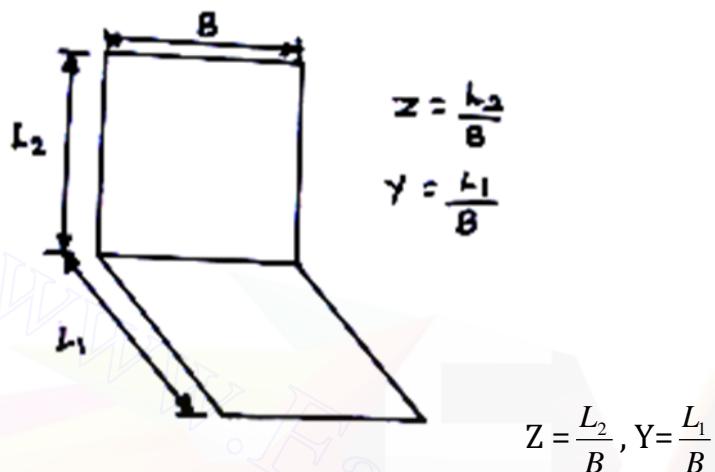
$$[A_5 = A_1 + A_3, F_{5-6} = F_{1-6} + F_{3-6}]$$

$$= A_1 F_{1-2} + A_1 F_{1-4} + A_3 F_{3-6} \quad [F_{1-6} = F_{1-2} + F_{1-4}]$$

$$A_5 F_{5-6} = A_1 F_{1-2} + A_5 F_{5-4} - A_3 F_{3-4} + A_3 F_{3-6} \quad [A_1 = A_5 - A_3, F_{1-4} = F_{5-4} - F_{3-4}]$$

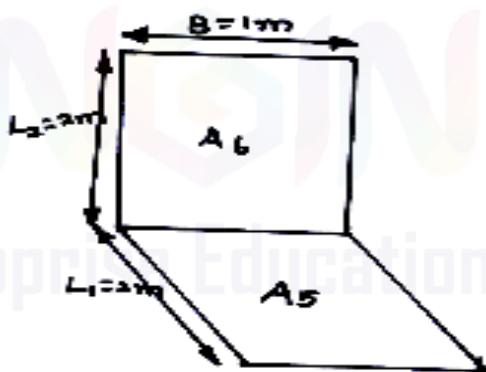
$$A_1 F_{1-2} = A_5 F_{5-6} - A_5 F_{5-4} + A_3 F_{3-4} - A_3 F_{3-6}$$

[Refer HMT data book, Page no.95]



Step: 3

Shape Factor for the area A₅ and A₆



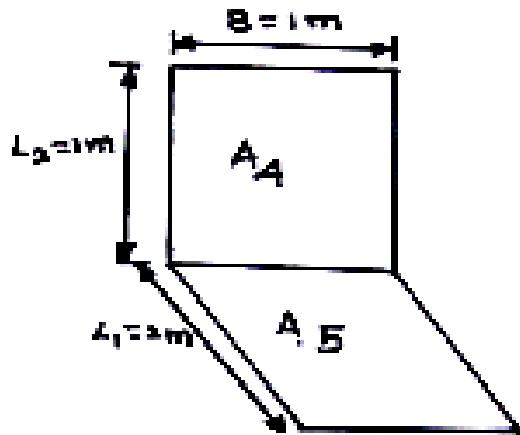
$$Z = \frac{L_2}{B} = \frac{2}{1} = 2$$

$$Y = \frac{L_1}{B} = \frac{2}{1} = 2$$

Z value is 2, Y value is 2 .From that, we can find Corresponding shape factor value is 0.14930

$$F_{5-6} = 0.14930$$

Shape Factor for the area A₅ and A₄



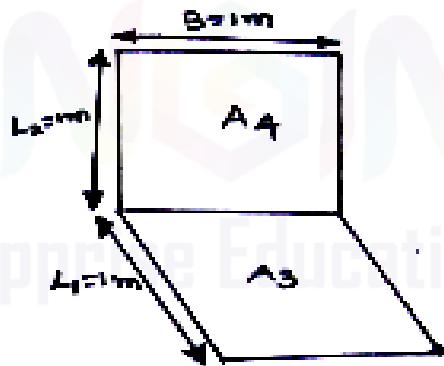
$$Z = \frac{L_2}{B} = \frac{1}{1} = 1$$

$$Y = \frac{L_1}{B} = \frac{2}{1} = 2$$

Z value is 1, Y value is 2 .From that, we can find Corresponding shape factor value is 0.11643

$$F_{5-4} = 0.11643$$

Shape Factor for the area A₃ and A₄



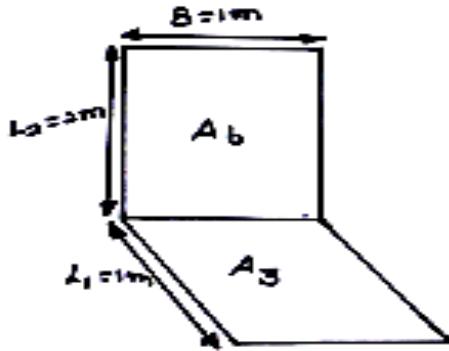
$$Z = \frac{L_2}{B} = \frac{1}{1} = 1$$

$$Y = \frac{L_1}{B} = \frac{1}{1} = 1$$

Z value is 1, Y value is 1 .From that, we can find Corresponding shape factor value is 0.2004

$$F_{3-4} = 0.2004$$

Shape Factor for the area A_3 and A_6 :



$$Z = \frac{L_2}{B} = \frac{2}{1} = 2$$

$$Y = \frac{L_1}{B} = \frac{1}{1} = 1$$

Z value is 2, Y value is 1 .From that, we can find Corresponding shape factor value is 0.23285

$$F_{3-6} = 0.23285$$

Step: 4

Substitute F_{3-6} , F_{3-4} , F_{5-4} and F_{5-6} in equation (1)

$$F_{1-2} = \frac{A_5}{A_1} [F_{5-6} - F_{5-4}] + \frac{A_3}{A_1} [F_{3-4} - F_{3-6}]$$

$$A_5 = 2 ; A_3 = A_1 = 1$$

$$F_{1-2} = \frac{2}{1} [0.14930 - 0.11643] + \frac{1}{1} [0.2004 - 0.23285]$$

$$F_{1-2} = 0.03293$$

$$\boxed{F_{1-2} = 0.03293}$$

5. (a) State and Prove Kirchhoff's law of thermal radiation.

This law states that the ratio of total emissive power to the absorptivity is constant for all surfaces which are in thermal equilibrium with the surroundings.

$$\frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2} = \frac{E_3}{\alpha_3} \dots\dots\dots$$

It also states that the emissivity of the body is always equal to its absorptivity when the body remains in thermal equilibrium with its surroundings.

$$\alpha_1 = E_1; \alpha_2 = E_2 \text{ and soon.}$$

(b) What is a black body? A 20 cm diameter spherical ball at 527°C is suspended in the air. The ball closely approximates a black body. Determine the total black body emissive power, and spectral black body emissive power at a wavelength of 3 μm.

A black body absorbs all incident radiation, regardless of wave length and direction. For a prescribed temperature and wave length, no surface can emit more energy than black body.

Given:

In sphere, (Black body)

Diameter of sphere, $d = 20 \text{ cm} = 0.2 \text{ m}$

Temperature of spherical ball, $T = 527^\circ\text{C} + 273 = 800 \text{ K}$

To Find:

(i) Total black body emissive power, E_b

(ii) Spectral black body emissive power at wavelength of $3\mu\text{m}$.

Solution:

(i) **Step:1** Total black body emissive power , E_b

$$E_b = \sigma AT^4 = 5.67 \times 10^{-8} \times \pi \times (0.2)^2 \times (800)^4$$

$$E_b = 2920 \text{ W}$$

(ii) **Step:2** Spectral black body emissive power: at $\lambda = 3\mu\text{m}$

$$\begin{aligned} E_{b\lambda} &= \frac{C_1}{\lambda^5 [\exp(\frac{C_2}{\lambda T}) - 1]} \\ &= \frac{0.374 \times 10^{-15}}{(3 \times 10^{-6})^5 [\exp(\frac{14.14 \times 10^{-13}}{3 \times 10^{-6} \times 800}) - 1]} \end{aligned}$$

$$E_{b\lambda} = 3824.3 \times 10^6 \text{ W/m}^2$$

$$E_{b\lambda} = 3824.3 \times 10^6 \text{ W/m}^2$$

6. Consider a cylinder furnace with outer radius = 1m and height=1 m. The top (surface 1) and the base (surface2) of the furnace have emissivities 0.8 and 0.4 and are maintained at uniform temperature of 700 K and 500 K

respectively. The side surface closely approximates a black body and is maintained at a temperature of 400 K. Find the net rate of radiation heat transfer at each surface during steady state operation. (May/June 2015)

Given:

Radius of the cylinder = 1m

Height of the cylinder = 1m

Top surface temperature $T_1 = 700 \text{ K}$

Base surface temperature $T_2 = 500 \text{ K}$

side surface temperature $T_3 = 400 \text{ K}$

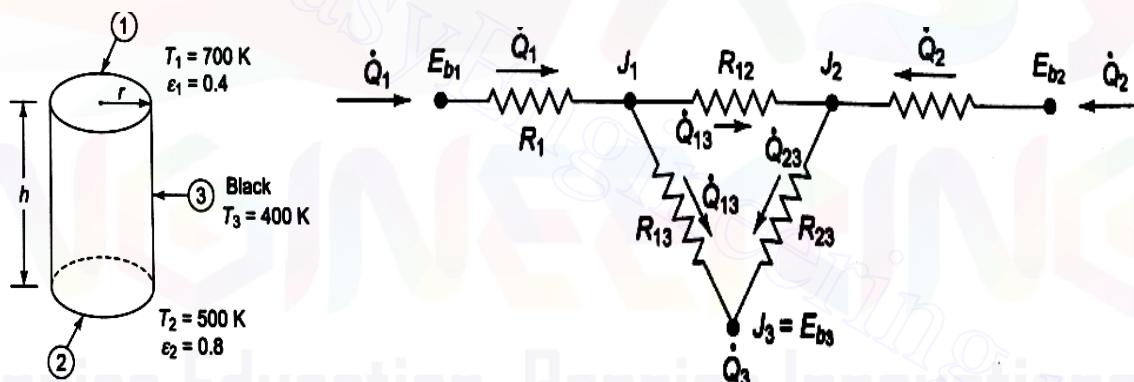
Top surface emissivities $\varepsilon_1 = 0.8$

Base surface emissivities $\varepsilon_2 = 0.4$

To Find:

- Net rate of radiation heat transfer at each surface

Solution:



The furnace and the radiation network are shown in above figure .writing the energy balance for the node 1 and 2,

Step: 1

$$\frac{E_{b1} - J_1}{R_1} = \frac{J_1 - J_2}{R_{12}} + \frac{J_1 - J_3}{R_{13}} \quad \dots \quad (1)$$

$$\frac{E_{b2} - J_2}{R_2} = \frac{J_2 - J_1}{R_{12}} + \frac{J_2 - J_3}{R_{13}} \quad \dots \quad (2)$$

$$E_{b1} = \sigma T_1^4 = 5.67 \times 10^{-8} (700)^4 = 13614 \text{ W/m}^2$$

$$E_{b2} = \sigma T_2^4 = 5.67 \times 10^{-8} (500)^4 = 3544 \text{ W/m}^2$$

$$E_{b3} = \sigma T_3^4 = 5.67 \times 10^{-8} (400)^4 = 1452 \text{ W/m}^2$$

$$A_1 = A_2 = \pi r^2 = \pi(1)^2 = 3.14 \text{ m}^2$$

Step: 2

From the HMT data Book [page no. 91]

The view factor from the base to top is found to be $F_{12} = 0.38$

Now , $F_{11} + F_{12} + F_{13} = 1$, we know that $F_{11} = 0$

$$F_{13} = 1 - F_{12} = 1 - 0.38 = 0.62$$

$$R_1 = \frac{1 - \varepsilon_1}{A_1 \varepsilon_1} = \frac{1 - 0.8}{3.14 \times 0.8} = 0.0796 \text{ m}^2$$

$$R_2 = \frac{1 - \varepsilon_2}{A_2 \varepsilon_2} = \frac{1 - 0.4}{3.14 \times 0.4} = 0.4777 \text{ m}^2$$

$$R_{12} = \frac{1}{A_1 F_{12}} = \frac{1}{3.14 \times 0.38} = 0.8381 \text{ m}^2$$

$$R_{23} = \frac{1}{A_2 F_{23}} = \frac{1}{3.14 \times 0.62} = 0.5137 \text{ m}^2 = R_{13}$$

Step: 3

On substitution, of this value in above equation(1) and (2)

$$\frac{13614 - J_1}{0.0796} = \frac{J_1 - J_2}{0.8381} + \frac{J_1 - 1452}{0.5137}$$

$$\frac{3544 - J_2}{0.4777} = \frac{J_2 - J_1}{0.8381} + \frac{J_1 - 1452}{0.5137}$$

By solving the above equations,

$$J_1 = 11418 \text{ W/m}^2 \text{ and } J_2 = 4562 \text{ W/m}^2$$

$$Q_1 = \frac{E_{b1} - J_1}{R_1} = \frac{13614 - 11418}{0.0796} = 27,588 \text{ W}$$

$$Q_2 = \frac{E_{b2} - J_2}{R_2} = \frac{3544 - 4562}{0.4777} = 2132 \text{ W}$$

$$Q_3 + \frac{J_1 - J_3}{R_{13}} + \frac{J_2 - J_3}{R_{23}} = 0$$

$$Q_3 = \frac{1452 - 11418}{0.5137} + \frac{1452 - 4562}{0.5137} = 25455 \text{ W}$$

Net rate of radiation heat transfer at each surface

Q₁ = 27,588W
Q₂ = 2132W
Q₃ = 25455W

7. The spectral emissivity function of an opaque surface at 1000 K is approximated as

$$\varepsilon_{\lambda 1} = 0.4, 0 \leq \lambda < 2 \mu\text{m};$$

$$\varepsilon_{\lambda 2} = 0.7, 2 \mu\text{m} \leq \lambda < 6 \mu\text{m};$$

$$\varepsilon_{\lambda 3} = 0.3, 6 \mu\text{m} \leq \lambda < \infty$$

Determine the average emissivity of the surface and the rate of radiation emission from the surface, in W/m² (Nov / Dec 2015)

Given:

Surface temperature= 1000 K

$$\varepsilon_{\lambda 1} = 0.4, 0 \leq \lambda < 2 \mu\text{m};$$

$$\varepsilon_{\lambda 2} = 0.7, 2 \mu\text{m} \leq \lambda < 6 \mu\text{m};$$

$$\varepsilon_{\lambda 3} = 0.3, 6 \mu\text{m} \leq \lambda < \infty$$

To Find: Rate of radiation emission from the surface, in W/m²

Solution:

The average emissivity can be determined by breaking the integral

Step:1

$$\begin{aligned}\varepsilon(T) &= \frac{\varepsilon_1 \int_0^{\lambda_1} E_{b\lambda}(T) d\lambda}{\sigma T^4} + \frac{\varepsilon_2 \int_{\lambda_1}^{\lambda_2} E_{b\lambda}(T) d\lambda}{\sigma T^4} + \frac{\varepsilon_3 \int_{\lambda_2}^{\infty} E_{b\lambda}(T) d\lambda}{\sigma T^4} \\ &= \varepsilon_1 f_{\lambda 1}(T) + \varepsilon_2 f_{\lambda 2}(T) + \varepsilon_3 f_{\lambda 3}(T)\end{aligned}$$

Where $f_{\lambda 1}$ and $f_{\lambda 2}$ are black body radiation function corresponding to $\lambda_1 T$ to $\lambda_2 T$

Step:2

$$\lambda_1 T = 2 \times 1000 = 2000 \mu\text{mK}, f_{\lambda 1} = 0.066728$$

$$\lambda_2 T = 6 \times 1000 = 6000 \mu\text{mK}, f_{\lambda 2} = 0.737818 \quad [\text{From HMT data Book Page No: 83}]$$

$$\varepsilon = 0.4 \times 0.066728 + 0.7(0.737818 - 0.066728) + 0.3(1 - 0.737818)$$

$$\varepsilon = 0.5751$$

Step:3

$$E = \varepsilon \sigma T^4 = 0.5715 \times 5.67 \times 10^{-8} \times (1000)^4$$

$$\boxed{E = 32608 \text{ W/m}^2}$$

$$\boxed{E = 32608 \text{ W/m}^2}$$

8. The inner sphere of a liquid oxygen container is 400 mm dia., outer sphere is 500 mm dia., both have emissivity 0.05.Determine the rate of liquid oxygen evaporation at-183°C, when the outer sphere temperature is 20° C. The latent heat of evaporation 210 KJ/kg .Neglect losses due to other modes of heat transfer. (May/ June 2016)

Given:

$$\text{Inner wall temperature } T_1 = -183^\circ\text{C} + 273 = 90\text{K}$$

$$\text{Outer wall Temperature } T_2 = 20^\circ \text{C} + 273 = 293 \text{K}$$

$$\text{Inner diameter } D_1 = 400 \text{ mm} = 0.4 \text{ m} = r_1 = 0.2 \text{ m}$$

$$\text{Outer diameter } D_2 = 500 \text{ mm} = 0.5 \text{ m} r_2 = 0.25 \text{ m}$$

$$\text{Emissivity, } \varepsilon_1 = \varepsilon_2 = 0.05$$

$$\text{Latent heat of evaporation} = 210 \text{ KJ/kg} = 210 \times 10^3 \text{ J/kg}$$

To Find:

Rate of liquid oxygen evaporation

Solution:

$$\text{Heat transfer } Q_{12} = \bar{\varepsilon} \sigma A_1 [T_1^4 - T_2^4]$$

$$\bar{\varepsilon} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2} \left(\frac{1}{\varepsilon_2} - 1 \right)}$$

$$A_1 = 4\pi r_1^2 = 4\pi 3.14 \times (0.2)^2 = 0.5026$$

$$A_2 = 4\pi r_2^2 = 4\pi 3.14 \times (0.25)^2 = 0.7853$$

$$= \frac{1}{\frac{1}{0.05} + \frac{0.5026}{0.7853} \left(\frac{1}{0.05} - 1 \right)}$$

$$\bar{\varepsilon} = 0.0310$$

$$Q_{12} = \bar{\varepsilon} \sigma A_1 [T_1^4 - T_2^4]$$

$$= 0.0310 \times 5.67 \times 10^{-8} \times 0.5026 [90^4 - 293^4]$$

$$Q = -6.4529 \text{ W}$$

$$\text{Rate of Evaporation} = \frac{\text{heatTransfer}}{\text{LatentHeat}}$$

$$= \frac{6.4529}{210 \times 10^3}$$

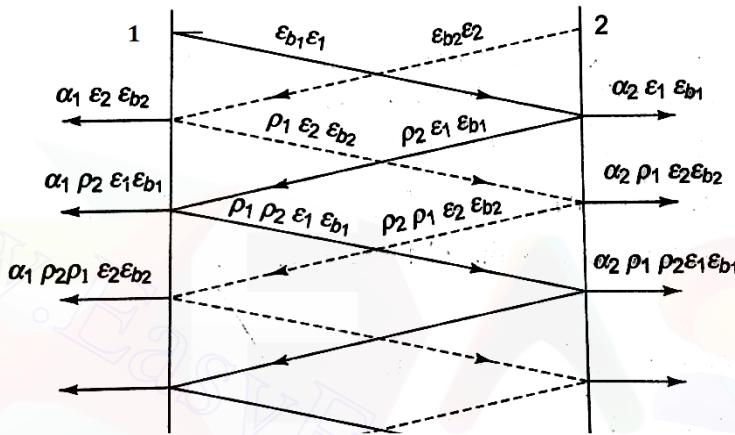
$$= 3.07 \times 10^{-5}$$

Rate of liquid oxygen evaporation = 3.07×10^{-5}

Rate of liquid oxygen evaporation = 3.07×10^{-5}

**9. Derive relation for heat exchange between infinite parallel planes.
(May/June 2014).**

The radiant interchange between two infinite parallel gray planes involves no geometry factor, since $F_{12} = F_{21} = 1.0$. let us consider two gray planes,



For gray surface $\alpha = \epsilon$ and $\rho = 1 - \epsilon$. Surface 1 emits $\epsilon_1 E_{b1}$ per unit time and area. surface 2 absorbs $\alpha_2 \epsilon_2 E_{b2}$ or $\alpha_2 \epsilon_1 E_{b1}$ and reflects $\rho_2 \epsilon_1 E_{b1}$ or $(1 - \epsilon_2) \epsilon_1 E_{b1}$ back towards A₁. the net heat transferred per unit of surface 1 to 2 is the emission $\epsilon_1 E_{b1}$ minus the fraction of $\epsilon_1 E_{b1}$ and $\epsilon_2 E_{b2}$ which is ultimately absorbed by surface 1 after successive reflections. Therefore.

$$(Q_{1-2})_{\text{net}} = \{A_1 \epsilon_1 E_{b1} [1 - \epsilon_1(1 - \epsilon_2) - \epsilon_1(1 - \epsilon_1)(1 - \epsilon_2)^2 - \epsilon_1(1 - \epsilon_1)^2(1 - \epsilon_2)^3 - \dots]\} -$$

$$\{A_2 \epsilon_2 E_{b2} [\epsilon_1 + \epsilon_1(1 - \epsilon_1)(1 - \epsilon_2) + \frac{\epsilon_1[(1 - \epsilon_1)^2(1 - \epsilon_2)^2 + \dots]}{1 - \frac{1}{1 - (1 - \epsilon_1)(1 - \epsilon_2)}}]\}$$

$$= A \frac{\epsilon_1 \epsilon_2}{\epsilon_1 + \epsilon_2 - \epsilon_1 \epsilon_2} [E_{b1} - E_{b2}] \quad \text{since } [A_1 = A_2 = A]$$

$$(Q_{1-2})_{\text{net}} = A \sigma \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} (T_1^4 - T_2^4)$$

$$(Q_{1-2})_{\text{net}} = A \sigma F_{1-2} (T_1^4 - T_2^4)$$

$$F_{1-2} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$(Q_{1-2})_{\text{net}} = A \sigma F_{1-2} (T_1^4 - T_2^4)$$

10.A gas mixture contains 20% CO₂ and 10% H₂O by volume. The total pressure is 2 atm. The temperature of the gas is 927°C. The mean beam length is 0.3 m. Calculate the emissivity of the mixture.

Given : Partial pressure of CO₂, P_{CO₂} = 20% = 0.20 atm

Partial pressure of H₂O, P_{H₂O} = 10% = 0.10 atm.

Total pressure P = 2 atm

$$\begin{aligned}\text{Temperature } T &= 927^\circ\text{C} + 273 \\ &= 1200 \text{ K}\end{aligned}$$

$$\text{Mean beam length } L_m = 0.3 \text{ m}$$

To find: Emissivity of mixture (ε_{mix}).

Solution: Step: 1

To find emissivity of CO₂

$$P_{CO_2} \times L_m = 0.2 \times 0.3$$

$$P_{CO_2} \times L_m = 0.06 \text{ m - atm}$$

From HMT data book, Page No.106, we can find emissivity of CO₂.

From graph, Emissivity of CO₂ = 0.09

$$\varepsilon_{CO_2} = 0.09$$

Step: 2

To find correction factor for CO₂

Total pressure, P = 2 atm

$$P_{CO_2} L_m = 0.06 \text{ m - atm.}$$

From HMT data book, Page No.107, we can find correction factor for CO₂

From graph, correction factor for CO₂ is 1.25

$$C_{CO_2} = 1.25$$

$$\varepsilon_{\text{CO}_2} \times C_{\text{CO}_2} = 0.09 \times 1.25$$

$$\boxed{\varepsilon_{\text{CO}_2} \times C_{\text{CO}_2} = 0.1125}$$

Step: 3**To find emissivity of H₂O :**

$$P_{\text{H}_2\text{O}} \times L_m = 0.1 \times 0.3$$

$$\boxed{P_{\text{H}_2\text{O}} L_m = 0.03 \text{ m - atm}}$$

From HMT data book, Page No.108, we can find emissivity of H₂O.From graph Emissivity of H₂O = 0.048

$$\boxed{\varepsilon_{\text{H}_2\text{O}} = 0.048}$$

Step: 4**To find correction factor for H₂O :**

$$\frac{P_{\text{H}_2\text{O}} + P}{2} = \frac{0.1 + 2}{2} = 1.05$$

$$\frac{P_{\text{H}_2\text{O}} + P}{2} = 1.05,$$

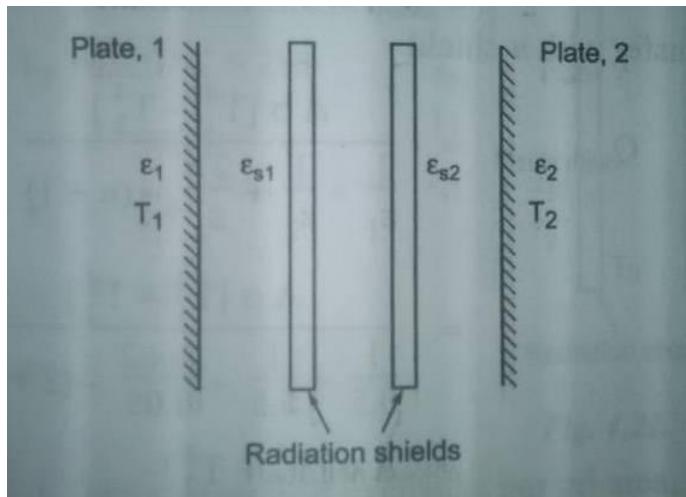
$$P_{\text{H}_2\text{O}} L_m = 0.03 \text{ m - atm}$$

From HMT data book, Page No.108 we can find emission of H₂O**PART C - 15 Marks (Questions and Answers)**

1. Two large parallel plates with $\varepsilon = 0.5$ each, are maintained at different temperatures and are exchanging heat only by radiation. Two equally large radiation shields with surface emissivity 0.05 are introduced in parallel to the plates. find the percentage of reduction in net radiative heat transfer.

Given:

Emissivity of plate 1, $\varepsilon_1 = 0.5$ Emissivity of plate 2, $\varepsilon_2 = 0.5$ Emissivity of shield, $\varepsilon_s = \varepsilon_{s1} = \varepsilon_{s2} = 0.05$ Number of shields, $n = 2$



To find:

Percentage of reduction in net radiative heat transfer

Solution:

Case 1:

Heat transfer without radiation shield

$$Q_{12} = \varepsilon * \sigma * A * [T_1^4 - T_2^4]$$

$$\varepsilon = 1 / (((1/\varepsilon_1) + (1/\varepsilon_2) - 1))$$

$$\varepsilon = 1 / (((1/0.5) + (1/0.5) - 1))$$

$$\varepsilon = 0.333.$$

$$Q_{12} = \varepsilon * \sigma * A * [T_{14} - T_{24}]$$

$$Q_{12} = 0.333 * \sigma * A * [T_{14} - T_{24}]$$

CASE 2: Heat transfer with radiation shield

$$\begin{aligned} Q_{\text{with shield}} &= (\sigma * A * [T_{14} - T_{24}]) / ((1/\varepsilon_1) + (1/\varepsilon_2) + (2n/\varepsilon_s) - (n+1)) \\ &= (\sigma * A * [T_{14} - T_{24}]) / ((1/0.5) + (1/0.5) + ((2*2)/0.05) - (2+1)) \\ &= (\sigma * A * [T_{14} - T_{24}]) / 81 \end{aligned}$$

$$Q_{\text{with shield}} = 0.0123 * (\sigma * A * [T_{14} - T_{24}])$$

We know that

Radiation in heat transfer due to radiation shield

$$\begin{aligned} &= (Q_{\text{WITHOUT SHIELD}} - Q_{\text{WITH SHIELD}}) / Q_{\text{WITHOUT SHIELD}} \\ &= ((0.333 * \sigma * A * [T_{14} - T_{24}]) - (0.0123 * (\sigma * A * [T_{14} - T_{24}]))) \\ &\quad (0.333 * \sigma * A * [T_{14} - T_{24}]) \\ &= 0.963 \end{aligned}$$

= 96.3 %

Percentage of reduction in net radiative heat transfer = 96.3 .

2. A black body at 3000 K emits radiation Calculate the following

1. Monochromatic emissive power at 1 μm wave length
2. Wave length at which emission is maximum
3. Maximum emissive power
4. Total emissive power
5. Calculate the total emissive of the furnace if it is assumed as a real surface having emissivity equal to 0.85

Given

Surface temperature $T = 3000\text{K}$

To find

1. Monochromatic emissive power $E_{b\lambda}$ at $\lambda=1 \mu = 1 \times 10^{-6}\text{m}$
2. Maximum wave length, (λ_{\max})
3. Maximum emissive power($E_{b\lambda}$)_{max}
4. Total emissive power, E_b
5. Emissive power of real surface at $\epsilon=0.85$

Solution

1. Monochromatic emissive power

From Planck's distribution law, we know that

$$E_{b\lambda} = \frac{\frac{c_1 \lambda^{-5}}{c_2}}{e^{\frac{\lambda T}{c_2}} - 1}$$

$$C_1 = 0.374 \times 10^{-15} \text{ W m}^2$$

$$C_2 = 14.4 \times 10^{-3} \text{ mK}$$

$$\lambda = 1 \times 10^{-6} \text{ m}$$

$$E_{b\lambda} = \frac{0.374 \times 10^{-15} [1 \times 10^{-6}]^{-5}}{e^{\frac{14.4 \times 10^{-3}}{1 \times 10^{-6} \times 3000}} - 1}$$

$$E_{b\lambda} = 3.10 \times 10^{12} \text{ W/m}^2$$

2. Maximum wave length (λ_{\max})

$$\lambda_{\max} T = 2.9 \times 10^{-3} \text{ mK}$$

$$\lambda_{\max} = \frac{2.9 \times 10^{-3}}{3000}$$

$$\lambda_{\max} = 0.966 \times 10^{-6} \text{ m}$$

3. Maximum emissive power $(E_{b\lambda})_{\max}$

$$(E_{b\lambda})_{\max} = 1.307 \times 10^{-5} T^5$$

$$= 1.307 \times 10^{-5} \times (3000)^5$$

$$(E_{b\lambda})_{\max} = 3.17 \times 10^{12} \text{ W/m}^2$$

4. Total emissive power E_b

$$E_b = \sigma \times T^4 \text{ (From HMT data book P.No 8)}$$

σ = Stefan Boltzman Constant

$$= 5.67 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$$

$$E_b = (5.67 \times 10^{-8}) \times (3000)^4$$

$$E_b = 4.59 \times 10^{-6} \text{ W/m}^2$$

5. Total emissive power of real surface

$$(E_b)_{\text{real}} = \epsilon \sigma T^4$$

ϵ - Emissivity = 0.85

$$(E_b)_{\text{real}} = 0.85 \times 5.67 \times 10^{-8} \times (3000)^4$$

$$(E_b)_{\text{real}} = 3.90 \times 10^6 \text{ W/m}^2$$

Result

$$1. E_{b\lambda} = 3.10 \times 10^{12} \text{ W/m}^2 \quad 2. \lambda_{\max} = 0.966 \times 10^{-6} \mu\text{m}$$

$$3. (E_{b\lambda})_{\max} = 3.17 \times 10^{12} \text{ W/m}^2 \quad 4. (E_b)_{\text{real}} = 3.90 \times 10^6 \text{ W/m}^2$$

UNIT: V MASS TRANSFER**PART A - 2 Marks (Questions and Answers)****1. What is mass transfer?**

The process of transfer of mass as a result of the species concentration difference in a mixture is known as mass transfer.

2. Give the examples of mass transfer.

Some examples of mass transfer.

1. Humidification of air in cooling tower
2. Evaporation of petrol in the carburettor of an IC engine.
3. The transfer of water vapour into dry air.

3. What are the modes of mass transfer? (Nov/Dec 2010)(Nov/Dec 2104)

There are basically two modes of mass transfer,

1. Diffusion mass transfer
2. Convective mass transfer

4. What is molecular diffusion?

The transport of water on a microscopic level as a result of diffusion from a region of higher concentration to a region of lower concentration in a mixture of liquids or gases is known as molecular diffusion.

5. What is Eddy diffusion?

When one of the diffusion fluids is in turbulent motion, eddy diffusion takes place.

6. What is convective mass transfer? (May/June 2006)

Convective mass transfer is a process of mass transfer that will occur between surface and a fluid medium when they are at different concentration.

7. State Fick's law of diffusion. (April/May 2012) (NOV-DEC 14)(Nov/Dec 16)

The diffusion rate is given by the Fick's law, which states that molar flux of an element per unit area is directly proportional to concentration gradient.

$$\frac{ma}{A} = -D_{ab} \frac{dC_a}{dx}$$

Where,

$$\frac{ma}{A} - \text{Molar flux, } \frac{\text{kg} - \text{mole}}{\text{s} - \text{m}^2}$$

Dab- Diffusion coefficient of species a and b, m²/s

$$\frac{dCa}{dx} - \text{Concentration gradient, kg/m}^3$$

8. What is free convective mass transfer?

If the fluid motion is produced due to change in density resulting from concentration gradients, the mode of mass transfer is said to be free or natural convective mass transfer.

Example: Evaporation of alcohol.

9. Define forced convective mass transfer.

If the fluid motion is artificially created by means of an external force like a blower or fan, that type of mass transfer is known as convective mass transfer.

Example: The evaporation of water from an ocean when air blows over it.

10. Define Schmidt and Lewis number. What is the physical significance of each? (NOV/DEC 13)

The dimensionless Schmidt number is defined as the ratio of momentum diffusivity to mass diffusivity $Sc = v/DAB$, and it represents the relative magnitudes of momentum and mass diffusion at molecular level in the velocity and concentration boundary layers, respectively. The Schmidt number diffusivity corresponds to the Prandtl number in heat transfer. A Schmidt number of unity indicates that momentum and mass transfer by diffusion are comparable, and velocity and concentration boundary layers almost coincide with each other.

The dimensionless Lewis number is defined as the ratio of thermal diffusivity to mass diffusivity $Le = \alpha / DAB$ and it represents the relative magnitudes of heat and mass diffusion at molecular level in the thermal and concentration boundary layers, respectively. A Lewis number of unity indicates that heat and mass diffuse at the same rate, and the thermal and concentration boundary layers coincide.

11. Define Sherwood Number. (April/May 2012)

It is defined as the ratio of concentration gradients at the boundary.

$$Sc = \frac{hmX}{D_{ab}}$$

hm- Mass transfer coefficient, m/s

D_{ab} -Diffusion coefficient, m^2/s

X- length, m

12. What is mass average velocity? (May/June 2010)

The bulk velocity of mixture , in which different components may have different mobilities ,is compared either on mass average . if liquid mixture of two components A and B if u_A and u_B are the mean velocities then the average velocity is

$$u_{\text{mass}} = (\rho_A u_A + \rho_B u_B) / \rho_A + \rho_B$$

13. Distinguish between mass concentration and molar concentration (April/May 2017)

Mass Concentration

Mass of a component per unit volume of the mixture. It is expressed in kg/m^3

$$\text{Mass concentration} = \frac{\text{Mass of a component}}{\text{Unit volume of mixture}}$$

Molar concentration

Number of molecules of a component per unit volume of the mixture. It is expressed in $\text{Kg - mole}/\text{m}^3$

$$\text{Molar concentration} = \frac{\text{Number of moles of component}}{\text{Unit volume of mixture}}$$

14. Define schmidt number and state its physical significance.) (Nov/Dec 16)

Schmidt number (Sc) is a dimensionless number defined as the ratio of momentum diffusivity (viscosity) and mass diffusivity, and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes.

Significance:

Analogous of Prandtl number in Heat Transfer. Used in fluid flows in which there is simultaneous momentum & mass diffusion. It is also ratio of fluid boundary layer to mass transfer boundary layer thickness.

PART B - 13 Marks (Questions and Answers)

1. A vessel contains binary mixture of O₂ and N₂ with partial pressure in the ratio 0.21 and 0.79 at 15°C =. The total pressure of the mixture is 1.1 bar. Calculate the following.

- I. Molar concentrations**
- II. Mass densities**
- III. Mass fractions**
- IV. Molar fraction of each species.**

[APRIL/MAY 2014; NOV/DEC 2015]

Given:

Partial pressure of O₂ = 0.21 x total pressure

$$(P_{O_2}) = 0.21 \times 1.1$$

$$P_{O_2} = 0.231 \times 10^5 \text{ N/m}^2$$

So partial pressure of N₂ = P_{N₂} = 86.9 × 10³ N/m²

Temperature T = 15° C = 288 K

To find

- I. Molar concentrations, C_{O₂}, C_{N₂}**
- II. Mass densities, ρ_{O₂}, ρ_{N₂}**
- III. Mass fractions, m_{O₂}, m_{N₂}**
- IV. Molar fraction of each species. x_{O₂}, X_{N₂}**

Solution:

STEP-1

$$\text{Molar concentration, } c_{O_2} = \frac{P_{O_2}}{GT}$$

Universal Gas Constant, G = 8314 J/kg mole K

$$c_{O_2} = \frac{0.231 \times 10^5}{8314 \times 288}$$

$$c_{O_2} = 9.64 \times 10^{-3} \text{ kg-mole/m}^3$$

$$C_{N_2} = \frac{P_{N_2}}{GT}$$

$$C_{N_2} = \frac{86.9 \times 10^3}{8314 \times 288}$$

$$C_{N_2} = 0.036 \text{ kg mole/m}^3$$

Total concentration,

$$C = C_{O_2} + C_{N_2} = 0.045 \text{ kg mole/m}^3$$

STEP-2

Molar concentration

$$C = \frac{\rho}{\mu}$$

$$= 9.64 \times 10^{-3} \times 32$$

$$\rho_{O_2} = 0.308 \text{ kg/m}^3$$

$$= 0.0362 \times 28$$

$$\rho_{N_2} = 1.013 \text{ kg/m}^3$$

$$\text{Overall density, } \rho = \rho_{O_2} \times \rho_{N_2}$$

$$= 0.308 + 1.10136$$

$$\rho = 1.3216 \text{ kg/m}^3$$

STEP-3

$$\text{Mass fractions } \dot{m}_{O_2} = \frac{\rho_{O_2}}{\rho} = \frac{0.308}{1.3216}$$

$$\dot{m}_{O_2} = 0.233$$

$$\dot{m}_{N_2} = \frac{\rho_{N_2}}{\rho} = \frac{1.0136}{1.3216}$$

$$\dot{m}_{N_2} =$$

0.766 STEP-4

$$\text{Mole fractions, } X_{O_2} = \frac{C_{O_2}}{C} = \frac{9.64 \times 10^{-3}}{0.045}$$

$$X_{O_2} = 0.210$$

$$X_{N_2} = \frac{C_{N_2}}{C} = \frac{0.0362}{0.045}$$

$$X_{N_2} = 0.804$$

RESULT:

I. Molar concentrations, $C_{O_2} = 9.64 \times 10^{-3} \text{ kg-mole/m}^3$

$$C_{N_2} = C_{O_2} = 0.036 \text{ kg-mole/m}^3$$

II. Mass densities, $\rho_{O_2} = 0.308 \text{ kg/m}^3$

$$\rho_{N_2} = 1.013 \text{ kg/m}^3$$

III. Mass fractions, $\dot{m}_{O_2} = 0.233$

$$\dot{m}_{N_2} = 0.766$$

IV. Molar fraction of each species. $X_{O_2} = 0.210$

$$X_{N_2} = 0.804$$

2. Air at 20°C ($\rho = 1.205 \text{ kg/m}^3$; $v = 15.06 \times 10^{-6} \text{ m}^2/\text{s}$; $D = 4.16 \times 10^{-6} \text{ m}^2/\text{s}$) flows over a tray (length = 32 cm, width = 42 cm) full of water with a velocity of 2.8 m/s. The total pressure of moving air is 1 atm and the partial pressure of water present in the air is 0.00658 bar. If the temperature on the water surface is 15°C calculate the evaporation rate of water.

(MAY/JUNE 2012; NOV/DEC 2014; NOV/DEC 2015; APRIL/MAY 2016)

Given:

Fluid temperature, $T_\infty = 20^\circ\text{C}$

Speed, $U = 2.8 \text{ m/s}$

Flow direction is 32 cm side. So, $x = 32 \text{ cm} = 0.32 \text{ m}$

Area, $A = 32 \text{ cm} \times 42 \text{ cm} = 0.32 \times 0.42 \text{ m}^2$

Partial pressure of water, $P_{w2} = 0.0068 \text{ bar}$

$$P_{w2} = 0.0068 \times 10^5 \text{ N/m}^2$$

Water surface temperature, $T_w = 15^\circ\text{C}$

To find:

Evaporation rate of water (M_w)

Solution:

Properties of air is given

$$\rho = 1.205 \text{ kg/m}^3;$$

$$v = 15.06 \times 10^{-6} \text{ m}^2/\text{s};$$

Diffusion coefficient $D = 4.16 \times 10^{-6} \text{ m}^2/\text{s}$

STEP-1

$$\text{Re} = \frac{UL}{\nu} = \frac{2.8 \times 0.32}{15.06 \times 10^{-6}} \\ = 0.594 \times 10^5 < 5 \times 10^5$$

Since $\text{Re} < 5 \times 10^5$, flow is laminar

Flat plate laminar flow:

$$\text{Sherwood number (Sh)} = [0.664 (\text{Re})^{0.5} (\text{Sc})^{0.333}] . \dots \{1\}$$

[From HMT data book, P.no-175]

STEP-2

$$\text{Sc} \rightarrow \text{Schmidt number} = \frac{\nu}{D_{ab}} = \frac{15.06 \times 10^{-6}}{4.16 \times 10^{-5}}$$

$$\text{Sc} = 0.3620$$

Sub Sc, Re in {1}

$$(\text{Sh}) = [0.664 (0.594 \times 10^5)^{0.5} (0.3620)^{0.333}]$$

$$\text{Sh} = 115.37$$

STEP-3

$$\text{Sherwood number Sh} = \frac{h_m L}{D_{ab}}$$

$$115.37 = \frac{h_m 0.32}{4.16 \times 10^{-5}}$$

$$h_m = 0.0149 \text{ m/s}$$

STEP-4

Mass transfer coefficient based on pressure difference is given

$$h_{mp} = \frac{h_m}{RT_w} = \frac{0.0149}{287 \times 288} \quad [\text{Tw}=15^\circ\text{C}+273=288 \text{ K}, \text{So R}= 287 \text{ J/kg K}]$$

$$h_{mp} = 1.80 \times 10^{-7} \text{ m/s}$$

Saturation pressure of water at 15°C

$$P_{w1} = 0.017 \text{ bar}$$

$$P_{w1} = 0.017 \times 10^5 \text{ N/m}^2 \quad [\text{From steam table (R.S khurmi) P.no-1}]$$

STEP-5

The evaporation of water

$$M_w = h_{mp} \times A (P_{w1} - P_{w2})$$

$$M_w = 2.66 \times 10^{-5} \text{ kg/s}$$

Result:

The evaporation rate of water $M_w = 2.66 \times 10^{-5} \text{ kg/s}$

- 3. Dry air at 27°C and 1 atm flows over a wet flat plate 50 cm long at a velocity of 50 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate.**

(NOV/DEC 2014; APRIL/MAY 2015) (NOV/DEC

Given:

Fluid temperature $T_\infty = 27^\circ\text{C}$

Velocity $u = 50 \text{ m/s}$

Length $x = 35\text{mm} = 0.035 \text{ m}$

To find:

Mass transfer co-efficient, (h_m)

Solution:**STEP-1**

Properties of air at 27°C :

$$V = 16 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\begin{aligned} Re &= \frac{UL}{\nu} = \frac{50 \times 0.035}{16 \times 10^{-6}} \\ &= 1.09375 \times 10^5 < 5 \times 10^5 \end{aligned}$$

Since $Re < 5 \times 10^5$, flow is laminar

Flat plate laminar flow:

$$\text{Sherwood number (Sh)} = [0.664 (Re)^{0.5} (Sc)^{0.333}] . \dots \{1\}$$

[From HMT data book, P.no-175]

STEP-2

$$[D_{ab}\text{-Diffusion coefficient (water+ air)} @ 27^\circ\text{C} = 25.38 \times 10^{-6} \text{ m}^2/$$

$$\text{Sc} \rightarrow \text{Schmidt number} = \frac{\nu}{D_{ab}} = \frac{16 \times 10^{-6}}{25.38 \times 10^{-6}}$$

$$\text{Sc} = 0.6304$$

STEP-3

Sub Sc, Re in {1}

$$(Sh) = [0.664 (1.09375 \times 10^5)^{0.5} (0.6304)^{0.333}]$$

$$Sh = 188.32$$

STEP-4

$$\text{Sherwood number Sh} = \frac{h_m L}{D_{ab}}$$

$$188.32 = \frac{h_m 0.35}{25.38 \times 10^{-6}}$$

$$h_m = 0.1365 \text{ m/s}$$

Result:

Mass transfer coefficient of water vapour $h_m = 0.1365 \text{ m/s}$.

4. CO₂ and air experience equimolar counter diffusion in a circular tube whose length and diameter are 1 m and 50 mm respectively. The system of total pressure of 1 atm and a temperature of 25°C. The ends of the tube are connected to large chambers in which the species concentrations are maintained at fixed values. the partial pressure of CO₂ at one end is 190 mm of Hg while at the other end is 95 mm Hg . Estimate the mass transfer rate of CO₂ and air through the tube.

[MAY/JUNE 2012; APRIL/MAY 2016]

Given:

Diameter, d=50mm=0.05m

Length=1m [x₂-x₁]

Total pressure , p=1 atm =1bar

Temperature, T=25°C= 298 K

Parital pressure of CO₂ at one end

$$P_{a1}=190\text{mm of Hg}=\frac{190}{760}\text{ bar}$$

$$P_{a1} = 0.25 \text{ bar} \quad [1 \text{ bar} = 760 \text{ mm of Hg}]$$

$$P_{a1} = 0.25 \times 10^5 \text{ N/m}^2 \quad [1 \text{ bar} = 10^5 \text{ N/mm}^2]$$

Partial pressure of CO₂ at other end

$$P_{a2} = 95 \text{ mm of Hg} = \frac{95}{760} \text{ bar}$$

$$P_{a2} = 0.0312 \text{ bar} \quad [1 \text{ bar} = 760 \text{ mm of Hg}]$$

$$P_{a2} = 0.0312 \times 10^5 \text{ N/m}^2 \quad [1 \text{ bar} = 10^5 \text{ N/mm}^2]$$

To find:

1. Mass transfer rate of CO₂

2. Mass transfer rate of air

Solution:

STEP-1

$$\frac{m_a}{A} = \frac{D_{ab}}{GT} \frac{[C_{a1} - C_{a2}]}{[X_2 - X_1]}$$

Diffusion coefficient (D_{ab}) for CO₂-Air combination is 11.89 × 10⁻⁶ m²/s

[HMT data book page no.180]

$$G\text{-Universal gas constant } -8314 \frac{J}{kg \cdot mole \cdot K} \quad (J/kg\text{-mole-K})$$

$$A\text{-Area} = \frac{\pi}{4} (d)^2$$

$$A = 1.9634 \times 10^{-3} \text{ m}^2$$

$$\frac{m_a}{A} = \frac{D_{ab}}{GT} \frac{[C_{a1} - C_{a2}]}{[X_2 - X_1]}$$

$$\frac{m_a}{A} = \frac{11.89 \times 10^{-6}}{8314 \times 298} \frac{[0.25 \times 10^5 - 0.031 \times 10^5]}{[1]}$$

$$\text{Molar transfer rate of CO}_2, m_a = 1.050 \times 10^{-7} \frac{kg - mole}{s}$$

STEP-2

We know,

Mass Transfer Rate CO₂ = Molar Transfer × Molecular Weight

$$= 1.050 \times 10^{-7} \times 44.01$$

[Molecular weight of CO₂ Refer HMT D.B Page 182]

Mass Transfer Rate CO₂ = 4.625 × 10⁻⁶ kg/s

$$\text{Mass Transfer Rate of Air} = m_b = -1.050 \times 10^{-7} \frac{\text{kg} - \text{mole}}{\text{s}}$$

STEP-3

$$[m_a = -m_b]$$

$$\begin{aligned}\text{Mass Transfer Rate Air} &= \text{Molar Transfer} \times \text{Molecular Weight of air} \\ &= 1.050 \times 10^{-7} \times 29\end{aligned}$$

$$\text{Mass Transfer Rate Air} = -3.045 \times 10^{-6} \text{ kg/s}$$

Result:

$$1. \text{ Mass transfer rate of CO}_2 = 4.625 \times 10^{-6} \text{ kg/s}$$

$$2. \text{ Mass transfer rate of air} = -3.045 \times 10^{-6} \text{ kg/s}$$

5. Discuss briefly the Analogy between heat and mass transfer.

[MAY/JUNE 2013; NOV/DEC 2015; APRIL/MAY 2016]

There is similarity among heat and mass transfer. The three basic equations dealing with these are

- I. Newtonian equation of momentum
- II. Fourier law of heat transfer
- III. Fick law of mass transfer

The momentum, heat and mass transfer equation can be written as

$$\text{Continuity equation, } \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\text{Momentum transfer, } u \frac{\partial u}{\partial x} + v \frac{\partial v}{\partial y} = v \frac{\partial^2 u}{\partial y^2}$$

$$\text{Heat transfer, } u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \alpha \frac{\partial^2 u}{\partial y^2}$$

$$\text{Mass transfer, } u \frac{\partial C_a}{\partial x} + v \frac{\partial C_n}{\partial y} = D \frac{\partial^2 C_a}{\partial y^2}$$

Heat and mass transfer takes place due to temperature difference. As per Fourier's law of conduction

$$Q = -kA \frac{dt}{dx}$$

Where Q = rate of heat transfer

K = thermal conductivity of material

A= Heat transfer area

$$\frac{dt}{dx} = \text{Temperature gradient}$$

As per Newton's law of cooling

$$Q = hA\Delta T$$

Where h= heat transfer coefficient

Mass transfer takes place due to concentration difference.

As per Fick's law of diffusion

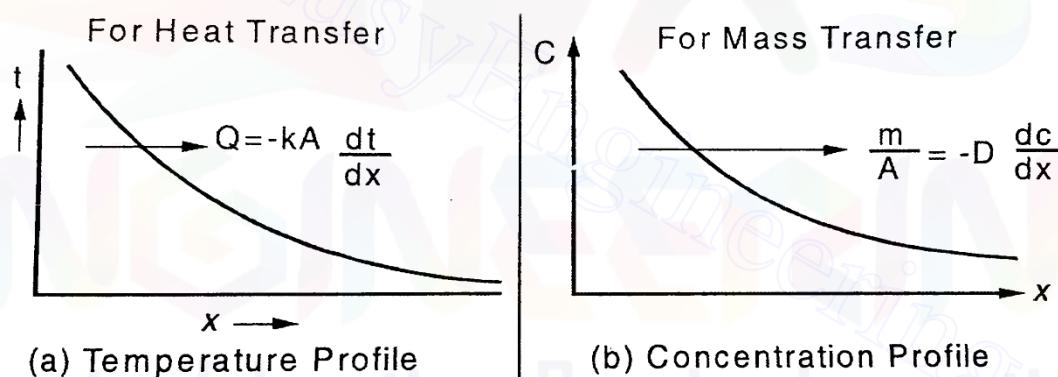
$$Na = \frac{m_A}{A} = -D_{AB} \frac{dC_A}{dx}$$

m_A = Mass flow rate of species A by diffusion.

A = Area through which mass is flowing

D_{AB} = Diffusion coefficient.

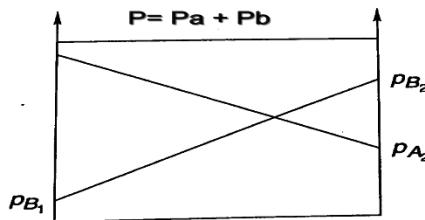
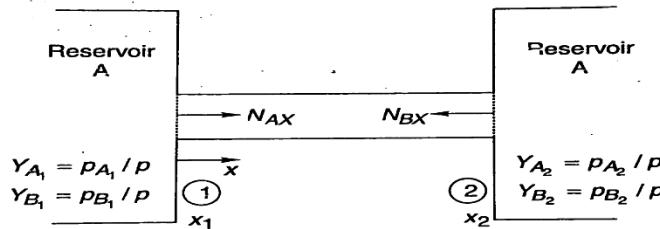
$$\frac{dC_A}{dx} = \text{concentration gradient.}$$



6. Explain Equimolar Counter diffusion in gases.

[APRIL/MAY 2013; NOV/DEC 2014]

Two large chambers 'a' and 'b' connected by a passage as shown below.



Equimolar Counter Diffusion in a Binary Mixture

Na and Nb are the steady state molar diffusion rates of component a and b respectively.

Equimolar diffusion is defined as each molecule of 'a' is replaced by each molecule of 'b' and vice versa. The total pressure $p = pa + pb$ is uniform throughout the system.

$$P = Pa + Pb$$

Differentiating with respect to x

$$\frac{dP}{dx} = \frac{dPa}{dx} + \frac{dPb}{dx}$$

Since the total pressure of the system remains constant under steady state conditions

$$\frac{dP}{dx} = \frac{dPa}{dx} + \frac{dPb}{dx} = 0$$

$$\frac{dPa}{dx} = -\frac{dPb}{dx}$$

Let the total molar flux is zero, $Na + Nb = 0$

$$\rightarrow Na = -Nb$$

$$-D_{BA} \frac{A}{GT} \frac{dPa}{dx} = D_{BA} \frac{A}{GT} \frac{dPb}{dx}$$

From flick's law,

$$D_{AB} = D_{BA} = D$$

$$Na = \frac{ma}{A} = -D \frac{A}{GT} \int_1^2 \frac{dPA}{dx}$$

$$\text{Molar flux, } Na = \frac{ma}{A} = -D \frac{A}{GT} \left[\frac{Pa_1 - Pa_2}{x_2 - x_1} \right]$$

Similarly,

$$Nb = \frac{mb}{A} = -D \frac{A}{GT} \left[\frac{Pb_1 - Pb_2}{x_2 - x_1} \right]$$

Where,

$$\frac{ma}{A} - \text{Molar flux } \frac{\text{kg} - \text{mole}}{\text{s} - \text{m}^2}$$

D- Diffusion coefficient

$$G - \text{Universal constant- 8314 } \frac{J}{\text{kg} - \text{mole} - \text{K}}$$

A- Area - m²

Pa₁- Partial pressure of constituent at 1 in N/m²

Pa₂- Partial pressure of constituent at 2 in N/m²

T - Temperature - K

- 7. An open pan of 150 mm diameter and 75 mm deep contains water at 25°C and is exposed to atmosphere air at 25°C and 50°C R.H. calculate the evaporation rate of water in grams per hour.**

[APRIL/MAY 2002]

Given:

Diameter, d = 150 mm = 0.150 m

Deep, (x₂-x₁) = 75 mm = 0.075 m

Temperature, T = 25°C+273 = 298 K

Relative Humidity = 50%

To Find:

Evaporation rate of water in grams per hour.

Solution:

Diffusion co-efficient (D_{ab}) [water + air] at 25°C

[From HMT data book, page no, 180]

$$D_{ab} = 25.83 \times 10^{-6} \text{ m}^2/\text{s}$$

STEP-1

We know that, for isothermal evaporation,

$$\text{Molar flux, } \frac{ma}{A} = \frac{D_{ab}}{GT} \frac{p}{(x_2 - x_1)} \ln \left[\frac{P - Pw2}{P - Pw1} \right]$$

$$\text{Area, } A = 0.0176 \text{ m}^2$$

$$P = \text{Total pressure} = 1 \text{ atm} = 1.013 \times 10^5 \text{ N/mm}^2$$

$Pw1$ = Partial pressure at the bottom of the test tube corresponding to saturation temperature 25°C .

At 25°C

$$\Rightarrow Pw1 = 0.03166 \times 10^5 \text{ N/mm}^2 \quad [\text{From steam table p.no 2}]$$

$Pw2$ = Partial pressure at the top of the pan corresponding to 25°C and 50°C relative humidity.

At 25°C

$$\Rightarrow Pw2 = 0.03166 \times 10^5$$

$$\text{R.H} = 50\% = 0.50$$

$$Pw2 = 0.03166 \times 10^5 \times 0.50$$

$$\rightarrow Pw2 = 1583 \text{ N/m}^2$$

STEP-2

$$\frac{ma}{0.076} = \frac{25.83 \times 10^{-6}}{8314 \times 298} \times \frac{1.013 \times 10^5}{0.075} \ln \left[\frac{1.013 \times 10^5 - 1583}{1.013 \times 10^5 - 0.03166 \times 10^5} \right]$$

$$\text{Molar rate of water vapour, } ma = 3.96 \times 10^{-9} \frac{\text{kg} - \text{mole}}{\text{s}}$$

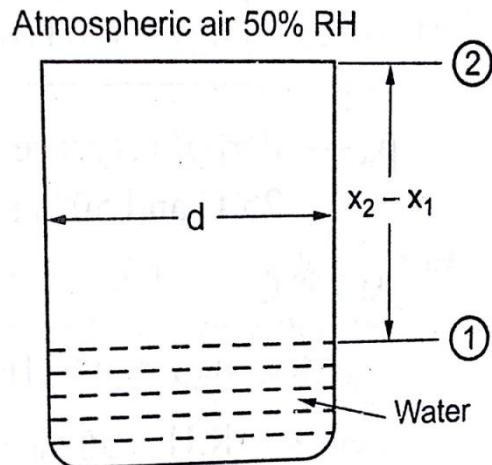
STEP-3

Mass rate of water vapour = molar rate of water vapour X molecular weight of steam

$$= 3.96 \times 10^{-9} \times 18.016 \text{ kg/s}$$

$$\text{Mass rate of water vapour} = 0.256 \text{ g/h}$$

Result:



Evaporation rate of water = 0.256 g/h.

Evaporation rate of water = 0.256 g/h.

PART C - 15 Marks (Questions and Answers)

1. Two large tanks ,maintained at the same temperature and pressure are connected by a circular 0.15m diameter direct, which is 3 m length .One tank contains a uniform mixture of 60 mole % ammonia and 40 mole % air and other tank contains a uniform mixture of 20 mole % ammonia and 80 mole % air. The system is at 273 K and 1.013×10^5 pa . Determine the rate of ammonia transfer between the two tanks.Assuming a steady state mass transfer.

Given:

$$\text{Diameter } d= 0.15 \text{ m}$$

$$\text{Length } (x_2-x_1)=3 \text{ m}$$

$$P_{a1} = \frac{60}{40} = 0.6 \text{ bar} = 0.6 \times 10^5 \text{ N/m}^2$$

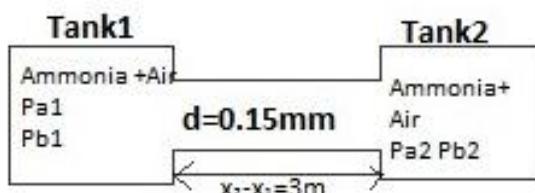
$$P_{b1} = \frac{40}{40} = 0.4 \text{ bar} = 0.4 \times 10^5 \text{ N/m}^2$$

$$P_{a2} = \frac{20}{40} = 0.2 \text{ bar} = 0.2 \times 10^5 \text{ N/m}^2$$

$$P_{b2} = \frac{80}{40} = 0.8 \text{ bar} = 0.8 \times 10^5 \text{ N/m}^2$$

$$T= 273 \text{ K}$$

$$P=1.013 \times 10^5 \text{ N/m}^2$$



a-Ammonia

b-Air

To find

Rate of ammonia transfer

Solution:

Equimolar counter diffusion

Molar flux,

$$\frac{ma}{A} = \frac{D_{ab}}{GT} \left[\frac{Pa_1 - Pa_2}{X_2 - X_1} \right]$$

Where G –universal constant =8314 J/Kg-mole-K

$$A = \text{area} = \frac{\pi}{4} d^2$$

$$A = \frac{\pi}{4} (0.15)^2$$

$$A = 0.017 \text{ m}^2$$

Dab-Diffusion co efficient of ammonia with air = $21.6 \times 10^{-6} \text{ m}^2/\text{s}$
 (From HMT data book P.No 180 (sixth edition)

$$\boxed{D_{ab} = 21.6 \times 10^{-6} \text{ m}^2/\text{s}}$$

$$(1) = \frac{ma}{0.017} = \frac{21.6 \times 10^{-6}}{8314 \times 273} X \frac{0.6 \times 10^5 - 0.2 \times 10^5}{3}$$

$$\boxed{\text{Molar transfer rate of ammonia , } m_a = 2.15 \times 10^{-9} \text{ Kg-mole/s}}$$

Mass transfer rate of ammonia = Molar transfer rate of ammonia x Molecular weight of ammonia

$$= 2.15 \times 10^{-9} \times 17.03 \text{ (Refer HMT data book P.No 182)}$$

$$\boxed{\text{Mass transfer rate of ammonia} = 3.66 \times 10^{-8} \text{ Kg/s}}$$

Result

$$\text{Mass transfer rate of ammonia} = 3.66 \times 10^{-8} \text{ Kg/s}$$

2. An open pan 20cm in diameter and 8 cm deep contains water at 25°C and is exposed to dry atmospheric air. If the rate of diffusion of water vapour is $8.5 \times 10^{-4} \text{ kg/h}$, estimate the diffusion co efficient of water in air.

Given :

$$\text{Diameter } d = 20 \text{ cm} = 0.20 \text{ m}$$

$$\text{Length } (x_2 - x_1) = 8 \text{ cm} = 0.08 \text{ m}$$

$$\text{Temperature } T = 25^\circ\text{C} + 273 = 298 \text{ K}$$

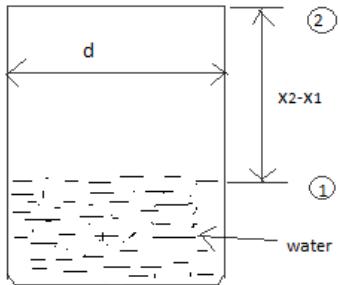
Diffusion rate (or)

$$\text{Mass rate of water vapour} = 8.54 \times 10^{-4} \text{ kg/h}$$

$$= \frac{8.54 \times 10^{-4} \text{ kg}}{3600 \text{ s}} \\ = 2.37 \times 10^{-7} \text{ kg/s}$$

To find

Diffusion coefficient Dab



Solution

Molar rate of water vapour

$$\frac{ma}{A} = \frac{Dab}{GT} \frac{p}{x_2 - x_1} X \ln \left[\frac{p - p_{w2}}{p - p_{w1}} \right]$$

$$m_a = \frac{Dab \times A}{GT} \frac{p}{x_2 - x_1} X \ln \left[\frac{p - p_{w2}}{p - p_{w1}} \right]$$

We know that

Mass transfer rate of steam = Molar transfer rate of steam x Molecular weight of steam

$$2.37 \times 10^{-7} = \frac{Dab \times A}{GT} \frac{p}{x_2 - x_1} X \ln \left[\frac{p - p_{w2}}{p - p_{w1}} \right] \times 18.016$$

Where

$$\begin{aligned} \text{Area } A &= \frac{\pi}{4} d^2 \\ &= \frac{\pi}{4} (0.20)^2 \end{aligned}$$

$$A = 0.0314 \text{ m}^2$$

G - universal constant = 8314 J/Kg-mole-K

P - Total Pressure = 1 atm = 1.013 bar = $1.013 \times 10^5 \text{ N/m}^2$

Pw₁- Partial pressure at the bottom of the test tube corresponding to saturation temperature 25°C

At 25°C (From Rs Khurmi Steam table P.No 2)

$$Pw_1 = 0.03166 \times 10^5 \text{ N/m}^2$$

Pw₂- Partial pressure at the top of the pan Hence air is dry and there is no water vapour So, Pw₂=0

$$Pw_2 = 0$$

(1) =

$$\frac{2.37 \times 10^{-7}}{= \frac{Dab \times 0.0314}{8314 \times 298} \times \frac{1.013 \times 10^5}{0.08} \times \ln \left[\frac{1.013 \times 10^5 - 0}{1.013 \times 10^5 - 0.03166 \times 10^5} \right] \times 18.016}$$

$$Dab = 2.58 \times 10^5 \text{ m}^2/\text{s}$$

Result

Diffusion coefficient , Dab = 2.58 x 10⁵ m²/s

BT 8402

MOLECULAR BIOLOGY

Q/A BANK

BT 8402**MOLECULAR BIOLOGY****3 0 0 3****UNIT I CHEMISTRY OF NUCLEIC ACIDS****9**

Introduction to nucleic acids: Nucleic acids as genetic material, Structure and physicochemical properties of elements in DNA and RNA, Biological significance of differences in DNA and RNA. Primary structure of DNA: Chemical and structural qualities of 3',5'-Phosphodiester bond. Secondary Structure of DNA: Watson & Crick model, Chargaff's rule, X-ray diffraction analysis of DNA, Forces stabilizes DNA structure, Conformational variants of double helical DNA, Hoogsteen base pairing, Triple helix, Quadruple helix, Reversible denaturation and hyperchromic effect. Tertiary structure of DNA: DNA supercoiling.

UNIT II DNA REPLICATION & REPAIR**9**

Overview of Central dogma. Organization of prokaryotic and eukaryotic chromosomes. DNA replication: Meselson & Stahl experiment, bi-directional DNA replication, Okazaki fragments, Proteomics of DNA replication, Fidelity of DNA replication, Inhibitors of DNA replication, Overview of differences in prokaryotic and eukaryotic DNA replication, Telomere replication in eukaryotes. D-loop and rolling circle mode of replication. Mutagens, DNA mutations and their mechanism, various types of repair mechanisms.

UNIT III TRANSCRIPTION**9**

Structure and function of mRNA, rRNA and tRNA. Characteristics of promoter and enhancer sequences. RNA synthesis: Initiation, elongation and termination of RNA synthesis, Proteins of RNA synthesis, Fidelity of RNA synthesis, Inhibitors of transcription, Differences in prokaryotic and eukaryotic transcription. Basic concepts in RNA world: Ribozymes, RNA processing: 5'- Capping, Splicing- Alternative splicing, Poly 'A' tail addition and base modification.

UNIT IV TRANSLATION**9**

Introduction to Genetic code: Elucidation of genetic code, Codon degeneracy, Wobble hypothesis and its importance, Prokaryotic and eukaryotic ribosomes. Steps in translation: Initiation, Elongation and termination of protein synthesis. Inhibitors of protein synthesis. Post- translational modifications and its importance.

UNIT V REGULATION OF GENE EXPRESSION**9**

Organization of genes in prokaryotic and eukaryotic chromosomes, Hierarchical levels of gene regulation, Prokaryotic gene regulation – lac and trp operon, Regulation of gene expression with reference to λ phage lifecycle

BT 8402 – MOLECULAR BIOLOGY

1. Differentiate primary and secondary structure of DNA

Primary structure:

Sequence of nucleotide chains. It is in these channels where the genetic information, and because the skeleton is the same for all the difference in the information lies in the different sequence of nitrogenous bases. This sequence has a code, which determines an information or otherwise, as the order of the bases.

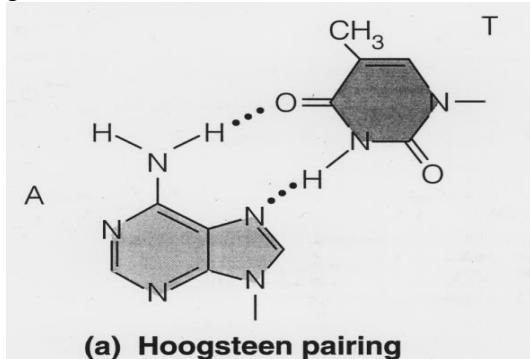
Secondary structure:

It is a double helix structure. Can explain the storage of genetic information and the mechanism of DNA replication. It was postulated by Watson and Crick, based on X-ray diffraction that Franklin and Wilkins had been made, and the equivalence of bases Chargaff, whereby the sum of adenines more guanines is equal to the sum of thymines more cytokines.

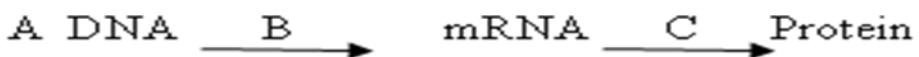
It is a double strand, right-handed or left-handed, depending on the DNA. Both chains are complementary, as adenine and guanine in a chain are joined, respectively, thymine and cytosine on the other. Both chains are antiparallel, then the 3' end of one faces the 5' end of the counterpart.

2. What is hogsteen base pairing?

A Hoogsteen base pair is a variation of base-pairing in nucleic acids such as the A. • T pair. In this manner, two nucleobases, one on each strand, can be held together by hydrogen bonds in the major groove.



3. Complete the following, label A, B and C and name the process central (Dogma)



A – Replication

B- Transcription

C- Translation

4. What is bidirectional replication?

DNA is double stranded molecule. Only one strand codes for proteins at any given point in the molecule. However, both strands are used during DNA replication. Each of the four bases in DNA (adenine, thymine, guanine, and cytosine) binds to a unique complementary base on the other strand. Therefore the base sequence on one strand determines the complementary sequence on the other

strand. During DNA replication the two strand separate from one another and each strand has a new complementary strand built onto it. This form of replication is called bi directional; also called as semi conservative; each new DNA molecule is composed of one conserved strand from the original molecule and one new strand.

5. Which is most unstable type of RNA molecule ? why ?

mRNA is the most unstable RNA .

RNA has the normal 2' hydroxy group, and that makes the phosphodiester bond unstable and susceptible to nucleophilic attack and self-hydrolysis. When RNA is single stranded (like in mRNA), the 2'-hydroxy group can more easily reach the phosphorus atom and cause the chain to be cut. However, when RNA is in the form of a double helix (like in tRNA and lots of rRNA parts), it is limited in movement and the hydroxy group can't as easily reach the phosphorus. For this reason, structure RNA molecules (in a double helix) are much more stable. mRNA is generally unstructured and so is much less stable.

6. What is a promoter? Why is promoter significant in gene-function ?

In genetics, a **promoter** is a region of DNA that initiates transcription of a particular gene. Promoters are located near the transcription start sites of genes, on the same strand and upstream on the DNA (towards the 5' region of the sense strand). Promoters can be about 100–1000 base pairs long. For transcription to take place, the enzyme that synthesizes RNA, known as RNA polymerase, must attach to the DNA near a gene. Promoters contain specific DNA sequences such as response elements that provide a secure initial binding site for RNA polymerase and for proteins called transcription factors that recruit RNA polymerase. These transcription factors have specific activator or repressor sequences of corresponding nucleotides that attach to specific promoters and regulate gene expression.

7. How many subunits are there in E.coli RNA polymerase . Add a note on core enzyme and holo enzyme of E.Coli RNA polymerase?

E. coli RNA Polymerase, Holoenzyme is the core enzyme saturated with sigma factor 70. The Holoenzyme initiates RNA synthesis from sigma 70 specific bacterial and phage promoters.

E. coli RNA Polymerase, Core Enzyme consists of 5 subunits designated α , α , β' , β , and ω . The enzyme is free of sigma factor and does not recognize any specific bacterial or phage DNA promoters. The enzyme retains the ability to transcribe RNA from nonspecific initiation sequences. Addition of sigma factors will allow the enzyme to initiate RNA synthesis from specific bacterial and phage promoters. The core enzyme has a molecular weight of approximately 400 kDa.

8. The beta chain of eukaryotic hemoglobin is composed of 141 aminiacids. What is the minimum number of nucleotides for an mRNA coding this polypeptide chain? Assuming that each nucleotide is 0.34nm long in mRNA how many triplet codes can simultaneously occupy space in ribosome that is 20 nm in diameter?

1. Total aminoacid = 141

1 aminiacid contains 3 nucleotide

141 amino acid contains = 141×3 (423=422 (coding) + 1 stopcodon (non coding))

Therefore, Minimum number of nucleotides coding the polypeptide chain = 422

2. length of 1 nucleotide = 0.34nm

Length of Triplet code = 0.34×3 (1.02 nm)

Triplet codes can simultaneously occupy space in ribosome that is 20 nm in diameter is = $20 / 1.02 = 19.6$

9. Justify the reason for arrangement of many prokaryotic genes in operons.

All the structural genes of an operon are turned ON or OFF together, due to a single promoter and operator upstream to them, but sometimes more control over the gene expression is needed. To achieve this aspect, some bacterial genes are located near together, but there is a specific promoter for each of them; this is called gene

Clustering. Usually these genes encode proteins which will work together in the same pathway, such as a metabolic pathway. Gene clustering helps a prokaryotic cell to produce metabolic enzymes in a correct order.

10. What is transcription attenuation? Give an example of the operon regulated by this process.

Transcriptional attenuation is a regulatory mechanism that causes premature termination of transcription under certain conditions, thereby preventing the expression of the mRNA required for expression of the corresponding gene products. Attenuation typically results from mRNA folding into alternative secondary structures, one of which is a Rho-independent terminator.

Ex. Trp operon

PART – B

11. a) List the biologically significant difference in DNA & RNA (TB1, 84-92)

(OR)

b) Discuss Watson and Crick model of DNA (TB1, 97-100)

12. a) Detail the list of events happening during DNA replication process in prokaryotes and discuss the enzyme involved in the process. (TB1, 209)

(OR)

b) i) Differentiate prokaryotic and eukaryotic replication (TB1, 271-273)

ii) Explain any one DNA repair mechanism (TB1, 293-305)

13. a) Distinguish between prokaryotic and eukaryotic transcription (TB1, 343-349)

(OR)

b) Outline the synthesis of mRNA with a neat sketch. (TB1, 317- 329)

14. a) Write about genetic code . Why only 32 RNAs are required for translating 61 codons

into 20 different amino acids (OR) (TB1, 367-378)

b) Differentiate prokaryotic and eukaryotic ribosomes. (TB1, 439-447)

15. a) What are the structural genes controlled by lac operon . Explain the catabolic repression effects of this operon. (OR) (TB1, 456-462)

b) Discuss the organization of genes in prokaryotes (TB1, 502-510)

PART – C

16. a) Give a detailed account on DNA as a genetic material, emphasizing their structure

(TB1, 79)(OR)

- b) Give a detailed account on prokaryotic transcription initiation, elongation and termination mechanisms with suitable diagram and factors involved in it. **(TB1, 343-349)**

TWO MARKS

UNIT I: CHEMISTRY OF NUCLEIC ACIDS

1. Define nucleic acid.

Nucleic acids are the polynucleotides having high molecular weight. The monomeric unit of which is nucleotide. **Nucleic acids** are biopolymers, or large biomolecules, essential for all known forms of life. Nucleic acids, which include DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), are made from monomers known as nucleotides. Each nucleotide has three components: a 5-carbon sugar, a phosphate group, and a nitrogenous base. If the sugar is deoxyribose, the polymer is DNA. If the sugar is ribose, the polymer is RNA. When all three components are combined, they form a nucleic acid

2. Define bacterial transformation.

Bacterial transformation is the exchange of genetic material between strains of bacteria by the transfer of a fragment of naked DNA from a donor cell to a recipient cell, followed by recombination in the recipient chromosome.

3.What are the properties of genetic material?

Stores genetic information, Physical and Chemical stability (The double stranded protects the DNA from chemical attack) Able to undergo mutation Stored information accessible to progeny

4.What is okazaki fragment?

Okazaki fragments are short, newly synthesized DNA fragments that are formed on the lagging template strand during DNA replication. They are complementary to the lagging template strand, together forming short double-stranded DNA sections. Okazaki fragments are between 1,000 to 2,000 nucleotides long in Escherichia coli and are between 100 to 200 nucleotides long in eukaryotes. They are separated by ~10-nucleotide RNA primers and are unligated until RNA primers are removed, followed by enzyme ligase connecting (ligating) the two Okazaki fragments into one continuous newly synthesized complementary strand

5.Explain cantenation.

Catenation is the ability of a chemical element to form a long chain-like structure via a series of covalent bonds. Catenation occurs most readily in carbon, which forms covalent bonds with other carbon atoms

6.What are Satellite DNA?

Satellite DNA consists of very large arrays of tandemly repeating, non-coding DNA. Satellite DNA is the main component of functional centromeres, and form the main structural constituent of heterochromatin. The name "satellite DNA" refers to how repetitions of a short DNA sequence tend to produce a different frequency of the nucleotides adenine, cytosine, guanine and thymine, and thus have a different density from bulk DNA - such that they form a second or 'satellite' band when genomic DNA is separated on a density gradient

7.Differentiate prokaryotic and eukaryotic promoters.

Prokaryotic promoters

In prokaryotes, the promoter consists of two short sequences at -10 and -35 positions upstream from the transcription start site. The sequence at **-10** is called the Pribnow box, or the -10 element, and usually consists of

the six nucleotides **TATAAT**. The Pribnow box is absolutely essential to start transcription in prokaryotes. The other sequence at -35 (the -35 element) usually consists of the six nucleotides TTGACA. Its presence allows a very high transcription rate.

Eukaryotic promoters

Eukaryotic promoters are extremely diverse and are difficult to characterize. They typically lie upstream of the gene and can have regulatory elements several kilobases away from the transcriptional start site. In eukaryotes, the transcriptional complex can cause the DNA to bend back on itself, which allows for placement of regulatory sequences far from the actual site of transcription. Many eukaryotic promoters, contain a TATA box (sequence **TATAAA**), which in turn binds a TATA binding protein which assists in the formation of the RNA polymerase transcriptional complex. The TATA box typically lies very close to the transcriptional start site (often within 50 bases).

8.What are the three enzymatic activities for DNA polymerase I?

DNA Polymerase I (or **Pol I**) is an enzyme that participates in the process of DNA replication and is exclusively found in prokaryotes. It is composed of 928 amino acids, and is an example of a processive enzyme - it can sequentially catalyze multiple polymerisations. Discovered by Arthur Kornberg in 1956,^[1] it was the first known DNA polymerase (and, indeed, the first known of any kind of polymerase). It was initially characterized in *E. coli*, although it is ubiquitous in prokaryotes. In *E. coli* and many other bacteria, the gene that encodes Pol I is known as **polA**.

9.Describe the biological significance of nucleic acids.

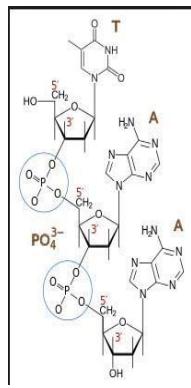
Nucleic acids are large molecules that carry tons of small details: all the genetic information. Nucleic acids are found in every living thing — plants, animals, bacteria, viruses, fungi — that uses and converts energy. Every single living thing has something in common. People, animals, plants, and more all are connected by genetic material. Every living thing may look different and act different, but deep down — way deep down in the nucleus of cells — living things contain the same chemical “ingredients” making up very similar genetic material. There are two types of nucleic acids: DNA (which stands for deoxyribonucleic acid) and RNA (which stands for ribonucleic acid). Nucleic acids are made up of strands of nucleotides, which are made up of a base containing nitrogen (called a nitrogenous base), a sugar that contains five- carbon molecules, and a phosphoric acid.

9.Explain Chargaff's rule.

Chargaff's rules states that DNA from any cell of all organisms should have a 1:1 ratio (base Pair Rule) of pyrimidine and purine bases and, more specifically, that the amount of guanine is equal to cytosine and the amount of adenine is equal to thymine

10.Describe the properties of phosphodiester bond

In DNA and RNA, the **phosphodiester bond** is the linkage between the 3' carbon atom of one sugar molecule and the 5' carbon atom of another, deoxyribose in DNA and ribose in RNA. Strong covalent**bonds** form between the phosphate group and two 5-carbon ring carbohydrates (pentoses) over two ester **bonds**.



11.Explain secondary structure of DNA.

Secondary structure is the set of interactions between bases, i.e., which parts of strands are bound to each other. In DNA double helix, the two strands of DNA are held together by Hydrogen bonds. The nucleotides on one strand base pairs with the nucleotide on the other strand.

12.List out the forces that stabilize the structure of DNA

The nitrogenous bases are positioned inside the helixstructure like "rungs on a ladder," due to the hydrophobic effect, and stabilized by hydrogen bonding. The two strands run in opposite directions to form the double helix. The strands are held together by hydrogen bonds and hydrophobic interactions.

13.Define secondary structure of DNA.

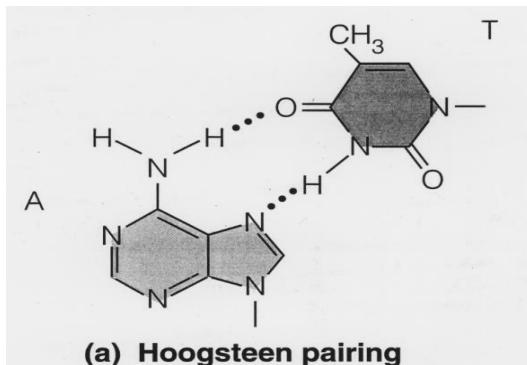
Secondary structure is the set of interactions between bases, i.e., which parts of strands are bound to each other. In DNA double helix, the two strands of DNA are held together by hydrogen bonds. The nucleotides on one strand base pairs with the nucleotide on the other strand.

14.Define phosphor diester bond.

A phosphodiester bond occurs when exactly two of the hydroxyl groups in phosphoric acid react with hydroxyl groups on other molecules to form two ester bonds. An example is found in the linking of twopentose (5 carbon sugar) rings to a phosphate group by strong, covalent ester bonds. Each ester bond is formed by a condensation reaction in which water is lost. This bond is a key structural feature of the backbone of DNA and RNA and links the 3' carbon of one nucleotide to the 5' carbon of another to produce the strands of DNA and RNA. In phosphodiester formation, two hydroxyl (OH) groups on the phosphate molecule bind to the 3' and 5' carbons on two independent pentose sugars. These are two condensation reactions, so two molecules of water are produced. The phosphate is then bonded to the sugars by two ester bonds, hence the nomenclature of phosphodiester bond. This reaction is catalysed by ligases, such as DNA ligase during DNA replication.

1. Define hogsteen base pairing.

A Hoogsteen base pair is a variation of base-pairing in nucleic acids such as the A • T pair. In this manner, two nucleobases, one on each strand, can be held together by hydrogen bonds in the major groove.



15. Define a triple helix DNA.

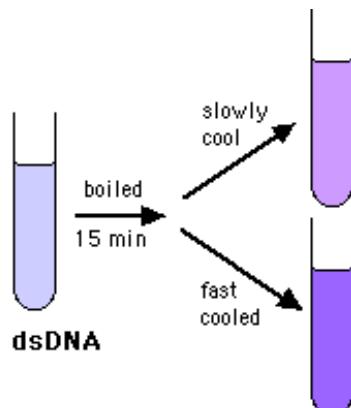
DNA can form multi-stranded helices through either folding of one of the two strands or association of two, three, or four strands of DNA. Triple-helical nucleic acids were first described in 1957 by Felsenfeld and Rich, who demonstrated that polyuridylic acid and polyadenylic acids strands in a 2:1 ratio were capable of forming a stable complex. In 1986, it was demonstrated that a short (15-mer) mixed-sequence triplex-forming oligonucleotide (TFO) formed a stable specific triple helical DNA complex. The third strand of DNA in the triplex structure (i.e. the TFO) follows a path through the major groove of the duplex DNA. The specificity and stability of the triplex structure is afforded via Hoogsteen hydrogen bonds, which are different from those formed in classical Watson-Crick base pairing in duplex DNA. Because purines contain potential hydrogen bonds with incoming third strand bases, the binding of the third strand is to the purine-rich strand of the DNA duplex.

16. Explain the quadruple structure of DNA.

The structures are called G-quadruplexes, because they form in regions of DNA that are full of guanine, one of the DNA molecule's four building blocks. The others are adenine, cytosine and thymine. A hydrogen bond is responsible for holding the four guanines together. The four stranded DNA usually presents itself right before cell division.

17. Explain the hyperchromic effect of DNA.

DNA's hyperchromic effect means that ssDNA absorbs more UV than does dsDNA. An insect, which can see in the UV range,* would see the hyperchromic effect something like that shown to the right. At first the DNA solution is only a little violet. If it is boiled and then slowly cooled, it ends up a little more violet than it started, but if it is rapidly cooled it becomes most violet. The reason that this happens is that in dsDNA the pi-electrons in the aromatic rings are more constrained because the H-bonded rings are in sandwich layers - overlapping with each other. But if the H-bonds are "boiled" away, the sandwich no longer exists and the pi-electrons are more free to move into different energy levels and thus able to absorb more UV energy.



19..Define a super coiled DNA.

A double helix (as of DNA) that has undergone additional twisting in the same direction as or in the opposite direction from the turns in the original helix. The term "supercoiling" means literally the coiling of a coil. A telephone cord for example, is typically a coiled wire. The twisted path often taken by that wire as it goes from the base of the phone to the receiver generally describes a supercoil. DNA is coiled in the form of a double helix. Let us define an axis about which both strands of the DNA coil. A bending or twisting of that axis upon itself is referred to as DNA supercoiling. DNA supercoiling is generally a manifestation of structural strain. Conversely, if there is no net bending of the DNA axis upon itself, the DNA is said to be in a relaxed state. It is probably apparent that DNA compaction must involve some form of supercoiling. Perhaps less apparent is the fact that replicating or transcribing DNA also must induce some degree of supercoiling.

20.What is the basic difference between B and Z type of DNA?

B Type:

In a DNA molecule, the two strands are not parallel, but intertwined with each other. Each strand looks like a helix. The two strands form a "**double helix**" structure, which was first discovered by James D. Watson and Francis Crick in 1953. In this structure, also known as the **B form**, the helix makes a turn every 3.4 nm, and the distance between two neighboring base pairs is 0.34 nm. Hence, there are about 10 pairs per turn. The intertwined strands make two grooves of different widths, referred to as the **major groove** and the **minor groove**, which may facilitate binding with specific proteins.

Z Type:

Another DNA structure is called the **Z form**, because its bases seem to zigzag. Z DNA is left-handed. One turn spans 4.6 nm, comprising 12 base pairs. The DNA molecule with alternating G-C sequences in alcohol or high salt solution tends to have such structure.

21.Relate hyperchromicity and denaturation of DNA

Hyperchromicity is the increase of absorbance (*optical density*) of a material. The most famous example is the hyperchromicity of DNA that occurs when the DNA duplex is denatured. The UV absorption is increased when the two single DNA strands are being separated, either by heat or by addition of denaturant or by increasing the pH level. The opposite, a decrease of absorbance is called **hypochromicity**. Heat denaturation of DNA, also called melting, causes the double helix structure to unwind to form single stranded DNA. When DNA in solution is heated above its melting temperature (usually more than 80 °C), the double-stranded DNA unwinds to form single-stranded DNA. The bases become unstacked and can thus absorb more light.

22.Mention two differences between prokaryotic DNA polymerase I and II

	DNA polymerase I	DNA polymerase II
1	Composed of 928 amino acids	Composed of 783 amino acids
2	Belongs to polymerase family A	Belongs to polymerase family B
3	Responsible for DNA repair and removing RNA primers	Responsible for proofreading, fidelity, and processivity of newly formed DNA

23.What is a molecular 'chaperone'?

Most biological structures assemble by themselves into larger structures; some (e.g., the icosahedral DNA bacteriophage P22) require help from an additional molecule that is not found in the final structure.

24.What properties of a protein ensure that it is localized to a particular part of a cell?

Nuclear , cytoplasmic, and extracellular proteins each have characteristic surfaces (cytoplasmic proteins have a balance of acidic and basic residues, extracellular proteins a slight excess of acidic residues, and nuclear proteins a pronounced excess of basic residues); then, we might imagine that newly-made proteins diffuse throughout the cell, to bind at a specific location. Individual proteins also have short peptide sequences (e.g., nuclear localization signals) that target the whole protein to a specific subcellular compartment (e.g., the nucleus).

25. Why are nuclei often round in shape?

Surface tension is a major determinant. The nucleus has a fluid system that is immiscible with its surroundings. Its surface tends towards the spherical minimum, and it is immersed in a medium that transmits on all sides a uniform fluid (hydrostatic) pressure; therefore, a nucleus is spherical.

26. Outline the general structure of the nucleosome. What is the evidence for this structure?

Structure: 146 bp of duplex DNA wrapped around a histone octamer (two copies of H3, H4, H2A, H2B) in 1.65 turns of a flat, left-handed superhelix.

Evidence: 2 copies of each core histone (and ~1 of H1) per ~200 bp DNA, the 'beads-on-a-string' structure seen by electron microscopy, nuclease digestion of linker DNA to give a nucleosomal ladder (repeat 180-260 bp) following by trimming of the linker to give the core particle with 146 bp DNA, the structure of the core particle determined by X-ray crystallography.

27.How can the lengths of DNA in the nucleosome, and between nucleosomes, be determined?

By progressive digestion of chromatin with nucleases (e.g., micrococcal nuclease), purification of DNA, and sizing the resulting fragments by gel electrophoresis. The distance between 'rungs' in the resulting nucleosomal 'ladder' gives the repeat length, while the length of the most resistant fragments gives the length of DNA in the nucleosome. The length of the linker can be obtained by subtraction.

28.Describe the evidence for and against the existence *in vivo* of a 'solenoid'.

For: electron microscopy of chromatin fibres in buffers of low ionic strength reveals helical solenoids with six to eight nucleosomes/turn and an 11 nm pitch.

Against: solenoids are not seen at a physiological salt concentration, or in electron micrographs of rapidly-frozen whole cells.

29.What is the evidence that the chromatin fiber is organized into loops in the interphase nucleus?

(i) it seems inconceivable that long DNA molecules are packed randomly like spaghetti, (ii) direct observation of lampbrush chromosomes (loops visible in unfixed material, but they might form when nuclei are dispersed), (iii) the demonstration of supercoiling in 'nucleoids' (but loops might be created artificially during reparation), (iv) the rate at which nucleases release chromatin from interphase nuclei (but isolated in hypotonic buffers) or permeabilized cells (isolated in isotonic buffers). Go onto discuss the analysis of residual fragments, and how the results suggest that attachments (and so loops) change continually.

1. Explain the central dogma of molecular biology.

The ‘Central Dogma’ is the process by which the instructions in DNA are converted into a functional product. It was first proposed in 1958 by Francis Crick, discoverer of the structure of DNA. The central dogma of molecular biology explains the flow of genetic information, from DNA or RNA, to make a functional product, a protein. The central dogma suggests that DNA contains the information needed to make all of our proteins, and that RNA is a messenger that carries this information to the ribosomes. The ribosomes serve as factories in the cell where the information is ‘translated’ from a code into the functional product. The process by which the DNA instructions are converted into the functional product is called gene expression. Gene expression has two key stages - transcription and translation. In transcription, the information in the DNA of every cell is converted into small, portable RNA messages. During translation, these messages travel from where the DNA is in the cell nucleus to the ribosomes where they are ‘read’ to make specific proteins. The central dogma states that the pattern of information that occurs most frequently in our cells is:

From existing DNA to make new DNA (DNA replication)

From DNA to make new RNA (transcription)

From RNA to make new proteins (translation).

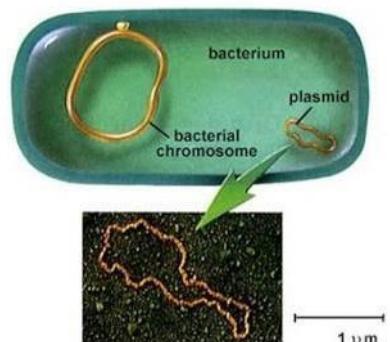
2. Differentiate prokaryotic and eukaryotic chromosome.

Chromosomes: The vehicle by which hereditary information is physically transmitted from one generation to the next; in a bacterium, the chromosome consists of a single naked circle of DNA; in eukaryotes, each chromosome consists of a single linear DNA molecules and associated proteins. [Read more](#)

Prokaryotic Chromosome vs Eukaryotic Chromosome

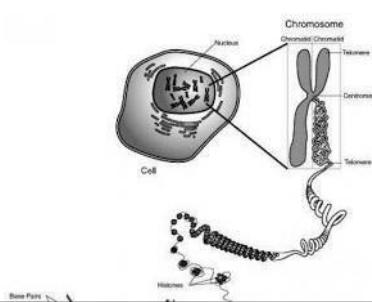
Prokaryotic Chromosome

- Found in cytoplasm.
- Circular chromosome attached to the inside of the cell membrane.
- Single chromosome plus plasmids.
- Made only of DNA.
- Copies its chromosome and divides immediately afterwards.



Eukaryotic Chromosome

- Found in nucleus
- Linear chromosomes
- Many chromosomes.
- Usually, 10-50 chromosomes in somatic cells.
- Human body cells have 46 chromosomes.
- Made of chromatin, a nucleoprotein (DNA coiled around histone proteins).
- Copies chromosomes, then the cell grows (G2 phase), then goes through mitosis to organise chromosomes in two equal groups.



c)

y which a double-stranded DNA molecule is copied to produce two identical DNA molecules. Replication is an essential process because, whenever a cell divides, the two new daughter cells must contain the same genetic information, or DNA, as the parent cell.

The replication process relies on the fact that each strand of DNA can serve as a template for duplication. DNA replication initiates at specific points, called origins, where the DNA double helix is unwound. A short segment of RNA, called a primer, is then synthesized and acts as a starting point for new DNA synthesis. An enzyme called DNA polymerase next begins replicating the DNA by matching bases to the original strand. Once synthesis is complete, the RNA primers are replaced with DNA, and any gaps between newly synthesized DNA segments are sealed together with enzymes.

