Chapter 1
Units and Measurements

TYPE A : MULTIPLE CHOICE QUESTIONS

1. The dimensions of Planck's constant are ***[1997]***
(a) $[ML^{-3}T^{-1}]$ (b) $[ML^{-2}T^{-1}]$
(c) $[M^0L^{-1}T^{-3}]$ (d) $[ML^2T^{-1}]$

2. The dimensional formula of magnetic flux is ***[1998]***
(a) $[ML^0T^{-2}A^{-1}]$ (b) $[ML^2T^{-2}A^{-1}]$
(c) $[ML^2T^{-1}A^3]$ (d) $[M^0L^{-2}T^{-2}A^{-2}]$

3. The dimensional formula of the constant a in Vander Waal's gas equation
$\left(P+\frac{a}{V^2}\right)(V-b)=RT$ is: ***[1999]***
(a) $[ML^4T^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^5T^{-3}]$ (d) $[ML^5T^{-2}]$

4. What is the dimensional formula of gravitational constant? ***[2000]***
(a) $[ML^2T^{-2}]$ (b) $[ML^{-1}T^{-1}]$
(c) $[M^{-1}L^3T^{-2}]$ (d) none of these

5. Which of the following pairs does not have similar dimensions ? ***[2001]***
(a) tension and surface tension
(b) stress and pressure
(c) Planck's constant and angular momentum
(d) angle and strain

6. The length and breadth of a metal sheet are 3.124 m and 3.002 m respectively. The area of this sheet upto four correct significant figure is : ***[2001]***
(a) 9.378 m^2 (b) 9.37 m^2
(c) 9.378248 m^2 (d) 9.3782 m^2

7. The dimensions of energy are ***[2002]***
(a) $[ML^3T^{-3}]$ (b) $[ML^{-1}T^{-1}]$
(c) $[ML^2T^{-2}]$ (d) $[MT^{-2}]$

8. Velocity of light is equal to ***[2002]***
(a) $\sqrt{\frac{1}{\varepsilon_0\mu_0}}$ (b) $\sqrt{\varepsilon_0/\mu_0}$
(c) ε_0/μ_0 (d) $\varepsilon_0\mu$

9. Using mass (M), length (L), time (T) and current (A) as fundamental quantities, the dimensions of permeability are : ***[2003]***
(a) $[M^{-1}LT^{-2}A]$ (b) $[ML^{-2}T^{-2}A^{-1}]$
(c) $[MLT^{-2}A^{-2}]$ (d) $[MLT^{-1}A^{-1}]$

10. Using mass (M), length (L), time (T) and current (A) as fundamental quantities, the dimensional formula of permittivity is : ***[2004]***
(a) $[ML^{-2}T^2A]$ (b) $[M^{-1}L^{-3}T^4A^2]$
(c) $[MLT^{-2}A]$ (d) $[ML^2T^{-1}A^2]$

11. "Parsec" is the unit of : ***[2005]***
(a) time
(b) distance
(c) frequency
(d) angular acceleration

12. Dimensions of electrical resistance are : ***[2005]***
(a) $[ML^2T^{-3}A^{-1}]$ (b) $[ML^2T^{-3}A^{-2}]$
(c) $[ML^3T^{-3}A^{-2}]$ (d) $[ML^{-1}L^3T^3A^2]$

13. The magnetic moment has dimensions of: ***[2006]***
(a) $[LA]$ (b) $[L^2A]$
(c) $[LT^{-1}A]$ (d) $[L^2T^{-1}A]$

14. Which of the following physical quantities do not have same dimensions? ***[2007]***
(a) pressure and stress
(b) tension and surface tension
(c) strain and angle
(d) energy and work.

15. What is the dimensions of impedance? ***[2007]***
(a) $ML^2T^{-3}I^{-2}$ (b) $M^{-1}L^{-2}T^3I^2$
(c) $ML^3T^{-3}I^{-2}$ (d) $M^{-1}L^{-3}T^3I^2$

16. The speed of light (c), gravitational constant (G) and planck's constant (h) are taken as fundamental units in a system. The dimensions of time in this new system should be ***[2008]***

(a) $G^{1/2}\ h^{1/2}\ c^{-5/2}$ (b) $G^{-1/2}\ h^{1/2}\ c^{1/2}$

(c) $G^{1/2}\ h^{1/2}\ c^{-3/2}$ (d) $G^{1/2}\ h^{1/2}\ c^{1/2}$

17. Dimensions of coefficient of viscosity is ***[2010]***

(a) $[MT^2]$ (b) $[ML^{-3}T^{-4}]$

(c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-1}T^{-1}]$

18. Which of the following pair of quantities do not have the same dimensions : ***[2011]***

(a) Potential gradient, electric field

(b) Torque, kinetic energy

(c) Light year, time period

(d) Impedance, reactance

19. The dimensional formula for torque is : ***[2011]***

(a) ML^2T^{-2} (b) $ML^{-1}T^{-1}$

(c) L^2T^{-1} (d) $M^2T^{-2}K^{-1}$

20. What is the fractional error in g calculated from $T = 2\pi\sqrt{\ell/g}$? Given fraction errors in T and l are $\pm$ x and $\pm$ y respectively? ***[2012]***

(a) $x + y$ (b) $x - y$

(c) $2x + y$ (d) $2x - y$

21. The dimensional formula of farad is ***[2012]***

(a) $[M^{-1}L^{-2}TQ]$ (b) $[M^{-1}L^{-2}T^2Q^2]$

(c) $[M^{-1}L^{-2}TQ^2]$ (d) $[M^{-1}L^{-2}T^2Q]$

22. The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and length are 4% and 3% respectively, the maximum error in the measurement of density will be ***[2013]***

(a) 7% (b) 9%

(c) 12% (d) 13%

23. The dimensions of $\left(\frac{1}{2}\right)\varepsilon_0 E^2$ (ε_0 : permittivity of free space, E electric field) are ***[2014]***

(a) $[MLT^{-1}]$ (b) $[ML^2T^{-2}]$

(c) $[ML^{-1}T^{-2}]$ (d) $[ML^2T^{-1}]$

24. The least count of a stop watch is 0.2 second. The time of 20 oscillations of a pendulum is measured to be 25 second. The percentage error in the measurement of time will be ***[2015]***

(a) 8% (b) 1.8%

(c) 0.8% (d) 0.1%

25. If e is the charge, V the potential difference, T the temperature, then the units of $\frac{eV}{T}$ are the same as that of ***[2016]***

(a) Planck's constant

(b) Stefan's constant

(c) Boltzmann constant

(d) Gravitational constant

26. If the capacitance of a nanocapacitor is measured in terms of a unit 'u' made by combining the electric charge 'e', Bohr radius 'a_0', Planck's constant 'h' and speed of light 'c' then ***[2016]***

(a) $u = \frac{e^2 h}{a_0}$ (b) $u = \frac{hc}{e^2 a_0}$

(c) $u = \frac{e^2 c}{h a_0}$ (d) $u = \frac{e^2 a_0}{hc}$

27. A force F is applied onto a square plate of side L. If the percentage error in determining L is 2% and that in F is 4%, the permissible percentage error in determining the pressure is ***[2017]***

(a) 2% (b) 4%

(c) 6% (d) 8%

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 28-30) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

28. **Assertion :** The dimensional formula for relative velocity is same as that of the change in velocity.

Reason : Relative velocity of P w.r.t. Q is the ratio of velocity of P and that of Q. ***[2002]***

29. **Assertion :** Specific gravity of a fluid is a dimensionless quantity.

Reason : It is the ratio of density of fluid to the density of water. ***[2005]***

30. **Assertion :** The error in the measurement of radius of the sphere is 0.3%. The permissible error in its surface area is 0.6%

Reason : The permissible error is calculated by the formula $\frac{\Delta A}{A} = \frac{4\Delta r}{r}$ ***[2008]***

Directions for (Qs.31-33) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

31. **Assertion :** When percentage errors in the measurement of mass and velocity are 1% and 2% respectively, the percentage error in K.E. is 5%.

Reason : $\frac{\Delta E}{E} = \frac{\Delta m}{m} + \frac{2\Delta v}{v}$ ***[2010]***

32. **Assertion :** The number of significant figures depends on the least count of measuring instrument.

Reason : Significant figures define the accuracy of measuring instrument. ***[2016]***

33. **Assertion:** In the measurement of physical quantities direct and indirect methods are used.

Reason : The accuracy and precision of measuring instruments along with errors in measurements should be taken into account, while expressing the result. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (d) $E = h\nu$, h is Planck's constant

$$[h] = \frac{[E]}{[\nu]} = \frac{ML^2T^{-2}}{T^{-1}} = ML^2T^{-1}$$

2. (b) $F = Bqv \Rightarrow F = \frac{\phi}{A}qv$

$$\phi = \frac{F.A}{qv} = \frac{MLT^{-2}L^2}{ATLT^{-1}} = ML^{+2}A^{-1}T^{-2}$$

3. (d) Here the dimension of $\frac{a}{V^2}$ will be equal to pressure so $\frac{a}{(L^3)^2} = ML^{-1}T^{-2}$

$a = ML^5T^{-2}$

4. (c) $F = \frac{G.M.M}{L^2} = MLT^{-2}$

$$G = \frac{MLT^{-2}L^2}{M^2} = M^{-1}L^3T^{-2}$$

5. (a) Tension will have dimension of force and surface tension will have dimension of force per unit length so they have different dimensions.

6. (a) Area of metal sheet $= 3.124 \times 3.002$
$= 9.378248$
Now, the result must have significant figures equal to the least of figure being multiplied, so, Area of metal sheet $= 9.378$ m^2

7. (c) Torque = Force × distance = Energy
$= MLT^{-2}L = ML^2T^{-2}$

8. (a) Velocity of light, $c = \sqrt{\frac{1}{\varepsilon_0\mu_0}}$

9. (c) $B = \mu ni$; $F = Bqv$

$F = \mu ni qv \Rightarrow \mu = \frac{F}{niqv}$

$$\mu = \frac{MLT^{-2}}{\frac{1}{L}A.AT.LT^{-1}}$$

[n is no. of turns per unit length]

$= MLA^{-2}T^{-2}$

10. (b) $F = \frac{1}{4\pi\epsilon_0}.\frac{q_1q_2}{r^2} \Rightarrow \epsilon_0 = \frac{q_1q_2}{4\pi Fr^2}$

$$\frac{AT.AT}{MLT^{-2}L^2} = \frac{A^2T^2}{ML^3T^{-2}} = M^{-1}L^{-3}A^2T^4$$

11. (b) Parsec is a unit of length on the astronomical scale. It is the distance of an object that will show a parallax of 1" of arc from opposite side of a baseline (radius) equal to the distance between sun and earth.

1 parsec $= 3.1 \times 10^{16}$ m

12. (b) $R = \frac{V}{I} = \frac{W}{qI}$ $\left(\text{Work} = V \times q \Rightarrow V = \frac{W}{q}\right)$

$$R = \frac{ML^2T^{-2}}{AT.A} = ML^2A^{-2}T^{-3}$$

13. (b) Magnetic moment of a coil carrying current is,
$M = I.A$
[A is area of cross section and i is current]
Dimension of $M = AL^2$

14. (b) Tension is a force and surface tension is force per unit area hence their dimensions are not same.

15. (a) Impedance is same as resistance but in ac circuit
∴ Dimension of impedance

$$= \frac{\text{dimension of voltage}}{\text{dimension of current}}$$

$$= \frac{[V]}{[I]} = \frac{[ML^2T^{-3}I^{-1}]}{I} = [ML^2T^{-3}I^{-2}]$$

16. (a) Let time, $T \propto c^xG^yh^z$
$\Rightarrow T = kc^xG^yh^z$

Taking dimensions on both sides

$[M^0L^0T^1] = [LT^{-1}]^x[M^{-1}L^3T^{-2}]^y[ML^2T^{-1}]^z$

i.e.,

$[M^0L^0T^1] = [M^{-y+z}L^{x+3y+2z}T^{-x-2y-z}]$

Equating power of M, L, T on both sides, we get

$-y+z=0 \quad \ldots(1)$

$x+3y+2z=0 \quad \ldots(2)$

$-x-2y-z=1 \quad \ldots(3)$

From (1) $\Rightarrow z = y$

Adding (2) and (3) $\Rightarrow y+z=1$

or $2y=1$ [From (1)]

i.e., $y=\frac{1}{2}$

$\therefore z = y = \frac{1}{2}$

Putting these values in (2) we get

$x+\frac{3}{2}+1=0$ or $x=\frac{-5}{2}$

Hence, $[T]=[G^{1/2}h^{1/2}c^{-5/2}]$

17. **(d)** Coefficient of viscosity, $\eta = \dfrac{F}{A\frac{dv}{dx}}$

$[F] = [\text{Force}] = MLT^{-2}$

$[A] = [\text{Area}] = L^2$

$\left[\frac{dv}{dx}\right] = [\text{Velocity gradient}] = \frac{LT^{-1}}{L} = T^{-1}$

$\therefore\ [\eta] = \frac{MLT^{-2}}{L^2T^{-1}} = [ML^{-1}T^{-1}]$.

18. **(c)** Light year has the dimensions of distance and time period is time.

19. **(a)** $\tau = Fr = MLT^{-2}L = ML^2T^{-2}$

20. **(c)** From $T = 2\pi\sqrt{\frac{\ell}{g}}$; $g = 4\pi^2\frac{\ell}{T^2}$

$$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + \frac{2\Delta T}{T} = (y+2x)$$

21. **(b)** $[C] = \left[\frac{Q}{V}\right] = \left[\frac{Q^2}{W}\right] = [M^{-1}L^{-2}T^2Q^2]$

22. **(d)** Density $= \frac{\text{Mass}}{\text{Volume}}$

$\rho = \frac{M}{L^3}$, $\quad \frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 3\frac{\Delta L}{L}$

% error in density = % error in Mass + 3 (% error in length) $= 4+3(3) = 13\%$

23. **(c)** Here $\left(\frac{1}{2}\right)\varepsilon_0E^2$ represents energy per unit volume

$[\varepsilon_0][E^2] = \frac{\text{Energy}}{\text{volume}} = \frac{[ML^2T^{-2}]}{[L^3]}$

$= ML^{-1}T^{-2}$

24. **(c)** $\frac{0.2}{25}\times100 = 0.8$

25. **(c)** $\frac{eV}{T} = \frac{W}{T} = \frac{PV}{T} = R$

and $\frac{R}{N}$ = Boltzmann constant.

26. **(d)** Let unit 'u' related with e, a_0, h and c as follows :

$[u] = [e]^a[a_0]^b[h]^c[C]^d$

Using dimensional method,

$[M^{-1}L^{-2}T^{+4}A^{+2}]$

$= [A^1T^1]^a[L]^b[ML2T^{-1}]^c[LT^{-1}]^d$

$[M^{-1}L^{-2}T^{+4}A^{+2}] = [M^cL^{b+2c+d}T^{a-c-d}A^a]$

$a = 2, b = 1, c = -1, d = -1$

$\therefore \quad u = \frac{e^2a_0}{hc}$

27. **(d)** As, pressure $P = \frac{F}{A} = \frac{F}{L^2}$

$\%\ \text{Error} = \frac{\Delta F}{F}\times100 + 2\frac{\Delta L}{L}\times100$

$= 4 + 2\times2 = 8\%$

Type B : Assertion Reason Questions

28. **(e)** Relative velocity which is vector subtraction of two velocities will also be a vector of the form of velocity so, its dimensional formula will remain unchanged. Relative velocity is measured not by calculating ratio but by calculating difference.

29. **(a)** Specific gravity of fluid

$$= \frac{\text{density of fluid}}{\text{density of water}}$$

It is a ratio.

30. **(c)** Area of the sphere, $A = 4\pi r^2$

% error in area = 2 × % error in radius

i.e., $\frac{\Delta A}{A} \times 100 = 2 \times \frac{\Delta r}{r} \times 100$

$= 2 \times 0.3\% = 0.6\%$

But $\frac{\Delta A}{A} = 4\frac{\Delta r}{r}$ is false.

31. **(a)** Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

Kinetic energy, $E = \frac{1}{2}mv^2$.

Differenting both side

$$\frac{\Delta E}{E} = \frac{\Delta m}{m} + \frac{2\Delta v}{v}$$

$$\frac{\Delta E}{E} = \frac{1}{100} + 2 \times \frac{2}{100} = \frac{5}{100} = 5\%$$

32. **(b)** Significant figure refers to the accuracy of measurement and accuracy of measurment also depends upon the least count of measuring instrument.

33. **(a)**

Chapter

2 Motion in a Straight Line

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If a car at rest accelerated uniformly to a speed of 144 km/hour in 20 second it covers a distance : *[1997]*

(a) 400 m (b) 1440 m
(c) 2880 m (d) 25 m

2. A ball is dropped from a bridge 122.5 m high. After the first ball has fallen for 2 second, a second ball is thrown straight down after it, what must be the initial velocity of the second ball be, so that both the balls hit the surface of water at the same time? *[1997]*

(a) 26.1 m/s (b) 9.8 m/s
(c) 55.5 m/s (d) 49 m/s

3. A particle is thrown vertically upwards. Its velocity at half of the height is 10 m/s, then the maximum height attained by it will be : $(g = 10\ m/s^2)$ *[1999]*

(a) 10 m (b) 20 m
(c) 15 m (d) 25 m

4. A body is released from the top of the tower H metre high. It takes t second to reach the ground. Where is the body after t/2 second of release ? *[2000]*

(a) at 3H/4 metre from the ground
(b) at H/2 metre from the ground
(c) at H/6 metre from the ground
(d) at H/4 metre from the ground

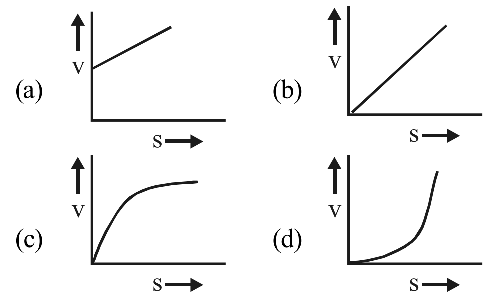
5. A body starts from rest with an acceleration a_1. After two seconds another body B starts from rest with an acceleration a_2. If they travel equal distances in fifth second after the starts of A, the ratio $a_1 : a_2$ will be equal to : *[2001]*

(a) 9 : 5 (b) 5 : 7
(c) 5 : 9 (d) 7 : 9

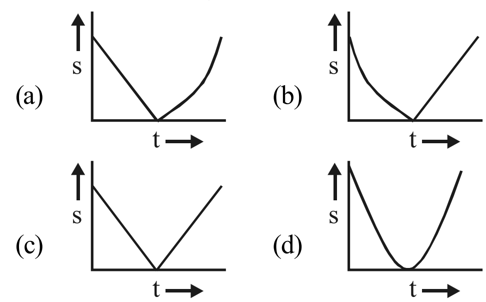
6. Three different objects m_1, m_2 and m_3 are allowed to fall from rest and from the same point O along three different frictionless paths. The speeds of the three objects, on reaching the ground, will be in the ratio of *[2002]*

(a) $m_1 : m_2 : m_3$ (b) 1 : 1 : 1
(c) $m_1 : 2m_2 : 3m_3$ (d) $\frac{1}{m_1} : \frac{1}{m_2} : \frac{1}{m_3}$

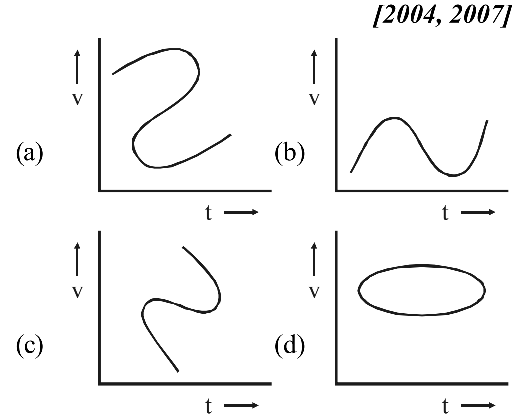
7. A body starting from rest moves along straight line with a constant acceleration. The variation of speed (v) with distance (s) is represented by the graph : *[2003]*



8. A ball is thrown vertically upwards. Which of the following plots represents the speed-time graph of the ball during its flight if the air resistance is not ignored? *[2003]*



9. Which of the following velocity-time graphs shows a realistic situation for a body in motion? *[2004, 2007]*



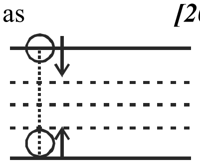
10. Two spheres of same size one of mass 2 kg and another of mass 4 kg are dropped simultaneously from the top of Qutab Minar(height = 72m). When they are 1m above the ground, the two spheres have the same: ***[2006]***
(a) momentum (b) kinetic energy
(c) potential energy (d) acceleration

11. A particle is thrown vertically upwards with a velocity of $4ms^{-1}$. The ratio of its accelerations after 1s and 2s of its motion is ***[2009]***
(a) 2 (b) 9.8
(c) 1 (d) 4.9

12. A body is thrown vertically upwards with a velocity of 19.6 ms^{-1}. The position of the body after 4 s will be ***[2009]***
(a) at the highest point
(b) at the mid-point of the line joining the starting point and the highest point
(c) at the starting point
(d) none of the above

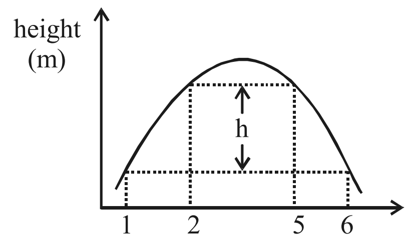
13. The position(x) of a particle at any time(t) is given by ***[2009]***
$$x(t) = 4t^3 - 3t^2 + 2$$
The acceleration and velocity of the particle at any time t = 2 sec are respectively
(a) 16 ms^{-2} and 22 ms^{-1}
(b) 42 ms^{-2} and 36 ms^{-1}
(c) 48 ms^{-2} and 36 ms^{-1}
(d) 12 ms^{-2} and 25 ms^{-1}

14. A stone is projected vertically up from the bottom of a water tank. Assuming no water resistance it will go up & come down in same time but if water drag is present then the time it takes to go up, t_{up} and the time it takes to come down, t_{down} are related as ***[2009]***
(a) $t_{up} > t_{down}$
(b) $t_{up} = t_{down}$
(c) $t_{up} < t_{down}$
(d) can not say



15. A student is standing at a distance of 50 metre from the bus. As soon as the bus begins its motion with an acceleration of 1 ms^{-2}, the student starts running towards the bus with a uniform velocity *u*. Assuming the motion to be along a straight road, the minimum value of *u*, so that the student is able to catch the bus is
(a) 8 ms^{-1} (b) 5 ms^{-1} ***[2010]***
(c) 12 ms^{-1} (d) 10 ms^{-1}

16. A ball is thrown upwards. Its height varies with time as follows :

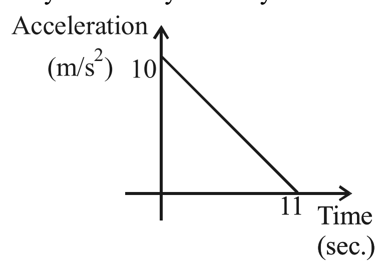


If the acceleration due to gravity is 7.5 m/s^2, then the height h is : ***[2011]***
(a) 10m (b) 15m
(c) 20m (d) 25m

17. The coordinates of a moving particle at any time t are given by $x = a\,t^2$ and $y = b\,t^2$. The speed of the particle is ***[2012]***
(a) $2\,t\,(a+b)$ (b) $2t\sqrt{(a^2+b^2)}$
(c) $2\,t\sqrt{(a^2-b^2)}$ (d) $\sqrt{(a^2+b^2)}$

18. A ball is released from the top of a tower of height h meters. It takes T seconds to reach the ground. What is the position of the ball at $\frac{T}{3}$ second
(a) $\frac{8h}{9}$ meters from the ground ***[2012]***
(b) $\frac{7h}{9}$ meters from the ground
(c) $\frac{h}{9}$ meters from the ground
(d) $\frac{17h}{18}$ meters from the ground

19. A body starts from rest at time t = 0, the acceleration time graph is shown in the figure. The maximum velocity attained by the body will be ***[2014]***



(a) 110 m/s (b) 55 m/s
(c) 650 m/s (d) 550 m/s

20. Two bodies begin a free fall from the same height at a time interval of N s. If vertical separation between the two bodies is 1 after n second from the start of the first body, then n is equal to *[2016]*

(a) $\sqrt{nN}$ (b) $\frac{1}{gN}$

(c) $\frac{1}{gN}+\frac{N}{2}$ (d) $\frac{1}{gN}-\frac{N}{4}$

21. From a balloon moving upwards with a velocity of 12 ms^{-1}, a packet is released when it is at a height of 65 m from the ground. The time taken by it to reach the ground is (g = 10 ms^{-2})

(a) 5 s (b) 8 s *[2017]*

(c) 4 s (d) 7 s

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 22-24) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

22. Assertion : A body can have acceleration even if its velocity is zero at a given instant of time.

Reason : A body is numerically at rest when it reverses its direction. *[1998]*

23. Assertion : A body with constant acceleration always moves along a straight line.

Reason : A body with constant acceleration may not speed up. *[1998]*

24. Assertion : Retardation is directly opposite to the velocity.

Reason : Retardation is equal to the time rate of decrease of speed. *[2002]*

Directions for (Qs.25-28) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

25. Assertion : Two balls of different masses are thrown vertically upward with same speed. They will pass through their point of projection in the downward direction with the same speed.

Reason : The maximum height and downward velocity attained at the point of projection are independent of the mass of the ball. *[2013]*

26. Assertion : The two bodies of masses M and m ($M > m$) are allowed to fall from the same height if the air resistance for each be the same then both the bodies will reach the earth simultaneously.

Reason : For same air resistance, acceleration of both the bodies will be same. *[2014]*

27. Assertion : In a free fall, weight of a body becomes effectively zero.

Reason : Acceleration due to gravity acting on a body having free fall is zero. *[2014]*

28. Assertion : Velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to the time axis.

Reason : In uniform motion of an object velocity increases as the square of time elapsed. *[2015]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** $u = 0, v = 144$ km/hour $= 144 \times \frac{5}{18}$ m/sec $= 40$ m/sec

$v = u + at$

$\Rightarrow a = \frac{v-u}{t} = \frac{40-0}{20} = 2$ m/sec^2

$\therefore s = ut + \frac{1}{2}at^2$

$= \frac{1}{2} \times 2 \times (20)^2 = 400$ m

2. **(a)** Time taken by the first object to reach the ground = t, so

$122.5 = ut + \frac{1}{2}gt^2$

$122.5 = \frac{1}{2} \times 10 \times t^2$

$\Rightarrow t = 5$ sec(approx)

Time to be taken by the second ball to reach the ground = 5 – 2 = 3 sec.

If u be its initial velocity then,

$122.5 = u \times 3 + \frac{1}{2}gt^2 = 3u + \frac{1}{2} \times 10 \times 9$

$3u = 122.5 - 45 = 77.5$

$u = 26$ (approx.)

3. **(a)** Let maximum height be H

From the formula, $v^2 = u^2 - 2gs$

$(10)^2 = u^2 - 2gH/2 = u^2 - gH$ ....(1)

For attaining maximum height, $v = 0$

$0 = u^2 - 2gH \Rightarrow u^2 = 2gH$

Putting the value of u^2 in (1),

$100 = 2gH - gH = gH$

$H = \frac{100}{g} = \frac{100}{10} = 10$ metre

4. **(a)** Applying $S = ut + \frac{1}{2}gt^2$ for the Ist case

$H = \frac{1}{2}gt^2$ ....(i)

Let H_1 be the height after t/2 secs. So distance of fall = $H - H_1$

$H - H_1 = \frac{1}{2}g\left(\frac{t}{2}\right)^2$

$\Rightarrow H - H_1 = \frac{1}{8}gt^2$ ....(ii)

Dividing (i) and (ii),

$\frac{H-H_1}{H} = \frac{1}{8} \times \frac{2}{1} = \frac{1}{4}$

$\Rightarrow 4H - 4H_1 = H \Rightarrow H_1 = \frac{3}{4}H$

5. **(c)** Distance travelled in fifth second for first body = distance travelled in 3rd second for second body,

$S_5 = S_3$

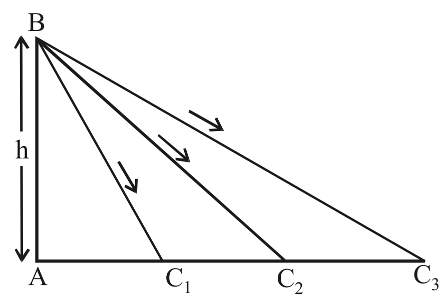
$S_t = u + \frac{(2t-1)a}{2}$

$S_5 = 0 + \frac{9}{2}a_1$

$S_3 = 0 + \frac{5}{2}a_2$

$\frac{9}{2}a_1 = \frac{5}{2}a_2 \Rightarrow \frac{a_1}{a_2} = \frac{5}{9}$

6. **(b)**



For paths BC_1, BC_2 & BC_3 the height is same that is h. The terminal velocity be v then for all cases, $v = \sqrt{2gh}$

So, all will have same value of terminal velocity.

7. **(d)** $v^2 = u^2 + 2as$

$v^2 = 2as$ as $u = 0$

The graph between v and s will be of the form of parabola which will be symmetric with respect to v-axis. So curve (d) is the right answer.

8. **(d)** For a body going in upward direction

$v = u - gt$

The slope of the graph, $\frac{dv}{dt} = -g$ (constant)

But when we take into account the effect of resistance it will have sharper slope. Curve (d) fits into this result.

9. **(b)** Time cannot reverse itself or it can only go forward. In graph (a), (c) & (d) some portion of graph has shown time changing in such a way or time is going from high value to low value which is not practical.

Graph (b) is the answer.

10. **(d)** Since their masses are different they will have different momentum, kinetic energy and potential energy. But their acceleration will be same which will be equal to g.

11. **(c)** We know that the acceleration in a motion under gravity is constant which is 9.8 ms^{-2}.

Hence, the required ratio will be $\frac{9.8}{9.8} = 1$

12. **(c)** Clearly the time taken by the particle to reach the highest point is given by

$v = u - gt$

or, $t = \frac{u - v}{g} = \frac{19.6 - 0}{9.8}$

or, t = 2 s.

Therefore, the particle will reach at the starting point itself after 4 s.

13. **(c)** We have $x(t) = 4t^3 - 3t^2 + 2$

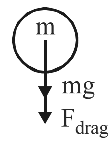
$\Rightarrow\ v = \frac{dx}{dt} = 12t^2 - 6t$

and $a = \frac{dv}{dt} = 24t$

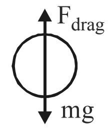
$\therefore$ v at t = 2s is $12(2)^2 - 6(2)$ i.e., 36 ms^{-1}

and a at t = 2s is 24×2 i.e., 48 ms^{-2}

14. **(c)** While moving up



& while moving down

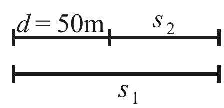


$\therefore\ a_{up} > a_{down}$

Hence to cover same distance $t_{up} < t_{down}$.