5. Explain the bi directional mode of replication in DNA.

DNA is double stranded molecule. Only one strand codes for proteins at any given point in the molecule. However, both strands are used during DNA replication. Each of the four bases in DNA (adenine, thymine, guanine, and cytosine) binds to a unique complementary base on the other strand. Therefore the base sequence on one strand determines the complementary sequence on the other strand. During DNA replication the two strand separate from one another and each strand has a new complementary strand built onto it. This form of replication is called bi directional; also called as semi conservative; each new DNA molecule is composed of one conserved strand from the original molecule and one new strand.

6. What are called okazaki fragments?

Okazaki fragments are the Short segments of DNA, 1000 to 2000 bases long, that later join up to form continuouslengths of DNA. Okazaki fragments occur in replicating DNA in both prokaryotes and eukaryotes. They form up on the‘lagging’ strand during replications and join by ligation. (Reiji Okazaki, Japanese geneticist.) They are the DNA sequences, 100 to 200 nucleotides long, synthesized on the lagging strand of DNA in DNA replication. Thefragments are subsequently ligated together to form a continuous strand. They are produced because of the need forDNA polymerase to always synthesize in a 5' to 3' direction.

7. Explain the fidelity of DNA.

The fidelity of a DNA polymerase is the result of accurate replication of a desired template. Specifically, this involves multiple steps, including the ability to read a template strand, select the appropriate nucleoside triphosphate and insert the correct nucleotide at the 3' primer terminus, such that Watson-Crick base pairing is maintained. To effectively discriminate correct vs. incorrect nucleotide incorporation, some DNA polymerases possess a 3' to 5' exonuclease activity. This activity, known as “proofreading,” is used to excise incorrectly incorporated mononucleotides, which are then replaced with the correct nucleotides. High- fidelity PCR uses DNA polymerases that couple low misincorporation rates with proofreading to give faithful replication of the target DNA of interest.

8. When is fidelity important?

When designing your PCR experiment, the first question you should ask is whether or not your application requires a high-fidelity polymerase. If the outcome of your experiment depends on the correct DNA sequence (e.g., cloning or next-generation sequencing applications), you'll want to minimize the incorporation of mismatched nucleotides by using a high-fidelity polymerase. Fidelity is less important for standard PCR or colony PCR to determine the presence or absence of an amplicon or to confirm that your plasmid has an insert. Because of the robust nature of certain high-fidelity polymerases, some researchers use them for all their amplifications, regardless of the PCR product's downstream use.

9. How do you measure fidelity?

Vendors use a variety of different methods to determine the fidelity of their DNA polymerases. One assay, first described by Thomas Kunkel, uses portions of the lacZ α gene in M13 bacteriophage to correlate host bacterial colony color changes with errors in DNA synthesis. Building on the Kunkel assay, Wayne Barnes' assay is a common permutation found in labs, in which PCR is used to copy the entire lacZ gene and portions of two drug-resistance genes, with subsequent ligation, cloning, transformation and blue/white-colony color determination. The readout of both assays is a white-colony phenotype caused by the disruption of β -galactosidase activity that results from errors in the lacZ gene. With these lacZ-based experimental approaches, the percentage of white colonies must be converted to the number of errors per base incorporated. For a more direct readout of fidelity, Sanger sequencing of individual cloned PCR products also can be used to score DNA polymerase fidelity and offers the advantage of detecting all mutations. Using this method, the entire mutational spectrum of a polymerase can be determined, and there is no need to correct for nonphenotypic changes.

10. Define out certain inhibitors of DNA replication

Alkylating antineoplastic agents, Nitrogen mustards, Topoisomerase inhibitors, Altretamine, Bleomycin, Dacarbazine, Dactinomycin, Mitobronitol, Mitomycins, Mitosene, Pingyangmycin, Plicamycin, Procarbazine, Temozolomide

11. Differentiate Eukaryotic and prokaryotic replication.

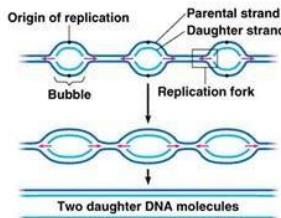
DNA replication in Prokaryotes

1. It occurs inside the cytoplasm
2. There is only one origin of replication per DNA molecule
3. Origin of replication is formed of about 100-200 or more nucleotides
4. Replication of DNA occurs at one point in each prokaryotic DNA molecule
5. Only two replication forks are formed in each replicating prokaryotic chromosome, as DNA replication is bidirectional
6. Prokaryotic chromosome has one replicon
7. One replication bubble is formed during DNA replication
8. Initiation of DNA replication in prokaryotes is carried out by protein DnaA and DnaB
9. DNA gyrase is needed
10. Okazaki fragments are large, 1000-2000 nucleotides long.
11. Replication is very rapid, some 2000 bp per second are added.



DNA replication in Eukaryotes

1. It occurs inside the nucleus
2. Origin of replication are many (over 1000) in each eukaryotic chromosome
3. Each origin of replication is formed of about 150 nucleotides
4. Replication of DNA occurs at several points simultaneously in each chromosome.
5. A number of replication forks are formed simultaneously in each replicating DNA.
6. Eukaryotic DNA molecules have large number of replicons (50,000 and above), but replication does not occur simultaneously on all replicons
7. Numerous replication bubbles are formed in one replicating DNA molecule.
8. Initiation of DNA replication is carried out by multisubunit protein, origin recognition complex.
9. DNA gyrase is needed
10. Okazaki fragment are short, 100-200 nucleotides long.
11. Replication is slow, some 100 nucleotides per second are added



10. Define telomere.

Telomeres are an essential part of human cells that affect how our cells age. Telomeres are the caps at the end of each strand of DNA that protect our chromosomes, like the plastic tips at the end of shoelaces. Without the coating, shoelaces become frayed until they can no longer do their job, just as without telomeres, DNA strands become damaged and our cells can't do their job.

11. Describe the role of telomere in the replication.

- DNA polymerase cannot replicate and repair DNA molecules at the ends of linear chromosomes.
- The ends of linear chromosomes, called telomeres, protect genes from getting deleted as cells continue to divide.
- The telomerase enzyme attaches to the end of the chromosome; complementary bases to the RNA template are added on the 3' end of the DNA strand.
- Once the lagging strand is elongated by telomerase, DNA polymerase can add the complementary nucleotides to the ends of the chromosomes and the telomeres can finally be replicated.
- Cells that undergo cell division continue to have their telomeres shortened because most somatic cells do not make telomerase; telomere shortening is associated with aging.
- Telomerase reactivation in telomerase-deficient mice causes extension of telomeres; this may have potential for treating age-related diseases in humans.

12. Describe the rolling circle mode of replication.

Rolling circle replication is the unidirectional mode of DNA replication employed by circular DNA molecules, such as plasmids and the genomes of bacteriophages and some eukaryotic viruses. In viruses with linear genomes, the ability to circularise once inside a cell is

crucial prerequisite for rolling circle replication. By replicating in this fashion, the virus can ensure that no genetic material is lost from its genome as a consequence of successive rounds of replication. Circularisation of linear phage genomes occurs by the interaction between cos sites (cohesive sites) in the viral genome.

The process begins with a plasmid or phage-encoded enzyme called relaxase, which creates a nick in the circular DNA at a site called the double-strand origin (DSO); the relaxase remains bound to the 5' phosphate at the site of this nick, so the 3' OH group is available as a primer for DNA synthesis by DNA polymerase III. The polymerase moves along the nicked strand, using the un-nicked strand as a template for replication, and a helicase displaces the nicked strand behind polymerase as a single-stranded DNA molecule. This procedure can be repeated multiple times to create numerous linear copies in a continuous head-to-tail series called a concatemer.

To make these linear strands double-stranded and circular again, an initiator protein makes another nick to terminate DNA synthesis. DNA polymerase III and RNA polymerase then work in conjunction to replicate the single-strand origin (SSO) of a linear strand to make it double-stranded. Finally, DNA polymerase I removes the primer, replacing it with DNA, and DNA ligase covalently binds the strands end-to-end to make the final circular structure.

13. What is D-Loop replication?

D-loop replication is a process by which chloroplasts and mitochondria replicate their genetic material. An important component of understanding D-loop replication is that many chloroplasts and mitochondria have a single circular chromosome like bacteria instead of the linear chromosomes found in eukaryotes. However, many chloroplasts and mitochondria have a linear chromosome, and D-loop replication is not important in these organelles. In many organisms, one strand of DNA in the plastid comprises heavier nucleotides (relatively more purines: adenine and guanine). This strand is called the H (heavy) strand. The L (light) strand comprises lighter nucleotides (pyrimidines: thymine and cytosine). Replication begins with replication of the heavy strand starting at the D-loop (also known as the control region). An origin of replication opens, and the heavy strand is replicated in one direction. After heavy strand replication has continued for some time, a new light strand is also synthesized, through the opening of another origin of replication. When diagrammed, the resulting structure looks like the letter D. The D-loop region is important for phylogeographic studies. Because the region does not code for any genes, it is free to vary with only a few selective limitations on size and heavy/light strand factors. The mutation rate is among the fastest of anywhere in either the nuclear or mitochondrial genomes in animals. Mutations in the D-loop can effectively track recent and rapid evolutionary changes such as within species and among very closely related species.

14. What are mutagens?

Chemical mutagens are classified as alkylating agents, cross-linking agents, and **polycyclic aromatic hydrocarbons** (PAHs). Alkylating agents act by adding molecular components to DNA bases, which alters the protein product. Cross-linking agents create covalent bonds with DNA bases, while PAHs are metabolized by the human body into other potentially mutagenic molecules.

Radiation is another potent mutagen. For biologists, the most significant forms of radiation are **light, heat, and ionizing radiation**. Ionizing radiation can penetrate cells and create ions in the cell contents. These, in turn, can cause permanent alterations in DNA; that is, mutations. Ionizing radiation includes: **x rays**, gamma rays, and the subatomic particles—neutrons, electrons ("beta" particles), and alpha particles (helium nuclei). Ionizing radiation alters the way two strands of DNA interact. This high **energy** radiation passes through cells and tissues, cutting up any DNA in its path. It can rearrange entire sections of the chromosomes, altering relatively long stretches of DNA. UV radiation causes covalent bonds to form between neighboring thymine bases in the

DNA, so altering the DNA product at that location.

15. Explain the importance of DNA repair mechanism.

DNA in the living cell is subject to many chemical alterations (a fact often forgotten in the excitement of being able to do DNA sequencing on dried and/or frozen specimens. If the genetic information encoded in the DNA is to remain uncorrupted, any chemical changes must be corrected. **A failure to repair DNA produces a mutation.** The recent publication of the human genome has already revealed 130 genes whose products participate in DNA repair. More will probably be identified soon.

16. What are the agents that can damage DNA?

- Agents that Damage DNA
- Certain wavelengths of radiation
- ionizing radiation such as gamma rays and X-rays
- Ultraviolet rays, especially the UV-C rays (~260 nm) that are absorbed strongly by DNA but also the longer-wavelength UV-B that penetrates the ozone shield.
- Highly-reactive oxygen radicals produced during normal cellular respiration as well as by other biochemical pathways.
- Chemicals in the environment
- many hydrocarbons, including some found in cigarette smoke
- some plant and microbial products, e.g. the aflatoxins produced in moldy peanuts
- Chemicals used in chemotherapy, especially chemotherapy of cancers

17. What are the Types of DNA Damage?

All four of the bases in DNA (A, T, C, G) can be covalently modified at various positions.

One of the most frequent is the loss of an amino group ("deamination") — resulting, for example, in a C being converted to a U. Mismatches of the normal bases because of a failure of proofreading during DNA replication. Common example: incorporation of the pyrimidine U (normally found only in RNA) instead of T. Breaks in the backbone. Can be limited to one of the two strands (a single-stranded break, SSB) or on both strands (a double- stranded break (DSB). Ionizing radiation is a frequent cause, but some chemicals produce breaks as well. Crosslinks Covalent linkages can be formed between bases on the same DNA strand ("intrastrand") or on the opposite strand ("interstrand").

18. Explain the Meselson–Stahl experiment

The Meselson-Stahl was an experiment by Matthew Meselson and Franklin Stahl with some additional help from a Canadian biologist, Mason MacDonald, and Indian-Canadian nuclear physicist, Amandeep Sehmbi, in 1958 which supported the hypothesis that DNA

Replicaton was semiconservative. In semiconservative replication, when the double stranded DNA helix is replicated, each of the two new double-stranded DNA helices consisted of one strand from the original helix and one newly synthesized. It has been called "the most beautiful experiment in biology. Meselson and Stahl decided the best way to tag the parent DNA would be to change one of the atoms in the parent DNA molecule. Since nitrogen is found in the nitrogenous bases of each nucleotide, they decided to use an isotope of nitrogen to distinguish between parent and newly copied DNA. The isotope of nitrogen had an extra neutron in the nucleus, which made it heavier.

19. What are the enzymes that contribute for excision repair mechanisms?

- DNA glycosylases.
- AP endonucleases.

- End processing enzymes.
- DNA polymerases.
- Flap endonuclease.
- DNA ligase
- MBD4.
- NEIL1.

20. List the natural agents that commonly cause damage in our DNA.

Water (deamination, depurination), oxygen (through the superoxide radical, hydrogen peroxide, and hydroxyl radical).

21. Outline the principles involved in eukaryotic DNA synthesis.

Restriction to S phase, semi-conservative replication, initiation at internal origins, simultaneous replication of many chromosomal segments as they move through polymerization sites in factories, strand separation to give a replication bubble flanked by two replication forks, requirements for primers and a primase, growth 5'-to-3', continuous and discontinuous synthesis on leading and lagging strands.

22. How would you demonstrate that active DNA polymerases are fixed to an underlying structure in the nucleus?

Permeabilize cells, treat -/+ nuclease, remove detached chromatin, measure remaining polymerizing activity by incorporation of radiolabeled dTTP; removing most chromatin leaves most activity.

23. Outline the different approaches used to label sites of DNA synthesis in eukaryotic nuclei, and the difficulties associated with each one.

By immunolabeling polymerases: not all enzyme active. *By autoradiography with [³H]thymidine:* slow entry and conversion to immediate precursor, dilution by endogenous pools, complications of rapidity of DNA synthesis, long path-length of -particles. *By immunolabeling after incubation with Br-dU:* slow entry and conversion, but higher resolution afforded by immuno-EM. *By immunolabelling after permeabilization with immediate precursors like Br-dUTP and biotin-dUTP:* control of elongation rate, but lysis might alter structure, and still limited resolution (even with immunogold labeling). Details of factories best seen after removing most chromatin.

24. What is the unwinding problem, and how might it be solved in theory and in practice?

Each strand in a DNA duplex is entwined about its partner, and must be untwined during replication.

Theoretical solutions: by rotation about ends (but if these are fixed the two strands remain interlocked), by cutting one or other of the strands (or both), passing one (or both) strands through the break, and resealing the break. *Practical solution:* topoisomerases cut, pass, and reseal.

25. Describe the structure of the origin of replication in *E. coli*.

OriC contains: four 9-mers containing a specific recognition sequence (i.e., 5'-TTAT(C/A)CA(C/A)) for the initiator protein dnaA, three 13-mers that melt easily, 11 potential sites (i.e., GATC) of methylation by the Dam methylase, and 2 back-to-back promoters that may be involved in the initiation of replication.

26. What is an 'autonomously-replicating sequence' (ARS)? How was the first one identified in yeast?

ARS: DNA sequence that enables circular plasmid lacking origin to replicate in yeast cells, usually equivalent to an origin of replication. **Discovery:** The first ARS was obtained as follows. Yeast mutants lacking the *LEU* gene cannot form colonies without added leucine. Even on transformation with a bacterial plasmid carrying the yeast *LEU⁺* gene, few colonies result; this is because the plasmid is unable to replicate along with the yeast chromosomes and is soon diluted out. However, if random pieces of yeast DNA are inserted into the plasmid, a few will now contain a yeast replication origin and so can replicate in yeast cells. Cells carrying such a plasmid will grow into a colony since they contain both the *LEU⁺* gene and a yeast origin that facilitates plasmid replication.

27. Outline the problem associated with replicating the ends of a chromosome, and some solutions.

A polymerase can extend a leading strand to the very end, but removal of a primer at the 5' end of the lagging strand leaves a gap that cannot be filled, as no 3'OH is available. **Solutions:** use protein-nucleotide priming (adenovirus), form a hairpin, concatamer, or circle (e.g., in vaccinia, T7 and lambdoid viruses), maintain ends by recombination (e.g., T4 bacteriophage), use telomerase.

28. Outline the properties of telomerase.

It is part protein and part RNA, protein part has homology with reverse transcriptases, RNA part contains 8-30 nucleotides of RNA containing 1.2-1.9 copies of the C-strand repeat that templates synthesis of telomeric DNA.

29. How were replication factories imaged in *B. subtilis*?

Using a PolC-GFP construct - one discrete spot is generally seen in the middle of the cell.

30. What is a proofreading activity?

A 3'->5' exonuclease (either part of the catalytic subunit of a DNA polymerase, or a subunit of the polymerizing complex) that removes mispaired bases immediately after they have been incorporated.

UNIT-III - TRANSCRIPTION

1. Define bacterial transformation.

Bacterial transformation the exchange of genetic material between strains of bacteria by the transfer of a fragment of naked DNA from a donor cell to a recipient cell, followed by recombination in the recipient chromosome.

2. What are the properties of genetic material?

- Stores genetic information
- Physical and Chemical stability (The double stranded protects the DNA from chemical attack)
- Able to undergo mutation
- Stored information accessible to progeny

3. Describe the basic rule for the replication of all nucleic acids.

- The primary role of any mode of replication is to duplicate the base sequence of the parent molecule. The specificity of base pairing adenine with thymine and guanine with cytosine provides the mechanism used by all replication systems.

- Nucleotide monomers are added one by one to the end of a growing strand by an enzyme called a DNA polymerase.
- The sequence of bases in each new or daughter strand is complementary to the base sequence in the original template or parent strand being copied that is, if there is an adenine in the parent strand, a thymine nucleotide will be added to the end of the growing daughter strand when the adenine is being copied.

4. Define a TATA box.

The TATA box (also called Goldberg-Hogness box) is a DNA sequence (cis-regulatory element) found in the promoter region of genes in archaea and eukaryotes; approximately 24% of human genes contain a TATA box within the core promoter

5. Explain any four general features of enhancers

Several DNA sequences of note have been detected in eukaryotic genes. The first that was described was an enhancer sequence. Enhancers have the ability to greatly increase the expression of genes in their vicinity

6. Define genetic code.

The genetic code is the set of rules by which information encoded in genetic material (DNA or mRNA sequences) is translated into proteins (amino acid sequences) by living cells.

7. Give any two inhibitors of protein synthesis in eukaryotes along with its action

Protein synthesis is a complex, multi-step process involving many enzymes as well as conformational alignment. However, the majority of antibiotics that block bacterial protein synthesis interfere with the processes at the 30S subunit or 50S subunit of the 70S bacterial

Ribosome.. The aminoacyl tRNA synthetases that activate each amino acid required for peptide synthesis are not antibiotic targets. Instead, the primary steps in the process that are attacked are

- The formation of the 30S initiation complex (made up of mRNA, the 30S ribosomal subunit, and formyl-methionyl-transfer RNA),
- The formation of the 70S ribosome by the 30S initiation complex and the 50S ribosome, and
- The elongation process of assembling amino acids into a polypeptide.

8. Why genetic activity is regulated?

- To discuss the structure and transcription of bacterial gene
- To describe the molecular mechanism and to regulate gene activity

9. What is temperature sensitive mutation?

A viral mutant that is able to replicate at one portion of a temperature range but not at another, the parent (wild type) strain being able to replicate over the whole temperature range.

10. Explain catenation.

Catenation is the ability of a chemical element to form a long chain-like structure via a series of covalent bonds. Catenation occurs most readily in carbon, which forms covalent bonds with other carbon atoms

11. What are Satellite DNA?

Satellite DNA consists of very large arrays of tandemly repeating, non-coding DNA. Satellite DNA is the main component of functional centromeres, and form the main structural constituent of heterochromatin. The name "satellite DNA" refers to how repetitions of a short DNA sequence tend to produce a different frequency of the nucleotides adenine, cytosine, guanine and thymine, and thus have a different density from bulk DNA - such that they form a second or 'satellite' band when genomic DNA is separated on a density gradient.

12. Define linkage

Two genes are said to be under linkage, or linked, when they reside in the same chromosome. For example, the research of the human genome discovered that the factor III of clotting gene and the factor V of clotting gene are located in the same chromosome (the human chromosome 1). The factor VII gene however is not linked to those genes since it is located in the chromosome 13

13. Explain suppressor sensitive mutation.

A conditionally lethal, host range, bacteriophage mutant that produces nonsense codons and can replicate only in a host bacterium able to translate the nonsense codon; the mutation's effects are lethal (i.e., prevent replication of the virus) in a bacterium without such a suppressor mechanism.

14. What is breathing means in DNA structure?

Recent claim is discussed that Watson-Crick pairs in the naked duplex DNA spontaneously flip into Hoogsteen pairs under ordinary conditions. The claim is considered within the historical retrospective and is put into the broader context of DNA biophysics.

15. Define double sieve mechanism

A model that explains the rarity of misacylation of amino acids by proposing that an amino acid larger than the correct one is rarely activated because (1) it is too large to fit into the active site of the tRNA synthetase (first sieving), and (2) the hydrolytic site of the same synthetase is too small for the correct amino acid (second sieving). Thus, an amino acid smaller than the correct one can be removed by hydrolysis.

16. Define cot value.

Renaturation is a bimolecular reaction where the reaction rate is directly proportional to the product of the concentrations of c of the two homologous DNA strands.

The renaturation rate is $= dc/dt = K_2[W][C]$

Integration of the above equation gives;

$$C/C_0 = 1/(1+k_2 C_0 t)$$

Where C is the concentration of single-stranded DNA at time t (in min), and C₀ is the concentration of DNA at time zero. $C/C_0 = 1/2$, then $K_2 = 1/2 C_0 t$

In other words, the product of the initial concentration of ssDNA, C₀ and the time required to renature 50% of the DNA, t_{1/2} is inversely proportional to the rate constant K₂ of the reaction. This C₀t_{1/2} is called the Cot value. The Cot value is directly proportional to the complexity of the genome.

17. Explain specialized transduction

Specialized transduction - only specific regions of chromosome located near attachment site are transduced, transducing particles carry both chromosomal DNA and phage DNA.

18. What are simple multigene families? Give example.

The term multigene families is used to include groups of genes from the same organism that encode proteins with similar sequences either over their full lengths or limited to a specific domain. DNA duplications can generate gene pairs. If both copies are maintained in subsequent generations then a multigene family will exist. A multigene family is a member of a family of related proteins encoded by a set of similar genes. Multigene families are believed to have arisen by duplication and variation of a single ancestral gene. Examples of multigene families include those that encode the actins, hemoglobins, immunoglobulins, tubulins, interferons, histones etc.

19. Differentiate prokaryotic and eukaryotic promoters

Prokaryotic promoters

In prokaryotes, the promoter consists of two short sequences at -10 and -35 positions upstream from the transcription start site. The sequence at -10 is called the Pribnow box, or the - 10 element, and usually consists of the six nucleotides TATAAT. The Pribnow box is absolutely essential to start transcription in prokaryotes. The other sequence at -35 (the -35 element) usually consists of the six nucleotides TTGACA. Its presence allows a very high transcription rate.

Eukaryotic promoters

Eukaryotic promoters are extremely diverse and are difficult to characterize. They typically lie upstream of the gene and can have regulatory elements several kilobases away from the transcriptional start site. In eukaryotes, the transcriptional complex can cause the DNA to bend back on itself, which allows for placement of regulatory sequences far from the actual site of transcription. Many eukaryotic promoters, contain a TATA box (sequence TATAAA), which in turn binds a TATA binding protein which assists in the formation of the RNA polymerase transcriptional complex. The TATA box typically lies very close to the transcriptional start site (often within 50 bases).

20. What are the three enzymatic activities for DNA polymerase I?

DNA Polymerase I (or Pol I) is an enzyme that participates in the process of DNA replication and is exclusively found in prokaryotes. It is composed of 928 amino acids, and is an example of a processive enzyme - it can sequentially catalyze multiple polymerisations. Discovered by Arthur Kornberg in 1956,^[1] it was the first known DNA polymerase (and, indeed, the first known of any kind of polymerase). It was initially characterized in E. coli, although it is ubiquitous in prokaryotes. In E. coli and many other bacteria, the gene that encodes Pol I is known as polA.

21. Mention the beneficial effects of capping and tailing of RNA

- Capping prevents 5' degradation from 5' exonucleases.
- Capping provides stability to mRNAs.
- Capping facilitates the transport of mRNA into cytoplasm otherwise they remain in the nucleus.
- Capping enhances the efficiency of translation of mRNAs.
- Capping enhances the efficiency of splicing at 5' end introns.
- Capping with poly (A) provides synergism during translation.
- Luciferase mRNAs have been used to determine its half-life and translation efficiency with or without cap and poly- (A) tail.
- Half-life of Luciferase mRNA without cap and without poly (A) is just 31 minutes, and translational activity is 2900 (as measured in terms of light emitted by ug of radioactive protein).
- But mRNAs without cap but with poly (A) tail shows half-life of 44 minutes. And its activity is

4480. The capped mRNA without poly (A) has half-life of 53 minutes and translation activity is 62000 a virtual 50% increase in its half-life and translational efficiency.

- The capped mRNA with poly- (A) tail, has a half-life of 100 minutes and its translational activity is 1,333 000; the relative effect of cap on its activity 200 fold.
- During translation mRNA cap and poly-A tail bind to each other through a protein eF4G and gets circularized.

22. Outline the basic principles involved in eukaryotic RNA synthesis.

Transcription between promoter (start) and termination (stop) signals, multi-subunit polymerases in factories, the basic steps of transcription, initiation of synthesis of new chains, synthesis 5'-to-3'.

23. How would you determine which parts of the genome are transcribed?

'Miller' spreads, 'S1 mapping', and RT-PCR.

24. Define the properties of the bacterial RNA polymerase.

The core enzyme (initiates poorly), σ (helps the core initiate), the holoenzyme, TATA and -35 boxes, closed and open complexes, rho independent and dependent terminators.

25. What are the untwining and supercoiling problems, and how are they resolved?

Untwining problem (and solution): a tracking polymerase is likely to generate a transcript that is entangled about the template (fix the polymerase and allow DNA to rotate). *Supercoiling problem (and solution):* transcription by both tracking and fixed polymerases generates twin domains of supercoiling (role of topoisomerase).

26. How is a 'Miller' spread prepared, and illustrate the appearance of a spread containing some ribosomal cistrons?

Preparation: isolate nuclei, disperse chromatin in a hypotonic solution, spin onto a grid.

Structure: series of 'Christmas' trees.

27. How can caps be isolated?

Exhaustively treat mRNA with endonucleases that cleave 3' phosphates next to bases (e.g., RNase T2) to leave 5' \rightarrow 5' links intact; purify resulting dinucleotides (each carrying several phosphates) free of mononucleotides on a column (separate molecules carrying different numbers of phosphate groups).

28. What is the role of the cap?

The cap binds the cap-binding complex, CBC, which tethers the nascent transcript to the factory, enhances 3' end formation, protects transcripts from degradation, facilitates export from the nucleus, and dissociates at the ribosome to be replaced by the translational regulator, eIF-4E.

29. What is 'nonsense mediated decay' (NMD), and how was it discovered?

NMD: mRNA with a stop codon in the normal position is stable in both nucleus and cytoplasm, but moving the stop codon near the 5' end leads to the loss - or NMD - of the message. *Discovery:* place stop codons at different positions in test genes (e.g., *TPI*) and then monitor transcript levels; stop codons close to the 5' end destabilize the transcript in both the nucleus and cytoplasm.

30. What is 'transcriptional interference', and how was it discovered?

Transcriptional interference: phenomenon where transcription of one gene prevents transcription of an adjacent gene. *Discovery:* Cells were transfected with a retroviral vector encoding

resistance to neomycin and azaguanine, and clones harboring a single copy of the vector selected. Expression of the 3' gene was suppressed when selection required expression of the 5' gene, and *vice versa*. In addition, hardly any cells grew in both neomycin and azaguanine.

UNIT-IV - TRANSLATION

1. Explain DNA foot printing.

DNA footprinting is a method of investigating the sequence specificity of DNA-binding proteins in vitro. This technique can be used to study protein-DNA interactions both outside and within cells. The regulation of transcription has been studied extensively, and yet there is still much that is not known. Transcription factors and associated proteins that bind promoters, enhancers, or silencers to drive or repress transcription are fundamental to understanding the unique regulation of individual genes within the genome. Techniques like DNA footprinting will help elucidate which proteins bind to these regions of DNA and unravel the complexities of transcriptional control.

2. Write a note on types of RNA splicing.

In molecular biology and genetics, splicing is a modification of the nascent pre-mRNA taking place after or concurrently with its transcription, in which introns are removed and exons are joined. This is needed for the typical eukaryotic messenger RNA before it can be used to produce a correct protein through translation. For many eukaryotic introns, splicing is done in a series of reactions which are catalyzed by the spliceosome, a complex of small nuclear ribonucleoproteins (snRNPs), but there are also self-splicing introns.

3. What is conditional mutant?

Mutation that has the wild-type phenotype under certain (permissive) environmental conditions and a mutant phenotype under other (restrictive) conditions

4. What is the reading frame of an mRNA?

A reading frame is a way of breaking the sequence of nucleotides in a nucleic acid such as a DNA or RNA into a set of consecutive triplets, called codons. When read as triplets, a nucleic acid molecule may in general have six reading frames, three reading in one direction along one strand and three reading in the other direction along the complementary strand. In general, only one reading frame in a given section of a nucleic acid is biologically relevant

5. Explain how hydrophobic interactions are important in stabilizing the DNA structure.

A noncovalent bond is a type of chemical bond, typically between macromolecules, that does not involve the sharing of pairs of electrons, but rather involves more dispersed variations of electromagnetic interactions. The noncovalent bond is the dominant type of bond between supermolecules in supermolecular chemistry. Noncovalent bonds are critical in maintaining the three-dimensional structure of large molecules, such as proteins and nucleic acids, and are involved in many biological processes in which large molecules bind specifically but transiently to one another. The energy released in the formation of noncovalent bonds is on the order of 1-5 kcal per mol. There are four commonly mentioned types of non-covalent interactions: hydrogen bonds, ionic bonds, van der Waals forces, and hydrophobic interactions.

6. What is denaturation mapping?

The identification of regions of low thermal (or alkali) stability (i.e., of high A+T content) in a duplex DNA molecule, by trapping the partly melted structure and blocking renaturation, e.g. with formaldehyde (which preferentially couples with the amino groups of the single-stranded regions), and subsequently examining the specimen by electron microscopy.

7. Explain generalized transduction

Transduction is a phenomenon in which bacterial DNA is transferred from one bacterial cell to another by a phage particle. Phage particles that contain bacterial DNA are called Transducing Particles. There are two types of transducing particles-generalized and specialized.

8. What do you understand by cyclically permuted?

A cyclic permutation or circular permutation is a permutation built from one or more sets of elements in cyclic order.

9. Distinguish redundant and synonyms in genetic code

The genetic code consists of 64 triplets of nucleotides. These triplets are called codons. With three exceptions, each codon encodes for one of the 20 amino acids used in the synthesis of proteins. That produces some redundancy in the code: most of the amino acids being encoded by more than one codon

10. Define leaky mutation

A mutant (typically an auxotroph) that results from a partial rather than a complete inactivation of the wild-type function.

11. Define transcription process

Flow of genetic information from DNA to the messenger RNA (mRNA) to express the genome for biosynthesis of proteins. The transcription process is otherwise called as synthesis of mRNA from DNA template either of the DNA strand by using enzyme RNA polymerase.

12. Write short notes on prokaryotic RNA polymerases.

RNA polymerase is the single enzyme present in the nucleus which is responsible for the synthesis of all kinds of RNAs like mRNA, tRNA and rRNA. RNA polymerase present in prokaryotic as well as eukaryotic cells is slightly differing in their structure and has many subunits. This cluster of enzyme is responsible for different functions during the mRNA synthesis or transcription process.

13. Mention briefly on sigma (σ) factor.

The sigma subunits present in the RNA polymerase of prokaryotic cell helps in recognition of start signals during mRNA synthesis. The sigma subunits are otherwise called sigma factors, which directs RNA polymerase in selecting the initiation sites. Once the RNA synthesis initiated, the sigma factors dissociate from the DNA and combine in the next transcription cycle.

14. Write on promoter and terminator region.

The promoter region or site is the special locations of DNA where the special region contain specific nucleotides are present in which the RNA polymerase binds for initiation of

transcription process. This is otherwise called promoter site. The terminator region is the special site of DNA, which contain specific nucleotide sequences, which are responsible for terminating or stop the transcription process. This is otherwise called terminator region.

15. Write short notes on prokaryotic promoter

The RNA polymerase binding site of the prokaryotic DNA region is called promoter region or promoter site. This region contain 41 – 44 bp in E.coli. Promoter is the start site, which contains 90% purine bases. The upstream from the promoter site is a 6 bp region described as TATAAT sequence or TATAAT box. This is otherwise called as pribnow box. This lies 10 bp region as – 10 sequence. I.e. – 18 to – 12 region. Another sequence is TTGACA is lying –35 sequences on upstream is called recognition region. The typical prokaryotic DNA use –35 and 10 sequences for transcription.

16. Describe pribnow box.

The pribnow box is otherwise described as the promoter region of DNA. The upstream from the promoter site is a 6 bp region described as TATAAT sequence or TATAAT box. This is otherwise called as pribnow box. This lies 10 bp region as – 10 sequence. I.e. –18 to –12 region.

17. Where is consensus TATA sequence seen? Write the significance of it.

The consensus TATA sequence is seen in the promoter region of prokaryotic DNA. This is more helpful in recognition of RNA polymerase to bind for transcription process. This consensus sequences occur at –10 bp of promoter region.

18. What is upstream and downstream site?

The upstream and downstream sites are occurring at the transcription region of DNA. The Upstream is the sequence region, which is prior to the start point of the promoter (from –1 sequence). The Downstream site is the region after the start point of the promoter region (from +1 sequence).

19. What is promoter complex?

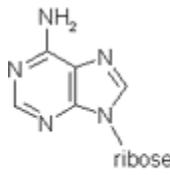
The promoter complex is described as the combine product occurred after the holoenzymes (RNA polymerase unit) binds at promoter site. When DNA is in double helix stage, it is called closed promoter complex. Once the double helix is unwinded, then it is called open promoter complex. After formation of promoter complex, the transcription state is begin to start.

20. List out the unusual bases found in t RNA

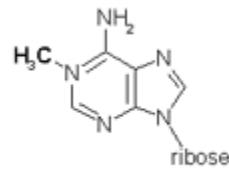
Unusual bases

tRNAs contain many unusual bases as shown by the illustrated side chains:

1-methyl adenosine is a modified adenosine base found on tRNA:

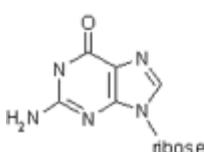


Adenosine

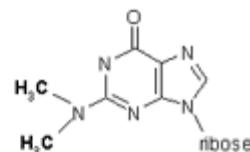


1-methyladenosine

N2, N2-dimethylguanosine is a modified guanosine:



Guanosine

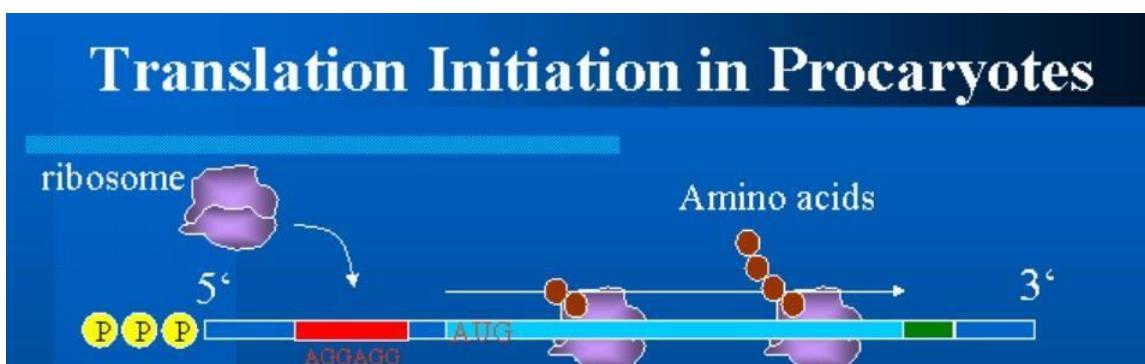


N², N²-dimethylguanosine

21. Describe few post translatory mechanisms

Post-translational modifications can occur on the amino acid side chains or at the protein's C- or N- termini. They can extend the chemical repertoire of the 20 standard amino acids by modifying an existing functional group or introducing a new one such as phosphate. Phosphorylation is a very common mechanism for regulating the activity of enzymes and is the most common post-translational modification. Many eukaryotic proteins also have carbohydrate molecules attached to them in a process called glycosylation, which can promote protein folding and improve stability as well as serving regulatory functions. Attachment of lipid molecules, known as lipidation, often targets a protein or part of a protein attached to the cell membrane. Other forms of post-translational modification consist of cleaving peptide bonds, as in processing a propeptide to a mature form or removing the initiator methionine residue. The formation of disulfide bonds from cysteine residues may also be referred to as a post- translational modification.

22. How shine-dalgarno sequence initiate translation?



In prokaryotes, a ribosome with tRNA which carries methionine binds to the specific region of mRNA and recognizes AUG codon nearby and protein synthesis begins. In this process the main factors are ribosome, tRNA with methionine(fMet-tRNA-Metf), and mRNA. In addition, at least initiation factors and GTP molecule are required to ensure the efficiency and fidelity of this process.

Bacterial mRNAs are commonly polycistronic. That means that they encode multiple proteins that are separately translated from the same mRNA molecule. Sometimes coding regions overlap, but it may not affect the fidelity of translation. Sometimes coding regions overlap by one base, which will be like UG [AUG].

In bacterial mRNA, ribosome binding site and start codon play important roles for translation initiation. Ribosome binding site is where the 30S small subunit binds first on mRNA. This site contains purine rich sequence which is called Shine-Dalgarno sequence. The 3' terminal of 16S rRNA in 30S subunit binds to this sequence and helps 30S subunit to bind to mRNA.

23. Write down the phases of protein synthesis

1. Activation of amino acids.
2. Initiation
3. Elongation
4. Termination
5. Folding and processing

24. Write short notes on Transpeptidation

- The peptide bond is formed in the second stage of the elongation cycle through the nucleophilic displacement of the P site tRNA by the amino group of the 3' linked aminoacyl tRNA in the A site.
- The nascent polypeptide chain is thereby lengthened at its C terminus by one residue and transferred to the A site tRNA a process called transpeptidation.
- Peptidyl transferase activity probably appears on the 23s RNA of ribosome. That can catalyse the reaction

25. Write short notes on Translocation

- If in the final stage of elongation cycle, uncharged P site tRNA is transferred to E site, it is former occupant having been previously expelled. Simultaneously, in a process known as translocation, the peptidyl tRNA in the A site, together with its bound mRNA is moved to the P site.
- The translocation process requires the participation of an elongation factor, EF-G that binds to the ribosome together with GTP and is only released upon hydrolysis of the GTP to GPP + Pi.
- EF-G release is pre-requisite for beginning the next elongation cycle because the ribosomal binding sites of EF-G and EF-TU partially overlap and hence their binding is mutually exclusive.

26. Write short notes on start and stop codons

If translation codons of three nucleotides determine which amino acid will be added next in the growing protein chain. The start codon is usually AUG, while the stop codons are UAA, UAG, and UGA. The open reading frame (ORF) is that portion of a DNA segment which will putatively code for a protein; it begins with a start codon and ends with a stop codon.

27. What are two types of codes?

There are several ways in which a codon could be read from a mRNA molecule. The two most important alternatives originally considered are the overlapping and nonoverlapping codes. In an overlapping code each base serves as the first base of some codon; in a nonoverlapping code, each base is used in only one codon.

28. Write short notes on Cycloheximide

Cycloheximide is a chemical inhibitor of the peptidyl transferase complex of the 60S subunit and hence inhibits formation of the peptide bond. Substances like Cycloheximide are commonly used in cancer chemotherapy.

29. Write short notes on components of Translation process

mRNA: – Eukaryotes: made in the nucleus, transported to the cytoplasm. – Prokaryotes: transcription and translation occur concurrently.

tRNA: Adaptor molecules that mediate the transfer of information from nucleic acids to protein

Ribosomes: manufacturing units of a cell; located in the cytoplasm. Contain ribosomal RNA and proteins.

Enzymes: required for the attachment of amino acids to the correct tRNA molecule, and for peptide bond formation between amino acids.

Proteins: soluble factors necessary for proper initiation, elongation and termination of translation.

30. When the ribosome encounters a stop codon?

- There is no tRNA available to bind to the A site of the ribosome,
- Instead a release factor binds to it.

UNIT V - REGULATION OF GENE EXPRESSION

1. Define Gene regulation

Gene regulation is the informal term used to describe any mechanism used by a cell to increase or decrease the production of specific gene products (protein or RNA). Cells can modify their gene expression patterns to trigger developmental pathways, respond to environmental stimuli, or adapt to new food sources. All points of gene expression can be regulated. This includes transcription, RNA processing and transport, translation and post-translational modification of a protein, and mRNA degradation.

2. What is Gene organization?

Genes inside the cell follow several layers of organisation to enable the long DNA to be compacted into the chromosome fibers. In the first level of packing, DNA is wrapped around 4 pairs of proteins called Histones in a “beads-on-string” fashion. These nucleosomes then coil around each other in the form of a helix, with around 6 nucleosomes forming one turn of a helix. These helices form the long chromatin fibers which, with series of turns and loops, forms the third level of spatial DNA organisation. Finally, these chromatin fibers are compactly packed inside the chromosome. In the Chromosome, the chromatin fibers are wrapped around a protein scaffold.

3. How does gene regulation occur?

A **gene (or genetic) regulatory network (GRN)** is a collection of molecular regulators that

interact with each other and with other substances in the cell to govern the gene expression levels of mRNA and proteins. These play a central role in morphogenesis, the creation of body structures, which in turn is central to evolutionary developmental biology (evo-devo).

The regulator can be DNA, RNA, protein and complexes of these. The interaction can be direct or indirect (through transcribed RNA or translated protein). In general, each mRNA molecule goes on to make a specific protein (or set of proteins). In some cases this protein will be structural, and will accumulate at the cell membrane or within the cell to give it particular structural properties. In other cases the protein will be an enzyme, i.e., a micro-machine that catalyses a certain reaction, such as the breakdown of a food source or toxin. Some proteins though serve only to activate other genes, and these are the transcription factors that are the main players in regulatory networks or cascades. By binding to the promoter region at the start of other genes they turn them on, initiating the production of another protein, and so on. Some transcription factors are inhibitory.

4. How many amino acids are present in a nascent polypeptide decoded from mRNA with the reading frame having 1002 nucleotides?

- In molecular biology, a **reading frame** is a way of dividing the sequence of nucleotides in a nucleic acid (DNA or RNA) molecule into a set of consecutive, non-overlapping triplets. Where these triplets equate to amino acids or stop signals during translation, they are called codons.
- A single strand of a nucleic acid molecule has a phosphoryl end, called the 5'-end, and a hydroxyl or 3'-end. These define the 5'→3' direction. There are three reading frames that can be read in this 5'→3' direction, each beginning from a different nucleotide in a triplet. In a double stranded nucleic acid, an additional three reading frames may be read from the other, complementary strand in the 5'→3' direction along this strand. As the two strands of a double stranded nucleic acid molecule are antiparallel, the 5'→3' direction on the second strand corresponds to the 3'→5' direction along the first strand.

5. Why DNA replication is called semi-conservative?

DNA replication is semi-conservative because each helix that is created contains one strand from the helix from which it was copied. The replication of one helix results in two daughter helices each of which contains one of the original parental helical strands. It is semi-conservative because half of each parent helix is conserved in each daughter helix.

6. What are introns?

An intron is a nucleotide sequence within a gene. It is a noncoding sequence. During the final maturation of the RNA product, the RNA removes it by splicing.¹ The term intron pertains to the DNA sequence within a gene as well as the corresponding sequence in the RNA transcripts.² It is used in contrast to the nucleotide sequences joined together in a mature RNA after splicing called exons. Sometimes, the term intron is used synonymously to intervening sequences. However, the latter is a broader term that includes inteins and UTRs, apart from the introns. Introns occur in the genes of many organisms (e.g. eukaryotes), including viruses. They are also present in the genes of mitochondria and chloroplasts. Introns are believed to be essential in allowing rapid evolution of proteins through exon shuffling.

7. Name the cell organelle where protein synthesis takes place

The rough **endoplasmic reticulum** is where most protein synthesis occurs in the cell. The function of the smooth **endoplasmic reticulum** is to synthesize lipids in the cell. The smooth ER also helps in the detoxification of harmful substances in the cell. **Ribosomes**- Organelles that help in the

synthesis of proteins.

8. Give reason – why DNA is acidic in nature

DNA is made of three types of molecules in equal proportions - basic nucleotides, sugar deoxyribose and acidic phosphate groups. The bases are on the inside of the helix and partly hidden from the outside. Deoxyribose and phosphates are on the outside, forming a backbone. Though the proportions are equal, the nucleotides are weak bases, so the overall pH is acidic.

9. Name the process by which RNA is synthesised from DNA.

Gene expression is the process by which the genetic code - the nucleotide sequence - of a gene is used to direct protein synthesis and produce the structures of the cell. Genes that code for amino acid sequences are known as 'structural genes'.

The process of gene expression involves two main stages:

Transcription: the production of messenger RNA (mRNA) by the enzyme RNA polymerase, and the processing of the resulting mRNA molecule. **Translation:** the use of mRNA to direct protein synthesis, and the subsequent post-translational processing of the protein molecule. Some genes are responsible for the production of other forms of RNA that play a role in translation, including transfer RNA (tRNA) and ribosomal RNA (rRNA).

10. Why lac operon switches off in the absence of Lactose in E.coli?

The lac operon, an inducible operon, is a mechanism used by bacterial cells as an economical means to restrict the expression of the structural genes necessary for metabolizing lactose, a disaccharide. These structural genes break down lactose when lactose is the best carbon source available within its environs. E.coli utilizes the lac operon as a means of controlling the expression of its lac genes in response to its environment. The primary carbon source of this bacterium is glucose because it does not require a large amount of energy for metabolism. It is a more efficient source of energy than lactose. In the presence of both glucose and lactose, the bacterium will choose to metabolize glucose.

11. Why Chargaff's rule is not applicable for RNA?

RNA is found as a single stranded molecule. Chargaff's rule states that DNA helices contain equal molar ratios of A to T and G to C. This is because DNA is found as a double stranded helix in which A and T and G and C bases pair complementarily. RNA only forms local helices meaning that it doesn't necessarily contain equal ratios.

12. Why the nucleotide ratio in RNA is not usually constant?

Due to the absence of complementary base pairing. RNA is single stranded. So, the nucleotide ratio is not constant in RNA.

13. Why is processed mRNA in eukaryotes is shorter than its gene?

Processed mRNA in eukaryotes is shorter than its gene because the eukaryotic gene is split gene and the transcribed mRNA has intron portions.

14. Name the process of RNA directed DNA synthesis

A reverse transcriptase (RT) is an enzyme used to generate complementary DNA

(cDNA) from an RNA template, a process termed reverse transcription. It is mainly associated with retroviruses. However, non-retroviruses also use RT (for example, the hepatitis B virus, a member of the Hepadnaviridae, which are dsDNA-RT viruses, while retroviruses are ssRNA viruses). RT inhibitors are widely used as antiretroviral drugs. RT activities are also associated with the replication of chromosome ends (telomerase) and some mobile genetic elements (retrotransposons).

Retroviral RT has three sequential biochemical activities:

- (a) RNA-dependent DNA polymerase activity,
- (b) ribonuclease H, and
- (c) DNA-dependent DNA polymerase activity.

These activities are used by the retrovirus to convert single-stranded genomic RNA into double-stranded cDNA which can integrate into the host genome, potentially generating a long-term infection that can be very difficult to eradicate. The same sequence of reactions is widely used in the laboratory to convert RNA to DNA for use in molecular cloning, RNA sequencing, polymerase chain reaction (PCR), or genome analysis

15. Why codons are redundant?

Degeneracy of codons is the redundancy of the genetic code, exhibited as the multiplicity of three-base pair codon combinations that specify an amino acid. The degeneracy of the genetic code is what accounts for the existence of synonymous mutations. Degeneracy of the genetic code was identified by Lagerkvist. For instance, codons GAA and GAG both specify glutamic acid and exhibit redundancy; but, neither specifies any other amino acid and thus are not ambiguous or demonstrate no ambiguity. The codons encoding one amino acid may differ in any of their three positions; however, more often than not, this difference is in the second or third position. For instance, the amino acid glutamic acid is specified by GAA and GAG codons (difference in the third position); the amino acid leucine is specified by UUA, UUG, CUU, CUC, CUA, CUG codons (difference in the first or third position); and the amino acid serine is

Specified by UCA, UCG, UCC, UCU, AGU, AGC (difference in the first, second, or third position). Degeneracy results because there are more codons than encodable amino acids. For example, if there were two bases per codon, then only 16 amino acids could be coded for ($4^2=16$). Because at least 21 codes are required (20 amino acids plus stop) and the next largest number of bases is three, then 4^3 gives 64 possible codons, meaning that some degeneracy must exist.

16. Why codons are sensible?

The gene is represented by the sequences of bases in the DNA molecule, which can, in a sense, be thought of as a "storage molecule" for genetic information. DNA is extremely stable, a property critical to the maintenance of the integrity of the gene. This stability is evidenced by the fact that DNA has been extracted from Egyptian mummies and extinct animals such as the woolly mammoth. It can be extracted from dried blood or from a single hair at a crime scene. Each cell contains a complete set of genes, but only certain of these genes are active or "expressed" at any one time. When a gene is active, a "disposable" copy is transcribed from the gene into codons contained in a messenger RNA (mRNA) molecule. Unlike the DNA molecule, the mRNA molecule is relatively unstable and short-lived. This is so that when a gene is turned off, the mRNA does not remain in the cell forever, running off more proteins on the ribosomes that are no longer needed by the cell.

17. Why redundancy concept of genetic code does not apply to all amino acids?

The genetic code is said to be redundant in that the same amino acid residue can be encoded by multiple, so-called synonymous, codons. If all properties of synonymous codons were entirely

equivalent, one would expect that they would be equally distributed along protein coding sequences. However, many studies over the last three decades have demonstrated that their distribution is not entirely random. It has been postulated that certain codons may be translated by the ribosome faster than others and thus their non-random distribution dictates how fast the ribosome moves along particular segments of the mRNA. The reasons behind such segmental variability in the rates of protein synthesis, and thus polypeptide emergence from the ribosome, have been explored by theoretical and experimental approaches. Predictions of the relative rates at which particular codons are translated and their impact on the nascent chain have not arrived at unequivocal conclusions. This is probably due, at least in part, to variation in the basis for classification of codons as “fast” or “slow”, as well as variability in the number and types of genes and proteins analyzed. Recent methodological advances have allowed nucleotide-resolution studies of ribosome residency times in entire transcriptomes, which confirm the non-uniform movement of ribosomes along mRNAs and shed light on the actual determinants of rate control. Moreover, experiments have begun to emerge that systematically examine the influence of variations in ribosomal movement and the fate of the emerging polypeptide chain.

18. Explain wobble hypothesis.

Even before the genetic code had been elucidated, Francis Crick postulated that base pairing of the mRNA codons with the tRNA anticodons would require precision in the first two nucleotide positions but not so in the third position (the precise conformation of **base pairs**, which refers to the **hydrogen bonding** between A-T (A-U in RNA) and C-G pairs is known as Watson-Crick base pairing). The third position, in general, would need to be only a purine (A or G) or a pyrimidine (C or U). Crick called this phenomenon wobble. This less than precise base pairing would require fewer tRNA species. For example, tRNA^{Glu} could pair with either GAA or GAG codons. In looking at the codon table, one can see that, for the most part, the first two letters are important to specify the particular amino acid. The only exceptions are AUG (Met) and UGG (Trp) which, as indicated above, have only one codon each.

19. What are all the exceptions to the universal genetic code?

Organism	Normal codon	Usual meaning	New meaning
Mammalian	AGA, AGG	Arginine	Stop codon
Mitochondria	AUA	Isoleucine	Methionine
	UGA	Stop codon	Tryptophan
Drosophila	AGA, AGG	Arginine	Serine
Mitochondria	AUA	Isoleucine	Methionine
	UGA	Stop codon	Tryptophan
Yeast	AUA	Isoleucine	Methionine
Mitochondria	UGA	Stop codon	Tryptophan
	CUA, CUU	CUC, CUG, Leucine	Threonine
Higher plant	UGA	Stop codon	Tryptophan
Mitochondria	CGG	Arginine	Tryptophan

Protozoan nuclei		UAA, UAG	Stop codons	Glutamine
Mycoplasma bacteria	capricolum	UGA	Stop codon	Tryptophan

20. Explain Lysogeny.

Lysogeny, or the **lysogenic cycle**, is one of two cycles of viral reproduction (the lytic cycle is the other). Lysogeny is characterized by integration of the bacteriophage nucleic acid into the host bacterium's genome or formations of a circular replicon in the bacterium's cytoplasm. In this condition the bacterium continues to live and reproduce normally. The genetic material of the bacteriophage, called prophage, can be transmitted to daughter cells at each subsequent cell division, and a later event (such as UV radiation or the presence of certain chemicals) can release it, causing proliferation of new phages via the lytic cycle. Lysogenic cycles can also occur in eukaryotes, although the method of DNA incorporation is not fully understood. The distinction between lysogenic and lytic cycles is that the spread of the viral DNA occurs through the usual prokaryotic reproduction, while the lytic phage is spread through the production of thousands of individual phages capable of surviving and infecting other cells. The key difference between the lytic cycle and the lysogenic cycle is that the lysogenic cycle does not lyse the host cell.^[2] Phages that replicate only via the lytic cycle are known as virulent phages while phages that replicate using both lytic and lysogenic cycles are known as temperate phages. In the lysogenic cycle, the phage DNA first integrates into the bacterial Chromosome to produce the prophage. When the bacterium reproduces, the prophage is also copied and is present in each of the daughter cells. The daughter cells can continue to replicate with the prophage present or the prophage can exit the bacterial chromosome to initiate the lytic cycle.

21. Give the importance of leader sequence

Some operons are under attenuator control, in which transcription is initiated but is halted before the mRNA is transcribed. This introductory region of the mRNA is called the leader sequence; it includes the attenuator region, which can fold back on itself, forming a stem-and-loop structure that blocks the RNA polymerase from advancing along the DNA.

22. Allolactose control of lac operon. Explain

The operon is under the control of the adjacent lacI gene, encoding the lactose repressor. The repressor is a regulatory gene. In the absence of allolactose, the inducer of the lac operon, the repressor tetramer binds to the lac operator (lacO) and prevents RNA polymerase from transcribing the operon.

23. Differentiate between positive and negative control mechanisms in bacteria.

Positive: binding of an activator (e.g., cAMP) to a DNA-binding protein (e.g., CAP) stimulates that latter's DNA binding, and so initiation by RNA polymerase.

Negative: binding of a repressor (e.g., the trp repressor) promotes DNA binding, preventing initiation.

24. Outline the effects that occur when tryptophan switches off expression of the trp operon.

Two molecules of tryptophan bind to the trp repressor (a helix-turn-helix homodimer), increasing its affinity for the operator; the two recognition helices tilt and enter the major groove about 10 bp apart to contact the edge of the relevant bases. Now, the bound complex prevents the template from attaching to the polymerase. When tryptophan is absent, the now-unoccupied repressor dissociates from the operator so the template can attach productively to the polymerase (and the operon is transcribed).

25. How does the catabolite activator protein promote expression of catabolic enzymes in bacteria?

Falling glucose levels increase the concentration of cAMP, which binds to CAP (a homodimer of a polypeptide containing a helix-turn-helix motif), promoting its affinity for target sequences embedded in the promoters of many genes encoding catabolic enzymes. Binding in the major groove narrows it, while the opposing minor groove widens; the result is a 40 kink. Now promoters attach more efficiently to polymerases, so catabolic enzymes are expressed at higher levels.

26. How was 'Dolly' the lamb cloned?

Dolly's genes are derived from the udder of a (white-faced) Finn Dorset ewe. Cells from this ewe were arrested by serum starvation in G0, fused (using an electrical pulse) with an enucleate egg (from a Scottish Blackface ewe) in meiotic metaphase II, and the reconstituted egg cultured in the ligated oviduct of a (Scottish Blackface) foster mother for 6 days. Then the egg was recovered, checked to see that it had developed into a blastocyst, reimplanted into a second (Scottish Blackface) foster mother, and allowed to develop to term (giving white-faced Dolly). Dolly's nuclear genes (excepting any mutant genes) are identical to those of her genetic mother (but not her foster mother).

27. By what mechanisms might selective gene expression be achieved?

E.g., DNA rearrangement (immunoglobulin genes) or amplification (rDNA genes) or loss (*Dipteran* embryos) or modification (methylation), alteration in the rate of transcriptional initiation (many genes) or elongation (heat-shock locus), transcript rearrangement (alternative splicing) or processing or degradation (histone mRNA), differential transport of mRNA out of the nucleus or to different locations (-actin), differential translation of mRNA, differential protein degradation or stabilization.

28. Give an example of an experiment showing that differential expression of a gene can require continuous regulation?

A typical muscle cell expresses the cell-adhesion molecule, N-CAM, on its surface. The stability of the switches involved in maintaining N-CAM expression were analyzed by fusing a mouse myoblast with a human lung fibroblast (which does not express any muscle-specific proteins); the resulting heterokaryon expressed N-CAM of both species. This suggests that a switch acting continuously on the muscle nucleus can also switch on N-CAM in the human nucleus.

29. Illustrate how the activity of rDNA genes can be inherited through mitosis.

NORs, tandem repeats of 45S rRNA genes carried on five pairs of human chromosomes with perhaps only 6 loci being transcribed, activity associated with UBF on mitotic chromosomes, those NORs carrying UBF tend to form nucleoli in daughters.

30. How would you demonstrate the effects of a maternal effect gene in *Drosophila*?

Cross the (grandparent) fly carrying the mutant maternal-effect allele with another fly carrying the same mutation (i.e., $-/+ \times -/+$). Although one-quarter of the resulting fertilized eggs are genotypically $-/-$, they contain maternal products of the $+$ gene, so the embryonic body plan is laid down normally. When such embryos reach adulthood they can be crossed with a wild-type male (i.e., $-/- \times +/+$); then, the resulting fertilized eggs have $+-$ genes in a cytoplasm that lacks any $+$ products from the mother. As a result, an apparently normal mother lays an egg that then develops abnormally.

PART B

S.N O	QUESTIONS	REFER ENCE	PAGE NO
UNIT I – CHEMISTRY OF NUCLEIC ACIDS			
1	Explain the Structure and physicochemical properties of elements in DNA and RNA	TB1	80-82
2	Describe in detail the Biological significance of differences in DNA and RNA	TB1	84-92
3	Write short notes on Primary structure of DNA. Describe the Chemical and structural qualities of 3',5'-Phosphodiester bond	TB1	94-96
4	Describe in detail the Secondary Structure of DNA by Watson & Crick model(<i>Dec 2016</i>)	TB1	97-100
5	Explain the following: Triple helix, Quadruple helix, Reversible denaturation and hyperchromic effect	TB1	112-113
6	What is Tertiary structure of DNA? Explain DNA supercoiling.	TB1	113-114
UNIT II – DNA REPLICATION & REPAIR			
1	Explain the experiment that proves semiconservative mode of replication(<i>Dec 2016</i>)	TB1	225-228
2	Explain the role of Inhibitors in DNA replication	TB1	232-235
3	Differentiate between prokaryotic and eukaryotic DNA replication	TB1	271-273
4	How are okazaki fragments generated with diagrams? (<i>Dec 2016</i>)	TB1	245, 248-250
5	Demonstrate the rolling circle mode of replication	TB1	255-258
6	What are the physical and chemical agents causing DNA mutations? (<i>Dec 2016</i>)	TB1	300
7	Give any two repair mechanisms that rectify the error due to mutations(<i>Dec 2016</i>)	TB1	306
UNIT III – TRANSCRIPTION			
1	Elucidate the Structure and function of mRNA, rRNA and tRNA	TB1	117
2	Narrate the Characteristics of promoter and enhancer sequences	TB1	316
3	Explain the process of RNA synthesis and the Proteins involved in RNA synthesis (<i>Dec 2015</i>)	TB1	317-329
4	Explain the Differences in prokaryotic and eukaryotic transcription(<i>Dec 2013</i>)	TB1	343-349
5	Explain RNA processing and 5'-Capping,	TB1	352-358
6	Describe the process of Alternative splicing, Poly 'A' tail addition and base modification	TB1	358-363
UNIT IV – TRANSLATION			
1	How will you Elucidate genetic code? What is Codon degeneracy? (<i>Dec 2013</i>)	TB1	367-378
2	Write notes on Prokaryotic and eukaryotic ribosomes	TB1	439-447

3	Narrate the Steps in translation	TB1	425-435
4	Explain the role of Inhibitors of protein synthesis.	TB1	441-443
5	What are Post- translational modifications? (<i>Dec 2015</i>)	TB1	443-445
6	Explain about origin and evolution of genetic code	TB1	369
UNIT V – REGULATION OF GENE EXPRESSION			
1	Explain the Organization of genes in prokaryotic and eukaryotic chromosomes	TB1	453-454, 502-510
2	Explain the Prokaryotic gene regulation in <i>lac</i> operon (<i>Dec 2016</i>)	TB1	456-462
3	Explain the Prokaryotic gene regulation in <i>trp</i> operon(<i>Dec 2015</i>)	TB1	479 – 480
4	Explain the Regulation of gene expression with reference to λ phage life cycle	TB1	598 – 613
5	What is operon concept? Explain in detail ara Operon in Ecoli(<i>Dec 2013</i>)		
6	Explain Hierarchical levels of gene regulation	TB1	502-510

PART C

S.N O	QUESTIO NS	REFER ENCE	PAGE NO
UNIT I – CHEMISTRY OF NUCLEIC ACIDS			
1	Describe the secondary structure of DNA with diagrams (<i>Dec 2016</i>)	TB1	97-100
2	Give an account on the forces that stabilises DNA (<i>Dec 2016</i>)	TB1	110-112
3	Give direct evidence that DNA is genetic material(<i>Dec 2013</i>)	TB1	79
UNIT II – DNA REPLICATION & REPAIR			
1	Explain the Organization of prokaryotic and eukaryotic chromosomes	TB1	209
2	What are Mutagens? Describe in detail the various types of repair mechanisms	TB1	293-305
3	Explain Telomere replication in eukaryotes	TB1	239-246
UNIT III – TRANSCRIPTION			
1	Describe the events of transcription with examples (<i>Dec 2016</i>)	TB1	315
2	How do splicing mechanism favours processing of primary transcripts? (<i>Dec 2016</i>)	TB1	359
3	Describe in detail about the post transcriptional modification in mRNA(<i>Dec 2013</i>)		
UNIT IV – TRANSLATION			
1	Explain genetic code dictionary and the properties of it and mechanisms of regulation (<i>Dec 2016</i>)	TB1	369
2	Describe the events of prokaryotic translation with diagram (<i>Dec 2016</i>)	TB1	430-435
3	What is the concept of genetic code? Describe the wobble hypothesis (<i>Dec 2013</i>)	TB1	367
UNIT V – REGULATION OF GENE EXPRESSION			
1	Explain the organisation of eukaryotic chromosome with diagrams (<i>Dec 2016</i>)	TB1	181

2	Lac operon is highly regulated. How? And give its implication in the generation of recombinant proteins (<i>Dec 2016</i>)	TB1	460
3	Explain eukaryotic gene regulation (<i>Dec 2013</i>)		

BT-8403

ENZYME TECHNOLOGY

AND

BIOTRANSFORMATION

UNIT-1 INTRODUCTION TO ENZYMES PART-A

1.what are Enzymes?

Enzymes are biomolecules that catalyze chemical/biochemical reactions and the rate is increased.

2. What are the differences between enzymes and chemical catalysts?

Enzymes are very efficient catalysts, often far superior to conventional chemical catalysts, Foremost amongst these are their specificity and selectivity not only for particular reactions but also in their discrimination between similar parts of molecules

3. List the six classes of enzymes. (May 2015)

Oxidoreductases, Transferases, hydrolases, Lyases, Isomerases and ligases.

4.What are the objectives of Enzyme Engineering?

Improved kinetic properties, Elimination of allosteric regulation, Enhanced substrate and reaction specificity, Increased thermostability, Alteration in optimal pH, Suitability for use in organic solvents, increased/decreased optimal temperature, etc.

5.What are Isozymes? Give example.

Isozymes (also known as isoenzymes) are enzymes that differ in amino acid sequence but catalyze the same chemical reaction. These enzymes usually display different kinetic parameters. An example of an isozyme is glucokinase, a variant of hexokinase

6.What are Oxidoreductases? Give example.

Oxidoreductases are involved in redox reactions, i.e., transfer of hydrogen or oxygen atoms between molecules. This class includes: dehydrogenases (hydride transfer), oxidases (e- transfer to O₂), oxygenase (oxygen atom transfer from O₂), and peroxidases (e- transfer to peroxides). Example, glucose oxidase (EC 1.1.3.4).

7.What is activation energy?

The free energy needed to elevate a molecule from its stable ground state to the unstable transition state is known as activation energy (denoted by ΔG*).

8.What are coenzymes? Give example.

An organic cofactor is commonly known as coenzyme. Some of these chemicals such as riboflavin, thiamine and folic acid.

9.What are Transferases? Give example.

Transferases catalyse the transfer of an atom or group of atoms (like acyl-, alkyl- and glycosyl groups) between two molecules. The transferred groups are different from those transferred by the other classes of enzymes like Oxidoreductases, etc. Example, aspartate aminotransferase (EC 2.6.1.1)

10.Define metallo –enzymes.

Enzymes that use a metal in the active site are called metallo-enzymes.

11.Describe the enzyme specificity.

One of the properties of enzymes that makes them so important as diagnostic and research tools is the specificity they exhibit relative to the reactions they catalyze. A few enzymes exhibit absolute specificity; that is, they will catalyze only one particular reaction. Other enzymes will be specific for a particular type of chemical bond or functional group.

12.What are Hydrolases? Give example.

Hydrolases are those enzymes, which catalyze hydrolytic reactions (and their reversals); this class includes esterases, glycosidases, proteases and lipases. Example, chymosin or rennin (EC 3.4.23.4).

13.What do you mean by the active site of an enzyme?

One particular portion of the enzyme surface has a strong affinity for the substrate

14.What are Lyases? Give example.

Lyases are involved in elimination reactions resulting in the removal of a group of atoms from the substrate molecule. This class includes aldolases, decarboxylase, dehydratases and some pectinases. Example, histidine ammonia lyase (EC 4.3.1.3).

15.What are the assumptions in induced fit model? (May 2017)

The active site is continually reshaped by interactions with the substrate as the substrate interacts with the enzyme.

16.What are Isomerases? Give example.

Isomerases catalyse the formation of isomers of molecules; they include epimerases, racemases and intramolecular transferases. Example, xylose isomerase (EC 5.3.1.5).

17.What is the role of entropy in catalysis.(Nov 2015)

Entropy is composed of translational, rotational, and internal entropies. When two molecules react without a catalyst there is a loss of rotational and translational entropies.

18.What are Ligases? Give example.

Ligases or synthetases catalyze the formation of covalent bonds between two molecules utilizing the energy obtained from hydrolysis of a nucleoside triphosphate like ATP or GTP. Example, glutathione synthase (EC 6.3.2.3).

19.What is meant by active site?(May 2015, Nov 2016)

An active site is the part of an enzyme that directly binds to a substrate and carries a reaction. It contains catalytic groups which are amino acids that promote formation and degradation of bonds. By forming and breaking these bonds, enzyme and substrate interaction promotes the formation of the transition state structure.

20.List the six classes of enzymes and brief on the role of each class. (May 2016)

class	Chemical Reaction Catalyzed	Sample Enzymes
Oxidoreductase	Oxidation-reduction in which oxygen and hydrogen are gained or lost	Cytochrome oxidase, lactate dehydrogenase
Transferase	Transfer of functional groups, such as an amino group, acetyl group, or phosphate group	Acetate kinase, alanine deaminase
Hydrolase	Hydrolysis (addition of water)	Lipase, sucrose
Lyase	Removal of groups of atoms without hydrolysis	Oxalate decarboxylase, isocitrate lyase
Isomerase	Rearrangement of atoms within a molecule	Glucose-phosphate isomerase, alanine racemase
Ligase	Joining of two molecules (using energy usually derived from the breakdown of ATP)	Acetyl-CoA synthetase, DNA ligase

21.Outline the concept of active site and energetics of ES complex formation (May 2016)

- The enzyme's active site binds to the substrate.
- Increasing the temperature generally increases the rate of a reaction, but dramatic changes in temperature and pH can denature an enzyme, thereby abolishing its action as a catalyst.
- The induced fit model states an enzyme binds to an active site and both change shape slightly, creating an ideal fit for catalysis.
- When an enzyme binds its substrate it forms an enzyme-substrate complex.
- Enzymes promote chemical reactions by bringing substrates together in an optimal orientation, thus creating an ideal chemical environment for the reaction to occur.
- The enzyme will always return to its original state at the completion of the reaction.

22.Explain the Koshland Induced fit Hypothesis (Nov 2015)

Daniel E Koshland formulated this hypothesis in 1959. According to this hypothesis the active site does not

have a rigid lock and key conformation. The binding of the substrate molecule to the enzyme molecule induces to modify the shape of the active site so that it becomes complementary to the substrate molecule. This is called induced fit. Induced fit is possible because of the flexibility of the protein molecules.

23.What are monomeric and oligomeric enzymes? Give examples (Nov 2016)

Enzymes having only one polypeptide chain are called monomeric enzymes. eg. DNA Polymerase Enzymes formed by non covalent bonding of a few monomers are called oligomeric enzymes. eg. pyruvate kinase.

PART B

1. How the enzyme commission developed a system of classification and its recommendations on nomenclature. (Nov 2015, Nov 2016)

The first general principle of these 'Recommendations' is that names purporting to be names of enzymes, especially those ending in -ase, should be used only for single enzymes, i.e. single catalytic entities. They should not be applied to systems containing more than one enzyme. When it is desired to name such a system on the basis of the overall reaction catalysed by it, the word system should be included in the name. For example, the system catalysing the oxidation of succinate by molecular oxygen, consisting of succinate dehydrogenase, cytochrome oxidase, and several intermediate carriers, should not be named succinate oxidase, but it may be called the succinate oxidase system. Other examples of systems consisting of several structurally and functionally linked enzymes (and cofactors) are the pyruvate dehydrogenase system, the similar 2-oxoglutarate dehydrogenase system, and the fatty acid synthase system

The second general principle is that enzymes are principally classified and named according to the reaction they catalyse. The chemical reaction catalysed is the specific property that distinguishes one enzyme from another, and it is logical to use it as the basis for the classification and naming of enzymes.

Several alternative bases for classification and naming had been considered, e.g. chemical nature of the enzymes (whether it is a flavoprotein, a hemoprotein, a pyridoxal-phosphate protein, a copper protein, and so on), or chemical nature of the substrate (nucleotides, carbohydrates, proteins, etc.). The first cannot serve as a general basis, for only a minority of enzymes have such identifiable prosthetic groups. The chemical nature of the enzyme has, however, been used exceptionally in certain cases where classification based on specificity is difficult, for example, with the peptidases (subclass EC 3.4). The second basis for classification is hardly practicable, owing to the great variety of substances acted upon and because it is not sufficiently informative unless the type of reaction is also given. It is the overall reaction, as expressed by the formal equation, that should be taken as the basis. Thus, the intimate mechanism of the reaction, and the formation of intermediate complexes of the reactants with the enzyme is not taken into account, but only the observed chemical change produced by the complete enzyme reaction. For example, in those cases in which the enzyme contains a prosthetic group that serves to catalyse transfer from a donor to an acceptor (e.g. flavin, biotin, or pyridoxal-phosphate enzymes) the name of the prosthetic group is not normally included in the name of the enzyme. Nevertheless, where alternative names are possible, the mechanism may be taken into account in choosing between them.

A consequence of the adoption of the chemical reaction as the basis for naming enzymes is that a systematic name cannot be given to an enzyme until it is known what chemical reaction it catalyses. This applies, for example, to a few enzymes that have so far not been shown to catalyse any chemical reaction, but only isotopic exchanges; the isotopic exchange gives some idea of one step in the overall chemical reaction, but the reaction as a whole remains unknown.

A second consequence of this concept is that a certain name designates not a single enzyme protein but a group of proteins with the same catalytic property. Enzymes from different sources (various bacterial, plant or animal species) are classified as one entry. The same applies to isoenzymes (see below). However, there are exceptions to this general rule. Some are justified because the mechanism of the reaction or the substrate specificity is so different as to warrant different entries in the enzyme list. This applies, for example, to the two cholinesterases, EC 3.1.1.7 and 3.1.1.8, the two citrate hydro- lyases, EC 4.2.1.3 and 4.2.1.4, and the two amine oxidases, EC 1.4.3.4 and 1.4.3.6. Others are mainly historical, e.g. acid and alkaline phosphatases (EC

3.1.3.1 and EC 3.1.3.2).

A third general principle adopted is that the enzymes are divided into groups on the basis of the type of reaction catalysed, and this, together with the name(s) of the substrate(s) provides a basis for naming individual enzymes. It is also the basis for classification and code numbers

Special problems attend the classification and naming of enzymes catalysing complicated transformations that can be resolved into several sequential or coupled intermediary reactions of different types, all catalysed by a single enzyme (not an enzyme system). Some of the steps may be spontaneous non-catalytic reactions, while one or more intermediate steps depend on catalysis by the enzyme. Wherever the nature and sequence of intermediary reactions is known or can be presumed with confidence, classification and naming of the enzyme should be based on the first enzyme- catalysed step that is essential to the subsequent transformations, which can be indicated by a supplementary term in parentheses, e.g. acetyl-CoA:glyoxylate C-acetyltransferase (thioester- hydrolysing, carboxymethyl-forming) (EC 2.3.3.9)

The first Enzyme Commission, in its report in 1961, devised a system for classification of enzymes that also serves as a basis for assigning code numbers to them. These code numbers, prefixed by EC, which are now widely in use, contain four elements separated by points, with the following meaning:

- the first number shows to which of the six main divisions (classes) the enzyme belongs,
- the second figure indicates the subclass,
- the third figure gives the sub-subclass
- the fourth figure is the serial number of the enzyme in its sub-subclass.

The subclasses and sub-subclasses are formed according to principles indicated below. The main divisions and subclasses are:

Class 1. Oxidoreductases.

To this class belong all enzymes catalysing oxidoreduction reactions. The substrate that is oxidized is regarded as hydrogen donor. The systematic name is based on donor:acceptor oxidoreductase. The common name will be dehydrogenase, wherever this is possible; as an alternative, reductase can be used. Oxidase is only used in cases where O₂ is the acceptor

The second figure in the code number of the oxidoreductases, unless it is 11, 13, 14 or 15, indicates the group in the hydrogen (or electron) donor that undergoes oxidation: 1 denotes a -CHOH- group, 2 a -CHO or -CO-COOH group or carbon monoxide, and so on, as listed in the key.

The third figure ,except in subclasses EC1.11,EC1.13,EC1.14 and EC1.15 indicates the type of acceptor involved: 1 denotes NAD(P)+,2 a cytochrome ,3 molecular oxygen,4 a disulfide. 5 a quinone or similar compound ,6 a nitrogenous group, 7 an iron- sulfur protein and 8 a flavin. In subclasses EC1.13 and EC 1.14 a different classification scheme is used and sub-subclasses are numbered from 11 onwards.

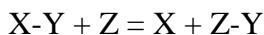
It should be noted that in reactions with a nicotinamide coenzyme this is always regarded as acceptor, even if this direction of the reaction is not readily demonstrated. The only exception is the subclass EC 1.6, in which NAD(P)H is the donor; some other redox catalyst is the acceptor.

Although not used as a criterion for classification, the two hydrogen atoms at carbon-4 of the dihydropyridine ring of nicotinamide nucleotides are not equivalent in that the hydrogen is transferred stereospecifically.

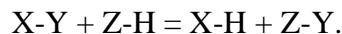
Class 2. Transferases

Transferases are enzymes transferring a group, e.g. a methyl group or a glycosyl group, from one compound (generally regarded as donor) to another compound (generally regarded as acceptor). The systematic names are formed according to the scheme donor:acceptor grouptransferase. The common names are normally formed according to acceptor grouptransferase or donor grouptransferase. In many cases, the donor is a cofactor (coenzyme) charged with the group to be transferred. A special case is that of the transaminases (see below).

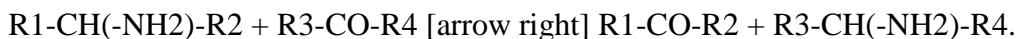
Some transferase reactions can be viewed in different ways. For example, the enzyme- catalysed reaction ,



may be regarded either as a transfer of the group Y from X to Z, or as a breaking of the X-Y bond by the introduction of Z. Where Z represents phosphate or arsenate, the process is often spoken of as 'phosphorolysis' or 'arsenolysis', respectively, and a number of enzyme names based on the pattern of phosphorylase have come into use. These names are not suitable for a systematic nomenclature, because there is no reason to single out these particular enzymes from the other transferases, and it is better to regard them simply as Y-transferasesIn the above reaction, the group transferred is usually exchanged, at least formally, for hydrogen, so that the equation could more strictly be written as:



Another problem is posed in enzyme-catalysed transaminations, where the -NH₂ group and -H are transferred to a compound containing a carbonyl group in exchange for the =O of that group, according to the general equation:



The reaction can be considered formally as oxidative deamination of the donor (e.g. amino acid) linked with reductive amination of the acceptor (e.g. oxo acid), and the transaminating enzymes (pyridoxal- phosphate proteins) might be classified as oxidoreductases. However, the unique distinctive feature of the reaction is the transfer of the amino group (by a well-established mechanism involving covalent substrate-coenzyme intermediates), which justified allocation of these enzymes among the transferases as a special subclass (EC 2.6.1, transaminases).

The second figure in the code number of transferases indicates the group transferred; a one-carbon group in EC 2.1, an aldehydic or ketonic group in EC 2.2, an acyl group in EC 2.3 and so on .

The third figure gives further information on the group transferred; e.g. subclass EC 2.1 is subdivided into methyltransferases (EC 2.1.1), hydroxymethyl- and formyltransferases (EC 2.1.2) and so on; only in subclass EC 2.7, does the third figure indicate the nature of the acceptor group.

Class 3. Hydrolases.

These enzymes catalyse the hydrolytic cleavage of C-O, C-N, C-C and some other bond, including phosphoric anhydride bonds. Although the systematic name always includes hydrolase, the common name is, in many cases, formed by the name of the substrate with the suffix -ase. It is understood that the name of the substrate with this suffix means a hydrolytic enzyme.

A number of hydrolases acting on ester, glycosyl, peptide, amide or other bonds are known to catalyse not only hydrolytic removal of a particular group from their substrates, but likewise the transfer of this group to suitable acceptor molecules. In principle, all hydrolytic enzymes might be classified as transferases, since hydrolysis itself can be regarded as transfer of a specific group to water as the acceptor. Yet, in most cases, the reaction with water as the acceptor was discovered earlier and is considered as the main physiological function of the enzyme. This is why such enzymes are classified as hydrolases rather than as transferases.

Some hydrolases (especially some of the esterases and glycosidases) pose problems because they have a very wide specificity and it is not easy to decide if two preparations described by different authors (perhaps from different sources) have the same catalytic properties, or if they should be listed under separate entries. An example is vitamin A esterase (formerly EC 3.1.1.12, now believed to be identical with EC 3.1.1.1). To some extent the choice must be arbitrary; however, separate entries should be given only when the specificities are sufficiently different.

Another problem is that proteinases have 'esterolytic' action; they usually hydrolyse ester bonds in appropriate substrates even more rapidly than natural peptide bonds. In this case, classification among the peptide hydrolases is based on historical priority and presumed physiological function.

The second figure in the code number of the hydrolases indicates the nature of the bond hydrolysed; EC 3.1 are the esterases; EC 3.2 the glycosylases, and so on.

The third figure normally specifies the nature of the substrate, e.g. in the esterases the carboxylic ester hydrolases (EC 3.1.1), thioester hydrolases (EC 3.1.2), phosphoric monoester hydrolases (EC 3.1.3); in the glycosylases the O-glycosidases (EC 3.2.1), N-glycosylases (EC 3.2.2), etc. Exceptionally, in the case of the peptidyl-peptide hydrolases the third figure is based on the catalytic mechanism as shown by active centre studies or the effect of pH.

Class 4. Lyases.

Lyases are enzymes cleaving C-C, C-O, C-N, and other bonds by elimination, leaving double bonds or rings, or conversely adding groups to double bonds. The systematic name is formed according to the pattern substrate group-lyase. The hyphen is an important part of the name, and to avoid confusion should not be omitted, e.g. hydro-lyase not 'hydrolyase'. In the common names, expressions like decarboxylase, aldolase, dehydratase (in case of elimination of CO₂, aldehyde, or water) are used. In cases where the reverse reaction is much more important, or the only one demonstrated, synthase (not synthetase) may be used in the name. Various subclasses of the lyases include pyridoxal-phosphate enzymes that catalyse the elimination of a β - or γ -substituent from an α -amino acid followed by a replacement of this substituent by some other group. In the overall replacement reaction, no unsaturated end-product is formed; therefore, these enzymes might formally be classified as alkyl-transferases (EC 2.5.1...). However, there is ample evidence that the replacement is a two-step reaction involving the transient formation of enzyme-bound α,β (or β,γ)-unsaturated amino acids. According to the rule that the first reaction is indicative for classification, these enzymes are correctly classified as lyases. Examples are tryptophan synthase (EC 4.2.1.20) and cystathionine β -synthase (EC 4.2.1.22).

The second figure in the code number indicates the bond broken: EC 4.1 are carbon-carbon lyases, EC 4.2 carbon-oxygen lyases and so on.

The third figure gives further information on the group eliminated (e.g. CO₂ in EC 4.1.1, H₂O in EC 4.2.1).

Class 5. Isomerases.

These enzymes catalyse geometric or structural changes within one molecule. According to the type of isomerism, they may be called racemases, epimerases, cis-trans-isomerases, isomerases, tautomerases, mutases or cycloisomerases.

In some cases, the interconversion in the substrate is brought about by an intramolecular oxidoreduction (EC 5.3); since hydrogen donor and acceptor are the same molecule, and no oxidized product appears, they are not classified as oxidoreductases, even though they may contain firmly bound NAD(P)+.

The subclasses are formed according to the type of isomerism, the sub-subclasses to the type of substrates.

Class 6. Ligases.

Ligases are enzymes catalysing the joining together of two molecules coupled with the hydrolysis of a diphosphate bond in ATP or a similar triphosphate. The systematic names are formed on the system X:Y ligase (ADP-forming). In earlier editions of the list the term synthetase has been used for the common names. Many authors have been confused by the use of the terms synthetase (used only for Group 6) and synthase (used throughout the list when it is desired to emphasize the synthetic nature of the reaction). Consequently NC-IUB decided in 1983 to abandon the use of synthetase for common names, and to replace them with names of the type X-Y ligase. In a few cases in Group 6, where the reaction is more complex or there is a common name for the product, a synthase name is used (e.g. EC 6.3.2.11 and EC 6.3.5.1).

It is recommended that if the term synthetase is used by authors, it should continue to be restricted to

the ligase group.

The second figure in the code number indicates the bond formed: EC 6.1 for C-O bonds (enzymes acylating tRNA), EC 6.2 for C-S bonds (acyl-CoA derivatives), etc. Sub-subclasses are only in use in the C-N ligases.

In a few cases it is necessary to use the word other in the description of subclasses and sub-subclasses. They have been provisionally given the figure 99, in order to leave space for new subdivisions. From time to time, some enzymes have been deleted from the List, while some others have been renumbered. However, the old numbers have not been allotted to new enzymes; rather the place has been left vacant and cross-reference is made according to the following scheme:

[EC 1.2.3.4 Deleted entry: old name] or

[EC 1.2.3.4 Transferred entry: now EC 5.6.7.8 - common name].

2. Write short note on (i) Development of enzyme (ii) Induced-Fit Model. (Nov 2016)

The word enzyme literally means “in yeast” (en=in, zyme=yeast). This is originated from the fact that ethyl alcohol and CO₂ are produced by the enzyme ‘zymase’, which is present in yeast cells.

The term ‘enzyme’ was introduced by Kuhne in 1878, although the first observation of enzyme activity in a test tube was reported by Payen and Persoz in 1833

(By the active agent (ferments) breaking down sugar to alcohol- called “diastase” first and now “amylase”.)

In 1897, Buchner observed the cell extract from yeast which fermented sugar even though no living cells were present. Model of enzyme action was proposed by Michaelis and Menten in 1913.

In 1926, Sumner crystallized for the first time an enzyme (urease).

The transition state theory of enzyme action was put forth by Pauling in 1948, and in 1951 Pauling and Corey discovered the α -helix and β -sheet structures of enzymes.

Sanger in 1953 determined the amino acid sequence of a protein (insulin). In 1986, Cech discovered catalytic RNA, while Lerner and Schultz developed catalytic antibodies

Enzymes are amazingly fast at catalyzing reactions and without them chemical reactions

During 1890's Fisher suggested the 'lock and key' model of enzyme action, while a mathematical in the body would be considerably slower than they are. More than a century ago, in 1894, Emil Fischer proposed that enzymes worked their magic via a model called the lock and key model, which is still used today. However, a more precise model proposed by Daniel Koshland in the 1950s, the induced fit model, is also used.

Daniel Koshland's Induced Fit Model

The induced fit model is an elaboration on the basic idea of the lock and key model. In this model, though, the key and the enzyme active site do not fit perfectly together. Instead, the substrate interacts with the active site, and both change their shape to fit together. This still means that only particular substrates can fit each enzyme type though.

Changes in Structure During the Induced Fit

The basis of chemical reactions is a change in atom arrangement and bonds between atoms. When the substrate interacts with the enzyme it undergoes a chemical reaction that allows the atoms to move relative to each other, the bonds to possibly lengthen or shorten and the most reactive groups to move closer to each other, causing a shape change. This shape change makes the substrate more amenable to alteration, as it holds the substrate in a transitional state, which helps speed up the reaction that that enzyme catalyzes.

Advantages of the Induced Fit Model

With the induced fit model, the way that the substrate has to change its structure may be useful in terms of the catalysis itself. It may represent the beginning of the reaction that the enzyme is catalyzing. Conversely, in the lock and key model, the catalysis follows after the substrate fits into the enzyme.

2. Mathematically explain in detail about the transition and collision theory and Compare.

Collision theory basically states that reactants need to do two things for a reaction to occur. They need to slam into one another with sufficient force

They also need to be at the correct angle

Turns out that getting a reaction to occur is a little like trying to stuff a shopping cart into a long row of shopping carts. If you don't line them up properly, then they won't fit together. If you don't shove your cart in hard enough, then your cart will not fit inside the other carts. And, of course, there also have to be other carts

Row of Shopping Cart, Uh, who's driving this thing?

(Source) Let's discuss this a little more scientifically. We can calculate how often molecules or atoms slam into one another, and it's described as the collision frequency (Z). We can also estimate the fraction (f) of the total number of collisions that will overcome the activation energy needed to get a reaction started. Finally, we can estimate how many collisions will happen with atoms or molecules lined up properly (l).

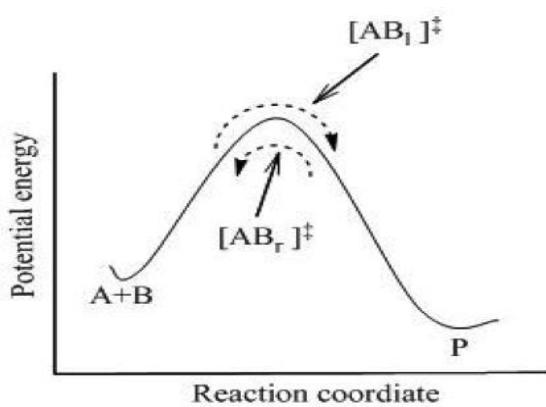
Using these factors, chemists have found that collision theory can be expressed mathematically. The rate constant $k = Z \times f \times l$. Just to be clear, the rate constant, k , is not the same as the rate of the reaction. Rather, the rate constant is used to calculate the rate of the reaction.

One of the things that collision theory helps to explain is why increasing temperatures result in an increase in reaction rates. Collision frequency increases with increasing temperature because atoms and molecules move more rapidly at higher temperatures. Temperature also increases the energy of collisions, which increases the value of f . Essentially, increasing temperature is a two-for-one deal for increasing the rate constant.

Transition-state theory goes hand-in-hand with collision theory. Transition-state theory states that a reaction follows a distinct reaction path that involves bonds being formed and being broken simultaneously. It's basically like watching a reaction in super-slow-motion, where atoms or molecules move and change position. Bond breaking and formation require energy, which is the reason that reactions have an **activation energy** to overcome. Remember, activation energy is the minimum amount of energy needed for a reaction to occur.

Another important concept in transition-state theory is the idea of an **activated complex**. Basically, the activated complex is a weird hybrid thing that is formed which is neither reactants nor products. As two reactants come closer and closer together, the atoms in each molecule start to move in response. Bonds between the reactants may start to break and new product bonds may start to form.

Activated complexes are highly unstable and are not observed *because* they are unstable. The activated complex is the point in a reaction where its **potential energy** is highest



4.(i). Explain any three reactions involving oxidoreductase.

Oxidation and reduction. Enzymes that carry out these reactions are called **oxidoreductases**. For example, alcohol dehydrogenase converts primary alcohols to aldehydes



In this reaction, ethanol is converted to acetaldehyde, and the *cofactor*, NAD, is converted to NADH. In

other words, ethanol is oxidized, and NAD is reduced. (The charges don't balance, because NAD has some other charged groups.) Remember that in redox reactions, one substrate is oxidized and one is reduced.
Accepted name: alcohol dehydrogenase

Reaction: (1) a primary alcohol + NAD^+ = an aldehyde + $\text{NADH} + \text{H}^+$
(2) a secondary alcohol + NAD^+ = a ketone + $\text{NADH} + \text{H}^+$

Other name(s): aldehyde reductase; ADH; alcohol dehydrogenase (NAD); aliphatic alcohol dehydrogenase; ethanol dehydrogenase; NAD-dependent alcohol dehydrogenase; NAD-specific aromatic alcohol dehydrogenase; NADH-alcohol dehydrogenase; NADH-aldehyde dehydrogenase; primary alcohol dehydrogenase; yeast alcohol dehydrogenase

Systematic name: alcohol:NAD⁺ oxidoreductase

Comments: A zinc protein. Acts on primary or secondary alcohols or hemi-acetals with very broad specificity; however the enzyme oxidizes methanol much more poorly than ethanol. The animal, but not the yeast, enzyme acts also on cyclic secondary alcohols.

Accepted name: aldehyde dehydrogenase (NAD)

Reaction: an aldehyde + $\text{NAD}^+ + \text{H}_2\text{O}$ = a carboxylate + $\text{NADH} + \text{H}^+$

Other name(s): CoA-independent aldehyde dehydrogenase; *m*-methylbenzaldehyde dehydrogenase; NAD-aldehyde dehydrogenase; NAD-dependent 4-hydroxynonenal dehydrogenase; NAD-dependent aldehyde dehydrogenase; NAD-linked aldehyde dehydrogenase; propionaldehyde dehydrogenase; aldehyde dehydrogenase (NAD)

Systematic name: aldehyde:NAD⁺ oxidoreductase

Comments: Wide specificity, including oxidation of D-glucuronolactone to D-glucarate. Formerly EC 1.1.1.70.

Accepted name: dihydropyrimidine dehydrogenase (NAD⁺)

Reaction: (1) 5,6-dihydrouracil + NAD^+ = uracil + $\text{NADH} + \text{H}^+$

(2) 5,6-dihydrothymine + NAD^+ = thymine + $\text{NADH} + \text{H}^+$

Other name(s): dihydropyrimidine dehydrogenase; dihydrothymine dehydrogenase; pyrimidine reductase; thymine reductase; uracil reductase; dihydrouracil dehydrogenase (NAD⁺)

Systematic name: 5,6-dihydropyrimidine:NAD⁺ oxidoreductase

Comments: An iron-sulfur flavoenzyme. The enzyme was originally discovered in the uracil-fermenting bacterium, *Clostridium uracilicum*, which utilizes uracil and thymine as nitrogen and carbon sources for growth. Since then the enzyme was found in additional organisms including *Alcaligenes eutrophus*, *Pseudomonas* strains and *Escherichia coli*.

(ii) Explain the Strain and transition state Mechanism of enzyme action (Nov 2016)

This is the principal effect of induced fit binding, where the affinity of the enzyme to the transition state is greater than to the substrate itself. This induces structural rearrangements which strain substrate bonds into a position closer to the conformation of the transition state, so lowering the energy difference between the substrate and transition state and helping catalyze the reaction. However, the strain effect is, in fact, a ground state destabilization effect, rather than transition state stabilization effect. Furthermore, enzymes are very flexible and they cannot apply large strain effect.

In addition to bond strain in the substrate, bond strain may also be induced within the enzyme itself to activate

For example:

Substrate, bound substrate, and transition state conformations of lysozyme.



The substrate, on binding, is distorted from the half chair conformation of the hexose ring (because of the steric hindrance with amino acids of the protein forcing the equatorial C6 to be in the axial position) into the chair conformation

residues in the active site.

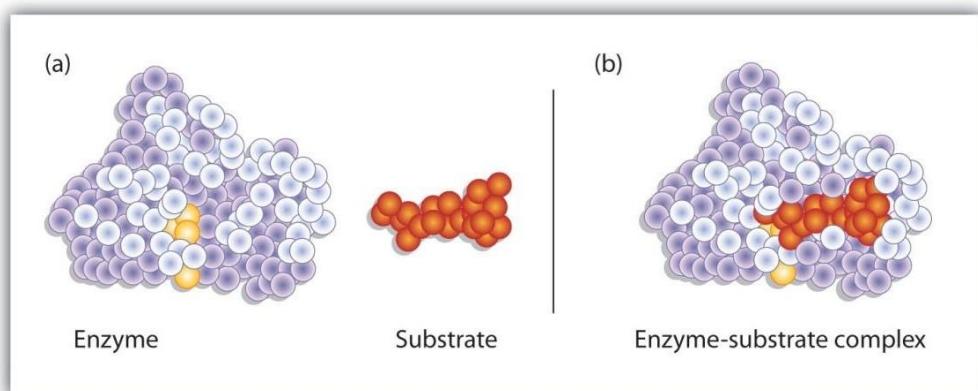
5.Explain with neat diagram the various models of enzyme action on substrate.

Enzyme-catalyzed reactions occur in at least two steps. In the first step, an enzyme molecule (E) and the substrate molecule or molecules (S) collide and react to form an intermediate compound called the *enzyme-substrate* (E–S) complex. (This step is reversible because the complex can break apart into the original substrate or substrates and the free enzyme.) Once the E–S complex forms, the enzyme is able to catalyze the formation of product (P), which is then released from the enzyme surface:



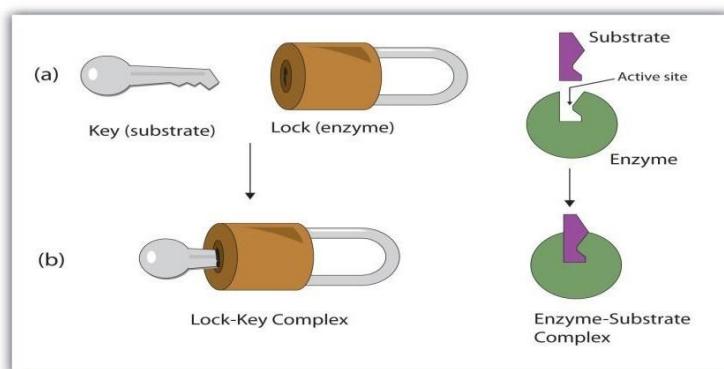
Hydrogen bonding and other electrostatic interactions hold the enzyme and substrate together in the complex. The structural features or functional groups on the enzyme that participate in these interactions are located in a cleft or pocket on the enzyme surface. This pocket, where the enzyme combines with the substrate and transforms the substrate to product is called the active site of the enzyme. It possesses a unique conformation (including correctly positioned bonding groups) that is complementary to the structure of the substrate, so that the enzyme and substrate molecules fit together in much the same manner as a key fits into a tumbler lock. In fact, an early model describing the formation of the enzyme-substrate complex was called the lock-and-key model. This model portrayed the enzyme as conformationally rigid and able to bond only to substrates that exactly fit the active site.

Substrate Binding to the Active Site of an Enzyme



The enzyme dihydrofolate reductase is shown with one of its substrates: NADP⁺ (a) unbound and (b) bound. The NADP⁺ (shown in red) binds to a pocket that is complementary to it in shape and ionic properties.

The Lock-and-Key Model of Enzyme Action

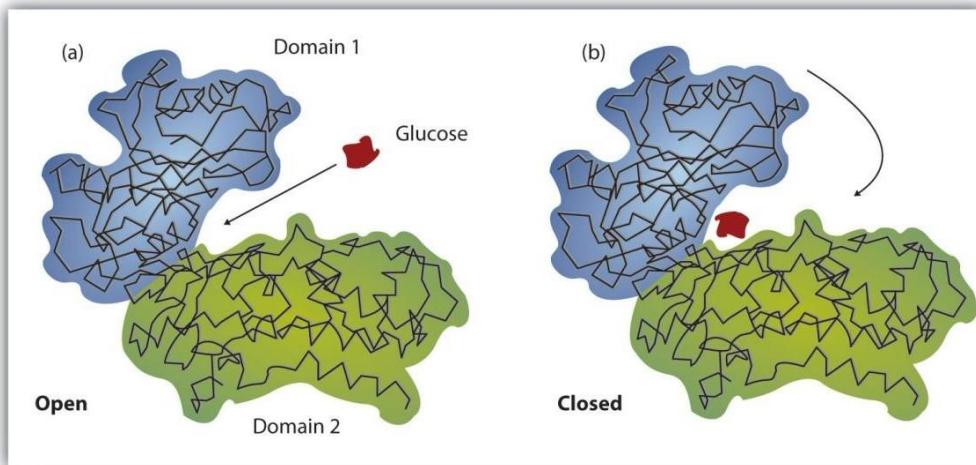


(a) Because the substrate and the active site of the enzyme have complementary structures and bonding groups, they fit together as a key fits a lock. (b) The catalytic reaction occurs while the two are bonded together in the enzyme-substrate complex.

Working out the precise three-dimensional structures of numerous enzymes has enabled chemists to refine the original lock-and-key model of enzyme actions. They discovered that the binding of a substrate often leads to a large conformational change in the enzyme, as well as to changes in the structure of the substrate or

substrates. The current theory, known as the induced-fit model, says that enzymes can undergo a change in conformation when they bind substrate molecules, and the active site has a shape complementary to that of the substrate only *after* the substrate is bound, as shown for hexokinase in Figure. After catalysis, the enzyme resumes its original structure.

The induced fit-model of enzyme action



(a) The enzyme hexokinase without its substrate (glucose, shown in red) is bound to the active site.

(b) The enzyme conformation changes dramatically when the substrate binds to it, resulting in additional interactions between hexokinase and glucose.

The structural changes that occur when an enzyme and a substrate join together bring specific parts of a substrate into alignment with specific parts of the enzyme's active site. Amino acid side chains in or near the binding site can then act as acid or base catalysts, provide binding sites for the transfer of functional groups from one substrate to another or aid in the rearrangement of a substrate. The participating amino acids, which are usually widely separated in the primary sequence of the protein, are brought close together in the active site as a result of the folding and bending of the polypeptide chain or chains when the protein acquires its tertiary and quaternary structure. Binding to enzymes brings reactants close to each other and aligns them properly, which has the same effect as increasing the concentration of the reacting compounds.

6. Write detailed note on Active site in enzymes.(Nov 2015, May 2017)

ACTIVE SITE:

The region which contains the binding and catalytic sites is termed the active site or active center of the enzyme. This comprises only a small proportion of the total volume of the enzyme and is usually at or near the surface, since it must be accessible to substrate molecules. In some cases, X – ray diffraction studies have revealed a clearly defined pocket or elect in the enzyme molecule into which the whole or part of each substrate can fit.

SALIENT FEATURES OF ACTIVE SITE:

The substrate molecules are usually much smaller than the enzyme molecules. They bind to a specific region or site of the enzyme molecule. Such sites are referred to as active site or catalytic site, which possess the following common features.

- ❖ The existence of active site is due to the tertiary or quaternary structure of the enzyme – protein molecules. Loss of native configuration leads to alterations of the active site.
- ❖ The active site of the enzyme consists of a very small portion or part of the enzyme molecule.
- ❖ The active sites are usually in the form of grooves or cervices or pockets occupying a small region in the outer surface of the enzyme molecule.
- ❖ The active site made up of amino acids – the common amino acids found at the active site are serine, asparate, histidine, lysine, cysteine, arginine, glutamate and tyrosine. Among these amino acids, serine is the most frequently found.

- ❖ The arrangement of side chains in the active site is well defined. It provides marked specificity to the enzyme molecule.
 - ❖ Water molecules are usually excluded from the active site.
 - ❖ The active site often includes both polar and non – polar amino acid residues, creating an arrangement of hydrophilic and hydrophobic microenvironment not found elsewhere on an enzyme molecule. Thus, the function of an enzyme may depend not only on the spatial arrangement of binding and catalytic sites, but also on the environment in which these sites occur.
 - ❖ Co – enzymes or cofactors are present as a part of the active sites in some enzymes.
 - ❖ Active site consists of two parts, namely, the substrate binding site and the catalytic site.
 - ❖ Only weak forces are used for binding of the substrate with its active site.
 - ❖ The configuration of the active site changes only slightly when a substrate approaches it for equilibrium.
- The following functional groups present at the active site of the enzyme molecule take part in catalysis:
- -COOH groups of dicarboxylic amino acid and terminal COOH group of a polypeptide chain.
 - -NH₂ groups of lysine and terminal NH₂ groups of a polypeptide chain.
 - Guanidine group of arginine
 - Imidazole group of histidine.
 - -OH group of serine and threonine
 - -SH group of cysteine and disulfide group of cystine
 - Phenolic group of tyrosine, etc.

7. Write detail note on (Nov 2015, May 2016, Nov 2016)

(i) Specificity of enzymes ii) Salient features of Enzymatic reactions

One of the properties of enzymes that makes them so important as diagnostic and research tools is the specificity they exhibit relative to the reactions they catalyze. A few enzymes exhibit absolute specificity; that is, they will catalyze only one particular reaction. Other enzymes will be specific for a particular type of chemical bond or functional group. In general, there are four distinct types of specificity:

Absolute specificity - the enzyme will catalyze only one reaction.

Group specificity - the enzyme will act only on molecules that have specific functional groups, such as amino, phosphate and methyl groups.

Linkage specificity - the enzyme will act on a particular type of chemical bond regardless of the rest of the molecular structure.

Stereochemical specificity - the enzyme will act on a particular steric or optical isomer.

Though enzymes exhibit great degrees of specificity, cofactors may serve many apoenzymes. For example, nicotinamide adenine dinucleotide (NAD) is a coenzyme for a great number of dehydrogenase reactions in which it acts as a hydrogen acceptor. Among them are the alcohol dehydrogenase, malate dehydrogenase and lactate dehydrogenase reactions.

Reaction specificity • The same substrate can undergo different types of reactions, each catalysed by a separate enzyme and this is referred to as reaction specificity. • An amino acid can undergo transamination, oxidative deamination, decarboxylation, racemization etc. • The enzymes however, are different for each of these reactions.

Substrate specificity • Absolute substrate specificity: • Certain enzymes act only on one substrate e.g. glucokinase acts on glucose to give glucose 6 - phosphate, urease cleaves urea to ammonia and carbon dioxide • Relative substrate specificity: • Some enzymes act on structurally related substances, May be dependent on the specific group or a bond present. • The action of trypsin is a good example for group specificity

Bond Specificity: • Most of the proteolytic enzymes are showing group (bond) specificity. • E.g. trypsin can hydrolyse peptide bonds formed by carboxyl groups of arginine or lysine residues in any proteins

Group Specificity: • One enzyme can catalyse the same reaction on a group of structurally similar

compounds, • E.g. hexokinase can catalyse phosphorylation of glucose, galactose and mannose.

i) Characteristics of enzymes are as follows:

- Enzymes possess great catalytic power.
- Enzymes are highly specific.
- Enzymes show varying degree of specificities.
- Absolute specificity where the enzymes react specifically with only one substrate.
- Stereo specificity is where the enzymes can detect the different optical isomers and react to only one type of isomer.
- Reaction specific enzymes, these enzymes as the name suggests reacts to specific reactions only.
- Group specific enzymes are those that catalyze a group of substances that contain specific substances.
- The enzyme activity can be controlled but the activity of the catalysts can not be controlled.
- All enzymes are proteins.
- Like the proteins, enzymes can be coagulated by alcohol, heat, concentrated acids and alkaline reagents.
- At higher temperatures the rate of the reaction is faster.
- The rate of the reaction involving an enzyme is high at the optimum temperature.
- Enzymes have an optimum pH range within which the enzymes function is at its peak.
- If the substrate shows deviations larger than the optimum temperature or pH, required by the enzyme to work, the enzymes do not function such conditions.
- Increase in the concentration of the reactants, and substrate the rate of the reaction increase until the enzyme will become saturated with the substrate; increase in the amount of enzyme, increases the rate of the reaction.
- Inorganic substances known as activators increase the activity of the enzyme.
- Inhibitors are substances that decrease the activity of the enzyme or deactivate it.
- Competitive inhibitors are substances that reversibly bind to the active site of the enzyme, hence blocking the substrate from binding to the enzyme.
- Incompetitive inhibitors are substances that bind to any site of the enzyme other than the active site, making the enzyme less active or inactive.

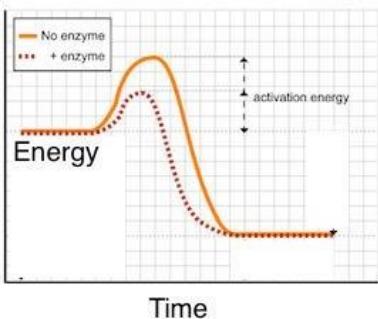
Irreversible inhibitors are substances that form bonds with enzymes making them inactive.

8. discuss in detail about mechanisms of enzymatic reaction

Enzymes speed up chemical reactions in the body, making things go faster than they normally would. But how do they accomplish this feat? Well, every reaction has an initial barrier called **activation energy**.

Activation energy is like the hump the reaction has to get over before it can get started. Even reactions that net a production of energy still need to break this barrier. Think of it like pushing a car that broke down. It's really hard to get started, but once you and your friends get some momentum going the car starts to roll and you can ease it to the side of the road.

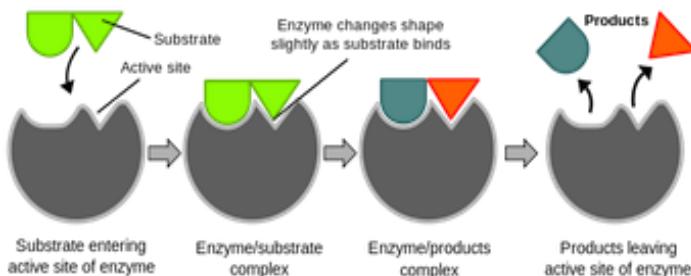
Enzymes lower the activation energy of a reaction, which helps it go faster. Some enzymes, like carbonic anhydrase, which converts carbon dioxide to bicarbonate in the blood, make the reaction proceed nearly a million times faster than without the enzyme just by lowering activation energy. How does the enzyme do this? The answer is in the way the enzyme binds the reactants it works with, called the **substrate**,



Energy used with and without an enzyme

Lock and Key Model

Enzymes and substrates are thought to bind together in a model called **lock and key**. In this model, the enzyme is considered the lock and the right key - the substrate - fits in it perfectly. Each enzyme is specific to only one or two substrates, giving the enzyme **specificity**. When the enzyme binds the substrate there is a slight change in the shape of the enzyme. It shifts slightly to fit with the substrate better. This is called **induced fit** and is thought of as an extension to the earlier lock and key model. The lock and key not only fit together, but need each other to achieve the final goal.



Induced fit model

When the enzyme binds the substrate, it holds it in a way that orients it for the reaction. For example, if two molecules are being attached by the enzyme, the enzyme holds them in a way that the sites that should be connected are easily accessible. Without the enzyme, the reactants would randomly have to land together this way, which is unlikely.

9.What are the chemical mechanisms that enzymes use to make it easier to get to the transition state?

Enzymologists have determined that a number of mechanisms seem to operate, including:

1. **Proximity.** Enzymes can bring two molecules together in solution. For example, if a phosphate group is to be transferred from ATP to glucose, the probability of the two molecules coming close together is very low in free solution. After all, there are many other molecules that the ATP and the sugar could collide with. If the ATP and the sugar can bind separately and tightly to a third component—the enzyme's active site—the two components can react with each other more efficiently.
2. **Orientation.** Even when two molecules collide with enough energy to cause a reaction, they don't necessarily form products. They have to be oriented so that the energy of the colliding molecules is transferred to the reactive bond. Enzymes bind substrates so that the reactive groups are steered to the direction that can lead to a reaction.
3. **Induced fit.** Enzymes are flexible. In this regard, they are different from solid catalysts, like the metal catalysts used in chemical hydrogenation. After an enzyme binds its substrate(s), it changes conformation and forces the substrates into a strained or distorted structure that resembles the transition state. For example, the enzyme hexokinase closes like a clamshell when it binds glucose. In this conformation, the substrates are forced into a reactive state.
4. **Reactive amino acid groups.** The side chains of amino acids contain a variety of reactive residues. For example, histidine can accept and/or donate a proton to or from a substrate. In hydrolysis reactions, an acyl group can be bound to a serine side chain before it reacts with water. Having enzymes with these catalytic functions close to a substrate increases the rate of the reactions that use them. For example, a proton bound to histidine can be donated directly to a basic group on a substrate.
5. **Coenzymes and metal ions.** Besides their amino acid side chains, enzymes can provide other reactive groups. Coenzymes are biomolecules that provide chemical groups that help catalysis. Like enzymes themselves, coenzymes are not changed during catalysis. This distinguishes them from other substrates, such as ATP, which are changed by enzyme action. Coenzymes, however, are not made of protein, as are most enzymes. Metal ions can also be found in the active sites of a number of enzymes, bound to the enzyme and

sometimes to the substrate.

10.What are enzymes? How will you classify it? What are the rules for classification and nomenclature? (Nov 2015)

Except for some of the originally studied enzymes such as pepsin, rennin, and trypsin, most enzyme names end in "ase". The International Union of Biochemistry (I.U.B.) initiated standards of enzyme nomenclature which recommend that enzyme names indicate both the substrate acted upon and the type of reaction catalyzed. Under this system, the enzyme uricase is called urate: O₂ oxidoreductase, while the enzyme glutamic oxaloacetic transaminase (GOT) is called L-aspartate: 2-oxoglutarate aminotransferase.

Enzymes can be classified by the kind of chemical reaction catalyzed.

1.Addition or removal of water

- A. Hydrolases - these include esterases, carbohydrases, nucleases, deaminases, amidases, and proteases
- B. Hydrases such as fumarase, enolase, aconitase and carbonic anhydrase

2.Transfer of electrons

- A. Oxidases
- B. Dehydrogenases

Transfer of a radical

Transglycosidases - of monosaccharides

Transphosphorylases and phosphomutases - of a phosphate group Transaminases - of amino group

Transmethylases - of a methyl group Transacetylases - of an acetyl group Splitting or forming a C-C bond

Desmolases

Changing geometry or structure of a molecule Isomerases

Joining two molecules through hydrolysis of pyrophosphate bond in ATP or other tri-phosphate Ligases

11.Explain the following (i) Principle of catalysis (ii) Role of entropy in catalysis(May 2015)

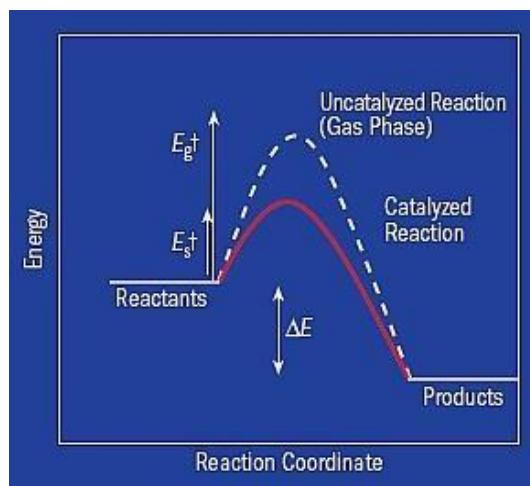
(i) Catalysis is the study of materials that can control chemical transformations. The ideal catalyst for a given chemical reaction satisfies two general criteria:

- It converts the starting chemicals (reactants) to the desired products with no production of undesired byproducts (in other words, it is perfectly selective)
- It enables the reaction to proceed at a very high rate (it is very active)
- proceed at a very high rate (it is very active)

In practice, real catalysts must compromise on one or both of these criteria, and the challenge of catalyst design is to find materials that will come as close to optimal performance as possible.

Figure 2. Potential energy surface illustrating how catalysts reduce the activation barriers of reactions.

Complex chemical reactions generally comprise many interrelated elementary reaction steps. Catalysts function by altering the kinetics and thermodynamics of the various elementary steps. By lowering the activation barrier for elementary steps that lead to desired products, for example, the catalyst can increase the rate of formation of those products (figure 2). Conversely, by raising the activation barrier for steps leading to undesired products, the catalyst can suppress the formation of those unwanted chemicals. The catalyst is thus seen to be a sort of master puppeteer, controlling the intricate interactions between different chemical species and elementary reactions to produce desired chemical products with a high degree of activity and selectivity



Catalysts can take many forms. Among the forms most actively investigated are homogeneous catalysts, wherein isolated metal atoms and associated ligands are suspended in solution, and heterogeneous catalysts, wherein metal clusters or nanoparticles are immobilized on support materials. Both types of catalysts find broad application in the fundamental sciences and industry.

UNIT 2 KINETICS OF ENZYME ACTION PART A

1. What are the factors that determine the rate of the enzymatic reaction?

Concentration of substrate, presence of inhibitors, temperature, pH etc.

2. Define Km and Vmax.(May 2016)

Km and Vmax are MichaelisMenton Parameters. Km is MichaelisMenton constant, Km is equal to S_0 at $V_{max}/2$. It is related to affinity of enzyme towards substrate. Vmax is the reaction rate when S_0 is very high.

3. What is uncompetitive inhibition?

Uncompetitive inhibition occurs when the inhibitor binds only to the enzyme–substrate complex, not to the free enzyme; the EIS complex is catalytically inactive. This mode of inhibition is rare and causes a decrease in both Vmax and the Km value.

4. What is E-H plot?

The plot between V_o and $V_o/[S_0]$ is called E-H plot.

5. Define turnover number and kcatal. (Nov 2016, May 2017)

In enzymology, turnover number (also termed kcat) is defined as the maximum number of molecules of substrate that an enzyme can convert to product per catalytic site per unit time and can be calculated as follows: $k_{cat} = V_{max}/[E]T$.

The katal (symbol: kat) is the SI unit of catalytic activity. For example, is that amount of trypsin which breaks a mole of peptide bonds per second under specified conditions.

6. What is the importance of Michaelis-Mentonquation?

M-M equation describes the kinetics of single substrate single active site enzymatic reactions. The importance of Initial velocity of the reaction for kinetics study was first insisted by M-M.

7. What are the disadvantages of M-M graphical evaluation of Km and V max?

The M-M parameters from M-M graph is highly significant because of hyperbolic shape of M-M graph.

8. What is competitive inhibition?

In competitive inhibition, the substrate and inhibitor cannot bind to the enzyme at the same time, as shown in the figure on the left. This usually results from the inhibitor having an affinity for the active site of an enzyme where the substrate also binds; the substrate and inhibitor *compete* for access to the enzyme's active

site.

9. Differentiate the sequential and ping-pong bi substrate enzyme reactions with an example.

The sequential model of allosteric regulation holds that subunits are not connected in such a way that a conformational change in one induces a similar change in the others.

10. What is Hans plot?

The plot between $[S_0]/V_o$ and $[S_0]$ is called Hans plot.

11. What is L-B Plot?

The plot between $1/V_o$ and $1/[S_0]$ is called L-B plot.

12. What is non-competitive inhibition?

Non-competitive inhibition is a form of mixed inhibition where the binding of the inhibitor to the enzyme reduces its activity but does not affect the binding of substrate. As a result, the extent of inhibition depends only on the concentration of the inhibitor.

13. Write the assumptions of Michaelis-Menton kinetics.

An equilibrium between enzyme, substrate and ES complex was instantly setup and maintained, the breakdown of ES complex to product is too slow to disturb the equilibrium.

14. What is quasi-first order reaction?

A single substrate reaction where the substrate concentration is maintained very higher, therefore the reaction is independent of substrate concentration.

15. What is substrate inhibition? Explain.

Substrate inhibition is where the substrate of an enzyme reaction inhibit the enzyme's activity.

16. What is denaturation and renaturation of Enzyme?

Denaturation is a process in which proteins lose their 3D-structure by application of some external stress or compound for example, treatment of proteins with strong acids or bases, high concentrations of inorganic salts, organic solvents (e.g., alcohol or chloroform), or heat. The original structure of some proteins can be regenerated upon removal of the denaturing agent and restoration of conditions favouring the native state. Proteins subject to this process, called renaturation, include serum albumin from blood, hemoglobin (the oxygen-carrying pigment of red blood cells), and the enzyme ribonuclease. Explain the effect of pH on enzyme action.

17. Explain the effect of pH on enzyme action.

The pH at which the rate or a suitable parameter is a maximum is called the *pH optimum* and the plot of rate or parameter against pH is called a *pH profile*.

18. What are the units to measure enzyme activity?

The katal (symbol: kat) is the SI unit of catalytic activity. Non-SI unit is Unit of Enzyme acivity.

19. What is the assumption of Briggs-Haldane on Michaelis-Menton Enzyme kinetics?

Steady state assumption is that the rate of change of ES is negligible compared to rate of change of product over the initial period of reaction, except during the very brief period.

20. What is E-C-B Plot?

The plot between V_{max} and K_m at fixed concentrations of $[S_0]$ is called E-C-B plot.

21. What are allosteric enzymes? (Nov 2015)

Allosteric enzymes, have the binding of one ligand enhances the attraction between substrate molecules and other binding sites. Example the binding of oxygen molecules to hemoglobin.

22. Explain the irreversible inhibition.

Irreversible inhibitors usually covalently modify an enzyme, and inhibition cannot therefore be reversed.

Irreversible inhibitors often contain reactive functional groups such as nitrogen mustards, aldehydes, haloalkanes or alkenes.

23. Write the unit of V_{max} and K_m .

Unit of V_{max} – mmol/mL.sec and unit of K_m is mmol/mL or mg/ml.

24. What are the different types of reversible enzyme inhibition?

Reversible inhibitors bind to enzymes with non-covalent interactions such as hydrogen bonds, hydrophobic interactions and ionic bonds. Competitive inhibition, uncompetitive inhibition, non-competitive inhibition and mixed inhibition are some types of reversible inhibition.

25. What is enzyme kinetics? (May 2015)

Enzyme kinetics is the study of the chemical reactions that are catalysed by enzymes. In enzyme kinetics, the reaction rate is measured and the effects of varying the conditions of the reaction are investigated. Studying an enzyme's kinetics in this way can reveal the catalytic mechanism of this enzyme, its role in metabolism, how its activity is controlled, and how a drug or an agonist might inhibit the enzyme.

26. What is enzyme inhibition? (May 2015)

Enzyme inhibition refers to the decrease of enzyme-related processes. The term seems to be used for two different situations:

- In enzyme production (see protein biosynthesis), inhibition refers to the halting or reduction of the production of an enzyme. This is the opposite of enzyme induction, which triggers or increases production.
- In enzyme activity, inhibition refers to the decrease of an enzyme's activity, caused by a substance called an enzyme inhibitor. The opposite of an enzyme inhibitor is called an enzyme activator.

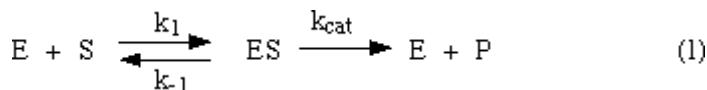
27. Define allosteric inhibitor. State the effect of it on enzyme binding. (Nov 2016)

Allosteric inhibitor is an effector molecule which binds to a site other than enzyme's active site. Thus decreasing enzymatic activity.

PART B

1. Briefly describe the kinetics of single substrate reactions and multi substrate enzyme reactions.(May 2015, May 2017)

In 1913, the German biochemist Leonor Michaelis (1875–1949) and the Canadian biochemist Maud L. Menten (1879–1960), building on the work of the French chemist Victor Henri (1872–1940), proposed a mechanism to explain the dependence of the initial rate of enzyme-catalyzed reactions on concentration. They considered the following scheme, in which ES is the enzyme–substrate complex:



In this model, the substrate S reversibly associates with the enzyme E in a first step, and some of the resulting complex ES is allowed to break down and yield the product P and the free enzyme back.

We would like to know how to recognize an enzyme that behaves according to this model. One way is to look at the enzyme's kinetic behavior -- at how substrate concentration affects its rate. So we want to know what rate law such an enzyme would obey. If a newly discovered enzyme obeys that rate law, then we can assume that it acts according to this model. Let's derive a rate law from this model.

For this model, let v_0 be the initial velocity of the reaction. The latter stands for the appearance of the product P in solution ($+ d[P]/dt$) whose **phenomenological rate equation** (first-order) is given by

$$v_0 = k_{cat}[ES] \quad (2),$$

containing an experimentally measurable (dependent) variable - v_0 , a kinetic parameter - k_{cat} , and another variable unknown to us - $[ES]$.

Before proceeding, one should state (and remember) some implicit assumptions:

- As long as initial velocity is considered, the concentration of product can be neglected (compared to that of the substrate, thus $[P] \ll [S]$), and
- The concentration of substrate is in large excess over that of the enzyme ($[E] \ll [S]$).

These assumptions, which hold in most kinetic experiments performed in test tubes at low enzyme concentration, are convenient when considering the mass conservation equations for the reactants

$[S]_0 = [S]_{\text{free}} + [ES] + [P]$ which now approximates to $[S]_0 = [S]$, while that for the enzyme is $[E]_{\text{total}} = [E]_{\text{free}} + [ES]$ (the possible formation of a complex EP is not considered here).

We want to express v_0 in terms of measurable (experimentally defined, independent) variables, like $[S]$ and $[E]_{\text{total}}$, so we can see how to test the mechanism by experiments in kinetics. So we must replace the unknown $[ES]$ in (2) with measurables.

During the initial phase of the reaction, *as long as the reaction velocity remains constant*, the reaction is in a **steady state**, with ES being formed and consumed at the same rate. During this phase, the rate of formation of $[ES]$ (one second order kinetic step) equals its rate of consumption (two first order kinetic steps). According to model(1),

Rate of formation of $[ES] = k_1[E][S]$.

Rate of consumption of $[ES] = k_{-1}[ES] + k_{\text{cat}}[ES]$.

So in the **steady state**,

$$k_{-1}[ES] + k_{\text{cat}}[ES] = k_1[E][S] \quad (3)$$

Remember that we are trying to solve for $[ES]$ in terms of measurables, so that we can replace it in (2). First, collect the kinetic constants, and the concentrations (variables) in (3):

$$(k_{-1} + k_{\text{cat}})[ES] = k_1[E][S], \quad (4)$$

and

$$(k_{-1} + k_{\text{cat}})/k_1 = [E][S]/[ES]$$

To simplify (4), first group the kinetic constants by defining them as K_m :

$$K_m = (k_{-1} + k_{\text{cat}})/k_1 \quad (5)$$

and then express $[E]$ in terms of $[ES]$ and $[E]_{\text{total}}$, to limit the number of unknowns:

$$[E] = [E]_{\text{total}} - [ES] \quad (6)$$

Substitute (5) and (6) into (4):

$$K_m = ([E]_{\text{total}} - [ES]) [S]/[ES] \quad (7)$$

Solve (7) for [ES]:

First multiply both sides by [ES] :

$$[ES] K_m = [E]_{\text{total}}[S] - [ES][S]$$

Then collect terms containing [ES] on the left:

$$[ES] K_m + [ES][S] = [E]_{\text{total}}[S]$$

Factor [ES] from the left-hand terms:

$$[ES](K_m + [S]) = [E]_{\text{total}}[S]$$

and finally, divide both sides by ($K_m + [S]$):

$$[ES] = [E]_{\text{total}} [S]/(K_m + [S]) \quad (8)$$

Substitute (8) into (2):

$$v_0 = k_{\text{cat}}[E]_{\text{total}} [S]/(K_m + [S]) \quad (9)$$

The maximum velocity V_{max} occurs when the enzyme is saturated -- that is, when all enzyme molecules are tied up with S, or $[ES] = [E]_{\text{total}}$. Thus,

$$V_{\text{max}} = k_{\text{cat}} [E]_{\text{total}} \quad (10)$$

Substitute V_{max} into (9) for $k_{\text{cat}} [E]_{\text{total}}$:

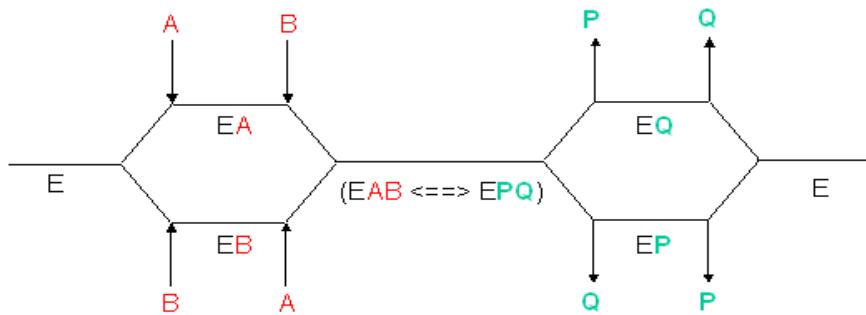
$$v_0 = V_{\text{max}} [S]/(K_m + [S]) \quad (11)$$

This equation expresses the initial rate of reaction in terms of a measurable quantity, the **initial** substrate concentration. The two kinetic parameters, V_{max} and K_m , will be different for every enzyme-substrate pair.

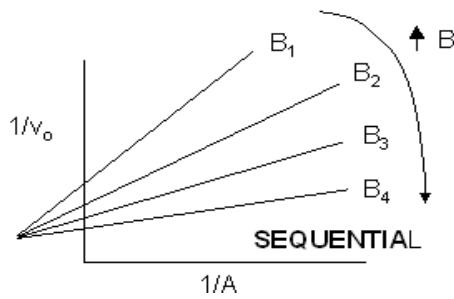
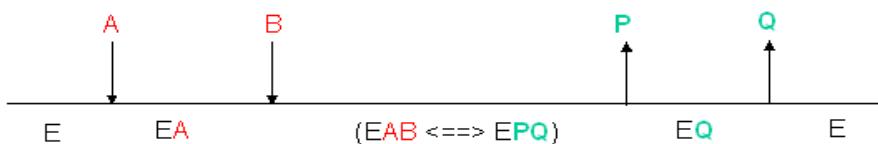
Sequential Mechanism

Sequential: Reactants (A,B) both bind before both products (P,Q) are released

A. **Random Sequential:** random order of reactants binding and products leaving



B. **Ordered Sequential:** specific order of reactants binding and products leaving



In this mechanism, both substrates must bind to the enzyme before any products are made and released. The substrates might bind to the enzyme in a random fashion (A first then B or vice-versa) or in an ordered fashion (A first followed by B). An abbreviated notationscheme developed by W.W. Cleland is shown below for the sequential random and sequential ordered mechanisms. For both mechanisms, Lineweaver-Burk plots at varying A and different fixed values of B give a series of intersecting lines. Derivative curves can be solved to obtain appropriate kinetic constants.

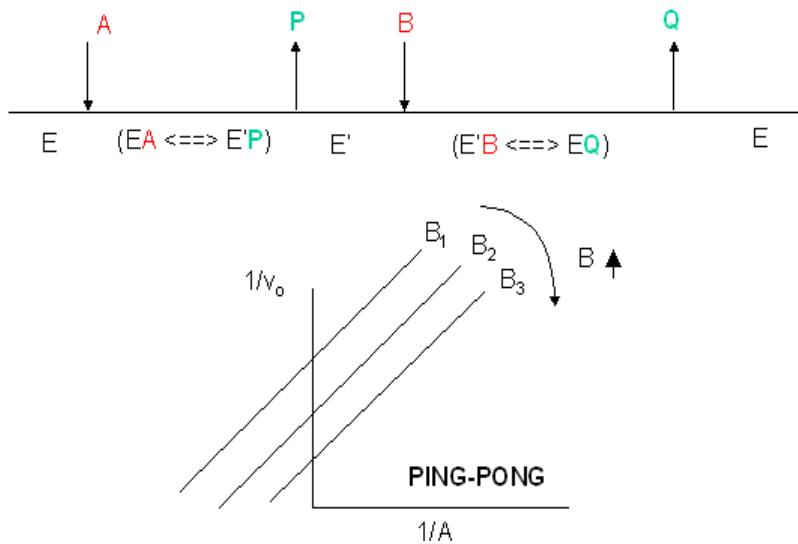
Ping-Pong Mechanism

In this mechanism, one substrate bind first to the enzyme followed by product P release. Typically, product P is a fragment of the original substrate A. The rest of the substrate is covalently attached to the enzyme E, which is designated as E'. Now the second reactant, B, binds and reacts with the enzyme to form a covalent adduct with the A as it is covalently attached to the enzyme to form product

This is now released and the enzyme is restored to its initial form, E. This represents a ping-pong mechanism. An abbreviated notation scheme is shown below for the ping-pong mechanisms. For this mechanism, Lineweaver-Burk plots at varying A and different fixed values of B give a series of parallel linesQ. An example of this type of reaction might be low molecular weight protein tyrosine phosphatase against the small substrate p-nitrophenylphosphate (A) which binds to the enzyme covalently with the expulsion of the product P, the p-nitrophenol leaving group. Water (B) then comes in and covalently attacks the enzyme, forming an adduct with the covalently bound phosphate releasing it as inorganic phosphate

In this particular example, however, you cannot vary the water concentration and it would be impossible to generate the parallel Lineweaver-Burk plots characteristic of ping-pong kinetic

Ping-Pong: Reactant A binds, followed by release of product (P), followed by binding reactant B, then release of product Q.



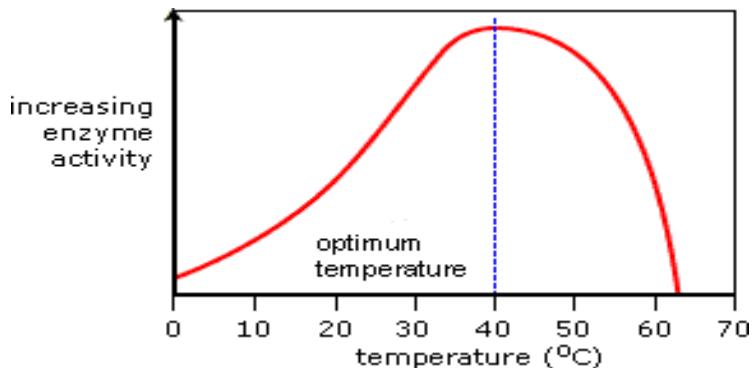
2. Describe about factors affecting enzyme

- The **activity** of an **Enzyme** is affected by its **environmental conditions**. Changing these **alter** the **rate of reaction** caused by the enzyme. In nature, organisms **adjust** the **conditions** of their enzymes to produce an **Optimum rate of reaction**, where **necessary**, or they may have enzymes which are **adapted** to function well in **extreme conditions** where they live.

Temperature

- Increasing temperature increases the **Kinetic Energy** that molecules possess. In a **fluid**, this means that there are **more random collisions** between molecules per unit time.
- Since enzymes catalyse reactions by **randomly colliding** with **Substrate molecules**, increasing temperature increases the **rate of reaction**, forming more product.
- However, increasing temperature also increases the **Vibrational Energy** that molecules have, specifically in this case **enzyme molecules**, which puts strain on the **bonds** that hold them together.
- As temperature increases, **more bonds**, especially the **weaker Hydrogen and Ionic bonds**, will break as a result of this strain. Breaking bonds within the **enzyme** will cause the **Active Site** to change shape.
- This change in **shape** means that the **Active Site** is less **Complementary** to the **shape** of the **Substrate**, so that it is less likely to catalyse the reaction. Eventually, the enzyme will become **Denatured** and will no longer function.
- As temperature increases, more enzymes' molecules' Active Sites' shapes will be less Complementary to the shape of their Substrate, and more enzymes will be Denatured. This will decrease the **rate of reaction**.
- In summary, as temperature increases, initially the **rate of reaction** will increase, because of increased Kinetic Energy. However, the effect of bond breaking will become greater and greater, and the

rate of reaction will begin to decrease.



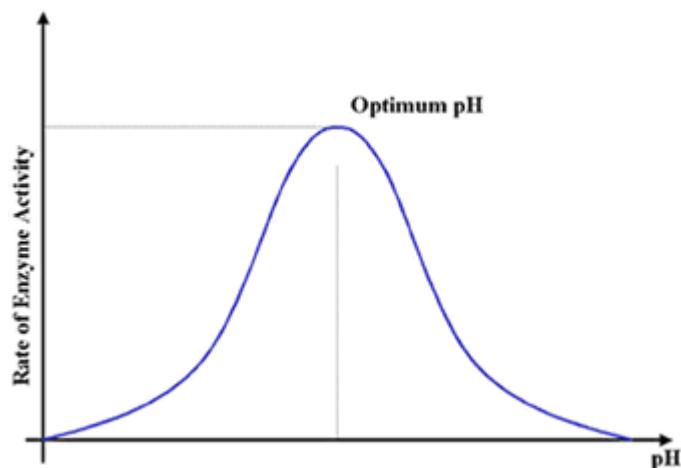
- The temperature at which the **maximum rate** of reaction occurs is called the enzyme's **Optimum Temperature**. This is different for **different enzymes**. *Most enzymes in the human body have an Optimum Temperature of around 37.0 °C.*

pH - Acidity and Basicity

pH measures the **Acidity** and **Basicity** of a solution. It is a measure of the **Hydrogen Ion (H^+) concentration**, and therefore a good indicator of the **Hydroxide Ion (OH^-) concentration**. It ranges from **pH1** to **pH14**. **Lower pH** values mean **higher H^+** concentrations and **lower OH^-** concentrations.

Acid solutions have pH values **below 7**, and Basic solutions (alkalis are bases) have pH values **above 7**. Deionised water is **pH7**, which is termed '**neutral**'.

- H^+ and OH^- Ions are **charged** and therefore **interfere** with **Hydrogen and Ionic bonds** that **hold together** an enzyme, since they will be **attracted or repelled** by the **charges** created by the bonds. This interference causes a **change in shape** of the **enzyme**, and importantly, its **Active Site**.
- **Different enzymes have different Optimum pH values**. This is the pH value at which the bonds within them are influenced by H^+ and OH^- Ions in such a way that the **shape** of their **Active Site** is the **most Complementary** to the **shape** of their **Substrate**. At the Optimum pH, the **rate** of reaction is at an optimum.
- Any **change in pH above or below the Optimum** will quickly cause a **decrease** in the **rate** of reaction, since **more** of the enzyme molecules will have **Active Sites** whose **shapes** are not (or at least are less) **Complementary** to the **shape** of their **Substrate**.



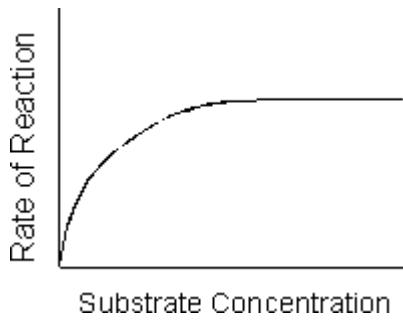
- Small changes in pH above or below the **Optimum** do **not** cause a permanent change to the enzyme, since the **bonds** can be **reformed**. However, **extreme changes** in pH can cause enzymes to **Denature** and permanently lose their function.
- Enzymes in different **locations** have **different Optimum pH** values since their **environmental conditions** may be different. *For example, the enzyme Pepsin functions best at around pH2 and is found in the stomach, which contains Hydrochloric Acid (pH2).*

Concentration

- Changing the **Enzyme** and **Substrate concentrations** affect the **rate** of reaction of an enzyme-catalysed reaction. **Controlling** these factors in a cell is one way that an organism **regulates** its **enzyme activity** and so its **Metabolism**.
- Changing the **concentration** of a **substance only** affects the rate of reaction if it is the **limiting factor**: that is, it the **factor** that is **stopping** a reaction from preceding at a **higher rate**.
- If it is the **limiting factor**, increasing concentration will **increase** the **rate** of reaction up to a **point**, after which any **increase** will **not affect** the rate of reaction. This is because it will **no longer** be the **limiting factor** and another **factor** will be **limiting** the **maximum rate** of reaction.
- As a **reaction proceeds**, the **rate of reaction** will **decrease**, since the **Substrate** will get **used up**. The **highest rate** of reaction, known as the **Initial Reaction Rate** is the **maximum reaction rate** for an **enzyme** in an **experimental situation**.

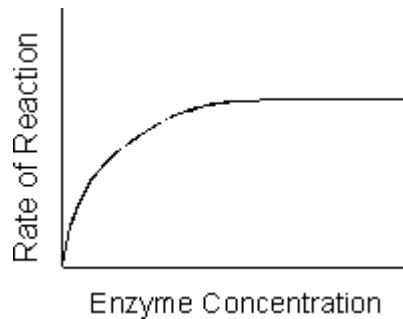
Substrate Concentration

- **Increasing Substrate Concentration increases** the **rate** of reaction. This is because **more substrate molecules** will be colliding with **enzyme molecules**, so **more product** will be formed.
- However, after a **certain concentration**, any **increase** will have **no effect** on the **rate** of reaction, since **Substrate Concentration** will **no longer** be the **limiting factor**. The **enzymes** will effectively become **saturated**, and will be working at their **maximum possible rate**.



Enzyme Concentration

- **Increasing Enzyme Concentration** will increase the **rate** of reaction, as **more enzymes** will be colliding with **substrate** molecules.
- However, this too will only have an effect up to a **certain concentration**, where the Enzyme Concentration is **no longer the limiting factor**.



2. Derive an expression for Competitive inhibition.

Enzymes play central roles in life processes. It holds for most enzymes that their function is needed only in certain conditions. When those conditions do not apply, the activity of a given enzyme can be futile or even harmful. Accordingly, the activity of most enzymes is under strict control. Enzymes can be regulated at multiple levels, ranging from transcriptional regulation of the expression of the enzyme-encoding gene through the direct regulation of the activity of the enzyme molecule by effector molecules to the controlled proteolytic decomposition of the enzyme. In this chapter, only those inhibitors will be reviewed that reversibly and specifically bind to enzymes through non-covalent interactions and inhibit the substrate-binding and/or catalytic apparatus of the given enzyme. These inhibitors can be classified into three mechanistic groups based on their mechanism of action: competitive, uncompetitive and mixed inhibitors. The type of inhibition can be determined through enzyme kinetic measurements.

Competitive inhibition

Competitive inhibitors compete for the substrate-binding site of the enzyme with the substrate, because the substrate and the inhibitor bind to identical or overlapping sites. Due to the overlapping nature of the binding sites, a ternary complex—in which the substrate and the inhibitor would simultaneously bind to the enzyme—cannot form. Accordingly, in the enzyme-inhibitor complex, the enzyme is completely inactive.

By popular—but quite misleading—terminology, these inhibitors are said to “displace” the substrate from

the enzyme. While this term is aimed to be expressive, it is totally inadequate to explain the mechanism of this type of inhibition. The popular term suggests that the inhibitor would bind to the ES complex and would thus somehow actively force the substrate to dissociate. As already mentioned, no ternary complex is formed—not even temporarily. This inhibitory mechanism simply obeys a thermodynamic principle: two equilibria exist in parallel, one between the enzyme and the inhibitor and another between the enzyme and the substrate. More precisely, the latter one is a quasi-equilibrium because, during the measurement, the enzyme and the substrate are in a steady-state (as shown in Figure 9.4). The equilibrium concentrations of the free compounds and those of the complexes are dictated by the total concentrations of the individual compounds and the affinity of their interactions.

The equilibrium between the enzyme and the inhibitor is described by Equation 1 in which the K_I term represents a dissociation constant:

$$(1) \quad K_I = \frac{[E][I]}{[EI]}$$

The two equilibria are not independent as the complexes, ES and EI, equilibrate with the same free enzyme pool, E. Increasing EI concentration by increasing the inhibitor concentration can be achieved only through a decrease in ES concentration, and vice versa: an elevated substrate concentration can increase the concentration of the ES complex only at the expense of the EI complex.

This mechanism is illustrated in Figure 1.

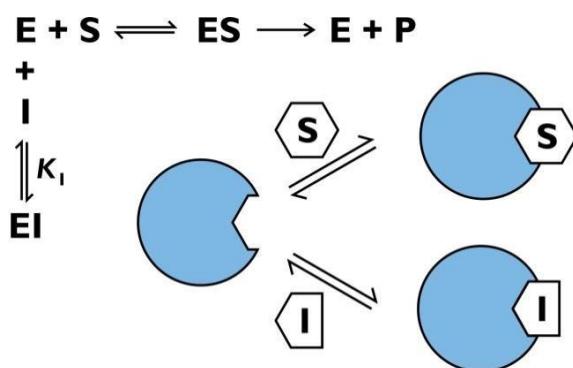


Figure 1. The scheme of competitive inhibition

When solving the Michaelis-Menten equation, we made use of the simple fact that the total enzyme concentration can be expressed as follows: $[E]_T = [E] + [ES]$. On the other hand, in the presence of a competitive inhibitor, $[E]_T = [E] + [ES] + [EI]$. Solving the Michaelis-Menten equation such that this difference is taken into consideration leads to Equation 2. (For brevity, the intermediate steps that yield this equation are not shown.)

It is readily apparent that, in the absence of inhibitor, the value of α is one and, as expected, we get the original equation. In the presence of inhibitor, the value of α exceeds one. The higher the concentration of the inhibitor compared to the value of the K_I dissociation constant, the higher the value of α . Equation 2 clearly indicates that the measured V_{max} will be invariant, regardless of the presence of the inhibitor. On the other hand, in the presence of a competitive inhibitor, the measured K_M will be higher than in the absence of the inhibitor.

$$V_0 = \frac{V_{\max}[S]}{(\alpha K_M + [S])}$$

The meaning of the term α in Equation 2 is explained in Equation 3:

$$\alpha = 1 + \frac{[I]}{K_I}$$

It is readily apparent that in the absence of inhibitor the value of alpha is one and as expected, we get the original equation. In the presence of inhibitor the value of alpha exceeds one. The higher the concentration of the inhibitor compared to the value of the K_I dissolution constant the higher the value of alpha. Equation 2 clearly indicates that the V_{\max} will remain invariant regardless of the presence of competitive inhibitor, the measured K_M will be higher than in the absence of the inhibitor. As in the case of this inhibitor type the substrate competes with the inhibitor, it is intuitively comprehensible that at infinity high substrate concentrations the presence of the inhibitor should not affect the measurements. I.e. The maximal rate of the reaction should not be changed. . However, as in the presence of a competitive inhibitor higher than normal substrate concentration is needed to achieve a (half-) maximal rate, the value of K_M must be higher than in the uninhibited case. That is exactly what Equation 2 expresses

When Equation 2 is rearranged according to the double reciprocal transformation, we get Equation 4, which is analogous to the uninhibited case:

$$\frac{1}{V_0} = \frac{\alpha K_M}{V_{\max}[S]} + \frac{1}{V_{\max}} \quad (4)$$

Equation 4 is graphically illustrated by the plots shown in Figure 2. The double reciprocal plots clearly show that, in the presence of a competitive inhibitor, the lines are steeper than in the uninhibited case; but the intercept on the y-axis, which refers to the $1/V_{\max}$ value, remains the same. The plot nicely illustrates the didactical strength of double reciprocal data analysis to demonstrate the mechanism of a reversible inhibitor.

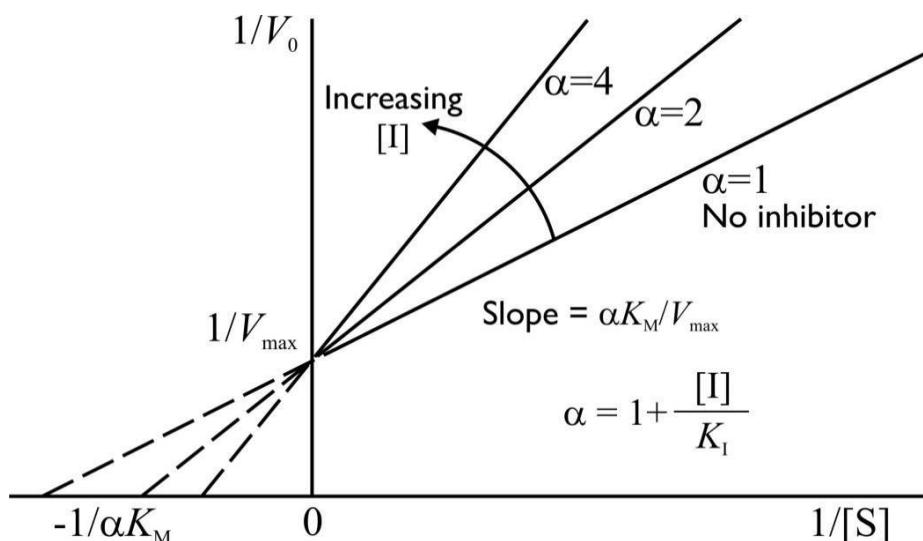


Figure 2. Double reciprocal Lineweaver-Burk analysis of competitive inhibition

As competitive inhibitors compete with the substrate for overlapping binding sites on the enzyme, it is not surprising that competitive inhibitors often resemble the substrate in terms of chemical structure, shape and polarity pattern. Due to this, competitive inhibitors are often used as useful reagents to study the substrate binding mechanism of enzymes. Comparative analysis of the structure of the substrate and that of a set of different competitive inhibitors can help in identifying the functionally most important parts of the substrate—those that provide the most binding energy in the ES complex. Note that such indirect approaches are important because direct analysis of the short-lived ES complex is a demanding scientific challenge.

4.Derive the Michaelis-Menten equation for single substrate enzyme catalysed reactions. Write the significance Michaelis-Menton parameters. (May 2016)

Ref.Question No.1

Significance of Michaelis-Menten Constant:

There are many advantages of knowing the Km values of enzyme-substrate systems:

- (i) By knowing the Km value of a particular enzyme-substrate system, one can predict whether the cell needs more enzymes or more substrate to speed up the enzymatic reaction.
- (ii) If an enzyme can catalyse a reaction with two similar substrates (e.g., glucose and fructose) in the cell, it will prefer that substrate for which the enzyme has lower Km value.
- (iii) Km value gives an approximate measure of the concentration of substrate of the enzyme in that part of the cell where reaction is occurring. For instance, those enzymes which catalyse reactions with relatively more concentrated substrates (such as sucrose), usually have relatively high Km value. On the other hand, the enzymes that react with substrates which are present in very low concentrations (such as hormones) have comparatively lower Km values for the substrates

5. Describe elaborately the different types of enzyme inhibition? Compare the competitive inhibition with uncompetitive and noncompetitive inhibition. (May 2015, May 2016)

Specific Inhibitors:

Specific Inhibitors exert their effects upon a single enzyme. Most poisons work by specific inhibition of enzymes. Many drugs also work by inhibiting enzymes in bacteria, viruses, or cancerous cells and will be discussed later.

Competitive Inhibitors:

A competitive inhibitor is any compound which closely resembles the chemical structure and molecular geometry of the substrate. The inhibitor competes for the same active site as the substrate molecule. The inhibitor may interact with the enzyme at the active site, but no reaction takes place. The inhibitor is "stuck" on the enzyme and prevents any substrate molecules from reacting with the enzyme. However, a competitive inhibition is usually reversible if sufficient substrate molecules are available to ultimately displace the inhibitor. Therefore, the amount of enzyme inhibition depends upon the inhibitor concentration, substrate concentration, and the relative affinities of the inhibitor and substrate for the active site.

Non competitive inhibitor

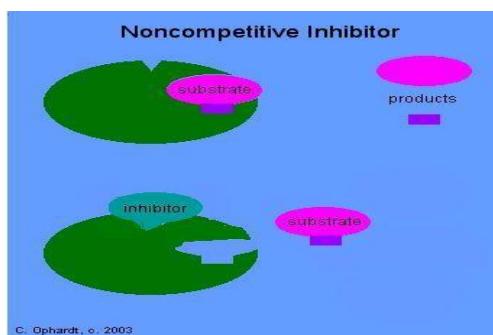
A noncompetitive inhibitor is a substance that interacts with the enzyme, but usually not at the active site.

The noncompetitive inhibitor reacts either remote from or very close to the active site. The net effect of a non competitive inhibitor is to change the shape of the enzyme and thus the active site, so that the substrate can no longer interact with the enzyme to give a reaction. Non competitive inhibitors are usually reversible, but are not influenced by concentrations of the substrate as is the case for a reversible competitive inhibitor. See the graphic on the left.

Irreversible Inhibitors form strong covalent bonds with an enzyme. These inhibitors may act at, near, or remote from the active site. Consequently, they may not be displaced by the addition of excess substrate. In any case, the basic structure of the enzyme is modified to the degree that it ceases to work.

Since many enzymes contain sulphydral (-SH), alcohol, or acid groups as part of their active sites, any chemical which can react with them acts as an irreversible inhibitor. Heavy metals such as Ag^+ , Hg^{2+} , Pb^{2+} have strong affinities for -SH groups.

Nerve gases such as diisopropylfluorophosphate (DFP) inhibit the active site of acetylcholine esterase by reacting with the hydroxyl group of serine to make an ester.



Uncompetitive inhibition

Some inhibitors bind only to the ES complex without binding to the free enzyme. This interaction scheme is illustrated in Figure 3.

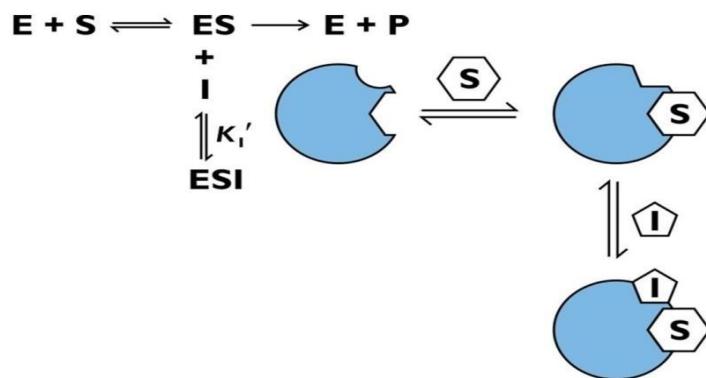


Figure 3. Uncompetitive inhibition

The kinetic equation of this type of inhibition can also be expressed as a modified version of the uninhibited case, as shown in Equation 9.57:

$$(1) \quad V_0 = \frac{V_{\max}[S]}{(K_M + \alpha'[S])}$$

The meaning of the K_I' term is shown in Equation 2:

$$(2) \quad K'_I = \frac{[ES][I]}{[ESI]}$$

However, as shown in Equation 1, α' is associated with K_I' instead of K_I :

$$(3) \quad \alpha' = 1 + \frac{[I]}{K'_I}$$

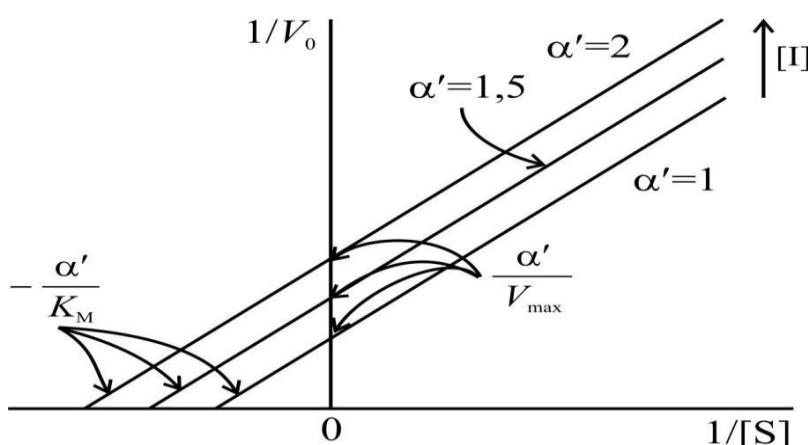
Double reciprocal transformation of Equation 1 results in Equation 4:

$$(4) \quad \frac{1}{V_0} = \frac{K_M}{V_{\max}[S]} + \frac{\alpha'}{V_{\max}}$$

A graphical illustration of Equation 4 is presented in Figure 4.

The plot clearly illustrates that both the K_M and V_{\max} values are divided by the value of α' (i.e. their reciprocal value is multiplied by the value of α'). This means that, unlike in the case of competitive inhibitors, the presence of an uncompetitive inhibitor results in a decreased V_{\max} value. Moreover, the K_M (i.e. the substrate concentration at which the reaction rate reaches its half maximum) also decreases, and it does so to exactly the same extent as the V_{\max} . As both kinetic parameters decrease to the same degree, the slopes of the lines do not change. This type of inhibition is dramatically different from the competitive one. Namely, the effect of an uncompetitive inhibitor, although its binding is reversible, cannot be abolished by increasing substrate concentration

$$\frac{1}{V_0} = \left(\frac{K_M}{V_{\max}} \right) \frac{1}{[S]} + \frac{\alpha'}{V_{\max}}$$



6. The following results were obtained at fixed total enzyme concentration

Sub. Conc. (mmol/L)	Initial velocity (absorbance/min)		
	Uninhibited	With 1 mmol/L of inhibitor 'A'	With 1 mmol/L of inhibitor 'b'
50	0.684	----	----
20	1.08	----	----
10	1.43	1.01	0.653

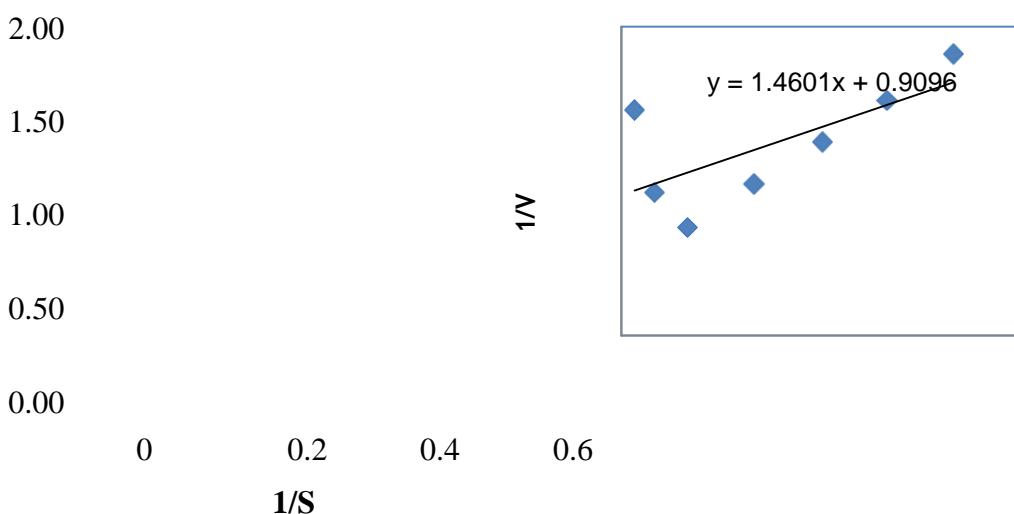
5.0	1.02	0.649	0.468
3.3	0.798	0.476	0.363
2.5	0.657	0.374	0.296
2.0	0.549	0.311	0.250

Find the type inhibition by inhibitor 'A' and 'B' and also calculate their apparent Vmax and apparent Km.

Sub. Conc . (mm o l/L)	Initial velocity (absorbance/min)			1/S	I/V for uninhibite d	I/V for inhibitor A	I/V for inhibitor B
	Uninhibi ted	With 1 mmol/L of inhibitor 'A'	With 1 mmol/L of inhibitor 'b'				
0	0.684	----	-	0.02	1.46	#VALUE!	#VALUE!

0	1.08	----	-	0.05	0.93	#VALUE!	#VALUE!
0	1.43	1.01	0.653	0.1	0.70	0.99	1.53
	1.02	0.649	0.468	0.2	0.98	1.54	2.14
.3	0.798	0.476	0.363	0.30 303	1.25	2.10	2.75
.5	0.657	0.374	0.296	0.4	1.52	2.67	3.38
	0.549	0.311	0.25	0.5	1.82	3.22	4

1/S vs 1/V for uninhibited rn



For uninhibited Reaction,

$$K_m/V_m = 1.4601$$

$$1/V_m = 0.9096 \quad i.e. V_m = 1.0994$$

$$i.e. K_m = 1.4601 * 1.0994 = 1.605$$

7. derive the monod changeux wyman model

The MWC scheme is very simple to implement at the molecular level and there are many natural molecular systems that employ this scheme. While the model is easy to implement on the molecular level, understanding how this model leads to cooperative behavior is rather tricky.

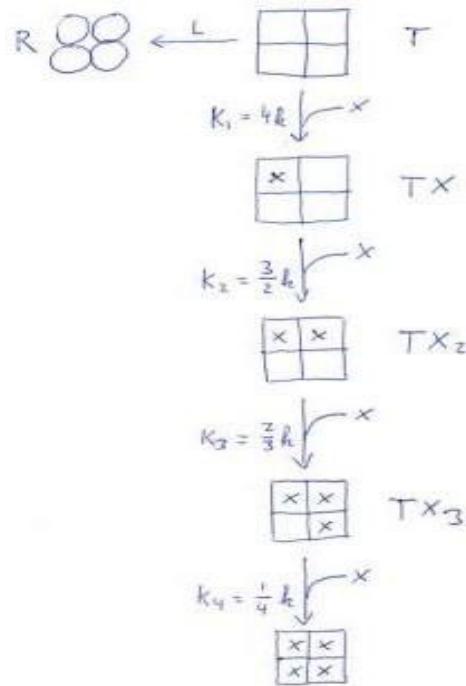
Here are the five assumptions that define the MWC model:

- 1) Identical subunits occupy equivalent positions in a protein. The contacts and environment of each of these subunits is identical.
- 2) Each subunit contains a unique receptor site for a ligand.
- 3) At least two conformational states are reversibly accessible for the protein and the microscopic binding constant for the two states differ. (To keep things simple we will assume that only one of the two forms can bind ligands i.e. the binding constant for the R state is infinitely small)
- 4) The conformational switching between these two states is concerted; the subunits are either all in one conformation, or they are all in the other conformation i.e. there are only two types of interfaces.
- 5) The microscopic binding constant for the ligand depends only on the conformational state of the protein, but not on the binding state of the other subunits.

The model

First lets look at the model then we can work through the math and see if we get the expected results. Finally we can then try to understand why the MWC model gives rise to cooperative behavior. Our system has five equilibria. The first is between the R state and the T state. R stands for relaxed and T for tense, but you could give them any other name if you want.

The other four equilibria are between the ligand bound forms. As the model states, the microscopic binding constant k between each of the monomers and the ligand is identical. However we have to apply statistical prefactors. For example there are 3 open binding sites on TX. So for each receptor we have 3 chances to go from TX to TX2, but there are only two ligand-bound monomers in TX2 giving us only 2 ways to go from TX2 back to TX. To correct for this we have to apply the statistical prefactor of $3/2$ to the binding constant k of the individual monomer to obtain the equilibrium constant $K_2 = 3/2 k = [TX_2]/([TX][X])$. After writing down our reaction scheme and identifying the statistical prefactors that relate our equilibrium constants to the microscopic binding constant k we can now write down all our equilibria. The goal as always is to write end up with an equation that relates the fraction receptor sites



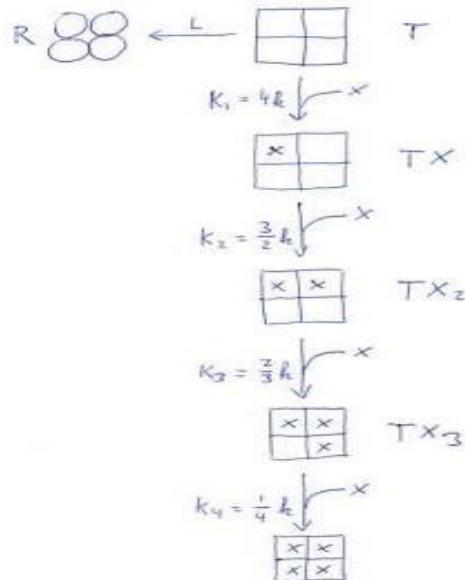
$$L = \frac{[R]}{[T]} \Rightarrow [R] = [T]L$$

$$4k = \frac{[TX]}{[T][X]} \Rightarrow [TX] = [T]4k[X]$$

$$\frac{3}{2}k = \frac{[TX_2]}{[TX][X]} \Rightarrow [TX_2] = \frac{3}{2}k[TX][X] = [T] \cdot \frac{3}{2} \cdot 4 \cdot k^2[X]^2 = [T] \cdot 6 \cdot k^2[X]^2$$

$$\frac{2}{3}k = \frac{[TX_3]}{[TX_2][X]} \Rightarrow [TX_3] = \frac{2}{3}k[TX_2][X] = [T] \cdot \frac{2}{3} \cdot \frac{3}{2} \cdot 4 \cdot k^3[X]^3 = [T] \cdot 4 \cdot k^3[X]^3$$

$$\frac{1}{4}k = \frac{[TX_4]}{[TX_3][X]} \Rightarrow [TX_4] = \frac{1}{4}k[TX_3][X] = [T] \cdot \frac{1}{4} \cdot \frac{2}{3} \cdot \frac{3}{2} \cdot 4 \cdot k^4[X]^4 = [T] \cdot k^4[X]^4$$



$$L = \frac{[R]}{[T]} \Rightarrow [R] = [T]L$$

$$4k = \frac{[TX]}{[T][X]} \Rightarrow [TX] = [T]4k[X]$$

$$\frac{3}{2}k = \frac{[TX_2]}{[TX][X]} \Rightarrow [TX_2] = \frac{3}{2}k[TX][X] = [T] \cdot \frac{3}{2} \cdot 4 \cdot k^2[X]^2 = [T] \cdot 6 \cdot k^2[X]^2$$

$$\frac{2}{3}k = \frac{[TX_3]}{[TX_2][X]} \Rightarrow [TX_3] = \frac{2}{3}k[TX_2][X] = [T] \cdot \frac{2}{3} \cdot \frac{3}{2} \cdot 4 \cdot k^3[X]^3 = [T] \cdot 4 \cdot k^3[X]^3$$

$$\frac{1}{4}k = \frac{[TX_4]}{[TX_3][X]} \Rightarrow [TX_4] = \frac{1}{4}k[TX_3][X] = [T] \cdot \frac{1}{4} \cdot \frac{2}{3} \cdot \frac{3}{2} \cdot 4 \cdot k^4[X]^4 = [T] \cdot k^4[X]^4$$

nowlets write down the

$$\bar{v} = \frac{\text{ligand sites occupied}}{\text{total # of receptors}} = \frac{[TX] + 2[TX_2] + 3[TX_3] + 4[TX_4]}{[R] + [T] + [TX] + [TX_2] + [TX_3] + [TX_4]}$$

the goal as always is to express our average number of ligands bound in terms of only the free ligand concentration and the binding and conformation equilibrium constants. Once again we do this by substituting our $[TX_i]$ by the appropriate expressions we derived above.

$$\bar{v} = \frac{\text{ligand sites occupied}}{\text{total # of receptors}} = \frac{[T]4k[X] + 2[T] \cdot 6 \cdot k^2[X]^2 + 3[T] \cdot 4 \cdot k^3[X]^3 + 4[T] \cdot k^4[X]^4}{[T]L + [T] + 4k[T][X] + [T] \cdot 6 \cdot k^2[X]^2 + [T] \cdot 4 \cdot k^3[X]^3 + [T] \cdot k^4[X]^4}$$

divide by $[T]$

$$\bar{v} = 4 \frac{k[X] + 3 \cdot k^2[X]^2 + 3 \cdot k^3[X]^3 + k^4[X]^4}{L + 1 + 4 \cdot k[X] + 6 \cdot k^2[X]^2 + 4 \cdot k^3[X]^3 + k^4[X]^4}$$

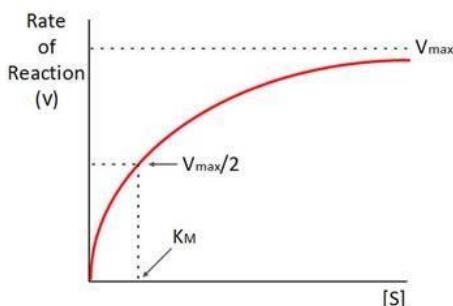
$$\bar{v} = 4 \frac{k[X](1 + 3 \cdot k[X] + 3 \cdot (k[X])^2 + (k[X])^3)}{L + 1 + 4 \cdot k[X] + 6 \cdot (k[X])^2 + 4 \cdot (k[X])^3 + (k[X])^4} = 4 \frac{k[X](1 + k[X])^3}{L + (1 + k[X])^4}$$

6. The following results were obtained for an enzyme catalyzed reaction.

Substrate conc. mmol/L	5	6.67	10	20	40
Initial velocity μmol/L.min	147	182	233	323	400

Calculate Michealis-Menten parameters using (i) graph for M-M equation (ii) LB plot (iii) E-H plot (iv) Hanes Plot

(i) Graph of M-M equation graph:



(ii)

LB Plot

Plot the graph $1/S$ Vs $1/V$ - Slope=

$$K_m/V_m \text{ Intercept}= 1/V_m$$

(iii)

E-H Plot

Plot the graph $1/S$ Vs $1/V$ - Slope= $-K_m$

$$\text{Intercept}= V_m$$

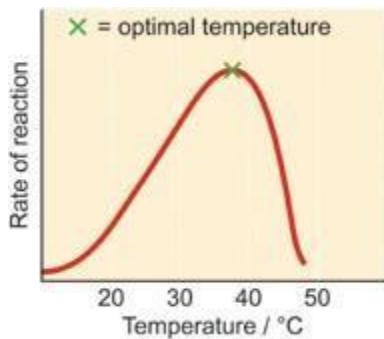
(iv)

Hanes Plot

Plot the graph $1/S$ Vs $1/V$ - Slope= $1/V_m$

Intercept= K_m/V_m

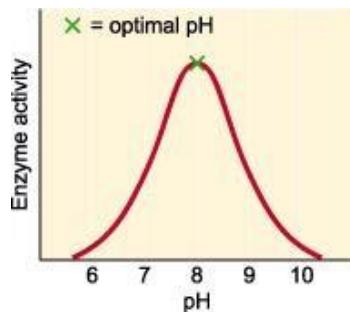
9.Explain the pH and temperature effect on enzymes & its deactivation kinetics.(Nov 2015, May 2016)



Temperature

As the temperature rises, reacting molecules have more and more kinetic energy. This increases the chances of a successful collision and so the rate increases. There is a certain temperature at which an enzyme's catalytic activity is at its greatest (see graph). This optimal temperature is usually around human body temperature (37.5 °C) for the enzymes in human cells.

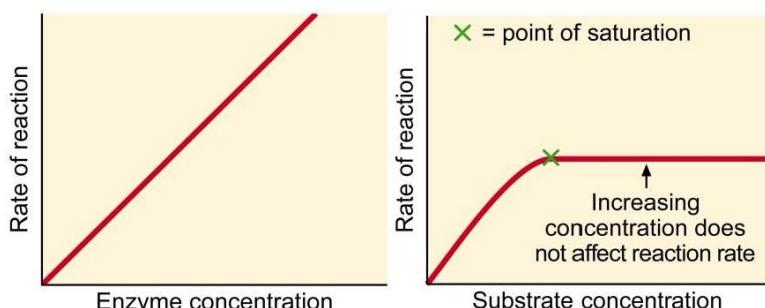
Above this temperature the enzyme structure begins to break down (**denature**) since at higher temperatures intra- and intermolecular bonds are broken as the enzyme molecules gain even more



kinetic energy.

pH

Each enzyme works within quite a small pH range. There is a pH at which its activity is greatest (the optimal pH). This is because changes in pH can make and break intra- and intermolecular bonds, changing the shape of the enzyme and, therefore, its effectiveness.



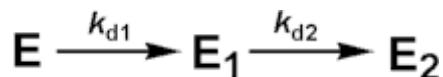
Concentration of enzyme and substrate

The rate of an enzyme-catalysed reaction depends on the concentrations of enzyme and substrate. As the concentration of either is increased the rate of reaction increases (see graphs).

For a given enzyme concentration, the rate of reaction increases with increasing substrate concentration up to a point, above which any further increase in substrate concentration produces no significant change in reaction rate. This is because the active sites of the enzyme molecules at any given moment are virtually saturated with substrate. The enzyme/substrate complex has to dissociate before the active sites are free to accommodate more substrate. (See graph)

Provided that the substrate concentration is high and that temperature and pH are kept constant, the rate of reaction is proportional to the enzyme concentration. (See graph)

b) The thermal denaturation of an enzyme may be modelled by the following serial deactivation scheme:



[1]

where k_{d1} and k_{d2} are the first-order deactivation rate coefficients, E is the native enzyme which may, or may not, be an equilibrium mixture of a number of species, distinct in structure or activity, and E_1 and E_2 are enzyme molecules of average specific activity relative to E of A_1 and A_2 . A_1 may be greater or less than unity (i.e. E_1 may have higher or lower activity than E) whereas A_2 is normally very small or zero. This model allows for the rare cases involving free enzyme (e.g. tyrosinase) and the somewhat commoner cases involving immobilised enzyme (see Chapter 3) where there is a small initial activation or period of grace involving negligible discernible loss of activity during short incubation periods but prior to later deactivation. Assuming, at the beginning of the reaction:

$$(2) \quad [E] = [E]_0$$

And(3)

$$[E_1] = [E_2] = 0$$

At time t ,

$$(4) \quad [E] + [E_1] + [E_2] = [E]_0$$

It follows from the reaction scheme [1],

$$(5) \quad -\frac{d[E]}{dt} = k_{d1}[E]$$

Integrating equation 1.25 using the boundary condition in equation 1.22 gives:

$$(6) \quad [E] = [E]_0 e^{(-k_{d1}t)}$$

From the reaction scheme 1],

$$(7) \quad -\frac{d[E_1]}{dt} = k_{d2}[E_1] - k_{d1}[E]$$

Substituting for [E] from equation 6,

$$(8) \quad -\frac{d[E_1]}{dt} = k_{d2}[E_1] - k_{d1}[E]_0 e^{(-k_{d2}t)}$$

Integrating equation 7 using the boundary condition in equation 3 gives:

$$(9) \quad [E_1] = \frac{k_{d1}[E]_0}{k_{d2} - k_{d1}} (e^{(-k_{d2}t)} - e^{(-k_{d1}t)})$$

If the term 'fractional activity' (A^f) is introduced where,

$$(10) \quad A^f = \frac{[E] + A_1[E_1] + A_2[E_2]}{[E]_0}$$

then, substituting for [E2] from equation 4, gives:

$$(11) \quad A^f = \frac{[E] + A_1[E_1] + A_2([E]_0 - [E] - [E_1])}{[E]_0}$$

therefore:

$$(12) \quad A^f = A_2 + \left(1 + \frac{A_1 k_{d1} - A_2 k_{d2}}{k_{d2} - k_{d1}} \right) e^{(-k_{d2}t)} - \frac{(A_1 - A_2) k_{d1}}{k_{d2} - k_{d1}} e^{(-k_{d1}t)}$$

When both A1 and A2 are zero, the simple first order deactivation rate expression results

$$(13) \quad A^f = e^{(-k_{d2}t)}$$

The **half-life** ($t_{1/2}$) of an enzyme is the time it takes for the activity to reduce to a half of the original activity (i.e. $A^f = 0.5$). If the enzyme inactivation obeys equation 1.33, the half-life may be simply derived,

$$(14) \quad \ln(1/2) = -k_{d1} t_{1/2}$$

therefore:

$$(15) \quad t_{1/2} = \frac{0.693}{k_{d1}}$$

10. Derive the Michaelis –Menten equation for single substrate enzyme catalyzed reactions (Nov 2015)

Ref Question no.1

11. Derive the kinetics for bisubstrate enzyme catalysed reaction by sequential mechanism. (Nov 2016)

Cleland Nomenclature for Enzymes

- Cleland has devised a standardized way of referring to bisubstrate (Bi-Bi) enzymatic reactions, which make up 60% of all enzymatic transformations. The substrates, products and stable enzyme forms are denoted as follows:
 - Substrates are lettered A, B, C and D, in the order that they are added to the enzyme
 - Products are lettered P, Q, R and S, in the order that they leave the surface of the enzyme

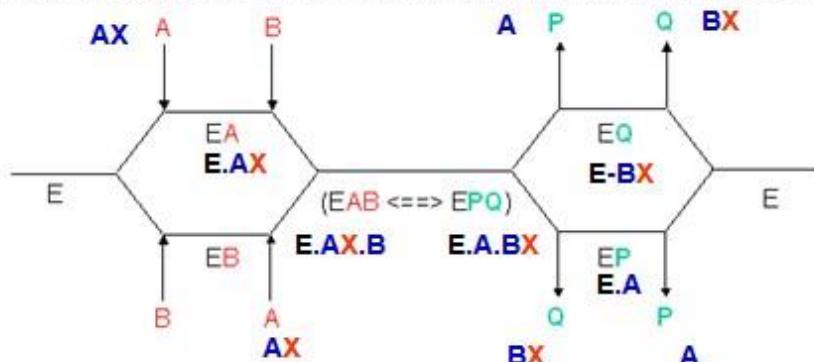
- Stable enzyme forms are lettered E, F and G, in the order that they occur
- The number of reactants in the reaction are designated by the terms Uni, Bi, Ter and Quad



These are transfer reactions so can be presented as

- The first important type of bi-bi reaction is known as sequential, which means that all substrates must add to the enzyme before any reaction takes place
- The sequential bi-bi can be
 - random, any substrate can bind first to the enzyme and any product can leave first
 - ordered, meaning that the substrates add to and products leave the enzyme in a specific order
 - A ternary complex (E + both substrates) is formed in both cases

A. Random Sequential: random order of reactants binding and products leaving



B. Ordered Sequential: specific order of reactants binding and products leaving



The general rate equation of Alberti (1953)

- Many two-substrate reactions obey the MM equation with respect to one substrate at constant concentration

$$v = \frac{V_{\max}[AX][B]}{K_m^B[AX] + K_m^{AX}[B] + [AX][B] + K_s^{AX}K_m^B}$$

- V_{\max} : max v_o when both AX and B are saturating
- K_m^{AX} : $[AX]$ which gives $1/2V_{\max}$ when B is saturating
- K_m^B : $[B]$ which gives $1/2V_{\max}$ when AX is saturating
- K_s^{AX} : dissociation constant for $E + AX \leftrightarrow EAX$

$$v = \frac{V_{\max} [AX][B]}{K_m^B [AX] + K_m^{AX}[B] + [AX][B] + K_s^{AX} K_m^B}$$

At very large [B]: $v = \frac{V_{\max} [AX]}{[AX] + K_m^{AX}}$

At constant but non saturating [B]: $v = \frac{V_{\max} K_1 [AX]}{[AX] + K_2}$

$$K_1 = \frac{[B]}{K_m^B + [B]} \quad K_2 = \frac{K_s^{AX} K_m^B + K_m^{AX} [B]}{K_m^B + [B]}$$

It works well for reactions using 1 or 2 substrate and producing 1 or 2 products but for more complex reactions, other approaches are used

General rate equation of Dalziel (1957)

$$\frac{[E]}{v} = \phi_0 + \frac{\phi_{AX}}{[AX]} + \frac{\phi_B}{[B]} + \frac{\phi_{AXB}}{[AX][B]}$$

ϕ terms: kinetic coefficients found from primary and secondary plots

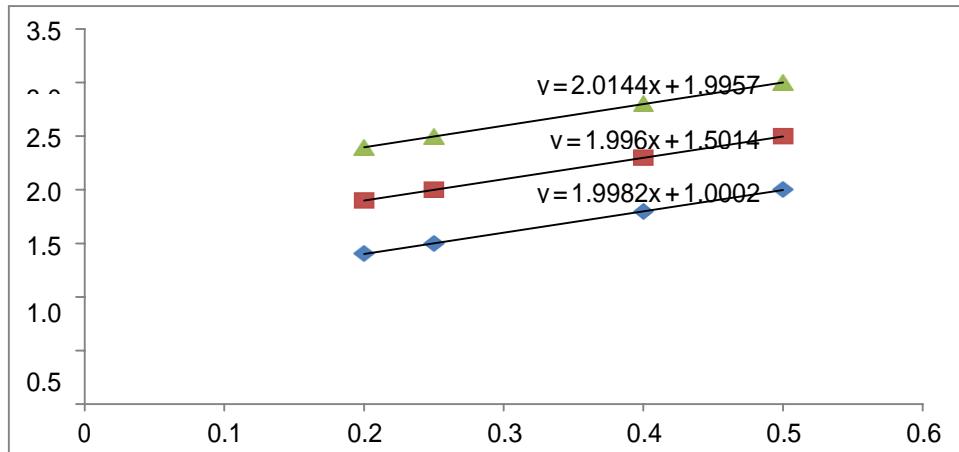
- Primary plots of $[E]/v$ versus $1/[AX]$ at constant $[B]$ are drawn for series of different $[B]$
- Secondary plots:
 - Slope vs $1/[B]$ \rightarrow intercept: ϕ_{AX} , slope: ϕ_{AXB}
 - Intercepts vs $1/[B]$ \rightarrow intercept: ϕ_0 , slope: ϕ_B

12.Explain different types of reversible enzyme inhibition. How do you distinguish them using kinetic data (May 2017)

Refer Question No.5

13.A single substrate enzyme catalysed reaction was investigated at series of inhibitor concentrations at fixed pH, temperature and enzyme concentration. Determine the type of inhibition (Nov 2016)

Initial Substrate conc. (mmol/L)	Initial velocity ($\mu\text{mol}/\text{L}\cdot\text{min}$) $I_0 = 0$	$I = 2 \text{ mmol/L}$	$I = 4 \text{ mmol/L}$
2	500	400	333
2.5	556	435	357
4	667	500	400
5	714	526	417



For Uninhibited reaction

$$K_m/V_m = 1.998$$

$$1/V_m = 1$$

For I=2 $K_m/V_m =$

$$1.996$$

$$1/V_m = 1.501$$

For I=4

$$K_m/V_m = 2.014$$

$$1/V_m = 1.995$$

UNIT 3 ENZYME IMMOBILIZATION AND BIOSENSORS

PART A

1.Define enzyme immobilization (May 2015)

Enzyme immobilization may be defined as confining the enzyme molecules to a distinct phase from the one in which the substrates and the products are present.

2.What are the methods available for the enzyme immobilization?

The various methods used for immobilization of enzymes may be grouped into the following 5 types:

- adsorption,
- covalent bonding,
- entrapment, and
- membrane confinement.

3.What are the inert supports used for the covalent immobilization?

The most commonly employed matrices are agarose, celluloses and polyacrylamides. Sepharose, an agarose, is available commercially as beads, is highly hydrophilic and is generally inert to microbial attack. Sepharose is activated by treating it with chloroformates, carbodiimides, glutaraldehyde or other compounds.

4.What is meant by encapsulation?(May 2015)

Encapsulation is another approach in enzyme immobilization by entrapping method. In this approach enzyme can be immobilized within capsules prepared from organic polymers, so that the enzyme can not escape, although low molecular weight substrates and products can enter and leave the capsule by diffusion through the membrane.

5.Why immobilized or whole cells are predominantly used rather than pure enzymes in industrial scale enzymatic conversions (May 2016)

Enzymes are costly items. Immobilization permits their repeated use. The

product is readily freed from the enzyme.

Immobilized enzymes can be used in nonaqueous systems as well.

Continuous production systems can be used, which is not possible with free enzymes.

Thermostability of some enzymes may be increased.

6.What are the types of matrixes available for enzyme immobilization?

Some of the commonly used matrices are ion exchange matrices, porous carbon, clays, hydrous metal oxides, glasses, and polymeric aromatic resins.

7.Define cross linking.

Cross-linking is the bonding that link one polymer chain to another. They can be covalent bonds or ionic bonds.

8.Give industrial applications of immobilized enzyme

Glucoamylase - Dextrans production

Penicillin amylases - Penicillin G and penicillin V Lactase

- Milk and whey

Glucose isomerase - D-glucose in glucose syrup

9.State the general application of immobilization.

Used of drug delivery and development of biosensors

10.physical method of immobilization technique is best justify

Enzymes are attached by weaker forces and it surface of the matrix, Therefore there is no mass transfer resistance and enzyme characteristics are not affected by immobilization.

11.What are the process factors to be considered for immobilization of enzyme?

Type of reactor PBR are FBR, substrate and product molecular size and liquid viscosity

12.Can the enzyme immobilized on polymeric matrix, influence reaction rate? Explain

Yes, increased mass transfer resistance affects the reaction rate in enzyme immobilized on polymeric matrix

13.Explain the entrapment method of immobilization?

Enzymes can be entrapped inside a cross linked gel matrix by allowing the gel to be formed in an aqueous solution containing one or more enzymes. The polymerization of the gel is carried out in the presence of enzyme(s). The enzyme is physically entrapped within the matrix and cannot escape by permeation.

14.List out some solid matrices & polymeric materials used for enzyme immobilization?

Alumina, amberlite CG-50, bentonite, calcium phosphate gels, carbon, car boxymethyl cellulose, carboxymethylsephadex, collagen, DEAE-cellulose, DEAE-sephadex, glass, silica gel titania (ceramics).

15.What are the reagents used to activate the functional groups on support material?

cyanogen bromide, acyl isourea and NaNO₂ + HCL.

16.Give a list of support materials for adsorbtion immobilization

Calcium phosphate gels, carbon, car boxymethyl cellulose, glasses, and polymeric aromatic resins

17.What are the disadvantages of immobilization though cross linking?

High binding force and possibility of binding on active site alters the characteristics of the enzyme

18.How the active site protected during immobilization?

Active site is protected by activation of matrices to bind the enzymes in non active sites.

19.Explain the mechanism of covalent bonding?

An enzyme can be covalently bound to support materials by different methods. The enzyme forms a covalent link with active groups of support material

20.How are polymeric matrices activated for covalent immobilization?

The reactants required to activate the support are with -OH group. Such supports can be activated for

covalent linking by treating with either triazines or cyanogen bromide. The reaction with enzyme protein in each case involves the -NH₂ group of the lysine.

21.What are major criteria for selecting support material?

The ideal carrier matrix has the following properties:

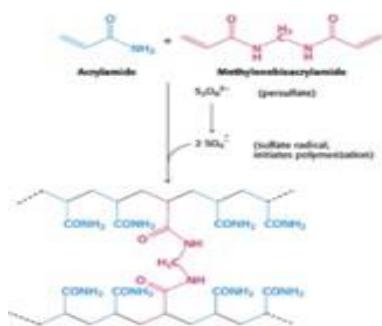
- (i) low cost,
- (ii) inertness,
- (iii) physical strength,
- (iv) stability,
- (v) regenerability after the useful lifetime of the immobilized enzyme,
- (vi) enhancement of enzyme specificity, and
- (vii) reduction in product inhibition

22.Give applications of immobilized enzymes in medical diagnosis

Glucose oxidase – Blood glucose level Urease –

Urea

23.Give the reaction mechanism in polyacrylamide gel preparation



24.what are the difference between gelentrapment and encapsulation

Both gelentrapment and encapsulation may be viewed as putting the enzyme molecule in a molecular cage. However, diffusion of the substrate to the enzyme and of the product away from the enzyme creates difficulties in gelentrapment

25.How enzymes are immobilized by cross linking?

Three types of basic approaches have been used in immobilizing enzymes by cross linking:

- (1) Cross linking of enzyme with glutaraldehyde to form an insoluble aggregate; e.g. papain.
- (2) Adsorption of enzyme onto a surface followed by cross linking; for instance, cross linking trypsin adsorbed to the surface of colloidal silica particles.
- (3) Impregnation of porous material with the enzyme followed by cross linking of the enzyme in the pores; for instance papain in collodion membrane.

26.What are biosensors?(Nov 2015)

A biosensor is an analytical device, which employs a biological material to specifically interact with an analyte; this interaction produces some detectable physical change, which is measured and converted into an electrical signal by a transducer. Finally, the electrical signal is amplified, interpreted and displayed as analyte concentration in the solution/preparation.

27.Give the classification of biosensors.

Types of biosensors

- (viii) Calorimetric biosensors
- (ix) potentiometric biosensors
- (x) amperometric biosensors
- (xi) Optical biosensors
- (xii) piezo-electric biosensors

28.What are an enzyme electrode and its application in health care? (Nov 2016)

The enzyme electrode is a combination of any electrochemical probe (amperometric, potentiometric or conductimetric) with a thin layer (10 - 200mm) of immobilised enzyme.

29.What is meant by hybrid Biosensor?

The hybrid Biosensor relates to an apparatus and method for monitoring cells and to a method for monitoring changes in cells upon addition of an analyte to the cell's environment, comprising a device which includes an array of microelectrodes disposed in a cell culture chamber, upon which array a portion of cells adhere to the surfaces of the microelectrodes.

30.Give an example on the use of enzymes in leather and detergent industry

Lipase – Leather Industry

Alkaline protease - detergent industry

31.State the application of biosensors in diagnosis

Glucose oxidase biosensor – Blood glucose Urease biosensor – Blood Urea

32.State the applications of enzymes in food and pharmaceutical industries

Rennet - milk industry Amylase –

Starch industry

Pencillin G acylase – Pencillin Industry

33.What are the main components of biosensors?

i. Biological component ii. Transducer iii. Signal processor

34.What are the physical changes accompanying with the reaction in biosensor

Analyte reacts in enzyme system and converted into product, the changes in concentration of substrate or product is converted into electrical signal by transducer ,processed and calibrated to concentration of analyte.

35.What is the function of Transducer in biosensors?

Transducer converts the changes in concentration of substrate or product into electrical.

36.What is the function of Amplifier in biosensors?

The signal produced in biological system and converted by transducer will be very low, amplifier increases the amplitude of a signal.