15. **(d)** Let the student travels distance s_1 in time t and catches the bus.

$s_1 = ut$ ...(1)



Distance travelled by the bus in time t

$s_2 = 0 + \frac{1}{2}at^2$ ...(2)

The student is able to catch the bus if,

$s_1 = d + s_2$

$ut = d + \frac{1}{2} 1 \times 1^2$

or, $2ut = 2d + t^2$

or, $t^2 - 2ut + 2d = 0$

Solving the quadratic equation

$t = -2 \pm \sqrt{4u^2 - 8d}$

$= -2 \pm 2\sqrt{u^2 - 2d}$

For t to be real

$u \geq \sqrt{2d}$

$\geq \sqrt{2 \times 50} = 10$ m/s.

16. **(b)** Velocity at highest point becomes zero

$\therefore\ 0 = u - at$

or $u = at$

$= 7.5 \times 3.5 = 62.25$ m/s

$y_1 = u \times 1 - \frac{1}{2} \times 7.5 \times 1^2$

$y_2 = u \times 2 - \frac{1}{2} \times 7.5 \times 2^2$

$h = y_2 - y_1 = 15$

17. (b) $\mathbf{r} = \mathbf{i}\,a t^2 + \mathbf{j}\,b t^2$, $\mathbf{v} = \frac{d\mathbf{r}}{dt} = \mathbf{i}\,2at + \mathbf{j}\,2bt$

$\therefore$ Magnitude of $\mathbf{v} = \sqrt{(4a^2t^2 + 4b^2t^2)}$

$= 2t\sqrt{(a^2 + b^2)}$

18. (a) $h = \frac{1}{2}gT^2$

now for t = T/3 second vertical distance moved is given by

$h' = \frac{1}{2}g\left(\frac{T}{3}\right)^2 \Rightarrow h' = \frac{1}{2} \times \frac{gT^2}{9} = \frac{h}{9}$

$\therefore$ position of ball from ground $= h - \frac{h}{9}$

$= \frac{8h}{9}$

19. (b) $V_i = 0, V_f = V_{max}$

ΔV = area under the curve $= 10 \times \frac{11}{2} = 55$

or $V_f - V_i = 55$ m/s since $V_i = 0$

$V_f = 55$ m/s

$V_f = V_{max} = 55$ m/s

20. (c) $y_1 = \frac{1}{2}gn^2$, $y_2 = \frac{1}{2}g(n-N)^2$

$\therefore \; y_1 - y_2 = \frac{1}{2}g[n^2 - (n-N)^2]$

$\Rightarrow \; 1 = \frac{g}{2}(2n - N)N$

$[\because y_1 - y_2 = 1]$

$\Rightarrow \; n = \frac{1}{gN} + \frac{N}{2}$

21. (a) $s = ut + \frac{1}{2}at^2$

$-65 = 12t - 5t^2$ on solving we get, $t = 5$s

Type B : Assertion Reason Questions

22. (a) When a body is thrown upwards vertically, at the highest point its velocity becomes zero but gravitational force continues to act on it so it has acceleration in downward direction even at the highest point. So assertion is true.

A body is numerically at rest but it reverses its direction due to acceleration present in it. Reason is true & it supports assertion.

23. (e) In case of circular motion, constant acceleration creates circular motion. In circular motion (uniform) the body in motion does not speed up inspite of acceleration.

24. (a) Retardation $= \frac{\text{decrease in velocity}}{\text{time}}$

It acts opposite to velocity.

25. (a) $h = ut - \frac{1}{2}gt^2$ and $v^2 = u^2 - 2gh$;

These equations are independent of mass.

26. (d) The force acting on the body of mass M are its weight *Mg* acting vertically downward and air resistance *F* acting vertically upward.

$\therefore$ Acceration of the body , $a = g - \frac{F}{M}$

Now M > m, therefore, the body with larger mass will have great acceleration and it will reach the ground first.

27. (d)

28. (c) In uniform motion the object moves with uniform velocity, the magnitude of its velocity at different instance i.e., at $t = 0$, $t = 1$, sec, $t = 2$sec ..... will always be constant. Thus velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to time axis.

Chapter 3

Motion in a Plane

TYPE A : MULTIPLE CHOICE QUESTIONS

1. Rain is falling vertically downwards with a velocity of 3 km/hr. A man walks in the rain with a velocity of 4 km/hr. The rain drop will fall on the man with a velocity of ***[1997]***

(a) 5 km/hr (b) 4 km/hr
(c) 1 km/hr (d) 3 km/hr

2. A body of mass 5 kg is moving in a circle of radius 1 m with an angular velocity of 2 rad/sec. Then the centripetal acceleration (in m/s^2) will be ***[1998]***

(a) 80 N (b) 30 N
(c) 10 N (d) 20 N

3. A body is projected at such angle that the horizontal range is three times the greatest height. The angle of projection is ***[1998]***

(a) 42° 8' (b) 53° 7'
(c) 33° 7' (d) 25° 8'

4. An aeroplane moves 400 m towards the north, 300 m towards west and then 1200 m vertically upwards, then its displacement from the initial position is ***[1998]***

(a) 1600 m (b) 1800 m
(c) 1500 m (d) 1300 m

5. The angle between $\left(\vec{P}+\vec{Q}\right)$ and $\left(\vec{P}-\vec{Q}\right)$ will be ***[1999]***

(a) 90° only
(b) between 0° and 180°
(c) 180° only
(d) none of these

6. Two equal vectors have a resultant equal to either of them, then the angle between them will be ***[2000]***

(a) 110° (b) 120°
(c) 60° (d) 150°

7. A stone tied to the end of a string of 80 cm long, is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 sec, then magnitude of acceleration of the same will be ***[2001]***

(a) 990 cm/sec^2 (b) 680 cm/sec^2
(c) 750 cm/sec^2 (d) 650 cm/sec^2

8. Two projectiles are projected with the same velocity. If one is projected at an angle of 30° and the other at 60° to the horizontal, the ratio of maximum heights reached, is ***[2001]***

(a) 1 : 3 (b) 2 : 1
(c) 3 : 1 (d) 1 : 4

9. A stone tied to a string is rotated with a uniform speed in a vertical plane . If mass of the stone is m, the length of the string is r and the linear speed of the stone is v, when the stone is at its lowest point, then the tension in the string will be (g = acceleration due to gravity) ***[2001]***

(a) $\frac{mv^2}{r}+mg$ (b) $\frac{mv^2}{r}-mg$

(c) $\frac{mv}{r}$ (d) mg

10. At the uppermost point of a projectile, its velocity and acceleration are at an angle of ***[2002]***

(a) 180° (b) 90°
(c) 60° (d) 45°

11. If vectors $\vec{P}=a\hat{i}+a\hat{j}+3\hat{k}$ and $Q=a\hat{i}-2\hat{j}-\hat{k}$ are perpendicular to each other, then the positive value of a is ***[2002]***

(a) zero (b) 1
(c) 2 (d) 3

12. The maximum range of a gun horizontal terrain is 10 km. If g = 10 m/s^2 what must be the muzzle velocity of the shell ***[2004]***

(a) 400 m/s (b) 200 m/s
(c) 100 m/s (d) 50 m/s

13. A projectile can have the same range R for two angles of projection. If t_1 and t_2 be the times of flights in the two cases, then the product of the two time of flights is proportional to ***[2006]***

(a) $\frac{1}{R^2}$ (b) R^2

(c) R (d) $\frac{1}{R}$

14. A car travels 6 km towards north at an angle of 45° to the east and then travels distance of 4 km towards north at an angle 135° to east. How far is the point from the starting point? What angle does the straight line joining its initial and final position makes with the east? ***[2008]***

(a) $\sqrt{50}$ km and $\tan^{-1}(5)$

(b) 10 km and $\tan^{-1}(\sqrt{5})$

(c) $\sqrt{52}$ km and $\tan^{-1}(5)$

(d) $\sqrt{52}$ km and $\tan^{-1}(\sqrt{5})$

15. If two forces of equal magnitudes act simultaneously on a body in the east and the north directions then ***[2009]***

(a) the body will displace in the north direction
(b) the body will displace in the east direction
(c) the body will displace in the north-east direction
(d) the body will remain at the rest.

16. Two vectors having equal magnitudes of x units acting at an angle of 45° have resultant $\sqrt{(2+\sqrt{2})}$ units. The value of x is ***[2009]***

(a) 0 (b) 1

(c) $\sqrt{2}$ (d) $2\sqrt{2}$

17. If R and H represent the horizontal range and the maximum height achieved by a projectile then which of the relation exists? ***[2009]***

(a) $\frac{H}{R}=4\cot\theta$ (b) $\frac{R}{H}=4\cot\theta$

(c) $\frac{H}{R}=4\tan\theta$ (d) $\frac{R}{H}=4\tan\theta$

18. The acceleration of a body in a non-uniform circular motion is 5 ms^{-2}. Which one of the following is correct? ***[2009]***

(a) The radial acceleration and the tangential accelerations are 3 ms^{-2} and 4 ms^{-2} respectively.
(b) The radial and the tangential accelerations are 2 ms^{-2} and 3 ms^{-2} respectively.
(c) The radial and the tangential accelerations are both 5 ms^{-2}.
(d) The radial and the tangential acceleration are 5 ms^{-2} and 3 ms^{-2} respectively.

19. An aircraft executes a horizontal loop with a speed of 150 m/s with its wings banked at an angle of 12°. The radius of the loop is (g = 10 m/s^2) ***[2010]***

(a) 10.6 km (b) 9.6 km
(c) 7.4 km (d) 5.8 km

20. For ordinary terrestrial experiments, the observer in an inertial frame in the following cases is ***[2010]***

(a) a child revolving in a giant wheel
(b) a driver in a sports car moving with a constant high speed of 200 kmh^{-1} on a straight road
(c) the pilot of an aeroplane which is taking off
(d) a cyclist negotiating a sharp curve

21. For a particle in a uniformly accelerated circular motion ***[2011]***

(a) velocity is radial and acceleration has both radial and transverse components
(b) velocity is transverse and acceleration has both radial and transverse components
(c) velocity is radial and acceleration is transverse only
(d) velocity is transverse and acceleration is radial only

22. For a given angle of the projectile if the initial velocity is doubled the range of the projectile becomes ***[2011]***

(a) Half (b) One -fourth
(c) Two times (d) Four times

23. If we can throw a ball upto a maximum height H, the maximum horizontal distance to which we can throw it is ***[2011]***

(a) 2H (b) $\sqrt{2}$H

(c) H (d) $\frac{H}{2}$

24. The vector sum of two forces is perpendicular to their vector differences. In that case, the forces ***[2012]***

(a) cannot be predicted
(b) are equal to each other
(c) are equal to each other in magnitude
(d) are not equal to each other in magnitude

25. A projectile can have the same range for two angles of projection. If h_1 and h_2 are maximum heights when the range in the two cases is R, then the relation between R, h_1 and h_2 is ***[2013]***

(a) $R=4\sqrt{h_1h_2}$ (b) $R=2\sqrt{h_1h_2}$

(c) $R=\sqrt{h_1h_2}$ (d) None of these

26. A projectile thrown with velocity v making angle θ with vertical gains maximum height H in the time for which the projectile remains in air, the time period is ***[2013]***

(a) $\sqrt{H\cos\theta/g}$ (b) $\sqrt{2H\cos\theta/g}$

(c) $\sqrt{4H/g}$ (d) $\sqrt{8H/g}$

27. A bomb is released from a horizontal flying aeroplane. The trajectory of bomb is ***[2013]***

(a) a parabola (b) a straight line

(c) a circle (d) a hyperbola

28. A stone tied to the end of a string of 1 m long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolution in 44 seconds, what is the magnitude and direction of acceleration of the stone? ***[2014]***

(a) π^2 m s^{-2} and direction along the radius towards the centre.

(b) π^2 m s^{-2} and direction along the radius away from the centre.

(c) π^2 m s^{-2} and direction along the tangent to the circle.

(d) $\pi^2/4$ m s^{-2} and direction along the radius towards the centre.

29. Two projectiles are fired from the same point with the same speed at angles of projection 60º and 30º respectively. Which one of the following is true? ***[2014]***

(a) Their maximum height will be same

(b) Their range will be same

(c) Their landing velocity will be same

(d) Their time of flight will be same

30. A ball is thrown from a point with a speed 'v_0' at an elevation angle of θ. From the same point and at the same instant, a person starts running with a constant speed $\frac{'v_0'}{2}$ to catch the ball. Will the person be able to catch the ball? If yes, what should be the angle of projection θ ? ***[2016]***

(a) No (b) Yes, 30°

(c) Yes, 60° (d) Yes, 45°

31. A boy playing on the roof of a 10 m high building throws a ball with a speed of 10m/s at an angle of 30º with the horizontal. How far from the throwing point will the ball be at the height of 10 m from the ground ? ***[2017]***

$[g = 10\text{m/s}^2, \sin 30^o = \frac{1}{2}, \cos 30^o = \frac{\sqrt{3}}{2}]$

(a) $5\sqrt{5}$ (b) 6

(c) 3 (d) $5\sqrt{3}$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Q. 32) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

32. Assertion : If a body is thrown upwards, the distance covered by it in the last second of upward motion is about 5 m irrespective of its initial speed

Reason : The distance covered in the last second of upward motion is equal to that covered in the first second of downward motion when the particle is dropped. ***[2000]***

Directions for (Qs.33-37) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

33. **Assertion :** The driver in a vehicle moving with a constant speed on a straight road is an inertial frame of reference.

    Reason : A reference frame in which Newton's laws of motion are applicable is non-inertial. ***[2009]***

34. **Assertion :** A tennis ball bounces higher on hills than in plains.

    Reason : Acceleration due to gravity on the hill is greater than that on the surface of earth. ***[2009]***

35. **Assertion :** When a particle moves in a circle with a uniform speed, its velocity and acceleration both changes.

    Reason : The centripetal acceleration in circular motion is dependent on angular velocity of the body. ***[2010]***

36. **Assertion :** Centripetal and centrifugal forces cancel each other.

    Reason : Centrifugal force is a reaction of centripetal force. ***[2011]***

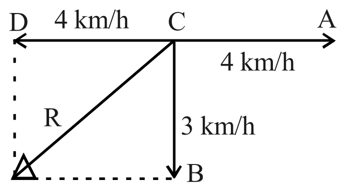
37. **Assertion :** The magnitude of velocity of two boats relative to river is same. Both boats start simultaneously from same point on one bank may reach opposite bank simultaneously moving along different paths.

    Reason : For boats to cross the river in same time. The component of their velocity relative to river in direction normal to flow should be same. ***[2015]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)**



In the figure, CB represents velocity of rain, CA represents velocity of the man. To find relative velocity of the rain with respect to man we add a velocity equal to that of man in opposite direction to the velocity of rain. It has been depicted by line CD. Now rain has two velocities simultaneously. Their resultatnt,

$R^2 = 4^2 + 3^2 \Rightarrow R = 5$

which gives us the value of relative velocity of rain.

2. **(d)** Centripetal acceleration $= \omega^2 r = 2 \times 2 \times 1$
$= 4\ m/s^2$

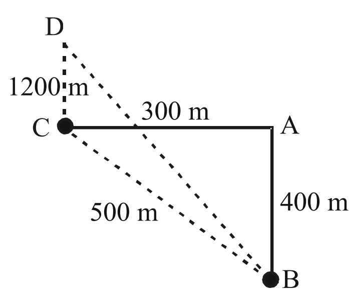
3. **(b)** $R = 3\,H$; $R = \dfrac{u^2 \sin 2\theta}{g}$; $H = \dfrac{u^2 \sin^2\theta}{2g}$

$$\frac{u^2 \sin 2\theta}{g} = \frac{3u^2 \sin^2\theta}{2g}$$

$$2\sin\theta\cos\theta = \frac{3\sin^2\theta}{2}$$

$$\tan\theta = \frac{4}{3} \Rightarrow \theta = 53°7'$$

4. **(d)**

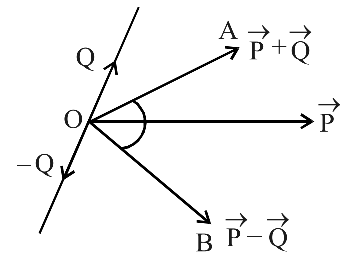


Here CD is perpendicular to the plane of paper. Required distance = BD

$BD^2 = CB^2 + CD^2 = 500^2 + 1200^2$

$BD = \sqrt{500^2 + 1200^2} = 1300\text{m}$

5. **(b)**



In the figure $\overrightarrow{OA}$ represents $(\vec{P}+\vec{Q})$, $\overrightarrow{OB}$ represents $(\vec{P}-\vec{Q})$. It is clear from the figure that angle between $\overrightarrow{OA}$ and $\overrightarrow{OB}$ may be between 0° and 180°.

6. **(b)** Applying the formula,

$$R^2 = P^2 + Q^2 + 2PQ\cos\alpha$$

$$P^2 = P^2 + P^2 + 2PP\cos\alpha$$

$$= 2P^2 + 2P^2\cos\alpha = 2P^2(1+\cos\alpha)$$

$$1+\cos\alpha = \frac{1}{2} \Rightarrow 2\cos^2\frac{\alpha}{2} = \frac{1}{2}$$

$$\cos^2\frac{\alpha}{2} = \frac{1}{4} \Rightarrow \cos\frac{\alpha}{2} = \frac{1}{2} = \cos 60°$$

$$\frac{\alpha}{2} = 60° \Rightarrow \alpha = 120°$$

7. **(a)** Centripetal acc$^n = \omega^2 r = (2\pi n)^2 \times r$

where frequency, $n = \dfrac{14}{25}$

$$\therefore \text{acc}^n = 4 \times \frac{22}{7} \times \frac{22}{7} \times \frac{14}{25} \times \frac{14}{25} \times 80$$

$$= 990\ \text{cm/sec}^2$$

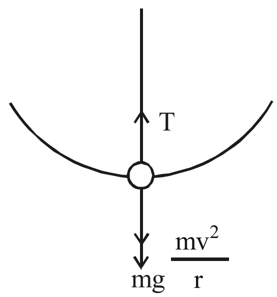
8. **(a)** For maximum height

$$H = \frac{u^2 \sin^2\alpha}{2g}$$

$$H_1 = \frac{u^2 \sin^2 30°}{2g};\ H_2 = \frac{u^2 \sin^2 60°}{2g}$$

$$H_1 : H_2 = \sin^2 30° : \sin^2 60° = \frac{1/4}{3/4} = 1 : 3$$

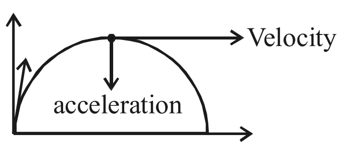
9. (a)



At the lowest point, as shown in the figure both mg and centrifugal force $\frac{mv^2}{r}$ will act in the same direction so,

$$T = mg + \frac{mv^2}{r}$$

10. (b)



As the figure implies, velocity acts in horizontal direction and acceleration due to gravity acts in vertical direction. So, angle between them is 90°.

11. (d) If $\vec{P}$ and $\vec{Q}$ are perpendicular to each other then $\vec{P}.\vec{Q} = 0$

(where vector $\vec{P} = a\hat{i} + a\hat{j} + 3\hat{k}$ and $\vec{Q} = a\hat{i} - 2\hat{j} - \hat{k}$)

$$(a\hat{i} + a\hat{j} + 3\hat{k})(a\hat{i} - 2\hat{j} - \hat{k}) = 0$$

$$a^2 - 2a - 3 = 0 \Rightarrow (a-3)(a+1) = 0$$

$$a - 3 = 0 \Rightarrow a = 3 \text{ and } a = -1$$

12. (a) For maximum range

$$R = \frac{u^2}{g} \Rightarrow u^2 = gR$$

$$u^2 = 16{,}000 \times 10 \Rightarrow u = 4 \times 100$$

$$u = 400 \text{m/sec}$$

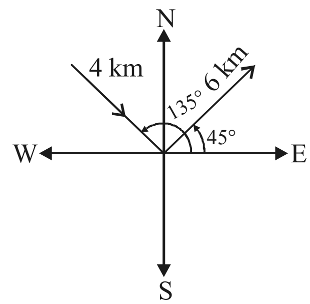
13. (c) $t_1 t_2 = \frac{2R}{g}$ (It is a formula)

$$t_1 t_2 \propto R$$

14. (c) Net distance travellel along x-direction,

$$S_x = 6\cos 45°\hat{i} - 4\cos 45°\hat{i}$$

$$= 2 \times \frac{1}{\sqrt{2}} = \sqrt{2} \text{ km}$$



Net distance travelled along y-direction

$$S_y = 6\sin 45°\hat{j} + 4\sin 45°\hat{j}$$

$$= 10 \times \frac{1}{\sqrt{2}} = 5\sqrt{2} \text{ km}$$

∴ Net distance travelled from the starting point,

$$S = \sqrt{S_x{}^2 + S_y{}^2} = \sqrt{(\sqrt{2})^2 + (5\sqrt{2})^2}$$

$$= \sqrt{2 + 25 \times 2} = \sqrt{52} \text{ km}$$

Angle which the resultant makes with the east direction

$$\tan\theta = \frac{y}{x} = \frac{5\sqrt{2}}{\sqrt{2}} \quad \text{or} \quad \theta = \tan^{-1}(5)$$

15. (c) The resultant $\vec{F}$ of two forces $\vec{F}_1$ and $\vec{F}_2$ acting in the east and the north direction respectively will act in the north- east direction as per the parallelogram law of vector addition.

16. (b) Here, $P = x$ units, $Q = x$ units, $\theta = 45°$

$$R = \sqrt{(2+\sqrt{2})} \text{ units}$$

We have, $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

or, $R = \sqrt{x^2 + x^2 + 2.x.x\cos 45°}$

or, $\sqrt{(2+\sqrt{2})} = \sqrt{2x^2 + 2x^2\frac{1}{\sqrt{2}}}$

$$= \sqrt{2x^2 + \sqrt{2}x^2}$$

or, $\sqrt{(2+\sqrt{2})} = \sqrt{x^2(2+\sqrt{2})}$

or, $\sqrt{(2+\sqrt{2})} = x\sqrt{(2+\sqrt{2})} \Rightarrow x = 1$

17. (b) $R = \dfrac{u^2 \sin 2\theta}{g} = \dfrac{2u^2 \sin\theta.\cos\theta}{g}$

$H = \dfrac{u^2 \sin^2\theta}{2g}$

$\therefore \dfrac{H}{R} = \dfrac{u^2\sin^2\theta}{2g} \times \dfrac{g}{2u^2 \sin\theta.\cos\theta}$

$= \dfrac{\sin\theta}{4\cos\theta}$

$\Rightarrow \dfrac{R}{H} = \dfrac{4\cos\theta}{\sin\theta}$ or, $\dfrac{R}{H} = 4\cot\theta$

18. (a) The acceleration of a body in a non-uniform circular motion is the resultant of the radial and the tangential accelerations. If

$a_r = 3\ ms^{-2}$ and $a_t = 4\ ms^{-2}$

then, $a = \sqrt{a_r^2 + a_t^2} = \sqrt{(3)^2 + (4)^2}$

$= \sqrt{9+16} = \sqrt{25} = 5\ ms^{-2}$

19. (a) Using the relation for the radius (r) of loop

$\tan\theta = \dfrac{v^2}{rg}$

or $\tan 12^\circ = \dfrac{(150)^2}{r \times 10}$

or $r = \dfrac{2250}{0.2125} = 10.6 \times 10^3\ m = 10.6\ km.$

20. (b) The car moving with a constant velocity has no acceleration. Hence, it is an inertial frame.

21. (b) For a uniformly accelerated motion there are two acceleration, one along the radius called radial acceleration and another along tangent called tangential acceleration. Velocity is directed along the tangent.

22. (d) $R = \dfrac{u^2 \sin 2\theta}{g}$

$R' = \dfrac{(2u)^2 \sin 2\theta}{g} = 4R.$

23. (a) $H = \dfrac{u^2}{2g} \Rightarrow u^2 = 2gH$

For maximum horizontal distance

$x_{max} = \dfrac{u^2}{g} = \dfrac{2gH}{g} = 2H$

24. (c) $\vec{P} = \text{vector sum} = \vec{A} + \vec{B}$

$\vec{Q} = \text{vector differences} = \vec{A} - \vec{B}$

Since $\vec{P}$ and $\vec{Q}$ are perpendicular

$\therefore \vec{P}.\vec{Q} = 0$

$\Rightarrow (\vec{A}+\vec{B}).(\vec{A}-\vec{B}) = 0 \Rightarrow A^2 = B^2$

$\Rightarrow |A| = |B|$

25. (a) $h_1 = \dfrac{u^2 \sin^2\theta}{2g}$

$h_2 = \dfrac{u^2 \sin^2(90-\theta)}{2g}$, $R = \dfrac{u^2 \sin 2\theta}{g}$

Range R is same for angle θ and $(90^\circ - \theta)$

$\therefore h_1 h_2 = \dfrac{u^2\sin^2\theta}{2g} \times \dfrac{u^2 \sin^2(90-\theta)}{2g}$

$= \dfrac{u^4(\sin^2\theta) \times \sin^2(90-\theta)}{4g^2}$

$[\because \sin(90-\theta) = \cos\theta]$

$= \dfrac{u^4(\sin^2\theta)\times\cos^2\theta}{4g^2}$

$[\because \sin 2\theta = 2\sin\theta\cos\theta]$

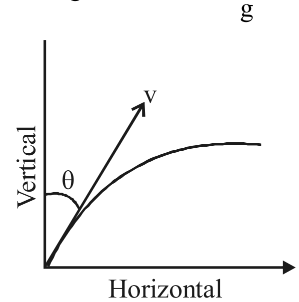
$= \dfrac{u^4(\sin\theta\cos\theta)^2}{4g^2} = \dfrac{u^4(\sin 2\theta)^2}{16g^2}$

$= \dfrac{(u^2\sin 2\theta)^2}{16g^2} = \dfrac{R^2}{16}$

or, $R^2 = 16\,h_1 h_2$ or $R = 4\sqrt{h_1 h_2}$

26. (d) Max. height $= H = \dfrac{v^2 \sin^2(90-\theta)}{2g}$ .....(i)

Time of flight, $T = \dfrac{2v\sin(90-\theta)}{g}$ ...(ii)

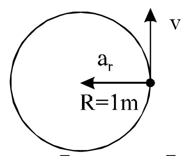


From (i), $\frac{v\cos\theta}{g} = \sqrt{\frac{2H}{g}}$,From (ii),

$T = 2\sqrt{\frac{2H}{g}} = \sqrt{\frac{8H}{g}}$.

27. (a) A parabola

28. (a) $a_r = \omega^2 R$



$a_r = (2\pi 2)^2 R$

$$= 4\pi^2 2^2 R = 4\pi^2\left(\frac{22}{44}\right)^2 (1) \quad \left[\because v = \frac{22}{44}\right]$$

$a_t = \frac{dv}{dt} = 0$

$a_{net} = a_r = \pi^2\ ms^{-2}$ and direction along the radius towards the centre.

29. (b) Given, $u_1 = u_2 = u$, $\theta_1 = 60°, \theta_2 = 30°$
In Ist case, we know that range

$$R_1 = \frac{u^2\sin 2(60°)}{g} = \frac{u^2 \sin 120°}{g} = \frac{u^2\sin(90°+30°)}{g}$$

$$= \frac{u^2(\cos 30°)}{g} = \frac{\sqrt{3}u^2}{2g}$$

In IInd case when $\theta_2 = 30°$, then

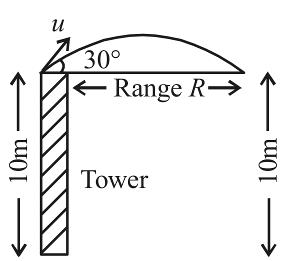
$$R_2 = \frac{u^2 \sin 60°}{g} = \frac{u^2\sqrt{3}}{2g} \Rightarrow R_1 = R_2$$

(we get same value of ranges).

30. (c) Yes, the person can catch the ball when horizontal velocity is equal to the horizontal component of ball's velocity, the motion of ball will be only in vertical direction w.r.t person for that $\frac{v_0}{2} = v_0\cos\theta$ or $\theta = 60°$

31. (d) From the figure it is clear that range is required

$$R = \frac{u^2\sin 2\theta}{g} = \frac{(10)^2\sin(2\times 30°)}{10} = 5\sqrt{3}$$



Type B : Assertion Reason Questions

32. (a) For the distance covered in the last second, final velocity becomes zero. So if we drop an object with zero velocity it will cover the same distance in one second while going downwards.
Now distance travelled in the later case

$$s = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2}\times 10\times 1$$

s = 5m

33. (c) A vehicle moving with constant speed on a straight road is an inertial frame. Newton's laws of motion is applicable only in inertial frame.

34. (c) Suppose that the tennis ball bounces with a velocity *u*. It will go up, till its velocity becomes zero. If *h* is the height up to which it rises on the hill, then

$$(0)^2 - u^2 = 2(-g')h$$

where g' is acceleration due to gravity on the hill.

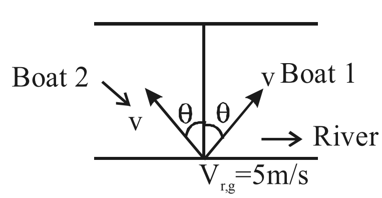
$$\therefore\ h = \frac{u^2}{2g'}$$

Since, the acceleration due to gravity on the hill (g') is less than that on earth (effect of height), it follows that tennis ball will bounce higher on hills than in plains.

35. (b) In uniform circular motion, the magnitude of velocity and acceleration remains same, but due to change in direction of motion, the direction of velocity and acceleration changes. Also the centripetal acceleration is given by $a = \omega^2 r$.

36. (d)

37. (a)



If component of velocities of boat relative to river is same normal to river flow (as shown in figure) both boats reach other bank simultaneously.