37.What are the three types of ion selective electrodes used in biosensors?

Glass electrodes for cations, Glass pH electrodes and Solid-state electrodes

38.Write the principle of Amperometric biosensors

Amperometric biosensors function by the production of a current when a potential is applied between two electrodes.

2. the principle of Calorimetric biosensors

Calorimetric biosensors measure the change in temperature of the solution containing the analyte following enzyme action and interpret it in terms of the analyte concentration in the solution.

3. Write the principle of Optical biosensors

The principle involves determining changes in light absorption between the reactants and products of a reaction, or measuring the light output by a luminescent process.

4. Write the principle of Immunobiosensors

Biosensors may be used in conjunction with enzyme-linked immunosorbent assays (ELISA). ELISA is used to detect and amplify an antigen-antibody reaction; the amount of enzyme-linked antigen bound to the immobilised antibody being determined by the relative concentration of the free and conjugated antigen and quantified by the rate of enzymic reaction.

5. Write the principle of Potentiometric biosensors

Potentiometric biosensors make use of ion-selective electrodes in order to transduce the biological reaction into an electrical signal.

6. Write the principle of Piezo-electric biosensors

Piezo-electric crystals (e.g. quartz) vibrate under the influence of an electric field. The frequency of this oscillation (f) depends on their thickness and cut, each crystal having a characteristic resonant frequency.

7. What are the advantages of micro-biosensors?

Decreased the detection time, more portability and these can detect pathogens rapidly and inexpensively.

8. What are the beneficial features of biosensors?

The biocatalyst must be highly specific for the purpose of the analyses, be stable under normal storage conditions and, except in the case of colorimetric enzyme strips and dipsticks (see later), show good stability over a large number of assays (i.e. much greater than 100). The reaction should be as independent of such physical parameters as stirring, pH and temperature as is manageable. This would allow the analysis of samples with minimal pre-treatment. If the reaction involves cofactors or coenzymes these should, preferably, also be co-immobilised with the enzyme. The response should be accurate, precise, reproducible and linear over the useful analytical range, without dilution or concentration. It should also be free from electrical noise. The complete biosensor should be cheap, small, portable and capable of being used by semi-skilled operators.

9. Give example for calorimetric biosensors

Cholesterol oxidase biosensor –

Cholesterol Amylase biosensor - Starch

10. Give example for potentiometric biosensors

Lipase - Lipids peroxidase -

H_2O_2 urease - urea

11. Give example for amperometric biosensors

Alcohol oxidase – Alcohol Cholesterol

oxidase - cholesterol

Glucose biosensor (based on glucose oxidase)

12. Give example for immunobiosensors

Immunosensors coupled with biological system used to detect TNT and RDX in soil and groundwater

13. List the disadvantages of entrapment technique used for enzyme immobilization(May 2016)

The disadvantages of entrapment technique used for enzyme immobilization are

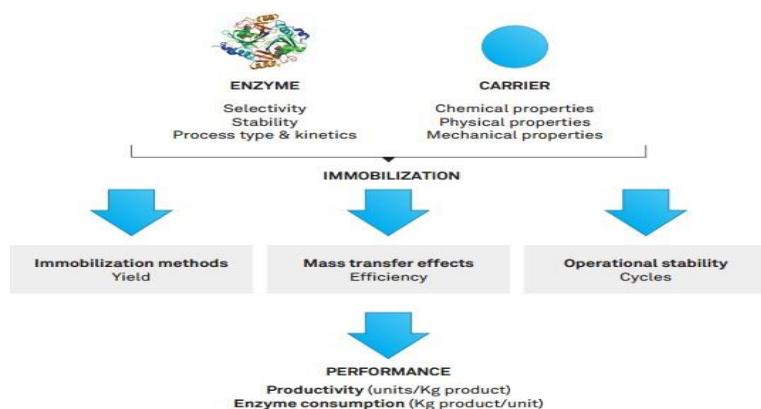
- Regeneration of enzyme is impossible
- Preparation is difficult
- Lack of control over microenvironmental conditions
- The enzyme may leak from the pores.

14. Give example for Piezoelectric biosensors

Formaldehyde - formaldehyde dehydrogenase

Diagnosis of Tularemia in brown

15. What are factors affecting the performance if immobilized enzyme?



16. What are the various factors that affect the performance of immobilized enzyme systems? (Nov 2015)

17. What are the limitations of enzyme biosensors? (May 2016)

- Heat sterilization is not possible because of denaturation of biological material,
- Stability of biological material (such as enzyme, cell, antibody, tissue, etc.), depends on the natural properties of the molecule that can be denatured under environmental conditions (pH, temperature or ions)
- The cells in the biosensor can become intoxicated by other molecules that are capable of diffusing through the membrane.

18. What are solid matrices commonly used for covalent binding of enzymes? How do you activate them? (May 2017)

Some of the commonly used matrices for covalent binding are cellulose, sephadex, sepharose, gluteraldehyde etc. Covalent bonding is directed to a specific group on the surface of the enzyme. Different methods of covalent bonding are diazotization, formation of peptide bond, group activation (use of cyanogen bromide to a support containing glucol group.) and use of polifunctional reagents.

19. What is Damköhler number? State its significance. (May 2017)

The Damköhler numbers (Da) are dimensionless numbers used in chemical engineering to relate the chemical reaction timescale (reaction rate) to the transport phenomena rate occurring in a system.

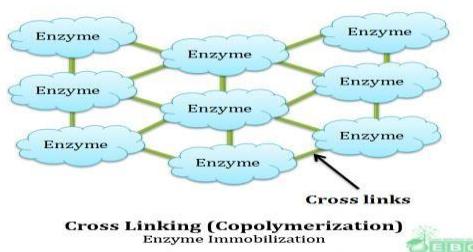
Da is associated with characteristic diffusion and reaction times therefore scaling is necessary.

- For $Da \gg 1$ the reaction rate is much greater than the diffusion rate distribution is said to be diffusion limited (diffusion is slowest so diffusion characteristics dominate and the reaction is assumed to be instantaneously in equilibrium)
- For $Da \ll 1$ diffusion occurs much faster than the reaction, thus diffusion reaches an ‘equilibrium’ well before the reaction is at equilibrium.

PART B

1. Describe the cross linking method of enzyme immobilization with its merits and demerits (Nov 2016)

(Cross linking (copolymerization):



Cross Linking (Copolymerization)
Enzyme Immobilization
www.easylifebiologyclass.com

This method is also called as copolymerization. In this method of immobilization enzymes are directly linked by covalent bonds between various groups of enzymes via polyfunctional reagents. Unlike other methods, there is no matrix or support involved in this method. Commonly used polyfunctional reagents are glutaraldehyde and diazonium salt. This technique is cheap and simple but not often used with pure enzymes. This method is widely used in commercial preparations and industrial applications. The greatest disadvantage or demerit of this method is that the polyfunctional reagents used for cross linking the enzyme may denature or structurally modify the enzyme leading to the loss of catalytic properties.

2. Give an overview of applications of immobilized enzymes

Applications of enzyme immobilization:

(1). Industrial production: Industrial production of antibiotics, beverages, amino acids etc. uses immobilized enzymes or whole cells.

(2). Biomedical applications: Immobilized enzymes are widely used in the diagnosis and treatment of many diseases. Immobilized enzymes can be used to overcome inborn metabolic disorders by the supply of immobilized enzymes. Immobilization techniques are effectively used in drug delivery systems especially to oncogenic sites.

(3). Food industry: Enzymes like pectinases and cellulases immobilized on suitable carriers are successfully used in the production of jams, jellies and syrups from fruits and vegetables.

(4). Research: A Research activity extensively uses many enzymes. The use of immobilized enzyme allow researcher to increase the efficiency of different enzymes such as Horse Radish Peroxidase (HRP) in blotting experiments and different Proteases for cell or organelle lysis.

(5). Production of bio-diesel from vegetable oils.

(6). Waste water management: treatment of sewage and industrial effluents.

(7). Textile industry: scouring, bio-polishing and desizing of fabrics.

(8). Detergent industry: immobilization of lipase enzyme for effective dirt removal from cloths.

3. i) List out the major advantages and disadvantages of immobilized enzymes over free enzymes(8)

ii) Compare physical and chemical methods of immobilization (8)

Advantages of immobilized enzymes:

- (1). Increased functional efficiency of enzyme
- (2). Enhanced reproducibility of the process they are undertaking
- (3). Reuse of enzyme
- (4). Continuous use of enzyme
- (5). Less labour input in the processes
- (6). Saving in capital cost and investment of the process
- (7). Minimum reaction time
- (8). Less chance of contamination in products
- (9). More stability of products
- (10). Stable supply of products in the market
- (11). Improved process control
- (12). *High enzyme substrate ratio*

Disadvantages of enzyme immobilization:

- (1). Even though there are many advantages of immobilized enzymes, there are some disadvantages also.
- (2). High cost for the isolation, purification and recovery of active enzyme (most important disadvantage)
- (3). Industrial applications are limited and only very few industries are using immobilized enzymes or immobilized whole cells.
- (4). Catalytic properties of some enzymes are reduced or completely lost after their immobilization on support or carrier.
- (5). Some enzymes become unstable after immobilization.
- (6). Enzymes are inactivated by the heat generated in the system

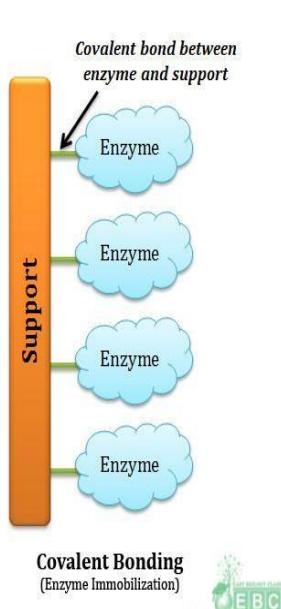
4. What is immobilization of enzymes? Explain covalent immobilization with its merits

and demerits (May 2017)

What is enzyme immobilization?

immobilization is defined as the imprisonment of cell or enzyme in a distinct support or matrix. The support or matrix on which the enzymes are immobilized allows the exchange of medium containing substrate or effector or inhibitor molecules. The practice of immobilization of cells is very old and the first immobilized enzyme was **amino acylase** of *Aspergillus oryzae* for the production of L-amino acids in Japan.

Covalent bonding:



This method involves the formation of covalent bonds between the chemical groups in enzyme and to the chemical groups on the support or carrier. It is one of the widely used methods of enzyme immobilization. Hydroxyl groups and amino groups of support or enzyme form covalent bonds more easily. Chemical groups in the support or carrier that can form covalent bonds with support are amino groups, imino groups, hydroxyl groups, carboxyl groups, thiol groups, methylthiol groups, guanidyl groups, imidazole groups and phenol ring.

Important functional groups of the enzyme that provide chemical groups to form covalent bonds with support or carrier are:

1. Alpha carboxyl group at 'C' terminal of enzyme
2. Alpha amino group at 'N' terminal of enzyme
3. Epsilon amino groups of Lysine and Arginine in the enzyme
4. β and γ carboxyl groups of Aspartate and Glutamate
5. Phenol ring of Tyrosine
6. Thiol group of Cysteine
7. Hydroxyl groups of Serine and Threonine
8. Imidazole group of Histidine
9. Indole ring of Tryptophan

Carriers or supports commonly used for covalent bonding are:

- (a). **Carbohydrates:** Eg. Cellulose, DEAE cellulose, Agarose
- (b). **Synthetic agents:** Eg. Polyacrylamide
- (c). **Protein carriers:** Collagen, Gelatin
- (d). **Amino group bearing carriers:** Eg. amino benzyl cellulose
- (e). **Inorganic carriers:** Porous glass, silica

Cyanogen bromide (CNBr)-agarose and CNBrSepharose Methods

of covalent bonding

(1). Diazoation: Bonding between amino group of support and tyrosil or histidyl group of enzyme. **(2).**

Peptide bond: Bonding between amino or carboxyl groups of the support and that of the enzyme. **(3).**

Poly functional reagents: Use of a bi-functional or multifunctional reagent (glutaraldehyde) which forms covalent bonds between the amino group of the support and amino group of the enzyme.

Advantages of covalent bonding:

- (a). Strong linkage of enzyme to the support
- (b). No leakage or desorption problem
- (c). Comparatively simple method
- (d). A variety of support with different functional groups available
- (e). Wide applicability

Disadvantages of covalent bonding (major problem with covalent bonding):

- (a). Chemical modification of enzyme leading to the loss of functional conformation of enzyme.
- (b). Enzyme inactivation by changes in the conformation when undergoes reactions at the active site. This can be overcome through immobilization in the presence of enzyme's substrate or a competitive inhibitor.

5. Describe the ionic adsorption method of enzyme immobilization with its merits and demerits(May 2017)

(1). Adsorption

Adsorption is the oldest and simplest method of enzyme immobilization. Nelson & Griffin used charcoal to adsorb invertase for the first time in 1916. In this method enzyme is adsorbed to external surface of the support. The support or carrier used may be of different types such as:

- (1). *Mineral support* (Eg. aluminum oxide, clay)
- (2). *Organic support* (Eg. starch)
- (3). *Modified sepharose and ion exchange resins*

There is no permanent bond formation between carrier and the enzyme in adsorption method. Only weak bonds stabilize the enzymes to the support or carrier. The weak bonds (low energy bonds) involved are mainly:

(a). Ionic interaction (b).

Hydrogen bonds (c). Van der Waal forces

For significant surface bonding the carrier particle size must be small (500 \AA to 1 mm diameter). The greatest advantage of adsorption method is that there will not be "pore diffusion limitations" since enzymes are immobilized externally on the support or the carrier.

Methods of adsorption:

- (1). Static process:** Immobilization to carrier by allowing the solution containing enzyme to contact the carrier without stirring.
- (2). Dynamic batch process:** Carrier is placed in the enzyme solution and mixed by stirring or agitation.
- (3). Reactor loading process:** Carrier is placed in the reactor, and then the enzyme solution is transferred to the reactor with continuous agitation.
- (4). Electrode position process:** Carrier is placed near to an electrode in an enzyme bath and then the current is put on, under the electric field the enzyme migrates to the carrier and deposited on its surface.

Advantages of adsorption method: (a). No pore

diffusion limitation (b). Easy to carry out

- (c). No reagents are required
- (d). Minimum activation steps involved
- (e). Comparatively cheap method of immobilization
- (f). Less disruptive to enzyme than chemical

methods

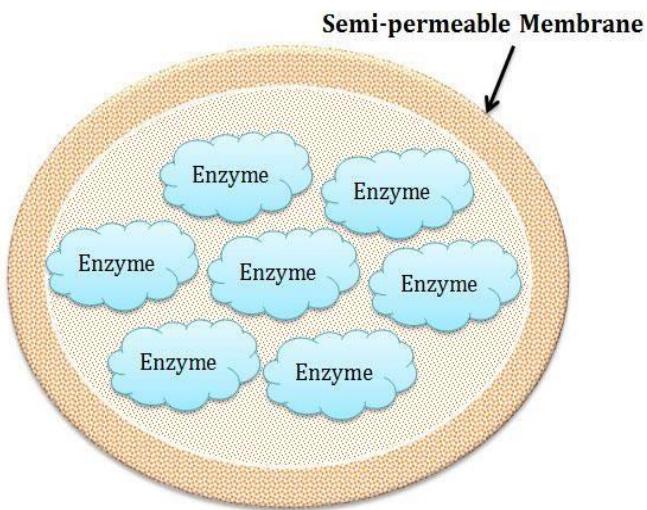
Disadvantages of adsorption method:

- (a). Desorption of enzymes from the carrier
- (b). Efficiency is less

6. Discuss the microencapsulation of enzymes. Give its merits and demerits(May 2017)

Encapsulation:

This type of immobilization is done by enclosing the enzymes in a membrane capsule. The capsule will be made up of semi permeable membrane like nitro cellulose or nylon. In this method the effectiveness depends upon the stability of enzymes inside the capsule.



Encapsulation
(Enzyme Immobilization)

Advantages of encapsulation:

- (a). Cheap and simple method
- (b). Large quantity of enzymes can be immobilized by encapsulation

Disadvantages of encapsulation:

- (a). Pore size limitation
- (b). Only small substrate molecule is able to cross the membrane

7. describe the methods of immobilization of enzymes using membranes with advantages and examples

Membrane confinement of enzymes may be achieved by a number of quite different methods, all of which depend for their utility on the semipermeable nature of the membrane. This must confine the enzyme whilst allowing free passage for the reaction products and, in most configurations, the substrates. The simplest of these methods is achieved by placing the enzyme on one side of the semipermeable membrane whilst the reactant and product stream is present on the other side. Hollow fibre membrane units are available commercially with large surface areas relative to their contained volumes ($> 20 \text{ m}^2 \text{ L}^{-1}$) and permeable only to substances of molecular weight substantially less than the enzymes. Although costly, these are very easy to use for a wide variety of enzymes (including regenerating coenzyme systems, without the additional research and development costs associated with other immobilisation methods. Enzymes, encapsulated within small membrane-bound droplets or liposomes may also be used within such reactors. As an example of the former, the enzyme is dissolved in an aqueous solution of 1,6-diaminohexane. This is then dispersed in a solution of hexanedioic acid in the immiscible solvent, chloroform. The resultant reaction forms a thin polymeric (Nylon-6,6) shell around the aqueous droplets which traps the enzyme. Liposomes are concentric spheres of lipid

membranes, surrounding the soluble enzyme. They are formed by the addition of phospholipid to enzyme solutions. The micro-capsules and liposomes are washed free of non-confined enzyme and transferred back to aqueous solution before use.

Table: Generalised comparison of different enzyme immobilisation techniques.

Characteristics	Adsorption	Covalent binding	Entrapment	Membrane confinement
Preparation	Simple	Difficult	Difficult	Simple
Cost	Low	High	Moderate	High
Binding force	Variable	Strong	Weak	Strong
Enzyme leakage	Yes	No	Yes	No

Applicability	Wide	Selective	Wide	Very wide
Running Problems	High	Low	High	High
Matrix effects	Yes	Yes	Yes	No
Large diffusional barriers	No	No	Yes	Yes
Microbial protection	No	No	Yes	Yes

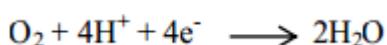
8. Glucose oxidase is substrate in an exothermic reaction. With this fact in mind outline the design of biosensor to measure the concentration of glucose in blood stream

The first generation glucose biosensors estimated glucose concentration in the sample based on hydrogen



peroxide production by glucose oxidase (GOx) utilizing dissolved oxygen as given below

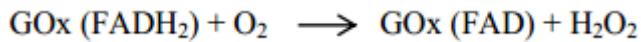
A negative potential is applied to the Pt working electrode for a reductive detection of the oxygen consumption as



The key point of above reaction lies in the redox center of the GOx (FAD) which performs the function of the initial electron acceptor. The interaction of glucose molecule with flavin adeninedinucleotide (FAD) of GOx results in its reduction.

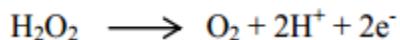


The rejuvenation of the cofactor of enzyme GOx occurs in the presence of molecular oxygen, resulting in the formation of hydrogen peroxide (H₂O₂) as,



Thus, the rate of reduction of oxygen is directly proportional to the glucose concentration that is enumerated by either measuring the reduced oxygen concentration or increased concentration of hydrogen peroxide.

Hydrogen peroxide thus produced as a byproduct is oxidized at platinum (Pt) anode. The electrons transferred are recognized by electrode and thus the number of electrons transferred is directly



proportional to the number of glucose molecules present.

Major drawbacks of first generation glucose biosensor:

- Interference from electroactive species present in blood, such as uric acid, ascorbic acid and other constituents of blood, at the high operational potential (+0.6V) required for amperometric measurement of hydrogen peroxide. This limits the high selectivity of the analyzer and results in inaccurate measurements of glucose concentration.
- Oxygen deficit – Sensors involving natural oxygen as the electron acceptor due to presence of oxidase enzyme, generally face errors resulting from fluctuations in oxygen tension due to the limited solubility of oxygen in biological fluids. This reduces the linear range of the biosensor.

9.Discuss the applications of enzymes biosensors in analytical, medical and environmental monitoring (May 2015)

A biosensor has a wide range of applications in different fields.

Medicinal Application: biosensors have been used in various diagnostic procedures to determine various tests.

Industrial application: various manufacturing processes can be monitored by biosensors to provide assistance with regard to increase the quality and quantity of product obtained.

Environmental application: it helps in measuring the toxicity of water bodies, microbial contamination of natural resources helping in developing steps towards a cleaner environment.

Military application: it helps to detect explosives, drugs etc., aiding in defence of the people.

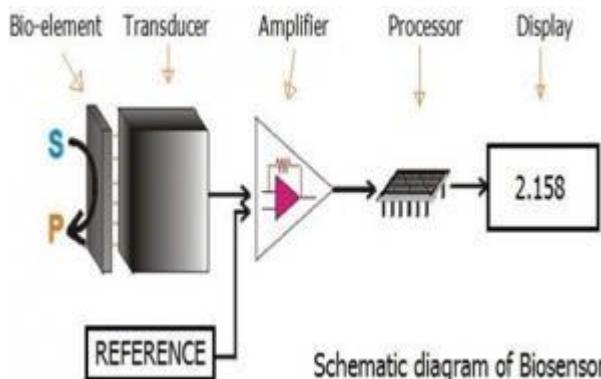
Another breakthrough in the field of biosensors was the production of a product called ‘smart skin’. It is a kind of biosensor which detects any chemical or biological attack nearby and warns the person using the same.

Drug development: a biosensor called ‘nano sensors’ has been developed which detects and analyse the binding of proteins to its targets which has proved very useful in drug designing. This also helps to monitor certain side effects caused by some medicines.

10.What are the major components of biosensor? Explain the working principle of biosensor with neat diagram(Nov 2016)

A biosensor mainly consists of two parts

- (i) a biological part: this constitutes of enzymes antibodies etc., which mainly interacts with the analyte particles and induce a physical change in these particles.
- (ii) a transducer part: which collects information from the biological part, converts, amplifies and display them. In order to form a biosensor, the biological particles are immobilized on the transducer surface which acts as a point of contact between the transducer and analyte. When a biosensor is used to analyse a sample, the biological part specific to the analyte molecules, interacts specifically and efficiently. This produces a physicochemical change of the transducer surface. This change is picked up by the transducer and gets converted into electric signals. These then undergo amplification, interpretation and finally display of these electric units accounting to the amount of analyte present in the sample.

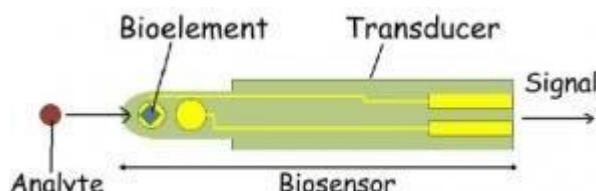


Schematic diagram of Biosensor

Bio Sensor

The Biosensor is used to detect the analyte so the Biosensor is an analytical device and it gathers the biological components with a Physicochemical detector. The sensing biological elements are biometric components interact with the recognize and analyze the study and the components like tissue, microorganisms, antibodies, nucleic acids and etc. The sensitive elements of biological can also generate by the biological engineering. The detector elements transform the signals from the interface of analyte with the biochemical elements into other signals like transducer and it can be measured more easily and qualified. The Biosensor devices are associated with the electronics and the signal processors and they are generally responsible for the display of the results and they are user-friendly. The Biosensor research has a significant role in the development of modern electronics. This article discusses about different types of Biosensors working and applications.

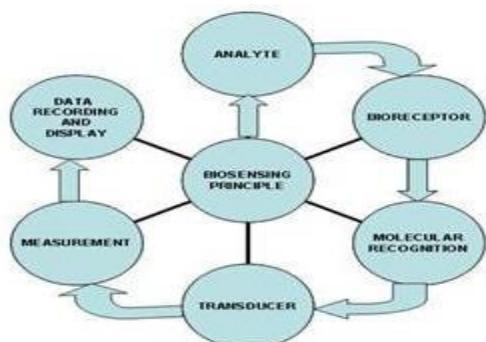
A Biosensor is an analytical device. The sensor which integrates the biological elements with the Physicochemical transducer to produce an electronic signal is proportional to a single analyte and which



is fetched into a detector.

Working of Biosensors

The preferred biological material like enzyme is preferred for conventional methods like physical or membrane entrapment and non covalent or covalent binding. The preferred biological material is in contact with the transducer. To produce a bound analyte through the analyte binds to the biological material which produces the electrical response to be measured. In some cases the analyte changed to a product and have some probability to associate with the release of heat, gases like oxygen, electrons or hydrogen ions.



11.Explain the different types of biosensor and give their advantage and disadvantages of biosensors(Nov 2016)

A biosensor is a device for the detection of an analyte that combines a biological component with a physicochemical detector component.

An analytical device which functions to analyse a sample for the presence of a specific compound is known as sensor. A sensor which utilizes biological material to specifically interact with an analyte is known as **biosensor**. An **analyte** refers to the compound which has to be ‘sensed’ or the presence of which has to be determined. The interaction of analyte and biosensor is measured and converted to signals, which are again amplified and displayed. A biosensor thus involves converting a chemical flow of information into electrical signals. The biological materials used in biosensors are mostly enzymes, antibodies, nucleic acids, lectins, a cell as a whole etc.

According to the mode of interaction biosensors are of two types:

Catalytic biosensor: The interaction of biological material in the biosensor and the analyte result in modification of analyte into new chemical molecule. The biological material used is mainly enzymes.

Affinity biosensor: Here, upon interaction, the analyte binds to the biomolecule on the biosensor.

These are mainly composed of antibodies, nucleic acids etc.

Essential properties of a biosensor:

- (i) *Specificity*: a biosensor should be specific to the analyte which it interact.
- (ii) *Durability*: it should withstand repeated usage.
- (iii) *Independent nature*: It should not be affected by variations in the environment like temperature, pH etc.
- (iv) *Stability* in results: the results produced by interaction should be corresponding to the concentration of analyte.
- (v) *Ease of use and transport*: it should be small in size so that it can be easily carried and used.

Types of biosensors:

- (i) *Calorimetric* biosensor: some enzyme- analyte reactions are exothermic and releases heat into the sample. This change in temperature is detected by the transducer. The amount of heat generated is proportional to the analyte concentration present and is processed likewise.
- (ii) *Potentiometric* biosensor: an electric potential is produced as a result of interaction which is detected by the transducer
- (iii) *Amperometric* biosensor: analyte when comes in contact with biological material induces a redox reaction. This results in movement of electrons which is picked up by transducer.
- (iv) *Optical* biosensors: in this, a biosensor reacts with analyte to absorb or release light which is identified by the transducer and interpreted.
- (v) *Acoustic wave* biosensors: biological component of biosensor undergoes a biomass change ascertained by transducer.

The **advantages** of biosensors include accuracy in results, minute detection capability, ease of use, versatile and continuous monitoring available.

9. Write in detail about the design of the enzyme electrode (May 2015, Nov 2016)

Electrode

Electrochemical electrodes (orEnzyme electrodes) are a new type of detector or**biosensor** that have been exclusively designed for thepotentiometric or amperometric assay of substrates, for instance : alcohol, amino acids, glucose, and lactic acid .

The enzyme electrode is a combination of any electrochemical probe(amperometric, potentiometric or conductimetric) with a thin layer (10 - 200mm) of immobilised enzyme. History

Enzyme electrodes are a type of biosensor that have enzyme as a biological component. The history of biosensors started in the year 1962 with the development of amperometric enzyme electrode for glucose by the scientist Leland

C. Clark. The year 1969 marks first potentiometric biosensor:urease immobilized on an ammonia electrode to detect urea.During the year 1972-75, first commercial glucose biosensor.

Biosensors are called enzymatic electrodes when an enzyme is the biological component and transduction is based on electrochemical principles. This type of biosensor now plays an important role, in particular, for biomedical and technological applications. Enzymes are proteins which present an outstanding ability for molecular recognition. The biochemical changes following this process are finally electrochemically transduced. Many enzymes have been characterized, particularly with respect to tertiary structure and are also commercially available. Therefore, it is not surprising that a great majority of the biosensors, so far described, are based on enzymes2.

Redox enzymes, called oxido-reductases, are probably the most frequently employed. They are classified with regard to the prosthetic group, a molecule tightly bound to the protein structure: flavin, quinone, heme or copper center. More than 80 flavin enzymes are known with FAD (flavin adenine dinucleotide) or FMN (flavin adenine mononucleotide) covalently or tightly attached. The active redox site of this molecule corresponds to the isoalloxazine group and the redox process depends strongly on pH. The redox potential of FAD has been studied in different enzymes and depending on the protein structure, it varies between -730 and -50 mV vs. SCE.

The enzymes which contain quinones as prosthetic group, called quinoenzymes, are less common. The redox active group is 2,7,9-tricarboxy- 1H- pyrrolo- (2,3-quinoline-4,5-dione) known as PQQ and since oxygen does not reoxidise it, they are dehydrogenases. Quinoenzymes used in electrochemical studies include alcohol dehydrogenase and glucose dehydrogenase.

10. Explain in detail about

Calorimetric Biosensors (8) ii) Potentiometric Biosensors (8)

Potentiometric Biosensors

The basic principle behind potentiometric sensor measurements is the development of a voltage related to the analyte activity (concentration) [A] in the sample through the Nernst relation:

$$E = E^\circ + \frac{RT}{nF} \ln [A]$$

Potentiometric sensors will generally require a reference electrode as well as the indicator (working) electrode to be in contact with the test sample solution. The use of ion-selective membranes can make these sensors sensitive to various ions (e.g, hydrogen, fluorine, iodine, chlorine ions) in addition to gases such as carbon dioxide and ammonia. Enzyme systems, that change the concentration of any of these ions or gases, can also be incorporated into the sensor in order to be able to measure enzyme concentrations, or to detect inhibitors (e.g., heavy metal ions, insecticides) or modulators of the enzyme.

Ideally, the potential difference between the indicator and reference electrode is proportional to the logarithm of the ion activity or gas fugacity. However, this is only the case when:

- The membrane or indicator electrode surface layer is 100% selective for the test analyte, or
- There is a constant or low enough concentration of interfering ions, and
- Potential differences at various phase boundaries (junction potentials) are either

negligible or constant, except at the membrane-sample solution interface.

Many of these sensors take the form of a pH electrode to measure the activities of enzymes (and hence the concentration of the specific substrate for that enzyme) which produce or consume protons as a result of catalysis. Examples of enzymes that can be used in this way are urease, glucose oxidase, penicillinase and acetylcholinesterase - to monitor the concentrations of urea, glucose, penicillin, and the neurotransmitter acetylcholine (or some pesticides that inhibit acetylcholinesterase) respectively.

Strengths:

- A wide concentration range for detection of ions (typically 1 μ M to 0.1 M).
- Can perform continuous measurements (ideal for clinical/environmental use).
- Inexpensive and portable.

Weaknesses:

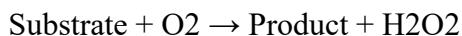
- pH buffers are often required to maintain optimum enzyme activity, and this can limit the dynamic range of detection of the analyte for enzyme-based sensors.

12.Explain in detail about

Amperometric Biosensors (8) ii) Optical Biosensors (8)

Amperometric Biosensors

These are the most commonly reported class of biosensor. They typically rely on an enzyme system that catalytically converts electrochemically non-active analytes into products that can be oxidized or reduced at a working electrode. This electrode is maintained at a specific potential with respect to a reference electrode. The current produced is linearly proportional to the concentration of the electroactive product, which in turn is proportional to the nonelectroactive enzyme substrate. Enzymes typically used in amperometric biosensors are oxidases that catalyze the following class of reactions:



As a result of the enzyme-catalyzed reaction, the substrate (analyte) concentration can be determined by amperometric detection of oxygen or hydrogen peroxide (H_2O_2). An example of this configuration would be an oxygen-consuming enzyme coupled to an oxygen-sensing electrode. The ambient oxygen concentration is then continuously monitored as it diffuses through a semi-permeable membrane and is reduced at a platinum (Pt) electrode. Other common configurations include the use of oxidases specific to various substrates to produce H_2O_2

During measurement, the working electrode may act as an anode or a cathode, according to the nature of the analyte. For example, a glucose-sensitive biosensor that uses glucose oxidase could detect the H_2O_2 produced by the enzymatic reaction by polarising the working electrode to a positive potential (+0.6V vs. SCE), or by polarising the working electrode to a negative potential (-0.65V vs. SCE) to monitor oxygen.

These sensors which use an oxidase enzyme and detect the products electrochemically are considered to be first generation devices which have a number of problems.

Strengths:

- The use of low-cost and disposable electrodes.
- High degree of reproducibility that is possible for these (one-time use) electrodes eliminates the cumbersome requirement for repeated calibration.
- The instrumentation for these biosensors is inexpensive and compact, allowing for the possibility of on-site measurements.

Weaknesses:

- Tend to have a small dynamic range due to saturation kinetics of the enzyme.
- Potential interference to the response if several electroactive compounds can generate false current values. (These effects have been eliminated, for clinical applications, through the use of selective

membranes, which carefully control the molecular weight of the charge of compounds that have access to the electrode.)

- Require oxygen for the enzyme activity to transfer electrons. If the oxygen content of the measured solution is too low then the reaction rate will depend on this rather than the glucose concentration.

One method to get round these issues involves the use of membranes as mentioned above.

The outer membrane can control the flux of oxygen and glucose between the sensed environment and the immobilised enzyme layer. This can prevent the sensor being dependent on O₂ concentration or on the diffusion barrier in an unstirred solution. The inner barrier is designed to prevent interferents which are electroactive at the same potential as H₂O₂ from reaching the electrode. Most of these interferents are larger molecules which enables this discrimination.

Other solutions to cross tolerance with interferants in H₂O₂ sensing may involve the use of the materials, enzymes etc. to lower the potentials used and avoid other electroactive substances. The paper mentioned on glucose sensing earlier in the course uses “Prussian Blue” immobilised in chitosan which has a dual effect of catalysing the peroxide sensing and blocking other molecules.

Amperometric biosensors operate by measuring the current generated by oxidation or reduction of redox species at an electrode surface, which is maintained at an appropriate electrical potential. The current observed has (hopefully) a linear relationship with the concentration of the analyte. However, the direct electron transfer between the redox-active site of an enzyme immobilized at an electrode surface is normally prohibited by an intervening, insulating, part of its polypeptide structure. Some kind of charge carrier has then to be used as an intermediate between the enzyme redox centre and the electrode. In glucose 4 oxidase the redox-active site is a flavin adenine dinucleotide (FAD) molecule at the heart of the protein

Optical Biosensors

There are two main areas of development in optical biosensors. These involve determining changes in light absorption between the reactants and products of a reaction, or measuring the light output by a luminescent process. The former usually involve the widely established, if rather low technology, use of colorimetric test strips. These are disposable single-use cellulose pads impregnated with enzyme and reagents. The most common use of this technology is for whole-blood monitoring in diabetes control. In this case, the strips include glucose oxidase, horseradish peroxidase (EC 1.11.1.7) and a chromogen (e.g. *o*-toluidine or 3,3',5,5'-tetramethylbenzidine). The hydrogen peroxide, produced by the aerobic oxidation of glucose, oxidising the weakly coloured chromogen to a highly coloured dye.

Peroxidase



The evaluation of the dyed strips is best achieved by the use of portable reflectance meters, although direct visual comparison with a coloured chart is often used. A wide variety of test strips involving other enzymes are commercially available at the present time. A most promising biosensor involving luminescence uses firefly luciferase (*Photinus*-luciferin 4-monooxygenase (ATP-hydrolysing), EC 1.13.12.7) to detect the presence of bacteria in food or clinical samples. Bacteria are specifically lysed and the ATP released (roughly proportional to the number of bacteria present) reacted with D-luciferin and oxygen in a reaction which produces yellow light in high quantum yield.

luciferase

ATP + D-luciferin + O₂

→ oxyluciferin + AMP + pyrophosphate + CO₂ + light(562 nm)

The light produced may be detected photometrically by use of high-voltage, and expensive, photomultiplier tubes or low-voltage cheap photodiode systems. The sensitivity of the photomultiplier-containing systems is, at present, somewhat greater (< 10⁴ cells ml⁻¹, < 10⁻¹² M ATP) than the simpler photon detectors which use photodiodes. Firefly luciferase is a very expensive

enzyme, only obtainable from the tails of wild fireflies. Use of immobilised luciferase greatly reduces the cost of these analyses.

11. Discuss in details about the applications of immobilized enzymes in biosensors with example

Biosensors are electrical, optical, chemical or mechanical devices with the capability to detect biological species selectively. They are often modified with biological entities to enhance their selectivity. Examples of biological recognition molecules include enzymes, antibodies and oligonucleotides. The ideal biosensor not only has to respond to low concentrations of analytes but also must have the ability to discriminate among species according to the recognition molecules that are immobilized on its surface. Biosensors have wide applications including biomarker detection for medical diagnostics and pathogen and toxin detection in food and water (Leung et al., 2007). Analytical technology based on biosensors is an extremely broad field which impacts on many major industrial sectors such as the pharmaceutical, healthcare, food and agricultural industries as well as environmental monitoring. Because of their exceptional performance, capabilities which include high specificity and sensitivity, rapid response, low cost, relatively compact size and user-friendly operations, these properties of biosensors make them an important tool for detection of various chemical and biological components (Amine et al., 2006). The development of biosensors based on immobilized enzymes came out to solve several problems such as loss of enzyme, maintainace of enzyme stability and shelf life of biosensors and additionally to reduce the time of enzymatic response and offer disposable devices which can be easily used in stationary or in flow system.

Biosensors based on principle of enzyme inhibition have by now been applied for a wide range of significant analytes such as Organophosphorus Pesticides (OP) organochlorine pesticides, derivatives of insecticides, heavy metals and glycoalkaloids. The choice of enzyme/analyte system is based on the fact that these toxic analytes inhibit normal enzymatic function. Typically, the percentage of inhibited enzyme (1%) that results after exposure to inhibitor is quantitatively related to the inhibitor (i.e., analyte) concentration (Ivanov et al., 2003a, b).

Malitest and Guascito (2005) have described the application of biosensors based on glucose oxidase immobilized by electropolymerization for heavy metal determination. Similarly, urease has been entrapped in both Polyvinyl Chloride (PVC) and cellulose triacetate layers on the surface of pH-sensitive iridium oxide electrodes and used for the determination of mercury. The immobilization of polyphenol oxidase during the anodic electropolymerization of polypyrrole has been also reported.

The biosensor has been used for the determination of atrazine concentration in low ppm level. The determination of pesticides with the help of biosensors have become increasingly important in recent years because of the widespread use of these compounds (El-Kaoutit et al., 2004).

12. Write a short note on

Piezoelectric Biosensors (8) Immunosensors (8) Piezoelectric Biosensors:

Piezoelectric biosensors are based on the principle of acoustics (sound vibrations), hence they are also called as acoustic biosensors. Piezoelectric crystals form the basis of these biosensors. The crystals with positive and negative charges vibrate with characteristic frequencies. Adsorption of certain molecules on the crystal surface alters the resonance frequencies which can be measured by electronic devices. Enzymes with gaseous substrates or inhibitors can also be attached to these crystals.

A piezoelectric biosensor for organophosphorus insecticide has been developed incorporating acetylcholine esterase. Likewise, a biosensor for formaldehyde has been developed by incorporating formaldehyde dehydrogenase. A biosensor for cocaine in gas phase has been created by attaching cocaine antibodies to the surface of piezoelectric crystal.

Limitations of Piezoelectric Biosensors:

It is very difficult to use these biosensors to determine substances in solution. This is because the crystals may cease to oscillate completely in viscous liquids.

immuno-Biosensors:

Immuno-biosensors or immunochemical bio-sensors work on the principle of immunological specificity, coupled with measurement (mostly) based on amperometric or potentiometric bio-sensors.

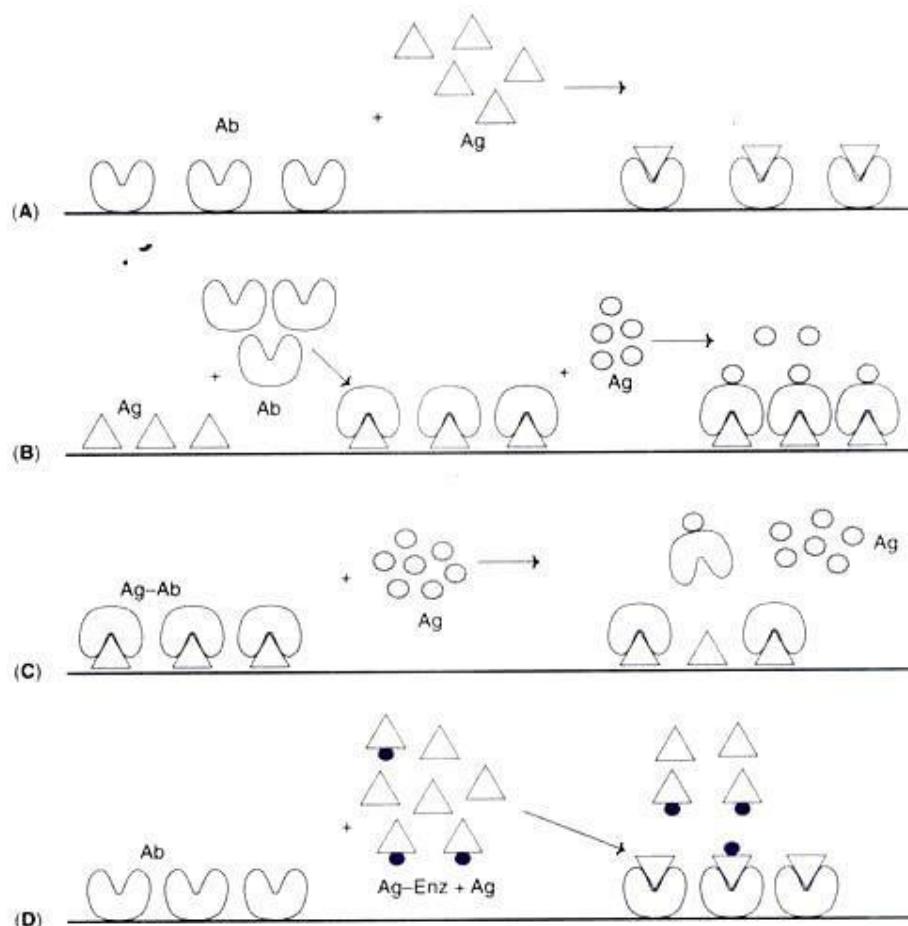


Fig. 21.18 : Diagrammatic representation of selected immunobiosensors (A) Direct binding of antigen to immobilized antibody, (B) Antigen-antibody sandwiches (immobilized antigen binds to antibody and then to a second antigen), (C) Antibody binds to immobilized antigen which gets partially released by a competitive free antigen, (D) Immobilized antibody binds to free antigen and enzyme labeled antigen (in competition).

Immunobiosensors

1. An immobilized antibody to which antigen can directly bind
2. An immobilized antigen that binds to antibody which in turn can bind to a free second antigen
3. An antibody bound to immobilized antigen which can be partially released by competing with free antigen.

4. An immobilized antibody binding free antigen and enzyme labeled antigen in competition.

For the biosensors 1-3, piezoelectric devices can be used. The immuno-biosensors using enzymes are the most commonly used. These biosensors employ thermometric or amperometric devices. The activity of the enzymes bound to immuno-biosensors is dependent on the relative concentrations of the labeled and unlabeled antigens. The concentration of the unlabeled antigen can be determined by assaying the enzyme activity.

13. What are micro-biosensors? Explain in detail with example Whole Cell Biosensors:

whole cell biosensors are particularly useful for multi-step or cofactor requiring reactions. These biosensors may employ live or dead microbial cells. A selected list of some organisms along with the analytes and the types of biosensors used is given in Table

TABLE 21.8 A selected list of organisms along with the analytes and the types of biosensors

Organism	Analyte	Type of biosensor
<i>Escherichia coli</i>	Glutamate	Potentiometric (CO_2)
<i>Sarcina flava</i>	Glutamine	Potentiometric (NH_3)
<i>Proteus morganii</i>	Cysteine	Potentiometric (H_2S)
<i>Nitrosomanas sp</i>	Ammonia	Amperometric (O_2)
<i>Lactobacillus fermenti</i>	Thiamine	Amperometric (mediated)
<i>Lactobacillus arabinosus</i>	Nicotinic acid	Potentiometric (H^+)
<i>Desulfovibrio desulfuricans</i>	Sulfate	Potentiometric (SO_4^{2-})
Cyanobacteria	Herbicides	Amperometric (mediated)
Many organisms	Biological oxygen demand (BOD)	Amperometric (O_2)

Organisms along with the Analytes and the Types of Biosensors

Advantages of microbial cell biosensors:

The microbial cells are cheaper with longer half-lives. Further, they are less sensitive to variations in pH and temperature compared to isolated enzymes.

Limitations of microbial cell biosensors:

The whole cells, in general, require longer periods for catalysis. In addition, the specificity and sensitivity of whole cell biosensors may be lower compared to that of enzymes.

14. Explain the physical and chemical techniques of enzyme immobilization(May 2015)

- PhysicalMethods
- ✓ Adsorption
- ✓ Entrapping
- ✓ Membrane confinement
- ChemicalMethods
- ✓ Covalent Bonding
- ✓ Cross Linking
- ✓ Complexation&Chelation

15. Outline the various methods of enzyme immobilization with their major advantage and disadvantage. Explain how the immobilizing matrices affect the enzyme activity (May 2016,

May 2017)

Different methods of enzyme immobilization are

- Physical Methods
- ✓ Adsorption
- ✓ Entrapping
- ✓ Membrane confinement
- Chemical Methods
- ✓ Covalent Bonding
- ✓ Cross Linking
- ✓ Complexation & Chelation

Advantages of immobilization are:

- Recovered at the end of the reaction thereby can be reused.
- Economy of the reaction is improved.
- Easy separation of enzyme from the products occurs.
- Stability of immobilised enzyme increases.
- Enhanced enzyme properties.
- Efficiency of the catalytic reaction is better in a few cases.
- Better control of reaction can be achieved.
- Catalytic processes can be operated continuously.
- Multi enzyme reaction possible.
- Potential in industrial & medicinal use.

Disadvantages of enzyme immobilization:

- (1). Even though there are many advantages of immobilized enzymes, there are some disadvantages also.
- (2). High cost for the isolation, purification and recovery of active enzyme (most important disadvantage)
- (3). Industrial applications are limited and only very few industries are using immobilized enzymes or whole cells.
- (4). Catalytic properties of some enzymes are reduced or completely lost after their immobilization on carrier.
- (5). Some enzymes become unstable after immobilization.
- (6). Enzymes are inactivated by the heat generated in the system

16. Design a enzyme electrode based biosensor for measuring ethanol in the fermentation process. (May 2017)

Alcohol content in fermentation broths can be realized by many conventional methods, for example hydrometry and gas chromatography. Considered the error limit or high expense or time-costing procedures of them, biosensor is a good alternative.

A colorimetric biosensor was proposed by Kuswandi et al. The sensor was constructed by polyaniline film immobilized alcohol oxidase. When ethanol is in presence, a color change from green to blue can be observed due to the oxidation of polyaniline by the enzyme reaction product H₂O₂. Through the computer processing software, the method can determine alcohol quantitatively range between 0.01 and 0.8% .

Gotoh et al. devised an amperometric alcohol sensor based on co-immobilized alcohol dehydrogenase and coenzyme NAD⁺, the enzyme electrode shown linear response to solution contains ethanol between 0.05 and 10v/v%. As a reagentless enzyme sensor, it can stand at least weeks of continual detections without addition of the coenzyme .

UNIT 4 PURIFICATION AND CHARACTERIZATION OF ENZYMES FROM NATURAL SOURCES

PART A

1. What are the major plant sources of enzymes? Give examples. Papain – Papaya, Bromelin – pineapple, Actinidin - Kiwi fruit

2. What are the major bacterial sources of enzymes? Give examples. (May 2017)
Beta-Amylase – *Bacillus*, Pullulanase -*Klebsiella* , Penicillin amidase - *Bacillus*

3. What are the major fungal sources of enzymes? Give examples. (May 2017)

Catalase – Aspergillus, Cellulase – Trichoderma, Dextranase - Penicillium

4. What are the major yeast sources of enzymes? Give examples. (May 2017)
Invertase – *Saccharomyces*, Lactase– *Kluyveromyces*, Lipase - *Candida*

5. What are the major animal sources of enzymes? Give examples.

Catalase – Liver, Chymotrypsin – Pancreas, Lipase – Pancreas

6. How are enzymes extracted? (Nov 2016)

The molarity and pH of the (solvent) buffer is suitably adjusted to achieve maximum solubility and activity of the enzyme. EDTA is often included in the extraction medium to remove heavy metals, and for disrupting the membranes of cells and cell organelles. Detergents such as Triton-X are also used sometimes to solubilise the membranes.

7. What are the different methods available for enzyme purification?

Enzyme purification involves three steps, electrophoresis, Dialysis and Chromatography.

8. What is coupled assay?

Even when the enzyme reaction does not result in a change in the absorbance of light, it can still be possible to use a spectrophotometric assay for the enzyme by using a coupled assay. Here, the product

Of one reaction is used as the substrate of another, easily detectable reaction. For example, figure 1 shows the coupled assay for the enzyme hexokinase, which can be assayed by coupling its production of glucose-6-phosphate to NADPH production, using glucose-6-phosphate dehydrogenase.

9. Define fold purification.

The enrichment of concentration of enzyme in each step of purification is known as fold purification.

10. What is intracellular enzyme?

An enzyme that remains within the cell in which it is formed

11. Explain briefly the principle involved in purification of enzymes?

Enzymes are proteinaceous in nature, standard extraction and purification procedures for enzymes are the same as those used for proteins except that the activity of the enzyme is assayed at each of the following four steps of extraction and purification.

12. Name the methods used to characterizing the molecular weight of enzymes.

SDS-electrophoresis, Size exclusion chromatography

13. What is extracellular enzyme?

An enzyme which is secreted outside the cell from which it originates

14. Give example for chromatographic methods used in enzyme purification.

(i) Adsorption or column chromatography; (ii) ion exchange chromatography;
(iii) gel filtration chromatography and (iv)affinity chromatography.

15. State the principle of electrophoresis.

Electrophoresis is a technique in which molecules (enzymes, proteins, amino acids, nucleotides and nucleic acids) are separated by differences in their net charge in the presence of an externally applied

electric field.

16. What is crude enzyme?(May 2015)

Enzyme present in unpurified fermentation broth is called crude enzyme

17. State the principle of chromatography.

Chromatography is a process whereby a mixture of solutes may be resolved into its components by exploiting differences in affinity of the solutes for particles of an insoluble matrix over which a solution of the components is passing. The insoluble matrix is called the stationary phase, while the solution which passes through it is called the mobile phase.

18. What are primary factors that affect the separation process?

The process used will mainly depend on the purity needed, Physico-chemical characteristics of fermentation broth and the cost, which is acceptable.

19. Name any four general protein isolation technique.

Adsorption, Precipitation, Extraction and Membrane separation processes

20. What is isoelectric precipitation .

When, an acid or base is added, the enzyme protein can be brought to its isoelectric pH. At this pH, there is no net charge on enzyme molecules and electrostatic repulsion between them is low so that they tend to aggregate. Therefore, adjusting the pH to the isoelectric point of a protein causes its precipitation.

21. What are the two methods used for protein precipitation.

Salting-out and solvent precipitation

22. What is salting-out in protein purification? (Nov 2015)

The salt competes with the protein for solvent molecules and thereby lowers its solvation. Salts can change the structure of the solvent, which can lead to large changes in protein conformation by altering the electrostatic interactions between charged groups on the protein surface and get precipitated.

23. What are the major unit operation used in enzyme isolation .

Filtration, centrifugation, extraction, precipitation, crystallization and drying

24. Name any two methods used for cell disruption.

Ultrasonication and alkali treatment

25. Microbes are preferred source of enzyme, why?

Microbes are preferred source of enzyme because it can be applied easily for Large scale production, enzyme characteristics can be increased and free or less regulation from government agencies .

26. Mention any two methods available to protect the target enzymes from protease attack during extraction from crude source (May 2016)

- Use of protease enzyme inhibitors during extraction
- Temperature at which extraction is carried out

27. write a short note on dialysis.

The separation of particles in a liquid on the basis of differences in their ability to pass through a membrane.

28. Design an assay procedure for an oxidoreductase which utilizes NADH as cofactor. (May 2016)

Spectrophotometric method can be used for the estimation. UV light is often used, since the common coenzymes NADH and NADPH absorb UV light in their reduced forms, but do not in their oxidized forms. An oxidoreductase using NADH as a substrate could therefore be assayed by following the decrease in UV absorbance at a wavelength of 340 nm as it consumes the coenzyme.

29. Microbes are preferred source of enzyme,why? (Nov 2015)

Microbes are preferred to plants and animals as sources of enzymes because:

- They are generally cheaper to produce.

- Their enzyme contents are more predictable and controllable,
- Reliable supplies of raw material of constant composition are more easily arranged, and
- Plant and animal tissues contain more potentially harmful materials than microbes, including phenolic compounds (from plants), endogenous enzyme inhibitors and proteases.

30. Define the enzyme activity units-katal and IU. Which one of the above is considered as SI unit? (Nov 2016)

katal is defined as the amount of enzyme causing loss of 1 mol substrate per second under specified conditions. International units(IU) is defined as as the amount of enzyme causing loss of 1 μmol substrate per minute under specified conditions.

31. Write any five commercially important enzymes and their sources (May 2017)

Cellulase- Cellulose containing plant materials, Amylase- saliva, Phosphatase- potato, Lysozyme- Egg white, Protease- *Bacillus* sp

32. Account on affinity chromatography for purification of enzyme proteins (May 2017)

This technique takes the advantage of the fact that many proteins specifically bind other molecules as part of their function. Upon passing the protein solution through such a column, only proteins that can bind the ligand will be retained. Then the conditions can be adjusted to effect release from the ligand.

PART B

1. Describe in detail the different steps involved in isolation, purification and characterization of an industrially important enzyme with example (May 2016, Nov 2016, May 2017)

Isolation and Purification - Isolation and purification is done immediately after termination of fermentation in a manner that retains the enzyme activity. If the cells are to be used for immobilization, the biomass is isolated and treated to make it ready for use.

The extracellular enzymes are recovered directly from broth, while enzymes localized within cells are isolated by rupturing the cells. Enzyme purification is based on various techniques whose efficacy and cost differ widely; the process used will mainly depend on the purity needed and the cost, which is acceptable.

α - Amylase - This enzyme is an endo hydrolase; it hydrolyzes starch into components, which have three or more linear α -1, 4-gulcan units. It stops hydrolysis when fragments with 2-6 glucose units remain; typically, such fragments contain an α -1,4-6 linked branch point residue.

The end products of starch hydrolysis are dextrans, which are used as adhesives and thickening agents in prepared foods. α -Amylase must be used at high temperatures. The enzyme from *Bacillus licheniformis* can be used for prolonged periods at 95°C and for a brief period at 105-110°C.

The bacteria are grown on complex media based on maize or potato starch supplemented with soybean meal or corn steep liquor (medium has 20% dry matter). The fermentation is carried out for about 5 days, then the broth is chilled and the cells and solids are removed by flocculation.

The enzyme is extracellular, and is recovered from the broth; it is always stabilized with Ca²⁺ ions. Its applications are: dextrin production, first stage in glucose manufacture, in brewing and bakery, for removal of starch in textile manufacture, etc.

Amyloglucosidase - Also called glucoamylase, this enzyme is an exohydrolase, and removes terminal glucose residues, one-by-one, from dextrans. This is produced by fungi, such as, *Aspergillus* or

Rhizopus. The strains used for enzyme production are regulatory mutants (enzyme synthesis not repressed by free glucose), which are grown on α -amylase digested starch (20% w/v) medium.

The fermentation lasts for 4-5 days at pH 4.5, and is N limited. The enzyme is extracellular and is concentrated to about 5% active enzyme. The dextrans obtained by α -amylase digestion of starch are further digested to glucose by glucoamylase.

Glucose Isomerase - Commercial glucose isomerase is, in fact, D-xylose ketol-isomerase, and is produced by several bacteria (Table 10.10). Some improved strains produce the enzyme constitutively. The bacteria are grown in aerated batch cultures at 30°C and 7.0 pH for 2-3 days.

The enzyme is intracellular, and is best used in the form of immobilized cells. The cells are suitably treated to increase their stability and catalytic activity.

Purified glucose syrup is heated to remove dissolved O₂ and increase glucose concentration to 40%. pH is adjusted between 7 and 8. The syrup is passed through a column containing immobilized bacterial cells with glucose isomerase activity; the temperature is kept at 60°C.

The enzyme longevity, under practical conditions, is 2,000-4,000 hr optimally; 20 tons or more product can be processed per kg of the catalyst. The end product of glucose isomerase action is a nearly 1 : 1 mixture of glucose and fructose; this has increased sweetness as compared to glucose and is virtually identical with 'invert sugar obtained from beet or cane sugar (sucrose).

Enzyme Biotechnology - Enzymes are biological catalysts, which initiate and accelerate thousands of biochemical reactions in living cells.

They process reactions which are otherwise not possible under normal conditions found in the cell. For instance, although, hydrolysis of starch in a test tube requires strong acidic medium and high temperature (boiling), in the alimentary canal it is hydrolysed and digested under normal conditions of acidity and temperature.

This is made possible by starch hydrolysing enzymes available in the stomach. In fact, almost all biochemical reactions require one or more enzymes for their completion. Non enzymatic conversions, though are known, but are very few.

Enzymes are proteinaceous in nature; they can be extracted from living tissues, purified and even crystallized. Under controlled conditions of isolation, they retain their original level of activity and in some cases even exhibit an increased activity. Thus, a purified enzyme can be used to carry on a specific biochemical reaction outside the cell.

Isolation and Purification of Enzymes - Enzymes are unstable molecules with a definite physico chemical organization. Even a slight change in this organization reduces the activity of enzyme and sometimes the enzyme is totally inactivated.

Therefore, the enzymes have to be isolated under controlled conditions of pH, ionic strength and temperature.

Since they are proteinaceous in nature, standard extraction and purification procedures for

enzymes are the same as those used for proteins except that the activity of the enzyme is assayed at each of the following four steps of extraction and purification.

Preparation of Crude Enzymes - Centrifugation

The enzyme extract is centrifuged to remove cell debris, cell organelles and sometimes other molecular aggregates, leading to partial purification of enzymes.

It also helps in characterization of an enzyme, since, depending upon its mass and shape the enzyme will move through a solution at a definite speed and occupy a characteristic position in the centrifuge tube.

For most cytosolic enzymes, centrifugation at about 30,000 g for 30 minutes is good enough to obtain a fair amount of activity in the supernatant.

However, if the enzyme is located in a specific cell organelle, an extract rich in that organelle is prepared through 'preparative centrifugation'. (Centrifugation for different durations at different velocities allows the cell organelles to sediment according to their sizes. All centrifugation operations are conducted in cold (0-4°C).

Precipitation

Enzymes and other proteins are highly charged molecules, and can be precipitated with appropriate charge neutralizing chemicals. Once their charges are broken, they form aggregates and settle down as precipitate.

When, an acid or base is added, the enzyme protein can be brought to its isoelectric pH. At this pH, there is no net charge on enzyme molecules and electrostatic repulsion between them is low so that they tend to aggregate. Therefore, adjusting the pH to the isoelectric point of a protein causes its precipitation.

Acids and bases, however, often inactivate the enzyme, so that their use for precipitation is not recommended in most cases. Instead ammonium sulphate and other salts are used for precipitation in a process called 'salting out'. Salts can change the structure of the solvent, which can lead to large changes in protein conformation by altering the electrostatic interactions between charged groups on the protein surface.

The salt also competes with the protein for solvent molecules and thereby lowers its solvation. In large scale enzyme precipitation, use of many other neutral salts is preferred over ammonium sulphate, which is corrosive and releases NH₃ at higher temperatures.

Some organic solvents like acetone, methanol and ethanol are also used for enzyme precipitation, since water miscible solvents decrease the solubility of proteins, leading to precipitation.

They are cooled upto 40 –60°C before their use, and precipitation is carried out at 0°C, because precipitation at room temperature causes denaturation of the enzyme, in most cases. Organic solvents are added drop by drop to avoid local concentration.

Water soluble non ionic polymers such as polyethylene glycol, alginate, pectate, carboxymethyl cellulose, polyacrylic and polymeta acrylic acids, etc. also cause enzyme precipitation.

Polyethyleneimine is also widely used as protein precipitant at large scale. They primarily act through the removal of solvent sphere of the enzyme protein.

Extraction of Enzymes - Fresh tissue is crushed into a paste with an extraction medium (often a buffer) in a mortar and pestle, or in a tissue homogenizer, or in a blender or by ultrasonic vibrations (sonication).

The molarity and pH of the buffer is suitably adjusted (which may vary for different enzymes) to achieve maximum solubility and activity of the enzyme. EDTA (ethylene diamine tetra acetic acid) is often included in the extraction medium to remove heavy metals (which otherwise inhibit enzyme activity), and for disrupting the membranes of cells and cell organelles. Detergents such as Triton-X are also used sometimes to solubilise the membranes.

Many enzyme proteins contain disulfide (S-S) bonds due to the presence of cysteine residues, which are easily broken during enzyme extraction leading to loss of enzyme activity. To overcome this problem are added, thiols such as mercaptoethanol whose sulphydryl (-SH) group is able to maintain the S-S linkage in enzymes.

If the extract is not homogeneous, the homogenate (extract) is filtered to remove cell debris, fibres etc., otherwise filtration may be avoided. All operations of extraction and purification are generally carried out in cold (0-4°C), since most of the enzymes get inactivated at higher temperatures.

Purification of Enzymes - Enzyme purification involves three steps, electrophoresis. These three techniques described in the following text

1. Dialysis
2. Chromatography.

Dialysis of Enzymes - Dialysis is the process that is used to remove small molecules from enzyme. For this, enzyme precipitate obtained in previous step is dissolved in a small quantity of buffer solution in which the enzyme was originally extracted. The solution is taken in a dialysis bag (may be a cellophane tube) and after sealing securely, the bag is suspended in either distilled water or a buffer of known molarity and ionic composition.

Some other salts or chemicals may have to be added sometimes in the outer solution, to prevent the loss of enzyme activity during dialysis. The dialysis is carried out for a few hours with regular change of the outer solution or distilled water. At large scale enzyme purification 'dialfiltration' instead of dialysis is used.

The enzyme solution is filtered for small molecules through a membrane generally mounted on a fibrous support, by pressure driven operations.

Chromatography for Enzyme Purification - Chromatographic separation of proteins is the most common method of enzyme purification.

Following four types of chromatography are available for this purpose:

- (i) adsorption or column chromatography; (ii) ion exchange chromatography;
- (iii) gel filtration chromatography and (iv) affinity chromatography.

Adsorption Chromatography for Enzyme Purification - In adsorption chromatography, the protein or enzyme solution suspected to contain other proteinaceous impurities is passed through a column of inert material packed in a glass or steel tube. Most commonly used column materials include finely divided solids such as charcoal, silica, alumina, calcium

phosphate, hydroxyapatite, etc.

The effluent solution is continuously collected in small fractions of 1.0 to 2.0 ml. The protein in each fraction is estimated by measuring the absorption at 280 nm using a UV spectrophotometer. The enzyme is also assayed in each fraction. Various spleen enzymes such as basic RNAase, acidic RNAase, acidic DNase, phosphodiesterase, phosphomonoesterase, etc. are often separated from each other using adsorption chromatography.

For large scale chromatographic separation of enzymes, the process is accelerated by using motors and other mechanical devices for packing the column, for loading the enzyme on the column and for eluting the enzyme.

Ion Exchange Chromatography for Enzyme Purification - In ion exchange chromatography, generally a cellulosic ion exchange is taken in the column. The proteins are separated according to their charges.

The resolution is quite high and the technique can facilitate large scale protein purification. This has been successfully employed for insulin purification, plasma fractionation and for purification of many other enzymes.

Gel Filtration Chromatography for Enzyme Purification - In this chromatography, various proteins are separated on the basis of differences in their molecular sizes. This type of chromatography is also known as molecular exclusion chromatography or molecular sieve chromatography.

The basic arrangement for gel filtration chromatography is similar to that for adsorption chromatography. A column made up of glass or steel is taken and packed with a gel.

The most commonly used gel is 'sephadex' which is a cross linked dextran produced by certain strains of bacteria. Several types of sephadex, namely G-10, G-30, G-50, G-100, G-150, G-200, etc. are available, which differ according to their pore sizes.

When a mixture of enzymes or proteins is poured on top of the column, different proteins move downwards according to their molecular sizes and come out from the column in order of decreasing sizes; the, larger molecules are eluted first. The elution volume is logarithmically proportional to the molecular size.

Gel filtration chromatography can also be used for determining the molecular weight of the protein by calibrating the column with proteins of known molecular weights.

Affinity Chromatography for Enzyme Purification - In this method, enzymes are purified according to their specificity for a particular substrate or cofactor.

One component of the mixture containing enzyme binds covalently to the solid support of the column, and the other components percolate down through the column. The basic requirements for affinity chromatography are the same as in adsorption or gel filtration chromatography but the packing gel must have some component which can bind with one component of the mixture.

Many commercial gels available for affinity chromatography contain functional groups attached to the 'spacer arms' of the gel. The "spacer arm" is a chemical linkage between the

functional group and the gel or matrix proper, so that the binding between functional group and the enzyme is kept away from the gel.

Thus the steric hindrance will be unlikely to prevent binding of the specific enzyme to the column.

Electrophoresis for Enzyme Purification -Electrophoresis is a technique in which molecules (enzymes, proteins, amino acids, nucleotides and nucleic acids) are separated by differences in their net charge in the presence of an externally applied electric field.

The technique is routinely used in enzyme purification and isozymes separation in the laboratories, although it has found only limited application at large scale, since the technique is time consuming and is a bit expensive.

Various types of instrumental approaches have been used to separate and purify charged molecules using electrophoresis. However, the most common method for purifying enzymes is through electrophoresis on polyacrylamide gel.

Polyacrylamide is a polymer of acrylamide and methylene bisacrylamide and when prepared as a gel it is transparent, thermostable, non-ionic and extremely regular in structure.

The gel may be taken either in the form of a column or a slab, although the latter is preferred over the former. The protein mixture is loaded in the gel and the components are separated under a direct current of constant voltage. The migration rate of the various components of the mixture is dependent upon their charge and molecular weight.

A variation of the above polyacrylamide gel electrophoresis is the sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE), which is used to determine the molecular weight of proteins. In this method, the separation is caused by the seiving action of the gel.

The proteins migrate through the gel depending on their shapes and mass to charge ratio. Gel electrophoresis is also used to separate various isozymes of a given enzyme. Isozymes perform the same catalytic function but differ in their regulatory and some kinetic aspects.

Final Step in Processing Enzymes - Most of the commercially available enzyme preparations, purified as above, are concentrated and sterile filtered, after purification. This is done to reduce both, the volume and the microbial contamination of the sample.

Often, before storage and transport, the sample is freeze dried with additives such as sugar substrates and dextrans.

2. Explain the different types of enzyme assay with example. Mention their major advantages and disadvantages (Nov 2015, Nov 2016)

Types of assay

All enzyme assays measure either the consumption of substrate or production of product over time. A large number of different methods of measuring the concentrations of substrates and products exist and many enzymes can be assayed in several different ways. Biochemists usually study enzyme- catalysed reactions using four types of experiments:

- (1) **Initial rate experiments.** When an enzyme is mixed with a large excess of the substrate, the enzyme-substrate intermediate builds up in a fast initial transient. Then the reaction achieves a steady- state kinetics in which enzyme substrate intermediates remains

approximately constant over time and the reaction rate changes relatively slowly. Rates are measured for a short period after the attainment of the quasi-steady state, typically by monitoring the accumulation of product with time. Because the measurements are carried out for a very short period and because of the large excess of substrate, the approximation free substrate is approximately equal to the initial substrate can be made. The initial rate experiment is the simplest to perform and analyze, being relatively free from complications such as back-reaction and enzyme degradation. It is therefore by far the most commonly used type of experiment in enzyme kinetics.

(2) **Progress curve experiments.** In these experiments, the kinetic parameters are determined from expressions for the species concentrations as a function of time. The concentration of the substrate or product is recorded in time after the initial fast transient and for a sufficiently long period to allow the reaction to approach equilibrium. We note in passing that, while they are less common now, progress curve experiments were widely used in the early period of enzyme kinetics.

(3) **Transient kinetics experiments.** In these experiments, reaction behaviour is tracked during the initial fast transient as the intermediate reaches the steady-state kinetics period. These experiments are more difficult to perform than either of the above two classes because they require rapid mixing and observation techniques.

(4) **Relaxation experiments.** In these experiments, an equilibrium mixture of enzyme, substrate and product is perturbed, for instance by a temperature, pressure or pH jump, and the return to equilibrium is monitored. The analysis of these experiments requires consideration of the fully reversible reaction. Moreover, relaxation experiments are relatively insensitive to mechanistic details and are thus not typically used for mechanism identification, although they can be under appropriate conditions.

Enzymes assays can be split into two groups according to their sampling method:
continuous assays, where the assay gives a continuous reading of activity, and
discontinuous assays, where samples are taken, the reaction stopped and then the concentration of substrates/products determined.

Enzyme assays measure either the disappearance of substrate over time or the appearance of product over time. Multiple methods have been developed to measure the concentration of substrates or products in a reaction, but all enzyme assays fall into two types: fixed-timed and continuous.

The **fixed-time (discontinuous)** assay measures enzyme concentration in fixed periods of time. A common fixed-time assay method is using a microplate reader to read multiple solution concentrations. Multiple dilutions series are placed into microplate wells: dilution series for the substrate; dilution series for the enzyme; and dilution series for the substrate + enzyme. To start the fixed-time assay a start solution is added to all the wells. After the reactions start, the solutions are incubated for a fixed-period of time: this period of time can be determined from a continuous enzyme assay. To stop the reactions, a stop solution is added to prohibit the enzyme from reacting with the substrate. With fixed-timed assays, one can measure many assays simultaneously.

The **continuous assay** uses a spectrophotometer to measure the appearance of product, or disappearance of substrate in real-time. With continuous assays, one can measure the linearity of the assay which can be used to conduct a fixed-timed assay. For best enzyme activity results, the optimum pH of an enzyme must be determined before conducting a continuous enzyme assay. The disadvantage of a continuous assay is that only one reaction can be measured at a time, but the advantage is the convenience of easily measurable reaction rates.

The **spectrophotometric assay** is the most common method of detection in enzyme assays.

The assay uses a spectrophotometer, a machine used to measure the amount of light a substance's absorbs, to combine kinetic measurements and Beer's law by calculating the appearance of product or disappearance of substrate concentrations. The spectrophotometric assay is simple, non-destructive, selective, and sensitive. For example, the NADH/NAD⁺ molecule is often used in enzymatic oxidation/reduction reactions. During these reactions NADH is often oxidized to NAD⁺, or NAD⁺ is reduced to NADH. NADH absorbs light at 340 nm, however NAD⁺ does not hold that property. A spectrophotometer can be used to measure the change in absorbance of 340 nm light, thus indicating a change in amount of NADH.

Coupling Reactions

In many reactions, changes in substrates or products are not observable by spectrophotometric methods because they do not absorb light. These reactions can be measured by coupling them to enzymes that can be detected via a spectrophotometer. Light absorbing non-physiological substrates or products are synthesized for enzymes with substrates and products that do not absorb light.

3. What are the methods of determination of molecular weight of enzymes? Explain

There are number of methods for molecular weight determination for proteins. Some methods like light scattering method, osmotic pressure method, depression in freezing point method, diffusion rate method are not in common use whereas gel filtration and ultra-centrifugation methods are commonly used methods. For sub unit molecular weight determination, sodium dodecyl sulfate polyarylamide gel electrophoresis is most commonly used method. The methods of molecular weight determination are described below (in brief):

Light scattering method

Enzymes are proteins and proteins do not make clear solution in aqueous medium. They form colloidal solutions. Colloids have the property of scattering the light called as *Tyndall effect*. If a beam of visible light is passed through a colloidal solution, a part of light is transmitted and other part gets scattered. The fractional decrease in the intensity of the incident light can be measured

and using the following formula, molecular weight of the enzyme protein may be

calculated:

$$M = -(\log_e I/I_0) / HCl$$

where I is the intensity of the transmitted light, I_0 is the intensity of incident light, H is the proportionality constant, C is concentration of enzyme protein in gm/ml, l is the length of the path (in cm) through the scattered solution.

The value of H may be determined using the following formula:

$$H = \frac{32 \left(\frac{\lambda^3 n^2}{N} \right) (n - n_0)^2}{3 N \lambda^4 c}$$

Where λ is the wave length of the incident light, n_0 and n are the indices of refraction of the solvent and solution, respectively, N is the Avogadro number and its value may be taken

$\times 10^{23}$, c is the concentration in gm/ml.

Therefore, one will have to determine the indices of refraction of the solvent and solution separately.

Osmotic pressure method

After determining the osmotic pressure of the enzyme protein solution, molecular weight may be determined using the following formula:

$$\Pi v = nRT$$

where Π is the osmotic pressure in atmospheres, v is volume in litres, n is the number of moles of the solute, R is the molar gas constant in litre-atmosphere, T is the absolute temperature, n may be taken as g/M where g is the amount of the solute (enzyme protein) in gm and M is the molecular weight.

Depression in freezing point method

On dissolving the enzyme protein in water, freezing point of water will decrease. The following formula may be used for molecular weight determination:

$$\Delta t = K_f M$$

where Δt is the depression in the freezing point, K_f is the molal freezing point or Cryoscopic constant, M is the molar concentration of the enzyme protein. If a solution containing an Avogadro number (6.02×10^{23}) of total dissolved particles either as undissociated molecules

ions or as a mixture of ions and undissociated molecules in 1000 gm of water (one molal solution) freezes at -1.858°C , then it is called cryoscopic constant. K_f for water is found to be

-1.858°C.

Diffusion rate method

Diffusion rate is measured by optical methods such as refractive index, light absorption, fluorescence and Tyndall effect which do not disturb the solution.

Diffusion coefficient represents the number of moles of the solute diffusing across unit area per unit time under a concentration gradient of unity. The following formula may be used for molecular weight determination:

$$D = \frac{\frac{RT}{6\eta} \sqrt{\frac{4N}{3M}}}{\frac{1}{V}}$$

Where D is the Diffusion Coefficient, R is the gas constant in ergs mole⁻¹ deg⁻¹, T is the absolute temperature, N is Avogadro number, η is the viscosity of the medium in poises, V is the partial specific volume, M is the molecular weight.

Partial specific volume is the increase in the volume when 1 gm dry substance is added to a large volume of the solvent. For proteins, its value is taken as 0.74.

Ultra-centrifugation method

Using analytical ultracentrifuge, one can determine the sedimentation constant. In fact, it is customary to express sedimentation velocity in terms of sedimentation constant which represents the velocity of particles in a unit cm-gm-sec (cgs) field of force.

If x represents the distance of the particles from the axis of rotation in the ultracentrifuge, then the rate at which they travel is

$$\frac{dx}{dt} = s \eta^2 x$$

η is the velocity of revolutions/second, ω is 2 π revolutions per second or 6.2832 revolutions per second and t is the time in seconds.

To calculate s, suppose if at time t₁, the boundary of the particles in the colloidal solution is x₁ cm from the axis of the centrifuge and at time t₂, it is x₂ cm from the axis, then

$$s = \frac{x_2 - x_1}{\omega^2 (t_2 - t_1)} \cdot \log \frac{x_2}{x_1}$$

For molecular weight determination, the following formula may be used:

$$RTs M = \frac{RTs}{D(1-V_p)}$$

Where R is the gas constant, T is the absolute temperature, s is the sedimentation constant, D is the diffusion coefficient, V is the partial specific volume, p is the density of the solution.

By equilibrium studies

If during centrifugation in the ultracentrifuge, the protein band remains in equilibrium i.e. no change in the position of the band on prolonged centrifugation, then, molecular weight of the protein may be calculated using the following formula:

$$2RT \log_e (C_2/C_1)$$

$$M = \frac{RT^2}{2} \frac{(V_p)^2}{(x_2 - x_1)}$$

Where C₂ and C₁ are concentrations at distances x₁ and x₂ from the axis of the rotation.

Gel filtration chromatography method

As described above, in gel filtration chromatography, separation is on the basis of molecular size and shape. If all standard proteins and enzyme protein are globular in nature, separation will be on the basis of molecular weight. Although any of the gel filtration matrix may be used, commonly used gel filtration matrix is Sephadex G-200. A calibrated column of Sephadex provides a simple way of determining the molecular weight of the enzyme. Calibrated column may be used repeatedly both for molecular weight determination and for routine separation. The packed gel filtration column may be calibrated using standard markers. There are following two commonly used methods for molecular weight determination:

Whitekar method: A semi log graph paper is used. Log molecular weight is plotted versus elution volume of the standard proteins. A straight line is obtained. After determination of the elution volume of the enzyme protein, from the graph, molecular weight may be calculated.

Andrews method: Here also a semi log graph paper is used. Log molecular weight is plotted versus elution volume/ void volume for the standard proteins. A straight line is obtained. After determination of the elution volume of the enzyme protein, from the graph, molecular weight may be calculated.

4. Describe in detail different types of chromatographic techniques used in purification of enzymes Chromatography is a separation technique based on partitioning of the proteins between moving phase and a stationary phase. The technique allows separation to be modified by changes in packing chemistry and elution buffer. Fully automatic high performance liquid chromatography equipments with more speed, resolution, sensitivity, reproducibility and recovery are available commercially.

For enzyme purification, commonly used chromatography techniques are: (i) Ion exchange

chromatography; (ii) Adsorption chromatography; (iii) Gel filtration chromatography and (iv) Affinity chromatography.

In general, the procedure of carrying the work is same in all types of chromatography. First, the enzyme protein sample to be purified is applied onto the pre-equilibrated column and thereafter, the effluent from the column is eluted with buffer with a series of steps of different solute concentrations, with a gradient of solute or with a specific ligand for the desired enzyme protein. The effluent eluted out from the column is collected as a series of fractions using a fraction collector, tested for enzyme activity and protein.

Ion exchange chromatography

The basic principle involved in ion exchange chromatography is binding of charged proteins onto the ion exchanger by electrostatic attraction (ionic bonds) between charged groups on the proteins and opposite charges on the exchanger. Conditions like pH are set in such a way that opposite charges be there between the proteins and ion exchanger. Unbound proteins are removed from the column by washing with the same medium used for pre-equilibrium.

Bound proteins are eluted by passing buffer of higher ionic strength (using salts like sodium or potassium chloride) or by using buffer of different pH. It is preferred to make a linear gradient of the salt or pH, instead of step-wise elution. Gradient elution is considered better since with gradient, there are more chances of removal of unwanted proteins. Fractions of the effluent are collected and analyzed for the desired enzyme activity.

Two types of ion exchangers are in common use for separation of enzymes: Anion exchangers and cation exchangers.

The most commonly used anion exchanger is diethyl amino ethyl cellulose (DEAE cellulose). Some other are amino ethyl cellulose (AE cellulose), triethyl amino ethyl cellulose (TEAE cellulose) and guanido ethyl cellulose (GE cellulose). The most commonly used cationexchanger is carboxy methyl cellulose (CM cellulose). The other examples of cation exchangers are phospho cellulose (P cellulose) and sulfo ethyl cellulose (SE cellulose). These exchangers have cellulose matrix, which is considered to be inert. The other matrices used in exchangers are Sephadex and Sepharose.

There may be a condition when enzyme protein of interest is not bound on the exchanger and unwanted proteins are bound. Although it is not considered to be a preferred way, however, if sufficient purification and recovery is obtained, the condition may be used. Under the conditions, some times, it is called negative chromatography. On an average, we apply 2 to 5 mg proteins per ml packed bed of the exchanger. In ion exchange chromatography, amount of the protein applied on the column is more important than the volume of the sample.

Regarding the dimensions of the packed exchanger bed, it is preferred to have 1:10 diameter to length ratio.

Adsorption chromatography

The basic principle in this type of chromatography is binding of the proteins on the matrix by physical

adsorption on the surface of insoluble matrix (through weaker bonds like hydrogen, van der Waals bonds). Afterwards, proteins are eluted from the column matrix by using a suitable elution buffer either having change in ionic concentration or pH. The commonly used matrices in adsorption chromatography are: (i) calcium phosphate gel; (ii) alumina gel and (iii) hydroxylapatite gel.

In this type of chromatography, gel to protein ratio is important for physical adsorption. It is preferable to carry a trial experiment in centrifuge tubes. A constant amount of the gel is put in each tube and different amounts of protein sample are added in each tube so that ratio of 0.1 to 2.0 in different tubes be obtained. After addition of sample, it is mixed with the gel and allowed to bind for few minutes. Afterwards, tubes are centrifuged and enzyme activity is determined in different tubes supernatants. If enzyme activity is present in a supernatant, it means binding of the enzyme protein (of interest) on the gel did not occur. From this trial experiment, one can determine, what will be the optimum gel to protein ratio so that enzyme protein of interest gets adsorbed on the gel surface. Afterwards, accordingly, size of the packed gel in the column be decided. For elution, generally either buffer of high ionic strength or buffer with salt like NaCl or KCl is used.

The gels used in adsorption chromatography are commercially available. The gels may also be prepared in the laboratory. It is found that older gels are more effective in separation compared to newly prepared gel. In the laboratory, calcium phosphate gel is prepared by addition of sodium tri phosphate to a diluted solution of calcium chloride and pH is adjusted to 7.4. A precipitate of calcium phosphate formed is washed to remove excess ions.

Alumina gel is prepared by the addition of a hot solution of aluminum ammonium sulfate to a solution containing ammonium sulfate, ammonia and water at 60°

The solution is cooled, the precipitate of alumina formed is washed with water to remove excess ions. Hydroxylapatite gel is prepared by addition of calcium chloride and di sodium hydrogen phosphate to a solution of one molar sodium chloride. The precipitate of hydroxylapatite formed is treated with alkali and heated to boiling for about 40 to 50 minutes. Afterwards, it is cooled and washed with water to remove excess ions.

Gel filtration (Molecular sieve) chromatography

The basic principle is based on the size and shape of the proteins. Here, gel particles have sponge like porous matrix as a structure with controlled dimension. The gel particles are swollen and equilibrated with appropriate medium and afterwards is packed in the chromatography column. Gel particles are spherical in shape. The molecules (proteins) to be separated enter in the porous matrix of the gel particles and too large molecules are not entered in the porous matrix and are eluted out from the column. Every gel is characterized by exclusion limit that means the proteins of more than that molecular weight will not enter in the matrix and eluted out as such (without separation). Void volume is considered as the space between the gel particles in the packed column. It is determined by passing bluedextran, which has very high molecular weight. Molecules with masses below the exclusion limit of the gel are eluted from the column in order of their molecular mass (weight) with the largest eluting first. Larger molecules have lesser of the interior volume of the gel available to them than the smaller molecules.

The commonly used gel filtration gels are of dextran, agarose, polyacrylamide. These gels are having

registered trade names of the manufacturers. For example, dextran gels having registered trade name 'Sephadex' are in much common use. Gel filtration chromatography (with matrix having much lesser exclusion limit such as Sephadex G-25) is also used for desalting purpose. Since in Gel filtration chromatography, separation is based on molecular weight (if shape of all the molecules is same), this chromatography has been commonly used for determination of molecular weight of proteins.

Affinity chromatography

The basic principle involves bio-specific interaction of the enzyme protein of interest with an immobilized ligand, which may be substrate, analogue of the substrate, inhibitor, activator. Inert materials like agarose, polyacrylamide, glass beads, cellulose etc have been used as supporting medium (matrix). The ligand is attached so that its enzyme interaction function is not impaired. Subsequently, elution is done by treatment resulting in dissociation of the desired enzyme ligand complex. Nowadays, affinity matrices (ligand immobilized with the matrix) are commercially available.

Immuno-affinity chromatography is also an affinity chromatography where antibody of the protein is used as ligand. The basic principle of antigen antibody interaction in this chromatography is applied. Although it is a good technique for purification of a protein, it is not in common use for enzymes since generally enzyme gets inactivated after binding with the antibody.

Besides, another affinity chromatography called Dye Affinity Chromatography is also used for enzyme purification. Specific dye bound matrices are available commercially which are used in Dye Affinity Chromatography. One such popular dye matrix is Green A. Binding affinity of the dye is ranging from 1 to 15 mg protein per ml gel. In dye affinity chromatography too, elution is done by using higher ionic strength (presence of salt in the elution medium).

5. Describe in the process of isolation, purification and characterization of an important fungal enzyme with example (May 2017)

Proteases are the single class of enzymes, which occupy a pivotal position with respect to their applications in both physiological and commercial fields. They perform both degradative and synthetic functions. Proteolytic enzymes catalyze the cleavage of peptide bonds in other proteins. Advances in analytical technique have demonstrated that proteases conduct highly specific and selective modifications of proteins.

A wide range of microorganisms including bacteria, fungi, yeast and also mammalian tissues produces alkaline proteases. The Proteolytic enzymes from Fungi are so far the most important group of enzymes produced commercially.

Method for Extraction, Purification and Characterization of Protease.

1. Screening of Neurospora for Protease Production
2. Extracellular Enzymatic activity of Microorganisms: Preparation of Crud Extract
3. Enzyme assay
4. Purification of Protease

5. Protease Assay after Purification.
6. Estimation of Standard and Purified Protease by Lowry's Method
7. Enzyme Kinetics: Effect of PH, Temperature and Substrate on activity of Protease.

6. Describe in detail the different steps involved in isolation, purification and characterization of an important plant enzyme with example

Along with vitamins and minerals, enzymes occur in food that is in a natural state. All raw food contains the proper types and proportion of enzymes necessary to digest itself. This occurs in our stomach when the food is eaten or in nature as the food ripens.

Four plant enzyme groups exist:

1. Proteases - break long protein chains into smaller amino acid chains and eventually into single amino acids
2. Amylases - reduce polysaccharides to disaccharides: lactose, maltose, and sucrose
3. Lipases - break triglycerides into individual fatty acids and glycerol
4. Cellulases - digest specific carbohydrate bonds found in fiber

Methods of enzyme purification

Fractionation of the proteins on the basis of solubility in aqueous solutions of salts or organic solvents

Chromatographic separation of the enzyme proteins Ion

exchange chromatography

Adsorption chromatography

Gel filtration (Molecular sieve) chromatography Affinity chromatography

Chromatofocusing Electrophoretic

techniques Isoelectrofocusing

Miscellaneous

Ultrafiltration Dialysis

Crystallization

7. Describe in detail the different steps involved in isolation, purification and characterization of an animal enzyme with example

Selection of Source: Commonly animal material, plant material (or) microbial source is used. For metabolic enzymes liver is the source. For insulin pancreas is the source. For ATPase mitochondria is the source. For protein synthesis ribosomes is the source. For carbohydrate synthesis plant material is the source. For industrial and commercial enzymes microbes are the source.

Solubilities of Protein: Since enzyme is a multiple acid-base group, its solubility properties depends on the concentration of the salt pH, polarity of the solvent and temperature. This is used for precipitating enzymes. 1. Effect of salt concentration The salt concentration is expressed in terms of ionic strength $I = \frac{1}{2} C Z_i^2$ where I=ionic strength C=molar concentration Z = ionic charge Usually ammonium sulphate is used in all laboratories by the process of salting-in and salting out. Salting in is the phenomenon that as the salt concentration of protein solution increases, the additional counter ions more effectively shield the protein molecules multiple ionic charges and thereby increases protein solubility. At high ionic strength the solubilities of proteins as well as those of most other substances

decreases. This effect is known as salting out. In addition to ammonium sulphate , NaCl , KCl , MgSO₄ , K₂SO₄ are also used for precipitation.

Before isolation the enzyme source should be in soluble form. The material has to be break open (lysis) in a hypotonic (homogenizer) or sonication (breaking the cell through ultrasonic vibration). If the enzyme is in organelle differential centrifugation followed by the use of detergent solutions (or) Butanol to get the enzyme.

Homogenisation The particular cell from a plant or animal or a microbe has to be ground well in a mortar or in a virtishomogenicer. It has to be ground well till a mixture of homogenised solution is obtained. In all the subsequent steps the pH, ionic strength and temperature has to be maintained.

Precipitation The enzymes are charged molecules which are precipitated by charge breaking chemicals, acids, bases, salts and organic solvents. The procedure of precipitation of enzymes by the addition of concentrated solution of salts is known as "Salting out". It is a complex process and involves disruption of various physical forces involved in enzyme solubilization . The added salts alter the structure of the solvents which can lead to large changes in enzyme configuration by altering the electrostatic interaction of charged group on enzyme surfaces and solvation of polar uncharged residues exposed to the solvent. The salt may also interfere with the formation of Vanderwaal's forces between hydrophobic groups of the aminoacids . Further, it may compete with the enzyme molecules thereby lower its solvation . In other words salt dehydrates enzyme molecules which then form aggregates and precipitate out. Commonly ammonium sulphate is used for precipitation. By measuring the amount of enzyme solution various concentration ranging from 0 to 30, 30 to 60, 60 to 90 and 90 to 100 percent of ammonium sulphate is used. Out of various percentages, with the available assay procedures one can estimate in which percentage of precipitation the desired enzyme is present. Once it is established, from the susbequent precipitation directly the required percentage and amount of ammonium sulphate can be taken. Care should be taken by adding ammonium sulphate from 0 to 4 degree centigrade and high degree of purity of chemicals. While adding ammonium sulphate magnetic stirring is done to prevent air entrainment which might inactivate the enzyme.

8. Explain the various microbial, plant and animal sources of enzymes and give their uses

Biologically active enzymes may be extracted from any living organism. A very wide range of sources are used for commercial enzyme production from *Actinoplanes* to *Zymomonas*, from spinach to snake venom. Of the hundred or so enzymes being used industrially, over a half are from fungi and yeast and over a third are from bacteria with the remainder divided between animal (8%) and plant (4%) sources (Table). A very much larger number of enzymes find use in chemical analysis and clinical diagnosis. Non-microbial sources provide a larger proportion of these, at the present time. Microbes are preferred to plants and animals as sources of enzymes because:

1. they are generally cheaper to produce.

2. their enzyme contents are more predictable and controllable,
 3. reliable supplies of raw material of constant composition are more easily arranged, and
 4. plant and animal tissues contain more potentially harmful materials than microbes, including phenolic compounds (from plants), endogenous enzyme inhibitors and proteases.
- Attempts are being made to overcome some of these difficulties by the use of animal and plant cell culture.

ENZYME	EC number	Source	Intra/extr a -cellular	Industrial use
<i>Animal enzymes</i>				
Catalase	1.11.1.6	Liver	I	Food;milk,cheese, egg beverages, salads
Lipase	3.1.1.3	Pancreas	E	Food;cheese,fats and oil
Rennet	3.4.23.4	Abomasum	E	Cheese
<i>Plant enzymes</i>				
Actinidin	3.4.22.14	Kiwi fruit	E	Food
α -Amylase	3.2.1.1	Malted barley	E	Brewing
β -Amylase	3.2.1.2	Malted barley	E	Brewing
Bromelain	3.4.22.4	Pineappl e latex	E	Brewing
β -Glucanase	3.2.1.6	Malted barley	E	Brewing
Ficin	3.4.22.3	Fig latex	E	Food
Lipoxygenase	1.13.11.12	Soybeans	I	Food
Papain	3.4.22.2	Pawpaw latex	E	Meat
<i>Bacterial enzymes</i>				
α -Amylase	3.2.1.1	<i>Bacillus</i>	E	Starch,Fats and Oils, Cheese, Beverages, Bakery,
β -Amylase	3.2.1.2	<i>Bacillus</i>	E	Starch,Beverages

Lactase	3.2.1.23	<i>Kluyveromyces</i>	I/E	Dairy;milk;cheese;edibleic e;dietary foods
Lipase	3.1.1.3	<i>Candida</i>	E	Food;cheese;fats and oils
Raffinase	3.2.1.22	<i>Saccharomyces</i>	I	Food;sugar and honey

9.

Write short note on

(ii)Protein precipitation

i)Protein extraction

(iii) Intracellular enzymes

(iv)Cell disruption

Cell disruption is the process of obtaining intracellular fluid via methods that open the cell wall. The overall goal in cell disruption is to obtain the intracellular fluid without disrupting any of its components. Though many cell disruption methods exist, certain factors must be considered in order to obtain viable cellular products.

Factors affecting cell disruption

- **Sample Size**

In most cases, sample size limits the ability to obtain pure forms of the intracellular fluid. It is necessary to use precise and accurate procedures when handling samples sizes on the order of micro liters or less. Large sample sizes pose problems in reproducibility of pure product.

- **Ability to disrupt the cell and the necessary conditions**

The ability to disrupt cells is dependent on the different components of the cell itself. The harder it is to disrupt the cell; more time and power are required to obtain the intracellular fluid.

- **Efficiency of disruption**

Disruption efficiency must be sacrificed for experiments that require pure and intact forms of the product under scrutiny. Not only that, the cost (explicitly and implicit) of processing cells is a major factor in laboratory experiments as well.

- **Stability of the component needed to be isolated**

It is important to combine materials in cell disruption with the conditions required to keep the component intact and pure. Different cell disruption methods have been created and enhanced to ensure the safety of the component under investigation.

- **Problems with Cell Disruption methods**

Though cell disruption is necessary for obtaining intracellular fluid, the process of doing so could pose problems in purification of certain biomolecules. Some adverse effects of cell disruption include, but not limited to:

- Heat generation
- Release of proteases
- Contamination (Nucleic acids, heavy metal, etc.)