Chapter 4 Laws of Motion

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A molecule of mass m of an ideal gas collides with the wall of the vessel with the velocity v and returns back with the same velocity. The change in the linear momentum of the molecule will be : ***[1997]***
(a) 4 mv (b) 8 mv
(c) 2 mv (d) – 2mv

2. If the force on a rocket, moving with a velocity 500 m/s is 400 N, then the rate of combustion of the fuel will be : ***[1997]***
(a) 0.8 kg/sec (b) 10.8 kg/sec
(c) 8 kg/sec (d) 1.6 kg/sec

3. The rocket engine lift a rocket from the earth, because hot gases : ***[1998]***
(a) push it against the air with very high velocity
(b) push it against the earth with very high velocity
(c) heat up the air which lifts the rocket with very high velocity
(d) react against rocket and push it up with very high velocity

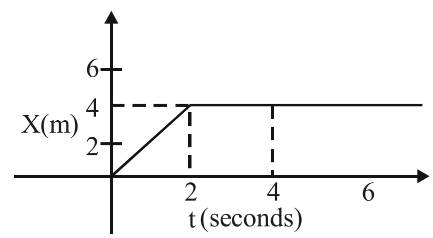
4. A 1 kg particle strikes a wall with a velocity 1 m/s at an angle 30° and reflects at the same wall in 0.1 second then the force will be: ***[1999]***
(a) $30\sqrt{3}$ N (b) 0
(c) $40\sqrt{3}$ N (d) $10\sqrt{3}$ N

5. A gun fires a bullet of mass 50 g with a velocity of 30 m/s. Due to this, the gun is pushed back with a velocity of 1 m/s, then the mass of the gun is : ***[2001]***
(a) 1.5 kg (b) 5.5 kg
(c) 0.5 kg (d) 3.5 kg

6. When the two surfaces are coated with the lubricant, then they will : ***[2001]***
(a) slide upon each other
(b) stick to each other
(c) roll upon each other
(d) none of these

7. The velocity of a bullet is reduced from 200 m/s to 100 m/s while travelling through a wooden block of thickness 10 cm. Assuming it to be uniform, the retardation will be : ***[2001]***
(a) $15\times10^4\ m/s^2$ (b) $10\times10^4\ m/s^2$
(c) $12\times10^4\ m/s^2$ (d) $14.5\ m/s^2$

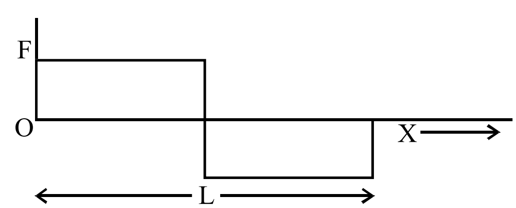
8. In the given figure, the position-time graph of a particle of mass 0.1 kg is shown. The impulse at t = 2 sec is : ***[2005]***



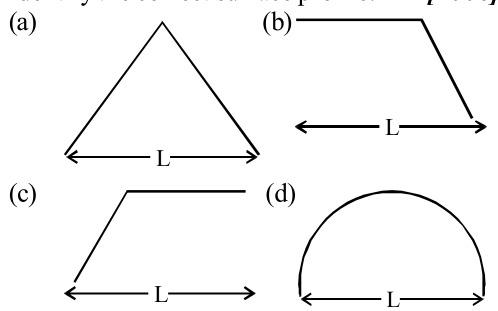
(a) $0.2\ kg\,m\,sec^{-1}$ (b) $-0.2\ kg\,m\,sec^{-1}$
(c) $0.1\ kg\,m\,sec^{-1}$ (d) $-0.4\ kg\,m\,sec^{-1}$

9. A person is standing in an elevator. In which situation he finds his weight less ? ***[2005]***
(a) When the elevator moves upward with constant acceleration
(b) When the elevator moves downward with constant acceleration
(c) When the elevator moves upward with uniform velocity
(d) When the elevator moves downward with uniform velocity

10. A person used force (F), shown in the figure to move a load with a constant velocity on a given surface.



Identify the correct surface profile: ***[2006]***



11. A man of mass 60 kg records his wt. on a weighing machine placed inside a lift. The ratio of wts. of man recorded when lift ascending up with a uniform speed of 2 m/s to when it is descending down with a uniform speed of 4 m/s will be ***[2007]***

(a) 0.5 (b) 1
(c) 2 (d) None of these

12. A smooth block is released at rest on a 45° incline and then slides a distance 'd'. The time taken to slide is 'n' times as much to slide on rough incline than on a smooth incline. The coefficient of friction is ***[2008]***

(a) $\mu_k = \sqrt{1-\frac{1}{n^2}}$ (b) $\mu_k = 1-\frac{1}{n^2}$

(c) $\mu_s = \sqrt{1-\frac{1}{n^2}}$ (d) $\mu_s = 1-\frac{1}{n^2}$

13. A parachutist after bailing out falls 50 m without friction. When parachute opens, it decelerates at 2 m/s^2. He reaches the ground with a speed of 3 m/s. At what height, did he bail out ? ***[2008]***

(a) 182 m (b) 91 m
(c) 111 m (d) 293 m

14. An 80 kg person is parachuting and is experiencing a downward acceleration of 2.8 m/s^2. The mass of the parachute is 5 kg. The upward force on the open parachute is (Take g = 9.8 m/s^2) ***[2009]***

(a) 595 N (b) 675 N
(c) 456 N (d) 925 N

15. When a horse pulls a wagon, the force that causes the horse to move forward is the force

(a) the ground exerts on it ***[2010]***
(b) it exerts on the ground
(c) the wagon exerts on it
(d) it exerts on the wagon

16. A gardener holds a hosepipe through which water is gushing out at a rate of 4kg s^{-1} with speed 2 ms^{-1}. The moment the speed of water is increased to 3 ms^{-1}, the gardener will experience a jerk of : ***[2011]***

(a) 20 Ns in backward direction
(b) 18 Ns in forward direction
(c) 10 Ns in backward direction
(d) 10 Ns in forward direction

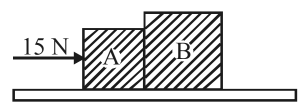
17. A 150 g tennis ball coming at a speed of 40 m/s is hit straight back by a bat to a speed of 60 m/s. The magnitude of the average force F on the ball, when it is in contact for 5 ms, is : ***[2011]***

(a) 2500 N (b) 3000 N
(c) 3500 N (d) 4000 N

18. A particle moves in a circle of radius 25 cm at two revolutions per second. The acceleration of the particle in meter per second^2 is ***[2012]***

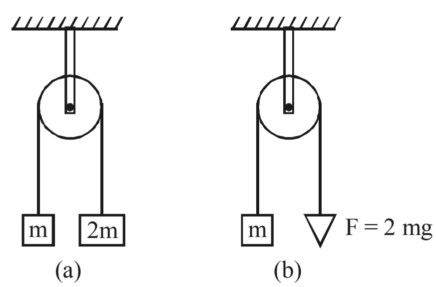
(a) π^2 (b) $8\pi^2$
(c) $4\pi^2$ (d) $2\pi^2$

19. On a smooth plane surface (figure) two block A and B are accelerated up by applying a force 15 N on A. If mass of B is twice that of A, the force on B is ***[2012]***



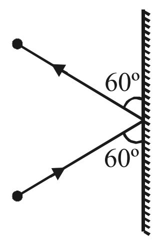
(a) 30 N (b) 15 N
(c) 10 N (d) 5 N

20. Two pulley arrangements of figure given are identical. The mass of the rope is negligible. In fig (a), the mass m is lifted by attaching a mass 2m to the other end of the rope. In fig (b), m is lifted up by pulling the other end of the rope with a constant downward force F = 2mg. The acceleration of m in the two cases are respectively ***[2013]***



(a) 3g, g (b) g/3, g
(c) g/3, 2g (d) g, g/3

21. A 3 kg ball strikes a heavy rigid wall with a speed of 10 m/s at an angle of 60º. It gets reflected with the same speed and angle as shown here. If the ball is in contact with the wall for 0.20s, what is the average force exerted on the ball by the wall? ***[2013]***



(a) 150 N (b) Zero

(c) $150\sqrt{3}$ N (d) 300 N

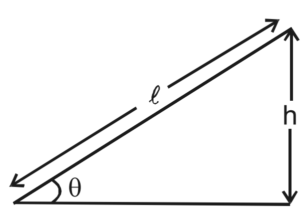
22. A mass is hanging on a spring balance which is kept in a lift. The lift ascends. The spring balance will show in its readings ***[2014]***

(a) an increase
(b) a decrease
(c) no change
(d) a change depending on its velocity

23. A ball of mass 0.5 kg moving with a velocity of 2 m/sec strikes a wall normally and bounces back with the same speed. If the time of contact between the ball and the wall is one millisecond, the average force exerted by the wall on the ball is : ***[2015]***

(a) 2000 newton (b) 1000 newton
(c) 5000 newton (d) 125 newton

24. A smooth inclined plane is inclined at an angle θ with horizontal. A body starts from rest and slides down the inclined surface. ***[2015]***

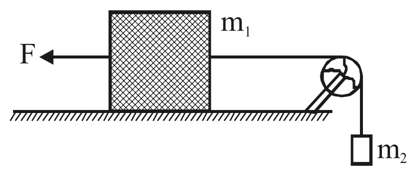


Then the time taken by it to reach the bottom is

(a) $\sqrt{\left(\frac{2h}{g}\right)}$ (b) $\sqrt{\left(\frac{2\ell}{g}\right)}$

(c) $\frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$ (d) $\sin\theta\frac{\sqrt{(2h)}}{g}$

25. A constant force $F = m_2g/2$ is applied on the block of mass m_1 as shown in fig. The string and the pulley are light and the surface of the table is smooth. The acceleration of m_1 is ***[2015]***



(a) $\frac{m_2 g}{2(m_1+m_2)}$ towards right

(b) $\frac{m_2 g}{2(m_1-m_2)}$ towards left

(c) $\frac{m_2 g}{2(m_2-m_1)}$ towards right

(d) $\frac{m_2 g}{2(m_2-m_1)}$ towards left

26. A smooth block is released at rest on a 45° incline and then slides a distance 'd'. The time taken to slide is 'n' times as much to slide on rough incline than on a smooth incline. The coefficient of friction is ***[2016]***

(a) $\mu_k = \sqrt{1-\frac{1}{n^2}}$ (b) $\mu_k = 1-\frac{1}{n^2}$

(c) $\mu_s = \sqrt{1-\frac{1}{n^2}}$ (d) $\mu_s = 1-\frac{1}{n^2}$

27. A hockey player is moving northward and suddenly turns westward with the same speed to avoid an opponent. The force that acts on the player is ***[2017]***

(a) frictional force along westward
(b) muscles force along southward
(c) frictional force along south-west
(d) muscle force along south-west

28. The retarding acceleration of 7.35 ms^{-2} due to frictional force stops the car of mass 400 kg travelling on a road. The coefficient of friction between the tyre of the car and the road is ***[2017]***

(a) 0.55 (b) 0.75
(c) 0.70 (d) 0.65

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 29-33) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

29. **Assertion :** On a rainy day it is difficult to drive a car or bus at high speed.
Reason : The value of coefficient of friction is lowered due to wetting of the surface. ***[1999]***

30. **Assertion :** A rocket moves forward by pushing the surrounding air backwards.
Reason : It derives the necessary thrust to move forward according to Newton's third law of motion. ***[2001]***

31. **Assertion :** The driver in a vehicle moving with a constant speed on a straight road is in a non-inertial frame of reference.
Reason : A reference frame in which Newton's laws of motion are applicable is non-inertial. ***[2004]***

32. **Assertion :** Use of ball bearings between two moving parts of a machine is a common practice.
Reason : Ball bearings reduce vibrations and provide good stability. ***[2006]***

33. **Assertion :** Angle of repose is equal to the angle of limiting friction.
Reason : When the body is just at the point of motion, the force of friction in this stage is called limiting friction. ***[2008]***

Directions for (Qs. 34-36) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

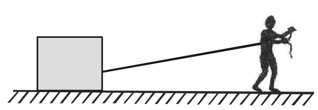
(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

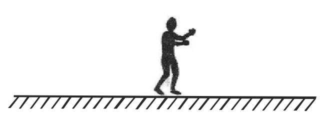
34. **Assertion :** There is a stage when frictional force is not needed at all to provide the necessary centripetal force on a banked road.
Reason : On a banked road, due to its inclination the vehicle tends to remain inwards without any chances of skidding. ***[2016]***

35. **Assertion :** Mountain roads rarely go straight up the slope.
Reason : Slope of mountains are large, therefore more chances of vehicle to slip from roads. ***[2016]***

36. **Assertion :** A man and a block rest on smooth horizontal surface. The man holds a rope which is connected to block. The man cannot move on the horizontal surface.



Reason : A man standing at rest on smooth horizontal surface cannot start walking due to absence of friction (The man is only in contact with floor as shown). ***[2017]***



HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (c) Initial momentum = mv
Final momentum = – mv
Change in momentum = mv – (– mv) = 2mv

2. (a) We know that

$$\text{Force} = \frac{dp}{dt} = \frac{d(mv)}{dt} = v\frac{dm}{dt}$$

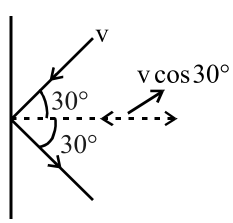
[when v is constant]
In the given case force = 400 N;
v = 500 m/sec.

We are required to calculate $\frac{dm}{dt}$ or rate of change of mass of the rocket.
In normal cases, force creates change in momentum. Here force is created due to change in momentum of the rocket by emission of fuel (a part of rocket).

$$\text{So, } \frac{dm}{dt} = \frac{\text{force}}{v} = \frac{400}{500} = 0.8\,\text{kg/sec}$$

3. (b) When the rocket gas pushes it against the earth with high velocity, there is production of reaction force which creates lift for the rocket.

4. (d)



Change in momentum of the ball perpendicular to the wall

$= m[v\cos\theta - (-v\cos\theta)]$

$= 2mv\cos\theta$

$= 2\times1\times1\times\cos 30° = 2\times\frac{\sqrt{3}}{2} = \sqrt{3},$

Rate of change of momentum

$$= \frac{\text{Change of momentum}}{\text{time}} = \frac{\sqrt{3}}{0.1} = 10\sqrt{3}$$

This will be equal to force, so force = $10\sqrt{3}$ N

5. (a) Applying conservation of momentum
MV = mv

$$M\times1 = \frac{50}{1000}\times30 = \frac{3}{2}$$

M = 1.5 kg

6. (a) If two surfaces are coated with lubricant then friction will be reduced so they can slide over each other if one is pushed on the other. It is friction which prevents relative motion between two surfaces.

7. (a) Using the formula, $v^2 = u^2 + 2as$

$$(100)^2 = (200)^2 - 2a\times\frac{10}{100}$$

$$2a\times\frac{10}{100} = (200)^2 - (100)^2 = 300\times100$$

$$a = \frac{3\times10^5}{2} = 15\times10^4\ \text{m/sec}^2$$

8. (a) Impulse = mu – mv

$= 0.1\times\frac{4}{2} - m\times0$ [v = 0 after two seconds]

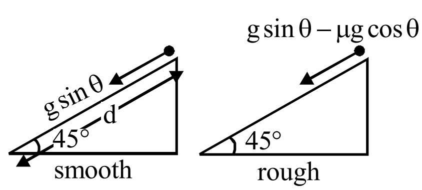
$= 0.2$ kg m sec^{-1}

9. (b) Person will feel his weight less when the lift goes down with some acceleration.

10. (a) In figure no. (a) and (c), a constant force equal to mg sinθ is required. After reaching the highest point, in case of figure (c), no force is required but in case of figure (a), body travels on its own. So a –ve force is acting on the body. In this way, figure (a) represents the given F – x curve.

11. (b) Net force of reaction acts on a body in a lift when it is accelerating. If lift moves up or down with uniform speed then acceleration a = 0, ∴ weight of man = mg is same in ascending or descending hence ratio = 1.

12. (b)



$$d = \frac{1}{2}(g\sin\theta)t_1,$$

$$d = \frac{1}{2}(g\sin\theta - \mu g\cos\theta)t_2$$

$$t_1 = \sqrt{\frac{2d}{g\sin\theta}},$$

$$t_2 = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$$

According to question, $t_2 = nt_1$

$$n\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$$

μ, applicable here, is kinetic friction as the block moves over the inclined plane.

$$n = \frac{1}{\sqrt{1-\mu_k}} \left(\because \cos 45° = \sin 45° = \frac{1}{\sqrt{2}}\right)$$

$$n^2 = \frac{1}{1-\mu_k} \quad \text{or} \quad 1-\mu_k = \frac{1}{n^2}$$

or $\mu_k = 1 - \dfrac{1}{n^2}$

13. (d) $v = \sqrt{2gh} = \sqrt{2\times 9.8\times 50} = 14\sqrt{5}$

$$S = \frac{v^2 - u^2}{2\times 2} = \frac{3^2 - 980}{4} \approx 243 \text{ m}$$

Initially he has fallen 50 m.

$\therefore$ Total height from where he bailed out $= 244 + 50 = 293$ m

14. (a) The net upward acceleration is $(9.8 - 2.8) = 7 \text{ m/sec}^2$

Total mass $= 80 + 5 = 85$ kg

So, net upward force is

$F = 85 \times 7 = 595$ N

15. (a) As per Newton's third law of motion, when a horse pulls a wagon, the force that causes the horse to move forward is the force the ground exerts on it.

16. (a) $F = \dfrac{dm}{dt}(\Delta v) = 4(2+3) = 20$ N.

17. (b) The change in momentum

$\Delta p = m(v_f - v_i)$

$= 0.150\,(60 - (-40))]$

$= 0.150 \times 100 = 15$ Ns

Thus, $F = \dfrac{\Delta p}{\Delta t} = \dfrac{15}{5\times 10^{-3}} = 3\times 10^3$ N

18. (c) Here $T = \dfrac{1}{2}$ sec the required centripetal acceleration for moving in a circle is

$$a_C = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2 = r\times(2\pi/T)^2$$

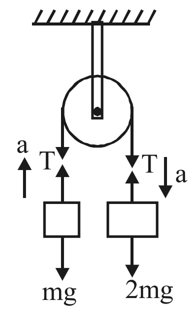
so $a_c = 0.25\times(2\pi/0.5)^2$

$= 16\pi^2 \times .25 = 4.0\pi^2$

19. (c) The acceleration of both the blocks $= \dfrac{15}{3x} = \dfrac{5}{x}$

$\therefore$ Force on $B = \dfrac{5}{x}\times 2x = 10$ N

20. (b) Let a and a' be the accelerations in both cases respectively. Then for fig (a),



(a)

$T - mg = ma$ ...(i)

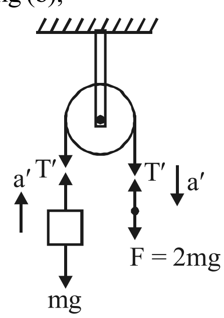
and $2mg - T = 2ma$ ...(ii)

Adding (i) and (ii), we get

$mg = 3ma$

$\therefore a = \dfrac{g}{3}$

For fig (b),



(b)

$T' - mg = ma'$ ...(iii)

and $2mg - T' = 0$ ...(iv)

Solving (iii) and (iv)

$a' = g$

$\therefore a = \dfrac{g}{3}$ and $a' = g$

21. **(c)** Change in momentum along the wall
$= mv\cos 60^\circ - mv\cos 60^\circ = 0$
Change in momentum perpendicular to the wall
$= mv\sin 60^\circ - (-mv\sin 60^\circ)$
$= 2mv\sin 60^\circ$
$\therefore$ Applied force

$$= \frac{\text{Change in momentum}}{\text{Time}}$$

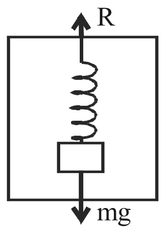
$$= \frac{2\ mv\sin 60^\circ}{0.20}$$

$$= \frac{2\times 3\times 10\times\sqrt{3}}{2\times 0.20} = 50\times 3\sqrt{3}$$

$= 150\sqrt{3}$ newton

22. **(a)** Let acceleration of lift $= a$ and

let reaction at spring balance $= R$



Applying Newton's law

$R - mg = ma \Rightarrow R = m(g+a)$

thus net weight increases, so reading of spring balance increases.

23. **(a)** $F = \dfrac{mv - (-mv)}{t} = \dfrac{2mv}{t} = \dfrac{2\times 0.5\times 2}{10^{-3}}$

$= 2\times 10^3$ N

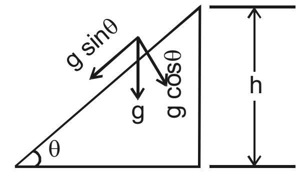
24. **(c)** So by second equation of motion, we get

$$S = ut + \frac{1}{2}at^2$$

here $S = \ell,\ u = 0,\ a = g\sin\theta$

$$t = \sqrt{\frac{2\ell}{a}} = \sqrt{\frac{2h}{g\sin^2\theta}} = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$$

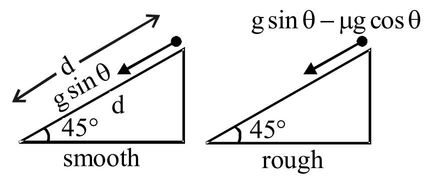
$$\left(\because\ \sin\theta = \frac{h}{\ell}\right)$$



25. **(a)** Let a be the acceleration of mass m_2 in the downward direction. Then
$T - m_2(g/2) = m_1 a$ ....(i)
and $m_2 g - T = m_2 a$ ....(ii)
Adding eqs. (1) and (2), we get
$(m_1 + m_2)a = m_2 g - m_2(g/2) = m_2 g/2$

$$\therefore\ a = \frac{m_2 g}{2(m_1 + m_2)}$$

26. **(b)**



When surface is smooth — When surface is rough

$$d = \frac{1}{2}(g\sin\theta)t_1^2,$$

$$d = \frac{1}{2}(g\sin\theta - \mu g\cos\theta)t_2^2$$

$$t_1 = \sqrt{\frac{2d}{g\sin\theta}},$$

$$t_2 = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$$

According to question, $t_2 = nt_1$

$$n\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$$

μ, applicable here, is coefficient of kinetic friction as the block moves over the inclined plane.

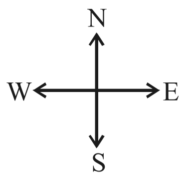
$$n = \frac{1}{\sqrt{1-\mu_k}}$$

$$\left(\because\ \cos 45^\circ = \sin 45^\circ = \frac{1}{\sqrt{2}}\right)$$

$$n^2 = \frac{1}{1-\mu_k} \quad \text{or} \quad 1 - \mu_k = \frac{1}{n^2}$$

or $\mu_k = 1 - \dfrac{1}{n^2}$

27. **(c)** Frictional force is always opposite to the direction of motion



28. **(b)** As we know, coefficient of friction $\mu = \frac{F}{N}$

$\Rightarrow \mu = \frac{ma}{mg} = \frac{a}{g}$ (a = 7.35 m s^{-2} given)

$\therefore \mu = \frac{7.35}{9.8} = 0.75$

Type B : Assertion Reason Questions

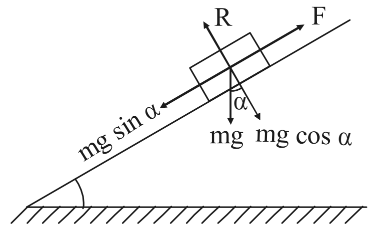
29. **(a)** On a rainy day, the roads are wet. Wetting of roads lowers the coefficient of friction between the types and the road. Therefore, grip on a road of car reduces and thus chances of skidding increases.

30. **(a)** A rocket moves forward taking the help of reaction force. For that it has to exert a force on the surrounding air so that it receives reaction force as per Newton's third law.

31. **(d)** A vehicle moving with constant speed on a straight road is an inertial frame. Newton's laws of motion is applicable only in inertial frame.

32. **(c)** Ball bearing are used to convert sliding friction to rolling friction. Sliding friction is less than rolling friction.

33. **(b)** The maximum value of static friction up to which body does not move is called limiting friction.



Angle of repose is defined as the angle of the inclined plane with horizontal such that a body placed on it is just begins to slide.
In limiting condition,
$F = mg \sin \alpha$ and $R = mg \cos \alpha$
where α–angle of repose.

So $\frac{F}{R} = \tan \alpha$

$\therefore \frac{F}{R} = \mu_s = \tan \theta = \tan \alpha \quad (\because \tan \theta = \mu_s)$

or $\theta = \alpha$
i.e., angle of friciton = angle of repose.

34. **(c)** The assertion is true for a reason that when the car is driven at optimum speed. Then the normal reaction component is enough to provide the centripetal force.

35. **(a)** Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
If roads of the mountain were to go straight up, the slope (θ) would have been large, the frictional force (μmg cos θ) would be small. Due to small friction, wheels of vehicle would slip. Also for going up a large slope, a greater power shall be required.

36. **(d)** The man can exert force on block by pulling the rope. The tension in rope will make the man move. Hence Assertion is incorrect.

Chapter 5

Work, Energy and Power

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If a spring extends by x on loading, then energy stored by the spring is (if T is the tension in spring and k is spring constant) ***[1997]***

(a) (b) $\frac{2T^2}{k}$

(c) $\frac{T^2}{2k}$ (d) $\frac{T^2}{k}$

2. A bullet is fired form a riffle. If the riffle recoils freely, then the kinetic energy of the rifle will be :

(a) same as that of bullet ***[1998]***

(b) more than that of bullet

(c) less than that of bullet

(d) none of these

3. A spring 40 mm long is stretched by applying a force. If 10 N force is required to stretch the spring through one mm, then work done in stretching the spring through 40 mm is : ***[1998]***

(a) 24 J (b) 8 J

(c) 56 J (d) 64 J

4. If the kinetic energy of the body becomes four times of its initial value, then the new momentum will : ***[1998]***

(a) become twice its initial value

(b) remain constant

(c) become four times its initial value

(d) become three times its initial value

5. If the water falls from a dam into a turbine wheel 19.6 m below (which have both KE + PE), then the velocity of water at the turbine is : (take g = 9.8 m/sec^2) ***[1998]***

(a) 19.6 m/s (b) 39.0 m/s

(c) 98.8 m/s (d) 9.8 m/s

6. If the force applied is F and the velocity gained is v, then the power developed is : ***[1998]***

(a) $\frac{v}{F}$ (b) Fv

(c) Fv^2 (d) $\frac{F}{v}$

7. Two bodies of masses m and 4m are moving with equal kinetic energy. Then the ratio of their linear momentum will be : ***[1999]***

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 1 : 2

8. A particle of mass m moving with velocity v collides with a stationary particle of mass 2m. Then the speed of the system after collision is :

(a) 2 v (b) $\frac{v}{2}$ ***[1999]***

(c) 3 v (d) $\frac{v}{3}$

9. Which one of the following is true ? ***[2000]***

(a) momentum is conserved in all collisions but kinetic energy is conserved in elastic collisions

(b) momentum is conserved in all collisions but not kinetic energy

(c) both momentum and kinetic energy are conserved in all collisions

(d) neither momentum nor kinetic energy is conserved in elastic collisions

10. A ball of mass 10 kg is moving with a velocity of 10 m/s. It strikes another ball of mass 5 kg, which is moving in the same direction with a velocity of 4 m/s. If the collision is elastic their velocities after collision will be respectively : ***[2000]***

(a) 12 m/s, 6 m/s (b) 12 m/s, 25 m/s

(c) 6 m/s, 12 m/s (d) 8 m/s, 20 m/s

11. A bullet of mass 10g leaves a riffle at an initial velocity of 1000 m/sec and strikes the earth at the same level with a velocity of 500 m/sec. The work in overcoming the resistance of air will be:

(a) 500 J (b) 5000 J ***[2000]***

(c) 3750 J (d) 475 J

12. A body of mass 5 kg has momentum of 10 kg m/sec. When a force of 0.2 N is applied on it for 10 sec, the change in its kinetic energy is ***[2000]***

(a) 4.4 J (b) 3.3 J

(c) 5.5 J (d) 1.1 J

13. A metal ball of mass 2 kg moving with speed of 36 km/hr is having a collision with a stationary ball of mass 3 kg. If after collision, both the balls move together, the loss in kinetic energy due to collision is : *[2001]*

(a) 80 J (b) 40 J
(c) 60 J (d) 160 J

14. A force $(3\hat{i}+4\hat{j})$ newton acts on a body and displaced it by $(3\hat{i}+4\hat{j})$ metre. The work done by the force is : *[2001]*

(a) 5 J (b) 25 J
(c) 10 J (d) 30 J

15. The kinetic energy of a body becomes four times its initial value. The new linear momentum will be

(a) eight times of the initial value *[2002]*
(b) four times of the initial value
(c) twice of the initial value
(d) remain as the initial value

16. A block of mass 10 kg is moving in x-direction with a constant speed of 10 m/sec. It is subjected to a retarding force F = – 0.1x joule/metre during its travel from x = 20 metre to x = 30 metre. Its final kinetic energy will be *[2005]*

(a) 475 joule (b) 450 joule
(c) 275 joule (d) 250 joule

17. When a ball is thrown up vertically with velocity v_0 it reaches a maximum height of h. If one wishes to triple the maximum height then the ball should be thrown with velocity : *[2005]*

(a) $\sqrt{3}\,v_0$ (b) $3v_0$
(c) $9v_0$ (d) $3/2v_0$

18. For inelastic collision between two spherical rigid bodies: *[2006]*

(a) the total kinetic energy is conserved
(b) the total potential energy is conserved
(c) the linear momentum is not conserved
(d) the linear momentum is conserved

19. If the water falls from a dam into a turbine wheel 19.6 m below, then the velocity of water at the turbines, is (take $g = 9.8\ m/s^2$) *[2007]*

(a) 9.8 m/s (b) 19.6 m/s
(c) 39.2 m/s (d) 98.0 m/s

20. A particle of mass 10 g is kept on the surface of a uniform sphere of mass 100 kg and radius 10 cm. Find the work to be done against the gravitational force between them to take the particle far away from the sphere (you may take $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$) *[2008]*

(a) 3.33×10^{-10} J
(b) 13.34×10^{-10} J
(c) 6.67×10^{-10} J
(d) 6.67×10^{-9} J

21. A vertical spring with force constant k is fixed on a table. A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring so that the spring is compressed by a distance d. The net work done in the process is *[2008]*

(a) $mg(h+d)-\frac{1}{2}kd^2$
(b) $mg(h-d)-\frac{1}{2}kd^2$
(c) $mg(h-d)+\frac{1}{2}kd^2$
(d) $mg(h+d)+\frac{1}{2}kd^2$

22. A shell of mass m moving with velocity v suddenly breaks into 2 pieces. The part having mass m/3 remains stationary. The velocity of other part will be *[2009]*

(a) $\frac{2}{3}v$ (b) $\frac{7}{5}v$
(c) $\frac{3}{2}v$ (d) none of these

23. A mass of 1 kg is hanging from a spring of spring constant 1 N/m. If Saroj pulls the mass down by 2m. The work done by Saroj is *[2009]*

(a) 1 J (b) 2 J
(c) 3 J (d) 4 J

24. A ball loses 15.0% of its kinetic energy when it bounces back from a concrete wall. With what speed you must throw it vertically down from a height of 12.4 m to have it bounce back to the same height (ignore air resistance)? *[2010]*

(a) 6.55 m/s (b) 12.0 m/s
(c) 8.6 m/s (d) 4.55 m/s

25. Two bodies of masses 0.1 kg and 0.4 kg move towards each other with the velocities 1 m/s and 0.1 m/s respectively. After collision they stick together. In 10 sec the combined mass travels

(a) 120m (b) 0.12m *[2010]*
(c) 12m (d) 1.2m

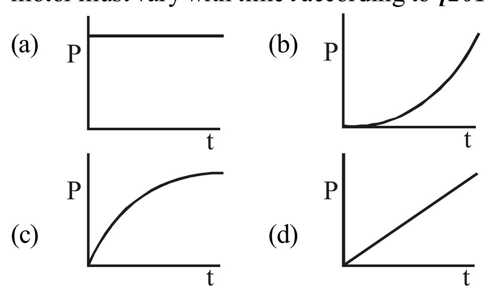
26. The potential energy of a certain particle is given by $U = \frac{1}{2}(x^2 - z^2)$. The force on it is : *[2011]*

(a) $-x\hat{i} + z\hat{k}$ (b) $x\hat{i} + z\hat{k}$
(c) $\frac{1}{2}(x\hat{i} + z\hat{k})$ (d) $\frac{1}{2}(x\hat{i} - z\hat{k})$

27. From a building two balls *A* and *B* are thrown such that *A* is thrown upwards and *B* downwards (both vertically). If v_A and v_B are their respective velocities on reaching the ground, then *[2012]*

(a) $v_A > v_B$
(b) $v_A = v_B$
(c) $v_A < v_B$
(d) their velocities depend on their masses.