- Foaming

(iv) **Protein precipitation**

Protein Precipitation is widely used in downstream processing of biological products in order to concentrate proteins and purify them from various contaminants. For example, in the biotechnology industry protein precipitation is used to eliminate contaminants commonly contained in blood. The underlying mechanism of precipitation is to alter the solvation potential of the solvent, more specifically, by lowering the solubility of the solute by addition of a reagent.

General Principles

- Repulsive electrostatic force
- Attractive electrostatic force
- Precipitate

formation Methods

- Salting out
- Energetics involved in salting out
- Hofmeister series
- Salting out in practice
- Isoelectric precipitation
- Precipitation with miscible solvents
- Non-ionic hydrophilic polymers
- Flocculation by polyelectrolytes
- Polyvalent metallic ions

(v) **Protein extraction**

Protein purification is a series of processes intended to isolate one or a few proteins from a complex mixture, usually cells, tissues or whole organisms. Protein purification is vital for the characterization of the function, structure and interactions of the protein of interest. The purification process may separate the protein and non-protein parts of the mixture, and finally separate the desired protein from all other proteins. Separation of one protein from all others is typically the most laborious aspect of protein purification. Separation steps usually exploit differences in protein size, physico-chemical properties, binding affinity and biological activity. The pure result may be termed protein isolate.

Preliminary steps

- Extraction
 - Precipitation and differential solubilization
 - Ultracentrifugation
 - Purification strategies
 - Size exclusion chromatography
- Separation based on charge or hydrophobicity
- Hydrophobic interaction chromatography
 - Ion exchange chromatography
 - Free-flow-
- electrophoresis Affinity chromatography
- Metal binding
 - Immunoaffinity chromatography
 - Purification of a tagged
- protein HPLC

(vi) **Intracellular enzymes**

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Enzymes that act inside cells are responsible for catalysing the millions of reactions that occur in metabolic pathways such as **glycolysis** in the mitochondria and in the **photosynthetic pathway** in the chloroplast. The lysosome contains many enzymes that are mainly responsible for destroying old cells.

10. Explain in detail about Development of enzymatic assays

When embarking on an assay development project the researcher should ask a number of questions in order to define the exact requirements of the assay.

Question to ask	Points to consider
What is the exact molecule to be assayed?	Isoform/splice variant Total or modified (e.g. phosphorylated / acetylated / methylated)? Soluble or membrane-bound?
Parameter to assay?	Amount of molecule present? Biological function?
Source of molecule?	Sample availability Volume of sample Likely concentration of molecule Stability of molecule
Quantitative or semi-quantitative?	Is semi-quantitative measurement of the molecule sufficient, or does the study require rigorous quantitation?

Having considered these questions regarding the molecule to be assayed, careful attention must be paid to a number of fundamental technical/practical issues that apply regardless of the particular molecule of interest or the specific assay format adopted.

Assay parameter	Key considerations
Specificity	Will the assay detect only the desired molecule?
Sensitivity	Will the assay detect the levels of the molecule in the samples of interest?
Dynamic range	Will the levels of the molecule fall within the dynamic range of the assay?
Interference	Will components in the assay sample interfere with the assay?
Robustness	Can the assay cope with small changes in the assay sample/equipment/operator?
Reproducibility	Does the assay display low inter and intra assay variability?
Accuracy (precision)	Is the assay capable of accurately determining the absolute amount/concentration of the molecule?
Analysis of assay performance	Is it appropriate/desirable to statistically analyse assay performance? Does the assay have sufficient discriminating power?

11. Explain the steps involved in the purification of bacterial enzyme.(May 2015,Nov 2015)

Preliminary steps

- Extraction
 - Precipitation and differential solubilization
 - Ultracentrifugation
 - Purification strategies
 - Size exclusion chromatography
- Separation based on charge or hydrophobicity
- Hydrophobic interaction chromatography
 - Ion exchange chromatography
 - Free-flow-electrophoresis
 - Affinity chromatography
 - Metal binding
 - Immunoaffinity chromatography
 - Purification of a tagged protein HPLC

12. Describe the method of enzyme characterizations and its importance in detail.(May 2015)

Protein characterization:

- i) molecular weight
- i. electrophoresis (SDS-PAGE --> *individual polypeptide chain molecular weights*)
- ii. gel filtration (calibrated column --> approx. *native molecular weight* if column run under nondenaturing conditions)
- iii. ultracentrifugation (depends on *size and shape*, but can give very accurate *molecular weight*)
- ii) isoelectric point (charge properties)
- i. isoelectric focusing (often used as the first dimension in 2-D gel separations to look at ALL the proteins in a complex mixture)
- iii) spectroscopic properties (give various kinds of structural and functional information)
 - i. UV-visible spectroscopy
 - 1. absorbance spectroscopy
 - 2. fluorescence spectroscopy
 - 3. circular dichroism spectroscopy
 - ii. NMR spectroscopy

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- iv) determination of primary structure
i. inference from sequence of nucleotides in the gene, and/or
ii. chemical methods
1. amino acid composition
2. amino terminal residue determination
3. Edman degradation
4. fragmentation and determination of overlapping fragment sequences
5. mass spectrometry (useful in many other ways, too, e.g. for identifying proteins, even in complex mixtures)
- v) complete 3-dimensional structure determination
i. X-ray diffraction from crystals of protein
ii. NMR of protein in solution (only for small proteins, with current technology)

13. Describe in detail the different steps involved in isolation, purification and characterization of an important intracellular enzyme. How do you characterize the purity of the enzymes (May 2016)

Refer Q.No 11&12

UNIT 5 BIOTRANSFORMATION APPLICATIONS OF ENZYMES

PART A

1. What are catalytic antibodies? (Nov 2016)

An abzyme (from antibody and enzyme), also called catmab (from catalytic monoclonal antibody), and most often called catalytic antibody, is a monoclonal antibody with catalytic activity. Abzymes are usually raised in lab animals immunized against synthetic haptans, but some natural abzymes can be found in normal humans (anti-vasoactive intestinal peptide autoantibodies) and in patients with autoimmune diseases such as systemic lupus erythematosus, where they can bind to and hydrolyze DNA.

2. Give the advantages and disadvantages for the utilization of catalytic antibody?

- Catalyse reactions cannot be done by natural enzymes
- Construction of catalytic antibodies having an opposite stereochemical preference is possible
- Efficiency is low than the naturel enzyme
- Production is tedious
- Product inhibition limits the overall performance

3. What are artificial enzymes ?(May 2015)

An **artificial enzyme** is a synthetic, organic molecule prepared to recreate the active site of an enzyme.

4. How are modified enzymes prepared to make them soluble in lipophilic solvents?

By covalent attachment of the amphipathic polymer PEG to the surface of enzymes

5. What is lipid coating?

Attachment of lipids such as simple long chain fattyacids or amphiphilic compounds to the enzyme surface by simple adsorption

6. What is bio imprinting?

The induction of a new catalytic specificity in an enzyme in an organic solvent. An enzyme and a weakly binding non-substrate/non-product (e.g. chymotrypsin and N-acetyl-D-tryptophan) are suddenly precipitated together from an aqueous solution by addition of a miscible organic solvent. The complex reverts to the native conformation and behaviour when redissolved in water, but if redissolved in a suitable organic solvent it will be found to possess a new enzymic activity, e.g. for synthesis of N-acetyl-D-tryptophan ethyl ester from N-acetyl-D-tryptophan and ethanol.

7. Biocatalytic transformations performed in organic media is advantageous - explain?

Over all yield is better in organic medium, nonpolar substrates are transformed at better rates due to their increased solubility, microbial contamination is negligible.

8. What is partition coefficient?

Partition-coefficient ($\log P$) or **distribution-coefficient** ($\log D$) is the ratio of concentrations of a compound in a mixture of two immiscible phases at equilibrium. These **coefficients** are a measure of the difference in solubility of the compound in these two phases.

9. List down the parameters that facilitate a biocatalytic reaction in a monophasic organic solvent system?

pH, enzyme state, choice of solvent, water content, effect of additives, super critical gases.

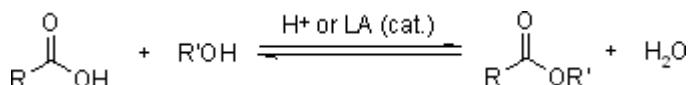
10. What are super critical gases?

A supercritical fluid is a state where matter is compressible and behaves like a gas (i.e. it fills and takes the shape of its container), which is not the case when it is in a liquid state (an incompressible fluid that occupies the bottom of its container). However, a supercritical fluid has the typical density of a liquid and hence its characteristics dissolving power. That is why we cannot define the supercritical fluid as a liquid or as a gas. This is a new state of matter in principle. Eg. Carbon dioxide, freons (CHF_3), hydrocarbons (ethane, ethane, propane), inorganic compounds (SF_6 , N_2O).

11. What are the draw backs of oxidation reaction by traditional method ?

Many oxidants are based on toxic metal ions such as chromium which are environmentally incompatible, undesired side reactions are common due to lack of specificity, Molecular oxygen cannot be used efficiently , extremely difficult to perform oxidation in a regio and stereo selective fashion.

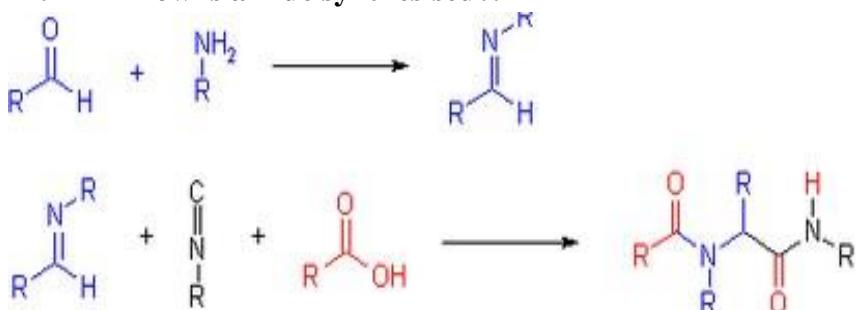
12. What is esterification?



13. What are the principles of enzymatic peptide synthesis ?

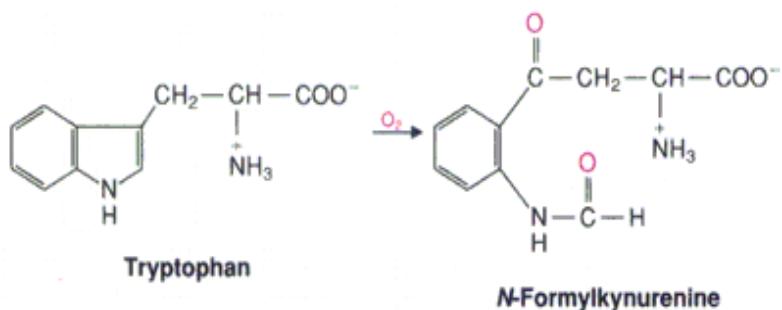
Reversal of hydrolysis, transpeptidation, aminolysis of esters.

14. How is amide synthesised?

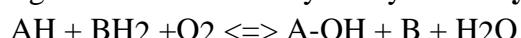


15. What are oxygenases? Give any two examples. (Nov 2015)

Oxygenases are enzymes that incorporate oxygen atoms from O_2 into the oxidized products. **Dioxygenases** are uncommon enzymes that incorporate both atoms of O_2 into one substrate. An example is tryptophan 2,3-dioxygenase, which catalyzes the reaction below:



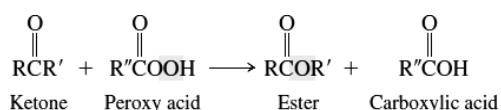
Monooxygenases are much more common than **dioxygenases**. They incorporate one atom from O_2 into a product and reduce the other atom to water. A **monooxygenase** has one substrate that accepts oxygen and another that furnishes the two H atoms that reduce the other oxygen to water. Because two substrates are oxidized, enzymes of this type are also called mixed-function oxidases. The general reaction catalyzed by**monooxygenases** is the following:



The substrate AH usually becomes hydroxylated by this class of enzymes, so they are also called **hydroxylases**. For example, this type of enzyme is used to hydroxylate steroids.

16. What is Baeyer-VilligerOxidation ?

An oxygen from the peroxy acid is inserted between the carbonyl group of a ketone and one of the attached carbons of the ketone to give an *ester*. Reactions of this type are known as **Baeyer–Villiger oxidations**.



17. Name the organisms that asymmetrically oxidizethio ethers?

Bacteria: *corynebacteriumequi*, *Rhodococcusequi*,

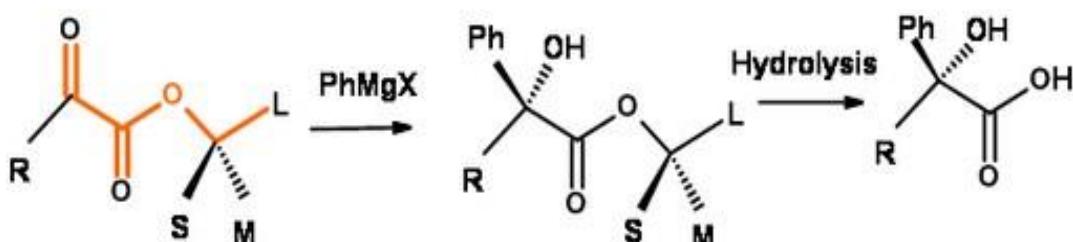
Fungi: *Helminthosporium sp.*, *Mortierellaisabellina*

18. Classify the enzymes employed in redox reactions?

Dehydrogenases, Oxygenases, Oxidases

19. Define prelog's rule? (Nov 2016)

The rule has been applied for asymmetric synthesis of $\alpha\alpha$ -hydroxyacids and for assigning the configuration of secondary and tertiary alcohols. The *anti* configurational arrangement of the two $\alpha\alpha$ - carbonyl moieties could be rationalized. The negative end of these dipoles would prefer to be as far removed as possible. The two lone pairs would sit on ether oxygen like the 'Rabbit Ears'. The keto- carbonyl would orient between the two ears. This will place the bonds shown in red in the same plane as the keto-carbonyl group. The attack from the side of the small (S) group is an extension of Cram's Rules. The asymmetric induction could be at times poor due to the large distance between the reaction center and the asymmetric center inducing asymmetry at the developing chiral center.



20. Name few naturally occurring epoxides?

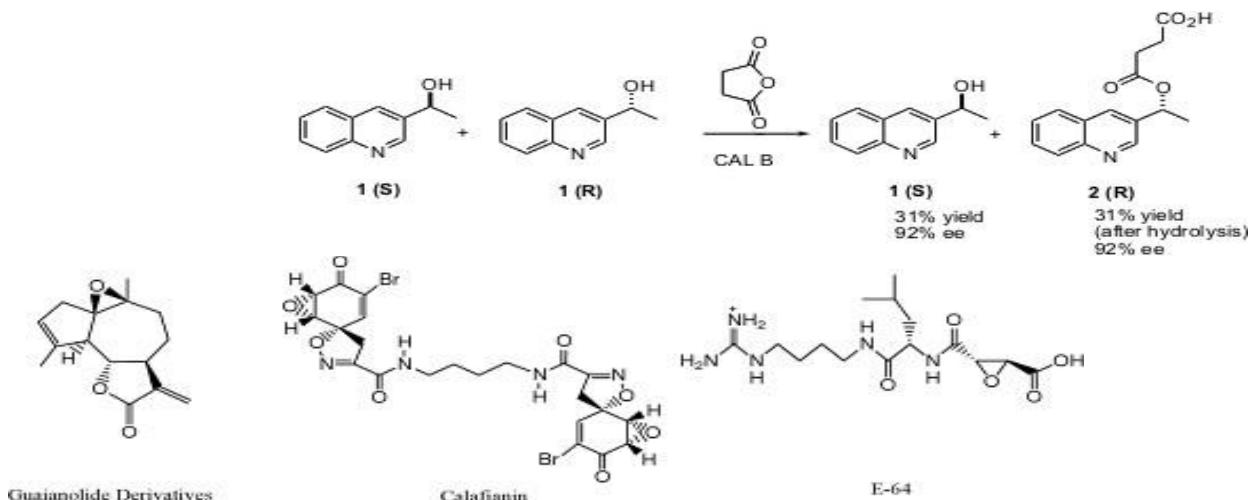


Figure 1. Naturally occurring epoxides

21. What is kazlauskasrule ?

A rule to predict which enantiomer of a secondary alcohol reacts faster in reactions catalyzed by cholesterol esterase, lipase from *Pseudomonas cepacia*, and lipase from *Candida rugosa*.

22. Write a short note on epoxide. (May 2015)

An epoxide is cyclic ether with a three-atom ring. This ring approximates an equilateral triangle, which makes it strained and hence highly reactive, more so than other ethers. They are produced on a large scale for many applications. In general, low molecular weight epoxides are colourless and nonpolar, and often volatile.

23. What are enzyme mimics? (Nov 2015)

Enzyme mimic (or Artificial enzyme) is a branch of biomimetic chemistry, which aims at imitating the function of natural enzymes. An enzyme mimic is a small molecule complex that models the molecular structure, spectroscopic properties, or reactivity of an enzyme, sometimes called bioinspired complexes.

23. What are abzymes? Give an example (May 2016, May 2017)

An abzyme (from antibody and enzyme), also called catmab (from catalytic monoclonal antibody), and most often called catalytic antibody, is a monoclonal antibody with catalytic activity. Abzymes are usually raised in lab animals immunized against synthetic haptens, but some natural abzymes can be found in normal humans (anti-vasoactive intestinal peptide autoantibodies) and in patients with autoimmune diseases such as systemic lupus erythematosus, where they can bind to and hydrolyze DNA. Ex. Cyclic phosphonate ester is the structural analog of the cyclic intermediate.

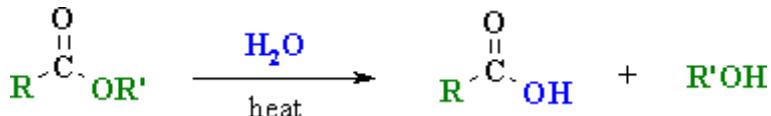
24. Outline the application of enzymes in organic synthesis with an example (May 2016, May 2017)

Enzymes es have many applications in organic synthesis. One of the most common is the resolution of a secondary alcohol. A shortcoming of this approach is that the separation of the residual alcohol from the product ester has required column chromatography, adding to the expense. Louisa Aribi-Zouïouche of the University of Annaba, Algeria, and Jean-CaludeFiaud of the University Paris-Sud, Orsay, have been exploring the use of succinic anhydride as an alternative to the more typical vinyl acetate or isopropenyl acetate acylating agents. Using this procedure, the residual alcohol and the product ester can be separated by simple acid-base extraction.

Illustrate the mechanism used for the hydrolysis of epoxides in prokaryotes and eukaryotes. (Nov 2016)

Part-B

1. Explain in detail about the hydrolytic reaction involving ester and amide



bond? Hydrolysis of Esters

Reaction type: Nucleophilic Acyl Substitution Summary

- Carboxylic esters hydrolyze to the parent carboxylic acid and an alcohol.
- Reagents : aqueous acid (e.g. H₂SO₄) / heat, or aqueous NaOH / heat (known as "*saponification*").
- These mechanisms are among some of the most studied in organic chemistry.
- Both are based on the formation of a tetrahedral intermediate which then dissociates.
- In both cases it is the C-O bond between the acyl group and the oxygen that is cleaved.

Hydrolytic reaction of amide bond

Step 1:

An acid/base reaction. Since we only have a weak nucleophile and a poor electrophile we need to activate the ester. Protonation of the amide carbonyl makes it more electrophilic.

Step 2:

The water O functions as the nucleophile attacking the electrophilic C in the C=O, with the electrons moving towards the oxonium ion, creating the tetrahedral intermediate.

Step 3:

An acid/base reaction. Deprotonate the oxygen that came from the water molecule.

Step 4:

An acid/base reaction. Need to make the -NH₂ leave, but need to convert it into a good leaving group first by protonation.

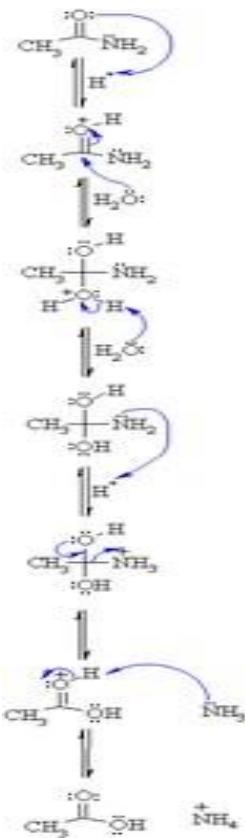
Step 5:

Use the electrons of an adjacent oxygen to help "push out" the leaving group, a neutral ammonia molecule.

Step 6:

An acid/base reaction. Deprotonation of the oxonium ion reveals the

carbonyl in the carboxylic acid product and regenerates the acid catalyst.



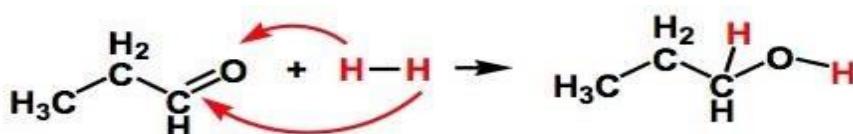
2.Explain in detail about the hydrolytic reaction involving Epoxides and nitriles?

2. Explain in detail about the reduction reaction involving aldehydes and ketones? (Nov 2016)

General equation: reduction of aldehydes and ketones

aldehyde + H₂ ---> primary alcohol ketone + H₂O --->
secondary alcohol

Reduction of an Aldehyde:



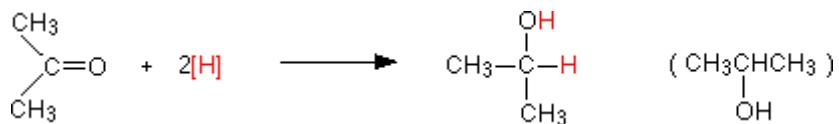
Example:

- 1) One hydrogen adds to the carbon with the double bond oxygen.
- 2) One hydrogen adds to the double bond oxygen.
- 3) The two electrons which were in the double bond are used in the bonding of both hydrogens.
- 4) The double bond is converted to a single bond.
- 5) The final product is a primary alcohol.

The reduction of a ketone

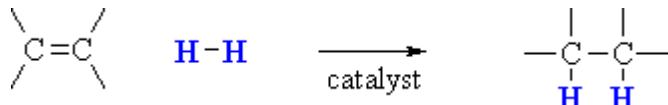
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For example, with propanone you get propan-2-ol:



Reduction of a ketone leads to a secondary alcohol. A secondary alcohol is one which has two alkyl groups attached to the carbon with the -OH group on it. They all contain the grouping -CHOH.

3. Explain in detail about the reduction reaction involving C=C?



Reaction Type: Electrophilic Addition

- Alkenes can be reduced to alkanes with H₂ in the presence of metal catalysts such as Pt, Pd, Ni or Rh.
- The two new C-H σ bonds are formed simultaneously from H atoms absorbed into the metal surface.
- The reaction is **stereospecific** giving only the *syn* addition product.
- This reaction forms the basis of experimental "*heats of hydrogenation*" which can be used to establish the stability of isomeric alkenes.

CATALYTIC HYDROGENATION

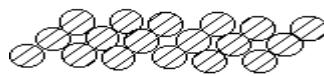
Step 1:

Hydrogen gets absorbed onto the metal surface.



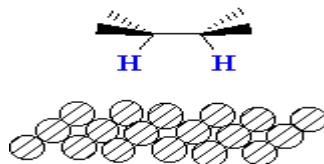
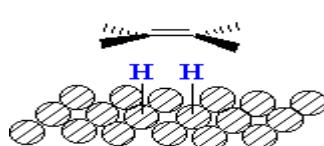
Step 2:

Alkene approaches the H atoms absorbed on the metal surface.



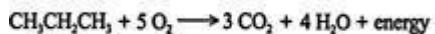
Step 3:

C=C reacts with the H atoms on the surface forming the two new C-H σ bonds



4. Explain in detail about the oxidation reaction involving alkanes and aromatic compounds? Alkanes can be oxidized to carbon dioxide and water via a free- radical mechanism. The energy released when an alkane is completely oxidized is called the **heat of combustion**. For

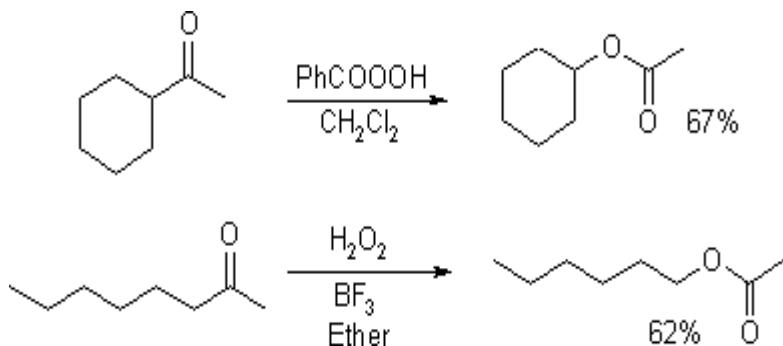
example, when propane is oxidized, the heat of combustion is 688 kilocalories per mole.



In a homologous series like the straight-chain alkanes, the energy liberated during oxidation increases by approximately 157 kilocalories for each additional methylene (CH_2) unit.

Heat of combustion data is often used to assess the relative stability of isomeric hydrocarbons. Because the heat of combustion of a compound is the same as the enthalpy of that compound in its standard state, and because potential energy is comparable to enthalpy, the differences in heats of combustion between two alkanes translate directly to differences in their potential energies. The lower the potential energy of a compound, the more stable it is. In the alkanes, the more highly branched isomers are usually more stable than those that are less branched.

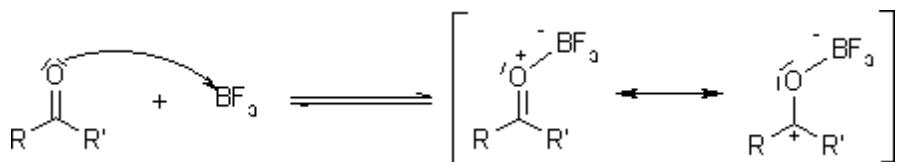
5. Explain in detail about the Baeyer-Villiger reactions? (Nov 2016)

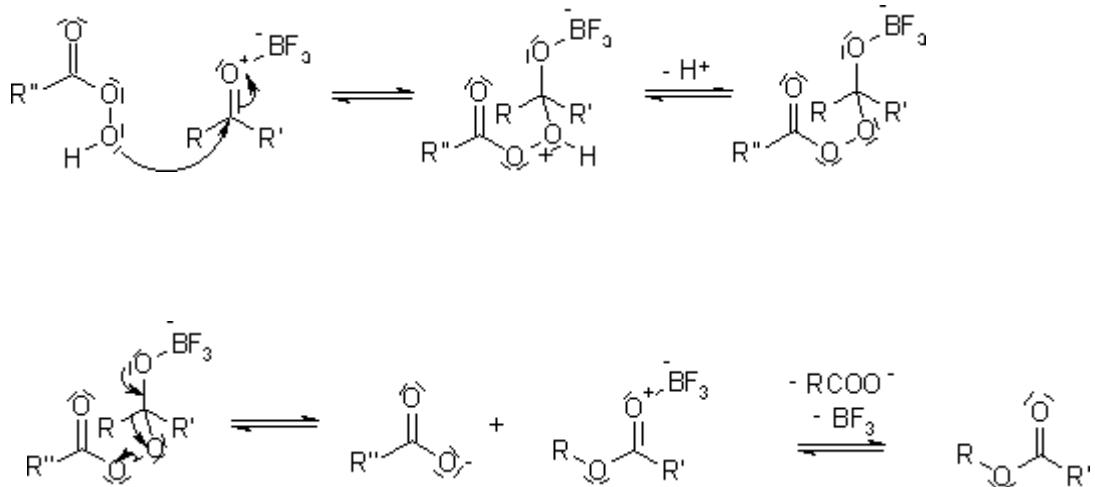


The Baeyer-Villiger Oxidation is the oxidative cleavage of a carbon-carbon bond adjacent to a carbonyl, which converts ketones to esters and cyclic ketones to lactones. The Baeyer-Villiger can be carried out with peracids, such as MCBPA, or with hydrogen peroxide and a Lewis acid.

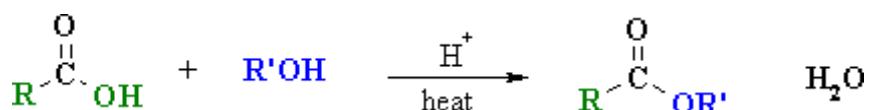
The regiospecificity of the reaction depends on the relative migratory ability of the substituents attached to the carbonyl. Substituents which are able to stabilize a positive charge migrate more readily, so that the order of preference is: *tert.* alkyl > cyclohexyl > sec. alkyl > phenyl > prim. alkyl > CH_3 . In some cases, stereoelectronic or ring strain factors also affect the regiochemical outcome.

Mechanism of the Baeyer-Villiger Oxidation





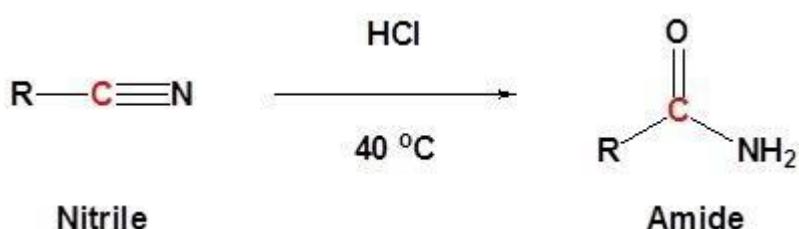
6. Discuss in detail about the synthesis of esters? (May 2016) Synthesis of Esters



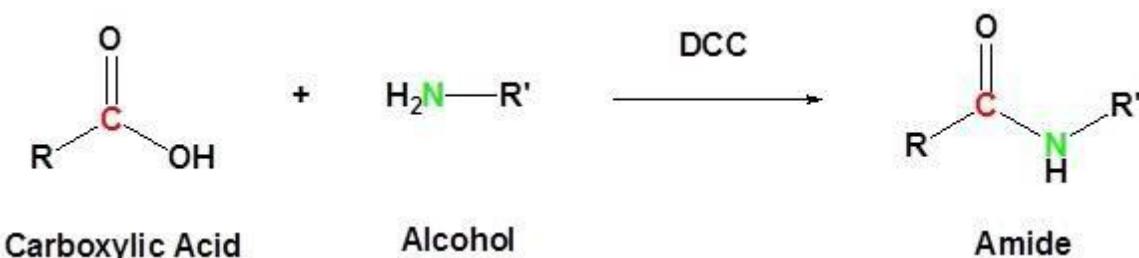
Reaction type: Nucleophilic Acyl Substitution

7. Discuss in detail about the synthesis of amides? (May 2016)
Synthesis of Amides

Nitriles can be converted to amides. This reaction can be acid or base catalyzed



Carboxylic acid can be converted to amides by using DCC as an activating agent

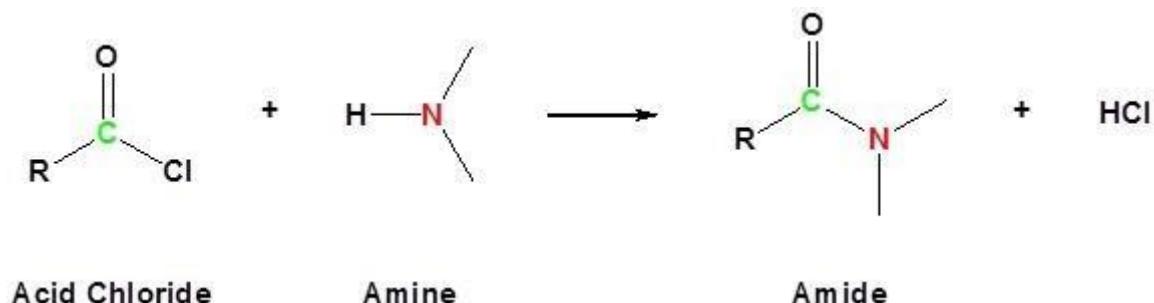


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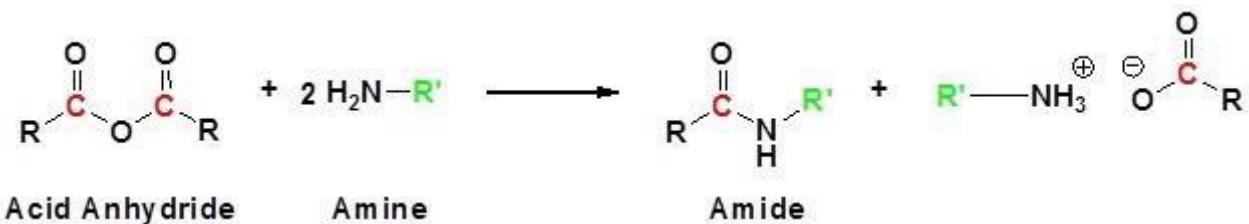
Direct conversion of a carboxylic acid to an amide by reaction with an amine.



Acid chlorides react with ammonia, 1° amines and 2° amines to form amides

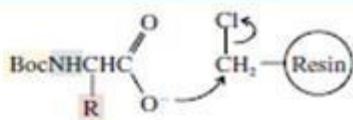


Acid Anhydrides react with ammonia, 1° amines and 2° amines to form amides

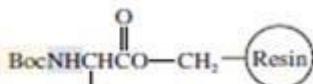


8. Discuss in detail about the synthesis of peptides? (May 2016, Nov 2016)

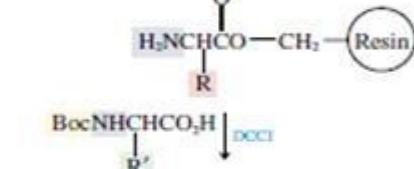
Step 1: The Boc-protected amino acid is anchored to the resin. Nucleophilic substitution of the benzylic chloride by the carboxylate anion gives an ester.



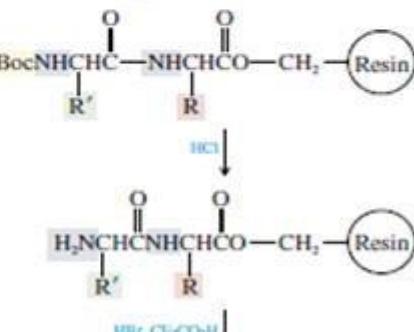
Step 2: The Boc protecting group is removed by treatment with hydrochloric acid in dilute acetic acid. After the resin has been washed, the C-terminal amino acid is ready for coupling.



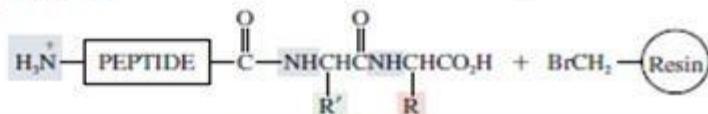
Step 3: The resin-bound C-terminal amino acid is coupled to an N-protected amino acid by using *N,N'*-dicyclohexylcarbodiimide. Excess reagent and *N,N'*-dicyclohexylurea are washed away from the resin after coupling is complete.



Step 4: The Boc protecting group is removed as in step 2. If desired, steps 3 and 4 may be repeated to introduce as many amino acid residues as desired.



Step n: When the peptide is completely assembled, it is removed from the resin by treatment with hydrogen bromide in trifluoroacetic acid.



9. Discuss in detail about the modified and artificial enzymes? (May 2015, May 2017)

An **artificial enzyme** is a synthetic, organic molecule prepared to recreate the active site of an enzyme.

Enzyme catalysis of chemical reactions occur with high selectivity and rate in a small part of the enzyme macromolecule known as the active site. There, the binding of a substrate close to functional groups in the enzyme causes catalysis by so-called proximity effects. It is therefore possible to create similar catalysts from small molecule mimics of enzyme active sites by combining, in a small molecule, the ability to bind substrate with catalytic functional groups. Since the artificial enzymes need to bind molecules, they are made based on a host-molecule such as a cyclodextrin, crown ethers or calixarene etc.

A number of artificial enzymes have been reported catalysing various reactions with rate increases up to 10^3 ; this is nevertheless substantially lower than natural enzymes that typically causes rate increases above 10^6 . One of the pioneers in artificial enzyme research is chemist Ronald Breslow. He has published a book on the subject entitled

Artificial Enzymes.

New approaches based on amino acids or peptides as characteristic molecular moieties have led to a significant expansion of the field of artificial enzymes or enzyme mimics. For instance, recent results by the group of Rob Liskamp have shown that scaffoldedhistidine residues can be used as mimics of certain metalloproteins and - enzymes. Especially the structural mimicry of

certain copper proteins (e.g. hemocyanin,tyrosinase and catechol oxidase), containing so-called type-3 copper binding sites, has been shown. This is a significant improvement since the use of scaffoldedhistidine residues is one step closer to the mimicry of enzymes by biological relevant species such as amino acids and peptides.

Recently, a new kind of artificial enzymes, **nanozymes** (or **nanozyme**), has been reported. Nanozymes are nanomaterials with enzyme-like characteristics. The term of nanozymes was coined by Flavio Manea, Florence Bodar Houillon, Lucia Pasquato, Paolo Scrimin in 2004. (Note: **nanozyme** (or **nanozymes**) has also been used in other cases.) They have been widely used in various areas, such as biosensing, bioimaging, tumor diagnosis and therapy, antibiofouling, etc. Several conferences (meetings) has been focused on the nanozymes. In 2015, a workshop for nanozyme has been held in 9th Asian Biophysics Association (ABA) Symposium. In Pittcon 2016, a Networking entitled "Nanozymes in Analytical Chemistry and Beyond" is devoted to nanozymes. A book chapter on nanozymes has been written by Xiyun Yan and coworkers. An integrated nanozymes have been developed for real time monitoring the dynamic changes of cerebral glucose in living brains

1. Describe in detail about the synthesis of catalytic antibodies with an example? (Nov 2015, May 2015)

Antibodies molecules are produced by the immune system to bind and neutralize foreign substances called antigens. Foreign proteins of bacteria and viruses, as well as some small chemical molecules called haptens, act as antigens, and elicit the production of antibodies to protect the host from harm. In fact, the human body is capable of producing antibodies to virtually any encountered antigen. Each antibody binds its own unique target similar to a key fitting in a lock.

Structurally, antibodies (immunoglobulin G-type) are "Y-shaped" molecules (see animation 1). They consist of two identical heterodimers joined together by disulfide bonds. Each heterodimer consists of a short peptide called the light chain and a longer peptide called the heavy chain. The heavy and light chains are also joined together by disulfide bonds. One end of the antibody contains conserved

regions, called constant domains (Fc, CH 1-3), that are formed by the interface of two of the two heavy chains. CH domains have similar amino acid compositions in most IgG's, despite the antigen to which the antibody binds. The opposite end of the molecule (Fv) is variable in structure and amino acid sequence, however. These variable domains are responsible for specifically binding antigen. The interface of two of the heavy and light chain variable regions (VL and VH) forms a single deep pocket (antigen binding site) that molds to the shape of the antigen. Notice that each IgG molecule contains two identical antigen binding sites because of the "Y-like" shape. "Hot spots" within the variable domains are called complementarity determining regions (CDRs). Amino acids within the CDRs specifically contact the antigen via non-covalent interactions to mediate binding to the foreign particles.

In most cases, antibodies tightly bind the antigen, but do not specifically alter its chemical nature. Natural enzymes within the body, on the other hand, bind biomolecules and subsequently catalyze their conversion to new products. According to "transition state theory," enzymes catalyze a reaction by stabilizing the chemical intermediate, or transition state, between substrates and products <link to enzyme unit>. Formation of this transition state geometry is energetically unfavorable in the absence of enzyme. However, enzymes provide the chemical momentum (activation energy) to push a reaction through its transition state. The net result of enzyme catalysis is the acceleration of the reaction rate.

Theoretically, if an antibody binds to a transition-state molecule, it may be expected to catalyze a corresponding chemical reaction by forcing substrates into transition-state geometry. But how can an be raised against such a fleetingly unstable chemical? The answer lies in the synthesis of "look-alikes" called transition-state analogs. These molecules are more stable than the transition state itself, but mimic its three-dimensional structure. If injected into the bloodstream of an animal, transition state analogs act as haptens, and elicit antibody production. Antibodies are isolated from the serum of the animal, and then screened by experimental assays to determine which catalyze the selected reaction.

In 1986, Peter Schultz and Richard Lerner demonstrated the feasibility of this proposal by generating abzymes that catalyze ester hydrolysis, the breakage of an ester bond through the addition of water. Animation 2 illustrates the hydrolysis reaction of p-nitrobenzoate. The mechanism involves the nucleophilic attack of the oxygen atom of water on the carbonyl atom in p-nitrobenzoate. This interaction produces a transition state with a tetrahedral geometry. Organic chemists have synthesized an analog of the proposed intermediate, also shown in Figure 2. By replacing the carbon at the center of the tetrahedron with phosphate, the chemical is stable for synthesis and injection into laboratory animals. The rates of reactions catalyzed with abzymes, as measured by kinetic parameters such as K_m and V_{max} , are up to a million-fold greater than the corresponding uncatalyzed reactions;

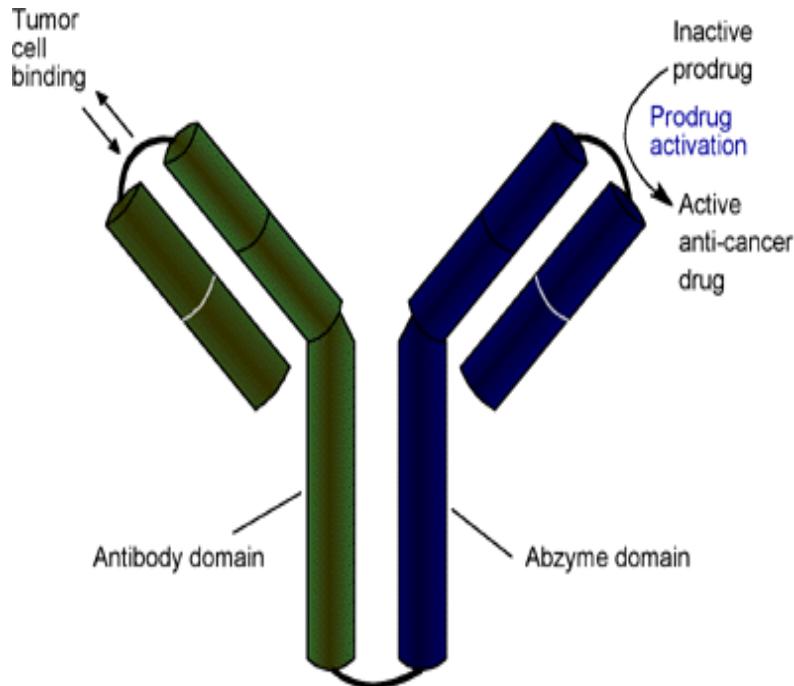
however, in many cases, catalytic antibodies have not yet approached the rates of reactions catalyzed by natural enzymes. Since the experiments of Schultz and Lerner, however, over 100 different abzymes have been generated that catalyze a wide variety of reactions.

Through the use of protein engineering, abzyme catalysis can be improved even further, perhaps even to surpass the activity of natural enzymes. Molecular biologists have developed methods to clone the array of genes that encode IgG molecules. The millions of gene products from an immunized animal are screened for the production of antibodies with desirable catalytic activities. Once candidates are isolated, these so-called "recombinant antibodies" can be produced in bacteria in large amounts. In this way, an antibody gene can be "immortalized" for unlimited study.

The activity of the original catalytic antibody. Scientists often target the CDR's for mutational analysis since these regions contain amino acids that directly contact the antigen. The resulting protein mutants are once again screened for improvement in function. In this way, a starting abzyme with moderate catalytic activity can be vastly improved.

Catalytic antibodies have great potential in the pharmaceutical industries. Abzymes have been implicated for use in the detoxification of cocaine. Catalytic antibodies have been generated that cleave the cocaine molecule at specific bonds (Figure 3), thereby eliminating the toxic effect of the drug. Notice the similarity between the hydrolysis of cocaine and the hydrolysis of p-nitrobenzoate in Figure 2. Both reactions proceed through tetrahedral intermediates and the transition-state analogs mimic this geometry. As a pharmaceutical reagent, anti-cocaine abzymes could treat patients who are addicted to cocaine, or reverse the lethal effects of a cocaine overdose.

Perhaps the most exciting application of abzyme technology is the specific targeting of cancer cells for destruction. Cancer cells contain unique determinants, called tumor cell antigens, on their surface that are lacking in normal cells. By utilizing antibodies that specifically bind these tumor cell antigens, cancer drugs can be delivered directly to the tumor. In the case of abzymes, scientists have envisioned antibodies with two distinct antigen binding sites (Figure 4): one site binds with high affinity to a tumor cell antigen, while the second site catalyzes the cleavage of a prodrug. The prodrug is a non-toxic precursor of a cytotoxic drug. First, the



Rader and List, 2000

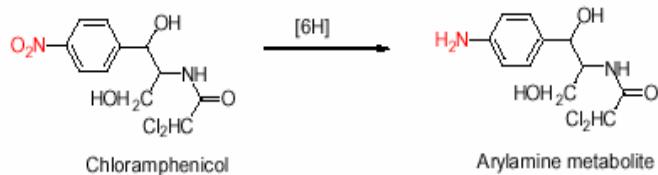
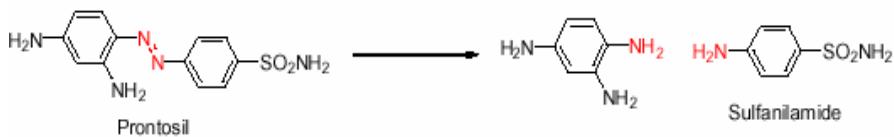
antibody is administered to patients, and it binds the tumor cells with high affinity. Secondly, the prodrug is introduced into the bloodstream, but only becomes activated in the vicinity of the targeted antibody. By this technique, tumors are selectively destroyed while healthy cells are spared from the toxic affect of cancer drugs.

While still in the early stages, other reports have indicated possible uses of abzymes to inactivate viruses. For instance, abzymes have been isolated that cleave viral coat proteins of human immunodeficiency virus (HIV). Researchers have also developed abzymes that catalyze the specific destruction of viral genes. Perhaps in the future, we will have the tools to treat a wide variety of diseases through the use of catalytic antibody technology.

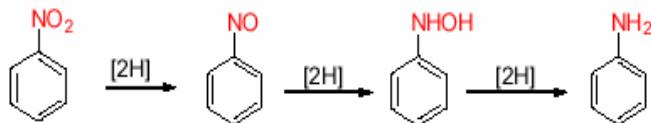
2. Explain in detail the enzyme in organic synthesis.(May 2015)



2. Explain in detail about the reduction reaction involved in biotransformation of enzymes.



Sequential Reduction of Nitro group by Intestinal Flora



Describe the following: (May 2016, May 2017)

- (i) **Biotransformation of steroids**
- (ii) **Synzymes**

Biotransformation of steroids

Biotransformation (regiospecific and steriospecific bioconversion) is a biological process whereby an organic compound is modified into reversible product. These involves simple, chemically defined reactions catalyzed by enzymes present in the cell. OR Microbial transformation • When the transformation of the organic compounds is carried out by microorganism then the process is called as microbial transformation.

- Naturally occurring steroids possess remarkable hormonal properties which are of therapeutic importance to human well-being, such as hormones of adrenal cortex (cortisone, cortisol, corticosterone), the progestational hormone (progesterone), the androgens or male sex hormones(testosterone, dihydrotestosterone) and the estrogens or female sex hormones (estradiol, estrone, etc.)
 - The pharmaceutical industry has great interest in the biotransformation of steroids for the production of steroid hormones. • Steroid hormones and their derivatives have been used for a wide range of therapeutic purposes. • Beside the established utilization as immunosuppressive, anti-inflammatory, anti-rheumatic, progestational, diuretic, sedative, anabolic and contraceptive agents, recent applications of steroid compounds include the treatment of some forms of cancer, osteoporosis, HIV infections and treatment of declared AIDS
 - Nowadays steroids represent one of the largest sectors in pharmaceutical industry with world markets in the region of US\$ 10 billion and the production exceeding 1,000 000 tons per year
- TYPES OF STEROIDAL TRANSFORMATION** • Oxidation – Hydroxylation – Dehydrogenation. – Epoxidations – Oxidation to ketone through hydroxylation – Ring A Aromatization – Degradation of

steroid nucleus

– Oxidation of alcohols to ketone: 3β -OH to 3-keto – Side chain cleavage of steroids – Decarboxylation of acids • Reduction – Double bond – aldehyde and ketone to alcohol • Hydrolysis • Isomerization • Resolution of racemic mixture • Other reactions – Aminations – Enolization of carbonyl compounds – Esterification. Hydroxylation • Hydroxylation involves the substitution of hydroxyl group directly for the hydrogen at the position, be it α or β , in the steroid with a retention of configuration. The oxygen atom in the hydroxyl

Group is derived from molecular oxygen (gaseous), not from water, and the hydroxyl group thus formed always retains the stereochemical configuration of the hydrogen atom that has been replaced.

Example : Certain microorganisms can introduce hydroxyl groups at any of several of the carbon atoms of the steroid molecule. • .

Fungi are the most active hydroxylating microorganisms, but some bacteria particularly the Bacilli, Nocardia and Streptomyces show fair good activity. The hydroxylation at the 11-position of progesterone was one of the first hydroxylation described

Dehydrogenation • Dehydrogenation with the concomitant introduction of a double bond has been reported for all four rings of the steroid nucleus, although the introduction of unsaturated bonds in Ring A is the only reaction of commercial importance. Example : • In 1955, Charney and co-worker observed that they could greatly enhance the anti-inflammatory properties of cortisol by causing the compound to be dehydrogenated at 1st position by *Corynebacterium simplex*. The resultant product, prednisolone, was 3-5 times more active than the parent compound and produced fewer side effects. cortisol prednisolone *Corynebacterium simplex* Epoxidation The epoxidation of steroid double bonds is a rare example of biological epoxidation. The 9,11- epoxidation of 9(11)-dehydro-compounds , and the 14, 15-epoxidation of 14(15)-dehydrocompounds

, using *Curvalaria lunata*. CH₃ CH₃ O*Curvalaria lunata*

Ring A Aromatization • The microbial aromatization of suitable steroid substrates can lead to ring A aromatic compounds, particularly the estrogens which constitutes an important ingredient in oral contraceptives drugs and play important role in replacement therapy for menopause treatment • Cell free extracts of *Pseudomonas testosteroni* could transform 19-nor-testosterone into estrone with small quantities of estradiol-17 β . 19-nortestosterone Estrone Estradiol-17 β

Degradation of steroid nucleus • Side chain degradation of steroids Selectively removal of the aliphatic side chain with out further breakdown of the steroid nucleus. The breakdown of the side chain to yield C-17 keto steroids can be done by several organisms as given below. (Nocardia species) COOH + CH₃-CH₂- COOH COOH + CH₃-COOH O C27 C24 C22 C17 + CH₃-CH₂-COOH

Reduction • Reduction of aldehydes and ketones to alcohols OH Estradiol Streptomyces

16. Hydrolysis • Hydrolysis of esters- *Flavobacterium dehydrogenans* contain a specific enzyme acetolase which hydrolyses the steroid acetates OAc OH Estradiol *Flavobacterium dehydrogenans*

Esterification • Usually involve acetylation O O Androstenedione OAc O Testosteron acetate
Sacromyces fragilis

• Steroid Ring Degradation

COMMERCIAL DEVELOPMENT THE CULTURE IN FERMENTATION TANK (AERATION & AGITATION) THE STEROID IS DISSOLVED IN SUITABLE SOLVENT ADDED AT DIFFERENT GROWTH STAGES RXN COMPLETE IN REASONABLE TIME

Fermentation condition of some steroids M/O Steroid substrate Steroid product Length of incubation ,

temperature, aeration Alcaligenes faecalis Cholic acid Ketocholic acids (90-100%) 2 days (monoketo acid) 4 days (diketo acid) 6 days (triketo acid) 37-39 ,surface culture Fusarium solani Progesterone 14 androstadiene-3, 17-dione(85%) 4 days , 25 C , rotary shaker (100 rpm) Corynebacterium mediolanum 21- acetoxy -3 β - hydroxy -5-pregn- 20-one 21-hydroxy-4- pregnene-3, 20- dione (30%) 6 days , 36-37 C , pure oxygen with agitation

ADVANTAGES • The ability of microorganisms, e.g., bacteria, to produce large amounts of biomass and a great variety of different enzymes in a short time. • The chemo-, regio-, and enantioselectivity of enzymes, because of their small size bacteria have by far the largest surface- to-volume ratio in the living world, which allows them to maximize their metabolic rates because of a high exchange of molecules and metabolites through their surface.

- Microorganisms have great potential for inducing new or novel enzyme systems capable of converting foreign substrates.
 - Microorganisms are capable of producing unique enzymes which are stable toward heat, alkali and acid.
 - A combination of microbial transformation and chemical transformations (chemo- enzymatic synthesis) can be exploited for partial, as well as the total synthesis of the organic compounds
- DISADVANTAGES**
- If the substrate is toxic, it can kill the microorganisms. Hence no transformation will be observed.
 - Alternatively, if the micro-organisms use the substrate as an energy source (carbon source food), no transformed or untransformed material will be recovered.
 - Very low chemical yields are obtained due to the involvement of a complex biological system
 - Many of the ground rules for applying biotransformations are not yet well understood or well-defined.
 - Many chemical reactions have no equivalent biotransformations and vice- versa

Synzymes

A number of possibilities now exist for the construction of artificial enzymes. These are generally synthetic polymers or oligomers with enzyme-like activities, often called synzymes. They must possess two structural entities, a substrate-binding site and a catalytically effective site. It has been found that producing the facility for substrate binding is relatively straightforward but catalytic sites are somewhat more difficult. Both sites may be designed separately but it appears that, if the synzyme has a binding site for the reaction transition state, this often achieves both functions.

Synzymes generally obey the saturation Michaelis-

Menten kinetics.. For a one-substrate reaction the reaction sequence is given by

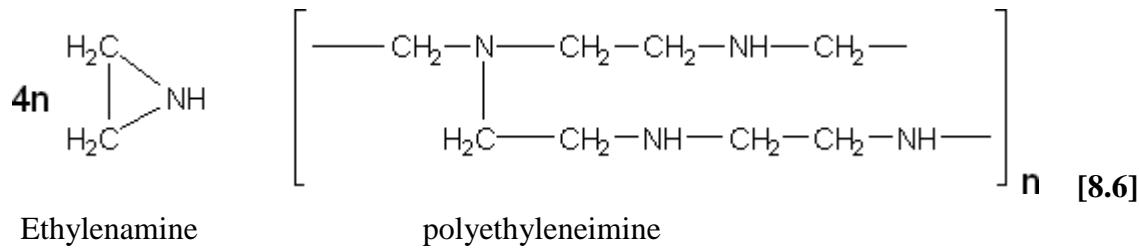


Some synzymes are simply derivatised proteins, although covalently immobilised enzymes are not considered here. An example is the derivatisation of myoglobin, the oxygen carrier in muscle, by attaching $(\text{Ru}(\text{NH}_3)_5)^{3+}$ to three surface histidine residues. This converts it from an oxygen carrier to an oxidase, oxidising ascorbic acid whilst reducing molecular oxygen. The synzyme is almost as effective as natural ascorbate oxidases.

It is impossible to design protein synzymes from scratch with any probability of success, as their conformations are not presently predictable from their primary structure. Such proteins will also

show the drawbacks of natural enzymes, being sensitive to denaturation, oxidation and hydrolysis. For example, polylysine binds anionic dyes but only 10% as strongly as the natural binding protein, serum albumin, in spite of the many charges and apolar side-chains. Polyglutamic acid, however, shows synzymic properties. It acts as an esterase in much the same fashion as the acid proteases, showing a bell-shaped pH-activity relationship, with optimum activity at about pH 5.3, and Michaelis-Menten kinetics with a K_m of 2 mm and V_{max} of 10^{-4} to 10^{-5} s $^{-1}$ for the hydrolysis of 4-nitrophenyl acetate. Cyclodextrins (Schardinger dextrans) are naturally occurring toroidal molecules consisting of six, seven, eight, nine or ten α-1, 4-linked D-glucose units joined head-to-tail in a ring (α-, β-, γ-, δ- and ε-cyclodextrins, respectively: they may be synthesised from starch by the cyclomaltodextrin glucanotransferase (EC 2.4.1.19) from *Bacillus macerans*). They differ in the diameter of their cavities (about 0.5–1 nm) but all are about 0.7 nm deep. These form hydrophobic pockets due to the glycosidic oxygen atoms and inwards-facing C-H groups. All the C-6 hydroxyl groups project to one end and all the C-2 and C-3 hydroxyl groups to the other. Their overall characteristic is hydrophilic, being water soluble, but the presence of their hydrophobic pocket enables them to bind hydrophobic molecules of the appropriate size. Synzymic cyclodextrins are usually derivatised in order to introduce catalytically relevant groups. Many such derivatives have been examined. For example, a C-6 hydroxyl group of β-cyclodextrin was covalently derivatised by an activated pyridoxal coenzyme. The resulting synzyme not only acted a transaminase but also showed stereoselectivity for the L-amino acids. It was not as active as natural transaminases, however.

Polyethyleneimine is formed by polymerising ethyleneimine to give a highly branched hydrophilic three-dimensional matrix. About 25% of the resultant amines are primary, 50% secondary and 25% tertiary:



The primary amines may be alkylated to form a number of derivatives. If 40% of them are alkylated with 1-iodododecane to give hydrophobic binding sites and the remainder alkylated with 4(5)-chloromethylimidazole to give general acid-base catalytic sites, the resultant synzyme has 27% of the activity of *a*-chymotrypsin against 4-nitrophenyl esters. As might be expected from its apparently random structure, it has very low esterase specificity. Other synzymes may be created in a similar manner.

Antibodies to transition state analogues of the required reaction may act as synzymes. For example, phosphonate esters of general formula $(R-PO_2-OR')^-$ are stable analogues of the transition state occurring in carboxylic ester hydrolysis. Monoclonal antibodies raised to immunising protein conjugates covalently attached to these phosphonate esters act as esterases. The specificities of these catalytic antibodies (also called abzymes) depends on the structure of the side-chains (i.e. R and R' in

(R-PO₂-OR')⁻) of the antigens. The Km values may be quite low, often in the micromolar region, whereas the V_{max} values are low (below 1 s⁻¹), although still 1000-fold higher than hydrolysis by background hydroxyl ions. A similar strategy may be used to produce synzymes by molecular 'imprinting' of polymers, using the presence of transition state analogues to shape polymerising resins or inactive non-enzymic protein during heat denaturation.

UNIT I - OVERVIEW OF FERMENTATION PROCESSES-9

- | |
|---|
| ✓ Overview of fermentation industry |
| ✓ General requirements of fermentation processes |
| ✓ Basic configuration of fermentor (CSTR) and ancillaries |
| ✓ Main parameters to be monitored and controlled in fermentation processes. |

PART – A

QUESTIONS AND ANSWERS

1. What are the 3 different divisions in Biotech historical development?

Periods of Ignorance, Discovery, Industrial development

2. Define fermentation? What are fermentation products?

The fermentation is a term used by microbiologist to describe any process for the productions of products by means of the mass culture of microorganisms.

The cell itself is referred to as biomass production.

The own metabolites of microorganisms is referred to as product for natural or genetically improved strain.

The microorganism of foreign products is referred to as product from Recombinant DNA technology (i.e.) genetically engineered strain.

Fermentation products

Production of cells (biomass) such as yeasts;

extraction of metabolic products such amino acids, proteins (including enzymes), vitamins, alcohol, etc., for human and/or animal consumption or industrial use such as fertiliser production; Modification of compounds (through the mediation of **elicitors** or through **biotransformation**); and Production of **recombinant** products.

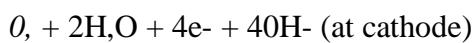
3. Give the principle of dissolved oxygen probe?

Dissolved oxygen is one of the most important indicators in a fermentation or bioreactor process. It determines the potential for growth. The measurement of dissolved oxygen is made by a sterilizable probe inserted directly into the aqueous solution of the reactor.

Two principles of operation are used for this measurement: the first is an electrochemical reaction while the second employs an amperometric (polarographic) principle.

The electrochemical approach uses a sterilizable stainless steel probe with a cell face constructed of a material which will enable oxygen to permeate across it and enter the electrochemical chamber which contains two electrodes of dissimilar reactants (forming the anode and cathode) immersed in a basic aqueous solution (Fig. 2). The entering oxygen initiates an oxidation reduction reaction which in turn produces an EMF which is amplified into a signal representing the concentration of oxygen in the solution.

In the amperometric (polarographic) approach, oxygen again permeates a diffusion barrier and encounters an electrochemical cell immersed in basic aqueous solution. A potential difference of approximately 1.3 V is maintained between the anode and cathode. As the oxygen encounters the cathode, an electrochemical reaction occurs:



The hydroxyl ion then travels to the anode where it completes the electrochemical reaction process:



The concentration of oxygen is directly proportional to the amount of current passed through the cell.

4. Define function of fermenter? And what is head space volume in fermenter?

The **bioreactor or fermentor** is the heart of the fermentation process. Here the function of the fermentor is to provide controlled environment for the growth of micro organisms or animal cells to obtain the desired product .Microbiological or biochemical reactions to produce value added products or to treat waste streams (bio fillings)

5. Head space volume

The bioreactor is divided into working volume and head space volume.

The working volume is the fraction of the total volume taken up by the medium, microbes, gas bubbles. The remaining volume is called the head space volume.

In fair fermentor typically working volume will be 70-80% of the total fermentor volume. This volume will however depend on the rate of foam formation during the reaction.

If the medium or fermentation has the tendency foam then a larger head space and a smaller working volume will needed to be used.

6. Define *On-line* and *Off-line* sensors.

On-line sensor. The sensor is part of fermentation equipment, but the measured value of the variable is not directly available for process control. The intervention of an operator to enter the measured value into the fermentation system for process control is necessary

Off-line sensors. The sensor is not a part of fermentation equipment. The measured value is not directly available for process control. The intervention of an operator is essential, first for the actual measurement and finally for entering the measured value into the fermentation system for process control.

7. What are the areas of operations for bioprocess engineer in a small scale industry

Utilities, fermentations, downstream, culture maintenance and development, QC and packing

8. What are intracellular products? (April / May 2012)

Recombinant products produced inside the cell and retained throughout the process

9. What are the 4 stages of fermentation industry?

Utilities, fermentation bay, downstream process, packaging.

10. State 4 important chromatographic separations

Affinity, Ion exchange, Gel filtration, HPLC

11. State 2 importance of flow sheeting

To know the arrangement of equipments, process stream connections.

12. What are the Utilities used in fermentation industry

DM water, Soft water, Steam, Chill water, air

13. What is meant by pasteurization (Nov / Dec 2012)

Partial sterilization by increasing temperature up to its boiling point and cooling

14. What are the two major divisions in Biotechnology?

Traditional Biotechnology, New era biotechnology

15. Name a high value low volume products of Biotechnology

Therapeutic proteins, erythropoietin, monoclonal antibodies etc.

16. What are the areas of operations for bioprocess engineer in a medium scale industry

Fermentation, Utilities, downstream operations, microbiology labs.

17. What are the areas of operations for bioprocess engineer in a larger scale industry

Fermentation and downstream operations.

18. What is upstream processing?

Operations to prepare fermentation process, Steam generations, compressed air generations

19. What is downstream processing?

Operations to prepare the fermentation products, Centrifugation, Cell disintegrations

20. What are extracellular products? (April/May 2012)

The cellular products produced and excreted to the medium from cell

21. Define flow sheeting.

Diagrammatic model of the Bioprocess, Block diagram, Pictorial representation

22. What are the Standards for pictorial representation (Nov / Dec 2012)

British standard BS1553, American national standard Institute (ASNI)

23. What are the Utilities used in fermentation industry

DM water, Soft water, Steam, Chill water, air

24. Explain the geometrical ratios of L/D, Impeller Dia/D

$L/D = 0.72$; Impeller Dia/D = 0.4

25. What is importance of aeration and agitation (April/May 2012)

To provide sufficient oxygen for metabolic requirement, and to ensure uniform suspension of microbial cells as homogeneous nutrient medium

PART B QUESTIONS

1. Mention the detailed sketch of Outline of Integrated Bioprocess with all unit operations.

Draw the schematic diagrammatic flow chart of the overall process from Raw material procurement to product recovery and effluent treatment. The flow chart should represent Medium raw material – Medium formulations – Sterilization- Stock culture – Shake flask level – seed fermentor – production fermentor – culture broth – cell separation – Biomass – cell lysis – Product extraction – product purification – product packaging and effluent treatment etc.

2. Describe briefly the concept of designing a fermenter. What factors do you consider as essential for a successful design and operation of a fermenter (Nov/Dec 2011)

A clear schematic representation of the vessel with steam entry and exit points, chill water circulation, impeller and aerators and its position, top plate with septum ports, sensors and its position, sampling and drain ports and their usages.

3. What are the various parameters that you need to monitor and control for the vb successful operation of a fermentor. (Nov/Dec 2011)

The Physical and chemical parameters to be monitored is to be listed first. The concept of Inline sensor, online sensor, Offline sensor to be explained in details with types of measurements. Selection criteria for the sensor for each parameters to be analyzed as response time, gain, sensitivity, accuracy, ease, speed of calibration, stability, precision

Temperature: types like Mercury in glass, bimetallic, Pressure bulb, Metal resistance or thermisters to be explained with diagram and principle of operation

Flow measurement and Control: Gases, rotameter types and principle of measurement, Thermal mass flow control with operational principle, calculation of flow with reference to temperature difference, electrical flow transducers, load cell etc, Metering pumps, types, operational principles

Pressure measurement: Bourdon tube pressure gauge with neat diagram, Diaphragm type pressure sensor used, Agitator shaft power by watt meter and rate of stirring by tachometer, Foam measurement and control by simple circuit loop. The importance of controlling dissolved oxygen, and Galvanic and Polarographic type of probes and its material of construction with electrolyte assembly. The concept of pH probe used in dissolved carbondioxide measurement to be explained with a measure of one unit pH change when 10 folds of dCO₂ raise to be stated.

4. Explain the configurations of the Bioreactor and its relative advantages (April / May 2010)

Other configurations of a fermentor for the specific purposes, Tower fermentor: Height; diameter is important with 6:1- bubble column air spurge at base even 16:1 with perforated plates positioned at intervals in the tower for maximum yeast production. Cylindro- conical vessels SS vertical tube with hemispherical top and a conical base with a included angle 70 dec. – agitated and design provides reduced process time and movement of fluid, sedimented yeast can be easily removed Air lift fermentor: air is the driving force- draw tube positioned, air enrich media, and low air media displacement- cultures grown with less shear force. 3 compartment multiple air lift loop fermentor- 3 draw tube assembly. The hydrodynamic fermentor types as deep jet model and loop model, cyclone column with neat diagram and principle of operations. Packed bed column and Rotating disc fermentor for immobilized cell system.

5. What are the general requirements of a fermentation process? (Nov/Dec 2011)

Refer to the class notes and explanations related to Bioreactor and its parts. A clear schematic representation of the vessel with steam entry and exit points, chill water circulation, impeller and aerators and its position, top plate with septum ports, sensors and its position, sampling and drain ports and their usages. The service line equipments such as steam generation, chill water circulation, air compressor, deionized water, autoclaving, laminar flow chamber etc to be explain with uses.

6. Explain about the different types and principles of Flow sheeting system. (Nov/Dec 2010)

It is the diagrammatic representation of the process into more explanatory ways. To know arrangement of equipment and Process stream and Process connection and process stream flow rate and operation condition. Types as Block diagram in boxes, and Pictorial representation as Piping and instrumental diagram and Process flow diagram and international standards and norms for figurative notations to be explained with example.

7. Write a detailed note on Material of construction and selection in fermentor fabrication.

Strict aseptic conditions- repeated steam sterilization-small scale possible to use glass stainless steel- 2 basic types used (i) A glass vessel with round flat bottom and top SS flanged carrying plate- borosilicate battery jars used (ii) A glass cylinder with SS top and bottom plates, sterilized in situ, max capacity is 30 cm. Material of construction should withstand pressure, Sterilization, Corrosion, potential toxicity, cost etc. AISI standard, Stainless steel composition, areas where wood, plastic and concrete used, corrosion resistance, thin hydrous oxide film on the surface of the metal, stabilized by chromium and non-porous, insoluble self healing material. Increased chromium content increases resistance, presence of molybdenum increases resistance of SS to halogen salts and seawater- electro polishing done, and Thickness of construction varies with size of the fermentor.

8. Discuss the types of seal system in fermentation (Nov/Dec 2010)

Aseptic requirement of fermentation- joints of glass to glass, glass to metal and metal to metal, glass to metal joins with gasket, lip seal and O ring type diagram and explain each, Nitryl /butyl rubbers used for seal, double O ring with steam lock according to level of operations. Explain the principle and operations of stuffing box packed gland seal, simple bush seal, and mechanical seal and magnetic drives, discuss its advantages and disadvantages

9. Explain the various Bioprocess development of Antibiotic era & Post antibiotic era

Periods of Bioprocess development: Period of ignorance (pre 1800), Period of Discovery (1800 -1900) and Period of industrial development (post 1900) Points related to Traditional Biotechnology, New era biotechnology, Different products in Biotechnology, History division in to Period of Ignorance: Domestic development, Wine, Brewing etc, Period of Discovery, invention of microscope, Pasteur and fermentation,

Leibig findings, Period of Industrial development: Antibiotic development as

Emmerich and low and Alexander Fleming, Recent development qualitative and quantitative development etc

10. With the help of case study, explain the general requirements of industrial scale fermentation processes. (Nov / Dec 2012)

Up stream processing: Utilities such as steam, Chill water, Air supply to be explained, media procurement, media formulation and medium sterilization to be explained Fermentation and condition to the production to be explained

Downstream processing; The sequential steps in separation of active principle from fermentation broth upto product packing. In the down stream process the unit operation cell lysis techniques ether by ultrasonification, bead beating, or French press cell lysis etc i.e Broth and biomass separation using Centrifugation or filtration, Cell lysis by ultrasonication, French pressure cell, Centrifugation and Cell free supernatant, Product extraction by protein separation techniques, Protein purification by ultrafiltration and chromatographic separation, and freedrying to be explained.

11. State the sensing and monitoring principles of Pressure, dO₂ and dCO₂ measurements. Nov 2014

Pressure measurement: Bourdon tube pressure gauge with neat diagram, Diaphragm type pressure sensor used, Agitator shaft power by watt meter and rate of stirring by tachometer, Foam measurement and control by simple circuit loop. The importance of controlling dissolved oxygen, and Galvanic and Polarographic type of probes and its material of construction with electrolyte assembly. The concept of pH probe used in dissolved carbondioxide measurement to be explained with a measure of one unit pH change when 10 folds of dCO₂ raise to be stated.

12. Write a detailed note on material of construction of fermentor (Nov / Dec 2011)

Material of construction should withstand pressure, Sterilization, Corrosion, potential toxicity, cost etc. AISI standard, Stainless steel composition, areas where wood, plastic and concrete used, corrosion resistance, thin hydrous oxide film on the surface of the metal, stabilized by chromium and non-porous, insoluble self healing material. Increased chromium content increases resistance, presence of molybdenum increases resistance of SS to halogen salts and seawater- electro polishing done, and Thickness of construction varies with size of the fermentor

13. Discuss about the different agitators and valves of fermentation system (April /May

2012)

Draw different types of Agitators, and concept of vortex formation and avoidance, and different valves system, Aseptic requirement of fermentation- joints of glass to glass, glass to metal and metal to metal, glass to metal joins with gasket, lip seal and O ring type diagram and explain each, Nitryl /butyl rubbers used for seal, double O ring with steam lock according to level of operations. Explain the principle and operations of stuffing box packed gland seal, simple bush seal, and mechanical seal and magnetic drives; discuss its advantages and disadvantages. The ancillary equipments, such as valves and its types to be mentioned with neat diagrams. The concept of coarse adjustment and fine adjustment and fitness for sterile usage etc. The types such as Gate valve, Globe valve, Piston valve, Needle valve, Plug valve, Ball valve, Butterfly valve, Pinch valve, Diaphragm valves to be explained with its fitness for sterile use and course or fine adjustments etc.

14. Write briefly explains about the main parameters to be controlled and monitored in fermentation process (15)

Process control

Process control is concerned with making adjustments to the process consequent upon the measurement of one or more of the variable that change as a result of the action of the process.

Sensors

Main classes of sensors (Classification)

Sensors penetrate into the interior of the fermenter.

Sensors operates on samples which is continuously withdrawn from the fermenter.

Sensors which do not come into contact with the fermentation broth or gases

Classification of sensors in relation to its application for process control

In-line sensor. The sensor is part of fermentation equipment and the measured value is, without intervention of an operator, directly used for process control.

On-line sensor. The sensor is part of fermentation equipment, but the measured value of the variable is not directly available for process control. The intervention of an operator to enter the measured value into the fermentation system for process control is necessary

Off-line sensors. The sensor is not a part of fermentation equipment. The measured value is not directly available for process control. The intervention of an operator is essential, first for

the actual measurement and finally for entering the measured value into the fermentation system for process control.

Parameters characterizing a bioreactor

The presence of the living microorganisms inside the bioreactor makes it more complicated than the conventional chemical reactor. As already indicated, it is extremely important to gather the knowledge about the state of the bioreactor prior to design and implementation of any control system for the reactor. The complete state of the biochemical reactor can be assessed by knowing the following parameters: physical parameters, chemical (extracellular) parameters, biochemical (intracellular), and biological parameters.³ The following subsections will list the various parameters in each category.

Physical parameters

The following are the important physical parameters for the operation of a bioreactor: agitation power, agitation speed, broth volume, color, expanded broth volume (density), foaming, gas flow rate, gas humidity, heat generation rate, heat transfer rate, liquid feed rate, liquid level, mass, osmotic pressure, pressure, shear rate, tip speed, temperature, turnover time, and viscosity.³ Many of these parameters have important implications in the control of bioreactors.

Chemical Parameters

The following list gives the different parameters that define the chemical environment inside the reactor: amino acids, carbon dioxide (gas), cation level, conductivity, inhibitor, intermediate(s), ionic strength, malliard reaction products, nitrogen (free and total), nutrient composition, oxygen, pH, phosphorous, precursor, product, redox and substrate.³

Biochemical (intracellular) parameters

Biochemical parameters are the intracellular parameters that indicate the metabolic state of the cell at any given time during the cell growth. These include amino acids, ATP/ADP/AMP, carbohydrates, cell mass composition, enzymes, intermediates, NAD/NADH, nucleic acids, total protein, and vitamins.

Biological parameters

Biological parameters characterize the bioreactor in terms of what is happening inside the reactor at the cellular level. The list includes age/age distribution, aggregation, contamination, degeneration, doubling time, genetic instability, morphology, mutation, size/size distribution, total cell count and viable cell count.

Process variables

Physical variables

Chemical variables (extracellular)

Air (gas) flow	Dissolved carbon dioxide
Bioreactor volume	Dissolved oxygen
Conductivity	Fluorescence
Foaming	Ionic strength
Liquid level	Nutrition concentration
Liquid flow	Off-gas constituents
Optical density	pH
Agitator speed	Nitrogen
Agitator power	Phosphorous
Pressure	Redox potential
Temperature	Substrate
Viscosity	Conductivity
Mass	Product
Broth volume	
Colour	

Biological variables

Biochemical variables (intracellular)

Age distribution	Amino acids
Aggregation	ATP / ADP / AMP
Microbial contamination	Carbohydrates

Degeneration	Cell mass composition
Doubling time	Enzymes
Genetic instability	Intermediates
Morphology	NAD / NADH
Mutation	DNA / RNA
Size distribution	Total protein
Total cell count	Vitamins
Viable cell count	Product

Exsamples of control function

Measurement	Possible control function
-------------	---------------------------

Pressure	
rpm	
Agitor shaft power	
Exit gas analysis	Change feed rate
<i>Flow rate</i>	<i>Change flow rate</i>
Foam	Foam control
<i>Medium analysis</i>	Change in medium composition
<i>Oxygen</i>	<i>Change feed rate</i>
pH	<i>Acid or alkaline addition</i>
	<i>Carbone source feed rate</i>
Redox	Additives to change redox
<i>Temperature</i>	<i>Heat / cool</i>
Weight	Change flow rate

15. What are the basic configuration of fermentor and ancillaries (5)

Basic configuration of fermenter

The bioreactor or fermentor is the heart of the fermentation process. Here the function of the fermentor is to provide controlled environment for the growth of micro organisms or animal cells to obtain the desired product .Microbiological or biochemical reactions to produce value

added products or to treat waste streams (bio fillings)

The typical process includes fermentations to produce antibiotics, enzymatic reactors to create ingredients HFCS and natural bio systems such as composting operations or bio filters.

Here the microbial fermentation can be viewed as a three phase systems involving,

liquid –solid

gas- solid

gas-liquid

Incase of **liquid phase**, contains dissolved nutrients, dissolve substrate & dissolved metabolites;

Incase of **solid phase**, consists of individual cells, pellets, insoluble substrates or precipitated some metabolic products;

Incase of **gaseous phase**, provides a reservoir for oxygen supply and for co₂ remove;

For each biotechnology process, the most suitable contaminated system must be design & monitored & controlled process.

The environment in which the desire biocatalyst can interact with the environment and material supply is known as fermentor;

Mode of operations:

Batch operations

Fed batch operations

Continuous operations

Parts of fermentor or bio reactor:

Shell

Head

Flange joint

Nozzles

Aeration and agitation

Baffling

Jackets

Supports

Shell:

Cylindrical, horizontal

Head space volume

The bioreactor is divided into working volume and head space volume.

The working volume is the fraction of the total volume taken up by the medium, microbes,

gas bubbles. The remaining volume is called the head space volume.

In fair fermentor typically working volume will be 70-80% of the total fermentor volume.

This volume will however depend on the rate of foam formation during the reaction.

If the medium or fermentation has the tendency foam then a larger head space and a smaller working volume will needed to be used.

Types of head:

Torispherical head

Semispherical head

Shallow disc head

Elliptical head

Hemispherical head

Conical head

The most commonly used foamed head for a pilot and industrial scale fermentor are torispherical or elliptical

Flange joint:

Heads of pressure vessels are to be of desirable type. There must be provided flange, the arrangement of bolting, similarly the nozzle and pipe systems may also be provided.

The use the use of such bolted flange connects which are readily removable to facilitate assembly of different components.

It consists of a pair of flanges one each attached to the two components to be joined, held screwly together by a series of bolts and studs.

Gasket:

The gasket is interposed between the two adjoining flange phases.

The joint must have structural integrity with negligible leakage during the process.

Nozzles:

Openings provided in the pressure vessels or reactors to satisfy certain requirements such as inlet and outlet connections or man holds and hand holds

This may be located on the shell or head according to functional requirements and are circular, elliptical, or round.

On the basis of method of foaming and attachments, the nozzles can be classified as,k

Reliable aspartic connect to the external piping

Feed drying

Simple reliable cleaning and sterilization procedures.

Aeration and agitation:

The primary purpose of aeration is to provide micro organisms in submerged cultures. With sufficient oxygen for metabolic requirements while agitation should be ensured that uniform suspension of microbial cells is achieved in a homogenous medium.

The variety of agitation system is available. The factors to be considered are,

Type of agitators

Circulation pattern

Location of agitator in the basic equipment

Diameter and width of the agitator

Method of baffling

Power requirements of the agitator

Shaft overhang

Type of stuffing box or seal, bearings , drives system etc

The structural components of fermentor in aeration and agitation are

Agitator (impeller)

Baffles

Aeration systems (sparger) stirrer glands and bearings

16. Write briefly explains about Application of fermentation process? (10)

APPLICATION OF FERMENTATION:

The various products of manufactured using fermentation. There are 5 major groups of commercial products.

Those that produce **microbial cells** or biomass products.

Those that produce **microbial enzymes**.

Those that produce **microbial metabolites**.

Those that produce **Recombinant products**.

Those that modified a compound which is added to the fermentation (the **biotransformation** process).

17. PRODUCTS OF FERMENTATION PROCESSES

The growth of micro-organisms or other cells results in a wide range of products. Each culture operation has one or few set objectives. The process has to be monitored carefully and continuously, to maintain the precise conditions needed and recover optimum levels of products. Accordingly, fermentation processes aim at one or more of the following:

- a) Production of cells (biomass) such as yeasts;
 - b) extraction of metabolic products such amino acids, proteins (including enzymes), vitamins, alcohol, etc., for human and/or animal consumption or industrial use such as fertiliser production;
 - c) Modification of compounds (through the mediation of **elicitors** or through **biotransformation**); and
 - d) Production of **recombinant** products.

MICROBIAL BIOMASS

Microbial biomass is produced commercially as **single cell protein** (SCP) using such unicellular algae as species of *Chlorella* or *Spirulina* for human or animal consumption, or viable yeast cells needed for the baking industry, which was also used as human feed at one time. Bacterial biomass is used as animal feed. The biomass of *Fusarium graminearum* is also produced, for a similar use.

MICROBIAL METABOLITES

Primary metabolites:

During the log or exponential phase organisms produce a variety of substances that are essential for their growth, such as nucleotides, nucleic acids, amino acids, proteins, carbohydrates, lipids, etc., or by- products of energy yielding metabolism such as ethanol, acetone, butanol, etc. This phase is described as the **tropophase**, and the products are usually called **primary metabolites**. Commercial examples of such products are given in Table

TABLE : Examples of commercially produced primary metabolites

Primary Metabolite	Organism	Significance
Ethanol	<i>Saccharomyces cerevisiae</i> <i>Kluyveromyces fragilis</i>	alcoholic beverages
Citric acid	<i>Aspergillus niger</i>	food industry

Acetone and butanol

Clostridium acetobutylicum

solvents

Lysine	<i>Corynebacterium</i>	nutritional additive
Glutamic acid	<i>glutamacium</i>	flavour enhancer
Riboflavin	<i>Ashbya gossippii</i>	nutritional
	<i>Eremothecium ashbyi</i>	
Vitamin B12	<i>Pseudomonas denitrificans</i>	nutritional
	<i>Propionibacterium shermanii</i>	
Dextran	<i>Leuconostoc mesenteroides</i>	industrial
Xanthan gum	<i>Xanthomonas campestris</i>	industrial

ii) Secondary metabolites:

Organisms produce a number of products, other than the primary metabolites. The phase, during which products that have no obvious role in metabolism of the culture organisms are produced, is called the **idiophase**, and the products are called **secondary metabolites**.

In reality, the distinction between the primary and secondary metabolites is not a straightjacket situation. Many secondary metabolites are produced from intermediates and end products of secondary metabolism. Some like those of the Enterobacteriaceae do not undergo secondary metabolism. Examples of secondary metabolites are given in Table 3.

TABLE 3

Examples of commercially produced secondary metabolites

Metabolite	Species	Significance
Penicillin	<i>Penicillium chrysogenum</i>	antibiotic
Erythromycin	<i>Streptomyces erythreus</i>	antibiotic
Streptomycin	<i>Streptomyces griseus</i>	antibiotic
Cephalosporin	<i>Cephalosporium acimonium</i>	antibiotic
Griseofulvin	<i>Penicillium griseofulvin</i>	antifungal antibiotic
Cyclosporin A	<i>Tolypocladium inflatum</i>	immunosuppressant
Gibberellin	<i>Gibberella fujikuroi</i>	plant growth regulator

Secondary metabolism may be **repressed** in certain cases. Glucose represses the production of actinomycin, penicillin, neomycin and streptomycin; phosphate represses streptomycin and tetracyclin production. Hence, the culture medium for secondary metabolite production should be carefully chosen.

PRODUCTION ENZYMES

Industrial production of enzymes is needed for the commercial production of food and beverages. Enzymes are also used in clinical or industrial analysis and now they are even added to washing powders (cellulase, protease, lipase). Enzymes may be produced by microbial, plant or animal cultures. Even plant and animal enzymes can be produced by microbial fermentation. While most enzymes are produced in the tropophase, some like the amylases (by *Bacillus stearothermophilus*) are produced in the idiophase, and hence are secondary metabolites. Examples of enzymes produced through fermentation processes are given in Table 4.

TABLE 4

Examples of commercially produced enzymes

Organism	Enzyme
<i>Aspergillus oryzae</i>	Amylases
<i>Aspergillus niger</i>	Glucamylase
<i>Trichoderma reesii</i>	Cellulase
<i>Saccharomyces cerevisiae</i>	Invertase
<i>Kluyveromyces fragilis</i>	Lactase
<i>Saccharomyces lipolytica</i>	Lipase
<i>Aspergillus</i> species	Pectinases and proteases
<i>Bacillus</i> species	Proteases
<i>Mucor pusillus</i>	Microbial rennet
<i>Mucor meihei</i>	Microbial rennet

FOOD INDUSTRY PRODUCTS

A very wide range of innumerable products of the food industry, such as sour cream, yoghurt, cheeses, fermented meats, bread and other bakery products, alcoholic beverages, vinegar, fermented vegetables and pickles, etc., are produced through microbial fermentation processes. The efficiency of the strains of the organisms used, and the processes are being continuously improved to market quality products at more reasonable costs.

RECOMBINANT PRODUCTS

Recombinant DNA technology has made it possible to introduce genes from any organism into micro-organisms and *vice versa*, resulting in **transgenic** organisms and the latter are made to produce the gene product. Genetically manipulated *Escherichia coli*, *Saccharomyces cerevisiae*, other yeasts and even filamentous fungi are now being used to produce interferon, insulin, human serum albumin, and several other products.

BIOTRANSFORMATION

Production of a structurally similar compound from a particular one, during the fermentation process is transformation, or **biotransformation**, or **bioconversion**. The oldest instance of this process is the production of acetic acid from ethanol.

Immobilised plant cells may be used for biotransformation. Using alginate as the immobilising polymer, digitoxin from *Digitalis lanata* was converted into digoxin, which is a therapeutic agent in great demand. Similarly, codeinone was converted into codeine and tyrosine from *Mucuna pruriens* was converted into DOPA.

ELICITORS

It is possible to induce production or enhance production of a compound in cultures by using **elicitors**, which may be micro-organisms. For example, *Saccharomyces cerevisiae* was an efficient elicitor in the production of glyceollin (*Glycine max*) and berberine (*Thalictrum rugosum*). *Rhizopus arrhizus* trebled diosgenin production by *Dioscorea deltoidea*. The production of morphine and codeine by *Papaver somniferum* was increased 18 times by *Verticillium dahliae*.

18. What are the essential requirements of a fermentor?

Any fermentor has to satisfy some basic requirements like:

The vessel must be strong enough to withstand the pressure of large volumes of aqueous medium.

The vessel should not corrupt the fermentation product or contribute toxic ions to the growth medium.

Usually pure culture is used in the fermentor. Therefore, provision for control of or prevention of growth of contaminating microorganisms must be provided.

If the fermentation is aerobic then provision must be made for rapid incorporation of sterile air into the medium in such a manner that oxygen of this air is dissolved. This is utilized by microorganism that evolves CO₂ which must be removed through a different flushing system.

Some form of stirring should be available.

The fermentor should provide facilities for the intermittent addition of anti foam agent as demanded by the foaming state of the medium.

The fermentor should posses a temperature control for the effective growth of the organisms.

The fermentor should also posses a mechanism for detecting pH values of culture medium and mechanism to adjust the pH according to the microbial growth.

There must be a drain in the bottom of the fermentor or some mechanism provided for removing the completed fermentation broth from the tank.

19. What are the Guidelines for Over Production of Media?

Prepare a range of media in which different types of nutrients become growth-limiting e.g. C, N, P, O

For each type of nutrient depletion use different forms of the growth-sufficient nutrient

Use a polymeric or complexed form of the growth-limiting nutrient.

Avoid the use of readily assimilated forms of carbon (glucose) or nitrogen (NH_4^+) that may cause catabolite repression.

Ensure that known cofactors are present (CO_3^{2-} , Mg^{2+} , Mn^{2+} , Fe^{2+}).

Buffer to minimize pH changes.

20. With a neat diagram, explain the configuration of fermentor and its ancillaries (Nov / Dec 2012)

21. Compare and explain on-line and off-line control (Nov/Dec 2014)

22. Discuss about the different process parameters and its control (April /May 2014)

UNIT II

RAW MATERIALS AND MEDIA DESIGN FOR FERMENTATION PROCESS -9

- | |
|---|
| ✓ Criteria for good medium |
| ✓ Medium requirements for fermentation processes, carbon, nitrogen, minerals, vitamins and other complex nutrients, oxygen requirements |
| ✓ Medium formulation of optimal growth and product formation |
| ✓ Examples of simple and complex media |
| ✓ Design of various commercial media for industrial fermentations – medium optimization methods |

PART – A QUESTIONS AND ANSWERS

1. State few characteristics of Ideal Production medium

Maximum yield of product, maximum rate of product formation, minimum yield of undesired products, less problem in down stream operations.

2. Define medium formulation and what are the limiting compounds?

Formulation

Possible to calculate the minimal quantities of nutrients which will be needed to produce a specific amount of biomass

Possible to calculate substrate concentrations necessary to produce required yields

May be medium components needed for product formation which are not required for biomass production

THE LIMITING SUBSTRATE:

Carbon, nitrogen, trace elements may be act as limiting substrate is also called inducer in some reactions.

3. What is the role of molasses and yeast extract in a complex medium?

Aspartic Acid A dicarboxylic amino acid found in plants and animals, especially in molasses from young sugarcane and sugar beets

4. Explain the use of precursor in the fermentation medium with suitable example?

Precursors and metabolic regulators

Regulation of the production of product

Precursors

Chemicals directly incorporated into the desired product increasing the yield

Inhibitors

Increasing the yield of desired product

Reducing the yield of undesirable related products

Also used to affect the cell-wall structure and increase permeability for release of metabolites

Precursors used in fermentation processes

Precursor	Product	Micro-organism
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Phenylacetic-acid related compounds	Penicillin G	<i>Penicillium chrysogenum</i>	1
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Phenoxy acetic acid	Penicillin V	<i>Penicillium chrysogenum</i>
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Chloride	Chlortetracycline	<i>Streptomyces aureofaciens</i>
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5. Mention the elemental composition of Bacterial cell.

Carbon : 50-53 % dry weight, Nitrogen: 12-15%, Hydrogen: 7%, Phosphorus: 2-3%, Sulphur: 0.2-1.0 %, Sodium&Calcium: 0.5-1.0%, Potassium: 1.0-4.5%

6. Write the properties of 'Ideal Antifoam'.

Antifoam should readily reduce the surface tension so that foaming can be suppressed, also it should not be assimilated by the organism and should be easily removed during downstream processing.

7. Write a note on addition of Precursors in the medium.

Precursors: are the chemicals added to incorporate into the product formed, They become part and parcel of the product. eg. CSL added to penG production increases 20 units to 100 units/cm³, CSL found to contain phenylethylamin, which is present in PenG molecules to yield more.

8. Explain about Serum based media.

Used for animal cell cultivation contains ~ 1000 components such as organic, inorganic salts, amino acids, vitamins, carbon sources, hormones, growth factors, hemoglobin, albumin, etc. Most of them are not needed for cell growth and differentiation of the cells. Serum based medium should be free from bacterial, viral or pyrogen free contamination. Eg. Foetal calf serum.

9. Mention the commonly used carbon sources.

Cane molasses, Beet molasses, Corn & Maize starch, Oils, fats, hydrocarbons, Whey.

10. Mention commonly used Nitrogen sources.

Inorganic forms : Ammonia, Nitrate salts etc Organic forms: Protein, Peptide and amino acid, urea. Complex media such as Corn steep liquor, Soya bean meal, Pharma media, Yeast extract.

11. What are the nutritional requirements for the growth of Microorganism?

Medium should contain Carbohydrates, Nitrogen, Minerals such as S, P, Mg, K, Fe, Zn, Cu, Mn, Chelators, growth factors, Precursors, inhibitors, inducers, Oxygen requirements for fast metabolism and better rheology, antifoams.

12. What is meant by Defined media?

Medium with known elemental composition and its concentration

13. State the Stoichiometry for growth and product formation.

Carbon and + Nitrogen +O₂ + other Biomass + Products + CO₂+H₂O+ heat
Energy sources sources requirements

14. What is meant by yield coefficient (Y)?

Y = Qty. Of cell dry matter product/ Qty of carbon substrate utilized

15. What is aim of Plackett-Burman design?

When more than five independent variables are used investigated, to find the most important variable in system, then can be optimized for further studies.

16. Mention any four criteria for large-scale production medium. (Nov / Dec 2012)

Maximum yield of product, maximum rate of product formation, minimum yield of undesired products, less problem in down stream operations.

17. Mention the types of Response surfaces outputs in medium design.

Mound, Rising ridge, Saddle etc

18. Write about Yeast extract.

Backers yeast undergoes autolysis at 50-55 deg C, Plasmolysis with high concentration of NaCl that releases aminoacids, peptides, vitamins etc

19. Mention the elemental composition of Bacterial cell.

Carbon: 50-53, Nitrogen: 12-15, Hydrogen: 7, Phosphorus: 2-3, sulphur: 0.2-1.0, Potassium; 1-4.5 % of dry weight.

20. Write a short note on Minimal medium.

In aerobic fermentation of microbial cell, should have minimum quantities, for economic design of media if component wastage is to be minimal. These minimal quantities of nutrients should be calculated for specific production of biomass and product without wasting.