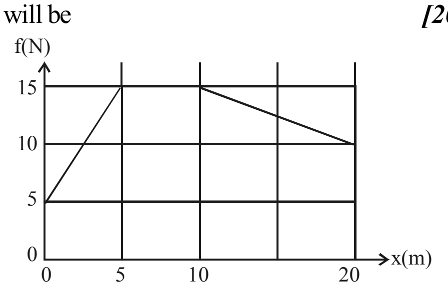
28. A motor drives a body along a straight line with a constant force. The power P developed by the motor must vary with time t according to *[2012]*



29. If the linear momentum is increased by 5%, the kinetic energy will increase by *[2013, 2014]*

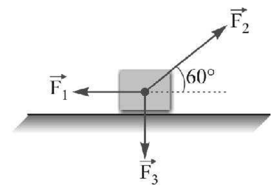
(a) 50% (b) 100%
(c) 125% (d) 10%

30. Figure here shows the frictional force versus displacement for a particle in motion. The loss of kinetic energy in travelling over s = 0 to 20 m will be *[2015]*



(a) 250 J (b) 200 J
(c) 150 J (d) 10 J

31. Figure shows three forces applied to a trunk that moves leftward by 3 m over a smooth floor. The force magnitudes are $F_1 = 5N$, $F_2 = 9N$, and $F_3 = 3N$. The net work done on the trunk by the three forces *[2017]*



(a) 1.50 J (b) 2.40 J
(c) 3.00 J (d) 6.00 J

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 32-34) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

32. **Assertion :** In an elastic collision of two billiard balls, the total kinetic energy is conserved during the short time of oscillation of the balls (i.e., when they are in contact).

Reason : Energy spent against friction does not follow the law of conservation of energy. *[2002]*

33. **Assertion :** Frictional forces are conservative forces.

Reason : Potential energy can be associated with frictional forces. *[2005]*

34. **Assertion :** A quick collision between two bodies is more violent than a slow collision; even when the initial and final velocities are identical.

Reason : The momentum is greater in first case. *[2008]*

Directions for (Qs. 35-40) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

35. **Assertion :** n small balls each of mass m colliding elastically each second on surface with velocity u. The force experienced by the surface is $2mnu$.

Reason : On elastic collision, the ball rebounds with the same velocity. ***[2010]***

36. **Assertion :** A helicopter must necessarily have two propellers.

Reason : Two propellers are provided in helicopter in order to conserve linear momentum. ***[2010]***

37. **Assertion :** If collision occurs between two elastic bodies their kinetic energy decreases during the time of collision.

Reason : During collision intermolecular space decreases and hence elastic potential energy increases. ***[2011]***

38. **Assertion :** The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume.

Reason : The molecules of a gas collide with each other and the velocities of the molecules change due to the collision. ***[2015]***

39. **Assertion :** If collision occurs between two elastic bodies their kinetic energy decreases during the time of collision.

Reason : During collision intermolecular space decreases and hence elastic potential energy increases. ***[2015]***

40. **Assertion :** Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.

Reason : Potential energy of a stretched or compressed spring, proportional to square of extension or compression. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(c)** Energy of spring $= \frac{1}{2}kx^2$

$T = kx \Rightarrow x = \frac{T}{k}$

$E = \frac{1}{2}k\left(\frac{T}{k}\right)^2 = \frac{1}{2}\frac{T^2}{k}$

2. **(c)** For recoil of riffle, momentum will be conserved

$MV = mv$

$$\frac{\text{K.E of riffle}}{\text{K.E of bullet}} = \frac{\frac{1}{2}MV^2}{\frac{1}{2}mv^2}$$

$$= \frac{M}{m}\times\left(\frac{m}{M}\right)^2 = \frac{m}{M}$$

As $m < M$, kinetic energy of riffle < kinetic energy of bullet.

3. **(b)** Force constant,

$k = \frac{F}{x} = \frac{10}{0.001} = 10^4 \, N/m$

Work done $= \frac{1}{2}kx^2 = \frac{1}{2}\times 10^4 \times\left(\frac{40}{1000}\right)^2$

$$= \frac{1}{2}\times 10^4 \times \frac{16}{10^4} = 8 \text{ joule}$$

4. **(a)** $E = \frac{p^2}{2m}; E \propto p^2$

$\frac{E_1}{E_2} = \frac{{p_1}^2}{{p_2}^2} \Rightarrow \frac{1}{4} = \left(\frac{p_1}{p_2}\right)^2 \Rightarrow \frac{p_1}{p_2} = \frac{1}{2}$

ratio of momentum = 1 : 2

5. **(a)** $v^2 = \sqrt{2gh} = \sqrt{2\times 9.8\times 19.6}$

$= 19.6 \, m/sec$

6. **(b)** Power $= \frac{\text{Work}}{\text{Time}} = \frac{F.s}{t} = F.\frac{S}{t} = F.v.$

7. **(d)** Relation between momentum and energy is

$E = \frac{p^2}{2m}; \; E = \frac{{p_1}^2}{2m}; \; E = \frac{{p_2}^2}{2\times 4m};$

$\frac{p_1^2}{2m}\times\frac{2\times 4\,m}{p_2^2} = \frac{E}{E} = 1$

$\frac{{p_1}^2}{{p_2}^2} = \frac{1}{4} \Rightarrow \frac{p_1}{p_2} = \frac{1}{2} \Rightarrow p_1 : p_2 = 1 : 2$

8. **(d)** Applying conservation of momentum,

$mv + 0 = (2m + m)v' = 3mv'$

$v' = \frac{mv}{3m} = \frac{v}{3}$

9. **(a)** Kinetic energy is not conserved in inelastic collision as some energy is stored as deformation at the point of collision in the form of potential energy. Since no deformation occurs in case of elastic collision so, kinetic energy is conserved. But momentum is conserved in both elastic and inelastic collisions as in both the cases, no external force is applied on them so, no change in momentum.

10. **(c)** Let their velocities after the collision be v_1 and v_2. As we know for elastic collision.

Relative velocity of approach

= relative velocity of separation

$10 - 4 = v_2 - v_1 \Rightarrow 6 = v_2 - v_1$

$\Rightarrow v_1 = v_2 - 6$

Applying conservation of momentum,

$10\times 10 + 5\times 4 = 10v_1 + 5v_2$

$120 = 10v_1 + 5v_2$

$120 = 10(v_2 - 6) + 5v_2 = 15v_2 - 60$

$15v_2 = 180 \Rightarrow v_2 = 12 \text{ cm/sec},$

$v_1 = 6 \text{ cm/sec}$

11. **(c)** Loss of kinetic energy of bullet

= The work done in over coming air resistance.

$= \frac{1}{2}\times\frac{10}{1000}(1000^2 - 500^2)$

$= \frac{1}{2}\times\frac{1}{100}\times 1500\times 500 = 3750J$

12. **(a)** Change in momentum,

$\Delta p = F.t = 0.2\times 10 = 2$

Initial value of velocity $= \frac{10}{5} = 2\,m/sec$

Initial energy $= \frac{1}{2}\times 5\times 2\times 2 = 10J$

Total final momentum $= 10 + 2$

$= 12$ kg m/sec

Final velocity $= \frac{12}{5}$ m/sec

Final energy $= \frac{1}{2}\times 5\times\frac{12}{5}\times\frac{12}{5}$

$= \frac{72}{5} = 14.4J$

Change in energy $= 14.4 - 10 = 4.4$ joule

13. (c) Let v be the common velocity.

Applying conservation of momentum

$2\times 10 + 3\times 0 = (2+3)v$

$v = \frac{10\times 2}{5} = 4\,m/sec$

[36 km/hour = 10m/sec]

Initial Energy $= \frac{1}{2}\times 2\times(10)^2 + 0 = 100$ J

Final Energy $= \frac{1}{2}\times 5\times 4\times 4 = 40J$

Loss of energy $= 100 - 40 = 60$ joule

14. (b) Work done $= \vec{F}.\vec{s}$

$= (3\hat{i}+4\hat{j}).(3\hat{i}+4\hat{j}) = 9 + 16 = 25$ joule

15. (c) The relation between kinetic energy and linear momentum is

$E = \frac{p^2}{2m}$ so $E \propto p^2$

If energy becomes four times then momentum will become twice as

$p \propto \sqrt{E}$

16. (a) We know that,

Change in kinetic energy

= work done on the object by force

Here, work done $= \int F\,dx = \int_{20}^{30} 0.1x\ \ dx$

$= 0.1\left[\frac{x^2}{2}\right]_{20}^{30} = \frac{0.1}{2}[30^2 - 20^2]$

$= 0.05[900 - 400] = 0.05\times 500 = 25$ joule

Now, initial kinetic energy

$= \frac{1}{2}\times 10\times 100 = 500$ joule

Final kinetic energy $= 500 - 25 = 475$ joule

[Direction of force is opposite to direction of motion]

17. (a) $\frac{1}{2}mv_0^2 = mgh$ .... (i)

$\frac{1}{2}mv^2 = mg\times 3h$ .... (ii)

Dividing $\frac{v^2}{v_0} = 3;\quad v^2 = 3v_0^2$

$\Rightarrow\ v = \sqrt{3}v_0$

18. (d) In inelastic collision, linear momentum is conserved.

19. (b) $v^2 - u^2 = 2as \Rightarrow v^2 - 0^2 = 2\times 9.8\times 19.6$

(Initial velocity = 0 as water falls from rest)

$\Rightarrow\ v = \sqrt{2\times 9.8\times 2\times 9.8}$

$= 2\times 9.8 = 19.6$ m/s

20. (c) $W = \frac{GMm}{R}$

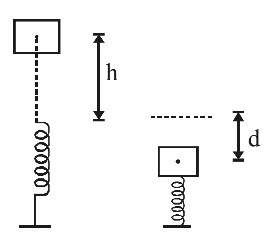
$W = \frac{6.67\times 10^{-11}\times 100}{0.1}\times\frac{10}{1000}$

$= 6.67\times 10^{-10}$ J

21. (a) Gravitational potential energy of ball gets converted into elastic potential energy of the spring.

$mg(h+d) = \frac{1}{2}kd^2$

Net work done $= mg(h+d) - \frac{1}{2}kd^2 = 0$



22. (c) (m) → v ⟶ (m/3) (m – m/3 = 2m/3)

v = 0 v' = ?

According to momentum conservation.

$mv = m/3\times 0 + \frac{2m}{3}v'$

$mv = \frac{2m}{3}v'$ $\boxed{v' = \frac{3}{2}v}$

23. **(b)** Workdone $= \int_0^2 F.dx = \int_0^2 kx\,dx = \left.\frac{1}{2}kx^2\right]_0^2$

$= \frac{1}{2}.1.(4-0) = 2\,J$

24. **(a)** Given: $h = 12.4$, $v = ?$

$\therefore \quad v^2 = u^2 + 2gh$

i.e., $v^2 = u^2 + 2 \times 9.8 \times 12.4$

$= u^2 + 243.04$

Kinetic energy of the ball when it just hits the wall

$= \frac{1}{2}mv^2 = \frac{1}{2}m(u^2 + 243.04)$

The K.E. of ball after the impact

$= \frac{(100-15)}{100} \times \frac{1}{2}m(u^2 + 243.04)$

$= \frac{85}{100} \times \frac{1}{2}m\ (u^2 + 243.04)$

Let v_2 be the upward velocity just after the collision with the ground.

So, $\frac{1}{2}mv_2^2 = \frac{85}{100} \times \frac{1}{2}m(u^2 + 243.04)$

$v_2^2 = \frac{85}{100}(u^2 + 243.04)$

Now, taking upward motion

$v = 0,\ u = v_2$

$\therefore \quad v^2 = u^2 - 2gh$

$0 = \frac{85}{100}(u^2 + 243.04) - 2 \times 9.8 \times 12.4$

$\frac{85}{100}u^2 = 36.46$

$u^2 = \frac{36.46 \times 100}{85} = 42.89$

$u = 6.55$ m/s

25. **(d)** According to conservation of momentum

$m_1v_1 + m_2v_2 = (m_1 + m_2)\,v$,

where v is common velocity of the two bodies.

$m_1 = 0.1$ kg $m_2 = 0.4$ kg

$v_1 = 1$ m/s, $v_2 = -0.1$ m/s,

$\therefore \quad 0.1 \times 1 + 0.4 \times (-0.1) = (0.1 + 0.4)\,v$

or $\quad 01. - 0.04 = 0.5\,v$,

$v = \frac{0.06}{0.5} = 0.12$ m/s

Hence, distance covered $= 0.12 \times 10 = 1.2$ m.

26. **(a)** $F_x = \frac{-dU}{dx} = x\frac{-d}{dx}\left(\frac{x^2 - z^2}{2}\right) = -x$

$F_Z = \frac{-dU}{dt} = \frac{-d}{dz}\left(\frac{x^2 - z^2}{2}\right) = z$

$\therefore \quad \vec{F} = -x\hat{i} + z\hat{k}$

27. **(b)** As the ball moves down from height 'h' to ground the P.E. at height 'h' is converted to K.E. at the ground (Applying Law of conservation of Energy).

Hence, $\frac{1}{2}m_Av_A^2 = m_Agh_A$ or $v_A = \sqrt{2gh}$;

Similarly, $v_B = \sqrt{2gh}$ or $v_A = v_B$

28. **(d)** $P = F \times v \Rightarrow P = F\,a\,t$

$\therefore \quad P \propto t$

29. **(d)** As $E = \frac{p^2}{2m}$

$\therefore \quad \frac{dE}{E} = 2\left(\frac{dp}{p}\right) = 2 \times 5\% = 10\%$

30. **(a)** Loss in K.E = Area under the curve

31. **(a)** $\vec{F} = -5\hat{i} + 9\cos 60°\hat{i} + 9\sin 60°\hat{j} - 3\hat{j}$

$= -5\hat{i} + \frac{9}{2}\hat{i} + \frac{9\sqrt{3}}{2}\hat{j} - 3\hat{j}$

$= -\frac{\hat{i}}{2} + \left(\frac{9\sqrt{3}}{2} - 3\right)\hat{j}$

$\vec{s} = -3\hat{i}$.

$W = \vec{F}.\vec{s} = \left[-\frac{\hat{i}}{2} + \left(\frac{9\sqrt{3}}{2} - 3\right)\hat{j}\right].(-3\hat{i})$

$= 1.5$ J.

Type B : Assertion Reason Questions

32. **(d)** In an elastic collision, no conversion of energy, so K.E. remains constant during the time of collision. There is no friction acting in this case. In case of friction too conservation of energy is followed provided we take into account all the transformations there.

33. (d) Frictional force is non-conservative as work done against frictional force can not be stored as potential energy.

34. (a) In a quick collision, time t is small.

As $F \times t$ = constant, therfore, force involved is large. I.e., collision is more violent in comparison to slow collision .

Momentum, $p = mv$ or $p \propto v$

i.e., momentum is directly proportional to its velocity, so the momentum is greater in a quicker collision.

35. (a) In elastic collision, kinetic energy remains conserved therefore the ball rebounds with the same velocity. According to Newton's second law

$F \times t$ = change in linear momentum.

$\therefore\ F \times 1 = m \times n\,(u + u) \Rightarrow F = 2mnu.$

36. (c) If there were only one propeller in the helicopter, the helicopter itself, would have turned in opposite direction of the direction of propeller due to conservation of angular momentum. Thus two propeller provides helicopter a steady movement.

37. (a)

38. (b) Total translational kinetic energy

$$= \frac{3}{2} nRT = \frac{3}{2} PV$$

In an ideal gas all molecules moving randomly in all direction collide and their velocity changes after collision.

39. (a)

40. (d) Potential energy $U = \frac{1}{2}kx^2$ *i.e.* $U \propto x^2$

This is a equation of parabola, so graph between U and x is a parabola not a straight line.

Chapter 6

System of Particles and Rotational Motion

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If there is change of angular momentum from 1J to 5 J in 5 second. Then the torque is : *[1997]*

(a) $\frac{3J}{5}$ (b) $\frac{4J}{5}$

(c) $\frac{5J}{4}$ (d) none of these

2. If the equation for the displacement of a particle moving on a circular path is given as $\theta = 2t^3 + 0.5$, where θ is in radians and t is in second. Then the angular velocity of the particle after two second will be : *[1998]*

(a) 36 rad/sec (b) 8 rad/sec

(c) 48 rad/sec (d) 24 rad/sec

3. The moment of inertia of a regular circular disc of mass 0.4 kg and radius 100 cm about an axis perpendicular to the plane of the disc and passing through its centre is: *[1999]*

(a) 0.2 kg m^2 (b) 0.02 kg m^2

(c) 0.002 kg m^2 (d) 2 kg m^2

4. A constant torque of 31.4 Nm is exerted on a pivoted wheel. If the angular acceleration of the wheel is 4 π rad/sec^2, then the moment of inertia will be : *[2001]*

(a) 5.8 kg-m^2 (b) 4.5 kg-m^2

(c) 5.6 kg-m^2 (d) 2.5 kg-m^2

5. The motion of planets in the solar system is an example of the conservation of : *[2003]*

(a) mass

(b) linear momentum

(c) angular momentum

(d) energy

6. The direction of the angular velocity vector along : *[2004]*

(a) the tangent to the circular path

(b) the inward radius

(c) the outward radius

(d) the axis of rotation

7. In an orbital motion, the angular momentum vector is : *[2004]*

(a) along the radius vector

(b) parallel to the linear momentum

(c) in the orbital plane

(d) perpendicular to the orbital plane

8. A horizontal platform is rotating with uniform angular velocity around the vertical axis passing through its centre. At some instant of time a viscous fluid of mass m is dropped at the centre and is allowed to spread out and finally fall. The angular velocity during this period : *[2005]*

(a) decreases continuously

(b) decreases initially and increases again

(c) remains unaltered

(d) increases continuously

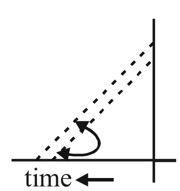
9. A solid sphere is rolling on a frictionless surface, shown in figure with a translational velocity v m/s. If it is to climb the inclined surface then v should be : *[2005]*

(a) $\geq \sqrt{\frac{10}{7}gh}$ (b) $\geq \sqrt{2gh}$

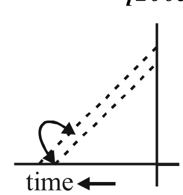
(c) 2gh (d) $\frac{10}{7}gh$

10. A ladder is leaned against a smooth wall and it is allowed to slip on a frictionless floor. Which figure represents the track of its centre of mass? *[2005]*

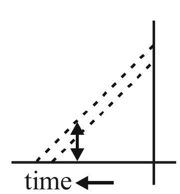
(a)



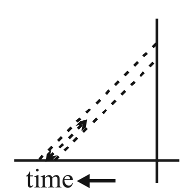
(b)



(c)



(d)

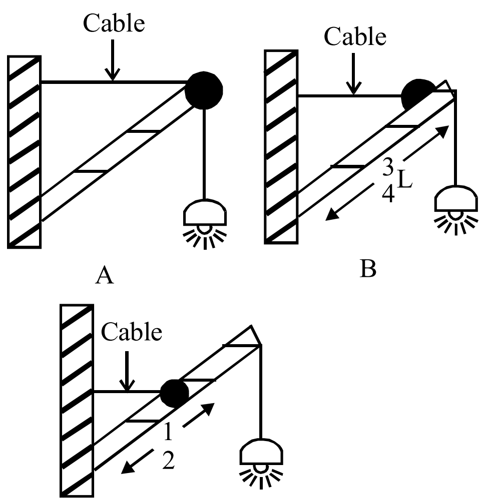


11. The moment of inertia of a rod about an axis through its centre and perpendicular to it is $\frac{1}{12}ML^2$ (where M is the mass and L, the length of the rod). The rod is bent in the middle so that the two halts make an angle of 60°. The moment of inertia of the bent rod about the same axis would be : ***[2006]***

(a) $\frac{1}{48}ML^2$ (b) $\frac{1}{12}ML^2$

(c) $\frac{1}{24}ML^2$ (d) $\frac{ML^2}{8\sqrt{3}}$

12. If a street light of mass M is suspended from the end of a uniform rod of length L in different possible patterns as shown in figure, then : ***[2006]***



A B C

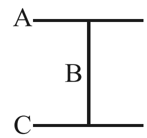
(a) Pattern A is more sturdy
(b) Pattern B is more sturdy
(c) Pattern C is more sturdy
(d) All will have same sturdiness

13. If a solid sphere of mass 1 kg and radius 0.1 m rolls without slipping at a uniform velocity of 1 m/s along a straight line on a horizontal floor, the kinetic energy is ***[2007]***

(a) $\frac{7}{5}$J (b) $\frac{2}{5}$J

(c) $\frac{7}{10}$J (d) 1 J

14. In the diagram shown below all three rods are of equal length L and equal mass M. The system is rotated such that rod B is the axis. What is the moment of inertia of the system? ***[2007]***



(a) $\frac{ML^2}{6}$ (b) $\frac{4}{3}ML^2$

(c) $\frac{ML^2}{3}$ (d) $\frac{2}{3}ML^2$

15. The direction of the angular velocity vector is along ***[2007]***

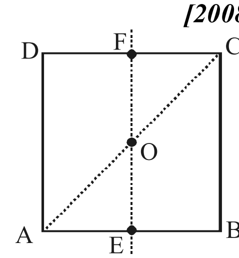
(a) the tangent to the circular path
(b) the inward radius
(c) the outward radius
(d) the axis of rotation

16. Four point masses, each of value m, are placed at the corners of a square ABCD of side ℓ. The moment of inertia of this system about an axis passing through A and parallel to BD is

(a) $2m\ell^2$ (b) $\sqrt{3}m\ell^2$ ***[2008]***

(c) $3m\ell^2$ (d) $m\ell^2$

17. For the given uniform square lamina ABCD, whose centre is O, ***[2008]***



(a) $I_{AC} = \sqrt{2}\, I_{EF}$

(b) $\sqrt{2} I_{AC} = I_{EF}$

(c) $I_{AD} = 3I_{EF}$

(d) $I_{AC} = I_{EF}$

18. A wheel has angular acceleration of 3.0 rad/s^2 and an initial angular speed of 2.00 rad/s. In a time of 2 s it has rotated through an angle (in radian) of ***[2008]***

(a) 6 (b) 10

(c) 12 (d) 4

19. The angular speed of a body changes from ω_1 to ω_2 without applying a torque but due to changes in moment of inertia. The ratio of radii of gyration in two cases is ***[2009]***

(a) $\omega_2 : \omega_1$ (b) $\sqrt{\omega_2} : \sqrt{\omega_1}$

(c) $\sqrt{\omega_2^2} : \sqrt{\omega_1^2}$ (d) $\sqrt{\omega_2^3} : \sqrt{\omega_1^3}$

20. A disc is rolling without slipping on a straight surface. The ratio of its translational kinetic energy to its total kinetic energy is ***[2009]***

(a) $\frac{2}{3}$ (b) $\frac{1}{3}$

(c) $\frac{2}{5}$ (d) $\frac{3}{5}$

21. Two particles of masses m_1 and m_2 ($m_1 > m_2$), initially at rest, move towards each other under an inverse square law force of attraction. Pick out the correct statement about the centre of mass (CM) of the system ***[2009]***

(a) The CM moves towards m_1

(b) The CM moves towards m_2

(c) The CM remains at rest

(d) The motion of CM is accelerated

22. A wire of mass m and length l is bent in the form of a circular ring, the moment of inertia of the ring about its axis is ***[2010]***

(a) $\left(\frac{1}{8\pi^2}\right)ml^2$ (b) $\left(\frac{1}{2\pi^2}\right)ml^2$

(c) $\left(\frac{1}{4\pi^2}\right)ml^2$ (d) ml^2

23. Which of the following is true about the angular momentum of a cylinder down a slope without slipping : ***[2011]***

(a) its magnitude changes but the direction remains same

(b) both magnitude and direction change

(c) only the direction change

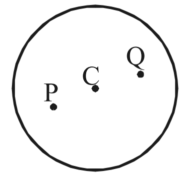
(d) neither change

24. A circular disc rotating with frequency $f_0 = 1.3$ rev/sec comes to a stop in 30 seconds. The approximate angular acceleration is : ***[2011]***

(a) $+0.27$ rad/sec^2 (b) -0.27 rad/sec^2

(c) $+0.54$ rad/sec^2 (d) $+0.27$ rad/sec^2

25. A disc is rolling (without slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let V_p, V_q and V_c be the magnitude of velocities of points P, Q and C respectively, then ***[2012]***



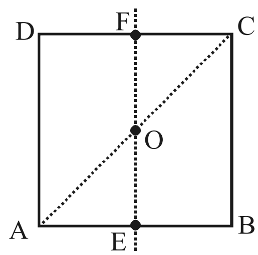
(a) $V_Q > V_C > V_P$

(b) $V_Q < V_C < V_P$

(c) $V_Q = V_P,\ V_C = \frac{1}{2}V_P$

(d) $V_Q = V_C = V_P$

26. For the given uniform square lamina ABCD, whose centre is O, ***[2012]***



(a) $I_{AC} = \sqrt{2}\ I_{EF}$ (b) $\sqrt{2}I_{AC} = I_{EF}$

(c) $I_{AD} = 3I_{EF}$ (d) $I_{AC} = I_{EF}$

27. One quarter sector is cut from a uniform circular disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the centre of the original disc. Its moment of inertia about the axis of rotation is ***[2013]***

(a) $\frac{1}{2}mR^2$ (b) $\frac{1}{4}mR^2$

(c) $\frac{1}{8}mR^2$ (d) $\sqrt{2}mR^2$

28. A particle is confined to rotate in a circular path decreasing linear speed, then which of the following is correct? ***[2013]***

(a) $\vec{L}$ (angular momentum) is conserved about the centre.

(b) Only direction of angular momentum $\vec{L}$ is conserved.

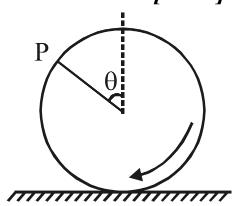
(c) It spirals towards the centre.

(d) Its acceleration is towards the centre.

29. A flywheel rotates about an axis. Due to friction at the axis, it experiences an angular retardation proportional to its angular velocity. If its angular velocity falls to half while it makes n rotations, how many more rotations will it make before coming to rest? ***[2013]***

(a) 2n (b) n
(c) n/2 (d) n/3

30. A wheel is rolling straight on ground without slipping. If the axis of the wheel has speed v, the instantenous velocity of a point P on the rim, defined by angle θ, relative to the ground will be ***[2014]***



(a) $v\cos\left(\frac{1}{2}\theta\right)$

(b) $2v\cos\left(\frac{1}{2}\theta\right)$

(c) $v(1+\sin\theta)$

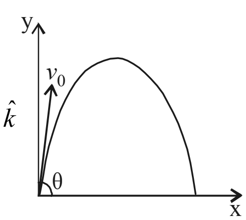
(d) $v(1+\cos\theta)$

31. Consider a thin uniform square sheet made of a rigid material. If its side is 'a' mass m and moment of inertia I about one of its diagonals, then ***[2016]***

(a) $I>\frac{ma^2}{12}$ (b) $\frac{ma^2}{24}<I<\frac{ma^2}{12}$

(c) $I=\frac{ma^2}{24}$ (d) $I=\frac{ma^2}{12}$

32. A small particle of mass m is projected at an angle θ with the x-axis with an initial velocity v_0 in the x-y plane as shown in the figure. At a time $t<\frac{v_0\sin\theta}{g}$, the angular momentum of the particle is ***[2016]***



(a) $-mg\,v_0t^2\cos\theta\,\hat{j}$

(b) $mg\,v_0t\cos\theta\hat{k}$

(c) $-\frac{1}{2}mg\,v_0t^2\cos\theta\,\hat{k}$

(d) $\frac{1}{2}mg\,v_0t^2\cos\theta\,\hat{i}$

33. A solid sphere rolls down two different inclined planes of same height, but of different inclinations. In both cases ***[2017]***

(a) speed and time of descent will be same
(b) speed will be same, but time of descent will be different
(c) speed will be different, but time of descent will be same
(d) speed and time of descent both are different

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 34-39) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

34. **Assertion :** Moment of inertia depends on the axis of rotation and the nature of distribution of the mass of the body.
Reason : Moment of inertia is the rotational inertia of the body. ***[1997]***

35. **Assertion :** The earth is slowing down and as a result the moon is coming nearer to it.
Reason : The angular momentum of the earth moon system is not conserved. ***[2003]***

36. **Assertion :** There are very small sporadic changes in the speed of rotation of the earth
Reason : Shifting of large air masses in the earth's atmosphere produce a change in the moment of inertia of the earth causing its speed of rotation to change. ***[2004]***

37. **Assertion :** For a system of particles under central force field, the total angular momentum is conserved.
Reason : The torque acting on such a system is zero. ***[2005]***

38. **Assertion :** A judo fighter in order to throw his opponent on to the mat tries to initially bend his opponent and then rotate him around his hip.
Reason : As the mass of the opponent is brought closer to the fighter's hip, the force required to throw the opponent is reduced. ***[2006]***

39. **Assertion :** The velocity of a body at the bottom of an inclined plane of given height is more when it slides down the plane, compared to, when it rolling down the same plane.
Reason : In rolling down a body acquires both, kinetic energy of translation and rotation. ***[2008]***

Directions for (Qs. 40-45) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

40. **Assertion :** The position of centre of mass of a body depends upon shape and size of the body.

Reason : Centre of mass of a body lies always at the centre of the body. ***[2009]***

41. **Assertion :** If polar ice melts, days will be shorter.

Reason : Moment of inertia decreases and thus angular velocity increases. ***[2010]***

42. **Assertion :** If no external force acts on a system of particles, then the centre of mass will not move in any direction.