21. Write the composition of Cane Molasses?

Water: 20%, ash: 8%, Total sugar: 40-60%, Total Nitrogen: 3%, Gums: 2%, Freeacids:2%

22. What is the necessity of adding Inducer in the medium?

Inducers are added to form certain specific products and also alters the cellwall permeability eg. glyceral

23. Explain Sulphite waste liquor and its uses.

The wood chips are hydrolysed by calcium bisulphate under high temperature and pressure, the spent liquor has 10-12% of solids of cellulose and 2% of sugar of hexoses and pentose, that is used in ethanol production.

PART B QUESTIONS

24. Give a detailed account on various Carbohydrate sources used in media design

Carbon source and importance, types of sources such as natural sources, Oils / fats, Hydrocarbons, etc, It decides the rate of process and product cost. eg, starch extracted from Maize grain or potatoes, starch is readily hydrolyzed by dilute acids and enzymes to give a variety of glucose syrups. Sucrose is obtained from sugarcane, beetroot etc.

The rate at which C source is metabolized can often influence the formation of biomass / Production of primary / secondary metabolites. Fast growth due to rapid utilization of sugar to decrease the production of secondary metabolites experimentally proved by glucose usage and lactose usage. Other carbohydrate sources used such as Oils and Fats, Molasses, cheese whey, cereals, sulphite waste liquor, rice straw, malt extract etc.

25. Explain the different Nitrogen sources used in medium design

Nitrogen sources such as inorganic and organic sources, energy supplements from nitrogen sources etc to be explained. Inorganic: Ammonia gas, ammonium salts and nitrates, pH control in defined medium. Ammonium salts, nitrates used the free acid will be liberated pH altered.

Nitrate reeducates is repressed by ammonia till its presence in medium, once diminished then nitrate assimilated. Hence mixture of two nitrogen sources regulates other's intake.

Organic : Supplied as amino acid, protein, urea, growth will be faster with a supply of organic nitrogen. Proteinecious nitrogen compounds forms as source for amino acids like corn steep liquor, soya bean meal, peanut meal, cotton seed meal, yeast extract. But storage affect by moisture, temperature.

26. Write a detailed account on Plackett-Burman design of media optimization.

The principle of Medium optimization, careful consideration of each elemental composition for efficient grown biomass and high productivity, method to use of trial

and error method, time consuming with X^n where x is no. Of levels and n is no. of variables. Plackett Burman design used when more than five independent variable are used, most important variable in a system can be found and optimized further. Technique allows use of X no. of experiments with X-1 variable and X must be 4 or multiples of 4, concept of dummy variable to be introduced, example chart to be drawn with high and low concentration of each variable. As the analysis for each variables the Difference to be found, Effect of each variable, mean square of variable to found, procedure of experimental error and finally the factor of each variable to be seen using F test. These values to see for the effect of each variable in the growth of microorganism.

27. Explain the various Response surface methods of optimization: (April / May 2011)

Three factors are taken for experiment and responses surface of contour plots or Topographical maps with constant elevation values. Response means the result of an experiment carried out at particular value of variable being investigated. To construct a contour plot, the responses of series of experiment, employing different conditions combinations are inserted on the surface of plot. The points giving same results are then joined together to make contour line, Strategy to arrive a optimum to made as 5 steps and further optimization can be done. Explain the types of Mound, Saddle, Rising ridge etc. The significance of Simplex method: two axis and experimental movement – Centroid and Crabwise way movement to meet the optimum etc.

28. Write notes on Precursors and Inducers in Medium formulation.

Precursors: are the chemical added to incorporated to the product formed eg. CSL added to penG production increases 20 units to 100 units/cm³, CSL found to be contain phenylethylamine, which seeded in PenG molecules to yield more.

Inducers: Chemical that are important, that only in the presence of such chemicals the product would be formed. Eg. Substrates or substrate analogues. All enzymes are inducible eg. Starch for amylase, Maltose for pullulanase, Pectin for pectinase, fatty acids for lipase etc.

29. Explain Plackett Burman and Reponse surface methods in the optimization (Nov / Dec 2013)

Three factors are taken for experiment and responses surface of contour plots or Topographical maps with constant elevation values. Response means the result of an experiment carried out at particular value of variable being investigated. To construct

a contour plot, the responses of series of experiment, employing different conditions combinations are inserted on the surface of plot. The points giving same results are then joined together to make contour line, Strategy to arrive at optimum is made as 5 steps and further optimization can be done. Explain the types of Mound, Saddle, Rising ridge etc.

30. Write briefly explains about medium requirements for fermentation processes? (5)

Medium requirements

Raw materials and media design for fermentation process

All micro organisms require water, source of energy, carbon, nitrogen, vitamins and oxygen if aerobic, minerals and phosphorus.

PRODUCTION MEDIA:

It must be cheap raw materials but at the same time special requirements for improve biosynthesis of products. The substrate cost frequently amount to us the 50% of the total manufacturing cost.

Raw materials for fermentation process containing pure C containing substrate like mono, di , poly saccharides , hydrocarbons, alcohols, etc . & complex substrates –molasses, cellulase wastes required, spent washes ,corn steep liquor, pharmaceutical media.

Carbon containing substrates:

Mono, di, polysaccharides, hydrocarbons, and alcohols, CO₂, etc.

Complex substrate:

Molasses, cellular base liquor, spent wash, corn steep liquor solids, pharmaceutical media and whey, etc

Source of nitrogen:

Nitrogen sources

Inorganic nitrogen

Ammonia gas, ammonium salts or nitrates

Organic nitrogen

Amino acid, protein or urea

Other proteinaceous nitrogen compounds

Corn-steep liquor, soy meal, peanut meal, cotton-seed meal, Distillers' solubles, meal and yeast extract

Best nitrogen sources for some secondary metabolites

Minerals

Micro-organisms require mineral elements for growth and metabolism

Essential minerals added as distinct compounds

Magnesium, phosphorus, potassium, sulfur, calcium and chlorine

Minerals present as impurities in other major ingredients

Cobalt, copper, iron, manganese, molybdenum and zinc

Complex media derived from plant and animal normally contain a considerable concentration of inorganic phosphate

Inorganic salts:

Phosphates, sulphates, chlorides, etc

Trace elements:

Fe, Zn, Cu, Mn, Mg etc

On a small scale it is relatively simple to devise medium containing pure compounds but the resulting media although supporting satisfactory

Chelators

Ethylene diamine tetraacetic acid (EDTA), citric acid, polyphosphates, etc.

Form complexes with the metal ions in the medium

The metal ions then may gradually be utilised by the micro-organism

Growth factors

Preformed components added to some micro-organisms

Vitamins, specific amino acids, fatty acids or sterols

Buffers

Control of pH

Internally

Calcium carbonate, phosphates

Carbon and nitrogen sources

Proteins, peptides and amino acids

Externally

Ammonia or sodium hydroxide

Sulfuric acid

Precursors and metabolic regulators

Regulation of the production of product

Precursors

Chemicals directly incorporated into the desired product increasing the yield

Inhibitors

Increasing the yield of desired product

Reducing the yield of undesirable related products

Also used to affect the cell-wall structure and increase permeability for release of metabolites

Precursors used in fermentation processes

Oxygen

Very important component of the medium in many processes

Fast metabolism

Oxygen limitation

Rheology

Viscosity influence

Polymers; starch and polysaccharides

Antifoams

Surface active agents reduce oxygen transfer

Foaming

Foaming may be caused by a component in the medium or some factor produced by the micro-organism

Proteins may denature at the air-broth interface and form a skin which does not rupture readily

Physical and biological problems may be created if foaming is uncontrolled

Reduction in working volume of the fermenter

Changes in bubble size

Lower mass and heat transfer rates

Invalid process data

Deposition of cells in upper parts of the fermenter

Contamination of air filter exits

Microbial infection

Siphoning leading to loss of product

Three ways of approaching the problem

Using a defined medium and a modification of some of the physical parameters (pH, temperature, aeration and agitation)

Using antifoam in the medium

Using a mechanical foam breaker

Antifoams

Surface active agents

Reduction of surface tension in the foams
Destabilizing protein films by
Hydrophobic bridges between two surfaces
Displacement of the absorbed protein
Rapid spreading on the surface of the film
Examples of suitable antifoams
Alcohols; stearyl and octyl decanol
Esters
Fatty acids and derivatives, particularly glycerides, which include cotton-seed oil, linseed oil, soy-bean oil, olive oil, castor oil, sunflower oil, rapeseed oil and cod liver oil
Silicones
Sulphonates
Miscellaneous; Alkaterge C, oxazaline, polypropylene glycol

Development of inocula

The culture used to inoculate has to satisfy the following criteria

Healthy, active state
Available in large volumes
Suitable morphological form
Free of contamination
Retain its product-forming capabilities
Recovery and purification

Choice of recovery process based on the following criteria

Intracellular or extracellular location of product
Concentration of product
Physical and chemical properties of desired product
Intended use of product
Minimal acceptable standard of purity
Magnitude of bio-hazard of product or broth
Impurities in fermenter broth

- a) **What are different types medium optimization methods and Write explain about any one? (10)**

Overview of response surface methodology

Response Surface Methodology

Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes .The most extensive applications of RSM are in the particular situations where several input variables potentially influence some performance measure or quality characteristic of the process. Thus performance measure or quality characteristic is called the **response**. The input variables are sometimes called **independent variables**, and they are subject to the control of the scientist or engineer. The field of response surface methodology consists of the experimental strategy for exploring the space of the process or independent variables, empirical statistical modeling to develop an appropriate approximating relationship between the yield and the process variables, and optimization methods for finding the values of the process variables that produce desirable values of the response.

Limitations

Large variations in the factors can be misleading (error, bias, no replication)

Critical factors may not be correctly defined or specified

Range of levels of factors too narrow or too wide --optimum can not be defined

Lack of use of good statistical principles

Over-reliance on computer -- make sure the results make good sense

Uses

To determine the factor levels that will simultaneously satisfy a set of desired specifications

To determine the optimum combination of factors that yield a desired response and describes the response near the optimum

To determine how a specific response is affected by changes in the level of the factors over the specified levels of interest.

To achieve a quantitative understanding of the system behavior over the region tested

To predict product properties throughout the region - even at factor combinations not actually run

To find conditions for process stability = insensitive spot

Full factorial design

Each factor is set at two levels, high(+) or low (-).For k factors the number of experiments is 2^k
The number of experiments increases rapidly.Satisfactory for up to 5 factors.

Central Composite Design

In statistics, a **central composite design** is an experimental design, useful in response surface methodology, for building a second order (quadratic) model for the response variable without needing to use a complete three-level factorial experiment.

After the designed experiment is performed, linear regression is used, sometimes iteratively, to obtain results. Coded variables are often used when constructing this design. The design consists of three distinct sets of experimental runs:

A factorial (perhaps fractional) design in the factors studied, each having two levels;

A set of *centre points*, experimental runs whose values of each factor are the medians of the values used in the factorial portion. This point is often replicated in order to improve the precision of the experiment;

A set of *axial points*, experimental runs identical to the centre points except for one factor, which will take on values both below and above the median of the two factorial levels, and typically both outside their range. All factors are varied in this way.

Plackett-Burman Designs

A two level fractional factorial design. Experiments numbers n are in multiples of 4

i.e. $n = 8, 12, 20, 24, 28, 32$ etc Factors $k \leq n - 1$ For $k < n-1$ use dummy factors

Most commonly used are $n=8$ and $n=12$

Limitations

Main effects may be aliased by two way interactions and Choice of layout by Plackett and Burman was set to minimize these. Thus ‘these designs are very useful for economically detecting large main effects, *assuming all interactions are negligible* when compared with the few important main effects’

Three Level Factorial Design

For higher order *Factorial* design the number of design points grows rapidly. In the *Three Level Factorial* design all possible combinations of the three discrete values of the parameter are used.

In Table a comparison between the number of experiments of a full *Three Level Factorial* design and other designs are shown. The number of design points can be reduced by skipping some higher order interactions between the input parameters.

Box-Behnken designs

Box-Behnken designs are experimental designs for response surface methodology in which each factor, or independent variable, is placed at one of three equally spaced values. (At least three levels are needed for the following goal.) The design should be sufficient to fit a quadratic model, that is, one containing squared terms and products of two factors. The ratio of the number of experimental points to the number of coefficients in the quadratic model should be reasonable (in fact, their designs kept it in the range of 1.5 to 2.6).

31. Write the criteria for good medium? (5)

It will produce maximum yield of biomass / product per gram of substrate.

It will produce maximum concentration of biomass / product.

It will permit the maximum rate of product formation .

There will be minimum yield of undesired formation.

It will be appear constituent quality & be readily available through out the year.

It will cause minimum problems during media making & sterilization.

It will cause minimum problem in other aspects of production process particularly aeration , agitation , extraction , purification , waste treatments.

The problem of developing a process from the laboratory scale to pilot scale & substituently industrial scale also be considered

b) Medium formulation:

32. Pseudomonas 5401 is to be used for production of SCP for animal feed. The substrate is fuel oil. The composition of pseudomonas 5401 is $\text{CH}_{1.83}\text{O}_{0.55}\text{N}_{0.25}$. The final cell concentration is 30 g/l. what minimum concentration of $(\text{NH}_4)_2\text{SO}_4$ must be provided in the medium if $(\text{NH}_4)_2\text{SO}_4$ is true sole of N_2 source. (8)

Given data:

Biomass: $\text{CH}_{1.83}\text{O}_{0.55}\text{N}_{0.25}$

For 1 mole of biomass 0.25 moles of N is required,

Amount of N required is = 0.25 g mole * 14 g/g mole

=3.5 g is N is required

therefore how much $(\text{NH}_4)_2\text{SO}_4$ is required

132.1g/ g mole of $(\text{NH}_4)_2\text{SO}_4$ = 28 g/g mole of N_2

? = 3.5 g is N

= 132.1 g/gmole of $(\text{NH}_4)_2\text{SO}_4$ *3.5 g of N_2

28 g/ g mole N_2

= 16.51 g of $(\text{NH}_4)_2\text{SO}_4$ required

Therefore, 1 mole of biomass required 16.51g of $(\text{NH}_4)_2\text{SO}_4$

30 g/l biomass = ?

Mol.wt of biomass $\text{CH}_{1.83}\text{O}_{0.55}\text{N}_{0.25}$.

= $12 + (1 \cdot 1.83) + (16 \cdot 0.55) + (14 \cdot 0.25)$

= 26.13 g/g mole

W.K.T = 30 g/l biomass

26.13 g/g mole

= 1.148g mole / l

1 mole of biomass required = 16.51g of $(\text{NH}_4)_2\text{SO}_4$

1.148g mole / l = ?

= 1.148g mole / l * 16.51g of $(\text{NH}_4)_2\text{SO}_4$

1 g mole of biomass

=18.955 g of $(\text{NH}_4)_2\text{SO}_4$ /l

- 33. How will you formulate medium for optimal growth (Nov/Dec 2013)**
- 34. Explain the advantages and considerations of Animal Cell culturing media**
- 35. What are the criteria for an ideal production medium**
- 36. Explain the process of medium formulations (April/May 2012)**
- 37. What are the Minerals and Growth factors required for cell culture (April/May 2012)**
- 38. What are the different precursors and its importance**
- 39. What is Oxygen requirement and related factors**
- 40. Explain the different plots of medium optimization.**
- 41. Discuss serum based medium and bioreactor design for Animal cell cultivation.**

42. PROBLEM NO: 1 Ref.EX .NO.7.1 (S & K)

Determine the amount of ammonium sulfate $(\text{NH}_4)_2\text{SO}_4$ to be supplied in a fermentation media where the final cell concentration is 30 g/l in a 10^3 L culture volume . Assume that the cells are 12% nitrogen by weight & ammonium sulfate is only the nitrogen source?

43. PROBLEM NO: 2

You have to formulate a carbon is a limited medium (xylose) (i.e.) suppose to be able to generate 28 g/l of E.coli , if the cell yield coefficient for E.coli growing on xylose is 0.4 . What cell concentration can be achieved with this medium?

Sl.no	COMPONENT	AMOUNT
Unit	----	g/l
1	Xylose	70
2	$(\text{NH}_4)_2\text{SO}_4$	20
3	KH_2PO_4	3.5
4	MgSO_4	1.5

44. PROBLEM NO: 3

From following data, find out which is the limiting reactant ,the cell yield coefficient for E.coli growing on this carbon source is 0.38 .

COMPONENT	AMOUNT (g/l)
Carbon source	80
K ₂ HPO ₄	8
(NH ₄) ₂ SO ₄	24
MgSO ₄	2

45. PROBLEM NO 4

A media formulation for a bacterium is shown below with the selection of carbon source being the only variable is known with complete certain similarly that all elements are provide in excess (related to carbon with the possible exception of N₂) & Determine for each of the carbon source below, whether carbon or nitrogen source is the grow the limiting elements in the media formulation

GIVEN DATA:

COMPOUND	AMT (g /l)
Carbon source	75
NH ₄ NO ₃	15
K ₂ PO ₄	12.2
MgSO ₄	4.4

Carbon source

COMPOUND	Y _{xs}
Glucose	0.52
Glycerol	0.37
Acetate	0.31

UNIT III
STERILIZATION KINETICS-9

✓ Thermal death kinetics of microorganisms
✓ Batch heat sterilization of liquid media
✓ Continuous heat sterilization of liquid media
✓ Filter sterilization of liquid media
✓ Air sterilization
✓ Design of sterilization equipment - batch and continuous.

PART – A QUESTIONS AND ANSWERS

1. List down various methods of Sterilization.

Steam, Dry heat, Pasteurization, Tyndallisation, Chemical, Ionizing radiation, filtration

2. Define Del factor

Measures fractional reduction in viable organism count produced by certain heat and time regime (degree of sterilization)

3. Write the importance of holding time in sterilization of medium?

4. What are the methods available for sterilization?

5. Define the sterilization criteria ▼ & give the value of industrially acceptable contamination risk

6. Advantage of continuous sterilization process?

7. Define Filter sterilization of liquid media

8. What are the advantages of filter sterilization?

Physical exclusion of microbes from air and liquid medium- thermal liable solutions can be sterilized.

9. State the need of sterilization in fermentation with two reasons.

Medium would have to support the growth of production organism and also contaminant cause less productivity. If fermentation is continuous, contaminates may outgrow the other and displace it from system

10. Explain the concept of HTST in sterilization.

The concept of high temperature and short time is the basis of continuous sterilization and same del factor can be attained.

11. List the advantages of ‘Continuous sterilization’.

Advantages as no contact of steam medium. No sedimentation so the process gets over quickly – disadvantages as Foaming may occur during heating.

12. Calculate the Del overall for the steam sterilization using logical data.

Consider the No as 10^{11} cell and Nt value as 10^{-3} and calculate del as $\ln(No/Nt)$

13. State and explain the log penetration equation.

$\ln(Nt/No) = -kx$ where Nt & No concentration of particle in the air before and after filtration; x is length of filter; k is constant.

14. State the Activation energy and Arrhenius constant for B. Stearothermophilus.

Activation energy (E) = 67.7 kcal/mole; Arrhenius constant = $1 \times 10^{36.2}$ / sec

15. Explain the concept of ‘Cooking effect’ in medium sterilization

During sterilization, the initial rise of yield is due to some nutrient made more available, this effect is called cooking effect.

16. State the process of tyndallization

Devised by Tyndall 1660, spontaneous generation, heating the material at atmospheric pressure to 100 deg C on successive days, useful in medium gets affected more than 100 deg C, where spores are present. These spores which survive the first heat treatment germinate into vegetative cells which are destroyed in the second heat generation.

17. State the uses of Dry heat of sterilization

Used in Incubators and ovens, used to sterilize glassware and heat stable solid materials, require much longer exposure as heat conduction is less rapid in air (poor thermal conductivity) than in steam spore become more heat resistant in the absence of moisture.

18. State the Mechanism of Ionizing radiation

The use of high energy electrons, UV rays, gamma rays used for the media and air sterilization, not fully reliable but highly used in plastic lab ware, petri-dishes. UV rays are effective in killing air borne microorganism.

19. What are the types of Filters used in Sterilization?

Depth filters: Variety of natural fibers such as cotton replaced by glass fibre (glasswool) to form as bed ensures removal of organisms.

Exclusion filters: The PTFE membranes with pore size 0.2-0.45um for all organisms to remove used. These filters are used in heat labile liquid sterilization. These are hydrophobic membranes cartridges for air filtration, they are unidirectional.

20. List down the mechanisms by which filters sterilization by membranes

Inertial impaction, Diffusion, Electro-static attraction and interception etc

21. Explain the phenomena of Interception of membrane filtration

The fibers of filter interwoven to define size of the openings, The particle which are large to these pores removed by direct interception. Even small particles also getting removed by interception because more than one particles arrive at pore simultaneously and irregular particle tend to bridge a pore which are much small still to filter small particles.

22. State the equation of del Holding calculation.

Del holding = Del overall - Del heating – Del cooling

23. State the mechanism of Continuous sterilization

Temp of the medium elevated in continuous heat exchanger and maintained in insulated serpentine holding coil for the holding period and cooled using flash coolers.

24. State the advantages of Spiral heat exchangers in Continuous sterilizer

Two streams are separated and no contact and no cross contamination.

This aids in self cleaning of suspended solids, sedimentation because of spiral route of flow

25. State the need of empty vessel sterilization

In order to minimize the time for sterilization and overall duration of the fermentation, medium is sterilized separately and the empty fermentation vessel is heated with heating coil and jacketed steam supply and after 20 minutes of sterilization, pre-sterilized medium is added with positive pressure.

PART B - QUESTIONS

1. Explain the various methods of sterilization process.

Dry heat: used in incubators / Ovens – used to sterilize glassware / heat stable solid materials – requires much longer exposure as heat conduction is less rapid in air because of poor thermal conductivity than in steam - Spore become more heat resistant in absence of moisture.

Pasteurization: It is not strictly a method of sterilization; it is method of making food and beverages for safe consumption. Techniques involved in heating the substance up to its boiling point for a short period, which is sufficient to kill many organisms, eg. Milk at 62 deg C for 30 minutes.

Tyndallization: devised by Tyndall 1860- spontaneous generation. Heating the material at atmospheric pressure to 100 deg C on successive days.- Useful in medium gets affected more than 100 deg C temperature, where spores are present – Those spores which survive the first heat treatment germinate into vegetative cells which are destroyed in the second heat generation.

Ionizing radiation: High energy electrons, UV rays gamma rays used for media and air sterilization, Not fully reliable- Radiation used in plastic lab ware, petridishes etc, UV lamps installed in culture or clean room, effective in killing air borne microorganisms. Chemical are not used in medium sterilization, only used in reactor washing. But used to disinfect apparatus, glassware etc. Used to clean pipettes, chemical sterilent is to be toxic volatile so that it can be removed easily. Ethylene oxide is best, not widely used because it is used as explosive. Other examples of chemical sterilents are Formaldehyde, phenolics such as Lysol.

2. Explain in detail the design and scale up of Batch sterilization process

The complete derivation procedure as per the class notes, related to batch sterilization process, where to mention the points like first order reaction of destruction of micro organism, explain V, N, t, K term separately, derive and show the Arrhenius plot and calculation of activation energy and prediction of reaction rate for any temp, define del factor and derive, state its importance and D&H plot to be shown.

3. Give a detailed account on design and scale up of Continuous sterilization process.

State the same del factor can be achieved by increasing the temperature and degreasing the time of exposure – HTST method only possible rapid heating and rapid cooling – using spiral heat exchangers (double spiral type)

two sheets of high grade Stainless steel curved around central axis to form double spiral setup – steam allowed in one spiral and medium allowed in another spiral – used as countercurrent principle of direction used for heating or cooling liquid. The design aspects should also be included as per Stanberry book. Advantages as no contact of steam medium. No sedimentation so the process gets over quickly – disadvantages as Foaming during heating.

4. Derive the Sterilization kinetics and explain its significance.

The complete derivation procedure as per the class notes, related to batch sterilization process, where to mention the points like first order reaction of destruction of micro organism, explain V, N, t, K term separately, derive and show the Arrhenius plot and calculation of activation energy and prediction of reaction rate for any temp, define del factor and derive, state its importance and D&H plot to be shown The complete derivation procedure as per the class notes, related to batch sterilization process, where to mention the points like first order reaction of destruction of micro organism, explain V, N, t, K term separately, derive and show the Arrhenius plot and calculation of activation energy and prediction of reaction rate for any temp, Del factor and its

importance. Deindoerfer and Humphrey 1959 used the term $\ln[N_0/N_t]$ as design criterion for sterilization, which has been called as “Del factor” or Nabla factor or Sterilization criterion. It measures fractional reduction in viable organism count produced by certain heat and time regime (degree of sterilization) ($\text{Del} = A \cdot t \cdot e^{-E/RT}$), state its importance and D&H plot etc

5. Explain the significance of Sterilization and various consequences of contamination in Bioprocess. (April/May 2009)

Medium would have to support the growth of production organism and also contaminant cause less productivity. If fermentation is continuous, contaminates may outgrow the other and displace it from system. The foreign organism may contaminate the final product. The contaminant might also produce product, hence difficult to extract other. The contaminant would degrade the desired product. Phage contamination in bacterial cells may cause cell lysis.

6. A continuous culture system is being contracted. The fermentation tank is to be 50000L in size and the residence time is to be 2 hrs. A continuous sterilizer to be used. The unsterilized medium contains 10^4 spores/L. The value of K_d has been determined to be 1 min⁻¹ at 121 deg C and 61 min⁻¹ at 140 deg . For each temperatures (121 deg C and 140 deg C) determine the required residence time in the holding section so as to ensure that 99% of the time in four weeks of continuous operation can be obtained without contamination. (Nov / Dec 2012)

7. It is required to provide a 20m^3 fermentor with air at a rate of $10\text{m}^3/\text{min}$ for a fermentation lasting 100 hrs. From an investigation of filter material to be used the optimum linear air velocity was shown to be 0.15m/sec at which the k value was 1.5351/cm. The air in the fermentation plant contained approx. 200 microbes/ m^3 . Calculate the dimension of the filter. Assume Standard acceptable degree of contamination i.e. 1 in 1000.

No = Total amount of air provided $\times 200$, No =
 $10 \times 60 \times 100 \times 200 = 12 \times 10^6$ Nt = acceptable degree of
contamination $N_t = 10^{-3}$

$$\ln \left\{ \frac{1}{10^3} / (12 \times 10^6) \right\} = -kX ; \quad \ln 8.33 \times 10^{-11} = -1.535X ; \quad X (\text{length}) = -23.21 / -1.535 = 15.12 \text{ cm},$$

Cross section of filter is volumetric air flow rate

divided linear air velocity $\Pi r^2 = 10/0.15 \times 60: r$
(radius) = 0.59m.

8. Explain the usage of ‘Chemical sterilents’ in Bioprocess technology. (April/May 2010)

Chemical are not used in medium sterilization, only used in reactor washing. But used to disinfect apparatus, glassware etc. Used to clean pipettes, chemical sterilent is to be toxic volatile so that it can be removed easily. Ethylene oxide is best, not widely used because it is used as explosive. Other examples of chemical sterilents are Formaldehyde, phenolics such as Lysol.

9. Explain the sterilization process using Pasteurization, Tyndalization and Ionizing radiation

Pasteurization: It is not strictly a method of sterilization; it is method of making food and beverages for safe consumption. Techniques involved in heating the substance up to its boiling point for a short period, which is sufficient to kill many organisms, eg. Milk at 62 deg C for 30 minutes. Tyndalization: devised by Tyndall 1860- spontaneous generation. Heating the material at atmospheric pressure to 100 deg C on successive days.- Useful in medium gets affected more than 100 deg C temperature, where spores are present – Those spores which survive the first heat treatment germinate into vegetative cells which are destroyed in the second heat generation.

Ionizing radiation: High energy electrons, UV rays gamma rays used for media and air sterilization, Not fully reliable- Radiation used in plastic lab ware, petridishes etc, UV lamps installed in culture or clean room, effective in killing air borne microorganisms.

10. Explain in details, how you will design Batch sterilization process. (April/May 2010)

The process sterilization, Heating Holding Cooling cycles, Temperature and time profile as per the class notes, Del overall calculation with design organisms, and Relationship of Del with temp and time profile using Richard’s graphical method, Calculation of Holding time with specific death rate of *Bacillus Sterothermophilus*. Scale up of batch sterilization on volume to be given

11. Write a detailed note on Filter sterilization, types and uses. (Nov 2013)

Physical exclusion of microorganisms for air and medium sterilization. Depth filters, Exclusion filters – Variety of natural fibers such as Cotton – replaced by glass fiber to form as bed ensures removal of organisms sterilized by steam also – but concentration of contaminants increased and pressure drop seen – efficiency of filtration to be

decreased. Used in input or exhaust air prefilter purpose. Exclusion filters are modern cartridges used membranes with pore size of 0.2 – 0.45micrometer for all organisms to remove used, heat labile liquid sterilization, antibiotics used. Large hydrophobic membrane used unidirectional steam flow used. State the table of differences of Depth and membrane filters

12. Discuss the various measures by which Contamination can be prevented in Bioprocess.

Avoidance of contamination steps such as using pure inoculums to start the fermentation – sterilizing the medium to be employed – sterilizing the fermentor vessels – sterilizing all material to be added to the fermentation process – maintaining aseptic conditions during the fermentation – Fermentation by protected medium – less pH, only some can grow etc to be explained in detail.

13. Derive the Sterilization kinetics and explain its significance. (Nov/Dec 2013)

The complete derivation procedure as per the class notes, related to batch sterilization process, where to mention the points like first order reaction of destruction of micro organism, explain V, N, t, K term separately, derive and show the Arrhenius plot and calculation of activation energy and prediction of reaction rate for any temp, define del factor and derive, state its importance and D&H plot to be shown The complete derivation procedure as per the class notes, related to batch sterilization process, where to mention the points like first order reaction of destruction of micro organism, explain V, N, t, K term separately, derive and show the Arrhenius plot and calculation of activation energy and prediction of reaction rate for any temp, Del factor and its importance. Deindoerfer and Humphrey 1959 used the term $\ln[N_0/N_t]$ as design criterion for sterilization, which has been called as “Del factor” or Nabla factor or Sterilization criterion. It measures fractional reduction in viable organism count produced by certain heat and time regime (degree of sterilization) ($\text{Del} = A \cdot t \cdot e^{-E/RT}$), state its importance and D&H plot etc

14. How will you design Continuous Sterilization process (Nov/Dec 2013)

State the same del factor can be achieved by increasing the temperature and decreasing the time of exposure – HTST method only possible rapid heating and rapid cooling – using spiral heat exchangers (double spiral type)

two sheets of high grade Stainless steel curved around central axis to form double spiral setup – steam allowed in one spiral and medium allowed in another spiral – used as countercurrent principle of direction used for heating or cooling liquid. The design

aspects should also be included as per Stanberry book. Advantages as no contact of steam medium. No sedimentation so the process gets over quickly – disadvantages as Foaming during heating.

- 15. How would you design of sterilization equipments? (April/May 2012)**
- 16. Explain the sterilization methods used for air and liquid media (Nov / Dec 2012)**
- 17. Explain the thermal death kinetics of microorganisms (Nov / Dec 2012) (Nov/Dec 2013)**
- 18. Explains the Batch heat sterilization process. (10)**
- 19. Describe the thermal death kinetics of microorganisms? (5)**
- 20. Explain the continuous heat sterilization process?(10)**
- 21. Explain the air sterilization process?(5)**

UNIT IV

METABOLIC STOICHIOMETRY AND ENERGETICS - 9

- | |
|---|
| ✓ Stoichiometry of cell growth and product formation |
| ✓ Elemental balances |
| ✓ Degrees of reduction of substrate and biomass |
| ✓ Available electron balances |
| ✓ Yield coefficients of biomass and product formation |
| ✓ Maintenance coefficients energetic analysis of microbial growth and product formation |
| ✓ Oxygen consumption and heat evolution in aerobic cultures |
| ✓ Thermodynamic efficiency of growth |

PART – A QUESTIONS AND ANSWERS

1. What is meant by Electron balance?

The number of electrons available for transfer to oxygen on combustion of substance to CO₂, H₂O and Nitrogen containing compounds.

2. Define yield and maintenance coefficient.

$$Y_x/s = \text{gram of biomass}$$

gram of substrate consumed

$$Y_p/s = \text{gram of product}$$

gram of substrate consumed

3. Define RQ

Respiratory quotient

$$RQ = \frac{\text{moles of CO}_2 \text{ formed}}{\text{moles of O}_2 \text{ consumed}}$$

moles of O₂ consumed

4. Define of Degree of reduction

The concept of degree of reduction has been developed and used for proton – electron balances in bioreactions

The degree of reduction (for organic compound) may be defined as

$$\gamma = \frac{\text{the no of equivalent of available electrons}}{\text{gram atom carbon}}$$

$$\gamma = \frac{\text{no of eqn. e}}{\text{gram atom carbon}}$$

g atom c

γ = for some key elements

C= 4, H=1, N=-3, O=-2, P=5 and S= 6

5. Elemental balances

$$C; \quad W = c + d$$

$$H; \quad x + gb = c \dots + 2e$$

$$O; \quad y + 2a + hb = c \dots + 2d + e$$

$$N; \quad z + ib = c \dots$$

6. With suitable examples, give the Ludeking - Piret Model for product formation

7. To calculate γ ethanol, γ glycerol, γ glucose, γ methane

The degree of reduction (for organic compound) may be defined as

γ = the no of equivalent of available electrons

gram atom carbon

γ = no of eqn. e

g atom c

γ = for some key elements

C= 4, H=1, N=-3, O=-2, P=5 and S= 6

Note: The γ for any key elements in a compound is equal to the valance of this element

For e.g of how to calculate the ' γ '

$$\text{Methane } (\text{CH}_4) = \frac{(1*4) + (4*1)}{1} = \frac{8}{1} = 8$$

$$\text{Glucose } (\text{C}_6\text{H}_{12}\text{O}_6) = \frac{6(4) + 12(1) + 6(-2)}{6} = \frac{24}{6} = 4$$

$$\text{Ethanol } (\text{C}_2\text{H}_5\text{OH}) = \frac{2(4) + 1(6) + 1(-2)}{2} = \frac{12}{2} = 6$$

A high degree of reduction indicates a low degree of oxidation

$$\gamma(\text{CH}_4) \quad \gamma(\text{C}_6\text{H}_{12}\text{O}_6) \quad \gamma(\text{C}_2\text{H}_5\text{OH})$$

Note: the available electrons are those that would be transferred to oxygen upon oxidation of a compound. to CO₂, H₂O and NH₃ = 0

8. Define ‘System’ and ‘Surrounding’ as Thermodynamic point of view.

System: consists of any matter identified for investigation (cell)

Surrounding: is the environment of system lies and set apart from it (medium)

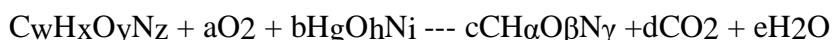
9. State and explain briefly the Steady state condition.

Continuous process: allows matter to flow in and out of system – if rates of mass input and output are equal – can be operated indefinitely. If all the properties of a system such as temperature, pressure concentration, volume, mass do not vary with time called Steady state.

10. State the General Mass Balance Equation.

Mass accumulated =	mass in through	-	Mass out	Mass	Mass
In system	system boundaries			thro.	
System	Generated - consumed	Boundary		by	
system	by system				

11. Write Elemental equation for Microbial aerobic growth using Carbon, Nitrogen and O₂.



12. Calculate Degree of reduction for Glucose

$$C_6H_{12}O_6 = 6(4) + 12(1) + 6(-2) = 24; \gamma = 24/6 = 4$$

13. How will you determine the microbial reaction is exo / endothermic.

Heat of the reaction can be determined and estimated using microbial stoichiometry and the concept of available electron. Δhc value is calculated for standard heat of reaction, $\Delta H_{rxn} = \Delta hc(\text{reactant}) - \Delta hc(\text{product})$ If the result is positive the reaction is endothermic and heat is absorbed or vice versa

14. What are the types of material balances?

Differential balance method, Integral balance method

15. Write a short note on Theoretical Oxygen Demand.

Oxygen requirement is directly related to the electrons available for transfer to Oxygen. Hence O₂ demand derived from electron balance.

16. Define ‘Respiratory Coefficient’.

It is the ratio of moles of CO₂ produced with moles of O₂ consumed

17. Define ‘Open System’ and ‘Closed System’ as Thermodynamic

point of view. Open system : If the system boundary allows masses to flow in and out of the system Closed system : If the system boundary

allows masses to flow in and out of the system

18. Define Yield Coefficient of biomass yield

It is the ratio of the quantity of biomass produced using quantity of carbon sources used

19. Explain Continuous process on Thermodynamic point of view

It is a open system that allows matter to flow in and out of system. If rates of mass input and out put are equals, then continuous processes can be operated indefinitely.

20. What is the equilibrium concept as thermodynamic point of view

In a system if all the opposing forces are exactly counter balanced, so that the properties of all system do not change with time. Then it is under equilibrium condition. System tend to approach equilibrium, when they are isolated from their surrounding, where there is no net change in system/surround, the energy of the system is minimum or static

21. State the General Steady state mass balance equation

Mass in + mass generated = mass out + mass consumed

22. What is meant by Engineering judgment in Material balance calculations

Stating all assumptions applied to the problem is called Engineering judgment. Real time situations are complex, so one or more assumptions are required for calculations. The omitted details are assumed, provided assumptions are reasonable. These assumptions to be stated exactly to reveal other, so that it can be improved or accepted.

23. Calculate the degree of reduction of Ethanol

$$\text{C}_2\text{H}_5\text{OH} = 2(4) + 6(1)+1(-2) = 12; \gamma = 12/2 = 6$$

24. State the Product yield in a biological reaction.

It is the ratio between gms of product formed / gms substrate consumed

25. State the equation for heat of the microbial reaction

Heat of the reaction can be determined and estimated using microbial stoichiometry and the concept of available electron. $\Delta h_c = -q \gamma x_c$; where Δh_c = Molar heat of combustion, q = heat evolved per mole of available electron transferred O₂ during combustion. γ = degree of reduction of defined compound and x_c = nol of carbon atoms in molecular formula.

PART B QUESTIONS

1. Explain in detail about the types and procedure of ‘Material balancing’.

Differential balance and Integral balance methods to be explained with principles,

First step is to understand the problem, with information available, by using best standard procedures, the unknown quantities should be calculated

Draw a clear process flow diagram showing all relevant information with simple box diagram with given variable masses with molar quantities.

Select a set of units, to make calculation much easier if all the values expressed in same types of units. Select a basis of calculation: to visualize the problem, focus on single quantity of material entering or leaving system

State all assumption applied to the problem with engineering judgment, omitted detail is assumed

Identify the particular component of the system involved in reaction then assemble, analyze, calculate and finalize the problem

2. Explain the following with suitable examples (i) System (ii) boundary (iii) Steady state (iv) Equilibrium

Thermodynamics are science dealing with properties of matter – useful in setting up material balances. System: consists of any matter identified for investigation (cell) Surrounding: is the environment of system lies and set apart from it. System boundary: system remain isolation from surrounding by system boundary- eg. Walls of the beaker or fermentor or any imaginary boundary – if boundary does not allow mass to pass from system to surrounding called Closed system – If boundary exchanges mass from to system and surrounding called Open system - Continuous process: allows matter to flow in and out of system – if rates of mass input and output are equal – can be operated indefinitely. If all the properties of a system such as temperature, pressure concentration, volume, mass do not vary with time called Steady state. If all the opposing forces are exactly counter balanced so the properties of the system do not change with time called equilibrium.

3. Discuss the Batch process, Fed batch process, and Continuous process with Thermodynamics point of view

Thermodynamics are science dealing with properties of matter – useful in setting up material balances. System: consists of any matter identified for investigation (cell) Surrounding: is the environment of system lies and set apart from it. System boundary: system remain isolation from surrounding by system boundary- eg. Walls of the beaker or fermentor or any imaginary boundary – if boundary does not allow mass to pass from system to surrounding called Closed system – If boundary exchanges mass from to system and surrounding called Open system

Batch process: operates in closed system. All materials are added to the system at the start of the process, The system is the closed and products removed only when the process is complete. Fed batch process: a type of semi batch process – allows only input of materials to the system but not output. Continuous process: allows matter to flow in and out of system – if rates of mass input and output are equal – can be operated indefinitely.

4. Derive and discuss growth stoichiometry & Elemental balance for biomass production.

Despite of thousands of intracellular reactions, the cell growth obeys the law of conservation of matter. Carbon, hydrogen, oxygen, nitrogen are consumed during growth to form new cells. We consider 2 extracellular products apart from new cell formation as CO₂ and H₂O.

For aerobic growth we write the eqn. as

C_wH_xO_yN_z + aO₂ + bHgOhNi – cCH_αO_βN_δ + dCO₂ + eH₂O. C_wH_xO_yN_z = formula of substrate (for glucose w=6, x=12, y=6, z=0) bHgOhNi = formula for Nitrogen source cCH_αO_βN_δ = formula for dry biomass, where a,b,c,d,e are stoichiometric coefficients. The mass balance can be done (stoch. Coeff X no. of atoms = atomic balance) C balance is w=c+d ; H balance is x+bg = cα + 2e ; O balance is y+2a+bh = cβ +2d+e ; N balance is z+bi = cδ

5. Production of Single cell protein from hexadecane is described by the following reaction equation: C₁₆H₃₄ + aO₂+bNH₃ ----cCH_{1.66}O_{0.27}N_{0.20} +dCO₂ +eH₂O Where CH_{1.66}O_{0.27}N_{0.20} represents the biomass. If RQ is 0.43, determine the Stoichiometry coefficients. (April/May 2009)

Answers as per the Solved example 4.7 about Stoichiometry coefficients for cell growth page no 76 of Pauline and Doran book.

6. Explain in detail about the types and procedure of ‘Material balancing’. (April / May 2011)

Differential balance and Integral balance methods to be explained with principles, First step is to understand the problem, with information available, by using best standard procedures, the unknown quantities should be calculated 1. Draw a clear process flow diagram showing all relevant information with simple box diagram with given variable masses with molar quantities. 2. Select a set of units, to make calculation much easier if all the values expressed in same types of units. 3. Select a basis of calculation: to visualize the problem, focus on single quantity of material

entering or leaving system 4. State all assumption applied to the problem with engineering judgment, omitted detail is assumed 5. Identify the particular component of the system involved in reaction then assemble, analyze, calculate and finalize the problem

7. **Humid air enriched with O₂ is prepared for gluconic acid fermentation. The air is prepared in special humidifying chamber. 1.5 lit/h of water enters the chamber at the same time as dry air and 15g mol/min dry O₂. All the water is evaporated. The out flowing gas is found to contain 1% w/w water. Draw and label the flow sheet for this process.**
8. **Derive and discuss growth stoichiometry and detailed elemental balance for biomass production. (April / May 2010)**

Let us choose units of 'g' and 'min' for the whole process. The information first converted to mass flow rates in these units. The density of water is taken to be 10^3 g/lit. $= 1.5 \text{ lit/h} = 1.5 \text{ lit/h} (10^3 \text{ g/l})(1\text{hr}/60\text{min}) = 25\text{g/min}$ Molecular weight of O₂ is 32. $= 15 \text{ gmol/min} = 15\text{gmol/min} (32\text{g/gmol}) = 480 \text{ g/min}$, Draw the flow sheet as per the class notes.

Despite of thousands of intracellular reactions, the cell growth obeys the law of conservation of matter. Carbon, hydrogen, oxygen, nitrogen are consumed during growth to form new cells. We consider 2 extracellular products apart from new cell formation as CO₂ and H²O. For aerobic growth we write the eqn. as C_wH_xO_yN_z + aO₂ + bHgOhNi - cCH_αO_βN_δ + dCO₂ + eH₂O. derivation to be done. Up to finding 5 coefficients from 4 balance equations.

9. **Acetobacter aceti bacteria convert ethanol to acetic acid under aerobic conditions. A continuous fermentation process for vinegar production is proposed using viable A. aceti cells immobilized on the surface of gelatin beads. The production target is 2kg h⁻¹ acetic acid; however the maximum acetic acid concentration tolerated by the cells is 12%. Air is pumped into the fermentor at a rate of 200 g mol per hour. Calculate**
10. **What minimum amount of ethanol is required?**
11. **What minimum amount of water must be used to dilute the ethanol to avoid acid inhibition?**
12. **What is the composition of the fermentor off gas?**
13. **State the 'Law of Conservation of Mass' and prove that Mass in = Mass out.**

Explanations and assumptions, - The General Mass balance equation and types of material balances like Differential balance and Integral balance- Simplification of General Mass balance equation and finally the steps involved in Mass balance calculations. State the following in full explanation as per the class notes date –

Law of conservation of mass

- 14. (ii) A continuous process is set for the Treatment of wastewater. Each day 10^5 kg of cellulose and 10^3 kg of bacteria enter in the feed stream, while 10^4 kg of cellulose and 1.5×10^4 kg of bacteria leave in the effluent. The rate of cellulose digestion by bacteria is 7×10^4 kg/day; the rate of bacterial growth is 2×10^4 kg/day. The rate of cell death by lysis is 5×10^2 kg/day. Write balances for cellulose and bacteria in the system. (April/May 2010)**

Cellulose is not generated by the process, only consumed hence

For Cellulose $(10^5 - 10^4 + 0 - 7 \times 10^4) = 2 \times 10^4$ kg of cellulose accumulation/day. For Bacteria: $(10^3 - 1.5 \times 10^4 + 2 \times 10^4 - 5 \times 10^2) = 5.5 \times 10^3$ kg/day of bacteria.

- 15. Write a note on theoretical O₂ demand in metabolic stoichiometry.**

- 16. (ii) Fumaric acid is produced from malic acid using the enzyme, fumarase. Calculate the standard heat of reaction for the following enzyme transformation:**
C₄H₆O₅C₄H₄O₄ + H₂O Standard heat of combustion of Maleic acid is -1328.8 KJ/gmol & that of Fumaric acid is -1334 KJ/gmol. (April/May 2010)

- 17. Xanthan gum is produced using Xanthomonas sp. in Batch culture. Laboratory experiments have shown that for each gram of glucose utilized by the bacteria, 0.23g oxygen and 0.01 g ammonia are consumed, while 0.75 g gum, 0.09g cells, 0.27 g gaseous CO₂ and 0.13 g H₂O are formed. Medium containing glucose and ammonia dissolved in 20000 liters water is pumped into a stirred fermentor and inoculated with culture. Air is sparged into the fermentor; the total amount of off-gas recovered during the entire batch culture is 1250 kg. Because of final high viscosity, the gum should not be allowed to exceed 3.5wt% A. How much glucose and ammonia are required? B. What percentage excess air is provided?**

- 18. Corn steep liquor contains 2.5 % invert sugars and 50% waste, the rest can be considered solid. Beet molasses containing 50% sucrose. 1% invert sugars, 18%**

waste and the remainder solids, is mixed with corn-steep liquor in a mixing tank. Water is added to produce a diluted sugar mixture containing 2%(w/w) invert sugars. 125 kg corn steep liquor and 45 kg molasses are fed into the tank. A. How much water is required? B. What is the conc. of sucrose in the final mixture?

19. Explain in detail about the types and procedure of Material balancing. (April/May 2011)
20. Explain heat generation by microbial growth (April/May 2012)
21. Explain the thermodynamic efficiency of growth. (Nov /Dec 2011)

Heat of the reaction can be determined and estimated using microbial stoichiometry and the concept of available electron. It is found that such heat energy is related to degree of reduction as follows; $\Delta h_c = -qr_{xc}$ Where Δh_c is molar heat of combustion, q is heat evolved per mole of available electron transferred O₂ during combustion r is degree of reduction defined compound, X_c is number of carbon atoms in molecular formula.

Δh_c value is calculated for standard heat of reaction, $\Delta H_{rxn} = \Delta h_c(\text{reactant}) - \Delta h_c(\text{product})$ If the result is positive the reaction is endothermic and heat is absorbed or vice versa.

22. Explain different models to predict specific growth rate. (April/May 2012)
23. Explain the models of cellular energetic and metabolism in aerobic growth of the Yeast
24. *Saccharomyces cerevisiae*. (Nov / Dec 2012)
25. Discuss the advantages and disadvantages of batch, fed-batch and continuous cultivation of cells. (Nov / Dec 2012)
26. Aerobic degradation of acetic acid by microbes can be represented by following reaction: C₆H₅COOH + aO₂ + bNH₃ → cC₅H₇NO₂ + dH₂O + eCO₂; Determine a,b,c,d and e if RQ=0.9 and Determine yield coefficients, Y_{x/s} and Y_{x/O₂} and determine degree of reduction for the substrate and bacteria (Nov/Dec 2013)
27. Give detailed note on Growth and Product stoichiometry. (Nov / Dec 2011)

Despite of thousands of intracellular reactions, the cell growth obeys the law of conservation of matter. Carbon, hydrogen, oxygen, nitrogen are consumed during growth to form new cells. We consider 2 extracellular products apart from new cell formation as CO₂ and H₂O. For aerobic growth we write the eqn. as C_wH_xO_yN_z + aO₂ + bHgOhNi → cCH_αO_βN_δ + dCO₂ + eH₂O. As per the class notes the further derivation to be done. Up to finding 5 coefficients from 4 balance equations. Another

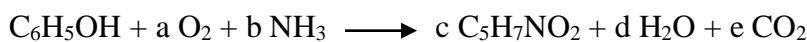
extracellular product $C_jH_kO_lN_m$ in the eqn. Hence it becomes $C_wH_xO_yN_z + aO_2 + bHgOhNi - cCH\alpha O\beta N\delta + dCO_2 + eH_2O + f C_jH_kO_lN_m$ with this explain the Product yield coefficient Y_p/s to be explained and theoretical product yield to be explained.

28. Derive expression of Mass balance equation for a biochemical reaction. (April/May 2011)

State the law of conservation of Mass and explain the General mass balance equation and state Differential balance, and integral balance. Simplification of General mass balance equation and derive upto $Mass_{in} = mass_{out}$. State the following in full explanation as per the class notes date – Law of conservation of mass

Explanations and assumptions, - The General Mass balance equation and types of material balances like Differential balance and Integral balance- Simplification of General Mass balance equation ($Mass_{accumulated} = mass_{in} - mass_{out} + mass_{generated} - mass_{consumed}$ by the system) and finally the steps involved in Mass balance calculations such as continuous process at steady state, the accumulation term must be zero, the system at steady state cannot accumulates mass. Hence ($Mass_{in} + Mass_{generated} = Mass_{out} + mass_{consumed}$) The total mass neither be created nor destroyed except for nuclear reaction, so generation and consumption terms must be zero ($Mass_{in} = Mass_{out}$)

29. Aerobic degradation of phenol ($C_6 H_5 OH$) by pseudomonas spp. Can be represented by following reaction

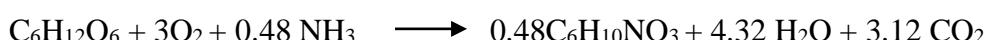


Determine a,b,c,d and e if $RQ = 0.82$

Determine the yield coefficient , $Y_{x/s}$ and Y_{x/o_2}

Determine degree of reduction for the substrate and bacteria and also calculate the approximate rate of heat evolution during fermentation.

30. The growth of Baker's yeast (*S.cerevisiae*) on glucose may be simply described by the following equation:



In a batch reactor of volume 10^5 l, the final desired yeast concentration is 50 gdw/l.

Using the above reaction stoichiometry:

Determine the concentration and total amount of glucose and $(\text{NH}_4)_2\text{SO}_4$ in the nutrient medium.

Determine the yield coefficient $Y_{x/s}$ and $mY_{x/02}$

Determine the total amount of oxygen required.

If the rate of growth at the exponential phase is $r_x = 0.7 \text{ gdw/l-h}$, determine the rate of oxygen consumption($\text{gO}_2/\text{l-h}$)

Calculate the heat removal requirements for the reactor

31. U-III-PROBLEM NO: 1 Ref. Ex: 4.8 (Doran)

Product yield and oxygen demand

The chemical reaction equation for respiration of glucose



Candida utilis cells convert glucose to CO_2 and H_2O during growth ,the cell composition is $\text{CH}_{1.84}\text{O}_{0.55}\text{N}_{0.2}+5\%$ ash, yield of biomass from substrate is 0.5 g/g ammonia is used as a nitrogen source .

What is the O_2 demand with growth compared to that without?

Candida utilis it's also able to grow with ethanol as substrate producing cells of the same composition as above. On a mass basis how does the maximum possible biomass yield from ethanol compared with the maximum possible yield from glucose?

32. U-III-PROBLEM NO: 2 Ex.p.4.7 dorron

O₂ requirement for growth on glycerol

Klebsiella aerogenes is produced from glycerol in aerobic culture with ammonia as nitrogen source the biomass contains 8% of ash ,0.4 g of biomass is produced for each g glycerol consumed and no major metabolic products are formed . what is the o₂ requirement for this culture in mass term .

33. U-III-PROBLEM NO: 3 Ex .no 4.13 Dorron .

O₂ demand for production of recombinant protein

Production of γ -protein by genetically engineered strain of E.coli is proportional to cell growth th elemental formula for biomass is $\text{CH}_{1.77}\text{O}_{0.49}\text{N}_{0.24}$.ammonia is used in the N2 source for aerobic respiration in glucose, the recombinant protein as an overall formula $\text{CH}_{1.55}\text{O}_{0.31}\text{N}_{0.25}$,the yield of biomass from glucose is measured at 0.48g/gthe yield ,the yield of recombinant

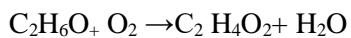


$$Y_{xs}=0.48$$

34. U-III-PROBLEM NO: Example 4.14 (Doran)

Effect of growth on O₂ demand:

The chemical reaction equation for conversion of ethanol ($\text{C}_2\text{H}_6\text{O}$) to acetic acid ($\text{C}_2\text{H}_4\text{O}_2$) is



Acetic acid is produced from ethanol during growth of acetobacter aceti which has the composition $\text{CH}_{1.8}\text{O}_{0.5}\text{N}_{0.2}$. The biomass yield from substrate is 0.14 g/g , product yield from substrate is 0.92 g/g . Ammonia is used as N₂ source how does growth in this culture affect O₂ demand for acetic acid production.

35. U-III-PROBLEM NO: 5 Example 4.10 doran

Ethanol production by yeast and bacteria :

both saccharomyces cerevisiae yeast and bacteria zymomonas motilis produce ethanol from glucose under anaerobic conditions biomass yield from glucose in 0.11 g/g . for yeast and 0.05 g/g for bacteria. In both cases the N₂ source is NH₃ . both cell composition are represented by the formula $\text{CH}_{1.8}\text{O}_{0.5}\text{N}_{0.2}$.

what is the yield of ethanol from glucose in both cases?

How do the yield calculated in a) . compare with the thermodynamic maximum.

36. U-III-PROBLEM NO:6 Stoichiometry of single cell protein synthesis:

cellulomonas bacteria used as single cell protein for human or animal food are produced from glucose under anaerobic conditions . all carbon in the substrate is converted into biomass, ammonia is used as N₂ source , the molecular formula is $\text{CH}_{1.56}\text{O}_{0.54}\text{N}_{0.16}$.the cells contain 5% ash , how does the yield of biomass from substrate in mass and molar terms. Compare with maximum possible biomass yields? Another system for manufacture of single cell protein in methylophilus methylotrophus. This maximum is produced aerobically from methanol with ammonia as N₂ source.the molecular formula for the biomass is $\text{CH}_{1.68}\text{O}_{0.36}\text{N}_{0.22}$ these cells contain 6% ash .

a)how does the mass yield of biomass compare with i)above ii) what is the main reason for the difference ?

b)if the actual yield of biomass from methanol is 42% the thermodynamic maximum.what is the oxygen demand?mass thermodynamic yield for methanol is 1.1g/g

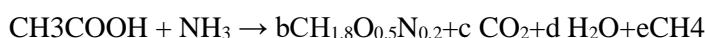
37. U-III-PROBLEM NO: 6 Detecting of unknown products

yeast growing in continuous culture produce 0.37g biomass / g of glucose consumed about 0.88g of O₂ is consumed per g of cell formed. The nitrogen source is ammonia and the biomass composition is $\text{CH}_{1.79}\text{O}_{0.56}\text{N}_{0.17}$.are other products also synthesized?

38. U-III-PROBLEM NO: 4 Example 4.8 (Doran)

product yield in anaerobic digestion

Anaerobic digestion of volatile acids by methane bacteria is represented by



For each kg of CH_3COOH consumed 0.67 kg of CO_2 evolved .how does the yield of methane under this condition compare with maximum possible yield.

39. Example :7.2(s&k)The growth of beayer's yeast (*s.cerevisiae*)

on the glucose may be simply described the following equation:



In batch reactor of volume 10^5L ,the final desired yeast concentrated is 56 g dry weight/lt stoichiometry.

- a)determine the concentration and total amount of glucose and $(\text{NH}_4)_2\text{SO}_4$ in the nutrient medium.
- b)determine the yield co.efficient Y_{xs} (biomass/glucose) and Y_{xO_2} (biomass/oxygen)
- c)determine the total amount of O_2 required.
- d)if the rate of growth and at exponential phase in $r_x=0.7$ g dry cell weight/lt.determine the rate of O_2 consumption(g O_2 / lt)
- e) calculate the heat-removal requirements for the reactor.

40. Example 7.3(s&k) The growth of *s.cerevisiae* on glucose under anaerobic condition can be described by the following overall reaction .



Determine the yield co.efficient (Y_{xs}), Y_{ETHS} , Y_{CO2S} , $YC_3H_8O_3S$,B.

41. Example 7.2(s&k)

Estimate the theoretical growth and product yield co.efficient for ethanol fermentation by *s.cerevisiae* as described by following overall reaction



UNIT V

KINETICS OF MICROBIAL GROWTH AND PRODUCT FORMATION - 9

Batch cultivation
Continuous cultivation
Simple unstructured models for microbial growth
Monod model
Growth of filamentous organisms
Product formation kinetics - Leudeking- Piret models
Substrate and product inhibition on cell growth and product formation
Biomass estimation – Direct and Indirect methods

PART – A QUESTIONS AND ANSWERS

1. Describe unstructured growth models.

These models view the cells as a single species in solution and attempt to describe the kinetics of cell growth based on cell and nutrient concentration profiles.

2. What are structured models?

Models, which incorporate the details of intracellular metabolism that views complex organization within the cell as Genetic system, Epigenetic system, metabolic system etc.

3. Explain Catabolism and Anabolism process

Catabolism: Energy containing molecules reduced to carbon-containing molecules are degraded to CO₂ and other oxidized end products, ATP etc.

Anabolism: Intermediates and end products formed from catabolism are incorporated into cell Constituents (DNA, RNA, lipids)

4. Explain the Segregated & Unsegregated view of modeling.

Segregated view = cell to cell heterogeneous consideration Unsegregated view = Average cell approximation

5. Why specific growth rate / doubling time should be calculated at the log phase of the cell.

This is the phase where μ will be equal μ_{max} hence it is right phase to calculate. The average time taken for the cell population to get doubled during the exponential phase of growth.

6. What is meant by ‘Balanced growth’ and Unbalanced growth

Balanced growth : When ‘Specific growth rate’ and ‘Specific cell number growth

rate' are equal, growth referred to be balanced, this is an ideal case.

Unbalanced growth: The variation in cell composition may occur even though cell number growth rate is constant, the cell mass growth rate will vary. This is the real time case.

7. State the significance of Plasmid instability.

The problem of plasmid loss – leads to large plasmid free population hence overall reactor efficiency decreases – Plasmid DNA mutation, segregation instability are the reasons – The total number of plasmids in generation must double in the next.

8. State and explain Luedeking & Piret Model

For lactic acid production by lactobacillus sp. Is a type of partially growth associated type where the production is found to depend on both concentration of cell as well as their growth rate. Hence the expression as $\gamma_p = \alpha\gamma_x + \beta x$; $\gamma_p = \alpha\mu_x + \beta x$

9. What are the different phases of microbial batch growth? (April/May 2012)

Lag, Log phase, decline phase, stationary phase, death phase.

10. What are the types of product formations? (Nov / Dec 2012)

Growth associated product (Ethanol), Non growth associated Product (Vitamins, antibiotic), Partially growth associated product (amino acid, xanthan)

11. Describe the complex organization within the cell in Structural model.

Genetic system, Epigenetic system, metabolic system etc.

12. Write Plasmid Replication Model of Structured microbial growth kinetics

$1/(upwo-u) = K_p/V^{max} (1+K_p/P_s)$ where upwo = Plasmid washout growth rate; u = sp. Growth rate, K_p = Saturation constant, V^{max} = maximum rate of plasmid synthesis; P_s is steady state plasmid number.

13. Mention the reasons behind Death phase of the microbial growth pattern.

The death phase of the cell culture is due to cell losing viability or by lyses due to produced metabolites.

14. State the equations for specific growth rate and doubling time of the cell culture

$\ln X_t = \ln X_0 + ut$ where X_0 is the initial biomass concentration and u is the specific growth rate Doubling time : $\ln 2/u$

15. Explain Monod model of microbial growth

It is assumed that only one substrate is limiting the growth and cell proliferation
 $U = u_{max}S/K_s + S$ where u_{max} is the maximum specific growth rate of the cells, K_s is the value of the limiting nutrient concentration.

16. State the simple model for fraction of Plasmid bearing cells as a function of time

$\gamma x^+ = (1-P) u^+ X^+$ where γx^+ is the rate of growth of P+ cell population

17. Mention the growth model of filamentous organism

Complicated multi-cellular and branched mould system that forms microbial pellets in the suspension. $(dx/dt) = \rho 4 \pi r^2$ where r is the radius of cell floc and ρ is the density of the medium

18. State the models of Substrate inhibition of cell growth

Competitive inhibition : $u = umS/Ks (1+s/ki)+S$ Non competitive inhibition : $u = um/(1+ks/s)(1+s/ki)$

19. State the models of Product inhibition of Cell growth Uncompetitive product inhibition : $u = umax / (Ks+s)(1+s/ki)$ Competitive product inhibition : $u = umS/Ks(1+p/Kp)+S$

20. Mention Single cell model and explain

Reaction occurring in a single cell is being considered as the representative of the whole microbial population. For E.coli the DNA synthesis mass balance is written as $dM/dt = u(p/v/Kmp + p3/v) (A/V/Kma + A/V)F$ Where M= mass of DNA; u= rate constant for maximum rate of DNA formation per time; P= mass of deoxynucleotides; V= Cell volume. A= glucose conc. F= number of replication events.

PART B-QUESTIONS

21. Explain the following (i)Unstructured growth & Unsegregate view (ii) Structured growth & segregate view

Phases of cell growth as the increase in cell number and cells to grow in size. Two phases involved in cell growth kinetics as Biological phase of cell and Environmental phase or growth medium. Single cell is a complicated multicomponent system and non homogeneous. Also the growing cell population show cell to cell heterogeneity. At a given point of time, in a given small region in space the cells vary with respect to age. These cells show different types of metabolic functions and activities. Hence by simplifying the complexity of cell population kinetics we can propose assumptions like, a single component becomes the rate – limiting nutrient and others are present in high concentration. A inhibitory product which accumulates in the medium components influence in cell kinetics. Normally the external controls such as pH, temp, and dO₂ concentrations are kept constant. Cellular components which are multicomponent are called Structured and single components representation is

unstructured. When heterogeneous cells are considered it is segregated view point. When average cellular property is considered then it is unsegregated.

22. Write a detailed note on Unstructured growth model with reference to (i) Malthus model (ii) Monod model

Simplest models, view the cells as a single species in solution and attempt to describe the kinetics of cell growth based on cell and nutrient concentration profiles. These models does not account for dependency of exponential growth rate on nutrient conc. Instead they devised to have a maximum achievable population for a given nutrient. Explain the principles of Malthus model, Verlhust, pearl, reed model etc. Monod model: simplest model, includes the effect of nutrient conc. Based on observation of the growth of E.coli at various glucose conc. It is assumed that only one substrate is important in determining the rate of cell proliferation, similar to MM equation of enzyme kinetics, infact if substrate transport to the cell is limited by the activity of a enzyme permease. Hence cell growth follows as $\mu = u_{max} S/K_s + S$ and for batch growth at constant volume it $dx/dt = u_{max} S X / K_s + S$ where u_{max} is the maximum specific growth rate of the cells, K_s is the value of the limiting nutrient conc. which results in a growth rate of half the maximum value $K_s = 1/2u_{max}$. To be explained with a plot of μ Vs substrate conc.

23. Illustrate in detail about ‘Models of microbial Product formation’

Products formation could be growth associated eg ethanol, Non growth associated eg. Vitamins, antibiotics, partially growth associated eg. Amino acid, Xanthan and lactic acid etc. Luekeking and Piret model to be explained for lactic acid production is a type of partially growth associated type where the production is found to depend on both concentration of cell as well as their growth rate. Hence the expression as $\gamma_p = \alpha\gamma_x + \beta x$; $\gamma_p = \alpha\mu x + \beta x$

Lactic acid is product arising from anaerobic fermentation of sugars such as glucose and lactose. Although the conversion of glucose to lactic acid is direct route for energy production, the production kinetics are not solely growth associated. State the kinetics expression for growth associated, non- growth associated and partially growth associated products formation. For growth associated kinetics the gluconic acid production to be stated and non-growth associated the penicillin production to be

stated with expressions.

24. State and explain the kinetic expression for Substrate Inhibited growth phase and Product inhibited growth phase.

Growth inhibited by the substrate can be simply modeled in well stirred tank reactor.



The effect of inhibitory substrate can be considered to result from reversible formation of a complex XS_2 which is no longer to form new cells. We should define the dimensionless variables as per the class notes to find the expression of μ_{\max} t value.

Products of cellular metabolism may also inhibit growth and hence slow the rate of their own production. Product inhibition effects on cell growth can be represented in a variety of ways. One common approach is analogous that the substrate inhibition as $\mu = \mu_{\max} S / (K_s + S)(1 + p/k_p)$ and the second approach is exponential expression $\mu = \mu_{\max} S / (K_s + S) e^{-k_p P}$. The exponential term is expanded in Taylor series and truncated after first term to achieve the final expression as $\mu = \mu_{\max} S / (K_s + S) \cdot (1 - K_p P)$

25. Derive and discuss the growth kinetics with plasmid instability

Discuss the problem of plasmid loss – leads to large plasmid free population hence overall reactor efficiency decreases – Plasmid DNA mutation, segregation instability are the reasons – The total number of plasmids in generation must double in the next. A simple model developed for fraction of plasmid bearing cells as the function of time to be derived. The parameters like Probability of plasmid loss per generation of cells, and difference in growth rate of P^+ and P^- cells populations are used. Finally the Fraction of plasmid bearing cells are $F = 1 - \alpha - p / 1 - \alpha - 2^{n(+p-1)} p$

26. (ii) A plasmid containing strain of E.coli to produce recombinant protein in 250 lit fermentors. The probability of plasmid loss in per generation is 0.005. The specific growth rate of P^- cells 1.4/h; the specific growth rate of P^+ cell is 1.2/h. Estimate the fraction of plasmid bearing cells after 18 hrs of growth. (April/May 2009)

Find n-value and alpha value and substitute in F expression. As per the class notes solving method and the answer should be $n=31$ generations α value = 1.17 and F value should be 0.45, means that after 18hrs of cultivation 45% of cells will contain the plasmid.

27. Explain Cell mass growth rate & Cell number growth rate. (ii) State

and explain the kinetic expression for Substrate Inhibited growth phase.

(April/May 2012)

A detailed note on the following i.e Occasionally the double time of Cell number and Cell dry weight may differ hence write as Cell mass growth rate or Specific growth rate (μ hr⁻¹) = $\mu=1/x$ dx/dt and Cell number growth rate or Specific cell number growth rate (v hr⁻¹) = $V=1/N$ dn/dt, Where ' μ ' and 'V' are equal, growth referred to be 'balanced' where there is adequate supply of nutrients, hence the cell composition is constant even though the concentration of all nutrients decreasing. Otherwise in 'unbalance growth' the variation in cell composition, may occur even though cell number growth rate is constant, the cell mass growth rate will vary.

28. Explain the Models of Product Inhibition kinetics & replication model. (Nov / Dec 2011)

Products of cellular metabolism may also inhibit growth and hence slow the rate of their own production. Product inhibition effects on cell growth can be represented in a variety of ways. One common approach is analogous that the substrate inhibition as $\mu = \mu_{max} S/(K_s+S)(1+p/k_p)$ and the second approach is exponential expression $\mu = \mu_{max} S/(K_s+S) e^{-k_p P}$. The exponential term is expanded in Taylor series and truncated after first term to achieve the final expression as

$$\mu = \mu_{max} S/(K_s+S). (1-K_p P)$$

Plasmid replication model: describes the replication of plasmids within the cells. The number of plasmids within cell, may vary depending on the nature of plasmids and growth rate of host. – The doubling of plasmid number within the cell is governed by two separate factors. The model is as follows. $1/(\mu p_w o = \mu) = K_p/V^{\max} (1+ K_p/P_s)$; low mol.wt. plasmids presents in high copy number

29. Write and derive MM equation with its representation of kinetic date types.

As per the class notes the MM equation to be derived with suitable assumptions and considerations such as the at low substrate conc. The reaction velocity is proportional to the substrate conc. and reaction is first order with respect to substrate. 2. As the substrate concentration is increased the reaction rate slows and no longer proportional to substrate concentration, which is mixed order 3. at still high substrate conc. The reaction rate becomes constant and independent of substrate conc. The reaction becomes Zero order. The final MM expression of $V = V_{max} [S]/\{[S]+K_m\}$ to be arrived. Then modification of MM equation as Line weaver-Burk plot to be explained with its importance.

30. State and explain the significance of Plasmid Instability with its Growth kinetics model

Plasmid loss through generation, leads to plasmid free population, Plasmid DNA mutation, segregational instability, structural instability; Explain the Growth kinetics with Plasmid Instability and its expression from the class notes - Discuss the problem of plasmid loss – leads to large plasmid free population hence overall reactor efficiency decreases – Plasmid DNA mutation, segregation instability are the reasons – The total number of plasmids in generation must double in the next. A simple model developed for fraction of plasmid bearing cells as the function of time to be derived. The parameters like Probability of plasmid loss per generation of cells, and difference in growth rate of P+ and P- cells populations are used as per the class notes. Finally the Fraction of plasmid bearing cells are $F=1-\alpha-p/1-\alpha-2^{n(+p-1)} p$

31. Write a detailed note on Structured growth model with reference to (i) Compartmental model (ii) Model of Ramakrishna et al.

Structured growth model recognize the complex metabolic reactions occurring within the cell. It also predicts the dynamic behavior of the cell with reference to its environment. The complex organization within the cell can be described in Genetic system, Epigenetic system, and metabolic system. The models which incorporate the details of intracellular metabolism are referred as “Structured model”. These models accounts for unbalanced growth, the composition of the major cellular constituents such as RNA, enzyme conc. etc vary as the result of changing external conditions.

State and explain the models like Compartmental model, Ramakrishna et al

32. Illustrate in detail of ‘Models of microbial Product formation’ (April / May 2011) (Nov 2013)

Products formation could be growth associated eg ethanol, Non growth associated eg. Vitamins, antibiotics, partially growth associated eg. Amino acid, Xanthan and lactic acid etc. Luekeking and Piret model to be explained for lactic acid production by lactobacillus sp. Lactic acid is product arising from anaerobic fermentation of sugars such as glucose and lactose. Although the conversion of glucose to lactic acid is direct route for energy production, the production kinetics are not solely growth associated. State the kinetics expression for growth associated, non-growth associated and partially growth associated products formation. For growth associated kinetics the gluconic acid production to be stated and non-growth associated the penicillin production to be stated with expressions.

33. Write a detailed note on Structured growth model with reference to (i) Model of Cellular Energetic (ii) Single cell Model. (November / December 2011)

Structured growth model recognize the complex metabolic reactions occurring within the cell. It also predicts the dynamic behavior of the cell with reference to its environment. The complex organization within the cell can be described in Genetic system, Epigenetic system, metabolic system. The models which incorporate the details of intracellular metabolism are referred as “Structured model”. These models account for unbalanced growth, the composition of the major cellular constituents such as RNA, enzyme conc. etc vary as the result of changing external conditions. State and explain the models like, Cellular energetics, Single cell model etc

34. Derive a detailed expression on Microbial growth kinetics under batch cultivation process. (November / December 2011)

Mathematical point of view, there is little difference between enzyme kinetics and cells, (cell metabolism depends on the integrated action of a multitudes of enzymes) Draw the batch growth curve for the microbial growth and mark the different phases as lag, acceleration phase, log or exponential phase and deceleration phase and stationary phase and death phase. Explain the enzymatic actions during the phases. $\Gamma_x = \mu x$; the fate of μ at each phase to be noted with reference to μ_{max} . Derive expression as $\ln X_t = \ln X_0 + \mu t$ and draw the graph on it. Explain the doubling time also as $t_d = \ln 2 / \mu$.

35. Explain the growth of filamentous organisms and its growth kinetics. (April/May 2012)

36. Find the maximum specific growth (U_m) and Monod constant (K_s), following the

37. literalized Monod equation procedure and using the data given in the table for the growth of yeast, on glucose in a 20 L fermenter. The cell growth is reasonably represented by Monod growth kinetics.

Substrate g/L :

U (h⁻¹) :

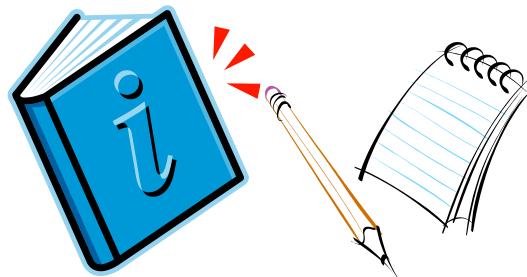
38. Explain the models for substrate and product inhibition. (Nov / Dec 2012) (Nov/Dec 2013)

39. Explain the simple unstructured kinetic models for microbial growth. (Nov / Dec 2012 & 2013)



V.S.B.ENGINEERING COLLEGE, KARUR-639 111

Department of Chemistry



GE8291 ENVIRONMENTAL SCIENCE AND ENGINEERING

QUESTION BANK

PART-A QUESTIONS AND ANSWERS

Prepared by
Department of Chemistry
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UNIT-I ENVIRONMENT, ECOSYSTEMS AND BIODIVERSITY

Environment

PART-A

1. Define environment.? Where from the word environment is derived and what does it refer to? (Apr/May 2019)

'Environment' is derived from the French word *Environ* which means to encircle or surround. All the biological and non-biological things surrounding an organism are thus included in environment. In simple, the interrelationship between living things and non-living things.

2. Write down the components of environment. (May-June 2013) (Nov-Dec 2014)

The components of environment can be broadly divided into two

a) **Abiotic components** - composed of all the non living components like temperature, water, minerals and gases etc. It includes 1. Lithosphere 2. Hydrosphere 3. Atmosphere

b) **Biotic components** - composed of all the living components (plants, animals & micro-organisms) It includes 1. Producers 2. Consumers 3. Decomposers

3. Write the classification of biological environment.

Floral/Plant Environment

Faunal /Animal Environment

Microbial environment

4. What is hazard?

Hazard is any substance that can hurt you or make you ill. It is expressed in degree. Degree of hazard is the function of risk, exposure, vulnerability and response.

5. Give some important physical hazards and their health effects. Or Give any two examples of physical hazards. (May - June 2016)

Physical hazards	Health effects
Radioactive radiations	Affect the cells, function of glands and organs and cancer.
UV radiations	Skin cancer.
Global warming	Increase in temperature causes famine, mortality.
Noise	Painful and irreparable damage to human ear.

6. Mention some important chemical hazards and their health effects. (Nov-Dec 2016)

Chemical hazards	Health effects
Combustion of fossil fuels: Liberates SO ₂ , NO ₂ , CO ₂ and particulate matter.	Asthma, bronchitis and other lung diseases.
Industrial effluents(toxic)	Kill cells and cause cancer, and death.
Pesticides like DDT and chlorinated pesticides	Affect the food chain
Heavy metals like Hg, Cd, Pb, fluoride and nitrate.	Contaminate water, cause ill effects.

7. How are hazards controlled?

Ventilation of the places should be improved.

Use of UV lamp and air conditioning systems.

Use of personal protective equipment like masks, gloves, protective clothes, eye shield.

Elimination of the sources of contamination of biological hazards.

ECOSYSTEMS

1. What are the components of Ecosystem?

An Eco system has two major components.

Biotic (or) Living components

Abiotic (or) Non living components

2. What are nutrient cycles (or) Bio-geochemical cycle?

The cycle flow of nutrients between the biotic and abiotic components is known as

Nutrient cycle (or) biogeochemical cycle

3. What is hydrological cycle? (Nov-Dec 2013)

The process of Evaporation, Condensation and Transpiration is known as hydrological cycle.

4. What is ecological succession? Mention their types. (Nov-Dec 2013)

The progressive replacement of one community by another till the development of

Stable community in a particular area is called ecological succession.

Types:

a) Primary succession

i) Hydrosere ii) Xerosere

b) Secondary succession

5. Why are plants called as producers?

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. As the green plants manufacture their own food they are known as Autotrophy.

6. What are food chains?(April-May2015) (Nov-Dec 2015)

The sequence of eaten and being eaten in an ecosystem is known as food chains

7. What is food web?

The interlocking pattern of eaten and being eaten in an ecosystem is known as food web.

8. What is ecological pyramid?

Graphical representation of structure and function of tropic levels of an ecosystem starting with producers at the bottom and each successive tropic levels forming the apex is known as ecological pyramids.

9. What are called Producers?

Producers are mainly the green plants, which can synthesize their food themselves by making use of CO₂ present in the air and water in the presence of sunlight by involving chlorophyll, through the process of photosynthesis. They are also known as photo autotrophs.

10. Name the four ecosystems.

- Forest ecosystems
- Grass land ecosystems
- Desert ecosystems
- Pond ecosystems

11. Explain the concept of an ecosystem. (Nov-Dec 2013)/What is an ecosystem? (Nov/Dec. 2019)

A group of organisms interacting among themselves and with environment is known as ecosystem.

12. Define the terms a) Producers and b) Consumers.

- a) Producers synthesis their food themselves through photosynthesis.
- b) Consumers are organisms which cannot prepare their own food and depends on food directly or indirectly on the producers.

13. What is meant by keystone species?(or)Define keystone species with suitable example.

(April-May2018)

With in a habitat each species connects to and depends on other species. But while each species contribute to habitat functioning, some species do more than others in the overall scheme of things. Without the work of these key species, the habitat changes significantly. These Species are called keystone species. When a keystone species disappears from its habitat, that Habitat changes dramatically. e.g. Elephant in forest eco system. Elephant is strong enough to digest large size fruits from tallest tree. If elephant is not existed, tallest tree will be extinct species

14. What are the characteristics of desert ecosystem?

- Air and climate is dry is hot.
- Soil is poor nutrients and organic matter.
- Annual rain fall is less than 25 cm.
- Vegetation is poor

15. What are autotrophic and heterotrophic components of an ecosystem? Give examples.

Autotrophic component: The members of autotrophic components are producers which are autotrops (self – nourishing organisms). They derive energy from sun light and make organic components from inorganic substances. Eg: Green plants, Algae, Bacteria etc

Heterotrophic components: The members of heterotrophic components are consumers and decomposers, which are heterotrops (depend on others for food). They consume autotrops (Producers).

16. Define primary production and secondary production.

Primary production: It is defined as the conversion of radiant energy into organic substances by photosynthesis by the primary producers (Plants)

Secondary production: .It is defined as distribution of energy in the form of food to the consumer (or) the energy stored by the consumer.

17. How does biome differ from an ecosystem?

The kind of organisms which can live in a particular ecosystem depends on their physical and metabolic adoptions to the environment of that place. On earth there are many sets of ecosystems which are exposed to same climatic conditions and having dominant species with similar life cycle, climatic adoptions and physical structure. This set of ecosystem is called a biome.

18. Define decomposer and give their significance.

The microorganism which feeds on dead organs is known as decomposer. Examples: bacteria and fungi.

19. Define ecology. (May-June 2014)

Ecology is the scientific study of interactions among organisms and their environment.

20. Mention two and secondary consumers in grassland ecosystem. (May-June 2016)

Primary consumers – Giraffe, Deer. Secondary consumers – Snake, Lizard.

21. How is nitrogen fixed in soil? (April-May 2017)

They contain symbiotic bacteria called rhizobia within nodules in their root systems, producing nitrogen compounds that help the plant to grow and compete with other plants. When the plant dies, the fixed nitrogen is released, making it available to other plants; this helps to fertilize the soil.

22. Define the ecosystem. (April-May 2018)

A group of organism interacting among themselves and with environment is known as ecosystem.

23. Write the various adaptive features of desert plants. (April-May 2018)

- ✓ Ability to collect and store water and
- ✓ Features that reduce water loss

24. What are indicator species? Give example. (April-May 2018)

An indicator species is an organism whose presence, absence or abundance reflects a specific environmental condition. Indicator species can signal a change in the biological condition of a particular ecosystem, and thus may be used as a proxy to diagnose the health of an ecosystem. For example, plants or lichens sensitive to heavy metals or acids in precipitation may be indicators of air pollution

25. Define oxygen cycle (Nov-Dec 2018)

Plants are able to use the energy of sunlight to convert carbon di oxide and water into carbohydrates and oxygen in a process called photosynthesis. This means that plants breathe in carbon di oxide and breathe out oxygen. Animals form the other half of the oxygen cycle.

26. What would happen to an ecosystem if all its producers were eliminated? (Nov/Dec 2019)

If it so, means food and energy were not available for consumers and the decomposers. The ecosystem has vanished.

BIODIVERSITY

1. What is In-situ conservation? (Nov-Dec 2017)

It involves protection of fauna and flora within its natural habitat, where the species normally occurs is called in-situ conservation.

2. What is Ex-situ conservation? (Nov-Dec 2017)

It involves protection of fauna and flora from the outside natural habitats.

3. Enumerate the human activities which destroy the biodiversity.

- The farmers prefer hybrid seeds; as a result, many plant species become extinct.
- For the production of drugs, pharmaceutical companies collect medicinal plants, become extinct.
- Tropical forest is the main sources of world's medicine. Every year these forests are disappearing due to agriculture, mining, logging.

4. Define the terms a) genetic diversity and b) species diversity (April-May 2017)

a) Genetic diversity: It is the diversity within species

b) Species diversity: It is the diversity between different species. The sum of varieties of all the living organisms at the species level is known as species diversity.

5. What do you understand by the terms flora and fauna?

Flora: Plants present in a particular region or period.

Fauna: Animal present in a particular region or period.

6. India is a mega diversity nation-Account.

India is one among the 12 mega diversity countries in the world. It has 89450 animal species accounting for 7.31% of the global faunal species and 47000 plants species accounting for 10.8% of the global floral species. The loss of biodiversity is about 33%.

7. What is a bio-diversity hot spot? Give example. (Nov-Dec 2018) (Nov/Dec 2019)

Biodiversity hotspots are the geographical areas which possess high endemic species.

In India the biodiversity hotspots are: 1. Eastern Himalayas 2. Western Ghats

8. Give few examples for endangered and endemic species.

Endangered species:

Reptiles : Tortoise, Python.

Mammals : Indian wolf, Red fox, Tiger.

Primates : Golden monkey.

Plants : Santalum.

Endemic species:

Flora: Sapria Himalayan, Ovaria lusida

Fauna: Monitor lizards, Indian salamander

9. Define biodiversity and mention its significance. (April-May 2015) (Nov-Dec 2015)

It is defined as the variety and variability among all groups of living organism and the ecosystem in which they occur.

Significance:

- It is very important for human life, as we depend on plants, microorganisms, earth's animals for our food, medicine and industrial products.
- It protects the fresh air, clean water and productive land.

10. Write the classification of biodiversity. (May-June 2014) (Nov-Dec 2016)

The concept of biodiversity may be analyzed in 3 different levels.

1. Ecosystem diversity
2. Species diversity
3. Genetic diversity

Ecosystem diversity: (Nov-Dec 2016)

- The richness and complexity of a biological community, including tropic levels, ecological processes food webs and material recycling.

Species diversity:

- The number of kinds of organisms within individual communities or ecosystems.

Genetic diversity:

- It is a measure of the variety of versions of same gene within individual species.

11. What are called endangered species? Mention with two examples (Nov-Dec 2014) (Nov-Dec 2017) (Nov-Dec 2018)

A species said to be endangered species, when its number has been reduced to a critical level. Unless it is protected and conserved it is in immediate danger of extinction.

Examples: Python and peacock

12. What are the major threats to biodiversity? (Nov-Dec 2014)

- Habitat loss.
- Poaching.
- Man – wild conflicts.

13. Explain vulnerable species.

A species said to be vulnerable species when its population is facing continuous decline due to habitat destruction or over exploitation. Such a species is still abandoned.

14. Write a note on nitrogen cycle. (Nov-Dec 2017)

The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into various chemical forms as it circulates among the atmosphere, terrestrial, and marine ecosystems. The conversion of nitrogen can be carried out through both biological and physical processes. Important processes in the nitrogen cycle include fixation, ammonification, nitrification, and denitrification. The majority of Earth's atmosphere (78%) is nitrogen, making it the largest source of nitrogen. However, atmospheric nitrogen has limited availability for biological use, leading to a scarcity of usable nitrogen in many types of ecosystems.

15. Mention two invasive species. (Nov-Dec 2017)

An invasive species is a plant, fungus, or animal species that is not native to a specific location (an introduced species), and which has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health

Eg. Flat worms, jelly fish, bony fish, sharks, rays, amphibians, reptiles.

16. What are called endemic species? (Nov-Dec 2017)

These species which are found only in a particular region are known as endemic species.

Eg. Endemic flora species- Sapria himalayana, Ovaria lurida,

Endemic fauna species- Monitor lizards, reticulated python.

17. What is habitat fragmentation? (Nov-Dec 2018)

Habitat fragmentation is the process by which habitat loss results in the division of large continuous habitats into smaller, more isolated remnants

18. Write the criteria to determine hotspot and name the hotspots in India. (Apr/May 2019)

- i. The richness of the endemic species is the primary criterion for recognizing hotspots.
- ii. The hotspots should have a significant percentage of specialized species.
- iii. The site is under threat.
- iv. It should contain important gene pools of plants of potentially useful plants.

Hotspots in India: Eastern Himalayas and Western Ghats

UNIT-I
PART-B
ENVIRONMENT

1. Discuss the structure of atmosphere.
2. Explain the community participation in environment management programmes.
3. What are the components of the environment? Explain their roles. (May - June 2016) (Nov/Dec 2019)

ECOSYSTEM

- Describe the types, characteristic features, structure and function of
4. Forest eco system (Nov-Dec 2013) (Nov-Dec 2015) (Nov/Dec 2019)
 5. Aquatic eco system (April-May 2015) (Nov-Dec 2015)
 6. Grass land ecosystem. (Nov-Dec 2014) (Nov/Dec 2015) (April-May 2017) (April-May 2018) (Apr/May 2019) (Nov/Dec.2019)
 7. Describe the types, characteristic features, structure and function of
 - i) Desert ecosystem (May-June 2013) (April-May 2018) ii) Estuarine ecosystem.
 8. Explain energy flow in ecosystem, food chain and food web. (Nov-Dec 2013)
 9. Explain ecological pyramids and their types. (May/June 2014) (April-May 2015) (Nov-Dec 2015) (Nov/Dec 2019).
 10. Discuss the structure and function of an ecosystem in detail. OR Discuss the components of ecosystem. (Nov/Dec 2014) (May - June 2016) (Nov-Dec 2016)
 11. Give the types and process of ecological succession. (May-June 2013) (April-May 2015) (Nov-Dec 2015) (Nov-Dec 2016) (April-May 2018)
 - a. With a neat sketch discuss the nitrogen cycle. (Nov-Dec 2014)
 12. Explain briefly in energy flow through ecosystem. (Nov-Dec 2015) (April-May 2018)
 13. Explain oxygen and nitrogen cycle briefly with diagrams. (May-June 2016)
 14. Write short notes on following Food web & Food chain (May/June 2014) (April-May 2018)
 15. Write the importance of biological hazard in the environment. (April-May 2017)
 16. Draw the process of food chain and food web. (April-May 2018)
 17. What is the importance of protecting the Biodiversity of earth? (Nov/Dec 2019)
 18. Identify and explain the major threats to the biodiversity of India. (Nov/Dec 2019)
 19. Discuss the two approaches of wildlife conservation in protected habitats. (April-May 2018)
 20. Mention the role of an individual in conservation of natural resources. (April-May 2018)
 21. Discuss the Ex-situ and In-situ conservation of biodiversity with their advantages and limitations. (Nov/Dec.2019)

BIODIVERSITY

1. Explain the conservation of biodiversity. (Nov-Dec 2013 and 2014) (April-May 2017)
2. Write a note on measuring biodiversity.
3. Explain the role of biodiversity at global, national and local levels. (May-June 2014)

4. Explain in-situ and ex-situ conservation along with their merits and limitations. (May - June 2016) (Nov-Dec 2016) (April-May2018)
5. Describe the term hotspot in biodiversity. (Nov-Dec 2014) (Nov-Dec 2017)
6. Discuss endangered and endemic species of India.
7. Discuss the status of India as a mega diverse nation of bio diversity. (May-June 2013) (Nov-Dec 2016) (April-May 2017)
8. Describe the structural features of ecosystem.
9. Discuss the importance of biodiversity. (Nov-Dec 2013)
10. Explain the values of biodiversity. (May-June 2013) (Nov-Dec 2014) (April-May2018) (Nov-Dec 2018)
11. Identify and explain the major threats to the biodiversity of India. (Nov-Dec 2013) (April-May2015) (Nov-Dec 2015)(May - June 2016) (Nov-Dec 2017)
12. Discuss uniqueness of different ecosystems; Forest ecosystem, Grassland ecosystem, Desert ecosystem and aquatic ecosystem. (Nov-Dec 2017)
13. Discuss human animal conflicts with special reference to media coverage/ten control measures for man-wild life conflict. (Nov-Dec 2017) (April-May2018) (Nov-Dec 2018)
14. What is bio diversity? Discuss the unique advantages of biodiversity(Nov-Dec 2018)

UNIT - II ENVIRONMENTAL POLLUTION

PART-A

1. Define pollution.

Pollution may be defined as the excessive discharge of undesirable substances into the natural quality of the environment and causing damage to humans, plants and animals.

2. What are suspended particulate matters? Give examples. (April-May 2018)

Suspended Particulate matters are the substances which cause undesirable effects on man and his environment. eg. Smoke, dust, soot, fumes, aerosols, liquid droplets, pollen grains etc.

3. What is photochemical smog?

- It is a mixture of brownish smoke and fog that frequently forms on clear, sunny days over large cities with significant amount of automobile traffic.
- It is mainly due to chemical reactions among nitrogen oxides and hydrocarbon by sunlight.

4. How will you control Air pollution?

Air pollution can be minimized by

- Using low sulphur coal in Industries.
- Removing NO_x during the combustion process.
- Using mass transport system, bicycles etc.
- Planting more trees etc.,

5. Define Acid rain. Write its type. (Nov-Dec 2013) (April-May 2015) (Nov-Dec 2018) (April-May 2019)

Excess amount of acid present in the rain is called acid rain. It has two types,

Wet deposition: It involves acid rain or snow or dew

Dry deposition: It is the particles such as polluting gases, dust particles and gaseous elements are just absorbed by the surface of the earth or the plant bodies.

6. What is PAN? Give its detrimental effects. (May - June 2016) (April-May 2017)

Definition: PAN is Peroxy Acetyl Nitrates formed by the photochemical reaction between hydrocarbons, nitrogen oxides and light.

Effects: Damages plants and art, React explosively and produce chemical smog.

7. Define BOD and COD (Nov-Dec 2013)

BOD-Biological Oxygen Demand is the quantity of dissolved oxygen required by bacteria for the oxidation of organic matter under aerobic conditions.

COD- Chemical Oxygen Demand is the measure of both biologically oxidisable & inert organic materials present in the sewage.

8. What are point sources and non-point sources of pollution?

Point sources- Point sources are discrete discharges from pipes and other conduits such as sewage treatment plants and Industrial facilities.

Non-Point sources- It is broad, unconfined area from which pollutants enter a body of water. eg., urban storm water run-off, run-off from farm fields, acid rain etc.,

9. Give the source of radioactivity.

Natural sources- Cosmic ray from outer space, radioactive radon-222, soil, rocks, air, water and food which contains one or more radioactive substances.

Anthropogenic sources- Nuclear power plants, nuclear accidents, X-rays diagnostic kits, test laboratories etc.

10. What are the important physical and chemical parameters affecting the quality of water? (OR) Mention the water quality parameters. (Nov-Dec 2016)

Physical parameters: Colour, Taste and odour, Turbidity and sediments.

Chemical parameter: P^H, Acidity, Alkalinity, Fluoride, Nitrogen Nitrates, Sulphates, Chloride.

11. What is the role of Citizen in reducing pollution?

Help more in pollution prevention than control.

Use ecofriendly products.

Cut down the use of CFC's.

Adopt and popularize renewable energy resources.

12. What is meant by air pollution?

Air pollution may be defined as the presence of impurities in excessive quantity and duration to cause adverse effects on plants, animals, human beings and materials.

13. List the types of air pollutants.

Particulate pollutants- Dust, Smoke, Fly ash, Smog, etc.

Gaseous pollutants - SO₂, SO₃, CO₂, CO, H₂S, aerosols, etc.

Internal Combustion Engines - CO₂, CO, SO₂, NO₂ and hydrocarbons

14. Define thermal pollution

Addition of excess of undesirable heat to water that makes it harmful to aquatic life and cause significant changes of normal activities of aquatic communities.