Reason : If net external force is zero, then the linear momentum of the system changes. ***[2011]***

43. **Assertion:** A rigid disc rolls without slipping on a fixed rough horizontal surface with uniform angular velocity. Then the acceleration of lowest point on the disc is zero.

Reason : For a rigid disc rolling without slipping on a fixed rough horizontal surface, the velocity of the lowest point on the disc is always zero. ***[2013]***

44. **Assertion :** For the planets orbiting around the sun, angular speed, linear speed and K.E. changes with time, but angular momentum remains constant.

Reason : No torque is acting on the rotating planet. So its angular momentum is constant. ***[2013]***

45. **Assertion :** Radius of gyration of body is a constant quantity.

Reason : The radius of gyration of a body about an axis of rotation may be defined as the root mean square distance of the particle from the axis of rotation. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** Torque $= \frac{dL}{dt} = \frac{\Delta L}{\Delta t}$,

Here $\Delta L = 5J - J = 4J$

$\Delta t = 5$ sec torque $= \frac{4}{5}J$

2. **(d)** $\theta = 2t^3 + 0.5$

$\omega = \frac{d\theta}{dt} = 6t^2 = 6 \times 2^2$

$= 6 \times 4 = 24$ radian / sec

3. **(a)** Moment of inertia of a circular disc

$= \frac{1}{2}MR^2 = \frac{1}{2} \times 0.4 \times 1 \times 1 = 0.2\ kg - m^2$

4. **(d)** Torque $= I\alpha$

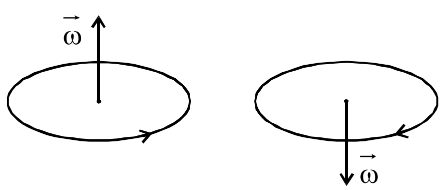
[I is moment of inertia and α is angular acceleration]

$31.4 = I \times 4\pi$

$I = \frac{31.4}{4\pi} = 2.50\ \ kg\text{-}m^2$

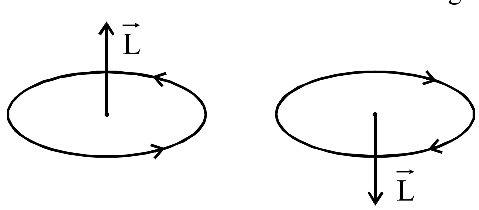
5. **(c)** For any circular motion the angular momentum is conserved as no torque is acting on it because centripetal force acts through the point of axis.

6. **(d)**



Angular velocity is a vector whose direction is perpendicular to the plane of circular path or axis of rotation. Its direction has been shown in the figure.

7. **(d)** Angular momentum is a vector quantity whose direction is perpendicular to plane of revolution. It has been shown in the figure.



8. **(b)** When the fluid spreads out, the moment of inertia of the system is increased. If we apply conservation of angular momentum.

$I\omega = I_1\omega_1$

As I increases due to water spreading out, the angular velocity decrease.

When water level falls, I decreases resulting in increased angular velocity.

9. **(a)** Applying law of conservation of energy for rotating body,

$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = mgh$

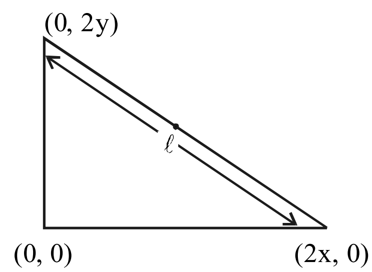
$\frac{1}{2}mv^2 + \frac{1}{2}\frac{2}{5}mr^2 \times \frac{v^2}{r^2} = mgh$

$\frac{v^2}{2} + \frac{2v^2}{10} = gh$

$\frac{5v^2 + 2v^2}{10} = gh \Rightarrow v^2 = \frac{10}{7}gh$

$v \geq \sqrt{\frac{10}{7}gh}$

10. **(a)**



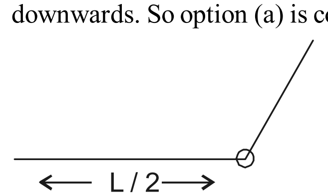
Let ℓ be the length of ladder and (x, y) be its centre of mass which is middle point of the ladder. From the figure it is clear that,

$(2x)^2 + (2y)^2 = \ell^2 \Rightarrow x^2 + y^2 = \frac{\ell^2}{4}$

So, locus of (x, y) is a circle with radius $\frac{\ell}{2}$.

As centre of mass will always go downwards. So option (a) is correct.

11. **(b)**



We know that for a body, moment of inertia

$M.I = \sum M r^2$

Now, bending of rod does not alter the distribution of individual particle, the body is made of, so the value of $\sum M r^2$ will not change. Hence the changed moment of inertia of the body will be $\frac{1}{12}ML^2$.

12. **(a)** Torque created due to weight of street light remains same in all the three cases. It is balanced by torque created by tension in the string. So if τ be the torque created by weight of lamp and T be tension in the string and d be perpendicular distance of cable from the axis then,

$\tau = T.d$

Tension will be least for largest d. This is in pattern A. So Pattern A is more sturdy.

13. **(c)** When a body rolls over a smooth surface, it has linear K.E. and rotational K.E.

$\therefore E = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

where $\omega = \frac{v}{r}$ and $I = \frac{2}{5}mr^2$ for solid sphere.

$\therefore K.E. = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right).\frac{v^2}{r^2}$

$= \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2 = \frac{7}{10} \times 1 \times 1^2$

$= \frac{7}{10}J$

14. **(a)** Moment of inertia of system
= M.I of A + M.I. of B + M.I of C
M.I of A = M. T through centre and perpendicular to length $= \frac{1}{12}ML^2$

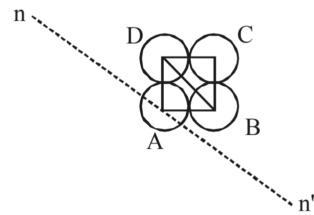
M.I of C = M.I of A $= \frac{1}{12}ML^2$

M.I of B = 0
(moment of mass about an axis passing through its own position is zero)

$\therefore$ Total M.I $= \frac{1}{12}ML^2 + \frac{1}{12}ML^2 = \frac{1}{6}ML^2$

15. **(d)** $\omega = \frac{2\pi}{T} = \frac{\theta}{t}$ in magnitude and direction is axis of rotation (direction in which θ changes with t)

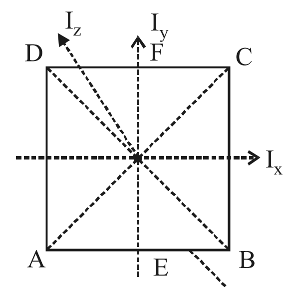
16. **(c)**



$I_{nn'} = 2 \times m\left(\frac{\ell}{\sqrt{2}}\right)^2 + m(\sqrt{2}\ell)^2$

$= m\ell^2 + 2m\ell^2 = 3m\ell^2$

17. **(d)** By the theorem of perpendicular axes,
$I_z = I_x + I_y$ or, $I_z = 2\,I_y$
($\because$ $I_x = I_y$ by symmetry of the figure)



$\therefore\ I_{EF} = \frac{I_z}{2}$ ... (i)

Again, by the same theorem,
$I_z = I_{AC} + I_{BD} = 2\,I_{AC}$
($\because$ $I_{AC} = I_{BD}$ by symmetry of the figure)

$\therefore\ I_{AC} = \frac{I_z}{2}$ ... (ii)

From (i) and (ii), we get $I_{EF} = I_{AC}$.

18. **(b)** Given : initial angular speed,
$\omega_0 = 2$ rad/s, angular acceleration,
$\alpha = 3$ rad/s^2, time, t = 2s
From the equation of the angular displacement,

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 = 2 \times 2 + \frac{1}{2} \times 3 \times (2)^2$

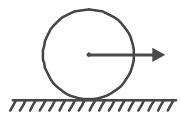
$= 4 + 6 = 10$ radians

19. **(a)** $I_1\omega_1 = I_2\omega_2$

$MK_1^2\omega_1 = MK_2^2\omega_2$

$$\left(\frac{K_1}{K_2}\right)^2 = \frac{\omega_2}{\omega_1} \Rightarrow \frac{K_1}{K_2} = \sqrt{\omega_2} : \sqrt{\omega_1}$$

20. (a) $\text{TKE} = \frac{1}{2}mv^2$



$\text{RKE} = \frac{1}{2}I\omega^2$

$\omega = v / R$

$$\Rightarrow \frac{\text{TKE}}{\text{TKE} + \text{RKE}} = \frac{2}{3}$$

21. (c) When no external force acts on the system and initially velocity of centre of mass is zero and so the centre mass remain at rest.

22. (c) Length of the wire $= l$.

Let it is bent in the form of a circular ring of radius r.

Thus, radius of the ring

$$r = \frac{l}{2\pi}$$

The moment of inertia of the ring about its axis,

$$I = mr^2 = m\left(\frac{l}{2\pi}\right)^2 = m \times \frac{l^2}{4\pi^2}$$

$$= \left(\frac{1}{4\pi^2}\right)ml^2.$$

23. (a) As axis of rotation is along the length of the cylinder are remain same, but speed increases continuously.

24. (b) Given, $\omega_0 = 2\pi f = 2\pi \times 13. = 2.6\pi$ rad/s

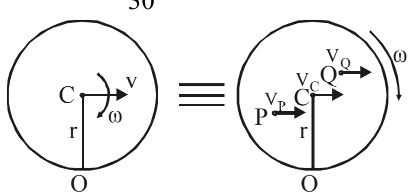
Using I equation of motion

$\omega = \omega_0 + \alpha t$

$0 = 2.6\pi + \alpha \times 30$

$$\Rightarrow \quad \alpha = \frac{2.6\pi}{30} = -0.27 \text{ rad / s}^2$$

25. (a)



(I) (II)

From Fig. (I), we have OC = r (radius)

Therefore, $v = r\omega$

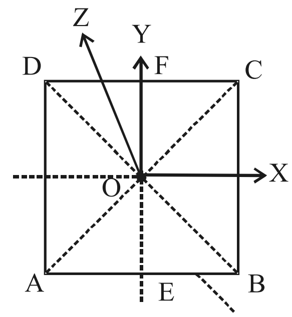
Since, ω = constant, therefore $v \propto r$

Now, form Fig (II), it is clear that the distance, $OP < OC < OQ \Rightarrow V_P < V_C < V_Q$ or $V_Q > V_C > V_P$.

26. (d) By the theorem of perpendicular axes,

$I_z = I_x + I_y$ or, $I_z = 2I_y$

($\because$ $I_x = I_y$ by symmetry of the figure)



$$\therefore \quad I_{EF} = \frac{I_z}{2} \qquad \text{...(i)}$$

Again, by the same theorem

$I_z = I_{AC} + I_{BD} = 2I_{AC}$

($\therefore$ $I_{AC} = I_{BD}$ by symmetry of the figure)

$$\therefore \quad I_{AC} = \frac{I_z}{2} \qquad \text{...(ii)}$$

From (i) and (ii), we get

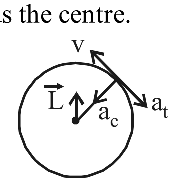
$I_{EF} = I_{AC}$.

27. (a) For complete disc with mass '4M', M.I. about given axis $= (4M)(R^2/2) = 2MR^2$

Hence, by symmetry, for the given quarter of the disc

$$\text{M.I.} = 2MR^2/4 = \frac{1}{2}MR^2$$

28. (b) Since v is changing (decreasing), L is not conserved in magnitude. Since it is given that a particle is confined to rotate in a circular path, it can not have spiral path. Since the particle has two accelerations a_c and a_t therefore the net acceleration is not towards the centre.



The direction of $\vec{L}$ remains same even when the speed decreases.

29. **(b)** α is propotional to ω

Let $\alpha = k\omega$ $\quad$ ($\because$ k is a constant)

$$\frac{d\omega}{dt} = k\omega \qquad [\text{also } \frac{d\theta}{dt} = \omega \Rightarrow dt = \frac{d\theta}{\omega}]$$

$$\therefore \frac{\omega d\omega}{d\theta} = k\omega \Rightarrow d\omega = kd\theta$$

Now $\displaystyle\int_{\omega}^{\omega/2} d\omega = k\int d\theta$

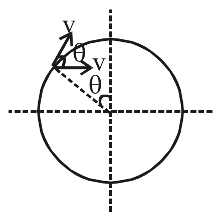
$$\int_{\omega/2}^{0} d\omega = k\int_{0}^{\theta} d\theta \Rightarrow -\frac{\omega}{2} = k\theta \Rightarrow -\frac{\omega}{2} = k\theta_1$$

$(\because \theta_1 = 2\pi n)$

$\therefore \theta = \theta_1$ or $2\pi n_1 = 2\pi n$

$n_1 = n$

30. **(b)**

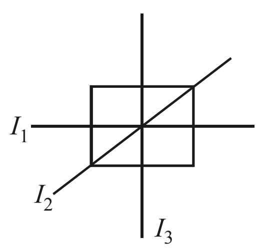


$$v_R = \sqrt{v^2 + v^2 + 2v^2 \cos\theta} = \sqrt{2v^2(1+\cos\theta)}$$

$$= 2v\cos\frac{\theta}{2}$$

31. **(d)** For a thin uniform square sheet

$$I_1 = I_2 = I_3 = \frac{ma^2}{12}$$



32. **(c)** $\vec{L} = m(\vec{r} \times \vec{v})$

$$\vec{L} = m\left[v_0 \cos\theta t\,\hat{i} + (v_0 \sin\theta t - \frac{1}{2}gt^2)\hat{j}\right]$$

$$\times\left[v_0 \cos\theta\,\hat{i} + (v_0 \sin\theta - gt)\hat{j}\right]$$

$$= mv_0 \cos\theta t\left[-\frac{1}{2}gt\right]\hat{k}$$

$$= -\frac{1}{2}mgv_0t^2 \cos\theta\hat{k}$$

33. **(b)** In pure rolling, mechanical energy remains conserved. Therefore, when heights of inclines are equal, speed of sphere will be same in both the case. But as acceleration down the plane, $a \propto \sin\theta$. Therefore, acceleration and time of descent will be different.

Type B : Assertion Reason Questions

34. **(b)** We know that

$$I = \frac{m_1r_1^2 + m_2r_2^2 + m_3r_3^3 + \ldots.. + m_nr_n^2}{m_1 + m_2 + m_3 + \ldots..}$$

where r_1, r_2, r_3 are distances of mass m_1, m_2, m_3 etc. from the axis. From the relation it is clear that I depends upon distribution of the masses and position of axis.

So, Assertion is correct.

We know that,

angular momentum $= I\omega$

Torque $= I\alpha$

If we compare these equations with equations like linear momentum $= mv$, force $= ma$, we find that I represents mass in angular motion. As mass represents inertia in linear motion, I represents inertia in angular motion.

But assertion and reason are mutually exclusive. So (b) is the answer.

35. **(c)** The angular momentum of earth-moon system will be conserved because no torque is acting on it.

So, $\tau = \dfrac{dL}{dt}$

If $\tau = 0$, $\dfrac{dL}{dt} = 0 \Rightarrow$ L is constant.

or angular momentum is constant. So Reason is incorrect.

So, $I_1\omega_1 = I_2\omega_2$

where I_1 & I_2 are momentia of inertia of earth and moon & ω_1 & ω_2 are their angular velocities. If earth slows down ω, will be decreased. So, I_2 will be decreased if we take ω_2 to remain constant.

$I_2 = m_2r_2^2$ where m_2 is mass of moon & r_2 is radius of moon's orbit, r_2 will be reduced to reduce I_2. Hence moon will come near to the earth. Hence Assertion is correct.

36. **(a)** Along with earth, particles of atmosphere also revolves around the axis of rotation. Now due to change in the constitution of atmosphere there is small change in the total moment of inertia of the whole system. Applying conservation of angular momentum

$$I\omega = I'\omega'$$

If I' changes, there is corresponding change in the angular velocity of the system.

37. **(a)** Under central force field, force acts along the line joining the bodies so it does not have rotatory effect i.e., torque is zero. Hence angular momentum is conservative.

38. **(a)** When mass of the opponent is brought nearby by his moment of inertia gets reduced which makes the operation of rotating him around the hip an easier exercise.

39. **(b)** In sliding down, the entire potential energy is converted into kinetic energy. While in rolling down, some part of the potential energy is converted into kinetic energy of rotation. Therefore linear velocity acquired is less.

40. **(c)** The position of centre of mass of a body depends on shape, size and distribution of mass of the body. The centre of mass does not lie necessarily at the centre of the body. Many objects have a point, a line or a plane of symmetry. The centre of mass of such an object then lies at that point, on that line or in that plane. Also the centre of mass of an object need not lie within the object, like no iron at the centre of mass of a horse shoe.

41. **(a)**

42. **(d)**

43. **(d)** For a disc rolling without slipping on a horizontal rough surface with uniform angular velocity, the acceleration of lowest point of disc is directed vertically upwards and is not zero (Due to translation part of rolling, acceleration of lowest point is zero. Due to rotational part of rolling, the tangential acceleration of lowest point is zero and centripetal acceleration is non-zero and upwards). Hence Assertion is incorrect.

44. **(a)**

45. **(d)** Radius of gyration of body is not a constant quantity. Its value changes with the change in location of the axis of rotation. Radius of gyration of a body about a given axis is given as

$$K = \sqrt{\frac{r_1^2 + r_2^2 + ...r_n^2}{n}}$$

Chapter 7

Gravitation

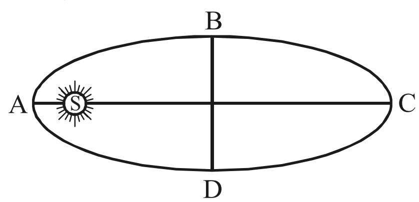
TYPE A : MULTIPLE CHOICE QUESTIONS

1. If a mass of a body is M on the earth surface, the mass of the same body on moon surface will be *[1997]*

(a) M (b) $\frac{M}{6}$

(c) zero (d) none of these

2. The earth rotates about the sun in an elliptical orbit as shown in figure. At which point its velocity will be maximum? *[1997]*



(a) at C (b) at A

(c) at D (d) at B

3. The ratio of the radii of two planets r_1 and r_2 is k. The ratio of acceleration due to gravity on them is r. Then the ratio of the escape velocities from them, will be : *[1997]*

(a) $\sqrt{\frac{r}{k}}$ (b) $\sqrt{\frac{k}{r}}$

(c) kr (d) $\sqrt{kr}$

4. The value of acceleration due to gravity, at earth surface is g. Its value at the centre of the earth, which we assume as a sphere of radius R and of uniform mass density, will be : *[1997]*

(a) $10\,R\,m/s^2$ (b) zero

(c) $5\,R\,m/s$ (d) $20\,R\,m/s^2$

5. Gravitational mass is proportional to the gravitational : *[1998]*

(a) intensity (b) field

(c) force (d) none of these

6. Escape velocity of a body when projected from the earth's surface is 11.2 km/sec. If it is projected at an angle of 50° from the horizontal, then escape velocity is: *[1999]*

(a) 12.8 km/sec (b) 16.2 km/sec

(c) 11.2 km/sec (d) 11.8 km/sec

7. Knowing that the mass of the moon is 1/81 times that of earth and its radius is 1/4 the radius of earth. If the escape velocity at the surface of the earth is 11.2 km/sec, then the value of escape velocity at the surface of the moon is *[2000]*

(a) 2.5 km/sec (b) 0.14 km/sec

(c) 5 km/sec (d) 8 km/sec

8. If the mass of moon is $\frac{M}{81}$, where M is the mass of earth, find the distance of the point from the moon, where gravitational field due to earth and moon cancel each other. Given that distance between earth and moon is 60R where R is the radius of earth *[2000]*

(a) 4 R (b) 8 R

(c) 2 R (d) 6 R

9. Potential energy of a satellite having mass m and rotating at a height of 6.4×10^6 m from the earth centre is *[2000]*

(a) $-0.2\,mg\,R_e$ (b) $-2\,mg\,R_e$

(c) $-0.5\,mg\,R_e$ (d) $-mg\,R_e$

10. The escape velocity from the earth is 11.2 km/sec. The escape velocity from a planet having twice the radius and the same mean density as the earth, is : *[2001]*

(a) 11.2 km/sec (b) 22.4 km/sec

(c) 15.00 km/sec (d) 5.8 km/sec

11. If v_0 be the orbital velocity of a satellite in a circular orbit close to the earth's surface and v_e is the escape velocity from the earth, then relation between the two is *[2002]*

(a) $v_e = 2v_0$ (b) $v_e = \sqrt{3}v_0$

(c) $v_e = v_0\sqrt{2}$ (c) $v_0 = v_e$

12. Hubble's law is related with ***[2002]***
(a) planetary motion
(b) speed of galaxy
(c) black hole
(d) comet

13. The radius of earth is about 6400 km and that of mass is about 3200 km. The mass of the earth is about 10 times of the mass. The object weighs 200 N on earth surface, then its weight on the surface of mars will be ***[2002]***
(a) 80 N (b) 40 N
(c) 20 N (d) 8 N

14. A satellite is launched into a circular orbit of radius R around the earth. While a second satellite launched into an orbit of radius 1.01R. The period of the second satellite is longer than the first one by approximately : ***[2002]***
(a) 3.0% (b) 1.5%
(c) 0.7% (d) 1.0%

15. The velocity with which a projectile must be fired so that it escapes earth's gravitation does not depend on : ***[2003]***
(a) mass of the earth
(b) mass of the projectile
(c) radius of the projectile's orbit
(d) gravitational constant

16. The difference in the length of a mean solar day and a sidereal day is about : ***[2003]***
(a) 1 minute (b) 4 minute
(c) 15 minute (d) 56 minute

17. The condition for a uniform spherical mass m of radius r to be a black hole is : [G = gravitational constant and g = acceleration due to gravity] ***[2005]***
(a) $\left(\frac{2Gm}{r}\right)^{1/2} \leq c$ (b) $\left(\frac{2gm}{r}\right)^{1/2} = c$
(c) $\left(\frac{2Gm}{r}\right)^{1/2} \geq c$ (d) $\left(\frac{gm}{r}\right)^{1/2} \geq c$

18. Height of geostationary satellite is ***[2007]***
(a) 16000 km (b) 22000 km
(c) 28000 km (d) 36000 km

19. The force of gravitation is ***[2007]***
(a) repulsive (b) conservative
(c) electrostatic (d) non-conservative

20. A long straight wire of radius *a* carries a steady current i. The current is uniformly distributed across its cross section. The ratio of the magnetic field at a/2 and 2a is ***[2008]***
(a) 1/2 (b) 1/4
(c) 4 (d) 1

21. Two bodies of masses m_1 and m_2 are initially at rest at infinite distance apart. They are then allowed to move towards each other under mutual gravitational attraction. Their relative velocity of approach at a separation distance r between them is ***[2008]***
(a) $\left[2G\frac{(m_1 - m_2)}{r}\right]^{1/2}$
(b) $\left[\frac{2G}{r}(m_1 + m_2)\right]^{1/2}$
(c) $\left[\frac{r}{2G(m_1 m_2)}\right]^{1/2}$
(d) $\left[\frac{2G}{r}m_1 m_2\right]^{1/2}$

22. A satellite *S* is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth. Then
(a) the acceleration of *S* is always directed towards the centre of the earth
(b) the angular momentum of *S* about the centre of the earth changes in direction, but its magnitude remains constant
(c) the total mechanical energy of *S* varies periodically with time
(d) the linear momentum of *S* remains constant in magnitude ***[2010]***

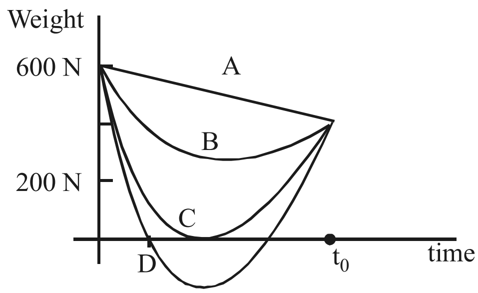
23. If the earth were to cease rotating about its own axis. The increase in the value of g in C.G.S. system at a place of latitude of 45° will be
(a) 2.68 (b) 1.68 ***[2010]***
(c) 3.36 (d) 0.34

24. A geostationary satellite is orbiting the earth at a height of 6 R from the earth's surface (R is the earth's radius). What is the period of rotation of another satellite at a height of 2.5 R from the earth's surface ***[2011]***
(a) $6\sqrt{2}$ hours (b) 10 hours
(c) $\frac{5\sqrt{5}}{\sqrt{3}}$ hours (d) none of the above

25. The angular speed of earth in rad/s, so that bodies on equator may appear weightless is : [Use $g = 10\ m/s^2$ and the radius of earth $= 6.4 \times 10^3$ km] ***[2011]***

(a) 1.25×10^{-3} (b) 1.56×10^{-3}
(c) 1.25×10^{-1} (d) 1.56

26. Suppose, the acceleration due to gravity at the Earth's surface is $10\ m\ s^{-2}$ and at the surface of Mars it is $4.0\ m\ s^{-2}$. A 60 kg pasenger goes from the Earth to the Mars in a spaceship moving with a constant velocity. Neglect all other objects in the sky. Which part of figure best represents the weight (net gravitational force) of the passenger as a function of time? ***[2012]***



(a) A (b) B
(c) C (d) D

27. Two masses m_1 and m_2 ($m_1 < m_2$) are released from rest from a finite distance. They start under their mutual gravitational attraction – ***[2012]***

(a) acceleration of m_1 is more than that of m_2.
(b) acceleration of m_2 is more than that of m_1.
(c) centre of mass of system will remain at rest in all the reference frame
(d) total energy of system does not remain constant

28. The escape velocity for a body projected vertically upwards from the surface of earth is 11 km/s. If the body is projected at an angle of 45º with the vertical, the escape velocity will be

(a) 22 km/s (b) 11 km/s ***[2013]***
(c) $\frac{11}{\sqrt{2}}$ km/s (d) $11\sqrt{2}$ km/s

29. The radii of two planets are respectively R_1 and R_2 and their densities are respectively ρ_1 and ρ_2. The ratio of the accelerations due to gravity at their surfaces is ***[2013]***

(a) $g_1 : g_2 = \frac{\rho_1}{R_1^2} : \frac{\rho_2}{R_2^2}$
(b) $g_1 : g_2 = R_1R_2 : \rho_1\rho_2$
(c) $g_1 : g_2 = R_1\rho_2 : R_2\rho_1$
(d) $g_1 : g_2 = R_1\rho_1 : R_2\rho_2$

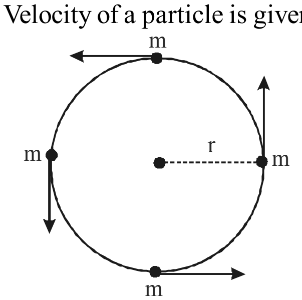
30. A body starts from rest from a point distance R_0 from the centre of the earth. The velocity acquired by the body when it reaches the surface of the earth will be (R represents radius of the earth). ***[2014]***

(a) $2GM\left(\frac{1}{R} - \frac{1}{R_0}\right)$
(b) $\sqrt{2GM\left(\frac{1}{R_0} - \frac{1}{R}\right)}$
(c) $GM\left(\frac{1}{R} - \frac{1}{R_0}\right)$
(d) $2GM\sqrt{\left(\frac{1}{R} - \frac{1}{R_0}\right)}$

31. The potential energy of a satellite of mass m and revolving at a height R_e above the surface of earth where R_e = radius of earth, is ***[2014]***

(a) $-mgR_e$ (b) $\frac{-mgR_e}{2}$
(c) $\frac{-mgR_e}{3}$ (d) $\frac{-mgR_e}{4}$

32. Four similar particles of mass m are orbiting in a circle of radius r in the same angular direction because of their mutual gravitational attractive force. Velocity of a particle is given by ***[2015]***



(a) $\left[\frac{GM}{r}\left(\frac{1+2\sqrt{2}}{4}\right)\right]^{1/2}$
(b) $\sqrt[3]{\frac{GM}{r}}$
(c) $\sqrt{\frac{GM}{r}(1+2\sqrt{2})}$
(d) $\left[\frac{1}{2}\frac{GM}{r}\left(\frac{1+\sqrt{2}}{2}\right)\right]^{1/2}$

33. Taking the gravitational potential at a point infinte distance away as zero, the gravitational potential at a point A is –5 unit. If the gravitational potential at point infinite distance away is taken as + 10 units, the potential at point A is *[2015]*

(a) – 5 unit (b) + 5 unit
(c) + 10 unit (d) + 15 unit

34. A particle of mass M is situated at the centre of a spherical shell of same mass and radius a. The gravitational potential at a point situated at $\frac{a}{2}$ distance from the centre, will be *[2016]*

(a) $-\frac{3GM}{a}$ (b) $-\frac{2GM}{a}$
(c) $-\frac{GM}{a}$ (d) $-\frac{4GM}{a}$

35. The distance of neptune and saturn from the sun is nearly 10^{13} and 10^{12} meter respectively. Assuming that they move in circular orbits, their periodic times will be in the ratio *[2016]*

(a) 10 (b) 100
(c) $10\sqrt{10}$ (d) 1000

36. The change in the value of 'g' at a height 'h' above the surface of the earth is the same as at a depth 'd' below the surface of earth. When both 'd' and 'h' are much smaller than the radius of earth, then which one of the following is correct? *[2017]*

(a) $d = \frac{3h}{2}$ (b) $d = \frac{h}{2}$
(c) $d = h$ (d) $d = 2h$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 37-39) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

37. **Assertion :** A balloon filled with hydrogen will fall with acceleration $\frac{g}{6}$ of the moon.
Reason : Moon has no atmosphere. *[2000]*

38. **Assertion :** The length of the day is slowly increasing.
Reason : The dominant effect causing a slowdown in the rotation of the earth is the gravitational pull of other planets in the solar system. *[2003]*

39. **Assertion :** An astronaut experience weightlessness in a space satellite.
Reason : When a body falls freely it does not experience gravity. *[2007]*

Directions for (Qs. 40-43) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

40. **Assertion :** In a free fall, weight of a body becomes effectively zero.
Reason : Acceleration due to gravity acting on a body having free fall is zero. *[2011]*

41. **Assertion :** The escape speed does not depend on the direction in which the projectile is fired.
Reason : Attaining the escape speed is easier if a projectile is fired in the direction the launch site is moving as the earth rotates about its axis.

42. **Assertion :** The earth without atmosphere would be inhospitably cold.
Reason : All heat would escape in the absence of atmosphere. *[2016]*

43. **Assertion :** Space rocket are usually launched in the equatorial line from west to east
Reason : The acceleration due to gravity is minimum at the equator. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** The mass of a body does not change unless we withdraw or add some mass to it. So mass of a body on the surface of moon will remain unchanged.

2. **(b)** When earth rotates around the Sun, the net torque acting on the body is zero. So, angular momentum will be conserved at all points.

$I_1\omega_1 = I_2\omega_2$

$\Rightarrow\ mv_1r_1 = mv_2r_2$

$v_1r_1 = v_2r_2$

At 'A' radius is minimum so, velocity of the earth will be maximum.