15. Write any four major water pollutants.

Infectious agents, Organic wastes, In-organic wastes and Demand of O₂

16. Name the sources of soil pollution. (May/June - 2013)

Biotic agents, Industrial waste, Urban wastes, Domestic wastes, Radioactive wastes and Agricultural wastes.

17. Write briefly how human activities can introduce thermal pollution in Streams.

The addition of heat to water that changes the physical, chemical and biological characteristics of water and also harmful to man, animal and aquatic life. The atomic and Thermal power plants may utilize water for cooling the reactor and resultant warmed water is often discharged into streams or lakes that cause thermal pollution.

18. What are the sources of thermal pollution? (May - June 2016)

Nuclear power plants, Thermal power plants, Hydro electric power plants, Industrial effluents, Domestic sewage, Hydro electric power

19. What is marine pollution? Mention few reasons / sources for marine pollution.(Nov-Dec2014) (April-May 2017) (April-May2018)

Dumping of waste and oil spillage in the ocean cause threat to marine system is called marine pollution. Dumping of wastes and Oil Spilling.

20. What is noise pollution? How it is caused? (or) Define the term noise pollution.(Nov/Dec 2013) (April-May2015) (Nov-Dec 2015)(April-May2018)

It is an unwanted sound created by human activities is called noise pollution. Blaring loudspeaker, bursting of crackers, road traffic, aircraft taking off, massive industries and from entertainment centers.

21. What is disposal?

Disposal is the discharge, deposit, injection, dumping, spilling, leaking or placing of waste into or any land, water or air.

22. Differentiate between recycling and reuse.

S.No.	Recycling	Reuse
1.	Reprocessing of the discarded materials into new useful products	Usage of discarded materials
2.	Eg. Preparation of cellulose insulation from paper Aluminium cans and glass bottles are melted and recast into new cans and bottles	Discarded refillable containers can be reused Discarded cycle tubes can be reused to manufacture rubber rings.

23. What is composting?

The decomposition and stabilization of solid wastes taken place by biochemical bacteriological process under the controlled conditions is called composting. It occurs in 2 ways.

Aerobic decomposition

Anaerobic decomposition

24. What are the sources of Urban and Industrial waste?

Urban waste consists of medical waste from hospitals, municipal solid wastes from homes, offices, markets, small cottage units and horticulture wastes from park, garden, orchards etc.,

Industrial waste consist of a large no: of materials including factory rubbish, packaging materials organic wastes, acids, alkalis, metals etc.,

25. When is a waste said to be hazardous?

A waste is said to be *hazardous* if it possess one or more of the following characteristics,
Toxicity b) Reactivity c) Ignitability d) Radioactivity

26. What are the general methods to removal of heavy metals by adsorption?

Using coconut shell carbons

Using fly ash

Using clay and coal based adsorbents.

27. What are the causes and effects of ozone layer depletion?

Causes: Chloro fluoro carbon and Hydro Chloro fluoro carbon

Effects: Increases the average temperature of the earth. It also affects the aquatic forms.

28. What are the major causes of earthquake? (May/June 2014)

Underground nuclear testing.

Volcanic eruptions

Pressure of manmade dams, reservoir and lakes

Movement of plates of earth.

29. Mention the effects of ozone on plants. (Nov-Dec 2014)

Ozone effects on plants are most pronounced when soil moisture and nutrients are adequate and ozone concentrations are high. Under good soil moisture and nutrient conditions the ozone will enter through openings into the leaf and damage the cells that produce the food for the plants.

30. Define hazardous waste (Nov-Dec 2014), (Nov-Dec 2019)

Radioactive and toxic wastes which poses a substantial or potential threats or illness to human health and the environment is called as hazardous waste.

31. Define green house effect. (Nov-Dec 2014)

The progressive warming up of earth surface due to blanketing effect of manmade CO₂ in the atmosphere.

32. Differentiate between sound and noise. (Nov-Dec 2014), (Nov-Dec 2019)

S.No	Sound	Noise
1	Below 120 dB	Above 120 dB
2	It does not make pollution	It makes pollution

33. How does ozone layer depletion take place? (Nov-Dec 2014)

It occurs due to the presence of CO₂, CFC in the atmosphere.

34. What is the role of individual in preventing pollution? (Nov-Dec 2015)

Plant more trees.

Use water, energy and other resources efficiently.

Reduce deforestation.

Use CFC free refrigerators.

35. Mention the measures to control thermal pollution caused by industry. (Nov-Dec 2016)

Cooling towers (Wet cooling tower & Dry cooling tower)

Cooling Ponds

Cooling Sprays

Artificial Lake

36. Mention the effects of nuclear wastes in humans. (April-May 2017)

- The waste released from chemical industries and from explosives are dangerous to human life.
- The dumped waste degrade soil and make unfit for irrigation.

37. What are mitigation procedures? Give example. (Nov-Dec 2017) (April-May 2018)

Mitigation is the effort to reduce loss of life and property by lessening the impact of disasters. In order for mitigation to be effective we need to take action now—before the next disaster—to reduce human and financial consequences later (analyzing risk, reducing risk, and insuring against risk). It is important to know that disasters can happen at any time and any place and if we are not prepared, consequences can be fatal.

Example:

- Disasters (e.g. Cyclone and earthquake) can happen at anytime and anyplace; their human and financial consequences are hard to predict.
- The number of disasters each year is increasing but only 50% of events trigger Federal assistance.

38. List the types of nuclear reactors. (April-May 2018)

- ❖ Thermal Reactors and
- ❖ Fast neutron reactor

39. Classify the pollution types. (April-May 2019)

Water, air, soil, marine, nuclear hazards, thermal, noise are the types of pollution

UNIT-II

PART-B

- 1. Write brief notes on solid waste management. State the measures recommended for proper management of the solid wastes. (Nov-Dec 2013) (May/June 2014) (April-May2015) (Nov-Dec 2016) (Nov-Dec 2019)**
- 2. Explain the causes, effects and control measure of water pollution.(Nov-Dec 2013) (May/June 2013) (May-June 2014) (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (April-May 2018)**
- 3. Explain the causes, effects and various methods of controlling air pollution. (May - June 2016) (May-June 2013) (Nov/Dec 2014) (April-May2015) (Nov-Dec 2015) (Nov-Dec 2018)**
- 4. Explain the concept of source, path receiver in the control of noise pollution. (Nov-Dec 2014) (Nov-Dec 2016) (April-May 2017)**
- 5. Explain the causes, effects and control measures of marine pollution. (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (Nov-Dec 2016) (April-May2018) (April-May2019)**
- 6. Explain the causes, effects and control measures of nuclear hazards and explain any two case studies on nuclear pollution. (April-May2015) (Nov-Dec 2015) (April-May2018)**
- 7. What are the causes and control measures for soil pollution. (Nov-Dec 2018) (April-May 2019)**
- 8. Explain the disaster management in detail. (Nov-Dec 2019)**
- 9. Discuss the role of individual in preventing pollution. (Nov-Dec 2014) (April-May2015) (April-May2018) (April -May 2019)**
- 10. Explain the causes, effects and control measures of thermal pollution.(Nov-Dec 2013) (May/June 2014) (May-June 2013) (Nov-Dec 2015)**
- 11. Describe the various chemical and photochemical reactions in the atmosphere. (Nov-Dec2014) (May - June 2016) (April-May 2017)**
- 12. Write informative notes on water treatment processes. (Nov-Dec 2014) (April-May2018)**
- 13. Discuss the significance of any six parameters of drinking water quality standards. (Nov/Dec 2014)**
- 14. Discuss about the causes, impacts and control measures of ozone depletion in the atmosphere. (Nov-Dec 2016) (April-May2018) (April-May 2019)**
- 15. What are the effects of heavy metals in aquatic environment? (April-May 2017)**
- 16. What is a particulate matter? How is it controlled by using equipment? (April-May 2017)**
- 17. Discuss physical, chemical, biological parameters to ensure drinking water quality.(Nov-Dec 2017)**
- 18. Demonstrate the various classes of water pollution and enumerate in detail about the following i) Domestic waste water ii) Industrial waste and iii) storm water (April-May 2018)**
- 19. Illustrate in detail about Green house effect and Global warming with neat sketch(April-May 2018)**
- 20. Discuss the measures that should be taken to de-pollute our waterways (Nov-Dec 2018)**

UNIT-III NATURAL RESOURCES

PART-A

1. What are renewable and non-renewable energy resources? Give examples.

Renewable energy resources are natural resources which can be regenerated continuously and are inexhaustible. They can be used again and again in an endless manner.

2. State the environmental effects of extracting and using mineral resources. (May - June 2016)

Devegetation and defacing of landscape	Air pollution
Ground water contamination	Subsidence of land
Surface water pollution	

3. Define sustainable forestry.

It is the optimum use of forest resources which meet the needs of the present without compromising the ability of future generations to meet their own needs.

4. Define overgrazing.

Overgrazing is a process of eating away the forest vegetation without giving it a chance to regenerate.

5. What is desertification? Give two reasons for it. (Nov-Dec 2018)

It is a progressive destruction or degradation of arid or semi arid lands to desert.

Reasons:

Deforestation, Overgrazing, Mining and quarrying

6. What is water logging? Mention about the problems in water logging.

Water logging is the land where water stand for the most of the year.

Problems: During water logged conditions, pore-voids in the soil get filled with water and the soil-Air gets depleted. In such condition the roots of the plants do not get adequate for respiration. So, mechanical strength of the soil decreases and the crop yield fails.

7. What do you mean by environmental impact? (Nov-Dec 2014)

Environmental impact is nothing but the effect on the natural environment caused by various human actions.

8. Define soil leaching. List the effects of soil leaching.

The process in which materials in or on the soil gradually dissolve and are carried by water seeping through the soil.

Effects of soil leaching:

It removes valuable nutrients from the soil.

It may carry buried wastes into ground water and contaminates it.

9. Write any four functions of forests.

Forests perform very important functions both to humans and to nature.

They are habitats to millions of plants, animals and wildlife.

They recycle rain water and remove pollutants from air.

They control water quality and quantity

10. What are the causes of deforestation?

Developmental projects, Mining operations, Raw materials for industries, Fuel Requirements
Shifting cultivation and Forest fires.

11. Compare merits and problems of dams.

Merits of dams:

- Dams are built to control flood and store flood water
- It's used for diverting part or all of the water from river into a channel
- Dams are used mainly for drinking and agricultural purposes
- Dams are built for generating electricity

Problems of dams:

- Displacement of tribal people
- Loss of non-forest land
- Loss of forests, flora and fauna
- Water logging and salinity due to over irrigation
- Reduced water flow and silt deposition in rivers
- Salt water intrusion at river mouth

12. What is meant by soil erosion?

Soil erosion is the process of removal of superficial layer of the soil from one place to another. Soil erosion also removes the soil components and surface litter.

13. Differentiate deforestation with forest degradation.

Forest degradation	Deforestation
It is the process of deterioration of forest materials.	It is the process of destruction of forest materials.
Slow process	Rapid process
Cannot be recovered	Can be recovered

14. Enumerate the desired qualities of an ideal pesticide.

- It must kill only the target species
- It must be a biodegradable
- It should not produce any new pests
- It should not produce any toxic pesticide vapour
- Excessive synthetic pesticide should not be used
- Chlorinated pesticides and organophosphate pesticides are hazardous, so they should not be used.

15. Write any two adverse effects caused by overgrazing.

Land degradation, soil erosion and loss of useful species.

16. Differentiate renewable and non-renewable energy resources.

S.No.	Renewable energy	Non-renewable energy
1	It is regenerated continuously	Cannot be regenerated
2	Inexhaustible	exhausted
3	It can be used again and again	Cannot be used again
4	It is pollution-free	Pollutes the atmosphere
5	It is developed in a long period	It is developed in a short period

17. Mention the various causes of desertification.

Deforestation, overgrazing, water management, mining and quarrying, climate change and pollution.

18. What are the effects of dams on tribal people?

Due to continuous removal of minerals, forest covers, the trenches are formed on the ground leading to the water logged area, which in turn contaminates the ground water.

During mining operations, the vibrations are developed, which leads to earthquake.

When materials are disturbed in significant quantities during mining process, large quantities of sediments are transported by water erosion.

19. What is eutrophication? (Apr/May 2019)

A large proportion of N and P fertilizers used in crop fields are washed off by the runoff water and reaches the water bodies causing over nourishment of the lakes. The process of accumulation of nutrients in the water bodies is called eutrophication.

20. What do you mean by land degradation? What are the reasons for land degradation? (Nov-Dec 2015) (May - June 2016)

Definition: It is the process of deterioration / destroys soil or loss of fertility of the soil.

Causes: Population, Urbanization, Fertilizers and pesticides, Damage of top soil, Soil erosion, Water logging and Salination.

21. Wood is renewable resource but not coal. Why?

Wood is renewable resources because we can get new wood by growing a sapling into a tree within 15-20 years. But the formation of coal from trees has taken million of years and cannot be regenerated in our life time.

22. Define the term sustainable development.

It is defined as all the natural resources must be used in such a way that it must be available for the future generation also.

23. Mention the major environmental impacts of mining. (Nov-2013) or State the environmental effects of extracting and using mineral uses. ((Nov /Dec 2019)

Mining reduces the shape and size of forest areas.

It produces noise pollution.

It develops the vibration and hence earthquake will occur.

Water surface will pollute due to discharge of wastages.

24. What are the changes caused by overgrazing? (Nov-2013) or what are the impacts of overgrazing? (Apr/May 2019)

Land degradation

Soil erosion

Loss of useful species

25. State the use of bio-energy as a non-conventional source of energy.

The cost of obtaining bio-energy through bio-gas plant is less than the cost of obtaining energy from fossil fuels.

Bio-mass consumes more CO₂ than is released during combustion of bio-mass.

It provides a stored form of energy and in many cases in a form suitable for vehicle propulsion.

26. What is environmental biochemistry?

It involves approaches to treat polluted air, waste water and solid waste using metabolic activities of micro-organisms.

27. What are xenobiotics?

Biochemistry, used in environmental science to understand the effects of environment on living organisms as they interact with environmental pollutants.

28. What is energy conversion?

It is a process of changing energy from one form to another form.

29. What is ECO-mark?

Environmentally friendly products are generally indicated by the symbol called ECO-mark.

It is a certification mark issued by the Bureau of Indian Standard (BIS) to environmental friendly products.

30. What is environmental ethics? (Nov/Dec-2013)

It refers to the issues, principles and guidelines relating to human interactions with their environment.

31. What is bio-gas? Mention its uses. (Nov-Dec 2016)

It is a mixture of various gases formed by an aerobic degradation of biological matter in the absence of free oxygen.

Composition of biogas:

Compound	%
Methane	50-75
CO ₂	25-50
N ₂	0-10
H ₂	0-1
H ₂ S	0-3
O ₂	0

Uses:

- It is used for cooking, heating water.
- It is used to run engines.
- It is used for running tube well and water pump set engine.
- It is used as an illuminant in villages.

32. State the reasons of over exploitations of forest. (May-June 2013)

Increasing agricultural production

Increasing industrial activities

Increase in demand of food resource

33. Write the ways of drought management. (May-June 2013)

Modern irrigation technology (drip irrigation) is very much useful to conserve water

Rain water harvesting programme is another fruitful method to conserve more water and to control drought.

34. Write the economic importance of forests. (Nov/Dec-2013)

Commercial uses (fuel, pulp, paper, gums, dyes, medicines, drugs, mining)

Ecological uses (production of O₂, reducing global warming)

Aesthetic value

Touristic value (ecotourism)

35. Write the problems due to constructions. (May/June-2014)

Deforestation, Pollution, Soil erosion, Devegetation.

36. Define non-renewable energy resources. (May/June-2014) (April-May2015) (Nov-Dec 2015)

Non renewable energy resources are natural resources which cannot be regenerated once and are exhaustible. They cannot be used again and again in an endless manner.

37. Define the term nuclear energy. (Nov-Dec 2014)

Energy release from nuclear fission reaction is known as nuclear energy.

38. Define renewable energy resources. (Nov-Dec 2014) (April-May2015) (Nov-Dec 2015)

Renewable energy resources are natural resources which can be regenerated. They can be used again and again in an endless manner.

39. Write the preventive methods of deforestation. (Nov-Dec 2014)

Planting more trees, Use of wood for fuel should be discouraged.

40. What is desertification? (April-May2015) (Nov-Dec 2018) (Nov-Dec 2019)

The progressive destruction of arid or semiarid lands to desert is known as desertification.

41. Write any two problems caused by high saline soils? (April-May 2017)

➤ Due to high saline soils, the soil becomes alkaline and crop yield decreases.

42. List some ways to protect soil. (April-May2018)

- ❖ Practice No-Till farming
- ❖ Use Terrace Farming
- ❖ Practice Contour Farming
- ❖ Plant Windbreaks

43. What is bioconversion of pollutants? Give example. (April-May2018)

Bioconversion is the change of pollutants into a source of energy by the action of micro organisms. It is the cheap and safe method.

e.g: Bioconversion of biomass into ethanol and methanol

44. What is habitat fragmentation?

Habitat fragmentation describes the emergence of discontinuities (fragmentation) in an organism's preferred environment (habitat), causing population fragmentation and ecosystem decay.

45. What are the ecological benefits of forests? (Nov /Dec 2019)

Ecological uses

1. production of O₂,
- 2) reducing global warming

46. Identify the main reasons for deprivation of food resources in the present human development.

UNIT-III

PART-B

1. Discuss the consequences of overdrawing surface and ground water. (Nov-Dec 2013) (Nov-Dec 2016)

2. Explain how the alternate energy sources play an important role in environmental impact.

3. Explain the environmental impacts of Mineral extraction/mining and use. (May/June-2013) (April-May2015) (Nov-Dec 2015) (April-May2018)/ Problems associated with Exploitation of Mineral resources with two case studies. (April-May2018) (Nov /Dec 2019)

4. Explain renewable and non-renewable energy resources with examples. Explain the merits and demerits of any two renewable energy resources. Why are non renewable energy resources preferred for energy utilization now-days? (May-2014) (Nov-Dec 2013) (May - June 2016)

5. Explain the major causes and ill effects of deforestation. (Nov-Dec 2013) (Nov-Dec 2014) (April-May2015) (Nov-Dec 2015) (Nov-Dec 2016) (April-May 2017) (April-May2018)

6. Explain briefly the various methods of harvesting solar energy.

7. Discuss the merits and demerits of wind energy and tidal power. (May/June-2013)

- 8. Describe the benefits and problems of constructing dams. (Nov/Dec-2013) (Nov-Dec 2015) (Nov-Dec 2018) or Illustrate the various environmental ill effects and benefits associated with dams with reference to a case study. (Nov /Dec 2019)**
- 9. Explain the environmental impacts of modern agriculture (May-June 2013, 2014) (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (Nov-Dec 2016) (April-May 2017)(Nov-Dec 2017)**
- 10. Explain any two conflicts over water confining to our nation.**
- 11. Discuss in detail the causes and consequences of over exploitation of forest resources. Or Enumerate the consequences of deforestation (Apr /May 2019)**
- 12. What are the ecological benefits of forests?**
- 13. Discuss the effects of dams on forest and tribal people. (or) Explain how construction of dams affects forests and tribal people. (Apr /May 2019)**
- 14. Discuss the timber extraction on forest and tribal people. (Nov/Dec-2013)**
- 15. Discuss the role of individual in conservation of natural resources. (Nov/Dec-2013) (April-May2018)**
- 16. Explain the hydrological cycle with its components with suitable sketch. (May/June-2014) (Nov/Dec 2014)**
- 17. Explain the production and uses of biogas with neat diagram. (Nov-Dec 2014) (April-May 2015) (May - June 2016) (April-May 2017) (OR) Energy conversion process with suitable example. (April-May2018)**
- 18. Explain bioconversion of pollutants with examples. (May - June 2016)**
- 19. Explain in detail about biochemical degradation of pollutants. (April-May2018)**
- 20. Write short notes on different types of energy sources. (May/June 2014)**
- 21. Discuss the following (i) Land resources (ii) land degradation (iii) soil erosion and (iv) desertification (Nov/Dec-2013) (May/June-2013)(Nov-Dec 2014) (Nov-Dec 2016)**
- 22. What are the changes caused by agriculture and overgrazing? (Nov-Dec 2014) (April-May2018)**
- 23. Write note on i). Food resources ii). Mineral resources. (April-May 2015) (April-May2018)**
- 24. Discuss the renewable sources of energy with respect to solar, wind and tidal power. (Nov-Dec 2017) (Apr /May 2019) or Identify the reason for growing energy demand. Discuss the advantages and limitations of solar energy, wind energy, and thermal power energy. (Nov-Dec 2019)**
- 25. Write on pros and cons of some of the renewable energy sources. (Nov-Dec 2018)**
- 26. Describe the problems associated with over exploitation of ground water. (April-May2018) (Nov /Dec 2019)**
- 27. What is deforestation and give its ill effects. (Nov /Dec 2019)**

28. Discuss the causes and effects of soil degradation. (Apr /May 2019)

29. Distinguish between commercial and ecological function of forest resources. (Apr /May 2019)

UNIT-IV SOCIAL ISSUES AND THE ENVIRONMENT

PART-A

1. Define sustainable development. (OR) Explain the term sustainability. (OR) Define sustainable life style. (Nov-Dec 2013) (May - June 2016) (Nov-Dec 2016) (Nov-Dec 2018) (Nov-Dec 2019)

Sustainable development can be summarized as 'meeting the needs of the present without compromising the ability of future generation to meet their own needs'.

2. Explain the concept of sustainable development.

The concept of sustainable development has the following underlying promises.

A symbiotic relationship between the consumer human race and the producer natural system.

Compatibility between ecology and economics.

3. What is the aim of national committee of environmental planning and co-ordination?

Conservation of natural resources.

Control of environmental pollution.

Environmental education.

Environmental laws.

4. Write down the components of Environmental Law.

Environmental Law includes official rules, decisions and actions concerning environmental quality, natural resources and ecological sustainability.

5. What are the major constitutional provisions in India for environmental protection?

Article 47

Article 48-A

Article 51-A (g)

Article 253.

6. State the Article-47 of the Indian Constitution.

Article 47 of the Constitution states that, "The State is to ensure as its primary duty of,

Raising standard of living of its people,

To increase the level of nutrition of the people,

To bring improvement in public health".

7. State the Article 48-A of the Indian Constitution.

Article 48-A of the Constitution states that, "the State shall endeavor for protection and improvement of the environment and for safeguarding the forest and wild life and improving the natural environment of the country".

8. State the Article 51-A (g) of the Indian Constitution.

According to Article 51-A (g) of the Constitution, it shall be the duty of every citizen of India 'to protect and improve the natural environment including forests, lakes, rivers, and wild life and to have compassion for living creatures'.

9. State the Article 253 of the Indian Constitution.

Article 253 of the Constitution empowers the parliament to make laws regarding preserving the environment. It states 'The parliament has power to make any law for the whole or any part of the territory of India for implementing any treaty, agreement or convention with any other country or countries or any decision made at any international conference, association or other body'.

10. List the major environmental conventions of 20th century.

World summit on sustainable development, The Earth Summit, World conference on women.

11. Name some of the acts enacted by the Indian Government to protect the environment.

The Water (prevention and control of pollution) Act 1974,1978

The Water (prevention and control of pollution) amended Act, 1987

The Air (prevention and control of pollution) Act 1981 amended in 1987.

The Environment (protection) Act 1972

The Public Liability Insurance Act 1991.

12. What are the common objectives of environmental legislation?

All the Acts were enacted to achieve the following:

To control further damage to the environment and ecosystem

To conserve the environment

To create authorities to administer the policy and contents of the legislation.

To provide penalties and prosecution for violation of laws.

13. List the major environmental protocols of 20th century.

Kyoto protocol

Montreal protocol.

14. Write notes on NGOs.

The groups working for social changes are called Non-Governmental Organizations (NGOs).

When the activities are concerned with environmental issues they are called environmental NGOs.

15. Write notes on ‘Green Peace’:

‘Green peace’ is one of the largest NGOs in the world with 1.6 million contributing members, carries out well-published confrontations with toxic waste dumpers, seal hunters and others who threaten very specific and visible resources.

16. List some of the NGOs available in India.

World Wide Fund for Nature India.

Indian Environmental Association, Mumbai.

Environmental Society of India (ESI), Chandigarh.

Sastrakalayatha, Kerala.

C. P. Ramaswami Ayer Environmental Education Centre.

17. How does the community participation involve in protecting the environment?

Community participation requires involvement in several areas:

Better theoretical knowledge about the environmental information (both Scientific and traditional)

Better practical guidelines and tools are need.

Better educational support.

18. Write a short note on the history of implementation of international treaties and conventions.

➤ Intercontinental shipping of hazardous waste

➤ Reforestation

➤ Over-fishing

Trade in endangered species

19. Write down the purpose / objectives of The Water (Prevention and Control of Pollution) Act, 1974. (Nov-Dec 2014)

The purpose of The Water Act is “to provide for the prevention and control of water pollution and the maintenance or restoring wholesomeness of water for the establishment, with a view to and carrying out the purpose of aforesaid of Boards for the prevention and control of water pollution, for conferring on and assigning to such Boards powers and functions relating thereto and for matters connected therewith”.

20. Write notes on Manufacture, Storage and Import of Hazardous chemical Rules, 1989.

These rules are applicable to three different types of flammable substances and about 450 hazardous chemicals. The importers of hazardous chemicals should inform the Board authorities of the following given details within 30 days, The place of entry in India, The name of address of the importer, Mode of transport and The quality of the chemicals and the safety details of the product.

21. What is meant by rain water harvesting? (Nov-Dec 2014)

Rain water harvesting is a technique of capturing and storing of rain water for further utilization.

22. What is environmental ethics? (Nov/Dec-2013) (April-May2018) (Nov-Dec 2019) (April-May 2019)

It refers to issues, principles and guidelines related to human interactions with their environment. (or) Ethics is a branch of philosophy. It deals with morals and values. An ethic is a principle for value that we use to decide whether an action is good or bad.

23. List the objectives of forest conservation act. (Nov/Dec-2013)

Protect and conserve the forest.

To ensure judicious use of forest products.

24. What is cyclone? (Nov/Dec 2013) (April-May 2017)

Cyclone is meteorological phenomena, intense depressions forming over the open oceans and moving towards the land.

25. What are biomedical wastes? Give example. (April-May2018)

Biomedical wastes are one type of bio-wastes generated from health care activities (hospitals, nursing homes, laboratories, etc.). They may be solid or liquid in nature.

26. What are landslides? (Nov-Dec 2014)

The movement of earthy materials like coherent rock, mud, soil and debris from higher region to lower region due to gravitational pull is called landslides.

27. Define floods.

Whenever the magnitude of water flow exceeds the carrying capacity of the channel within its banks, the excess of water over flows on the surroundings causes floods.

28. What are the advantages of rain water harvesting? (Nov-Dec 2015) (Nov-Dec 2019)

To increase the ground water level.

To avoid the water scarcity.

29. Define consumerism. (April-May2015) (Nov-Dec 2015) (Nov-Dec 2016)

Consumption of resources by the people is known as consumerism.

30. What do you mean by disaster management? (April-May2015)

Disaster Management can be defined as the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters.

31. State any two biomedical waste handling rules. (May - June 2016)

"Act" means the Environment (Protection) Act, 1986 (29 of 1986)

Bio-Medical Waste (Management and Handling) Rules, 1998

32. Write any four principles of green chemistry. (Nov-Dec 2016) (Nov-Dec 2019)

- Prevention
- Use of Renewable Feedstocks
- Design Less Hazardous Chemical Synthesis
- The use of Safer Chemicals

33. What is nuclear holocaust? (Nov-Dec 2017)

It means destruction of biodiversity by nuclear equipments and nuclear bombs. In a holocaust a large number of living beings are totally destroyed. Usually these kind of destructions are happened in a nuclear war.

34. Write on EIA? (Nov-Dec 2017) (Nov-Dec 2019)

EIA (Environmental Impact Assessment) is defined as a formal process of crediting the environmental consequences of any development projects. It is used to identify the environmental, social and economic impacts of the project prior to decision making.

35. What is a watershed? (Nov-Dec 2017) (April-May2018)

Watershed is defined as the land area from which water drains under the influence of gravity into a stream, lake, reservoir or other body of surface water.

36. Define the term the Man induced landslide. (April-May2018)

These are basically the human activities like construction of roads, buildings, dams, etc. These have strong bearing on the Man Induced Landslides

37. Write the various uses of sustainable development indicators. (April-May2018)

It was developed by the OECD (Organization for Economic Co-operation and *Development*) from earlier work by the Canadian government. Increasingly widely accepted and internationally adopted, it can be applied at a national level, at sectoral levels, at the levels of an industrial firm, or at the community level. Pressure indicators measure policy effectiveness more directly -- whether emissions increase or decrease, whether forest depletion waxes or wanes, and whether human exposure to hazardous conditions grows or shrinks. Pressure indicators are thus particularly useful in formulating policy targets and in evaluating policy performance. They can also be used prospectively to evaluate environmental impacts of socioeconomic scenarios or proposed policy measures.

38. What is green chemistry?

Green chemistry is the use of chemical products and processes that reduce or eliminate substances hazards to human health or the environment.

39. Define e-waste(Nov-Dec 2018)

Electronic waste or e-waste describes discarded electrical or electronic devices.

Eg: used and discarded computers, printer, cartridges, mobile phone, photocopy machines etc.

40. When does rehabilitation arise? Mention any one problem to government during rehabilitation. (April-May2017)

Rehabilitation arises due to

- ✓ Developmental activities
- ✓ Due to disaster
- ✓ Due to conservation initiatives

In India, most of the displacements have resulted due to land requirements by the government for various reasons. The government of India has the land Acquisition Act 1897.

41. Mention the objectives of wasteland reclamation. (Nov-Dec 2019)

- To improve the physical structure and quality of the marginal soils.
- To improve the availability of good quality water for irrigation purpose.
- To prevent soil erosion, flood and landslides.
- To avoid over-exploitation of natural resources.

42. What are the major effects of Global warming? (Nov-Dec 2019)

- Raise of sea level
- Water scarcity
- Destruction of terrestrial ecosystems
- Human health issues

UNIT-IV

PART - B

1. What is meant by rain water harvesting? Name and discuss in brief the types of rainwater harvesting. (Or) Depict the process of rainwater harvesting and mention its objectives. (Apl-May 2019) (Nov-Dec 2013) (Nov-Dec 2014) (April-May 2015) (April-May2018)

2. Explain forest conservation act. (May-June 2013) (Nov-Dec 2014) (April-May 2017) (April-May2018)

3. Write the factors influence the unsustainable to sustainable development. (Or) Discuss the recent approaches to achieve sustainable development. (Apl-May 2019) (Or) Suggest important measures to be adopted in achieving sustainable development. (May-June 2013) (May - June 2016) (Nov-Dec 2019)

4. Discuss the phenomenon of global warming and the factors contributing to it (Nov-Dec 2013) (April-May2018) (Nov-Dec 2019) (Or) Outline the effects of global warming. (Nov-Dec 2019) (Apl-May 2019)

Write a note on watershed management. (Nov/Dec-2013)

5. Discuss briefly on The Environment protection act 1986and The Air Act (Nov/Dec-2013)(Nov-Dec2013)(May/June2014)(April-May2015)(Nov-Dec 2015) (Nov-Dec 2016)(April-May 2017) (Nov-Dec 2017)

6. Explain the important provision in the wild life protective act (Nov-Dec 2014) (April-May2018), (Apl-May 2019) air protection act, water protection act (May/June 2014) (May - June 2016) and environment protection acts. (Apr-May 2015) (Nov-Dec 2015) (Nov-Dec 2018) (Nov-Dec 2019)

7. Discuss the issues involved in the enforcement of environmental legislation.

8. Explain the powers and functions of state pollution control board. (Nov-Dec 2019)

- 9. Discuss the energy requirement in detail for sustaining urban life.**
- 10. Describe the measures to conserve water.**
- 11. Write a note on waste land reclamation. (May-June-2013) (May-June 2014) (April-May 2015) (Nov-Dec 2015)**
- 12. Write about resettlement and rehabilitation of people. (Nov-Dec 2014) (April-May 2018)**
- 13. What are the major urban problems related to energy? (Nov/Dec-2013) (May-June 2013)**
- 14. Write short notes on nuclear accidents and holocaust with case studies. (Nov/Dec-2013) (May-June 2013) (April-May 2015)**
- 15. Explain the Water (prevention and control of pollution act) 1974. (May-2014) (Nov/Dec 2014) (Nov-Dec 2019)**
- 16. Explain the following**
 - Floods**
 - Earthquake (Nov-Dec 2013) (May/June 2014) (Nov-Dec 2014) (Nov-Dec 2015)**
 - Cyclone (Nov-Dec 2015) (Nov-Dec 2016) (Nov-Dec 2018)**
 - Landslides (May-June 2013) (Nov-Dec 2018)**
- 17. Explain the following (May-June 2013)**
 - i).Consumerism ii).Waste products
- 18. Explain in detail, how biomedical wastes are managed and handled? (Nov-Dec 2015) (Nov-Dec 2016)**
- 19. What is green chemistry and what are its 12 principles?. (May - June 2016) (April-May 2017)(Nov-Dec 2017) (April-May 2018)**
- 20. Discuss the various applications of green chemistry for achieving sustainable development. (May - June 2016)**

- 21. What is ECO mark? Explain. (Nov-Dec 2016)**
- 22. Explain the role of state and central pollution control board. (April-May 2018)**
- 23. Discuss about the effects of nuclear hazards. (April-May 2018)**
- 24. Distinguish between natural and enhanced green house effect. (Nov-Dec 2019)**
- 25. Write about climate change. (Apl-May 2019)**
- 26. Discuss the features of forest conservation act. (Apl-May 2019)**

UNIT-V HUMAN POPULATION AND THE ENVIRONMENT PART-A

- 1. List the problems of population growth./ Population explosion. (April-May 2018)**
 - Increasing demands for food and natural resources.
 - Inadequate housing and health services.
 - Loss of agricultural lands.
 - Unemployment and socio-political unrest.
 - Environmental pollution.

- 2. Define doubling time. (Nov – Dec 2013)**

Population explosion can be better understood by considering the doubling time.
i.e., the number of years needed for a population to double in size.

$$T_d \text{ (Doubling time)} = 70/r$$

Where, r = annual growth rate

If a nation has 2% annual growth, its population will double in next 35 years.

3. What is total fertility rate?

It is the average number of children delivered by a woman in her life time.

The TFR value varies from 2 in developed countries to 4.7 in developing countries.

4. Define population explosion. (Nov-Dec 2013) (April-May2015) (Nov-Dec 2015) (May - June 2016) (April- May2018) (Nov- Dec 2018) (Nov-Dec 2019)

The enormous increase in population, due to low death rate (mortality) and high birth rate (Natality) is termed as population explosion.

5. Differentiate between HIV and AIDS

HIV	AIDS
Human Immuno deficiency Virus	Acquired Immune Deficiency Syndrome
It is a virus	It is a disease

6. What are the reasons behind the increased population growth in the less developed nations compared with developed nations?

The rapid population growth is due to decrease in death rate and increase in birth rate.

The availability of antibiotics, immunization, increased food production, clean water and air decreases the famine- related deaths and infant mortality. In agricultural based countries, children are required to help parents in the fields that is why population increases in the developing countries.

7. Define population equilibrium.

A state of balance between birth rate and death rate in a population is known as population equilibrium.

8. What are the major precautions to avoid AIDS?

Avoid indiscriminate sex and encourage the use of condoms and also avoid the use of shaving razors, needles and syringes.

Prevention of blood born HIV transmission.

Aids awareness programmes should be encouraged.

Counseling services should be provided.

9. What are the causes of population explosion? (Nov-Dec 2014) (Nov-Dec 2019)

Invention of modern medical facilities reduces the death rate (mortality) and increases the birth rate (Natality).

Increase of life expectancy.

10. What are the objectives / advantages of family welfare programme? (April-May2015)

Slowing down the population explosion by reducing the fertility.

Pressure on the environment due to over exploitation of natural resources is reduced.

11. Define immigration and emigration.

Immigration: It denotes the arrival of individuals from neighboring population.

Emigration: It denotes the dispersal of individuals from the original population to new areas.

12. What are the factors which do not influence transmission of HIV?

Tears, food and air, cough, handshake, mosquito, flies, insect bites, urine, saliva during normal kissing, sharing of utensils, cloths, toilet, bathroom, etc.

13. How does HIV functions in human body?

White blood cells (WBC) responsible in the formation of antibodies are called T helper cells. T helper cells are the key infection fighters in the immune system. The HIV enter into the human body and destroys the T cells, as a result of which various types of infection diseases occur.

14. Define population equilibrium.

A state of balance between birth rate and death rate in a population is known as population equilibrium.

15. State the role of information technology in environment.

Information technology plays a vital role in the field of environmental education. Information technology means collection, processing storage and dissemination of information. A number of software has been developed to study about the environment.

16. Mention some ill effects of HIV/AIDS.

Large number of deaths occur which affect environment and natural resources.

Due to large number of deaths there is loss of labour and level of production decreases

More water is required for maintaining hygiene in AIDS affected locality.

The people affected by HIV cannot perform work well due to lack of energy.

17. What is meant by NIMBY syndrome?

NIMBY means Not In My Back Yard, which describes the opposition of residents to the nearby location of something they consider undesirable, even if it is clearly a benefit for many.

18. Define population density. (Apl-May2019)

It is expressed as the number of individuals of the population per unit area (or) unit volume.

19. Define population equation.

$$P_{t+1} = P_t + (B-D) + (I-E)$$

Where, P_t and P_{t+1} = sizes of population in an area at two different points in time t and $t+1$

B = birth rate, D = death rate, I = immigration and E = emigration

20. Write the objectives/importance of value education. (Nov-Dec 2014) (Nov-Dec 2019)

To improve the integral growth of human beings.

To create attitudes and improvement towards sustainable lifestyle.

To increase awareness about our national history, our cultural heritage, constitutional rights,

To create and develop awareness about the values and their significance and role.

21. What are human rights?

Human rights are the fundamental rights, which are possessed by all human beings, irrespective of their caste, nationality, sex and language.

22. Name any two schemes of human health program initiated by Indian Government on effects of population growth.

National Vector borne Disease Control Program

National Iodine Deficiency Disorders Control Program

National Cancer Control Program

National Aids Control Program

23. What is meant by human demography?

The study of statistics on human populations including elements such as growth rate, age and sex ratios, distribution, density and their effects on socioeconomic and environmental conditions.

24. What are the reasons for declining Birth rate?

The non-availability of anti-biotic, immunization, decreased food production, clean water and air.

25. Why is variation important within a population?

In order to improve the economic status of the people and decrease of population growth, the variation is important within a population. Generally the following variation must be present within a population.

Pre-productive population (0-14 Years)
Re-productive population (15-44 years)
Post reproductive population (Above 45 years)

26. What are the various schemes of various organizations towards women welfare?

The National Network for Women and Mining
United Nations Decade for Women
International Convention on the Elimination of All forms of Discrimination against women.
NGO's as Mahila Mandals.
Ministry for Women and Child development.

27. State the human right to food and environment.

All human beings have the right to get sufficient healthy food, safe drinking water and healthy environment.

28. Mention about the applications of remote sensing in forestry.

Sustainable forest management requires reliable information on the type, density and extent of forest cover, wood volume and biomass, forest fire, pest and disease induced losses, encroachment etc., remote sensing provides all such information clearly.

29. What is NEDS?

NEDS is National Emission Data System and is developed by the Environmental Protection Agency of USA. This NEDS works for coding, storage, retrieval and analysis of nationwide air emission data.

30. Give some Examples for Bell shaped variation of population.

France, UK, USA, Canada, etc..

31. What is meant by remote sensing? (May/June-2013)

It is used more commonly to denote identification of earth features by directing the characteristics electromagnetic radiation that is reflected/emitted by the earth.

32. What is value education? (Nov/Dec-2013) (May/June-2014) (April-May 2017) (Nov-Dec 2019)

It is an instrument used to analyze our behavior and provide proper direction. It teaches well the distinction between right and wrong, to be helpful loving, generous and tolerant.

33. Write the reason for child labour. (May/June-2014)

Poverty

Want of money

34. What are the objectives and benefits of environmental impact assessment (EIA)? (May/June-2014) (Nov-Dec 2016) (Nov- Dec 2017) (Nov- Dec 2018)

EIA is defined as a formal process of predicting the environmental consequences of any developmental projects.

Objectives of EIA

To identify who is the party

To identify why problems arise.

Benefits of EIA

To maintain the biodiversity.

To save money and time.

35. What are the sources of HIV infection? (Nov-Dec 2014)

HIV from infected person can pass to normal person through blood contact.

Using needles or syringes, contaminated with small quantities of blood from infected person.

36. State the role of information technology in environmental. (Nov-Dec 2015)

It means data collection, processing, reporting and dissemination of the environment.

37. Mention any two family welfare programs adopted in India. (May - June 2016)

National population policy

National health policy

38. What are the objectives of women welfare systems? (Nov-Dec 2016)

- To improve employment opportunities.
- To provide educations.
- To generate awareness about the environment.
- To restore dignity and status.

39. What is mitigation? (Nov-Dec 2017)

The implementation of measures designed to reduce the undesirable effects of a proposed action on the environment

40. What is child abuse? (Nov-Dec 2017)

Child abuse is when a parent or caregiver, whether through action or failing to act, causes injury, death, emotional harm or risk of serious harm to a child. There are many forms of child maltreatment, including neglect, physical abuse, sexual abuse, exploitation and emotional abuse.

41. Define GIS remote sensing. (April-May2018) (Apl-May2019)

GIS applications enable the storage, management, and analysis of large quantities of spatially distributed data. These data are associated with their respective geographic features. For example, water quality data would be associated with a sampling site, represented by a point. Data on crop yields might be associated with fields or experimental plots, represented on a map by polygons.

42. Name some test available to find HIV infection. (April-May2018)

- ELISA test (**Enzyme-Linked Immuno Sorbent Assay**)
- Western blot test

43. Mention any two welfare programs for children adopted in India. (April-May2017)

- ✓ Mid-Day meal scheme
- ✓ Integrated child development services
- ✓ Pulse polio immunization programme.

44. What is human development index?

The Human Development Index is a result of measure of a country's overall achievement in its social and economic dimensions. The social and economic dimensions of a country are based on the health, level of education attainment and standard of living.

UNIT-V

PART-B

- 1. Discuss briefly on the reasons and effects of the population explosion. (Nov-Dec 2013) (Nov-Dec 2015) (Nov-Dec 2016)**
- 2. What are the modes of transmission of HIV how it can be prevented? (Nov/ 2013) (Apr-May 2017) (Nov-Dec 2015) (OR) Write a note on AIDS in developing countries. (May-June 2013) (May-June 2014) (Nov-Dec 2013) (Apr-May 2015) (May - June 2016) (Apr-May 2017)/ How to give value education on HIV/AIDS? Explain. (Apr-May 2018) (Apr-May 2018) (Nov-Dec 2018)**
- 3. Explain in detail about women welfare and child welfare. (Nov/Dec-2013) (May/June-2014) (Nov- Dec 2014) (Apr-May 2015) (Nov-Dec 2015) (May-June 2016) (Apr-May 2018) (Nov-Dec 2019)**
- 4. Write a note on the various methods of family planning. (Nov/Dec 2013) (May-Jun 2014)/ What are the family welfare programmes available? Explain. (Nov- Dec 2018) (Apr-May 2019)**
- 5. Define human rights and discuss the salient features of the universal declaration of human rights by UN? (Apr-May 2015) (Nov-Dec 2015)**
- 6. Write a short note on value education.(May-June 2013) (Nov-Dec 2014) (Apr-May 2015) (Nov-Dec 2015) (Nov-Dec 2016) (Nov-Dec 2019) (Apr-May 2019)**
- 7. Discuss the influence of environmental parameters on human health. (OR) Discuss the factors influencing human health under current environmental conditions. (Nov-Dec 2016) (Apr-May 2019)**
- 8. Explain the role of information technology in environment protection and ten role of IT in human health protection. (Nov/Dec-2013 and 2014) (Apr-May 2015) (Nov-Dec 2016) (Apr-May 2017) (Nov-Dec 2017) (Apl-May 2018) (Nov- Dec 2018) (Nov-Dec 2019)**
- 9. Write a neat diagram and explain the variation in population growth among various nations. (Or) What are sparsely populated areas? Give examples and reasons for poor population in those areas.(Nov- Dec 2013) (Nov-Dec 2014) (May-June 2016)**
- 10. Explain a note on EIA. (May - June 2016) (Apr-May 2017)**
- 11. Discuss the linkages among population explosion, development and environment. ((Nov-Dec 2017)**
- 12. Illustrate and explain the three population variation based on age structure in different nations. (Nov-Dec 2019)**
- 13. Explain the applications of remote sensing in environment management. (Nov-Dec 2019)**
- 14. Write short notes on various rights of human. (Apr-May 2019)**

PART-C

- 1. Explain about any two methods of biodegradation of pollutants. (Nov-Dec 2016)**
- 2. Mention a case study on Man – Wild life conflicts. (Nov-Dec 2016)**
- 3. Mention a case study on Productive use of biodiversity. (Nov-Dec 2016)**
- 4. Illustrate any two methods of harnessing alternative sources of energy. (Nov-Dec 2016)**
- 5. Describe in detail about any one pollution related case study. (Nov-Dec 2016)**
- 6. Enlist the rules of management and handling biomedical waste and analyse critically the problems associated with the implementation. (April-May 2017) (Nov-Dec 2017)**
- 7. Analysis the environmental effects of extracting and using mineral resources and write the remedies taken. (April-May 2017)**
- 8. India is a mega diversity nation. Explain in detail about this statement. Explain the in situ and ex situ conservation of biodiversity. (Nov-Dec 2017)**
- 9. Explain in detail and how will you calculate the rain water harvesting potential for your house? (April-May 2018)**
- 10. Compare physical and chemical, characteristics of Marian water with terrestrial water. (April-May 2018)**
- 11. Give a case study of any anthropogenic(Manmade) pollution disaster know to you and discuss the effect of these on environment(including the human population) in which they happen. (April-May 2018)**
- 12. Discuss the desirable changes in lifestyle that will help conserve the environment. (Nov- Dec 2018)**
- 13. Discuss mitigation and adaptation measures with regard to climate change. (Nov- Dec 2018)**

PART B
UNIT I
ENVIRONMENT, ECOSYSTEM AND BIODIVERSITY

1. Explain in detail about the Components of environment. (Nov/Dec 2019)

The ecosystem/environment consist of the following three components

1. Abiotic or non living components
2. Biotic or living components
3. Energy components

1. Abiotic or non living components

Non living components are called Abiotic components.

Example: Air, water, soil and minerals

Abiotic components are sub divided into three categories

- a. Atmosphere
- b. Lithosphere
- c. Hydrosphere

a. Atmosphere:

Structure

The air that covers the earth is known as atmosphere. It is 500 km from earth. It is essential for all living organisms. 78% N₂, 21% O₂ and 1% other gases.

Structure of atmosphere

Region	Altitude in Km	Temperature in °C	Chemical species
Troposphere	0 -18	15 to -56	N ₂ ,H ₂ O,CO ₂ ,O ₂
Stratosphere	18 – 50	-56 to -2	Ozone
Mesosphere	50 – 85	-2 to -92	NO ⁺ ,O ²⁺
Thermosphere	85 – 500	-92 to 1200	NO ⁺ ,O ⁺ ,O ²⁺

Troposphere (0 to 18 km)

75% atmospheric air contain moisture

Stratosphere (18 to 50 km)

- consists of large amount of O₃
- free from moisture and clouds
- prevents UV radiation from sun

Mesosphere (50 to 85 km)

- a. less ozone
- b. more nitrogen oxide

Thermosphere (or) Ionosphere (upto 500 kms)

- Temperature raises upto 1200°C
- Contains charged particles like O₂⁺,O⁺,NO⁺, etc.,

Exosphere: (upto 1600 kms)

- Temperature is high due to solar radiation.
- Only H₂ and He is present.

Function of atmosphere:

- It maintains heat balance on the earth by absorbing the IR radiations.
- Gases present in atmosphere are essential for sustaining life.

Oxygen – supports life
Carbon dioxide – essential for photosynthesis of plants
Nitrogen – essential nutrient for plant growth.

b. Lithosphere:

It consists of soil and rock components of earth.

Function:

- Home for human beings and wild life.
- Store house of minerals and organic matter.

c. Hydrosphere:

The aquatic envelope of the earth. It includes oceans, lakes, streams, river and water vapour.
In the hydrosphere 97% of water is not suitable for drinking and only 3% is fresh water.

Functions of hydrosphere:

- Drinking purpose
- Irrigation
- Power production
- Industries and transport

2. Biotic or living components

The living components of environment are called biotic components.

Example: Animals, plants and micro organisms

3. Energy components

The components flow across biotic and Abiotic components.

Example: Solar energy, geochemical energy

2. Discuss the Structure and functions of an Ecosystem: (Nov/Dec 2014) (May-June 2016) (Nov-Dec 2016)

Ecosystem

An ecosystem is defined as a natural functional ecological unit comprising of living organisms and their non-living environment that interact to form a stable self supporting system.

Eg: Pond, lake, desert, grassland, forest, etc.

Structure (or) Components of an Ecosystem:

An ecosystem has two major components.

I. Biotic (living) components

II. Abiotic (non-living) components.

I. Biotic components:

The living organisms in an ecosystem collectively form its community called biotic components

Examples:

Plants (producers), animals (consumers), and microorganisms (decomposers).

Members of biotic components of an ecosystem.(or)Classification biotic components:

There are three types

1. Producers (Plants)
2. Consumer (Animals)
3. Decomposers (Micro-organisms)

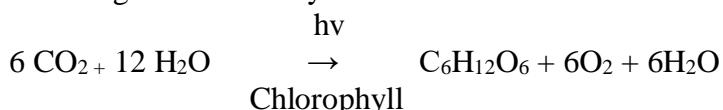
1. Producers (Autotrophs)

Producers synthesize their food themselves through photosynthesis.

Examples: All green plants, trees.

Photosynthesis

The green pigments called chlorophyll, present in the leaves of plants, converts CO₂ and H₂O in the presence of sunlight into carbohydrates.



This process is called photosynthesis.

2. Consumers (Heterotrophs)

Examples:

(i) Plant eating species

Insects, rabbit, goat, deer, cow, etc.,

(ii) Animals eating species

Fish, lion, tiger, etc

Consumers can not prepare their own food. They depend on the producers.

Classification of consumers

Consumers are further classified as

(i) Primary consumers (Herbivores) (Plant eaters)

They depend on the plants for their food.

Examples:

Insects, rat, goat, deer, cow, horse, etc

(ii) Secondary consumers (primary carnivores) (meat eaters)

They directly depend on primary consumers (Herbivores) for their food.

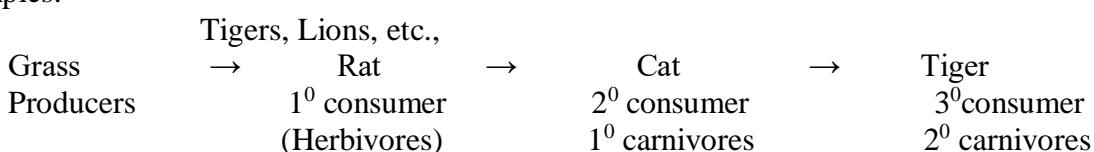
Examples:

Frog, cat, snakes, foxes, etc....

(iii) Tertiary consumers (Secondary carnivores) (meat eaters):

They directly depend on primary carnivores for their food.

Examples:



3. Decomposers

Examples:

Microorganisms like bacteria and fungi.

They attack the dead bodies of Producers and consumers and decompose them into simpler compounds. During the decomposition inorganic nutrients released. These inorganic nutrients together with other organic substances are then utilized by the producers for the synthesis of their own food.

II. Abiotic (non living) components

The non living components (physical and chemical) of an eco system called abiotic (non living) components.

Examples;

Climate, soil, water, air, energy, nutrients, etc.,

1. Physical components

They include the energy, climate, raw materials and living space that the biological community needs. They are useful for the growth and maintenance of its member.

Examples: Air, water, soil, sunlight, etc

2. Chemical components

They are the sources of essential nutrients.

Examples:

- (i) Organic substances : protein, lipids, carbohydrates, etc
- (ii) Inorganic substances: All micro (Al, Co, Zn, Cu) and macro elements (C,H,O,P,N,P,K) and few other elements.

Function of an Ecosystem:

The function of an eco system is to allow flow of energy and cycling of nutrients.

Types of functions

They are three types.

1. Primary function
2. Secondary function
3. Tertiary function

1. Primary function

It is manufacture of Starch (Photosynthesis)

2. Secondary function

It is distributing energy in the form of food to all consumers.

3. Tertiary function

All living systems die at particular stage. These dead systems are decomposed to initiate the third function of ecosystems namely “cycling”.

The functioning of an ecosystem may be understood by studying the following terms.

- (a) Energy and material flow
- (b) Food chains
- (c) Food webs
- (d) Food pyramids

3. Explain the energy flow in ecosystem in food chain and food web. (Nov-Dec 2013) (April-May 2018)

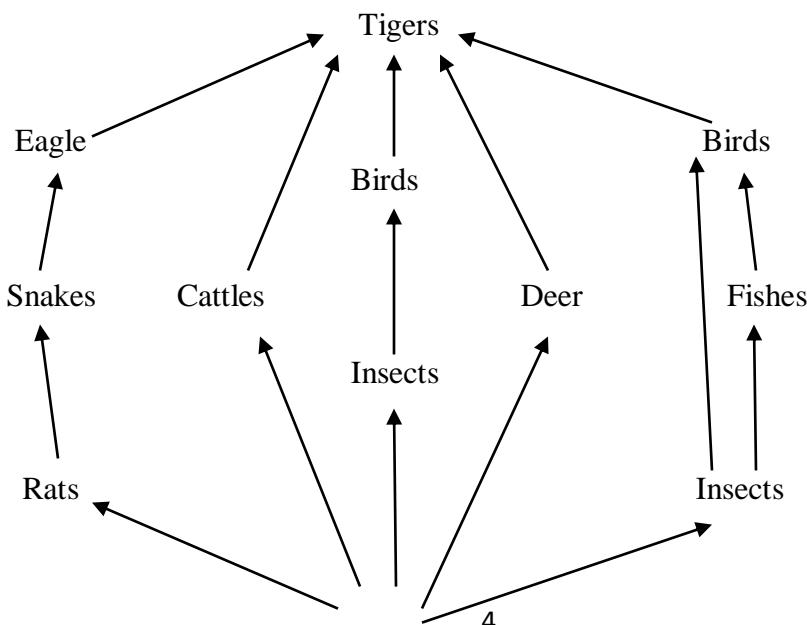
Food chain

This sequence of eating and being eaten in an eco system is known as food chain.

Grass	→	Rat	→	Cat	→	Tiger
Producers		1 ⁰ consumer		2 ⁰ consumer		3 ⁰ consumer
		(Herbivores)		(1 ⁰ carnivores)		(2 ⁰ carnivores)

Food web

The interlocking pattern of various food chains in an ecosystem is known as food web.



Grass

Energy flow in ecosystem

Energy is defined as the capacity to do work. The flow of energy from producer level to top consumer level is called energy flow.

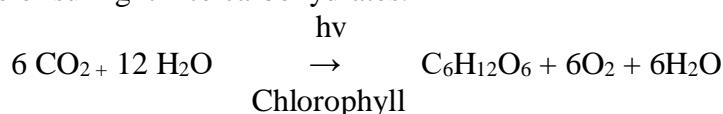
The flow of energy in an ecosystem is unidirectional. It flows from producer level to consumer level and never in the reverse direction.

The process of energy flow involves transfer of energy from autotrophy to various components of heterotrophy and help in maintaining bio diversity. The main source of energy in the ecosystem is sunlight. About 90% of energy is lost during flow of energy from one trophic level to the next one.

Sun → Producer → Herbivores → Carnivores → Top carnivores → Decomposers

Photosynthesis

The green pigments called chlorophyll, present in the leaves of plants, converts CO_2 and H_2O in the presence of sunlight into carbohydrates.



This process is called photosynthesis

1. Ist law of Thermodynamics:

It states that “energy can neither be created nor destroyed, but it can be converted from one form to another.”

Example:

Energy for an ecosystem comes from the sun. It is absorbed by plants, wherein it is converted into stored chemical energy.

i.e., Solar energy is converted into chemical energy.

2. IInd law of thermodynamics

It states that, “whenever energy is transferred, there is a loss of energy through the release of heat.”

Example:

This occurs when energy is transferred between trophic levels. There will be a loss of energy (about 80-90%) in the form of heat as it moves from one trophic level to another trophic level. The loss of energy takes place through respiration, running, hunting etc.

Respiration equation



4. Explain the types, characteristic features, structure and functions of Forest ecosystem. (Nov-Dec 2013) (Nov-Dec 2015) (Nov-Dec 2017) (Nov-Dec 2019)

Forest ecosystem

Definition: It is a natural ecosystem consisting of dense growth of trees and wild animals
40% forest area is in the world. 19% forest area is in India,

Types:

1. Tropical rain forests

They are found near equator.

Trees : Teak and sandal

Animals : Tiger and Lion

2. Tropical deciduous forests

They are found little away from near equator.

Trees : Maple and oak

Animals : Deer and fox

3. Tropical scrub forests

Dry climate for longer time.

Trees : Small deciduous trees and shrubs

Animals : Deer and fox

4. Temperate rain forests

They are found in temperate areas with adequate rain fall.

Trees : Pines and red wood

Animals : Fox, bear

5. Temperate deciduous forests

They are found in areas with moderate temperature.

Trees : Oak, hickory

Animals : Deer, fox

Characteristics:

Warm temperature

Adequate rain fall

Protects biodiversity

Soil is rich in organic matter

Structure and function

Abiotic components:

Soil, sun light, temperature etc

Biotic components :

Producer : trees and shrubs

Consumer : Primary consumer – elephants, deer etc.

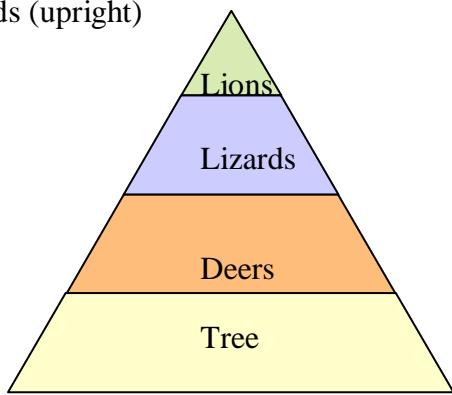
Secondary consumer – snakes, birds, lizards etc

Tertiary consumer – lions, tigers etc

Decomposers : fungi, bacteria

Functional components:

Ecological pyramids (upright)



5. Explain the types, characteristic features, structure and functions of grassland ecosystem (Nov-Dec 2014) (Nov/Dec 2015) (April-May 2017) (Nov-Dec 2017) (April-May2018) (April-May2019) (Nov-Dec 2019)

Grassland ecosystem:

Grassland occupies 20% of earth's surface.

Some trees and shrubs are also present in grassland.
Limited grazing helps to improve net primary production.
But overgrazing leads to desertification.

Types – depending on the climate

1. Tropical grass lands
Found near the borders of tropical rain forests.
Eg. Savannas in Africa.
Animals – Zebra, giraffes etc.
2. Temperate grasslands
Flat and gentle slopes of hills.
Very cold winter and very hot summer
3. Polar grasslands
Found in arctic polar region
Organism – arctic wolf, fox, etc.

Characteristics:

Plain land occupied by grasses,
Soil is very rich in nutrients,
Ideal place for grazing,
Low or uneven rain fall.

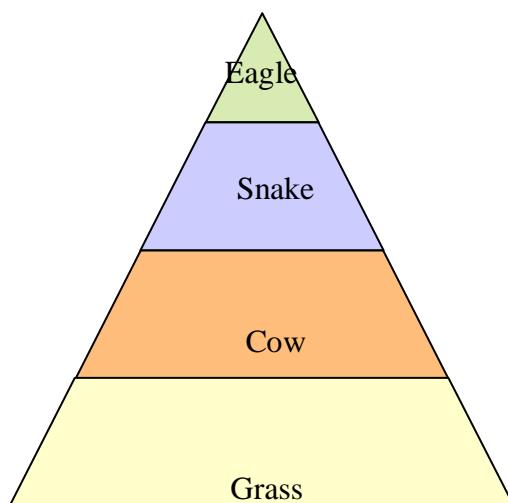
Structure and function:

Abiotic: soil pH, nutrients, soil moisture, temp, climatic conditions,

Biotic:

Producer : Grass and shrubs
Consumer : Primary – Cows, Buffaloes, deer, sheep.
Secondary – snakes, birds, lizards etc
Tertiary – Hawks, Eagles etc
Decomposers: fungi, bacteria

Functional components: Ecological pyramid



6. What is Biodiversity? Discuss the unique advantages of bio-diversity. (Nov-Dec 2018)

/What are the classifications (or) levels of biodiversity?

Biodiversity

It is the sum of total of various types of microbes, plants and animals (producers, consumers and decomposers) in a system.

Classification (or) levels of biodiversity

The concept of biodiversity may be analyzed in 3 different levels. They are

1. Genetic diversity
2. Species diversity
3. Ecosystem diversity

1. Genetic diversity

It is the diversity within species. Variation of genes within the species.

Genes are the basic units of hereditary information transmitted from one generation to another.

Examples:

- a. Rice varieties:

All rice varieties belong to species "Oryziasativa". But there are 1000 of rice varieties, which show variation at genetic level differ in their size, shape, color and nutrient content.

- b. Teak wood varieties

There are number of teak wood varieties found available.

Eg: Indian teak, Burma teak

2. Species diversity

It is the diversity between different species. The sum of varieties of all the living organisms at the species level is known as species diversity.

Examples:

Total number of living species in the earth are about more than 20 million. But, of which only about 1.5 million living organisms have been identified.

- a. Plant species: Apple, mango, grapes etc
- b. Animal species: Lion, Tiger, elephant, deer etc

3. Ecosystem diversity

The diversity at the ecological or habitat level is known as ecosystem diversity. A large region with different ecosystems can be considered as ecosystem diversity.
Example: River eco system

The river which includes the fish, aquatic insects, mussels and variety of lands that have adopted. It explains the interaction between living organism and physical environment in an ecosystem.

7. Explain the values of biodiversity (May-June 2013) (Nov-Dec 2014) (April-May2018)

Biodiversity is must for the stability and proper functioning of the biosphere.

Types of values/uni of biodiversity

They are classified as follows.

1. Consumptive use value

2. Productive use values
3. Social values
4. Ethical values
5. Aesthetic value
6. Option values

1. Consumptive use value:

Biodiversity products are harvested and consumed directly.

Eg: Food, Drug, fuel

Food

Many wild plants and animals are consumed by human beings.
90% food crops are obtained from tropical wild plants

Eg

Codonopsis in Himalayan region.
Molluscs, spiders and wild herbivores are consumed by tribals

Drugs and medicine

70% modern medicines are derived from plant and plant extracts.
20000 plant species are believed to be used medicinally in Unani, Ayurveda, Siddha.

Eg

- For natural medicinal products
- Penicillin – fungus is the source – Antibiotic
 - Quinine – chincona bark - Malaria treatment
 - Morphine – poppy bark – Analgesic

Twenty years before, once the drugs were not introduced, childhood leukemia was fatal. Now the remission rate for childhood leukemia is 99%.

Fuel

Fire woods are used by villagers and tribals.
Coal, petroleum and natural gas are also the products of fossilized biodiversity.

2. Productive use values

Biodiversity products have obtained a commercial value.
These products are marketed and sold.
These products may be derived from the animals and plants.

Animal products

Silk (Silk-worm), Wool (Sheep), Musk (Musk deer), Tusk (Elephants)

Plant product

Wood (Paper and pulp industry), Cotton (textile industry), Fruits and vegetables (Food industry)

3. Social values

These values are associated with the social life, religion and spiritual aspects of the people.

Examples:

- i) Holy plants : Tulsi, lotus...
- ii) Holy animals : Cow, snake, rat, peacock, etc.

4. Ethical values

It involves ethical issues like “all life must be preserved”.

In India, biodiversity is considered to have great value on religious and cultural basis. Our rich heritage teaches us to worship plants, animals, rivers, mountains.

Eg

The river Ganga-Holy river
Vembu, Tulsi, Vengai are worshipped by the Tamilians

5. Aesthetic values

The beautiful nature of plants and animals insist us to protect biodiversity. The most important aesthetic value of biodiversity is eco-tourism.

Eg

Eco tourism

People from far place spent a lot of time and money to visit the beautiful areas, where they can enjoy the aesthetic value of biodiversity. This type of tourism is known as eco-tourism.

6. Optional values:

The optional values are the potentials of biodiversity that are presently unknown and need to be known.

Eg

Searching a species for causing the diseases of cancer and AIDS

8. Explain In-situ and Ex-situ conservation of biodiversity. (or) What are the measures recommended for conservation of biodiversity? (May - June 2016) (Nov-Dec 2016) (April-May 2018) (Nov-Dec 2019)

Conservation of biodiversity

There are two types of biodiversity conservation

1. In-situ or on-site conversion (within habitat)
2. Ex-situ conservation (outside habitat)

1. In-situ conservation:

- Conservation of species in its natural habitat, in place where the species normally occurs
- The strategy involves establishing small or large protected areas, called protected areas
- Today in world, there are 9800 protected areas and 1500 national parks

Methods:

1. Nature or biosphere reserves

Biosphere reserves cover large area, more than 5000 sq.km. It is used to protect species for long time.

Role of biosphere reserves

- It gives long term survival of evolving ecosystems.
- It protects endangered species.
- It protects maximum number of species and communities.
- It serves as site of recreation and tourism.
- It is also useful for educational and research purposes.
- It remains and functions as an open system and changes in land use are not allowed.

Restriction

No tourism and explosive activities are permitted.

(Eg) Nilgiri Bio reserve-Tamil nadu

Gulf of Mannar -Tamil nadu

2. National parks

It is an area dedicated for the conservation of wildlife along with its environment. It is a small reserve covering an area of about 100-500 sq.km. Within the biosphere reserves, one or more

national parks are also exists.

(Eg) Gir national park-Gujarat-Indian Lion
Kaziranga-Assam-One horned Rhino

Role of National park

- It is used for enjoyment through tourism, without affecting the environment.
- It is used to protect, propagate and develop the wildlife.

Restriction

- Grazing of domestic animals inside the national park is prohibited.
- All private rights and forestry activities are prohibited within a national park.

3. Wild life sanctuaries

It is an area, which is reserved for the conservation of animals only. At present, there are 492 wildlife sanctuaries in India.

(Eg) Mudumalai wildlife sanctuaries-Tamil nadu-Tiger, Elephant
Vedanthangal bird sanctuary-Tamil nadu-Water birds

Role of Wild life sanctuaries

- It protects animals only.
- It allows the operations such as harvesting of timber, collection of forest products and forestry operations provided it does not affect the animals adversely.

Restriction

Killing, hunting, shooting of wild animals is prohibited.

4. Gene Sanctuary

It is an area, where the plants are conserved.

Ex:

In Northern India, two gene sanctuaries are found.

- One gene sanctuary for Citrus and
- One gene sanctuary for Pitcher plant (insect eating plant).

Advantages

- It is very cheap and convenient method.
- The species gets adjusted to the natural disasters.

Disadvantages

- A large surface area of the earth is required
- Maintenance of the habitats is not proper due to shortage of staff and pollution.

5. Other projects for conservation of animals

For the conservation of certain animals, some special projects are framed in our country.

Eg:

Project Tiger, project elephant

2. Ex- situ conservation:

- It involves maintenance of plants and animals outside the natural habitat
- **Methods:**
 1. Long term captive breeding
 2. Shortage term propagation and release
 3. Animal translocation and re introductions
 4. Seed bank
 5. Reproductive technology

- (i) Embryo transfer technology
- (ii) Cloning.

National Bureau of Plant Genetic Resources (NBPGR)

It is located in Delhi. It uses cryo preservation techniques to preserve agricultural and horticultural crops.

National Bureau of Animal Genetic Resources (NBAGR)

It is located in Karnal, Haryana. It preserves the semen of domesticated bovine animals.

National Facility for Plant Tissue Culture Repository (NEPTCR)

It develops the Facility of varieties of crop plants of trees by tissue culture. This facility has been created within the NEPTCR.

Advantages

- Survival of endangered species is increasing due to special care and attention.
- In captive breeding, animals are assured food, water, shelter and also security and hence longer life span.
- It is carried out in cases of endangered species, which do not have any chance of survival, in the world.

Disadvantages

- It is expensive method.
- The freedom of wildlife is lost.
- The animals cannot survive in natural environment.
- It can be adopted only for few selected species

9. "India is a mega biodiversity nation" - Explain. (May-June 2013) (Nov-Dec 2016) (April-May 2017)

Mega diversity

There are nearly 170 countries in the world and 12 of them contain 70% of our planet's biodiversity.

Mega diversity regions

The following 12 countries Australia, Brazil, China, Colombia, Ecuador, the United States, India, Indonesia, Madagascar, Mexico, Peru and Democratic Republic of the Congo regions are known as mega diversity regions. These countries have the world's selected few rich floral land and faunal zones.

India as a mega diversity nation

India is one among the 12 mega diversity countries in the world. It has 89450 animal species accounting for 7.31% of the global faunal species and 47000 plant species which accounts for 10.8% of the world floral species. The loss of biodiversity or endemism is about 33%.

Distribution of species in some groups of flora and fauna in India.

Group wise species distribution			
Plants	Number	Animals	Number
Fungi	23000	Mollusca	5042
Bacteria	850	Lower groups	9979
Algae	2500	Anthropoda	57525
Bryophytes	2564	Amphibian	2546

Gymnosperms	64	Birds	1228
Pteridophytes	1022	Reptiles	428
Angiosperms	15000	Mammals	372

Endemism

The species which are confined to a particular area are called endemic species. Our country has a rich endemic flora and fauna. About 33% of the flowering plants, 53% of fresh water fishes, 60% amphibians, 36% reptiles and 10% mammalian are endemic species.

Plant diversity

Nearly 5000 flowering plants and 166 crops plant species have their origin in India.

Marine diversity

More than 340 coral species of the world are found here. Several species of mangrove plants and sea grasses are also found in our country.

Agro-diversity

There are 167 crop species and wild relatives. India is considered to be the centre of origin of 30,000 to 50,000 varieties of rice, mango, turmeric, ginger etc.

Animal biodiversity

There are 75,000 animal species including 5,000 insect. India is a home to about nearly 2,00,000 living organism.

RED DATA BOOK

It is a catalogue of text facing risk of extinction.

Red list is to

- Provide awareness to the degree of threat to biodiversity.
- Provide global index on already decline of biodiversity.
- Identification of species at high risk of extinction.
- Help in conservation action.
- Information about international agreements.

India's biodiversity is threatened due to habitat destruction, degradation, fragmentation and over exploitation of resources.

According to RED DATA book 44 plant species are critically endangered, 54 endangered and 143 are vulnerable.

India's rank 2nd in terms of the number of threatened mammals and 6th rank among the countries with the most threatened birds.

10. What are the major threats to biodiversity? (Nov-Dec 2013) (May-June 2016) (Nov-Dec 2017) (April-May 2018) Discuss the man-wildlife conflict in India with cases from recent incidents. (Nov- Dec 2018) (Nov-Dec 2019)

Threats to biodiversity:

Habitat loss

- Deforestation activities (cutting trees for timber, removal of medicinal plants)
- Production of hybrid seeds requires wild plants as raw material, farmers prefer hybrid reeds, many plant species become extinct
- Increase in the production of pharmaceutical companies made several number of medicinal plants and species on the verge of extinction.
- Removal of forest-cover for road laying and also due to soil erosion

- Illegal trade of wild life
- Population explosion, construction of dam, discharge of industrial effluents use of pesticides.

Poaching of wild life

1. Subsistence poaching: Killing animals to provide enough food
2. Commercial poaching: Hunting and killing animals to sell their product

Factors influencing poaching

1. Human population
2. Commercial activities

Due to poaching, illegal wild life smuggling because of huge profit

Eg.

1. Rhinoceros – for horns,
2. Bengal tigers-Its fur sell is more than \$1,00,000 in the foreign market.
3. Sea Horse, Star turtle – sold to foreign market.
4. Baleen- To prepare combs
5. Blubber- to prepare lamp oils and lubricating oils
6. Elephant – for ivory,
7. Elephant feet- to make ash tray

Man-wild life conflicts:

Man wildlife conflicts arise when wildlife starts causing immense damage and danger to the man. Under such condition it is very difficult for the forest department to compromise the affected villagers and to gain the villagers support for wild life conservation

Eg

1. In Sambalpur Orissa 195 humans were killed.
2. Very recently two men were killed by leopards in powai,Mumbai
3. 14 persons were killed by the leopards in Sanjay Gandhi National Park, Mumbai.

Factors influencing(or causes) Man-wild life conflicts:

1. Shrinking of forest
2. Human encroachment into forest
3. Often villagers put electric wiring around cropland
4. Due to lack of water and food in forest areas, wild animals move out of forest

Remedial activity:

1. Adequate crop and cattle compensation schemes
2. Cropping pattern should be changed near the forest
3. Adequate water and food should be made available within forest
4. The development and construction work around forest should be stopped.

11. What is the importance of protecting the biodiversity of earth?

- (i) Biodiversity is very important for human life because we depend on plants, micro organisms, medicine nad industrial products
- (ii) Biodiversity protects the fresh air clean water and productive land
- (iii)It is also important for forestry, fisheries and agriculture
- (iv)It provides immediate benefits to the society such as recreation and tourism
- (v) Drugs, herbs, food and other important raw materials can be derived from plants and animals
- (vi)It also preserves the genetic diversity of plants and animals
- (vii) Ensures the sustainable utilization life supporting systems on earth
- (viii) It leads to conservation of essential ecological diversity and life supporting systems

- (ix) The biodiversity loss results in ecological and environmental deterioration, it is essential to conserve the biodiversity.

UNIT II

ENVIRONMENTAL POLLUTION

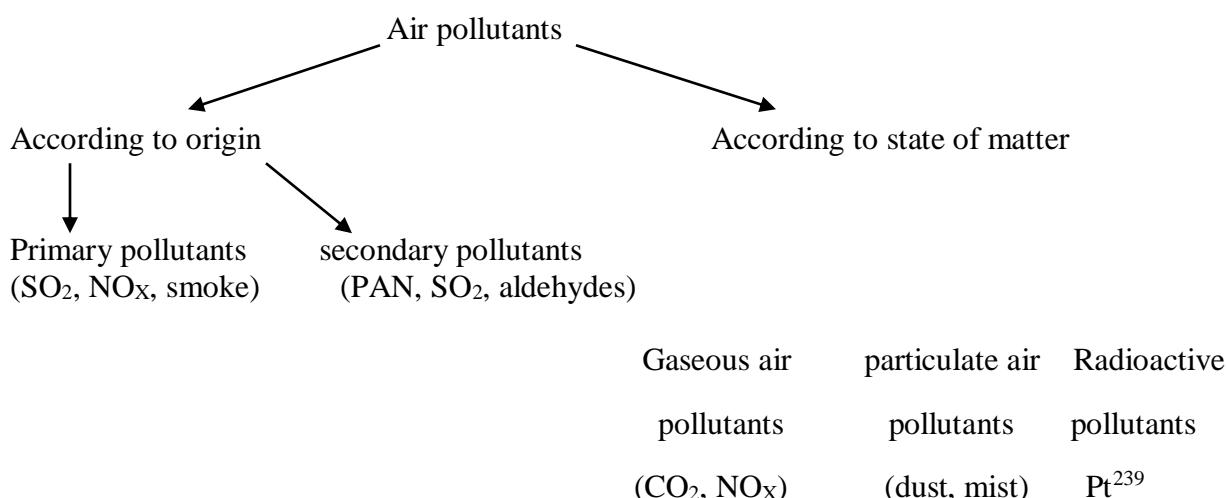
1. Mention the sources and effects and control measures of various air pollutants. (May-June 2013) (Nov/Dec 2014) (April-May 2015) (Nov-Dec 2015) (May - June 2016) (OR) What are the causes and control measures of Air pollution? (Nov- Dec 2018)

Air pollution

Definition

Air pollution is defined as the presence of one (or) more contaminants like dust, smoke, mist and odour in the atmosphere which causes damage to plants, animals and human beings.

Classification of air pollutants:



Sources of air pollution

Natural sources

1. Volcanic eruption
2. Forest fires
3. Biological decay
4. Sea salt spray
5. Pollen grains of flowers

Man made sources (anthropogenic)

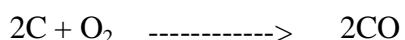
- thermal power plants (fly ash, SO₂)
- industrial units
- vehicle emission-
- fossil fuel burning
- Agricultural activities
- Metallurgical plants (SO₂, CO₂)
- Fertilizer plants, Textile mills,
- Refineries, Paper and pulp mills

Common air pollutants:

[i] Gaseous air pollutants:

1. Oxides of carbon CO

It is formed by the incomplete combustion of carbon containing fuels.



Sources

Cigarette smoking, burning fossil fuels. 77% CO comes from motor vehicle exhaust.

CO₂

Smoke from burnt fuels (coal, petroleum etc)

2. Oxides of nitrogen

NO, NO₂, NO₃, N₂O₅, N₂O₃, N₂O₄, N₂O

NO and NO₂ are important air pollutants

Sources

It is formed by the combustion of fossil fuels in automobiles, nitric acid manufacturing industries, fertilizer industries etc



3. Oxides of sulphur SO₂

It is formed mostly by the combustion of sulphur containing fossil fuels like coal and oil.



4. Particulates (SPM)

Suspended droplets, solid particles (sizes 0.1μ to 100μ)

5. Ozone (O₃)

It is highly reactive irritating gas with an unpleasant odour that forms in the troposphere. It is major component of photochemical smog.

Human source:

Chemical reactions with volatile organic compounds and nitrogen oxides.

Environmental effects:

Moderates the climate

6. Hydrocarbons:

Lower HC get accumulated due to

CH₄, C₂H₂, C₂H₄ causes air pollution from natural & forest fires, car engines etc.

7. Chlorofluorocarbon:

- As a coolant in refrigerator etc
- As a propellant in cleaning solvents etc.

8. Photochemical smog:

Photochemical smog is a mixture of more than 100 primary and secondary pollutants formed under the influence of sunlight. Its formation begins inside automobile engines and the boilers in coal burning power and industrial plants.

Effects:

1. CO&CO₂, NO_x, SO_x causes respiratory disorder, headache, visual difficulty, suffocation, Trigger heart attacks.
2. CO reacts with hemoglobin and reduces the ability of to carry O₂ to body cells and tissues, which causes headaches and anemia. CO has 210 times affinity more than oxygen for hemoglobin.
3. CO₂ raises temperature of sea level and contribute 55% global warming
4. NO_x, SO_x, H₂S, causes cardiac, respiratory diseases attack building materials, eye

irritation, chlorosis, necrosis in plants.



Acid rain

Methods of control of air pollution.

Control methods

I Source control

II Using equipments

I. Source control

1. Using non conventional energy
2. Using bio filters
3. Planting more trees because they remove particulates and CO and absorb noise.
4. Reducing vehicle exhausts
5. Using only unleaded petrol
6. Using mass transport
7. Use fuels that have low sulphurs and ash containing.

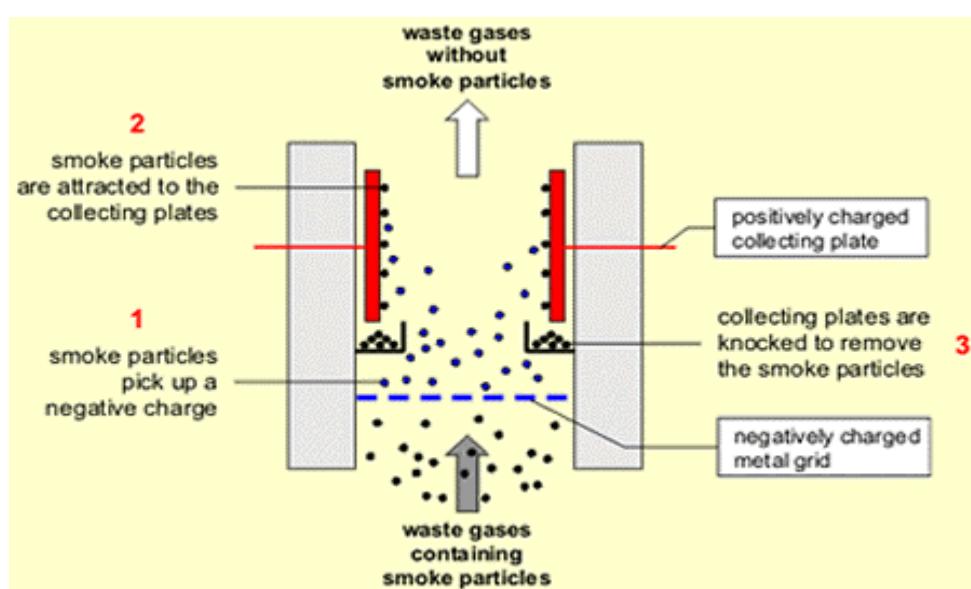
II. Using equipments:

Electrostatic precipitator

Principle

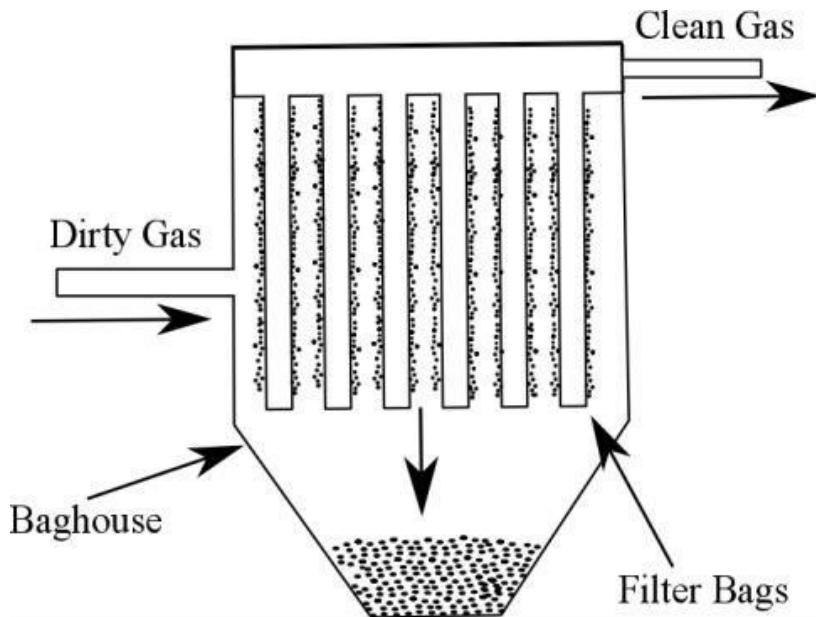
Electrically charged particles in the pollution are separated from the gas stream under the influence of the electrical field.

Removes 98% of the particles



Bag house filter (fabric filter)

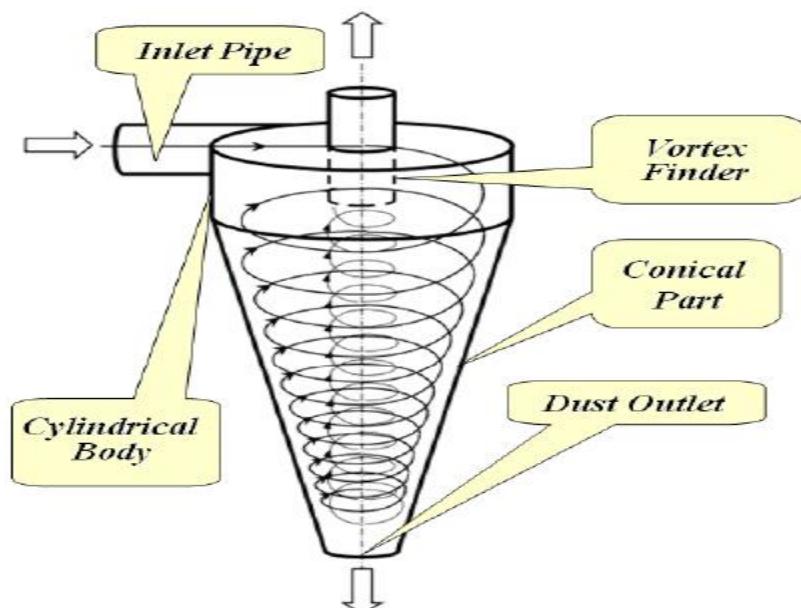
A stream of the polluted gas is passed through a fabric that filter pollutants and allow clean gas to pass through.



Cyclone collector

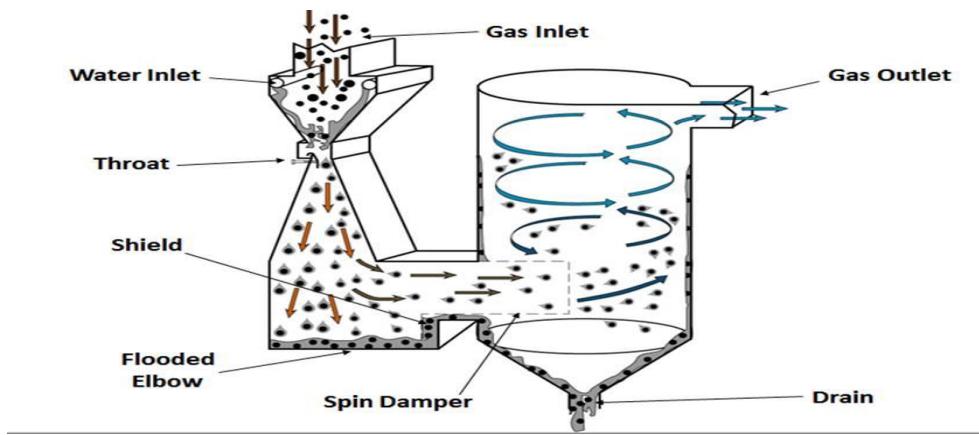
Gas containing particulate is allowed to flow into a light-circular spiral filtered.

The centrifugal forces disperse particulate towards the walls of the chamber, which settling down due to gravity.



Wet scrubber

Particulates, vapour and gases are removed by passing the polluted gas through a liquid solution.



Mainly used on coal burning power plants. Green belt Plants absorbs CO_2 , H_2S and HNO_3

Planting trees in a series around the industry and along the road to absorb air pollution and noise by 10% Slow down air movements and help in deposition of particulates.

2. Discuss in detail about chemical and photochemical reactions in the atmosphere. (Nov-Dec 2014) (May - June 2016) (April-May 2017)

Formation of smog

Smog is a mixture of smoke and fog in suspended droplet form. The brownish smoke like appearance that frequently forms on clear, sunny days over large cities with significant amounts of automobile traffic.

Types of Smog

There are two types of smog.

1. London smog
2. Los Angles smog (or) Photochemical smog.

1. London smog

- ✓ It is a coal smoke and smog. It is the mixture of $\text{SO}_2 + \text{SO}_3 + \text{Humidity}$.
- ✓ It is bad in morning hours and worse after sun rise. It is due to sunlight induced oxidation of $\text{SO}_2 + \text{SO}_3$, followed by reaction with humidity giving H_2SO_4 .

2. Los Angles Smog (or) Photochemical smog

It is not related to smoke or fog. It is formed by the combination of NO , NO_2 , CO_2 , H_2O , CO , SO_2 and unburnt HC particles. The important reaction is dissociation of NO_2 in sunlight.

These oxidized HC with ozone in the presence of humidity causes photochemical smog.

Health effects of smog

- ✓ Causes irritation to eyes and lungs.
- ✓ Damage the plants.
- ✓ Irritates nose, throat, etc.
- ✓ It also causes bronchial irritation.

Environmental effects of smog

- ✓ Produces acid rain and damages plants, trees
- ✓ Smog can reduce visibility.

Remedial measures of smog

- ✓ By decreasing nitrogen oxides and HC level in the air.
- ✓ By using unleaded petrol in the automobiles.

PAN (peroxy acetyl nitrates) (Lachrymatory substance)

It is a secondary pollutant present in photochemical smog. It is a lachrymatory substance. It is thermally unstable and decomposes into peroxy ethanoyl radicals and nitrogen dioxide gas. It is an oxidant and more stable than ozone.

Health effect

At lower concentrations

It is a powerful respiratory and eye irritants, toxic in nature.

At higher concentrations

Cause extensive damage to vegetation, causing skin cancer.

Production of PAN

They are formed by the photochemical reaction between HC, nitrogen oxides and sun light. It occurs in 2 steps.

Step-I

Unburnt HC undergo oxidation to give aldehydes, ketones and dicarbonyl compounds, which creates peroxyacetyl radicals.

Step-II

Peroxyacetyl radicals combine with nitrogen dioxide to form peroxyacetyl nitrates.

Sources

- ✓ It comes from degradation of isoprene, HC and acylation.
- ✓ Blended gasoline with ethanol.

Environmental effects

- ✓ Damages plants and art.
- ✓ React explosively.
- ✓ Plays a very large role in photochemical smog.

3. Explain the mechanism of Ozone layer depletion. (Nov-Dec 2016) (April-May2018)

Ozone layer depletion (Nov-Dec 2019)

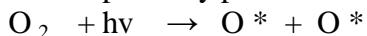
Between 10Km and 50Km presence of ozone layer in the atmosphere, which is above the sea level. The concentration of O_3 is 10ppm.

Importance:

- O_3 protects us from damaging UV radiation of the sun. It filters UV-B radiation.
- Now a days certain parts of O_3 layer is becoming thinner and O_3 holes are formed. Because of this more UV-B radiation reaches the earths surface.
- UV-B radiation affects DNA molecules, causes damages to the outer cell of plants and animals.
- It causes skin cancer and eye disease in human beings.

Formation of O_3

It is formed in the atmosphere by photochemical reaction



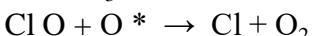
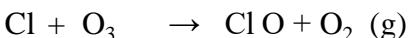
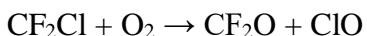
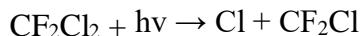
The atomic oxygen reacts with molecular O_2 to form O_3



Where M = third body like nitrogen.

Causes of O_3 layer depletion

Refrigerators, air conditioners, aerosol sprays and cleaning solvents release CFC s into the atmosphere. CFCs releases chlorine which breaks O_3 to O_2



Each chlorine atom is capable of breaking several O_3 molecules. It is a chain reaction.

- 1% loss of O_3 results in 2% increase in UV rays reaching the earth surface .
- Due to the continuous attack of chlorine free radical thinning of ozone layer which leads to the formation of ozone hole.

Ozone depletion chemicals

Chloro Flouro carbon(CFC)-Refrigerants, blowing agent ,

Hydro Chloro Fluoro Carbon(HCFC)- Refrigerants, blowing agent ,

Bromo Fluro Carbon(BFC)-Fiore extinguishers.

Some times atmospheric sulphur dioxide is converted in to H_2SO_4 which increases the rate of O_3 layer depletion.

Effects ozone layer depletion:

Effects on human beings

1. UV rays causes skin cancer.
2. Increases the rate of non melanin skin cancer in fair colored people.
3. Prolonged expose to UV rays leads to actiniakatatities (slow blindness) and cataracts.

Effects on aquatic system :

1. UV rays affects phytoplankton , fish , larval crabs.
2. phytoplankton consumes large amounts of CO_2 .Decrease in phytoplankton results in more amount of CO_2 in atmosphere. This contributes to global warming
3. Ozone depleting chemicals can causes global warming.

Effects on agriculture

Yield of vital crops rice, corn etc will decrease.

Effects on materials

Degradation of paints, plastics and other polymer materials will result in economic loss.

Effects on climate

The earth's temperature will increase.

Control measures:

- Manufacturing and using of O_3 depleting chemicals should be stopped.
- Use of methyl bromide .which is a crop fumigant should be controlled.
- Replacing CFC s by other materials which are less damage.

4. What are the sources, effects and control measures of acid rain.

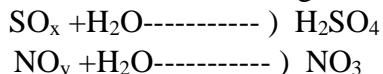
Acid rain

Normal rain water is always slightly acidic (pH 5-5.6) because of CO₂ present in the atmosphere gets dissolved in it. Because presence of SO₂ and NO₂ gases as pollutants in the atmosphere.

The pH of the rain is further lowered. This type of precipitation of water is called acid rain.

Formation

Acid rain means the presence of excessive acids in the rain water. The thermal power plants industry and vehicles release NO₂ and SO₂ into the atmosphere due to the burning of coal and oil. These gases react with water vapour in the atmosphere and form acids like HNO₃, H₂SO₄. These acids descend onto the earth as acid rain through rain water.



Acid deposition has two parts.

Wet deposition

Snow, sleet and mist are collectively known as wet deposition.

Dry deposition

Gases, dust and smog are collectively known as dry deposition.

Sources of acid rain

1. 70% is due to oxides of sulphur and 30% is due to oxides of nitrogen.
2. Burning of fuels etc.

Effects of acid rain

Effect on human being:

- Human nervous system respiratory system and digestive system are affected by acid rain.
- It causes premature death from heart and lung disorder like asthma, bronchitis.

Effect on building:

- At present Taj Mahal in Agra is suffering due to SO₂ and H₂SO₄ fumes from Madura refinery.
- Acid rain corrodes houses, monuments, statues, bridges and fences.
- Acid rain causes corrosion of metals.

Effect on Terrestrial Ecosystem.