3. **(d)** $v_e = \sqrt{2gr}$

$\frac{v_e'}{v_e''} = \sqrt{\frac{2g_1r_1}{2g_2r_2}} = \sqrt{k.r}$

4. **(b)** The value of acceleration due to gravity at the centre of earth is zero.

5. **(c)** Inertial mass is free from gravitational force. It depends upon only mass. Gravitational mass is dependent on gravitational force.

6. **(c)** Escape velocity does not depend on the direction of throw of object. This is because gravitational field is a conservative field.

7. **(a)** For escape velocity, $v_e = \sqrt{\frac{2GM}{R}}$

$v_e' = \sqrt{\frac{2GM/81}{R/4}} = \sqrt{\frac{4\times 2GM}{81R}} = \frac{2}{9}\sqrt{\frac{GM}{R}}$

$v_e' = \frac{2}{9}\times 11.2 = 2.5\ \text{km/sec}$

8. **(d)** Let at a distance x from the earth, field equalises each other. So, applying Newton's law of gravitation

$\frac{GM}{x^2} = \frac{GM/81}{(60R-x)^2}$

$\frac{1}{x^2} = \frac{1}{81(60R-x)^2}$

$\Rightarrow \frac{1}{x} = \frac{1}{9(60R-x)}$

$x = 540R - 9x \Rightarrow 10x = 540R$

$x = 54R;$

Distance of the point from moon $= 60R - 54R = 6R$

9. **(d)** Potential energy of a satellite $= \frac{-GMm}{R}$

$= \frac{-GM\times R_e m}{R_e^2} = -mgR_e$

10. **(b)** For escape velocity the formula is,

$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G\frac{4}{3}\pi R^3\rho}{R}}$

[ρ is density of the planet, R is radius.]

$= \sqrt{\frac{8}{3}G\pi R^2\rho}$

$v_e = R\sqrt{\frac{8}{3}G\pi\rho}$

$v_e \propto R$

If radius becomes twice, v_e will also become twice. So new escape velocity

$= 2\times 11.2 = 22.4$ km/sec

11. **(c)** We know that,

$v_0 = \sqrt{gr}\ \ \&\ \ v_e = \sqrt{2gr}$

So, $v_e = \sqrt{2}v_0$

12. **(b)** Hubble's law states that speed of a star is directly proportional to distance from the star i.e.

$v \propto r \Rightarrow v = Hr$

where H is Hubble's constant.

13. **(a)** We know that $g = \frac{GM}{R^2}$

Value of g for Mass $= \frac{G.M/10}{(R/2)^2}$

[Radius of mass is 1/2 that of earth]

$= \frac{GM}{10}\times\frac{4}{R^2} = \frac{2}{5}\frac{GM}{R^2}$

So, $g' = \frac{2}{5}g$

If $mg = 200$ N, $mg' = \frac{200\times 2}{5} = 80$N.

14. (b) We know that relation between radius of orbit and time period of revolution is $T^2 \propto R^3$

$$\frac{T'}{T} = \left(\frac{1.01}{1}\right)^{3/2} = \left(1+\frac{1}{100}\right)^{3/2}$$

$$= 1+\frac{3}{2}\times\frac{1}{100} = 1+\frac{3}{200}$$

$$\frac{T'}{T} - 1 = 1+\frac{3}{200} - 1$$

$$\frac{T'-T}{T} = \frac{3}{200} \Rightarrow \frac{\Delta T}{T} = \frac{3}{200}$$

$$\frac{\Delta T}{T}\times 100 = \frac{3\times 100}{200}$$

% Change in $T = 1.5\%$

15. (b) The value of escape velocity for a planet is

$$v_e = \sqrt{2gR}$$

It does not depend upon the mass of the body.

16. (b) Solar day is the time taken by earth to complete one rotation about its axis with respect to sun. Sidereal day is the time taken by earth to complete one rotation about its axis with respect to distant star.

There is a difference of 4 minutes between solar day and sidereal day. Solar day is longer as earth has to rotate greater angle to attain same position with respect to sun due to its own motion (revolution) round the sun. Its position with respect to distant star remains almost fixed.

17. (c) A black hole does not allow light to escape its surface. In other words for a black hole body escape velocity becomes $\geq$ velocity of light

Now for a body of mass m,

$$\text{Escape velocity} = \left(\frac{2Gm}{r}\right)^{1/2}.$$

$$\text{So, } \left(\frac{2Gm}{r}\right)^{1/2} \geq c$$

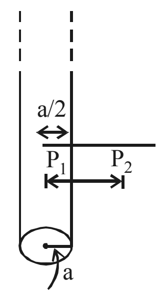
18. (d) The height of geostationary satellites is given by $h = \left(\frac{T^2R^2g}{4\pi^2}\right)^{1/3} - R$

$T = 24$ hr, $R = 6.4\times 10^6$m, $g = 9.8$ m/s^2 and comes out to be 35930 km.

19. (b) The work done by force of gravitation does not depend on path taken hence force of gravitation is conservative.

20. (d) Here, current is uniformly distributed across the cross-section of the wire, therefore, current enclosed in the amperean path formed at a distance

$$r_1\left(=\frac{a}{2}\right)$$



$$= \left(\frac{\pi r_1^2}{\pi a^2}\right)\times I, \text{ where I is total current}$$

$\therefore$ Magnetic field at

$$P_1(B_1) = \frac{\mu_0 \times \text{current enclosed}}{\text{Path}}$$

$$= \frac{\mu_0 \times \left(\frac{\pi r_1^2}{\pi a^2}\right)\times I}{2\pi r_1} = \frac{\mu_0 \times I r_1}{2\pi a^2}$$

Now, magnetic field at point P_2,

$$(B_2) = \frac{\mu_0}{2\pi}.\frac{I}{(2a)} = \frac{\mu_0 I}{4\pi a}.$$

$$\therefore \text{ Required Ratio} = \frac{B_1}{B_2} = \frac{\mu_0 I r_1}{2\pi a^2}\times\frac{4\pi a}{\mu_0 I}$$

$$= \frac{2r_1}{a} = \frac{2\times\frac{a}{2}}{a} = 1.$$

21. (b) By applying law of conservation of momentum,

$$m_1v_1 - m_2v_2 = 0 \Rightarrow m_1v_1 = m_2v_2 \ldots (i)$$

Where v_1 and v_2 are the velocities of masses m_1 and m_2 at a distance r from each other.

By conservation of energy,

Change in P.E = change in K.E.

$$\frac{Gm_1m_2}{r} = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \ \ldots (ii)$$

Solving eqn. (i) and (ii) we get

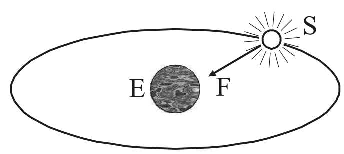
$$v_1 = \sqrt{\frac{2Gm_2^2}{r(m_1+m_2)}} \text{ and } v_2 = \sqrt{\frac{2Gm_1^2}{r(m_1+m_2)}}$$

Relative velocity of approach, v_R

$$= |v_1| + |v_2| = \sqrt{\frac{2G}{r}(m_1+m_2)}$$

22. (a) Force on satellite is always directed towards earth, So, acceleration of satellite S is always directed towards centre of earth. Net torque of this gravitational force F about centre of earth is zero. Therefore, angular momentum (both in magnitude and direction) of S about centre of earth is constant throughout.

Since, the force F is conservative in nature, therefore, mechanical energy of satellite remains constant. Speed of S is maximum when it is nearest to earth and minimum when it is farthest.



23. (b) $\lambda = 45°$; $R = 6400 \times 10^3$ m

$$\omega = \frac{2\pi}{24 \times 60 \times 60}$$

The value of acceleration due to gravity with latitude λ due to rotation of earth is,

$g' = g - R\omega^2 \cos^2 \lambda$

$g - g' = R\omega^2 \cos^2 \lambda$

$$= \frac{6400 \times 10^3}{2} \times \left(\frac{2 \times 3.14}{24 \times 60 \times 60}\right)^2$$

$$= \frac{6400 \times 10^3 \times 4 \times 3.14 \times 3.14}{2 \times 24 \times 60 \times 60 \times 24 \times 60 \times 60}$$

$= 16.89 \times 10^{-3}$ m/sec^2

$= 16.89 \times 10^{-1}$ cm/sec^2

$= 1.68$ cm/sec^2

24. (a) $T = 2\pi\sqrt{\dfrac{r^3}{GM}}$

$$\therefore \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{6R + R}{2.5R + r}\right)^3 = 8$$

$$T_2 = \frac{T_1}{\sqrt{8}} = \frac{24}{\sqrt{8}} = 6\sqrt{2}\text{ hr}$$

25. (a) $\omega' = \sqrt{g/R} = \sqrt{\dfrac{281}{6.4 \times 10^6}}$

$= 1.25 \times 10^{-3}$ rad/s

26. (c) $g \propto \dfrac{1}{R^2}$ so we will not get a straight line.

Also F = 0 at a point where Force due to Earth = Force due to Mars

27. (a) Same force acts on both masses

Hence $a \propto \dfrac{1}{m}$ $\quad (F = ma)$

In absence of external force (remember mutual gravitational force is an internal force for the system) total energy remains constant.

28. (b) Since escape velocity $\left(v_e = \sqrt{2gR_e}\right)$ is independent of angle of projection, so it will not change.

29. (d) $g \propto \rho R$

30. (b) $\text{P.E.} = \displaystyle\int_{R_0}^{R} \frac{GMm}{r^2}dr = -GMm\left[\frac{1}{R} - \frac{1}{R_0}\right]$

The K.E. acquired by the body at the surface $= \dfrac{1}{2}mv^2$

$$\therefore \frac{1}{2}mv^2 = -GMm\left[\frac{1}{R} - \frac{1}{R_0}\right]$$

$$v = \sqrt{2GM\left(\frac{1}{R_0} - \frac{1}{R}\right)}$$

31. (b) At a height h above the surface of earth the gravitational potential energy of the particle of mass m is

$$U_h = -\frac{GM_e m}{R_e + h}$$

Where M_e & R_e are the mass & radius of earth respectively.

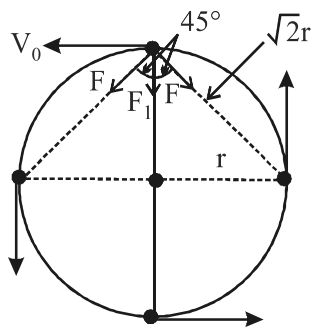
In this question, since $h = R_e$

So $U_{h=R_e} = -\dfrac{GM_e m}{2R_e} = \dfrac{-mgR_e}{2}$

32. (a) Centripetal force = net gravitational force

$$\frac{mv_0^2}{r} = 2F\cos 45° + F_1$$

$$= \frac{2GM^2}{(\sqrt{2}r)^2}\frac{1}{\sqrt{2}} + \frac{Gm^2}{4r^2}$$



$$\frac{mv_0^2}{r} = \frac{Gm^2}{4r^2}[2\sqrt{2}+1]$$

$$\Rightarrow \left(\frac{GM(2\sqrt{2}+1)}{4r}\right)^{1/2}$$

33. **(b)** The gravitational potential V at a point distant 'r' from a body of mass m is equal to the amount of work done in moving a unit mass from infinity to that point.

$$V_r - V_\infty = -\int_\infty^r \vec{E}.d\vec{r} = -GM\left(1/r - 1/\infty\right)$$

$$= \frac{-GM}{r}\left(\text{As } \vec{E} = \frac{-dV}{dr}\right)$$

(i) In the first case

$$\text{when } V_\infty = 0,\ V_r = \frac{-GM}{r} = -5 \text{ unit}$$

(ii) In the second case $V^\infty = +10$ unit

$V_r - 10 = -5$

or $V_r = +5$ unit

34. **(a)** Potential at the given point = Potential at the point due to the shell + Potential due to the particle

$$= -\frac{GM}{a} - \frac{2GM}{a} = -\frac{3GM}{a}$$

35. **(c)** $T^2 \propto R^3$ (According to Kepler's law)

$T_1^2 \propto (10^{13})^3$ and $T_2^2 \propto (10^{12})^3$

$$\therefore \frac{T_1^2}{T_2^2} = (10)^3 \text{ or } \frac{T_1}{T_2} = 10\sqrt{10}$$

36. **(d)** Variation of g with altitude is,

$$g_h = g\left[1 - \frac{2h}{R}\right];$$

variation of g with depth is,

$$g_d = g\left[1 - \frac{d}{R}\right]$$

Equating g_h and g_d, we get $d = 2h$

Type B : Assertion Reason Questions

37. **(a)** A balloon will not experience any buoyant force on the moon because it has no atmosphere, so it will have free fall under gravitational pull of the moon with acceleration equal to $\frac{g}{6}$.

38. **(c)** The length of the day is slowly increasing not due to gravitational pull of other planets in the solar system but due to viscous force between the earth and the atmosphere around it. So Assertion is correct but Reason is incorrect.

39. **(a)** When a body falls freely its accelerating force is g thus apparent weight of body $= M(g-g)$ is zero. Hence astronaut falling freely in space experiences weightlessness as its gravitational force is counter balanced by centripetal force of satellite.

40. **(c)**

41. **(b)**

42. **(b)** In the absence of atmosphere, all the heat will escape from earth's surface which will make earth in hospitably cold.

43. **(b)** Space rocket are usually launched from west to east to take the advantage of rotation of earth.

Also $g' = g - \omega^2 R \cos^2 \lambda$, at equator $\lambda = 0$, and so $\cos \lambda = 1$, and g' is least.

Chapter 8

Mechanical Properties of Solids

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If S is stress and Y is Young's modulus of a material of wire, then energy stored in the wire per unit volume is : ***[1997]***

(a) $2S^2Y$ (b) $\frac{S}{2Y}$

(c) $\frac{2Y}{S^2}$ (d) $\frac{S^2}{2Y}$

2. Longitudinal strain is possible in : ***[1998]***

(a) Liquid (b) Gases

(c) Solid (d) All of these

3. Which one of the following affects the elasticity of a substance ? ***[1999]***

(a) Change in temperature

(b) Hammering and annealing

(c) Impurity in substance

(d) All of these

4. If in a wire of Young's modulus Y, longitudinal strain X is produced then the potential energy stored in its unit volume will be : ***[2001]***

(a) $0.5YX^2$ (b) $0.5Y^2X$

(c) $2YX^2$ (d) YX^2

5. According to Hook's law of elasticity, if stress is increased, then the ratio of stress to strain : ***[2001]***

(a) becomes zero (b) remains constant

(c) decreases (d) increases

6. The bulk modulus of a metal is 10^{10} N/m^2 and Poisson's ratio 0.20. If average distance between the molecules is 3Å then the interatomic force constant : ***[2002]***

(a) 5.4 N/m (b) 7.5 N/m

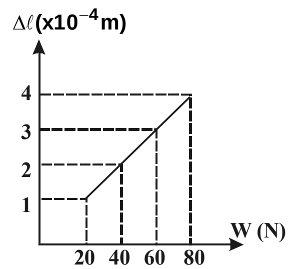
(c) 7.5 N/m (d) 30 N/m

7. Shear modulus is zero for ***[2007]***

(a) solids (b) liquids

(c) gases (d) liquids and gases

8. The adjacent graph shows the extension ($\Delta\ell$) of a wire of length 1 m suspended from the top of a roof at one end and with a load W connected to the other end. If the cross-sectional area of the wire is 10^{-6} m^2, calculate the Young's modulus of the material of the wire. ***[2008]***



(a) 2×10^{11} N/m^2 (b) 2×10^{-11} N/m^2

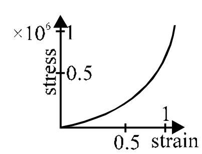
(c) 3×10^{-12} N/m^2 (d) 2×10^{-13} N/m^2

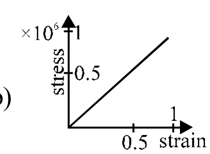
9. There are two wire of same material and same length while the diameter of second wire is two times the diameter of first wire, then the ratio of extension produced in the wires by applying same load will be ***[2013]***

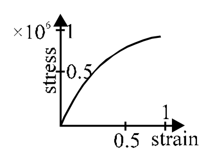
(a) 1 : 1 (b) 2 : 1

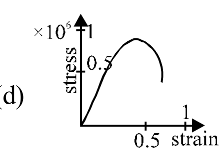
(c) 1 : 2 (d) 4 : 1

10. Stress vs strain curve for the elastic tissue of the aorta, the large tube (vessel) carrying blood from the heart, will be : [stress is proportional to square of the strain for the elastic tissue of the aorta] ***[2015]***

(a) 

(b) 

(c) 

(d) 

11. An iron rod of length 2m and cross-sectional area of 50 mm^2 stretched by 0.5 mm, when a mass of 250 kg is hung from its lower end. Young's modulus of iron rod is *[2017]*

(a) 19.6×10^{20} N/m^2 (b) 19.6×10^{18} N/m^2
(c) 19.6×10^{10} N/m^2 (d) 19.6×10^{15} N/m^2

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 12) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

12. **Assertion :** Stress is the internal force per unit area of a body.
Reason : Rubber is more elastic than steel. *[2002]*

Directions for (Qs. 13-15) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

13. **Assertion:** Strain causes the stress in an elastic body.
Reason: An elastic rubber is more plastic in nature. *[2014]*

14. **Assertion:** Hollow shaft is found to be stronger than a solid shaft made of same equal material.
Reason: Torque required to produce a given twist in hollow cylinder is greater than that required to twist a solid cylinder of same length and material. *[2016]*

15. **Assertion:** Solids are least compressible and gases are most compressible.
Reason: solids have definite shape and volume but gases do not have either definite shape or definite volume. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(d)** Energy stored in stretched wire per unit volume $= \frac{1}{2} \times \text{stress} \times \text{strain}$

$= \frac{1}{2} \times S \times \frac{S}{Y} = \frac{1}{2}\frac{S^2}{Y}$

2. **(c)** Longitudinal strain is possible only in solids because only solids can have length which can be stretched by applying force.

3. **(d)** The elasticity of a material depends upon the temperature of the material. Hammering & annealing reduces elastic property of a substance.

4. **(a)** Potential energy stored per unit volume of a wire

$= \frac{1}{2} \times \text{Stress} \times \text{Strain}$

$= \frac{1}{2} \times Y \times X \times X \qquad [\text{Stress} = Y \times X]$

$= 0.5YX^2$

5. **(b)** The Ratio of stress to strain is always constant. If stress is increased, strain will also increase so that their ratio remains constant.

6. **(a)** Young's modulus,

$Y = 3K(1 - 2\sigma) = 3 \times 10^{10}(1 - 2 \times 0.2)$

$= 1.8 \times 10^{10}\ \text{N/m}^2$

$\therefore$ Interatomic force constant is

$K = Yr = 1.8 \times 10^{10} \times 3 \times 10^{-10} = 5.4\ \text{N/m}$

7. **(d)** Shear modulus is applicable to solids where deforming force causes change in shape of body. For fluids it is not possible since they have no fixed shape.

8. **(a)** $Y = \frac{F}{A} \Big/ \frac{\Delta l}{l} = \frac{20 \times 1}{10^{-6} \times 10^{-4}}$

$= 2 \times 10^{11}\ \text{N/m}^2$

9. **(d)** $\because$ Both wires are same materials so both will have same Young's modulus, and let it be Y. $Y = \frac{\text{stress}}{\text{strain}} = \frac{F}{A.(\Delta L/L)}$,

F = applied force

A = area of cross-section of wire

Now,

$Y_1 = Y_2 \Rightarrow \frac{FL}{(A_1)(\Delta L_1)} = \frac{FL}{(A_2)(\Delta L_2)}$

Since load and length are same for both

$\Rightarrow r_1^2 \Delta L_1 = r_2^2 \Delta L_2$,

$\left(\frac{\Delta L_1}{\Delta L_2}\right) = \left(\frac{r_2}{r_1}\right)^2 = 4 \quad \Delta L_1 : \Delta L_2 = 4:1$

10. **(a)** As stress $\propto$ strain^2 hence graph (a) correctly dipicts.

11. **(c)** $Y = \frac{F/A}{\Delta \ell / \ell} = \dfrac{\dfrac{250 \times 9.8}{50 \times 10^{-6}}}{\dfrac{0.5 \times 10^{-3}}{2}}$

$= \frac{250 \times 9.8}{50 \times 10^{-6}} \times \frac{2}{0.5 \times 10^{-3}} \Rightarrow 19.6 \times 10^{10}\ \text{N/m}^2$

Type B : Assertion Reason Questions

12. **(c)** Stress is internal force (restoring force) developed within the body of the object. Since it is easier to stretch rubber so it is less stressful and therefore less elastic.

13. **(a)**

14. **(a)** Torque required to produce a given twist in hollow cylinder is greater than solid cylinder thus both are correct.

15. **(b)** The incompressibility of solids is primarily due to the tight coupling between the neighbouring atoms. Molecules in gases are very poorly coupled to their neighbours.

Chapter 9

Mechanical Properties of Fluids

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A big drop of radius R is formed by 729 small drops of water of radius r, then the radius of each small drop will be : ***[1997]***

(a) $\frac{R}{9}$ (b) $\frac{R}{900}$

(c) $\frac{R}{1800}$ (d) $\frac{R}{9000}$

2. The work done in splitting a drop of water of 1 mm radius into 10^6 droplets is (surface tension of water 72×10^{-3} N/m) : ***[1998]***

(a) 5.98×10^{-5} J (b) 10.98×10^{-5} J

(c) 16.95×10^{-5} J (d) 8.95×10^{-5} J

3. The excess pressure inside the first soap bubble is three times that inside the second bubble then, the ratio of volume of the first to the second bubble will be : ***[1998]***

(a) 1 : 27 (b) 3 : 1

(c) 1 : 3 (d) 1 : 9

4. The rain drops are in spherical shape due to ***[1998]***

(a) surface tension (b) viscosity

(c) residual pressure (d) thrust on drop

5. If work done in increasing the size of a soap film from 10 cm × 6 cm to 60 cm × 11 cm is 2×10^{-4} J. What is the surface tension ? ***[2000]***

(a) $2\times10^{-8}\ \text{Nm}^{-1}$ (b) $2\times10^{-2}\ \text{Nm}^{-1}$

(c) $2\times10^{-4}\ \text{Nm}^{-1}$ (d) none of these

6. A hole is made at the bottom of the tank filled with water (density 1000 kg/m^3). If the total pressure at the bottom of the tank is 3 atmosphere (1 atmosphere = 10^5 N/m^2), then the velocity of efflux is ***[2000]***

(a) $\sqrt{200}$ m/s (b) $\sqrt{400}$ m/s

(c) $\sqrt{500}$ m/s (d) $\sqrt{800}$ m/s

7. A spherical drop of water has 1 mm radius. If the surface tension of water is 70×10^{-3} N/m. Then the difference of pressures between inside and outside of the spherical drop is : ***[2001]***

(a) 140 N/m^2 (b) 140 N/m

(c) 35 Nm^2 (d) none of these

8. Bernoulli's principle is based on the law of conservation of : ***[2001, 2013]***

(a) mass

(b) energy

(c) angular momentum

(d) linear momentum

9. Scent sprayer is based on ***[2002]***

(a) Bernoulli's theorem

(b) Archimedes principle

(c) Charle's law

(d) Boyle's law

10. A soap bubble in vacuum has a radius 3 cm and another soap bubble in vacuum has radius 4 cm. If two bubbles coalesce under isothermal condition. Then the radius of the new bubble will be : ***[2002]***

(a) 7 cm (b) 5 cm

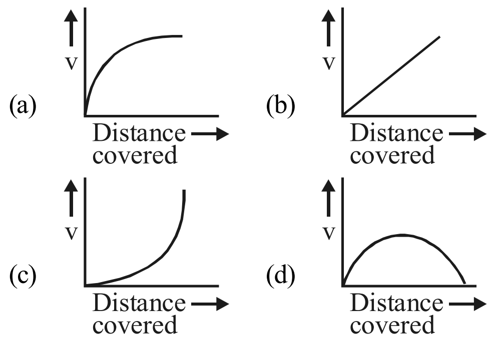
(c) 4.5 cm (d) 2.3 cm

11. Two small drops of mercury, each of radius R coalesce to form a single large drop. The radio of the total surface energies before and after the change is : ***[2003]***

(a) $1 : 2^{1/3}$ (b) $2^{1/3} : 1$

(c) 2 : 1 (d) 1 : 2

12. A lead shot of 1 mm diameter falls through a long column of glycerine. The variation of its velocity v with distance covered is represented by : ***[2003]***



13. In old age arteries carrying blood in the human body become narrow resulting in an increase in the blood pressure. This follows from : ***[2004]***

(a) Pascal' law
(b) Stoke's law
(c) Bernoulli's principle
(d) Archimedes principle

14. A sphere of mass M and radius R is falling in a viscous fluid. The terminal velocity attained by the falling object will be proportional to : ***[2004]***

(a) R^2 (b) R
(c) 1/R (d) $1/R^2$

15. For a constant hydraulic stress on an object, the fractional change in the object's volume $(\Delta V / V)$ and its bulk modulus (B) are related as : ***[2005]***

(a) $\frac{\Delta V}{V} \propto B$ (b) $\frac{\Delta V}{V} \propto \frac{1}{B}$

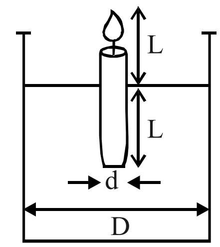
(c) $\frac{\Delta V}{V} \propto B^2$ (d) $\frac{\Delta V}{V} \propto B^{-2}$

16. The apparent depth of water in cylindrical water tank of diameter 2R cm is reducing at the rate of x cm/minute when water is being drained out at a constant rate. The amount of water drained in c.c. per minute is : (n_1 = refractive index of air, n_2 = refractive index of water) ***[2005]***

(a) $\frac{x\pi R^2 n_1}{n_2}$ (b) $\frac{x\pi R^2 n_2}{n_1}$

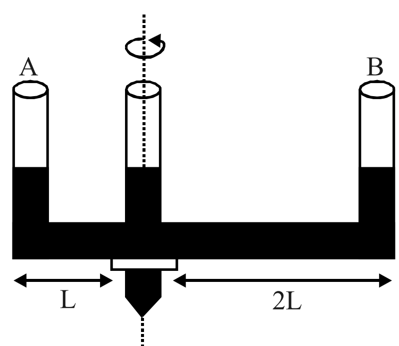
(c) $\frac{2\pi R n_1}{n_2}$ (d) $\pi R^2 x$

17. A candle of diameter d is floating on a liquid in a cylindrical container of diameter D (D >> d) as shown in figure. If it is burning at the rate of 2 cm/hour then the top of the candle will : ***[2005]***



(a) remain at the same height
(b) fall at the rate of 1 cm/hour
(c) fall at the rate of 2 cm/hour
(d) go up at the rate of 1 cm/hour

18. A given shaped glass tube having uniform cross-section is filled with water and is mounted on a rotatable shaft as shown in figure. If the tube is rotated with a constant angular velocity ω then ***[2005]***



(a) water levels in both sections A and B go up
(b) water level in section A goes up and that in B comes down
(c) water level in section A comes down and that in B it goes up
(d) water levels remain same in both sections

19. By sucking through a straw, a student can reduce the pressure in his lungs to 750 mm of Hg (density = 13.6 gm/cm^3). Using the straw, he can drink water from a glass upto a maximum depth of : ***[2006]***

(a) 10 cm (b) 75 cm
(c) 13.6 cm (d) 1.36 cm

20. Work of 3.0×10^{-4} joule is required to be done in increasing the size of a soap film from 10 cm × 6 cm to 10 cm × 11 cm. The surface tension of the film is ***[2007]***
(a) 5×10^{-2} N/m (b) 3×10^{-2} N/m
(c) 1.5×10^{-2} N/m (d) 1.2×10^{-2} N/m

21. If the terminal speed of a sphere of gold (density = 19.5 kg/m^3) is 0.2 m/s in a viscous liquid (density = 1.5 kg/m^3), find the terminal speed of a sphere of silver (density = 10.5 kg/m^3) of the same size in the same liquid ***[2008]***
(a) 0.4 m/s (b) 0.133 m/s
(c) 0.1 m/s (d) 0.2 m/s

22. Water is filled in a container upto height of 3m. A small hole of area 'A_0' is punched in the wall of the container at a height 52.5 cm from the bottom. The cross sectional area of the container is A. If $A_0/A = 0.1$ then v^2 is (where v is the velocity of water coming out of the hole) ***[2008]***
(a) 50 m^2/s^2 (b) 50 .5 m^2/s^2
(c) 51 m^2/s^2 (d) 52 m^2/s^2

23. A boy has 60 kg weight. He wants to swim in a river with the help of a wooden log. If relative density of wood is 0.6, what is the minimum volume of wooden log? ***[2010]***
(density of river water is 1000 kg/m^3)
(a) 0.66 m^3 (b) 150 m^3
(c) $\frac{3}{1}$ m^3 (d) $\frac{3}{20}$ m^3

24. The work done in blowing a soap bubble of radius 0.2m, given that the surface tension of soap solution is 60×10^{-3} N/M is : ***[2011]***
(a) $24\pi \times 10^{-4}$J (b) $24\pi \times 10^{-4}$J
(c) $96\pi \times 10^{-4}$J (d) $1.92\pi \times 10^{-4}$J

25. Water rises to a height of 10 cm in capillary tube and mercury falls to a depth of 3.1 cm in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the approximate ratio of surface tensions of water and mercury is ***[2012]***
(a) 1 : 0.15 (b) 1 : 3
(c) 1 : 6 (d) 1.5 : 1

26. The lift of an air plane is based on ***[2012]***
(a) Torricelli's theorem
(b) Bernoulli's theorem
(c) Law of gravitation
(d) Conservation of linear momentum.

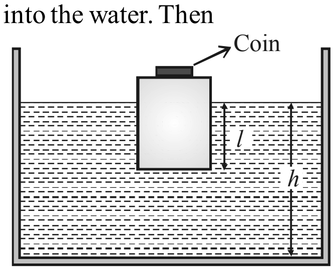
27. A spherical solid ball of volume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_1 ($\rho_2 < \rho_1$). Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed v, i.e., $F_{viscous} = -kv^2$ ($k > 0$). The terminal speed of the ball is ***[2013]***
(a) $\sqrt{\frac{Vg(\rho_1 - \rho_2)}{k}}$ (b) $\frac{Vg\rho_1}{k}$
(c) $\sqrt{\frac{Vg\rho_1}{k}}$ (d) $\frac{Vg(\rho_1 - \rho_2)}{k}$

28. A ring is cut from a platinum tube 8.5 cm internal and 8.7 cm external diameter. It is supported horizontally from the pan of a balance, so that it comes in contact with the water in a glass vessel. If an extra 3.97. If is required to pull it away from water, the surface tension of water is ***[2013]***
(a) 72 dyne cm^{-1} (b) 70.80 dyne cm^{-1}
(c) 63.35 dyne cm^{-1} (d) 60 dyne cm^{-1}

29. A water tank of height 10m, completely filled with water is placed on a level ground. It has two holes one at 3 m and the other at 7 m from its base. The water ejecting from ***[2014]***
(a) both the holes will fall at the same spot
(b) upper hole will fall farther than that from the lower hole
(c) upper hole will fall closer than that from the lower hole
(d) more information is required

30. Which of the following relation is true ? ***[2014]***
(a) $3Y = K(1 - \sigma)$ (b) $K = \frac{9\eta Y}{Y + \eta}$
(c) $\sigma = (6K + \eta)Y$ (d) $\sigma = \frac{05.Y - \eta}{\eta}$

31. A wooden block, with a coin placed on its top, floats in water as shown in fig. the distance l and h are shown there. After some time the coin falls into the water. Then ***[2014]***



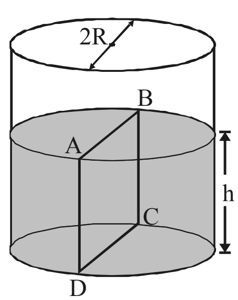
(a) ℓ decreases and h increases
(b) ℓ increases and h decreases
(c) both ℓ and h increases
(d) both ℓ and h decreases

32. 1 m^3 water is brought inside the lake upto 200 metres depth from the surface of the lake. What will be change in the volume when the bulk modulus of elastically of water is 22000 atmosphere? ***[2015]***
(density of water is 1×10^3 kg/m^3 atmosphere pressure = 10^5 N/m^2 and g = 10 m/s^2)
(a) 8.9×10^{-3} m^3 (b) 7.8×10^{-3} m^3
(c) 9.1×10^{-4} m^3 (d) 8.7×10^{-4} m^3

33. The excess of pressure inside a soap bubble is twice the excess pressure inside a second soap bubble. The volume of the first bubble is n times the volume of the second where n is ***[2015]***
(a) 0.125 (b) 0.250
(c) 1 (d) 2

34. A steel wire is suspended vertically from a rigid support. When loaded with a weight in air, it extends by ℓ_a and when the weight is immersed completely in water, the extension is reduced to ℓ_w. Then the relative density of material of the weight is ***[2016]***
(a) ℓ_a / ℓ_w (b) $\dfrac{\ell_a}{\ell_a - \ell_w}$
(c) $\ell_w / (\ell_a - \ell_w)$ (d) ℓ_w / ℓ_a

35. Water is filled up to a height h in a beaker of radius R as shown in the figure. The density of water is ρ, the surface tension of water is T and the atmospheric pressure is P_0. Consider a vertical section ABCD of the water column through a diameter of the beaker. The force on water on one side of this section by water on the other side of this section has magnitude ***[2016]***

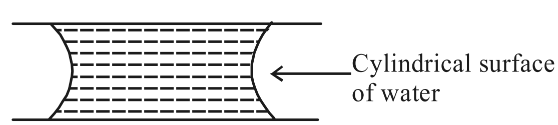


(a) $|2P_0Rh + \pi R^2 \rho gh - 2RT|$
(b) $|2P_0Rh + R\rho gh^2 - 2RT|$
(c) $|P_0\pi R^2 + R\rho gh^2 - 2RT|$
(d) $|P_0\pi R^2 + R\rho gh^2 + 2RT|$

36. A vessel contains oil (density = 0.8 gm/cm^3) over mercury (denisty = 13.6 gm/cm^3). A homogeneous sphere floats with half of its volume immersed in mercury and the other half in oil. The density of the material of the sphere in gm/cm^3 is ***[2016]***
(a) 3.3 (b) 6.4
(c) 7.2 (d) 12.8

37. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring such that it is half submerged in a liquid of density σ at equilibrium position. The extension x_0 of the spring when it is in equilibrium is: ***[2016]***
(a) $\dfrac{Mg}{k}$ (b) $\dfrac{Mg}{k}\left(1 - \dfrac{LA\sigma}{M}\right)$
(c) $\dfrac{Mg}{k}\left(1 - \dfrac{LA\sigma}{2M}\right)$ (d) $\dfrac{Mg}{k}\left(1 + \dfrac{LA\sigma}{M}\right)$

38. If two glass plates have water between them and are separated by very small distance (see figure), it is very difficult to pull them apart. It is because the water in between forms cylindrical surface on the side that gives rise to lower pressure in the water in comparison to atmosphere. If the radius of the cylindrical surface is R and surface tension of water is T then the pressure in water between the plates is lower by ***[2017]***



(a) $\dfrac{2T}{R}$ (b) $\dfrac{4T}{R}$
(c) $\dfrac{T}{4R}$ (d) $\dfrac{T}{R}$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 39-44) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

39. **Assertion :** In a pressure cooker the water is brought to boil. The cooker is then remove from the stove. Now on removing the lid of the pressure cooker, the water starts boiling against.
Reason : The impurities in water bring down its boiling point *[2004]*

40. **Assertion :** Smaller drops of liquid resist deforming forces better than the larger drops
Reason : Excess pressure inside a drop is directly proportional to its surface area. *[2004]*

41. **Assertion :** For Reynold's number Re > 2000, the flow of fluid is turbulent.
Reason : Inertial forces are dominant compared to the viscous forces at such high Reynold's numbers. *[2005]*

42. **Assertion :** A thin stainless steel needle can lay floating on a still water surface.
Reason : Any object floats when the buoyancy force balances the weight of the object *[2006]*

43. **Assertion :** Machine parts are jammed in winter.
Reason : The viscosity of lubricant used in machine parts increase at low temperatures. *[2007]*

44. **Assertion :** A bubble comes from the bottom of a lake to the top.
Reason : Its radius increases. *[2008]*

Directions for (Qs. 45-49) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

45. **Assertion :** A large force is required to draw apart normally two glass plates enclosing a thin water film.
Reason : Water works as glue and sticks two glass plates. *[2010]*

46. **Assertion :** Falling raindrops acquire a terminal velocity.
Reason : A constant force in the direction of motion and a velocity dependent force opposite to the direction of motion, always result in the acquisition of terminal velocity. *[2011]*

47. **Assertion :** The velocity of flow of a liquid is smaller when pressure is larger and vice-versa.
Reason : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant. *[2013, 14]*

48. **Assertion :** The buoyant force on a submerged rigid object can be considered to be acting at the centre of mass of the object.
Reason : For a rigid body a force field distributed uniformly through its volume can be considered to be acting at the centre of mass of the body. *[2015]*

49. **Assertion:** The pressure of water reduces when it flows from a narrow pipe to a wider pipe.
Reason: Since for wider pipe area is large, so flow of speed is small and pressure also reduces proportionately. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (a) Equating volume in both cases,

$$\frac{4}{3}\pi R^3 = 729 \times \frac{4}{3}\pi r^3$$

$$\Rightarrow r^3 = \frac{R^3}{729}$$

$$\Rightarrow r = \frac{R}{9}$$

2. (d) Radius of new droplet if be r then,

$$10^6 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times (0.001)^3$$

$$r^3 = 10^{-15} \Rightarrow r = 10^{-5}$$

Increase in surface area

$$= \left[4\pi \times (10^{-5})^2 \times 10^6\right] - \left[4\pi \times (10^{-3})^2\right]$$

$$= \left[4\pi \times 10^{-4}\right] - \left[4\pi \times 10^{-6}\right] = 4\pi 10^{-6}[100 - 1]$$

$$= 4\pi \times 10^{-6} \times 99 = 4\pi \times 10^{-6} \times 99$$

Work done

= surface tension × increase in surface area

$$= 72 \times 4\pi \times 99 \times 10^{-6} \times 10^{-3} = 8.95 \times 10^{-5}\ \text{J}$$

3. (a) Excess pressure in first soap bubble,

$$p_1 = \frac{4T}{r_1}$$

∴ excess pressure inside second bubble,

$$p_2 = \frac{4T}{r_2}$$

On dividing these, we get

$$\frac{p_1}{p_2} = \frac{r_2}{r_1}$$

but $p_1 = 3p_2 \Rightarrow \frac{r_1}{r_2} = \frac{1}{3}$

$$\Rightarrow \left(\frac{r_1}{r_2}\right)^3 = \frac{1}{27}$$

So, ratio of their volumes is,

$$\frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \frac{v_1}{v_2} \Rightarrow \frac{v_1}{v_2} = \frac{1}{27}$$

4. (a) The surface of water tends to contract which is known as surface tension. In case of water droplets, the surface tension attains minimum value when its shape is spherical. So water droplets are spherical in shape.

5. (d) Work done

= Increase in surface area × Surface tension

$$2 \times 10^{-4} = \frac{2(60 \times 11 - 10 \times 6) \times T}{100 \times 100}$$

$$T = \frac{2 \times 10^{-4}}{2 \times 6 \times 10^{-2}} = \frac{1}{6} \times 10^{-2}\ \text{Nm}^{-1}$$

6. (b) We know that velocity of efflux, $v = \sqrt{2gh}$

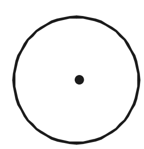
At the bottom of tank pressure is 3 atmosphere. So, total pressure due to water column

$$= h\rho g = 2 \times 10^5 \text{ (two atmosphere)}$$

$$\Rightarrow gh = \frac{2 \times 10^5}{\rho} = \frac{2 \times 10^5}{10^3} = 2 \times 10^2$$

$$\Rightarrow v = \sqrt{2 \times 2 \times 10^2} = \sqrt{400}\ \text{m/sec}$$

7. (a)



Excess pressure, $\Delta p = \frac{2T}{r}$

$$= \frac{2 \times 70 \times 10^{-3}}{1 \times 10^{-3}} = 140\ \text{newton/m}^2$$

8. (b) Bernoulli's principle is based on the law of conservation of energy. We equate total energy (pressure energy, potential energy and kinetic energy) of a flowing liquid at different points flowing under constant pressure difference.

9. (a) Bernoulli's theorem states that when there is greater speed in liquid, pressure is reduced. When air is pumped inside the pipe, the velocity of air inside increases which creates low pressure there. The liquid in the basic is then travelled in upward direction. This is theory of Scent Sprayer.

10. (b) If r_1, r_2, r be radius of soap bubbles before and after the coalesce & p_1, p_2 and p the pressure then, applying gas laws equation

$$p_1V_1 + p_2V_2 = pV$$

$$\frac{4T}{r_1}\times\frac{4}{3}\pi r_1^3 + \frac{4T}{r_2}\times\frac{4}{3}\pi r_2^3 = \frac{4T}{r}\times\frac{4}{3}\pi r^3$$

$$r_1^2 + r_2^2 = r^2$$

$$3^2 + 4^2 = r^2 \Rightarrow r = \sqrt{25} = 5 \text{ cm.}$$

11. (b) Let r be radius of common drop

$$\frac{4}{3}\pi r^3 = 2\times\frac{4}{3}\pi R^3$$

$$r = (2)^{\frac{1}{3}} R$$

Surface energy before the coalesce

$$= 2\times 4\pi R^2 T$$

Surface energy after the coalesce = $4\pi r^2 T$

$$\text{Ratio} = \frac{2\times 4\pi R^2 T}{4\pi r^2 T} = \frac{2R^2}{2^{2/3}R^2}$$

$$= \frac{2^{\frac{1}{3}}.2^{\frac{2}{3}}}{2^{\frac{2}{3}}} = \frac{2^{\frac{1}{3}}}{1}$$

12. (a) When a body falls through a viscous liquid, its velocity increases due to gravity but after some time its velocity becomes uniform because of viscous force becoming equal to the gravitational force. Viscous force itself is a variable force which increases as velocity increases, so curve (a) represents the correct alternative.

13. (c) In old age arteries carrying blood when there in narrow arteries pressure is increased. Actually due to narrowness and other obstruction the velocity of the flow of blood gets decreased. This results in increased pressure inside the blood vessel, according to Bernoulli's principle.

14. (a) For a falling body in viscous fluid the terminal velocity is related to radius as follows.

$$V_T = \frac{2}{9\eta}R^2(\rho-\sigma)g \Rightarrow v_T \propto R^2$$

15. (b) $B = \dfrac{\text{Stress}}{\text{Volume strain}} = \dfrac{\text{Stress}}{\Delta V/V}$

$$\frac{\Delta V}{V} = \frac{\text{Stress}}{B}$$

As stress is constant. So, $\dfrac{\Delta V}{V} \propto \dfrac{1}{B}$

16. (b) If apparent depth = d_A and real depth = d_R

$$\frac{d_R}{d_A} = \frac{n_2}{n_1} \Rightarrow d_A = \frac{n_1}{n_2}d_R$$

$$\Delta d_A = \frac{n_1}{n_2}\Delta d_R \qquad \text{..............(i)}$$

Now, $V = \pi R^2 d_R$

$$\Delta V = \pi R^2 \Delta d_R$$

$$\Delta d_R = \frac{\Delta V}{\pi R^2}$$

Putting it in equation (i),

$$\Delta d_A = \frac{n_1}{n_2}\frac{\Delta V}{\pi R^2} \Rightarrow \Delta V = \frac{n_2}{n_1}\pi R^2.x.$$

17. (b) The candle floats on the water with half its length above and below water level. Let its length be 10 cm. with 5 cm. below the surface and 5 cm. above it. If its length is reduced to 8 cm. It will have 4 cm. above water surface. So we see tip going down by 1 cm. So rate of fall of tip = 1 cm/hour.

18. (a) Water level in both A and B will go up. The pressure difference thus created will provide the necessary centripetal force for the water body to rotate around the vertical axis.

19. (c) Pressure difference created = 10 mm of Hg

This must be equal to the pressure of water column being created in the straw. If height of water column be h

$$h\rho g = \frac{10}{10}\times 13.6\times g$$

$h \times 1 = 13.6 \Rightarrow h = 13.6$ cm.

20. (b) Area increased $= (10 \times 11) - (10 \times 6)\ cm^2$
$= 110 - 60 = 50\ cm^2$

Since film has 2 sides

$\therefore$ total increased area $= 50 \times 2 = 100\ cm^2$

work done = surface tension × increase in surface area

$\Rightarrow$ Surface tension

$$= \frac{\text{Work done}}{\text{increasein surface area}}$$

$$= \frac{3 \times 10^{-4}}{100\ cm^2} = \frac{3 \times 10^{-4}}{100 \times 10^{-4}\ m^2}$$

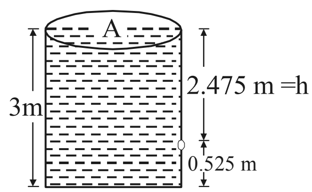
$= 0.03\ N/m = 3 \times 10^{-2}\ N/m$

21. (c) $V_T = \dfrac{2r^2(d_1 - d_2)g}{9\eta}$

$$\frac{V_{T_2}}{0.2} = \frac{(10.5 - 1.5)}{(19.5 - 1.5)} \Rightarrow V_{T_2} = 0.2 \times \frac{9}{18}$$

$\therefore V_{T_2} = 0.1\ m/s$

22. (a) The square of the velocity of flux



$$v^2 = \frac{2gh}{1 - \left(\frac{A_0}{A}\right)^2}$$

$$= \frac{2 \times 10 \times 2.475}{1 - (0.1)^2} = 50\, m^2/s^2$$

23. (d) Archimedes principle states that weight of body displaced by liquid = upthrust.

$60 \times g + V \times 0.6 \times 10^3\ g = V \times 1000\ g$

$60 + 600\ V = 1000V$

$60 = 400\ V$

$$V = \frac{60}{400} = \frac{3}{20} m^3$$

where, V is the volume of wooden log.

24. (d) $W = T\Delta A = T \times 2[4\pi R^2]$
$= 60 \times 10^{-3} \times 8\pi \times (0.2)^2$
$= 1.92\,\pi \times 10^{-4} J$

25. (c) $h = \dfrac{2\sigma\cos\theta}{r\rho g} \Rightarrow \sigma \propto \dfrac{h\rho}{\cos\theta}$

$$\Rightarrow \frac{\sigma_w}{\sigma_m} = \frac{h_w \rho_w}{\cos\theta_w} \times \frac{\cos\theta_m}{h_m \rho_m}$$

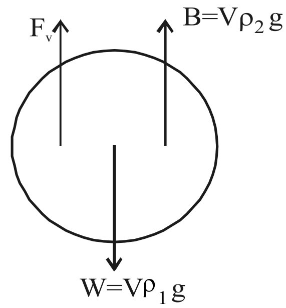
$$= \frac{10 \times 1}{\cos 0°} \times \frac{\cos 135°}{-3.1 \times 13.6}$$

$$= \frac{10 \times (-0.707)}{-3.1 \times 13.6} \approx \frac{1}{6}$$

26. (b) Apply Bernoulli's theorem.

27. (a) The condition for terminal speed (v_t) is

Weight = Buoyant force + Viscous force



$\therefore\ V\rho_1 g = V\rho_2 g + kv_t^2$

$$\therefore\ v_t = \sqrt{\frac{Vg(\rho_1 - \rho_2)}{k}}$$

28. (a) $(2\pi r_1 + 2\pi r_2)\sigma = mg$

$$\left[2\pi \times \frac{8.7}{2} + 2\pi \times \frac{8.5}{2}\right]\sigma = 3.97 \times 980$$

$\Rightarrow \sigma = 72\ \text{dyne cm}^{-1}$

29. (a) Velocity of water from hole

$A = v_1 = \sqrt{2gh}$

Velocity of water from hole B

$= v_2 = \sqrt{2g(H_0 - h)}$

Time of reaching the ground from hole B

$= t_1 = \sqrt{2(H_0 - h)/g}$

Time of reaching the ground from hole A

$= t_2 = \sqrt{2h/g}$

30. (d) $Y = 2\eta(1+\sigma) \Rightarrow \sigma = \dfrac{0.5Y - \eta}{\eta}$

31. (d) As the block moves up with the fall of coil, l decreases, similarly h will also decrease because when the coin is in water, it displaces water equal to its own volume only.

32. (c) $K = \dfrac{P}{\Delta V / V} \qquad \therefore \ \Delta V = \dfrac{PV}{K}$

$P = h\rho g = 200 \times 10^3 \times 10\ N/m^2$

$K = 22000\ atm = 22000 \times 10^5\ N/m^2$

$V = 1m^3$

$$\Delta V = \frac{200 \times 10^3 \times 10 \times 1}{22000 \times 10^5} = 9.1 \times 10^{-4} m^3$$

33. (a) Given, $\dfrac{4T}{r_1} = 2 \times \dfrac{4T}{r_2}$ or $r_2 = 2r_1$

$$\frac{4}{3}\pi r_1^3 = n \times \frac{4}{3}\pi r_2^3 = n \times \frac{4}{3}\pi(2r_1)^3$$

or $n = \dfrac{1}{8} = 0.125$

34. (b) Let V be the volume of the load and ρ its relative density

So, $Y = \dfrac{FL}{A\ell_a} = \dfrac{V\rho g L}{A\ell_a}$ .....(1)

When the load is immersed in the liquid, then

$Y = \dfrac{F'L}{A\ell_w} = \dfrac{(V\rho g - V \times 1 \times g)L}{A\ell_w}$ ....(2)

($\because$ Now net weight = weight – upthrust)

From eqs. (1) and (2), we get

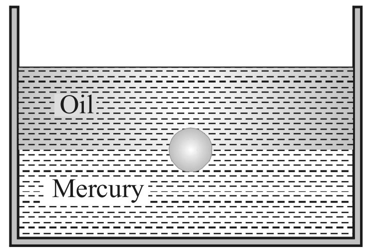
$$\frac{\rho}{\ell_a} = \frac{(\rho - 1)}{\ell_w} \text{ or } \rho = \frac{\ell_a}{(\ell_a - \ell_w)}$$

35. (b) Net force = Average pressure × Area – T × 2R

$$\left(P_0 + \rho g\frac{h}{2}\right)(2Rh) - T2R$$

$$\Rightarrow |2P_0Rh + R\rho g h^2 - 2RT|$$

36. (c)



As the sphere floats in the liquid. Therefore its weight will be equal to the upthrust force on it

Weight of sphere $= \dfrac{4}{3}\pi R^3 \rho g$ ...(i)

Upthrust due to oil and mercury

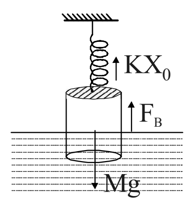
$$= \frac{2}{3}\pi R^3 \times \sigma_{oil} g + \frac{2}{3}\pi R^3 \sigma_{Hg} g \qquad \text{...(ii)}$$

Equating (i) and (ii)

$$\frac{4}{3}\pi R^3 \rho g = \frac{2}{3}\pi R^3 0.8g + \frac{2}{3}\pi R^3 + 13.6g$$

$$\Rightarrow 2\rho = 0.8 + 13.6 = 14.4 \Rightarrow \rho = 7.2$$

37. (c) From figure, $kx_0 + F_B = Mg$



$$kx_0 + \sigma\frac{L}{2}Ag = Mg$$

[$\because$ mass = density × volume]

$$\Rightarrow kx_0 = Mg - \sigma\frac{L}{2}Ag$$

$$\Rightarrow x_0 = \frac{Mg - \dfrac{\sigma LAg}{2}}{k} = \frac{Mg}{k}\left(1 - \frac{LA\sigma}{2M}\right)$$

Hence, extension of the spring when it is in equilibrium is, $x_0 = \dfrac{Mg}{k}\left(1 - \dfrac{LA\sigma}{2M}\right)$

38. **(d)** Here excess pressure, $P_{excess} = \frac{T}{r_1} + \frac{T}{r_2}$

$$P_{excess} = \frac{T}{R} \qquad \because \begin{pmatrix} r_1 = R \\ r_2 = O \end{pmatrix}$$

Type B : Assertion Reason Questions

39. **(c)** The water starts boiling a second time because when pressure cooker cools down pressure inside gets reduced. Reduced pressure brings down the B.P. of water. The reduced B.P. makes the water boil a second time.

40. **(b)** Smaller drops have larger excess pressure inside. The excess pressure is related to radius as follow

$$p = \frac{4T}{r}$$

That is why smaller droplets resist deforming forces.

41. **(a)** Reynold number

$$= \frac{\text{Inertial force per unit area}}{\text{Viscous force perunit area}}$$

So for higher value of Reynold's number, inertial force is dominant.

42. **(b)** Assertion and Reason are correct. But Reason does not explain Assertion. Explanation of Assertion is that it is the surface tension of the water surface which is balancing the weight of the steel needle.

43. **(a)** Viscosity of a liquid decreases with increase in temperature and vice versa i.e,

$$\eta = \frac{1}{\sqrt{T}}$$

$\therefore$ at low temperatures viscosity increases

$\Rightarrow$ Viscous drag increases

$$F = -\eta A \frac{dv}{dx}$$

$\Rightarrow$ force required to move the body or machine increases hence, machines are fammed.

44. **(b)** The pressure will be greater at the bottom than at the top. So the air bubble moves from the bottom to the top i.e., from higher to lower pressure. Further in coming from bottom to top, the pressure decreases and hence volume increases (By Boyle's law, PV = constant), thus radius also increases.

45. **(c)** In this case, atmospheric pressure does not comes into it because it acts in all direction. The force which is effective in case of water between two pieces of glass is adhesive force. As, adhesive forces are considered that between two different bodies; cohesive forces are internal forces of a body, resulting from attraction between the molecules of it. The attractive force between water and glass (the glass contain silicium atoms, negatively charged and water is a polar molecule so that the positive side of water is attached and causes part of the bound) keep them firmly tovether. Due to the big surface of the glass slide, the resultant force is also big. So we have to apply a large force in order to separate two glass plates enclosed with water film.

46. **(c)** **47.** **(d)** **48.** **(c)**

49. **(d)** Pressure of water reduces when it comes from wide pipe to narrow pipe. According to equation of continuity, av = constant. As the water flows from wider tube to narrow tube, its velocity increases. According to Bernouli prinicple, where velocity is large pressure is less.

Chapter 10

Thermal Properties of Matter

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If the temperature of a black body increases from 7°C to 287°C, then the rate of emission of radiation energy is: *[1997]*

(a) 8 times (b) 16 times
(c) 2 times (d) 4 times

2. The radiation from the sun, incident normally at the surface of the earth is 20kcal/m^2 min. What would have the radiant energy, incident normally on the earth if the sun had a temperature, twice of the present one ? *[1997]*

(a) 80kcal/m^2 min (b) 320kcal/m^2 min
(c) 160kcal/m^2 min (d) 40kcal/m^2 min

3. The thermal conductivity of a rod is 2. What is its thermal resistivity ? *[1997]*

(a) 0.5 (b) 1
(c) 0.25 (d) 2

4. The instrument used to measure the temperature of the source from its thermal radiation is : *[1997]*

(a) hydrometer (b) barometer
(c) thermopile (d) pyrometer

5. The surface temperature of a body is 727°C and that of another body is 327°C. The ratio of total energies radiated by them is : *[1997]*

(a) 625 : 81 (b) 125 : 27
(c) 8 : 27 (d) 9 : 25

6. A Centigrade and Fahrenheit thermometers are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers a temperature of 140°C.
The fall of the temperature as registered by the centigrade thermometer is : *[1998]*

(a) 40° (b) 80°
(c) 50° (d) 90°

7. On a cold morning, a metal surface on touching is felt colder than a wooden surface, because the metal has : *[1998]*

(a) low thermal conductivity
(b) high thermal conductivity
(c) high specific heat
(d) low specific heat

8. The relative humidity on a day, when partial pressure of water vapour is 0.012×10^5 pa at 12°C is (take vapour pressure of water at this temperature as 0.016×10^5 pa) : *[1998]*

(a) 70% (b) 40%
(c) 75% (d) 25%

9. The absolute zero is the temperature at which :

(a) all substances exist in solid state *[1998]*
(b) molecular motion ceases
(c) water freezes
(d) none of these

10. A quantity of heat required to change the unit mass of a solid substance to its liquid state, while the temperature remains constant, is known as

(a) latent heat of vaporation *[1998]*
(b) latent heat of fusion
(c) heat of condensation
(d) specific heat

11. Woolen clothes keep the body warm because the wool : *[1998]*

(a) decreases the temperature of the body
(b) is a good conductor of heat
(c) increases the temperature of the body
(d) is a bad conductor of heat

12. Heat travels through vacuum by : *[1998]*

(a) convection (b) radiation
(c) conduction (d) all of these

13. A black body has maximum wavelength λ_m at 2000 K. Its corresponding wavelength at 3000 K is: *[1999]*

(a) $\frac{16}{81}\lambda_m$ (b) $\frac{3}{2}\lambda_m$
(c) $\frac{81}{16}\lambda_m$ (d) $\frac{2}{3}\lambda_m$

14. When a solid is converted into a gas, directly by heating then this process is known as: ***[1999]***
(a) Sublimation (b) Vaporization
(c) Condensation (d) Boiling

15. The sun emits a light with maximum wave length 510 nm while another star emits a light with maximum wavelength of 350 nm. The ratio of surface temperature of sun and the star will be :
(a) 0.68 (b) 2.1 ***[2000]***
(c) 1.45 (c) 0.46

16. The real coefficient of volume expansion of glycerine is 0.000597 per°C and linear coefficient of expansion of glass is 0.000009 per °C. Then the apparent volume coefficient of expansion of glycerine is ***[2000]***
(a) 0.000558 per °C (b) 0.00057 per °C
(c) 0.00027 per °C (d) 0.00066 per °C

17. The colour of a star indicates its : ***[2001]***
(a) velocity (b) temperature
(c) size (d) length

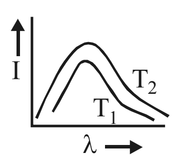
18. A black body is heated from 27°C to 127°C. The ratio of their energies of radiation emitted will be: ***[2001]***
(a) 9 : 16 (b) 27 : 64
(c) 81 : 256 (d) 3 : 4

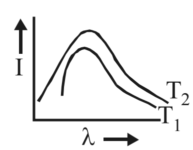
19. A black body is at a temperature 300 K. It emits energy at a rate, which is proportional to ***[2002]***
(a) $(300)^4$ (b) $(300)^3$
(c) $(300)^2$ (d) 300

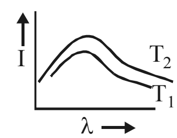
20. The density of a substance at 0°C is 10 g/cc and at 100°C, its density is 9.7 g/cc. The coefficient of linear expansion of the substance is ***[2002]***
(a) 10^{-2} (b) 10^{-2}
(c) 10^{-3} (d) 10^{-4}

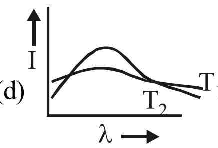
21. A black body, at a temperature of 227°C, radiates heat at a rate of 20 cal $m^{-2}s^{-1}$. When its temperature is raised to 727°C, the heat radiated by it in cal $m^{-2}s^{-1}$ will be closest to : ***[2003]***
(a) 40 (b) 160
(c) 320 (d) 640

22. Shown below are the black body radiation curves at temperatures T_1 and T_2 ($T_2 > T_1$). Which of the following plots is correct? ***[2003]***

(a) 

(b) 

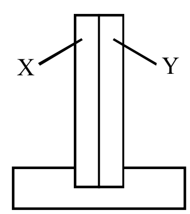
(c) 

(d) 

23. Suppose the sun expands so that its radius becomes 100 times its present radius and its surface temperature becomes half of its present value. The total energy emitted by it then will increase by a factor of : ***[2004]***
(a) 10^4 (b) 625
(c) 16 (d) 16

24. Three objects colored black, gray and white can withstand hostile conditions upto 2800°C. These objects are thrown into a furnace where each of them attains a temperature of 2000°C. Which object will glow brightest? ***[2006]***
(a) the white object
(b) the black object
(c) all glow with equal brightness
(d) gray object

25. A bimetallic strip consists of metals X and Y. It is mounted rigidly at the base as shown. The metal X has a higher coefficient of expansion compared to that for metal Y. When the bimetallic strip is placed in a cold bath: ***[2006]***



(a) It will bend towards the right
(b) It will bend towards the left
(c) It will not bend but shrink
(d) It will neither bend nor shrink

26. If the temperature of a black body increases from 7°C to 287°C then the rate of energy radiation increases by ***[2007]***
(a) $\left(\frac{287}{7}\right)^4$ (b) 16
(c) 4 (d) 2

27. The wavelength of maximum energy released during an atomic explosion was 2.93×10^{-10} m. The maximum temperature attained must be, (Weins constant = 2.93×10^{-3} mK) ***[2010]***
(a) 5.86×10^7 K (b) 10^{-13} K
(c) 10^{-7} K (d) 10^7 K

28. If the temperature of the sun were to increase from T to 2T and its radius from R to 2R, then the ratio of the radiant energy received on earth to what it was previously will be ***[2014]***