- Reduce the rate of photosynthesis and growth in terrestrial vegetation.
- Acid rain retards the growth of crops like beans, potatoes, carrots, spinach.
- Beneficial organisms are killed ex earthworm
- It weakens the trees.

Effect on Terrestrial and lake Ecosystem

- Acid rain reduces fish population, black flies, mosquitoes, deer flies occurs largely which causes number of complications in Ponds, Rivers and lakes.
- Activity of bacteria and other microscopic animals is reduced in acidic water.
- The dead materials are not rapidly decomposed. Hence the nutrients like N, P are locked up in dead matter.
- Self purification of water body decreases.

Control of acid rain:

- Emission of NO₂ and SO₂ from industries from power plants should be reduced by using pollution control equipments.
- Liming of lakes and soils should be done to correct the adverse effect of acid rain.
- In thermal points low sulphur content coal should be used. Replacement of coal by natural gas would reduce the problem.

5. Write in detail about green house effects and global warming. (April-May2018)

Global warming

Definition

The raise of earth's surface temperature due to intense green house effect is called global warming.

Causes:

The level of carbon dioxide in the atm has increased by 25%, the level of nitrous oxide by 19% and the level of methane by 100%.

Green house effect

Green house gases are CO₂, Methane .Nitrous oxide NO₂, CFC

Green house gases

CO₂

- 55% of green house gases from GHG and 76% from industries.
- Progressive warming up of a gas surface due to blanketing effect of manmade CO₂ atmosphere.

Chlorofluorocarbon

- Refrigerators, air conditioners, aerosol sprays and cleaning solvents release CFC s into the atmosphere.
- As expanders in the foam products.
- Atmospheric concentration of CFC is 0.00225ppm that is increasing at a rate of 0.5% unusally.

Methane

- Production and use of oil and natural gas.
- Incomplete combustion of organic material.

Nitrous oxide

- Combustion of biomass and nitrogen rich fuel.
- Break down of nitrogen fertilizers.
- Released from nylon products.

Effects of global warming

1. Sea level increases as result of melting and thermal expansion of ocean.
2. High CO₂ level in the atmosphere have a long term negative effect on crop production and forest growth.
3. Global rainfall pattern will change .Drought and floods will become more common. Raising temperature will increase domestic water demand.
4. Many plants and animal species will have a problem of adapting. Many will be at the risk of extinction, more towering verities will thrive.
5. As the earth becomes warmer the floods and drought becomes more frequent. There would be increase in water-borne diseases.

Measures to check global warming:

1. CO₂ emission can be cut by reducing the use of fossil fuel.
2. Plant more trees.
3. Shifting from coal to natural gas.
4. Stabilize population growth.
5. Remove efficiently CO₂ from smoke stocks.
6. Removal atmospheric CO₂ by utilizing photo synthetic algae.

6. Explain the causes, effects & control measures of Water pollution. (Nov-Dec 2013) (May/June 2013) (May-June 2014) (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (April-May 2018) (OR) Discuss the measures that should be taken to de-pollute our waterways (Nov-Dec 2018).

Definition

The alteration in physical, chemical & biological characteristics of water causes harmful effects on humans and aquatic life.

Point source

Ex: flow of water pollutants from sewerage system, industrial effluent etc.

Non-point source

Ex: agricultural land (pesticides, fertilizers, mining, construction sites)

Ground water pollution:

- It forms 6.2% of the total availability on the planet earth.
- It seems to less prone to pollution
- There are number of potential source of ground water.
- Arsenic, fluoride and nitrate are posing serious to health hazards

Surface water pollution

Sewage

Pouring the drain and sewage in fresh water bodies etc.

Industrial effluents

It contains toxic chemicals, acids, alkalis, cyanides, phenols etc and synthetic detergents which is used in washing and cleaning produce foam and pollute water.

Agrochemicals

Fertilizers, pesticides etc washed by run off.

Oil

Oil spillage into sea water during drilling and shipment pollute it.

Waste heat

It is emitted from industrial discharges increases the temperature of water bodies.

Common water pollutants and their effects:

sources	effects
1.Infectious agents [or] pathogens Sewage contains bacteria, viruses etc	Water borne diseases like cholera, dysentery, typhoid etc.
2.Oxygen demanding wastes Organic matter decomposed by aerobic bacteria in water.	Lowering DO level which is harmful to aquatic population.
3.Inorganic chemicals Plant nutrients [N&P] surface run off industrial and house hold runoff.	Fluorosis, blue baby syndrome, eutrophication.

4.Organic chemicals Run off from farms, industries etc[DDT]	Nervous damage and cancer to human health Biomagnifications.
5.Sediment Land erosion	Increase turbidity and reduce light penetration.
6.Radioactive materials From nuclear power plants, mining etc	Genetic mutations, birth defects and cancer.
7.Heat[thermal pollution] Cooling of water in nuclear power stations and industries etc.	Lower dissolved oxygen levels and affects the aquatic life,

Controlling of water pollution:

1. All domestic and municipal effluents be drained to water bodies only after treatment
2. Use of pesticides in agriculture should be limited. Only standard quality pesticides should be used.
3. Chemicals like potassium permanganate should be sprayed regularly to protect water from micro organisms.
4. Radio active substances can be removed by Ion-exchange method.
5. Plants, trees and forests control pollution and they act as natural air conditions.
6. Bacteria are killed by passing chlorine gas into water bodies.
7. Highly qualified and experienced persons should be consulted from time to time for effective control of water pollution.
8. Inorganic wastes can be treated chemically.
9. Acids and bases are removed by neutralization
10. Sewage is treated by biochemical oxidation. The chemicals retards the growth of plants and retard reproduction process.

7. What are the sources, effects & control measures of Marine pollution? (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (Nov-Dec 2016) (April-May2018) (Nov-Dec 2019)

Marine Pollution

The discharge of waste substances into the sea resulting in harm to the aquatic living beings, hazards to the human health hindrances to the fishery and impairment of quality use of sea water.

Sources:

1. Dumping the wastes:

Dumping of untreated wastes and sewages in the oceans by coastal towns, cities and industries. Rivers on the way to sea carry huge amount of sewage garbage agricultural discharge pesticide heavy metals. Huge quantity of plastic dumped in to the sea.

Effects:

Many marine birds ingest plastic that causes gastrointestinal disorders.

2. Oil:

This is discharged in to the sea as cracks of oil tankers, accidental spillage, warships. This causes devastation of marine environment.

Effects:

Oil spills inhibit photosynthesis and the growth of planktons. All aquatic animals depend either directly or indirectly on planktons the basis of trophic chain.

3. Radio active materials enter the ocean from nuclear weapon testing.

4. Toxics:

Toxic waste is the most harmful form of marine pollution. Once toxic wastes affects an organism it quickly passes along the food chain and as sea food which cause various problems.

5. Marine Debris:

Garbage like plastic bags, ropes helium balloons

Effects of marine pollution:

1. Heavy metals and organic pollutants damages birds by thinning of egg shells and tissue damage of egg.
2. Oil pollution causes damage to marine animals and plants including algae bird, fish etc.
3. Oil spilling in the sea causes abnormal low body temperature in birds resulting in hypothermia. During Exxon Valdez accident 150 rare species of bald eagles are affected by ingested oil.
4. Oil films are able to retard the rate of oxygen uptake by water.
5. Hydrocarbon and benzpyrene accumulate in food chain and consumption of fish by man may cause cancer.

Control of marine pollution:

Nature and world conservation union suggest the principles

1. The industrial unit on the coastal lines should be equipped with pollution control instrument.
2. Urban growth near the coast should be regulated. Methods of removal of oil

Physical methods.

- a) skimming the oil off the surface with suction device
- b) Floating oil can be absorbed using absorbing materials like ploy urethane foam. Chopped straw and saw dust also used to absorbed oil from the sea water.
- c) Chemical methods like dispersion , emulsification and using chemical additives are used to coagulated the oil

Protective method:

1. Municipal and industrial waste should be treated before disposing in to sea
2. Coastal waste are periodically analyzed for detecting pollution level
3. Soil erosion in the coastal land should be arrested be suitable techniques
4. Recreation beaches should be maintained to meet hygienic and aesthetic standard.

8. Briefly describe the sources effects and control of noise pollution. (Nov-Dec 2014) (Nov-Dec 2016) (April-May 2017)

It may be defined as unwanted sound which gets dumped into the atmosphere.

Causes:

Industrial noise

Most noise sources are compressors, generators power looms, grinding mills, furnaces. These are used in many industrial processes and installed partially in closed and open sheds.

Domestic noise

Transistors radio, TV, other musical instruments, Air conditioners, washing machines. They affect users as well as the neighbors.

Traffic noise

Continuous movement of vehicles causes traffic noise. It affects not only those who are moving but also those who live near the roads, railway links, and airports

Effects of noise pollution

1. Physiological effects

Headache increase in the rate of heart beat, pain in heart, emotional disturbances, hearing loss.

2. Annoyance

A noise is said to be annoying if the exposed individual or groups of individuals reduce the noise avoid or leave the noisy area if possible. Both loudness and annoyance increase with increasing sound levels.

3. Recently it has been reported that the blood also thickened by excessive noise

4. Impulsive noise also causes psychological and pathological disorders.

5. Ultrasonic sound can affect digestive respiratory cardiovascular system and semi circular canals of internal ear.

6. It causes muscle to contract leading to nervous breakdown, tension etc.

Control measures:

Source Control

1. Modification of source such as acoustic treatment to machine surface designed changes limiting the operational timings.

2. Oiling: Proper oiling will reduce the noise from the machine.

3. Transmission path intervention:

Containing the source inside a sound insulating enclosure, construction of noise barrier or provision of sound absorbing material along the path.

4. Planting of trees:

Planting of trees like neem, tamarind, coconut etc near schools hospitals reduce the noise to the extent of 8 to 10 db.

5. Selection of machinery:

Careful selection of machine tools and equipments to be used may help to lower the noise levels in machine shop.

9.What are the major sources and the measures to be taken to prevent soil pollution? (Nov-Dec 2018) (Nov-Dec 2019)

Soil pollution

Contaminations of the soil by human and natural activities which may cause harmful effects on living beings.

Effects on living beings

This may be due to the following factors.

(i) Industrial wastes:

(ii) Industries are the major causes for soil pollution Textiles, steel, paper,cement, oil, dyeing and other industries are responsible for soil pollution. Toxic organic compounds and phenol destroy the fertility of the soil.

(iii) Biological agents

Fungi, protozoa, bacteria are important Biological agents for soil pollution.

The human and animal wastes, garbage, waste water generates heavy soil pollution.

(iv) Radio active pollutants:

Atomic reactor, nuclear radio active devices releases radio active pollutants. These pollutants enter the land and accumulate there by causing soil pollution.

(v) Pesticides:

Pesticides pollute the soil. There are of two types

(1) Chlorinated hydrocarbon insecticide

Common chlorinated hydrocarbon insecticides are DDT, BHC.

(2) Organic phosphorous pesticides.

Organophosphorous insecticides are synthetic chemicals like Malathion and parathion.

DDT reduces the activity of sex hormones of male and female. The land with fungicides, insecticides causes diseases to human beings.

Fertilizers

These discharge N, Na, K, S, Nitrates etc., into the soil. The nitrate causes cancer.

Polymer, Plastics & other water:

These materials appear as garbage. Solid wastes and their quantities increase day by day. They pollute the atmospheres, land and also water badly.

Agricultural practices:

Modern agriculture practices pollute the soil to a large extent. Today huge quantities of fertilizers, pesticides, weedicides are added to increase the crop field. Apart from these farm wastes, manure debris, soil erosion containing inorganic chemicals are causing soil pollution.

Effect of soil pollution

1. Organic wastes enter the soil pores and decompose. Pathogenic bacteria spread infection
2. Compounds containing As, Hg, Cr, Ni, Zn and Fe are toxic to life.
3. Fluorides affect plant development
4. Water logging and salinity increase the dissolved salt content in the soil. Some plants are very sensitive to soil PH and salinity. Thus land becomes unfit for irrigation.

Control of soil pollution

1. Treat the sewage before land disposal
2. Rotate the crop pattern to allow the soil replenish the nutrients.
3. Preserve and protect top fertile soil, control soil erosion by tree plantation.
4. Fertilizers may be applied only after estimating the soil and crop measures.
5. Production of natural fertilizers Excessive use of chemical fertilizers and insecticides should be avoided. Bio pesticides should be used instead of toxic chemical pesticides.
6. Proper hygienic condition- People should be trained regarding the sanitary habits.
7. Recycling and reuse of waster – The wastes such as paper, plastic, metals.

10.Explain in detail about solid waste management/soil waste management/waste shed management. (Nov-Dec 2013) (May/June 2014) (April-May 2015) (Nov-Dec 2016)

Solid waste management. (Nov-Dec 2019)

Management of solid waste is very important to minimize adverse effect of solid waste.

Types of solid waste: Urban waste and industrial waste

Sources of urban and industrial wastes

1. Sources of urban waste: domestic waste like food waste, waste paper, glass bottles, polythene bags etc
2. Commercial waste like packing materials cans, bottles, polythene bags etc
3. Construction wastes like concrete, wood, debris etc .Biomedical waste like Anatomical waste, infectious waste etc

Classification of urban waste:

1. Biodegradable wastes – urban solid waste materials that can be degraded by micro organisms are called biodegradable waste. E.g. food, vegetables, Tea leaves, dried leaves etc.

2. Non biodegradable waste. Urban solid wastes that cannot be degraded by microorganisms are

called non biodegradable wastes.

Sources of industrial wastes

The main source of industrial waste is chemical industries, metal and mineral processing industries. E.g.

1. Nuclear power plants generate radioactive wastes
2. Thermal power plants produce fly ash in large quantities
3. Chemical industries produce toxic and hazardous materials.
4. Other industries produce packing materials acid, alkalis, scrap metals, rubber, plastic, glass wood etc

Effect of solid waste

1. Biodegradable materials in the disposed municipal waste undergo decomposition. This produces foul smell and breeds various types of insects which spoil land well.
2. Industrial waste containing toxic metals and hazardous waste affect soil characteristics.
3. Toxic substances name percolate into the ground and contaminates the ground water.
4. Burning of some industrial waste or domestic waste produces furan, dioxins and poly chlorinated biphenyls which are harmful to human beings.

Steps involved in solid waste management

Reduce, reuse and recycle: if the usage of raw materials is reduced the generation of waste also gets reduced.

Reuse of waste materials: discarded refillable containers can be reused. Waste generation during manufacture of rubber bands is reduced by making rubber bands from discarded cycle tubes. Recycling of materials.

Recycling is the reprocessing of discarded materials into new useful products.

Ex.

Old aluminium cans glass bottles are melted into new cans and bottles.

Preparation of cellulose insulations from paper.

Preparation of fuel pallets from kitchen wastes.

Disposal of solid waste:

Land Fill:

Solid wastes are placed in sanitary land fill system in alternate layers of 80cm thick refuse covered with selected earth fill of 20cm thickness. After 2 or 3 years solid waste volume shrinks by 25-30% and the land is used for parks, roads and small buildings.

Waste disposal is dumping in sanitary land fill which is employed in Indian cities. This method involves spreading the solid waste on the ground. Compacting it and then covering it with soil at suitable intervals.

Advantages:

1. Simple and economical. Segregation is not required.
2. Natural resources are returned to soil and recycled .
3. Converts low lying, marshy waste land into useful areas.

Disadvantages:

1. Large area needed.
2. Bad odour.
3. High transportation cost.
4. Sources of mosquito, flies.
5. Insecticides and pesticides are to be applied at regular intervals.

6. Causes fire hazard due to methane formation in wet weather.

INCINERATION

In this method the municipal solid wastes are burnt in a furnace called incinerator. The combustible substances such as rubbish, garbage, and dead organisms and non combustible matter such as glass, metals are separated before feeding into incinerator. The non combustible can be left out for recycling and reuse. The left out ashes and clinkers from the incinerator may be about 10-20 % which is disposed by land fill or some other methods.

The heat produced in the incinerator during burning is used as steam power for generation of electricity through turbines. The wet solid waste is dried in pre heaters and then taken into large incinerating furnaces called destructors which incinerate 100- 150tons per hour. The temperature maintained is about 700 ° C and increase to 1000° C when electricity is to be generated.

Advantages:

1. Requires little space
- 2 .Hygienic point of it is safest.
3. Incinerated plants of 300 tons per day capacity generate 3 MW of power.

Disadvantages:

1. Capital and operational cost is high.
2. Needs skilled persons.
3. Formations of smoke, dust and ash causes air pollution.

COMPOSTING:

In this method bulk organic waste is converted in to manure by biological action. Compostable waste is dumped in underground trenches in layer of 1.5 meters and is finally covered about 20 cms and left for decomposition. Microorganism like actinomycetes is added for active decomposition.

Within two to three days biological action starts .The organic matter decomposed by actionomycetes and lot of heat is liberated. The temperature of the compost increases by 75°C and finally the refuse is converted to a brown coloured powder known as humus and is used in agricultural fields. The compost contains N,P and other minerals.

Advantages:

1. Recycling occurs
2. Number of industrial solid wastes can also be treated by this method.

11. Case studies related to pollution

(i)The Bhopal gas tragedy:

The world's worst industrial accident occurred in Bhopal, MadyaPradesh on 03.12.84.

Name of company: Union carbide India Ltd, Manufacture of pesticides, using **methyl isocyanate (MIC)**

The reactor exploded due to failure of its cooling system and 40 tons of MIC leaked.

Effect:

- (i) MIC is toxic gas, lower concentration of MIC affects lungs and eyes
- (ii) Higher concentration of MIC removes oxygen from lungs and cause death

Effects in Bhopal:

1. MIC spread over 40 sq.km area.

2. 5000 persons were killed
3. 65000 people suffered from severe eye, respiratory problems
4. 1000 persons became blind.

(ii) Chernobyl nuclear disaster(Nuclear pollution/Nuclear accidents)

On 26.04.1986, the meltdown of the Chernobyl nuclear reactor in Russia has leaked out the radioactive rays and radioactive material.

Effects:

1. 2000 people have been killed
2. People suffered due to the illness such as degeneration of the cells, severe bleeding, anemia, skin cancer
3. Animals, plants are also affected by nuclear radiation

12. Discuss the role of individual in preventing pollution. (Nov-Dec 2014) (April- May2015)

(April-May2018)(Nov-Dec 2019)

- (1)Pollution prevention from the source itself.
- (2)Recycled and environmentally safer materials used.
- (3)Eliminate or reduce the pollutants.
- (4)To promote a more effective use of energy, materials and resources.
- (5)Rubbish and garbage should be placed in a container rather burning or disposing them on land.
- (6)Improper disposal of hazardous wastes, pesticides, paints, solvents and gasoline should be avoided.
- (7)Septic tank system should be located far away from the water course.
- (8)Natural vegetation cover in the top soil should not be removed.
- (9) Implement a law, appliances should be purchased with a label of ENERGY STAR.

UNIT-III

NATURAL RESOURCES

- 1. What is deforestation? Discuss the ill effects of deforestation. (Nov-Dec 2013) (Nov-Dec 2014) (April-May 2015) (Nov-Dec 2015) (Nov-Dec 2016) (April-May 2017) (April-May 2018) (April-May 2019) (Nov-Dec 2019)**

Deforestation:

It is process of removal of forest resources due to natural or man-made activities (i.e.) destruction of forests.

Causes of deforestation:

1. Developmental projects:

Developmental projects causes deforestation in two ways.

- Through submergence of forest area.
- Destruction of forest area. (eg) big dams, hydroelectric projects, road construction.

2. Mining operations:

It reduces forest areas. (e.g.) Mica, coal, Manganese and lime stone.

3. Raw materials for industries:

Wood is an important raw material for various purposes. (e.g.) making boxes, furniture and paper, etc.

4. Fuel requirement:

Wood is the important fuel for rural and tribal population.

5. Shifting cultivation:

Replacement of natural forest ecosystem for mono specific tree plantation. (eg) teak

6. Forest fires:

Forest fire destructs thousands of forest.

7. Overgrazing: Overgrazing by cattle reduces the cultivation land.

Consequences of deforestation (or) ill effects (or) impact of deforestation

1. Economic loss
2. Loss of biodiversity and genetic diversity.
3. Destructs the habitats of various species
4. Reduction in stream flow
5. Increases the rate of global warming
6. Disruption of weather patterns and global climate
7. Degradation of soil and acceleration of the rate of soil erosion.
8. Induces and accelerates mass movement/ landslides.
9. Increases flood frequency, magnitude/ severity.
10. Breaks the water and nutrient cycle.

Preventive measures (or) avoid of deforestation (or) methods of conservation of forests

1. New plants of more or less of the same variety should be planted to replace the trees cut down for timber

2. Use of wood for fuel should be discouraged.
3. Forest pests can be controlled by spraying pesticides by using aero planes
4. Forest fire must be controlled by modern techniques.
5. Overgrazing by cattle must be controlled.
6. Steps should be taken by the government to discourage the migration of people into the islands from mainland.
7. Education and awareness programmes must be conducted.
8. Strict implementation of law of Forest conservation Act.

Case study:

Deforestation in the Himalayan region, involves clearing of natural forests and plantation of monoculture like eucalyptus. Nutrient in the soil is poor, therefore soil losing their fertility. Hence, the Himalayan area facing the serious problem of deforestation.

1a) What are the ecological benefits of forests? Distinguish between commercial and ecological functions of forests resources?

Ecological benefits/uses/functions of forests

- (i) **Production of oxygen** – trees produce oxygen by photosynthetic process
- (ii) **Reducing global warming** – the main green house gas CO₂ is absorbed by forest for photosynthetic process
- (iii) **Wild life habitat** – forests are homes for millions of wild animals and plants.
- (iv) **Regulation of hydrological cycle** – Forested watersheds like sponges, absorbs the rainfall, slow down the run off, and slowly releasing the water for recharge of springs.
- (v) **Soil conservation** – Forests bind the soil particles tightly in their roots and prevent soil erosion
- (vi) **Pollution moderators** – Forests can absorb many toxic gases and help in keeping air pureThey can also absorb noise and help in preventing air and noise pollution

Commercial benefits/uses/functions of forests

Forest resources can supply the following products for commercial use.

- (i) **Timber** – forest trees are used to make timbers
- (ii) **Pulp wood** - forest pulpwood trees are used to make pulp and paper
- (iii) **Food products** – Forest resources supply fruits, condiments, spices, beverages, etc.
- (iv) **Fodder** – Trees can supply fodder for cattle
- (v) **Rubber/gum** – Forests can supply products like rubber latices, gum to rubber industries.
- (vi) **Fibres** – Many types of fibres are produced from forest based trees
- (vii) **Drugs & Medicines** – Forests can supply a number of drugs and medicines to the pharmaceutical industry

2. Discuss in detail the impacts of modern agriculture. (OR) Explain in detail the effects due to pesticides and fertilizers usage in modern agriculture. (May-June 2013, 2014) (Nov/Dec 2014) (Nov-Dec 2015) (May - June 2016) (Nov-Dec 2016) (April-May 2017)(Nov-Dec 2017)

Agriculture:

Agriculture is an art, science and industry of managing the growth of plants and animals for human use. It includes cultivation of the soil, growing and harvesting crops, breeding and raising livestock, dairying and forestry.

Types of agriculture:

1. Traditional agriculture
2. Modern (or) industrialized agriculture

Traditional agriculture:

Small plot, simple tools, surface water, organic fertilizer and a mixture of crops are enough. They produce enough food to feed their family and to sell it for their income.

Modern agriculture:

Hybrid seeds of single crop variety, high tech equipment's lot of fertilizers, pesticides and water to produce large amount of single crops.

Effects of modern agriculture:

1. Problems in using fertilizers:

a. Excess of fertilizers causes micronutrient imbalance.

(e.g) Punjab and Haryana deficiency of nutrient zinc in the soil affect the productivity of the soil.

b. Blue baby syndrome(nitrate pollution)

Nitrate present in the fertilizer causes blue baby syndrome, when the amount exceeds the limit 25mg/lt leads to death.

c. Eutrophication:

Nitrogen and phosphorus in the crop fields washed out by run off water in the water bodies, which increases the nourishment of the lakes called eutrophication. Hence algal species increases rapidly. Lifetime of the species is less and they decompose easily and pollute the water which affects the aquatic life.

2. Problems in using pesticides:

First generation pesticide: Sulphur, arsenic, lead and mercury.

Second generation pesticide: DDT

Number of side effects:

1. Death of non-target organism.
2. Producing new pest–super pest
3. Bio magnification—Most of the pesticides are non-bio degradable, keep on Concentrating in the food chain and it is harmful to human beings.
4. Risk of cancer:
 - a. It directly acts as carcinogen
 - b. It indirectly supports immune system.

3.Water logging:

Land where water stand for most of the year.

Causes of water logging:

1. Excessive water supply
2. Heavy rain
3. Poor drainage

Remedy:

1. Preventing excessive irrigation
2. Sub surface drainage technology
3. Bio drainage like trees like Eucalyptus

4. Salinity:

The unobserved water can be evaporated but salt can't be evaporated. That salt contents are deposited on the surface of the soil. Hence thin salt layer formed in the crop lands. It's called salinity.

3. Explain the role of individual in conservation of natural resources. (Nov/Dec-2013) (April-

May 2018)

Measures for conservation of Natural Resources

1) Conservation of Energy

- (i) Switching of lights, fans and electrical gadgets when not in use
- (ii) Use solar heater
- (iii) Dry the clothes in sun light
- (iv) Growing of trees near houses and office buildings to keep them cool and minimize use of air conditioners need not be used always
- (v) Use Pressure cooker
- (vi) Use bicycles or go by walking

2) Conservation of Water

- i) Minimize water use
- ii) Arrest water leaks
- iii) Reuse wastewater generated from kitchen washings and cloth washing
- iv) Use drip irrigation
- v) Rainwater harvesting

3) Conservation of Soil

- i) Grow different types of plants, herbs, trees and grass in open areas and house backyards
- ii) Do not uproot trees for construction of buildings
- iii) Irrigate plants with less amount of water
- iv) Use sprinkling irrigation
- v) Use green manure in gardens
- vi) Use mixing cropping so that soil nutrients will be restored

4) Conservation of Food Resources

- i) Eat minimum food/Avoid over eating
- ii) Don't waste food and food materials
- iii) Cook only required amount of food
- iv) Don't store large amount of food grains that could not be stored properly.

5) Conservation of Forest

- i) Use non-timber products
- ii) Plant more trees and protect them
- iii) Control grazing in forest lands
- iv) Minimize use of papers and fuel wood
- v) Avoid constructing dams, roads in forest areas.

4. Discuss briefly on the consequences of overdrawing of ground water. (Nov-Dec 2013) (Nov-Dec 2016) (Nov-Dec 2019)

Reasons- Increased population, rapid industrialization.

Effects of over utilization of groundwater:

1) Decrease of ground water:

Due to increased usage of ground water, the ground water level decreases
Reason:

- a) The erratic and inadequate rainfall
- b) The building construction activities reducing the percolation of rain water and increases in surface runoff.

2) Ground subsidence:

When the ground water withdrawal is more than its recharge rate, the sediments in the aquifer get compacted, which results in shrinking of land surface

Problems:

1. Structural damage
2. Fracture in pipes

3. Lowering of water table:

Overutilization of groundwater in arid and semiarid regions for agriculture disturbs the state of equilibrium of the reservoir.

Problems:

1. Lowering of water table
2. Decreased pressure in the aquifers and changes in the speed and direction of water flow.

4. Intrusion of salt water:

In coastal area, over exploitation of ground water would lead to rapid intrusion of salt water from the sea

Problems:

Water cannot be used for drinking and agriculture

5. Earthquake and landslides:

Overutilization of ground water leads to decrease in ground water level, which cause earthquake and landslides

6. Drying up of wells:

As a result of overutilization of ground water, the level of ground water getting depleted at much faster rate than regeneration. It leads to Drying up of wells

7. Pollution of water:

When the ground water level near the agricultural land decreases, water, containing the nitrogen as nitrate fertilizer, percolates into the ground and pollute the groundwater

Problems:

Water becomes not potable if nitrate concentration exceeds 45 mgs/lit

5. Give an account on conflicts over water.

Nearly 1.2 billion people do not have access to safe drinking water-Fresh water is becoming scarce; Conflict between States (Sharing of Cauvery between Karnataka and TamilNadu; Sharing of Krishna water between Karnataka and Andhra Pradesh; Sharing of Siruvani water between Kerala and TamilNadu) and between Countries (e.g. India vs. Pakistan over sharing of Indus; India vs Bangladesh over sharing of Brahmaputra; Iran-Iraq conflict over Shatt-al-Arab water; USA-Mexico conflict over Colorado river)

Causes of Water conflicts

- 1) Conflict through use
- 2) Conflict due to construction of Dams and Power stations
- 3) Conflict due to pollution (Pollution of Thenpennaiyar by Bangalore Sewage)

Management of Water conflicts

- 1) Enacting laws
- 2) Pollution control
- 3) Interlinking of rivers
- 4) Nationalization of water
- 5) Powers for National Water Authority

Local Managers

- 1) Neerkatti in South India

2) Havaldars in Maharashtra

3) Churpun in ladakh

Cauvery Water Dispute

Dispute between Karnataka and TamilNadu. Increasing demands for agriculture and industry by both States. Cauvery Water Dispute Tribunal awarded 205 TMC to be available at Mettur. Karnataka refused to give this amount. Meantime the water flow is getting reduced even in the Karnataka side.

Ethiopia-Sudan-Egypt water conflict:

The Jordan, Tigris-Euphrates and Nile are shared by the above three countries. Ethiopia controls 80% of Nile's flow and intends to increase it. Sudan tries to divert more. Egypt is badly affected. Nile delta basin is becoming a desert. As the population of Egypt will be doubled in the next 15-20 years the water crisis will become more critical.

6. Enumerate the various benefits and drawbacks of constructing dams.(or) Explain ill effects and benefits associated with dams with 2 case studies. (Nov/Dec-2013) (Nov-Dec 2015) (Nov-Dec 2018) (Nov-Dec 2019)

Dams

Benefits

- 1) Control of floods
- 2) Facilitates diversion of water through channels
- 3) Useful to off take water for drinking and irrigation
- 4) Can generate electricity
- 5) Aquaculture can be developed
- 6) Used for recreation and tourism
- 7) Facilitates navigation and fishing

Problems

A. Upstream problems

- 1) Displacement of tribal people
- 2) Loss of forest and non-forest lands
- 3) Loss of flora and fauna
- 4) Cause landslips, sedimentation and siltation
- 5) Stagnation and water logging around reservoirs
- 6) Retards plant growth
- 7) Breeding vectors and spread of water borne diseases
- 8) Induce earth quake
- 9) Navigation blocked

B. Downstream problems

- 1) Water logging and salinity due to over irrigation
- 2) Reduced water flow and reduced silt deposition in the delta
- 3) Salt water intrusion at river mouth
- 4) Fertility of land reduced as the nutrients are deposited in the dam on its storage side
- 5) Structural defects may cause cracks and sudden flooding

7. What are the environmental impacts of mineral extraction? Explain with 2 case studies. (May/June-2013) (April-May2015) (Nov-Dec 2015) (April-May2018) (Nov-Dec 2019)

MINERAL RESOURCES

Minerals: Minerals are naturally occurring substances having definite chemical composition and physical properties

Ores: Ores are minerals from which useful substances particularly metals can be extracted for profitable use.

Formation of mineral deposits

The mineral deposits have been formed at particular spots on earth by biological processes over millions of years.

Biological processes

- 1) Biological decomposition of dead animals and organic matter
- 2) Concentration of minerals during cooling of molten rock
- 3) Evaporation of seawater
- 4) Weathering, transportation and sedimentation

Classification of mineral resources

- 1) **Identified Resources:** Identified by geological measurements
- 2) **Undiscovered resources:** Assumptions on the basis of geological knowledge and theory
- 3) **Reserves:** Identified reserves with extractable minerals

Uses/Exploitation of minerals

- 1) Industrial plants and machinery
- 2) Housing and settlement materials
- 3) Energy generation
- 4) Defense equipment's
- 5) Ornaments and Jewelry
- 6) As fertilizers (phosphates)
- 7) Communication equipment's (telephone wires, cables, electronic devices)
- 8) Making alloys for various purposes
- 9) Medicines (Ayurvedic medicines)

Examples of Metallic Minerals

Aluminum-food packing

Chromium-alloys, chrome tanning

Copper-vessels and electrical wires

Iron-heavy machineries and household articles

Lead-Leaded gasoline, car batteries, paints and ammunition, pipes

Manganese-high resistant steel alloys

Platinum-automobiles, automatic converters, Jewelry

Gold-Ornaments, medical use

Silver-photography

Nickel-Chemical industry

Examples of Non-metallic minerals

Silicate minerals-bricks, pavements

Limestone-concrete, neutralizing acidic soils, cement industry

Gypsum-Plaster, wall-board, agriculture

Sulphur pyrites-Medicine and car battery

Classification of Minerals

1) Based on composition

- a) *Non-metallic minerals*: quartz, feldspar, dolomite, calcite
- b) *Metallic minerals*: Iron, aluminum, copper zinc

2) Based on usage

- a) *Critical minerals*: Iron, aluminum, copper and gold
- b) *Strategic minerals*: Manganese, cobalt, platinum and chromium

Mineral wealth of India

STATE	MINERALS AVAILABLE

Andhra Pradesh	Coal, manganese, Copper, mica, lead
Assam	Petroleum
Bihar	Iron, coal, copper, aluminum, tin, mica
Goa	Iron, manganese
Gujarat	Copper, aluminum, petroleum, lead, zinc
Karnataka	Iron, manganese, copper, Gold, aluminum, chromium
Kashmir	Aluminum, gypsum
Kerala	Monazite, ilmenite (Ti), rutile(Ti)
Madhya Pradesh	Coal, manganese, aluminum, marble
Maharashtra	Iron, Coal, manganese, aluminum, chromium, petroleum
Orissa	Iron, coal, copper, aluminum, tin, chromium, lead
Rajasthan	Manganese, copper, tin, marble, mica, lead, zinc, precious stones, gypsum
Sikkim	Copper, magnesite
TamilNadu	Iron, manganese, aluminum, chromium, magnesite, ilmenite(Ti), rutile(Ti), gypsum,
West Bengal	Coal

MINING

Definition: Mining is the process of extraction of metals from a mineral deposit.

Types of mining

- 1) Surface mining
- 2) Underground mining
 - (i) Open-pit mining: for Fe, Cu, limestone, sandstone and marble mining
 - (ii) Strip mining: Stripped using bulldozers and stripping wheels

7 a) What are the environmental impacts of mining?

- 1) **Devegetation-** Top soil and vegetation are removed from the mining area. Large scale devegetation/deforestation leads to many ecological losses.
- 2) **Defacing of landscape –** Landscape is badly affected. Huge quantities of debris and tailings with scars and disruptions spoil the aesthetic value and may cause soil erosion.
- 3) **Groundwater contamination--** Mining pollutes the ground water. Sulphur present as impurity in many ores is converted into sulphuric acid through microbial action and makes the water acidic.
- 4) **Surface water pollution –** drainage from the acid mines contaminate the nearby streams and lakes thereby affecting the aquatic life. Radioactive substances like uranium contaminate the water bodies and kill aquatic animals.
- 5) **Air pollution –** to separate and purify metal from ore, smelting is done which emits large quantities of air pollutants damages the vegetation nearby and has serious health impacts.
- 6) **Subsidence of land:** Caused due to underground mining and results in cracks in houses, tilting of buildings, bending of rail tracks, and leaking of gas from cracked pipelines leading to serious disasters.
- 7) **Occupational health hazards –** Miners suffer from respiratory and skin diseases due to exposure to suspended particulate matter and toxic substances.

Effects of mining

- 1) Rapid depletion of minerals
- 2) Leading to wastage and dissemination of mineral deposits
- 3) Environmental pollution
- 4) Heavy energy requirement

Management of Mineral Resources

- 1) Efficient use
- 2) Protection from illegal mining
- 3) Search for new deposits
- 4) Re-use and Re-cycling of metals
- 5) Eco-friendly mining technology
- 6) Microbial leaching technique for concentrating low-grade ores

8. Comment upon the types of energy harnessed from wind, sun and Oceans (Apl-May 2019). Or Identify the reasons for growing energy demand. Discuss the advantage and limitations of solar, wind and thermal power energy. (Nov-Dec 2019)

Non-renewable energy: Coal, petroleum, natural gas and nuclear fuels

Renewable energy: Wood, solar energy, wind energy, hydropower, tidal energy

Merits of renewable energy

- 1) Unlimited supply
- 2) Provides energy security
- 3) Promotes sustainable development
- 4) Reliable and modular in size
- 5) Decentralized energy production

Wind energy

Wind:

Moving air is called wind.

Wind energy:

Energy recovered from the force of wind is called wind energy.

Energy recovered from the force of the wind is called ‘wind energy’

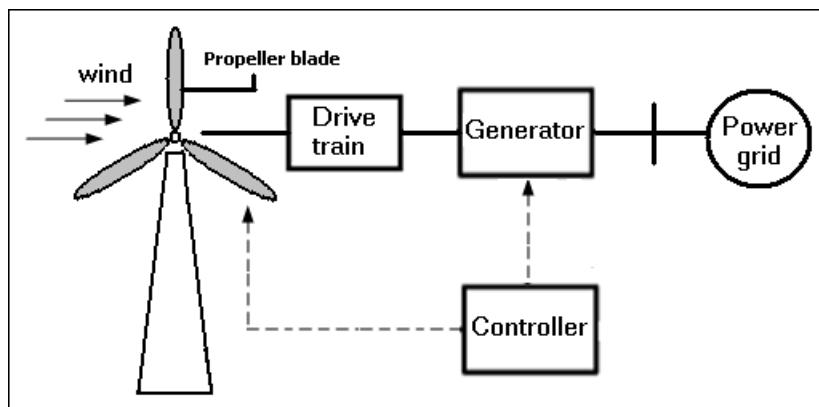


Fig: Wind mill

Wind mill:

Wind Energy → Kinetic energy → Mechanical energy → Electrical Energy

Working:

- It consists of wheel having blades; the wheel rotates about an axle mounted on a pole;
- The wind energy used to rotate the wheel. The axle is connected to a generator which rotates between two poles of a strong magnet.

- When wind falls on the wheel of wind mill, it rotates axle and electric current is produced.

Wind Farm:

The region where large number of wind mills is erected to produce electricity is called wind farm.

Advantages

- Not give pollution
- Very cheap and economic
- Renewable

Disadvantages:

- ✗ Makes unwanted sound
- ✗ Interfere with electromagnetic signals

Uses:

- ✓ Used to move sail boats in lakes and rivers
- ✓ Used to operate water pumps
- ✓ Used to run the flour mills
- ✓ Used to produce electricity.

Electricity produced: 100kw

Solar energy

Energy released due to nuclear fusion reactions in the Sun. Energy is released as heat and light.

Method of collecting Solar energy

1) Photo voltaic cells

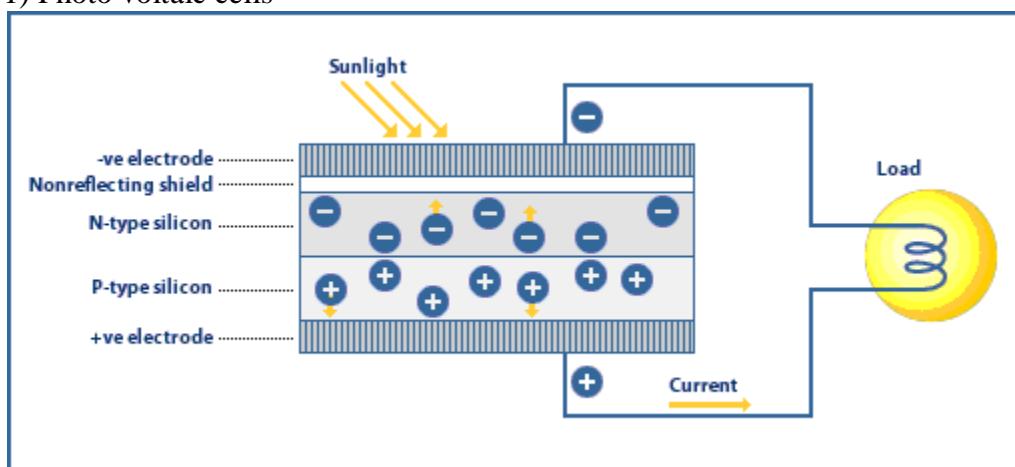


Fig: Solar cell

Working:

- The solar rays are fall on the top of the p-type semiconductor.
- The electrons are flow from the valence band to conduction band.
- The potential difference occurs between the semiconductors. Now the electrons are generated and hence current is generated.

Advantages:

- Pollution free (eco friendly).
- Lifetime long.
- Need not be recharged.
- Used in remote & isolated areas.
- Low maintenance cost.

Disadvantages:

- ✗ Storage of solar energy is not possible.
- ✗ Produces only DC.
- ✗ High Capital cost
- ✗ Not available throughout the year.

Uses:

- ✓ Lighting purposes.
- ✓ In water pumps.
- ✓ In electronic devices.
- ✓ Silicon solar cell used in space crafts.

2) Solar heat collectors

3) Solar water heater

Ocean Energy

1) **Tidal energy**-flow of seawater into the reservoir during high tide and reverse flow during the low tide-*Such units are located near the bays and estuaries; seawater is inexhaustible, pollution free.*

2) **Ocean Thermal Energy (OTE)**

In tropical oceans the difference in temperature between surface level and deeper sea level is high (>20°C). Warm surface water boils a low boiling liquid like ammonia. The vapor is used to drive a turbine. The cool water is used to condense the vapor back into liquid.

Significance of OTE

- (1) OTE is continuous and renewable
- (2) Pollution free
- (3) The electric power generated can be used to produce hydrogen

9. What are conventional/non-renewable energy sources? (Nov-Dec 2013) (May-2014) (May - June 2016) (Apl-May 2019)

Non-renewable energy sources

1) Coal:

Coal is a solid fossil fuel formed from plants that lived 300-400 million years and were subjected to intense heat and pressure.

Anthracite contains 90% carbon

Bituminous coal contains 80% carbon

Lignite contains 70% carbon

Peat contains 60% carbon.

India has 5% of world's coal reserve but of poor heat capacity.

Disadvantages of using coal

- 1) CO₂ produced on burning of coal causes global warming
- 2) Produces oxides of sulfur and nitrogen causing pollution

2) Petroleum:

It is a thick liquid fuel containing combustible hydrocarbons with small amounts of S, O, N as impurities.

It is a liquid fossil fuel formed by decomposition of dead animals and plant that were buried under ocean and subjected to high temperature and pressure for millions of years.

Fractional distillation

The various hydrocarbons in petrol/crude oil are separated by fractionating.

About 25% of world's crude oil reserves are in Saudi Arabia. The crude oil reserves in the world can last for another 40 years.

3) LPG:

The petroleum gas obtained during cracking and fractional distillation is converted into liquid under high pressure which is called LPG.

LPG is colorless and odorless gas. Some mercaptan is added to produce bad odour for easy detection of leaks.

4) Natural Gas:

It is found above oil in oil wells. It is a mixture of 50-90% methane and small amount of other hydrocarbons. Its calorific value is 12000-14000 kcal/m³.

Dry gas: If the natural gas contains lower hydrocarbons like methane and ethane it is called 'dry gas'.

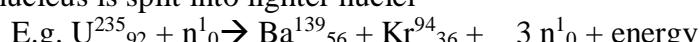
Wet gas: If the natural gas contains higher hydrocarbons like propane, butane along with methane it is called wet gas.

Nuclear energy

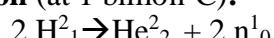
Nuclear Fission:

Energy is obtained on bombardment with fast neutrons.

Here heavier nucleus is split into lighter nuclei



Nuclear Fusion (at 1 billion°C):



Comparison of Coal with Nuclear Power

- 1) Coal is a fossil fuel
- 2) Coal power meets 90% energy needs of the world.
- 3) Energy changes taking place are very small
- 4) Generation of coal power is governed by temp and pressure.
- 5) Products formed are not new
- 6) Atomic No. of elements involved do not change.
- 7) No loss in mass during combustion
- 8) During nuclear reaction, no change occurs in nucleus
- 9) CO₂ causes Green House Effect.
- 10) Air pollution can be minimized
- 11) Pollutants themselves may be radioactive.

10. Explain the role of alternate (renewable) energy sources in environmental impacts.

Uses of alternate energy sources

Need for Alternate energy sources

- 1) Fossil fuels have impact on environment so we need alternate energy sources
- 2) Least pollution generating energy sources needed
- 3) Hydroelectric power causes ecological imbalance
- 4) Hydel power plants pollute aquatic and terrestrial biota.
- 5) Radioactive pollutants are chronically hazardous
- 6) Burning of coal, oil, wood, dung cakes and petroleum products pollute air, soil and underground water.
- 7) Disposal of fly ash requires larger land.

Objectives

- 1) Provide more energy for growing population
- 2) Reduce environmental pollution
- 3) Reduce safety and security issues related with the use of nuclear energy.

Alternate energy sources

- 1) Wind energy
- 2) Hydrogen fuel cell
- 3) Tidal energy
- 4) Geothermal energy
- 5) Solar energy

11. Explain the biochemical degradation of pollutants. (April-May2018)

Most of the organic matter, present in waste water, includes degradable carbohydrates, proteins and lipids of different complexities. The treatment of such waste water aims at oxidizing or degrading the organic compounds, so as to decrease the biological oxygen demand (BOD).

Types:

1. Very easily degradable
2. Easily degradable
3. Potentially degradable
4. Very slowly degradable

1. Very easily degradable

Pollutants

Simple sugars, amino acids, organic acids, simple short polymers.

Organisms

Bacteria, fungi, protozoa and algae posses the ability to degrade these pollutants.

Generally it constitutes a small amount of the pollutants in the environment that are quickly removed by the microbes for their growth. It occurs under aerobic conditions.

Time for removal

These pollutants are removed within hours of their release.

2. Easily degradable

Pollutants

Branched and straight chained polysaccharides, proteins, fatty acids.

Organisms

More than one bacterial strain accelerates the degradation process.

Generally degradation of such pollutants do not necessarily require adaptation of the micro-organisms.

Time for removal

These pollutants are removed in 10-14 days.

3. Potentially degradable

Pollutants

Complex substances like saturated fatty oils, lipo proteins, fats and aliphatic aromatic HC.

Organisms

Extremely high bacterial densities are required for these degradation.

Degradation of such pollutants occurs slowly with prolonged exo-enzyme activity at high bacterial densities. Bacteria are able to perform the degradation of such pollutants, but to accelerate degradation artificial conditions are required for enhancing the bacterial growth.

Time for removal

These pollutants are removed in 3 weeks.

4. Very slowly degradable

Pollutants

Ligno cellulose, Organo chlorines, PCB, OC, insecticides, some aromatic HC.

Organisms

Very high microbial biomass is required for these degradation. Degradation of such pollutants required a comparatively high concentration of exo-enzymes to initiate the degradation process. Artificial inoculation, growth subsidization and addition of growth supporting substances (vitamins, nutrients) accelerate the degradation time.

Time for removal

These pollutants are removed in 3 weeks.

12. Explain the manufacture of Biogas.

Biogas is a renewable energy source . Biogas can be produced from raw materials such as agricultural waste, [manure](#), [municipal waste](#), [plant material](#), [sewage](#), [green waste](#) or [food waste](#).

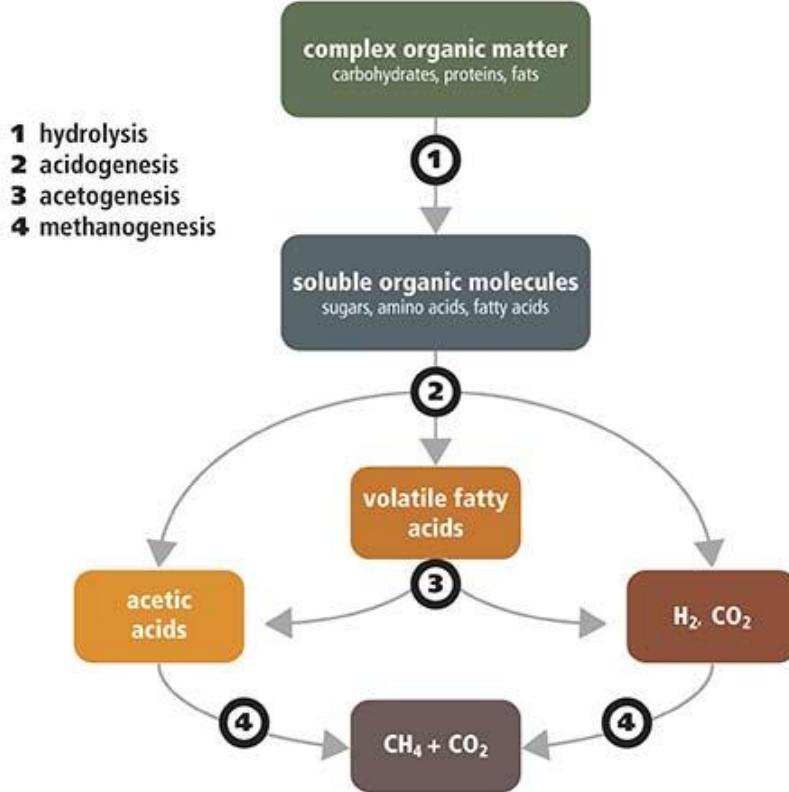
Composition of biogas

- Biogas is generated by the activity of anaerobic bacteria
- Composition depends on: the composition of **raw material**, **organic loading to digesters**, **time** and **temperature** of anaerobic digestion

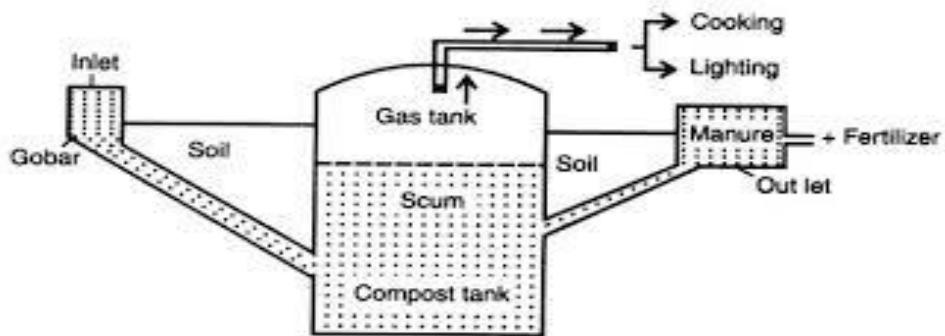
Composition of biogas

Substances	Symbol	Percentage
Methane	CH ₄	50 - 70
Carbon Dioxide	CO ₂	30 - 40
Hydrogen	H ₂	5 - 10
Nitrogen	N ₂	1 - 2
Water vapour	H ₂ O	0.3
Hydrogen Sulphide	H ₂ S	Traces

Flow chart:



Block diagram:



Working method:

1. Slurry(animal dung+water) is fed into the digester through the inlet chamber.
2. The slurry, in the digester is left for about two months for fermentation by using anaerobic microorganisms.
3. As a result, bio gas is collected in the dome.
4. When the sufficient amount of bio gas is collected in the dome, it exerts a large pressure on the slurry and this in turn forces the spent slurry to the over flow tank through the outlet chamber.
5. Once the bio gas plant starts functioning more and more slurry may be fed into the digester to get continuous supply of bio gas.

Uses:

1. Bio gas is used for cooking food and heating water.
2. It is used to run engines.
3. It is used in gas turbines and fuel cells for producing electricity.

UNIT IV

SOCIAL ISSUES AND THE ENVIRONMENT

1. What is rain water harvesting? Name and discuss in brief the types of rain water harvesting.
(Nov-Dec 2013) (Nov-Dec 2014) (April-May 2015) (April-May 2018)

Rain water harvesting

It is a technique of capturing and storing of rainwater for further utilization.

Objectives

1. To reduce run-off losses
2. To avoid floods
3. To meet increasing demands of water
4. To raise water table by recharging ground water
5. To reduce ground water contamination from salt water intrusion
6. To store excess water for use at subsequent time
7. To prevent salinity increase in coastal areas

Need for rain water harvesting

1. Essential because surface water is inadequate to meet our demand and we have to depend on ground water.
2. Due to rapid urbanization, filtration of rainwater into the sub soil has decreased drastically.

Rain water harvesting methods

There are two main techniques for rain water harvesting:

1. Storage of rain water on the surface for future use
2. Recharge of ground water

Recharge of ground water is a recent concept and the structures used for the purpose are:

Recharge pits

Constructed for recharging the shallow aquifers.

Constructed 1-2m wide and 6m deep which are backfilled with gravels and coarse sand.

Trenches

Constructed when the permeable stream is available with gravels and coarse sand.

Dug wells

Utilized as recharge structure.

Hand pumps

May be used for recharging aquifers.

Recharge wells

Recharge wells of 100-300mm diameter are constructed for recharging the deep aquifers.

Modern techniques of rain water harvesting

Roof top rain water harvesting

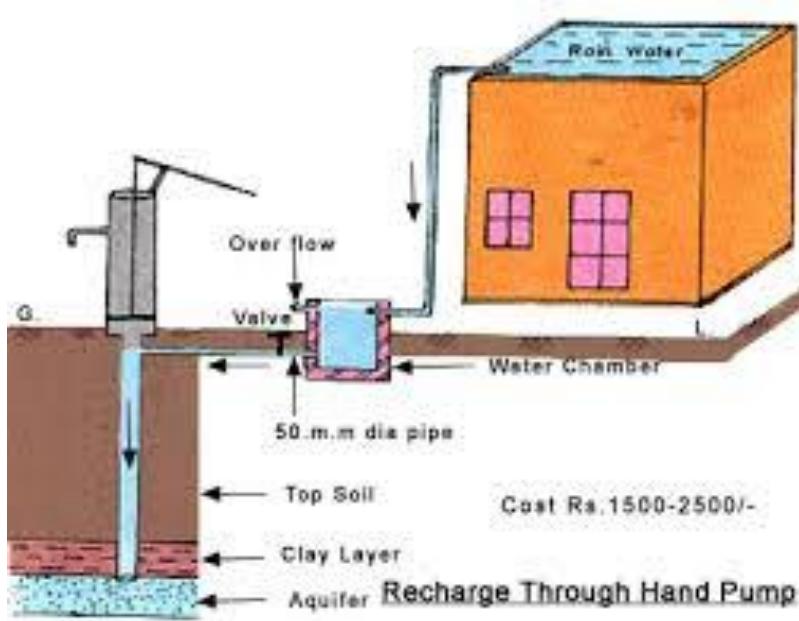


Figure: Roof top rain water harvesting

- Low cost and effective technique for urban houses and buildings
- Rain water from the roof is turned away to some surface tank or pit through delivery system.
- Also later used to recharge underground aquifers.

Advantages of rainwater harvesting

- Increases the well water availability
- Raise ground water level
- Minimizes soil erosion
- Upgrading the social and environmental status etc
- It helps in recharging aquifers.

2. Discuss the watershed management practices. (Nov/Dec-2013)

Watershed management

Water shed (or) drainage basin:

It is defined as land area from which water drains under the influence of gravity into stream, lake, reservoir (or) other body of surface water.

Watershed management of rain fall and resultant run off is called watershed management.

Factors affecting watershed

1. Overgrazing, deforestation, mining, construction activities affect and degrade watershed.
2. Droughty climate also affects the water shed.

Need or objectives of watershed management

1. To raise the ground water level.
2. To protect the soil from erosion by run off.
3. To minimize the risks of floods, drought and landslides.
4. To generate huge employment opportunities in backward rain fed areas to ensure security for livelihood.

Watershed management techniques

- Trenches (pits) were dug at equal intervals to improve ground water storage.
- Earthen dam or stone embankment must be constructed to check run off water.
- Farm pond can be built to improve water storage capacity of the catchment's area.

Maintenance of watershed

Water harvesting

Proper storage of water in water shed can be used in dry season in low rainfall areas.

Afforestation and agro-forestry

It helps to prevent soil erosion and retention of moisture in watershed areas

Mechanical measures for reducing soil erosion

Terracing, contour cropping, minimize soil erosion and run off on the slopes of water sheds.

Scientific mining and quarrying minimize the destructive effect of mining in water shed areas.

Public participation

It is essential for water shed management. People should be motivated for maintaining water harvesting structures implemented by the government.

Livestock population

It should be reduced in surrounding villages of water shed.

Advantages of Watershed projects

- Improved access to drinking water in project areas during drought
- Increase in cultivation area leading to increase in employment
- Increase in crop yield, resulting better income to rural population
- Improved availability of fodder for animals and increase in milk yield
- Increase in employment & involvement of women

3. Describe the important waste land reclamation practices. (May-June-2013) (May-June 2014)

(April-May 2015) (Nov-Dec 2015)

Waste land reclamation

Waste land

- The land which is not in use is called waste land.
- Waste land is unproductive, unfit for cultivation, grazing etc.
- 20% of the geographical area of India is waste land.

Types of waste land:

1. Uncultivable waste land

Uncultivable waste land: Barren rocky areas, hilly slopes, sandy deserts.

2. Cultivable waste land.

Cultivable waste land: These are cultivable but not cultivated for more than 5 years.

Ex Degraded forest land, Gullied water logged, marsh lands, saline lands.

Causes of waste land formation:

1. Over exploitation of natural resources.
2. Industrial and sewage wastes.
3. Due to soil erosion, deforestation, water logging, salinity etc.
4. Mining activities destroy the forest and cultivable land.

Objects of waste land reclamation:

1. To prevent soil erosion, flooding and land slides.
2. To avoid over exploitation of natural resources.
3. To improve the physical structure and quality of the soil.
4. To conserve the biological resources and natural ecosystem.

Methods waste land reclamation:**Drainage:**

Excess water is removed by artificial drainage. This is for water logged soil reclamation.

Leaching:

Leaching is a process of removal of salt from the salt affected soil by applying excess amount of water.

Leaching is done by dividing the field into small plots.

In continuous leaching 0.5to 1.0cm .

Water is required to remove 90% of soluble salts.

Irrigation practices:

High frequency irrigation with controlled amount of water helps to maintain better availability of water in the land .

Application of green manure and bio fertilizers

It improves saline soil.

Application of gypsum:

Soil sodality (sodium held in soil) can be reduced with gypsum. Ca of gypsum replaces sodium from the exchangeable sites. This converts clay back into calcium clay.

Social Forestry programme:

These programmes involves strip plantation on road, canal sides, degraded Forest land etc.

4. Discuss about the Forest Act and Wildlife act. (Nov-Dec 2014) (April-May2018) (Apl-May 2019) (Nov-Dec 2019)**Forest (conservation) Act, 1980**

It deals with conservation of forest and includes reserve forest, protected forest and any forest land irrespective of ownership.

Objectives of forest act:

- (i) To protect and conserve the forest
- (ii) To ensure judicious use of forest products

Important features

1. The reserved forests shall not be diverted without the prior permission of the central government
2. The forest may not be used for non forest purposes
3. Illegal non forest activity stopped under this act

1992 Amendment

1. This amendment allows transmission lines, seismic surveys, exploration drilling and hydro electric project in forest area without cutting trees or with limited cutting of trees – prior approval CG to be sought.
2. Wild life sanctuaries, National parks etc. are prohibited from exploration except with CG prior approval.
3. Cultivation of coffee, rubber, tea (cash crop), fruit bearing trees, oil yielding trees, trees of medicinal values are also prohibited in reserved forest area without prior approval from CG.
Has this may create imbalance to ecology of the forest.
4. Tusser (a type of silk yielding insect) cultivation in forest area is allowed since it discourages monoculture practices in forests and improves biodiversity.
5. Plantation of mulberry for rearing silk worm is prohibited.

6. Proposal sent to CG for non-forestry activity must have a cost benefit analysis and environmental impact statement (EIS).

Draw backs of the forest (conservation) act 1980

- Inheritance of exploitative and consumerist elements of the British period
- Tribal people (i.e.) inhabitants of forest are left by the act
- Instead of attracting public support (tribal) it has intrigued in the human rights.
- Protection of trees, birds and animals have marginalized poor people.

State the important provisions in Wildlife act (Apl-May 2019) (Nov-Dec 2019)

Wildlife [protection] act, 1972:

- Land mark in the history of wildlife legislation.
- 1976 the powers are transferred from state to central government. [
- I B of W L] was created in 1952 in our country which after WLA, 1972, took up the task of setting National parks and sanctuaries.

Objectives of wildlife act

1. to maintain essential ecological processes and life supporting systems
2. to preserve biodiversity
3. to ensure a continuous use of species

Important features of Wildlife [protection] Act

1. The act covers the rights and non rights of forest dwellers
2. It provides restricted grazing in sanctuaries but prohibits in national parks
3. It also prohibits the collection of non-timber forest
4. Defines wild life related terminology.
5. Provide appointments of advisory Board, wildlife warden, their powers & duties etc.
6. Prohibition of hunting of endangered species [was first] mentioned.
7. List of endangered species is provided.
8. The Act imposes ban on trade & commerce of scheduled animals.
9. Provide captive breeding programme for endangered species.

Many conservation projects for endangered species were started under this act.

Lion 1972;

Tigers 1973

Crocodile [1974];

Deer 1981.

Draw backs of wild life (protection) act

- Fall out of Stockholm conference not localized
- Ownership certificate of animals article – illegal trading
- Trade through J & K. This act not applicable to J&K
- Offender to get just 3 years imprisonment and or Rs.25000/- fine.

5. State the important provisions in Air Act(Nov/Dec-2013)(Nov- Dec2013)(May/June2014) Water Act. (May/June 2014) (May - June 2016) (April-May2015)(Nov-Dec 2015) (Nov-Dec 2016) (April-May 2017) (Nov-Dec 2017) (Nov- Dec 2018) (Apl-May 2019) (Nov-Dec 2019)

Objectives:

- To prevent, control and abatement of air pollution
- To maintain the quality of air
- To establish a board for the prevention control of air pollution

Important features

1. The central board may lay down the standards for the quality of air

2. The central board coordinates and settle dispute between state boards.
3. The state board empowered to lay down standards for emission of air pollutants.
4. The state board is to examine industries whether they meet standards prescribed
5. The direction of central board is mandatory on state boards.
6. Violation of law is punishable with imprisonment
7. Noise pollution – inserted in 1987
8. Section 20 provides for emission standard to auto mobile
9. Section 19 provides for SG to declare “air pollution control area” in consultation with SPCB

*** Water (prevention and control of pollution) Act 1974: (Nov- Dec 2018)**

Objectives:

- (i) Prevention and control of water pollution
- (ii) Maintaining and restoring the water
- (iii) Establishing central and state boards for the prevention and control of water pollution

Important features

Maintaining and restoring the wholesomeness of water by preventing and controlling its pollution. The salient features and provisions of Act are summed as follows.

1. This act aims to protect water from all kinds of pollution
2. This act aims to preserve the quality of water in all aquifers
3. The states are empowered to restrain any person from discharging a pollutant/sewage/effluent into any water body without the consent of the board
4. Any contravention of the guidelines or standards would attract penal action including prison Sentence
5. The act is not clear about definition of pollutant, discharge of pollutant, toxic pollutant
6. Maintenance and Restoration of Quality – surface and ground water
7. Establishment of central pollution control board (CPCB) and state pollution control board(SPCB)
8. Confers powers and functions to CPCB and SPCB
9. The act provides for funds, budgets, accounts and audits of the CPCB & SPCB

6. State the important provisions in Environment protection Act. Nov/Dec-2013)(Nov-Dec2013)(May/June2014)(April-May2015)(Nov-Dec 2015) (Nov-Dec 2016) (April-May 2017) (Nov-Dec 2017) (Nov- Dec 2018)

Environment (Protection) Rules, 1986

SPCB is to follow the guidelines provided in schedule VI. Some are as follows

1. Advises industries for treating the waste water and gases – use of technology – achieve prescribed std.
 2. Encourage recycling and reusing the wastes
 3. Encourage recovery of biogas, energy and reusable matter
 4. Discharge of effluents and emissions into environment is permitted by SPCB after taking into account capacity of the receiving water body
 5. To emphasize clean technology to increase fuel efficiency and decrease environmental pollutants
- The act provides for environmental Audit for checking complying with the environmental laws and regulations.

Objectives

- (i) to protect and improvement of the environment
- (ii) to prevent hazards to all living creatures and property
- (iii) to maintain harmonious relationship between humans and their environment\

Important features

CG is to take action to protect and improve environment and SG to co ordinate actions. CG to set up

1. Standard of quality of air, water or soil
2. Maximum permissible limits of concentration of pollutants (including noise pollutant)
3. Procedures and safe guard for handling hazardous items
4. Prohibition of using hazardous items
5. Prohibition and restriction of certain industries in certain area
6. Procedure and safe guard for prevention of accidents
7. The government has authority to close or prohibit or regulate any industry if any industry violates Act
8. If the violation continues additional fines may be imposed
9. The act empowers the officer of central government to inspect the site or plant or the machinery for preventing pollution and to collect the samples of air, water, soil or other material from any factory or its premises for testing.

7. Describe the steps involved in management of Bio medical waste. (Nov-Dec 2015) (Nov-Dec 2016)

Step – I : Generation and accumulation

- It is generated by health care centers.
- It should be collected in the containers.
- It should not be mixed with other wastes.
- Those containers should be marked with bio hazard symbol.
- Discarded sharp materials should be collected in needle boxes.

Classification of biomedical wastes.

Category No	Types of waste	Treatment or Disposal
1	Human anatomical wastes: Ex : Body parts, organs, body tissues.	Incineration or Deep burial
2	Animal wastes Ex : Body parts, bleeding parts, body fluid	Incineration or Deep burial
3	Microbiology and biotechnology wastes Ex : Wastes from laboratory cultures, specimens of micro organisms	Incineration or microwaving.
4	Waste sharps Ex : Needles, syringes, blade, glass	Disinfection or microwaving
5	Discarded medicines and cytotoxic drugs Ex : Contaminated medicine, outdated wastes	Incineration or microwaving.
6	Solid wastes Ex : wastes from disposed items	Autoclaving or microwaving
7	Solid wastes Ex : Items contaminated with blood, cotton, beddings	Incineration or microwaving.
8	Liquid wastes Ex : From the laboratory (washing & Cleaning)	Discharge drains
9	Incineration ash Ex : Ash of bio medical wastes.	Disposal in municipal landfill

10	Chemical wastes Ex : Chemicals used in hospital & laboratory	Chemical treatment
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Step – II :

Handling refers to the act of manually moving biomedical waste between the point of generation, accumulation areas, storage locations and on-site treatment facilities.

No untreated bio-medical wastes shall be kept stored beyond a period of 48 hours.

Step – III :

On-site treatment

It uses relatively expensive equipments and is used only by large hospitals & major universities.

Off-site treatment

It's a hiring of a biomedical waste disposal service.

Type of treatment

Incinerator: Destroy pathogens & sharps

Autoclave: By the use of steam and pressure, reduce microbiological contents.

For liquids- used to disinfect biomedical wastes.

8. What functions are performed by the central & state pollution control boards? (April-May2018) (Apl-May 2019) (Nov-Dec 2019)

1. Central pollution control Board (CPCB):

1. Advices CG in matters – prevention and control of water pollution
2. Co ordinates SPCB and provide technical assistance and guidance
3. Training programs for prevention and control of pollution by mass media and other ways
4. Publishes statistical and technical details about pollution
5. Prepares manual for treatment and disposal of sewerage and trade effluents
6. Lays standard for water quality parameters
7. Plans nation-wide programs for prevention, control or abatement of pollution
8. Laboratories for analysis of water, sewage or trade effluents

State pollution control Board (SPCB):

SPCB has similar functions as SPCB and governed by CPCB

1. SPCB advises state government with respect to location of any industry that might pollute
2. Lays standard for effluents to take samples from streams, wells or trade effluents or sewage passing through an industry. Samples taken are analyzed at recognized labs. If the sample is not confirming to the water quality std, then the unit is neglected
3. Every industry to obtain consent from PCB before commencing an effluent unit by applying in prescribed form with fee.

9. Twelve principles of green chemistry. (May - June 2016) (April-May 2017)(Nov-Dec 2017) (April-May2018)

1. Prevention

It is better to prevent waste than to treat or clean up waste after it has been created.

2. Atom Economy

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Syntheses

Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals

Chemical products should be designed to affect their desired function while minimizing their toxicity.

5. Safer Solvents and Auxiliaries

The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6. Design for Energy Efficiency

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feedstocks

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8. Reduce Derivatives

Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

9. Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

11. Real-time analysis for Pollution Prevention

Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

10. Write notes on (i) Floods (ii) Cyclones (Nov-Dec 2015) (Nov-Dec 2016) (iii) Earth quake (Nov-Dec 2013) (May/June 2014) (Nov-Dec 2014) (Nov-Dec 2015) (OR) State the different natural calamities/disaster and explain any one in detail (or) Discuss some natural disasters and the measures to be taken to cope up with them (Nov- Dec 2018) (Nov-Dec 2019)

Natural calamities/disaster:

1. Flood
2. Cyclone
3. Earthquake
4. Landslide
5. Tsunami

(i) Floods: A flood is an overflow of water from its natural course due to their reduced carrying capacity by sediments and heavy rains.

Causes of Floods

- 1) Heavy rainfall, melting of snow, sudden release of water from dams
- 2) Overflowing of lakes and rivers during rainy season
- 3) Reduction in carrying capacity of water courses due to sediments or blocking of drainage channels carrying the water (buildings and structures coming up)
- 4) Deforestation, over grazing, uncontrolled mining,
- 5) Deforestation

Effects of Flood

- 1) Submergence of land
- 2) Erosion, silting and sedimentation affecting cultivable land
- 3) Extinction of species
- 4) Death of human and livestock and damage to property

Preventive measures

- 1) Construction of dams and reservoirs
- 2) Canal management-embankments
- 3) Removal encroachments adjacent to water courses which are subject to floods
- 4) Flood warning
- 5) Check dams, percolation ponds

(ii) Cyclone

Causes:

1. An atmospheric closed circulation, rotating anti- clock wise in the northern hemisphere and clock wise in southern hemisphere .
2. Cyclone is an area of low pressure in the centre and high pressure outside. Powerful swirling storm that measures from 300- 500 km in diameter. The wind in the centre of cyclone blows in the speed of 120km/hr.
3. The main requirement of formation of tropical cyclone is that the sea surface temperature (SST) must be below 25°C. The tropical cyclone move like a spinning top at the speed of 10-30 Km/hr.
4. In India cyclone originates from Bay of Bengal are more in number and intensity. Relatively less south-west Indian Ocean and Arabian Sea. In India cyclones occur during October-December or April-May.

Effects:

1. Damage to human life, crops, roads, transport, and communication could be heavy.
2. Cyclone slows down developmental activities of the area.

Management:

1. Meteorological Departments forecast by satellite images the weather conditions which reveal the strength and intensity of the storm.
2. Radar systems is used to detect cyclone and cyclone warning.
3. The effect of cyclone is minimized by planting more trees on the coastal belts, constructional dams, wind breaks etc.

(iii) Earthquake: Sudden vibration occurs in the earth crust.

Causes:

1. Earthquakes are caused due to disequilibrium in any part of the earth crust.
2. It is caused by hydrostatic pressure of reservoirs, dams, lakes
3. Underground nuclear testing
4. Decrease of underground water level

Severity of an earthquake

S.No	Richter Scale	Severity of an earthquake
1	Less than 4	Insignificant
2	4-4.9	Minor
3	5-5.9	Damaging
4	6-6.9	Destructive
5	7-7.9	Major
6	More than 8	Great

Effects:

1. It causes landslides
2. It collapses houses and people die in thousand if severity is major.
3. It results in deformation of ground surface.
4. Tsunami, the seismic waves caused by earthquakes, causes great loss of life and property.

Management:

1. By constructing earthquake resistant buildings
2. Wooden houses are preferred in earthquake prone areas.
3. Seismologist indicates the possibility of occurrence of earthquakes

11. Write the factors influence the unsustainable to sustainable development. Or Discuss the recent approaches to achieve sustainable development. (Apl-May 2019) Or Suggest important measures to be adopted in achieving sustainable development. (May-June 2013) (May-June 2016) (Nov-Dec 2019)

Sustainable development is defined as meeting the needs of the present generation without compromising the requirement of future generation.

Sustainable development aims at:

- Optimum use of natural resources.
- High degree of reusability
- Minimum wastage
- Least generation of toxic by products/pollutants
- Maximum productivity

Significance of sustainable development

- Promoting equality
- Economic efficiency
- Ecological harmony
- Sustaining our natural resources
- Improving the quality of life

The above goals can be achieved through the following equality.

- a) Inter generational equality- It states that we should handover a healthy environment to our future generation
- b) Intra generational equality- It emphasizes that the technological development of rich countries should support the economic growth of the poor countries and help to improve their wealth.

Approaches for sustainable development:

- Conserving all non renewable sources by recycling and reuse
- Controlling and avoiding pollution
- Developing appropriate technologies with minimum environmental hazards
- The stock and supply of natural resources are to be known by the people
- Degradation of resources should be avoided by educating the people
- Providing environmental education and awareness, the attitude of the people towards our earth and resources can be changed
- Economic policies are to be framed as so to protect and develop farm, sustainable agriculture and fertile soil.

12. Discuss the phenomenon of global warming and the factors contributing to it. (Nov-Dec 2013) (Apl-May 2018) (Nov-Dec 2019) Or Outline the effects of global warming. (Nov-Dec 2019) (Apl-May 2019)

Definition

The raise of earth's surface temperature due to intense green house effect is called global warming.

Causes:

The level of carbon dioxide in the atm has increased by 25%, the level of nitrous oxide by 19% and the level of methane by 100%.

Effects of global warming

1. Sea level increases as result of melting and thermal expansion of ocean.
2. High CO₂ level in the atmosphere have a long term negative effect on crop production and forest growth.
3. Global rainfall pattern will change .Drought and floods will become more common. Raising temperature will increase domestic water demand.
4. Many plants and animal species will have a problem of adapting. Many will be at the risk of extinction, more towering verities will thrive.
5. As the earth becomes warmer the floods and drought becomes more frequent. There would be increase in water-borne diseases.

Measures to check global warming:

1. CO₂ emission can be cut by reducing the use of fossil fuel.
2. Plant more rees.
3. Shifting from coal to natural gas.
4. Stabilize population growth.
5. Remove efficiently CO₂ from smoke stocks.
6. Removal atmospheric CO₂ by utilizing photo synthetic algae.

13. Distinguish between natural and enhanced green house effect. (Nov-Dec 2019)

S.No	Natural green house effect	Enhanced green house effect
1	The green house effect is the trapping of heat under the atmosphere, which is a natural effect.	When green house gases concentrations are too high, they trap too much heat and increase the temperature on earth by human activities causing the enhanced greenhouse effect.
2	The natural green house gases are CO ₂ and water vapour which contributes to average global temperature of about 15°C .	The enhanced green house gases are CFC, CH ₄ , NO, HCFC increases the average global temperature beyond 15°C
3	Heat trapped by green house gases in the atmosphere keeps the planet warm enough to allow us and other species to exist.	It causes global warming, raise in sea level, affects agriculture, affects human health.

UNIT V

HUMAN POPULATION AND THE ENVIRONMENT

1. Explain the population explosion on the environment. (Nov-Dec 2013) (Nov-Dec 2015) (Nov-Dec 2016)

The enormous increase in population, due to low death rate (mortality) and high birth rate (natality) is termed as '**the population explosion**'.

Causes:

1. Invention of modern medical facilities reduces the death rate and increase the birth rate.
2. Increase of life expectancy is another important reason for the population explosion.

Effects:

1. Poverty:

Infant mortality is one of the most tragic indicators of poverty. There are still 34 developing countries where 1 in 10 children die before the age of 5 due to poverty.

2. Population explosion leads to environmental degradation.
3. Population explosion causes over exploitation of natural resources which lead to scarcity.
4. The economic inequity, communal war and increase in disease are arises due to population explosion.
5. Unemployment, low living standard, development of slums, scarcity in basic amenities are also due to population explosion.

2. Explain variation of population among nations.

At present the world's population has crossed 6 billion. Less developed countries have 80% of the total world population and developed countries have 20% of the world population.

Variation of population based on age structure:

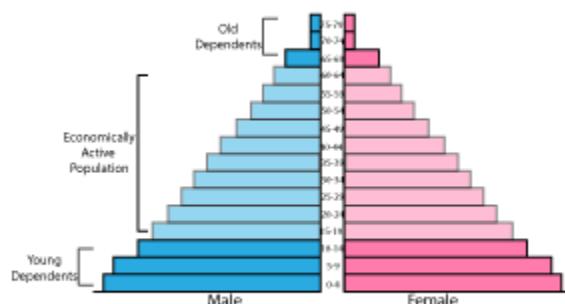
Age structure of population can be classified into three classes.

- (i) Pre-productive population (0-14 years)
- (ii) Reproductive population (15-44 years)
- (iii) Post productive population (above 45 years)

Variation of population is now explained based on the above three classes.

1. Pyramid shaped variation of population: (increase)

Ex: India, Bangladesh, Ethiopia, Nigeria etc.



The above figure shows that the pre-productive population is more, indicated at the base of the pyramid, and post productive population is less, and indicated at the top of the pyramid. But the less number of old age people indicates less loss of population due to death.

2. Bell shaped of population (stable)

Ex: USA, UK, Canada etc.,

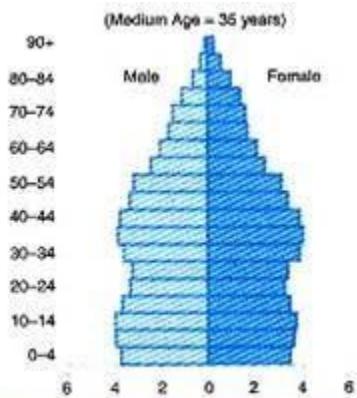


Fig. 6.2. Stable age pyramid

The above figure shows the pre productive population and reproductive population are more or less hence the population growth is stable.

3. Urn shaped variation of population (decrease):

Ex: Germany, Italy, Sweden, Japan etc.,

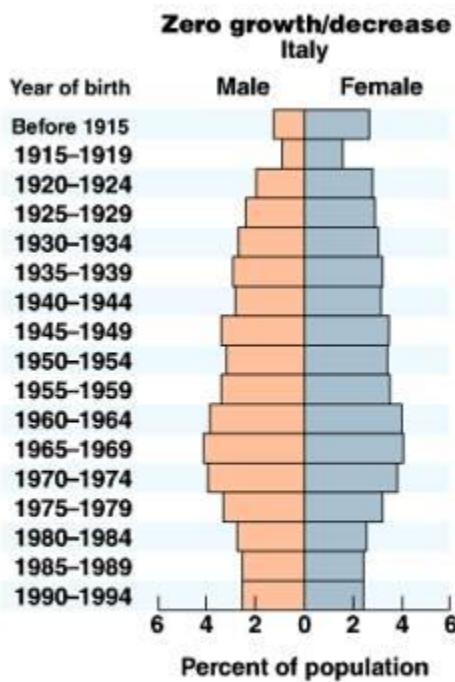


Fig. 5.2 Urn shaped Population structure

The above figure shows that the pre-productive population is smaller than the reproductive population. In the next 10 years, the number of people in the reproductive age group is less than the before, resulting in a decrease of population growth.

3. Describe in detail about the family planning programme. (Nov-Dec 2013) (May-Jun 2014)

Family planning provides educational and clinical services that help people to design their family. Such programmes provide information on birth spacing, birth control and health care for pregnant and infants; but it may vary from culture to culture.

Objectives:

1. Reduce the infant mortality rate to below 30 to 1000 infants.
2. Achieve 100% registration of births, deaths, marriage and pregnancy.
3. Encourage late marriage and later child bearing.
4. Encourage breast feeding.
5. Enables to improve women's health, education and employment.
6. Prevent and control of communicable diseases like AIDS.
7. Making school education up to age 14 compulsory and free.
8. The family norms for the small family is strongly promoted.

Family planning methods:

The '**traditional method**' includes taboos and folk medicine.

The following '**modern methods**' have also been followed;

a) Permanent method:

In this method the family planning is done by a minor surgery.

- i) **Tubectomy:** It is female sterilization done by tying the ovary tubes.
 - ii) **Vasectomy:** It is male sterilization done by tying the tubes carry the sperm.
- Both the above methods are,
- ✓ Very simple
 - ✓ Painless
 - ✓ No post operative problems.

b) Temporary method:

- i) Using condoms:- used by male to prevent the movement of sperm to uterus.
- ii) Using Copper Ts:- Used by female to prevent the movement of ovum.
- iii) Oral contraceptive pills and injectable drugs: used both by male and female.

Family planning programme in India

- The family planning programme was started in the year 1952.
- The family planning campaign by Indian Government in 1970s.
- In 1978, the Government raised the minimum legal age for marriage as 21 for male and 18 for female.
- In 1981, the funding for the family planning programme was raised due to population explosion.

4. Write a detailed account on human rights. (Apr-May 2015) (Nov-Dec 2015) (Apr-May 2019)

Human rights are the fundamental rights which are possessed by all human beings irrespective of their caste, nationality, sex and language.

These are natural rights and cannot be taken back by any act or legislation.

Universal Declaration of Human Rights:

The declarations of human rights by UN were established in 1948.

- 1) Human Right to Freedom- every citizen has the right to express their views.
- 2) Human Right to Property- has the right to earn their own property.
- 3) Human Right to Freedom of religion-all the religion is equal before the law.
- 4) Human Right to Freedom of culture and education- have equal rights both in culture and cultivation.
- 5) Human Right to Constitutional remedies- the court has the power to protect the basic rights of

the citizens.

- 6) Human Right to Equality-all are equal before law.
- 7) Human Right to Against exploitation-to fight against exploitation, eg. Child labour.
- 8) Human Right to Right to food and environment-have the right to get sufficient, safe and hygienic food, water.
- 9) Human Right to Good health - to have physical and mental health.

5. Explain the need and importance of value education. (May-Jun 2013) (Nov-Dec 2014) (Apr-May 2015) (Nov-Dec 2015) (Nov-Dec 2016) (Apr-May 2018)

Value education is a tool used to analyze our behavior and provide proper direction to our youths. It teaches them what is right and wrong; teaches them to be compassionate, helpful, loving, generous and tolerant.

Objectives of value education:

- (1) Improve integral growth of human beings
- (2) Improve attitudinal improvements towards sustainable lifestyle.
- (3) Awareness on notational history, culture, heritage, constitutional rights, national integration, community development and environment protection.
- (4) Awareness about values and their significance and role.
- (5) Understand environment and linkages between air, water and land.
- (6) Know about living and non-living things and their interaction with environment.

Concept of value education:

- (1) Why to use less resources and energy?
- (2) Why to keep surroundings clean?
- (3) Why to use less fertilizers and pesticides and instead use biofertilizers?
- (4) Why to save water?
- (5) Why to separate biodegradable and non-biodegradable wastes?

Methods imparting value education:

- (1) Telling – own narration of the situation.
- (2) Modeling – individual perceived as ideal values as models.
- (3) Role playing – acting out of true feelings.
- (4) Problem solving –decision making
- (5) Studying biographies of great men- to elicit good deeds and thoughts for emulation.

Types of values:

- (1) Universal/Social values- not to spit in the street
- (2) Cultural values- not to wear chapels inside temples
- (3) Individual values- related to individual goals and objectives.
- (4) Global value- don't emit pollutants
- (5) Spiritual value-leave all desire.

6. Describe the causes, preventive measures and effects of HIV/AIDS: (May-Jun 2013) (Nov-Dec 2013) (May-Jun-2014) (Apr-May 2015) (Nov-Dec 2015) (May-Jun 2016) (Apr-May 2017) (Apr-May 2017) (Apr-May 2018) (Nov-Dec 2018)

AIDS-Acquired immuno deficiency syndrome

HIV-Human immune deficiency virus.

It was discovered in **1983**.

It was spread from Africa through **African Monkeys**.

The virus may spread through **HIV contaminated polio vaccine** prepared from monkeys.

It was spread through **hepatitis-B viral vaccine** in Los Angels and New York.

Also spread through **small pox vaccine** program from Africa.

Facts:

- 1) 90% AIDS affected people in developing countries.
- 2) 13% affected people live in Africa
- 3) All countries in Africa affected.
- 4) 3 million people so far died.
- 5) India ranks 2nd with 5.1 million affected people.
- 6) Largest in India is in Maharashtra and TamilNadu.
- 6) In TamilNadu 24667 cases identified.

Factors influencing the transmission of HIV:

- 1) Spreads through blood contact (during unprotected sex with infected person)
- 2) The HIV virus spread through the usage of contaminated needles and syringes.
- 3) Infected Mother to baby during pregnancy, delivery and mother feeding.
- 4) Blood transfusion from infected person.
- 5) male to female transmission is 4 times powerful
- 6) Women at the age group of 18-20 are more vulnerable.

AIDS not transmitted by:

Food, tears, air, cough, handshake, mosquito, flies, insect bites, urine, saliva, sharing of utensils, clothes, toilet, bathroom etc.

Functions of HIV in body:

- 1) Death occurs due to weakening of immune system (not by the disease itself).
- 2) White blood cells form antibodies called T-helper cells. T-helper cells fight diseases (and responsible for immunity). HIV destroys T-helper cells-hence even cancer can easily develop.
- 3) Normally no symptom-some get fever, head ache and fatigue.
- 4) HIV is present in large amounts in semen and vaginal fluid.
- 5) HIV very active in human body and readily multiplies and kills more and more T—cells.
- 6) Consumption of alcohol increases the susceptibility
- 7) Remains infected throughout life
- 8) No vaccine available.

Minor symptoms:

- 1) Persistent cough for more than 1 month
- 2) General skin disease
- 3) Viral infection
- 4) Fungus infection in mouth and throat
- 5) Frequent fever, headache and fatigue

Major symptoms:

- 1) Fever for more than 1 month
- 2) Diarrhea for more than 1 month.
- 3) Cough & TB for more than 6 months
- 4) Fall of hairs
- 5) 10% weight loss within a short period

CONTROL/PREVENTION:

- 1) Health education to the public.
- 2) Prevention of blood borne HIV transmission.
- 3) Primary health care through voluntary health agencies and health workers
- 4) Counseling to infected persons.
- 5) Drug treatment, nutrient diet, less stress.

Effects of HIV/AIDS:

- 1) Larger death which affects the environment and natural resources
- 2) Loss of man power and production loss due to larger death.

3) More water is to be used by AIDS infected persons to maintain hygienic.

4) Will live as unproductive persons (loss of human resource)

SCREENING TEST FOR AIDS

The purpose of screening is early diagnosis and treatment. Screening tests are usually administered to people without current symptoms, but who may be at high risk for certain diseases or conditions.

Screening Tests

People who are at increased risk of HIV infection may be screened for the virus. Screening tests include:

- ELISA test -This test is used to detect HIV infection. If an ELISA test is positive, the Western blot test is usually performed to confirm the diagnosis. The ELISA test may be negative if you were recently infected with HIV. Many people with HIV (95%) will have a positive test within three months of the time they became infected. Most people with HIV (99%) will have a positive test within six months. If an ELISA test is negative, but you think you may have HIV, get tested again in 1-3 months.
- Western Blot -This test is very specific at identifying HIV. It is used to confirm a positive ELISA test result.
- OraQuick Rapid HIV-1 antibody test-This is a preliminary test using saliva. This test should be confirmed by an ELISA test.

7. What is EIA? Explain the objectives, benefits and process of EIA. (May-Jun 2016) (Apr-May 2017)

EIA is **Environmental Impact Assessment**; it is defined as a formal process of predicting the environmental consequences of any development projects.

Objectives:

1. To identify the main issues and problems of the parties.
2. To identify who is the party.
3. To identify what are the problems of the parties.
4. To identify why the problems are arise.

Benefits:

1. Cost and time of the project is reduced.
2. Performance of the project is improves.
3. Biodiversity is maintained.
4. Human health is not much affected.
5. Usage of natural resources minimized.

Process of EIA:

1. Scoping:

It is used to identify the key issues of the planning process at the earliest and to identify the possible alternatives.

2. Screening:

It is used to decide whether an EIA is required or not based on the information collected.

3. Identifying and evaluating alternatives:

It involves knowing alternatives sites and techniques and their impacts.

4. Mitigating measures dealing with uncertainty:

It reviews the action taken to prevent or minimize the adverse effects of a project.

5. Environmental statements:

It reports the findings of the EIA

8. Describe in detail about the women welfare and child welfare. (Nov-Dec 2013) (May-Jun 2014) (Nov-Dec 2014) (Apr-May 2015) (Nov-Dec 2015) (May-Jun 2016) (Apr-May 2018)

WOMEN WELFARE

Women are suffering a lot as they are soft, weak, helpless and economically dependent.

Need for women welfare:

As the Women facing the problems, it is essential to reform the policies and awareness.

- 1) Women suffer gender discrimination (devaluation at home, at workplace, in matrimony, in public life and power)
- 2) High incidences of dowry deaths, rape, domestic violence, criminal offences and mental torture to women
- 3) Male dominates society violates women's rights
- 4) In policy making at home and in society women are neglected.

Objectives of women welfare:

- 1) To provide education
- 2) To impart vocational training
- 3) To generate awareness about environment
- 4) To improve employment opportunities
- 5) To awareness of problems of having more children and preventive measures
- 6) To restore dignity, status, equality and respect for women.

NATIONAL COMMISSION FOR WOMEN

A national commission for women has been created by the Government of India. The objectives are,

- 1)To examine constitutional and legal rights of women
- 2) To review existing legislations
- 3) To sensitize enforcement and administrative machinery to women's causes.

Schemes for women welfare:

- 1) National network for women and mining (**NNWM**) - it is fighting for a 'gender audit' of India's mining companies.
- 2) UN decade for women- the inclusion of women welfare issues.
- 3) International convention on the elimination of all forms of discrimination against women (**CEDAW**)- for the protection and promotion of women's socio economic upliftment.
- 4) NGOs and Mahila mandals- creates awareness in village women-on education and make them economically independent.
- 5) Ministry for women and child development- creates awareness by giving education.

CHILD WELFARE

Children are the assets of a society. But most of the children are involved in working as child labors in industries.

Reasons for child labor:

- 1) Poverty
- 2) Head of the family not alive
- 3) Both parents leave the children/die
- 4) Want of money.

Schemes for child welfare:

- 1) UN conventions on rights of child (or) International law:
 - ✓ Right to survival
 - ✓ Right to Participation
 - ✓ Right to development
 - ✓ Right to protection.
- 2) World summit on children- It targets mainly on the well being of children.
- 3) Ministry of Human Resources Development (MHRD): It concentrates on the Child's health, education, nutrition, safe drinking water, sanitation and environment

4) Centre for Science and Environment (CSE) Children are more susceptible than adult in environmental contamination; need better and cleaner environment.

9. Describe the role and applications of IT in human health. (Nov-Dec 2013 and 2014) (Apr-May 2015) (Nov-Dec 2016) (Apr-May 2017) (Nov-Dec 2017) (Apr-May 2018) (Nov-Dec 2018)

Information Technology (It) means Data collection, processing, reporting and dissemination of information.

The tools used are Internet (WWW), Geographical Information system (GIS) etc.

APPLICATION OF IT:

1) **Remote sensing:** It can be used to gather information. The main applications are

- in agriculture – provide valuable information for land and water development.
- in forestry- provide information on density of forest, biomass encroachment etc.
- in land cover- provide mapping , spatial resolution etc.,
- in water resources- provide information about flood monitoring, irrigation water management, inventorying surface water bodies etc monsoon activity.

2) **Data base:** The data base can be easily manageable and quickly retrieved.

Applications:

- The Ministry of Environment & Forest: database on biotic system, database on diseases.
- National management information system (NMIS):data base for R&D
- Environment Information system (ENVIS): data base for pollution control, environmental management etc.

3) **Geographical Information system (GIS):** It is a technique of superimposing various thematic maps using digital data on a large number of inters related aspects.

Application:

- thematic maps containing water resources, soil type, forest land, cropland, grass land as superimposed layers-
- Interpretation of polluted zones, degraded lands.
- To check unplanned growth and environmental problems

4) **Satellite data:**

- Provide reliable data about forest cover
- Gives information about monsoon pattern, ozone layer depletion, smog etc.

IT AND HUMAN HEALTH

Information Technology plays a vital role in human health. The Health services involves,

- 1) Finance and accounting
- 2) Pathology
- 3) Patient administration and clinical systems

Application of IT in Health Services:

- 1) Data on birth rate, death rate, immunization and sanitation programs, water supply etc. are maintained accurately.
- 2) To monitor the health of the patient
- 3) Outbreak of epidemics can be easily conveyed.
- 4) Consulting on-line consultancy with expert doctors
- 5) Centralized control of hospitals
- 6) Drugs purchase administration

10. Explain the applications of remote sensing in environment management (Nov-Dec 2019)

1. **In agriculture:** In India, the agriculture sector sustains the livelihood of around 70% of the population and contributes to about 35% of the net national product. We require judicious and optimal management of both land and water resources along with the use of high yielding variety

seeds, optimal fertilizer input, postcentral etc., Remote sensing can provide valuable information for land and water management.

2. In forestry: Sustainable forest management requires reliable information on the type, density and extent of forest cover, wood volume and biomass, forest fire, pest and disease induced losses, encroachment etc., Remote sensing provides all such information clearly.

3. In land cover: Spatial information on land use is required at different scales depending upon use. Remote sensing data is converted to map, the spatial resolution plays a role on the scale of mapping.

4. Water resources: Remote sensing data has been used in many applications related to water resources such as surface water body mapping, ground water targeting, wetland, inventory, flood monitoring, reservoir sedimentation, water quality, run-off modeling, snowcover monitoring, irrigation water management and many more. One of the most simple applications is inventorying surface water bodies.