(a) 32 (b) 16
(c) 4 (d) 64

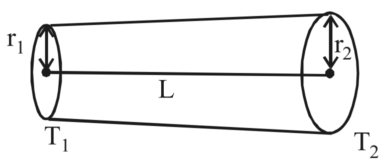
29. A crystal has a coefficient of expansion 13×10^{-7} in one direction and 231×10^{-7} in every direction at right angles to it. Then the cubical coefficient of expansion is ***[2014]***

(a) 462×10^{-7} (b) 244×10^{-7}
(c) 475×10^{-7} (d) 257×10^{-7}

30. Two identical rods of copper and iron are coated with wax uniformly. When one end of each is kept at temperature of boiling water, the length upto which wax melts are 8.4 cm amd 4.2 cm, respectively. If thermal conductivity of copper is 0.92, then thermal conductivity of iron is

(a) 0.23 (b) 0.46 ***[2015]***
(c) 0.115 (d) 0.69

31. The rate of heat flow through the cross-section of the rod shown in figure is ($T_2 > T_1$ and thermal conductivity of the material of the rod is K) ***[2015]***



(a) $\dfrac{K\pi r_1 r_2 (T_2 - T_1)}{L}$

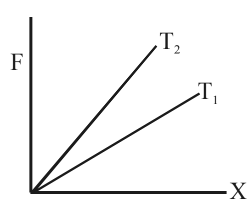
(b) $\dfrac{K\pi(r_1 + r_2)^2 (T_2 - T_1)}{4L}$

(c) $\dfrac{K\pi(r_1 + r_1)^2 (T_2 - T_1)}{L}$

(d) $\dfrac{K\pi(r_1 + r_1)^2 (T_2 - T_1)}{2L}$

32. The diagram below shows the change in the length X of a thin uniform wire caused by the application of stress F at two different temperatures T_1 and T_2. The variation shown suggests that ***[2015]***

(a) $T_1 > T_2$
(b) $T_1 < T_2$
(c) $T_2 > T_1$
(d) $T_1 \geq T_2$



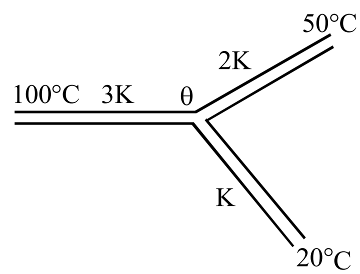
33. A glass flask of volume 1 litre is fully filled with mercury at 0ºC. Both the flask and mercury are now heated to 100ºC. If the coefficient of volume expansion of mercury is 1.82×10^{-4}/ºC, volume coefficient of linear expansion of glass is 10×10^{-6}/ºC, the amount of mercury which is spilted out is ***[2015]***

(a) 15.2 ml (b) 17.2 ml
(c) 19.2 ml (d) 21.2 ml

34. Steam is passed into 22 g of water at 20°C . The mass of water that will be present when the water acquires a temperature of 90°C is (Latent heat of steam is 540 cal/gm) ***[2016]***

(a) 24.8 gm (b) 24 gm
(c) 36.6 gm (d) 30 gm

35. There rods of the same dimensions have thermal conductivities 3K, 2K and K. They are arranged as shown in fig. with their ends at 100°C, 50°C and 20°C. The temperature of their junction is ***[2017]***



(a) 60° (b) 70°
(c) 50° (d) 35°

36. A beaker is filled with water at 4°C. At one time the temperature is increased by few degrees above 4°C and at another time it is decreased by a few degrees below 4°C. One shall observe that: ***[2017]***

(a) the level remains constant in each case
(b) in first case water flows while in second case its level comes down
(c) in second case water over flows while in first case its comes down
(d) water overflows in both the cases

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 37-50) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

37. **Assertion :** The equivalent thermal conductivity of two plates of same thickness in contact is less than the smaller value of thermal conductivity.
Reason : For two plates of equal thickness in contact the equivalent thermal conductivity is given by : ***[1997]***

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}$$

38. **Assertion :** Melting of solid causes no change in internal energy.
Reason : Latent heat is the heat required to melt a unit mass of solid. ***[1998]***

39. **Assertion:** Fahrenheit is the smallest unit measuring temperature.
Reason: Fahrenheit was the first temperature scale used for measuring temperature. ***[1999]***

40. **Assertion:** Bodies radiate heat at all temperature.
Reason: Rate of radiation of heat is proportional to the fourth power of absolute temperature. ***[1999]***

41. **Assertion :** Woolen clothes keep the body warm in winter
Reason : Air is a bad conductor of heat. ***[2002]***

42. **Assertion :** Bodies radiate heat at all temperatures.
Reason : Rate of radiation of heat is proportional to the fourth power of absolute temperature. ***[2002]***

43. **Assertion :** A tube light emits white light.
Reason : Emission of light in a tube takes place at a very high temperature. ***[2003]***

44. **Assertion :** It is hotter over the top of a fire than at the same distance of the sides.
Reason : Air surrounding the fire conducts more heat upwards. ***[2003]***

45. **Assertion :** A body that is good radiator is also a good absorber of radiation at a given wavelength.
Reason : According to Kirchhoff's law the absorptivity of a body is equal to its emissivity at a given wavelength. ***[2005]***

46. **Assertion :** In pressure-temperature (P-T) phase diagram of water, the slope of the melting curve is found to be negative.
Reason : Ice contracts on melting to water. ***[2005]***

47. **Assertion :** For higher temperature the peak emission wavelength of a blackbody shifts to lower wavelengths.
Reason : Peak emission wavelengths of a black body is proportional to the fourth-power of temperature. ***[2005]***

48. **Assertion :** Perspiration from human body helps in cooling the body.
Reason : A thin layer of water on the skin enhances its emissivity. ***[2006]***

49. **Assertion :** A hollow metallic closed container maintained at a uniform temperature can act as a source of black body radiation.
Reason : All metals act as black bodies. ***[2007]***

50. **Assertion :** A brass tumbler feels much colder than a wooden tray on a chilly day.
Reason : The thermal conductivity of brass is more than the thermal conductivity of wood. ***[2008]***

Directions for (Qs. 51) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

51. **Assertion :** Two thin blankets put together are warmer than a single blanket of double the thickness.
Reason : Thickness increases because of air layer enclosed between the two blankets. ***[2010]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** For black body radiation

$$E=\sigma T^4$$

[E is energy radiated per unit time per unit area, T is temperature of the body]

$$\frac{E_2}{E_1}=\left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{E_2}{E_1}=\left(\frac{273+287}{273+7}\right)^4$$

$$=\left(\frac{560}{280}\right)^4=\frac{16}{1} \Rightarrow E_2=16E_1$$

2. **(b)** We know that, for a source, emitting energy E at temperature T

$$E=\sigma T^4 \Rightarrow E_1=\sigma(2T)^4$$

$$\frac{E}{E_1}=\frac{\sigma T^4}{16\sigma T^4}=\frac{1}{16}$$

Now radiation falling on the earth will be proportional to radiation being emitted so.

$$\frac{E}{E_1}=\frac{20}{X}$$

Here, X is the radiation falling in the earth in the latter case.

$$\frac{20}{X}=\frac{1}{16}$$

$$\Rightarrow X=20\times 16=320\,\text{kcal}/\text{m}^2\,\text{min}$$

3. **(a)** $\text{Conductivity}=\dfrac{1}{\text{Resistivity}}$

Thermal conductivity = 2

$\text{Thermal resistivity}=\dfrac{1}{2}=0.5$

4. **(c)** Thermopile is a combination of thermocouple which generates electrical energy when one end is kept at higher temperature with respect to the other end. It is helpful in measuring the temperature of a hot and radiating body.

5. **(a)** We know that

$$E=\sigma T^4$$

$$\frac{E_1}{E_2}=\left(\frac{T_1}{T_2}\right)^4=\left(\frac{727+273}{327+273}\right)^4$$

$$=\left(\frac{1000}{600}\right)^4=\frac{625}{81}$$

6. **(a)** From the formula,

$$\frac{C}{5}=\frac{F-32}{9}$$

$$\Rightarrow \frac{C}{5}=\frac{140-32}{9}=\frac{108}{9}$$

So, fall of temperature in °C is

$100-60=40°C$

7. **(b)** Metal appears cool on touching because heat flows from body (at higher temperature) to iron (at lower temperature). This can happen only when metal conducts heat. Wooden surface does not feel cool as it is non-conductor of heat.

8. **(c)** Relative Humidity

$$=\frac{\text{Partial pressure of water vapour}}{\text{Vapour pressure of water}}$$

$$=\frac{0.012\times 10^5\times 100}{0.016\times 10^5}=\frac{12}{16}\times 100=75\%$$

9. **(b)** Absolute zero is the temperature at which molecular motion ceases when vibrational energy exists.

10. **(b)** During fusion of solid into liquid some energy is used up to transform the state of matter from solid to liquid. Since it does not increase the kinetic energy of particles, there is no increase in the temperature of the material. So, phase transformation takes place at constant temperature.

11. **(d)** Wool is a bad conductor of heat. It does not allow heat to pass on from body to surrounding. So, body is kept warm.

12. **(b)** The process of convection and conduction requires some medium made of material particle for transmission of heat. In vacuum there is no material. So, heat travels in vacuum by radiation.

13. **(d)** Applying Wein's displacement law,

$$\lambda_m T=\text{constant}$$

$$\lambda_{1m}T_1=\lambda_{2m}T_2$$

$$\lambda_m\times 2000=\lambda\times 3000$$

$$\lambda=\frac{2}{3}\lambda_m$$

14. (a) Sublimation is conversion of a solid directly into gas by heat.

15. (a) Applying Wein's displacement law,

$\lambda_m T =$ constant

$$\frac{\lambda'_m}{\lambda''_m} = \frac{T_2}{T_1} \Rightarrow \frac{510}{350} = \frac{T_2}{T_1}$$

$$\frac{T_2}{T_1} = \frac{51}{35} \Rightarrow \frac{T_1}{T_2} = \frac{35}{51} = 0.68$$

16. (b) Coefficient of volume expansion of glycerine

$= 0.000597$ per°C

Coefficient of volume expansion of glass

$= 3 \times 0.000009 = 0.000027$per°C

Apparent coefficient of volume expansion

$= 0.000597 - 0.000027$

$= 0.00057$per°C

17. (b) The colour of the star indicates its temperature. Higher the wavelength emitted lower will be its temperature. This is from Wein's displacement Law, $\lambda_m T =$ constant.
A blue coloured star will have high temperature than red coloured star.

18. (c) We know that

$$E = \sigma T^4$$

Where E is rate of emission of radiation of a body at temperature T.

$$E_1 = \sigma(27 + 273)^2$$

$$E_2 = \sigma(127 + 273)^2$$

$$\frac{E_1}{E_2} = \frac{(300)^4}{(400)^4} = \frac{81}{256}$$

19. (a) For black body radiation

$E = \sigma T^4$ or $E \propto T^4$

Rate of emission of energy $\propto (300)^4$

20. (a) The coefficient of volume expansion,

$$\gamma = \frac{\Delta\rho}{\rho_1 \times \Delta t}$$

$$= \frac{\rho_1 - \rho_2}{\rho_1(T_2 - T_1)} = \frac{10 - 9.7}{10(100 - 0)} = 3 \times 10^{-4}$$

Coefficient of linear exapansion

$$\alpha = \frac{\gamma}{3} = \frac{3 \times 10^{-4}}{3} = 10^{-4}$$

21. (c) We know that

$$E = \sigma T^4 \Rightarrow \frac{E_1}{E_2} = \frac{T_1^4}{T_2^4}$$

$$\Rightarrow \frac{E}{20} = \frac{(727 + 273)^4}{(227 + 273)^4} = \frac{(1000)^4}{(500)^4}$$

$$\frac{E_1}{20} = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$$

$$\Rightarrow E_1 = 20 \times 16 = 320 \text{ cal m}^{-2}\text{ s}^{-1}$$

22. (a) From Wein's displacement law,
$\lambda_m T =$ constant i.e.
at greater temperature λ_m will be small λ_m is the wavelength of the radiaton having highest intensity. In figure (a) curve representing T_2 has λ_m smaller than that for T_1 so, (a) is the right answer.

23. (b) $E = \sigma T^4$, here, E is energy radiated per unit area. Total energy emitted $= \sigma T^4 \times A$
Total energy emitted by sun after expansion

$$= \sigma \times \left(\frac{T}{2}\right)^4 \times 100 \times 100 \text{ A}$$

[When radius becomes 100 times, area becomes 100^2 times]

$$= A\sigma T^4 \times \frac{1}{16} \times 100 \times 100 = 625 \times \sigma T^4 \text{ A}$$

So, total energy emitted is 625 times.

24. (b) Black has greatest emissivity and greatest absorbtivity as compared with other colours. At 2000°C it will have greatest emissivity so it will glow brightest.

25. (b) As coefficient of thermal expansion of X is more. On cooling, it will shrink more. So the strip will bend towards the left.

26. (b) By Stefan's law, energy radiated per sec by a black body is given by $E = A\sigma T^4$
where A = area of black body, σ = Stefan's constant. For a black body at temperature T_1, $E_1 = A\sigma T_1^4$, at T_2, $E_2 = A\sigma T^4$
(Since A,σ all same)

$\therefore \dfrac{E_2}{E_1} = \dfrac{T_2^4}{T_1^4}$

$\Rightarrow E_2 = \left(\dfrac{T_2}{T_1}\right)^4 E_1$

$T_2 = 287°C = 287 + 273 = 560\,K,$
$T_1 = 7°C = 7 + 273 = 280\,K,$

$\therefore E_2 = \left(\dfrac{560}{280}\right)^4 E_1 = 2^4 E_1 = 16\,E_1$

$\therefore$ Rate of energy radiated increases by 16 times.

27. (d) $\lambda_m \times T = b$ (Wein's displacement Law)

$T = \dfrac{2.93\times10^{-3}}{2.93\times10^{-10}} = 10^7\,K$

28. (d) $E = \sigma A T^4$

$A \,\alpha\, R^2 \quad \therefore E \alpha\, R^2T^4$

$\therefore \dfrac{E_2}{E_1} = \dfrac{R_2^2\,T_2^4}{R_1^2\,T_1^4}$

put $R_2 = 2R, R_1 = R$

$T_2 = 2T, T_1 = T$

$\Rightarrow \dfrac{E_2}{E_1} = \dfrac{(2R)^2(2T)^4}{R^2T^4} = 64$

29. (a) $\gamma = \alpha_1 + \alpha_2 + \alpha_3$

$= 13\times10^{-7} + 231\times10^{-7} + 231\times10^{-7}$

$= 475\times10^{-7}$

30. (a) Use $\dfrac{K_1}{K_2} = \dfrac{\ell_1^2}{\ell_2^2}$

31. (a) $r_{eff} = \sqrt{r_1r_2}$

$\dfrac{dQ}{dt} = \dfrac{KA(T_2 - T_1)}{L} = \dfrac{K\pi r_1r_2(T_2 - T_1)}{L}$

32. (a) When same stress is applied at two different temperatures, the increase in length is more at higher temperature. Thus $T_1 > T_2$.

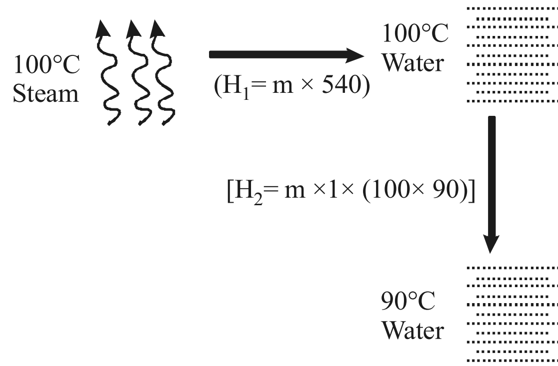
33. (a) $\Delta V = V_0(\gamma_m - \gamma_g)\Delta T$

$= 1[1.82\times10^{-4} - 3\times(10\times10^{-6})]\,100$

$= 1[1.82\times10^{-4} - 0.3\times10^{-4})]\,100$

$= 15.2$ ml

34. (a) Let m g of steam get condensed into water (By heat loss). This happens in following two steps.



Heat gained by water (20°C) to raise it's temperature upto 90°C $= 22 \times 1 \times (90 - 20)$
Hence, in equilibrium, heat lost = Heat gain
$\Rightarrow m \times 540 + m \times 1 \times (100 - 90)$
$= 22 \times 1 \times (90 - 20)$
$\Rightarrow m = 2.8$ gm
The net mass of the water present in the mixture = 22 + 2.8 = 24.8 gm.

35. (b) $\dfrac{dQ}{dt} = KA\dfrac{\Delta T}{L}$

For the first rod, $\left(\dfrac{dQ}{dt}\right)_1 = \dfrac{3KA}{L}(100 - \theta)$

Similarly, $\left(\dfrac{dQ}{dt}\right)_2 = 2K\dfrac{A}{L}(\theta - 50)$

$\left(\dfrac{dQ}{dt}\right)_3 = K\dfrac{A}{L}(\theta - 20)$

Now, $\left(\dfrac{dQ}{dt}\right)_1 = \left(\dfrac{dQ}{dt}\right)_2 + \left(\dfrac{dQ}{dt}\right)_3$

$\Rightarrow 3(100 - \theta) = 2(\theta - 50) + (\theta - 20)$

$\Rightarrow \theta = 70°$

36. (d) water expands on both sides of 4 °C.

Type B : Assertion Reason Questions

37. (a) For equivalent thermal conductivity, the relation is

$\dfrac{1}{K_R} = \dfrac{1}{K_1} + \dfrac{1}{K_2}$; If $K_1 = K_2 = K$

$\dfrac{1}{K_R} = \dfrac{1}{K} + \dfrac{1}{K} = \dfrac{2}{K} \Rightarrow K_R = \dfrac{K}{2}$

Which is less than K.

If $K_1 > K_2$ suppose $K_1 = K_2 + x$

$\dfrac{1}{K} = \dfrac{1}{K_1} + \dfrac{1}{K_2} = \dfrac{K_2 + K_1}{K_1K_2}$

$\Rightarrow \dfrac{1}{K} = \dfrac{K_2 + K_2 + x}{(K_2 + x)K_2} \Rightarrow K = \dfrac{K_2^2 + K_2x}{2K_2 + x}$

Now, $K_2 - K = K_2 - \dfrac{K_2^2 + K_2 x}{2K_2 + x}$

$= \dfrac{2K_2^2 + K_2 x - K_2^2 - K_2 x}{(2K_2 + x)}$

$= \dfrac{K_2^2}{2K_2 + x} = \text{positive}$

So, $K_2 > K$, so the value of K is smaller than K_2 and K_1.

38. (e) Melting of solid causes change in its internal energy.
Latent heat is the heat required to melt one unit mass of solid. Option (e) is correct.

39. (e) Here, Assertion is incorrect & Reason is correct. The temperature difference between boiling point of water and freezing point of water has been divided into 100 parts in ºC scale, 180 parts in Fahrenheit scale, 80 parts in Reaumer scale and 212 parts in Rankine scale. So, Rankine scale is the smallest unit. Assertion is incorrect.
Fahrenheit was the first temperature scale used for measuring temperature. So, the Reason is correct.

40. (a) Bodies radiate heat at all temperatures. It is true.
We also know that, $E \propto T^4$.
So, Reason is also correct and its explains Assertion.

41. (a) Woolen clothes keep the body warm. The air trapped in clothes are bad conductor of heat.

42. (e) Bodies radiate heat at all temperature. The rate of radiation of heat is proportional to the fourth power of absolute temperature is
$E = \sigma T^4$ which is Stefan's Boltzmann's law

43. (c) In tube light, the gas contains vapour of metals. In metallic atoms, electronic transition occurs due to which light of a particular wavelength is emitted. So emission of white light is due to electronic transition and not due to vibration of atoms as in hot substances. So, Assertion is correct but Reason is incorrect.

44. (c) It is hotter over the top of a fire. It is because of convection current established over the fire. As air warms up, its density decreases as a result of which it goes up and makes upper layer of air hot.
The Reason is incorrect.

45. (c) According to Kirchoff's law
$\dfrac{e_\lambda}{a_\lambda} = E_\lambda$.
Here, E_λ is emissivity of black body which is constant, so, $e_\lambda \propto a_\lambda$. It means good emitter are good absorber of radiation.

46. (a) The slope of melting curve in phase diagram is negative for water as due to increase in temperature vapour, pressure of ice decreases. The Reason is that ice contracts on melting.

47. (c) According to Wein's displacement law,
$\lambda_m T = \text{constant}$
Naturally, when T increases λ_m decreases.
λ_m is peak emission wavelength
and $E = \sigma T^4$
Here, E is energy being radiated per unit area per unit time.

48. (c) Perspiration envolves exchange of heat from body to surrounding. Water takes heat from the body and gets converted into vapour. Hence, body cools down.
A thin layer of water on the skin will reduce rather than increase its emissivity. So, Assertion is correct but Reason is incorrect.

49. (d) A perfect black body is one which absorbs all heat radiations (whatever be the wavelength) incident on it. No natural object is a perfect black body. Best approximations are lamp black and platinum black. Fery's black body is a double walled metallic sphere coated with lamp black on the inside and nickel on outside. It has a narrow opening opposite a conical projection inside.
$\therefore$ Both Assertion and Reason are incorrect.

50. (a) Brass is a metal and good conductor. On a cold day, when brass tumbler is touched heat transfers from our body to brass, since our body looses heat so the tumbler feels cold. On the other hand, transfer of heat from our body to wood is slow and less, hence wooden tray appears warm.

51. (c) Two thin blankets put together are more warm because an insulating layer of air (as air is good insulator of heat) is enclosed between two blankets due to which it gives more warmness.

Chapter 11

Thermodynamics

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest, when the expansion is : ***[1998]***
(a) isothermal (b) adiabatic
(c) isobaric (d) all of these

2. In an adiabatic process the quantity which remains constant is: ***[1999]***
(a) total heat of system
(b) temperature
(c) volume
(d) pressure

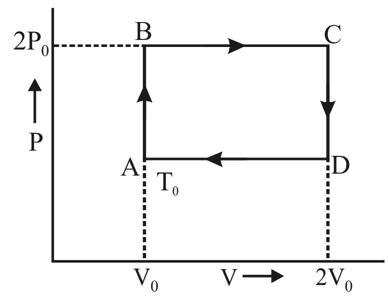
3. During the adiabatic expansion of two moles of a gas the internal energy of a gas is found to decrease by 2 joule. The work done on gas during the process will be equal to ***[2000]***
(a) – 2 J (b) 3 J
(c) 1 J (d) 2 J

4. Which one of the following is not a thermodynamical co-ordinate ? ***[2001]***
(a) V (b) R
(c) T (d) P

5. The latent heat of vaporization of water is 2240 J. If the work done in the process of vaporization of 1g is 168 J, then increase in internal energy is
(a) 1940 J (b) 2072 J ***[2002]***
(c) 2240 J (d) 2408 J

6. The volume of a gas is reduced adiabatically to (1/4) of its volume at 27ºC. If $\gamma = 1.4$. The new temperature will be : ***[2002]***
(a) $300 \times (4)^{0.4}$ K (b) $150 \times (4)^{0.4}$ K
(c) $250 \times (4)^{0.4}$ K (d) none of these

7. N moles of a monoatomic gas is carried round the reversible rectangular cycle ABCDA as shown in the diagram. The temperature at A is T_0. The thermodynamic efficiency of the cycle is :



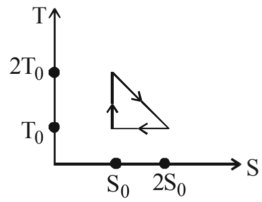
(a) 15% (b) 50% ***[2004]***
(c) 20% (d) 25%

8. When you make ice cubes, the entropy of water
(a) does not change ***[2006]***
(b) increases
(c) decreases
(d) may either increase or decrease depending on the process if used

9. In an adiabatic change, the pressure and temperature of a monoatomic gas are related as $P \propto T^C$, where C equals ***[2007]***
(a) $\frac{2}{5}$ (b) $\frac{5}{2}$
(c) $\frac{3}{5}$ (d) $\frac{5}{3}$

10. Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature T_0, while box B contains one mole of helium at temperature $\left(\frac{7}{3}\right)T_0$. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common final temperature (ignore the heat capacity of boxes). Then, the final temperature of the gases, T_f in terms of T_0 is ***[2008]***
(a) $T_f = \frac{3}{7}T_0$ (b) $T_f = \frac{7}{3}T_0$
(c) $T_f = \frac{3}{2}T_0$ (d) $T_f = \frac{5}{2}T_0$

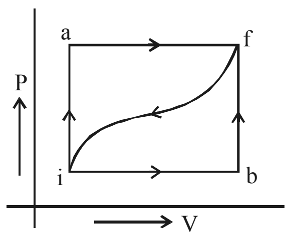
11. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is **[2008]**



(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) $\frac{2}{3}$ (d) $\frac{1}{3}$

12. When a system is taken from a state i to f along the path iaf (as shown in the figure). Q = 50 cal and W = 20 cal; along path ibf, Q = 36 cal. **[2009]**



(i) What is W along path ibf ?

(ii) If W = 13 cal for path fi, what is Q for the path f_i ?

(iii) Take $E_{int,\,i}$ = 10 cal then what is $E_{int,f}$?

(a) 30, 20, 40 cal (b) 6, – 43, 40 cal

(c) 10, – 20, 30, cal (d) 15, 35, 25 cal

13. The change in the entropy of a 1 mole of an ideal gas which went through an isothermal process from an initial state (P_1, V_1,T) to the final state (P_2, V_2,T) is equal to **[2010]**

(a) zero (b) R lnT

(c) $R \ln \frac{V_1}{V_2}$ (d) $R \ln \frac{V_2}{V_1}$

14. An ideal gas is subjected to an isothermal expansion such that its volume changes from V_i to V_f and pressure from P_i to P_f. The work done on the gas is : **[2011]**

(a) $W = +nRT \log \frac{V_f}{V_i}$

(b) $W = -nRT \log \frac{V_f}{V_i}$

(c) $W = nRT \log \frac{P_f}{P_i}$

(d) $W = -nRT \log \frac{P_f}{P_i}$

15. Two moles of a monoatomic ideal gas is confined in a container and is heated such that its temperature increases by 10°C. The approximate change in its internal energy is **[2011]**
(R = 8.31 J/mole-K)

(a) + 250 joules (b) + 350 joules

(c) – 250 joules (d) + 450 joules

16. If ΔQ and ΔW represent the heat supplied to the system and the work done on the system respectively, then the first law of thermodynamics can be written as **[2013]**

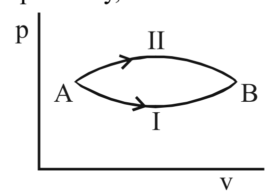
(a) $\Delta Q = \Delta U + \Delta W$

(b) $\Delta Q = \Delta U - \Delta W$

(c) $\Delta Q = \Delta W - \Delta U$

(d) $\Delta Q = -\Delta W - \Delta U$

17. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then **[2013, 2014]**



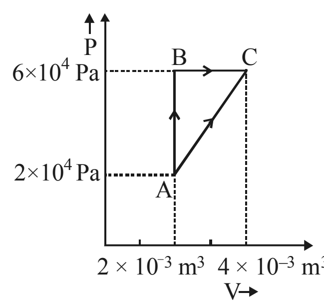
(a) relation between ΔU_1 and ΔU_2 can not be determined

(b) $\Delta U_1 = \Delta U_2$

(c) $\Delta U_1 < \Delta U_2$

(d) $\Delta U_1 > \Delta U_2$

18. Figure below shows two paths that may be taken by a gas to go from a state A to a state C.



In process AB, 400 J of heat is added to the system and in process BC, 100 J of heat is added to the system. The heat absorbed by the system in the process AC will be **[2016]**

(a) 500 J (b) 460 J

(c) 300 J (d) 380 J

19. The internal energy change in a system that has absorbed 2 kcals of heat and done 500 J of work is *[2017]*
(a) 6400 J (b) 5400 J
(c) 7900 J (d) 8900 J

20. In a heat engine, the temperature of the source and sink are 500 K and 375 K. If the engine consumes 25×10^5 J per cycle, the work done per cycle is *[2017]*
(a) 6.25×10^5 J (b) 3×10^5 J
(c) 2.19×10^5J (d) 4×10^4 J

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 29-32) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

21. **Assertion :** In isothermal process whole of the heat supplied to the body is converted into internal energy.
Reason : According to the first law of thermodynamics : *[1997]*
$\Delta Q = \Delta U + p\Delta V$

22. **Assertion :** In adiabatic compression, the internal energy and temperature of the system get decreased.
Reason : The adiabatic compression is a slow process. *[2001]*

23. **Assertion :** The isothermal curves intersect each other at a certain point.
Reason : The isothermal change takes place slowly, so, the isothermal curves have very little slope. *[2001]*

24. **Assertion :** When a bottle of cold carbonated drink is opened, a slight fog forms around the opening.
Reason : Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours. *[2003]*

25. **Assertion :** Thermodynamic process in nature are irreversible.
Reason : Dissipative effects cannot be eliminated. *[2004]*

26. **Assertion :** Reversible systems are difficult to find in real world. *[2005]*
Reason : Most processes are dissipative in nature.

27. **Assertion :** Air quickly leaking out of a balloon becomes cooler.
Reason : The leaking air undergoes adiabatic expansion. *[2005]*

28. **Assertion :** In an isolated system the entropy increases.
Reason : The processes in an isolated system are adiabatic. *[2006]*

29. **Assertion :** The Carnot cycle is useful in understanding the performance of heat engines.
Reason : The Carnot cycle provides a way of determining the maximum possible efficiency achievable with reservoirs of given temperatures. *[2006]*

30. **Assertion :** When a glass of hot milk is placed in a room and allowed to cool, its entropy decreases.
Reason : Allowing hot object to cool does not violate the second law of thermodynamics. *[2006]*

31. **Assertion :** In free expansion of an ideal gas, the entropy increases.
Reason : Entropy increases in all natural processes. *[2007]*

32. **Assertion :** The isothermal curves intersect each other at a certain point.
Reason : The isothermal changes takes place rapidly, so the isothermal curves have very little slope. *[2008]*

Directions for (Qs. 33-34) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

33. **Assertion :** Adiabatic expansion is always accompanied by fall in temperature.
Reason : In adiabatic process, volume is inversely proportional to temperature. *[2011, 2013, 2014]*

34. **Assertion :** The heat supplied to a system is always equal to the increase in its internal energy.
Reason : When a system changes from one thermal equilibrium to another, some heat is absorbed by it. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** We know that
$Q = \Delta E$ + work done by gas
Work done by gas $= Q - \Delta E$
Work done by gas is maximum when ΔE is minimum. For Isothermal Change, $\Delta E = 0$. So, for isothermal expansion work done is maximum.

2. **(a)** In adiabatic process there is no exchange of heat with the surroundings, so total heat of the system remains constant.

3. **(a)** Gas is expanding at the cost of internal energy of the gas. Work done by the gas is 2 joule. So, work done on the gas $= -2$ joule.

4. **(b)** R is a constant term. To define a thermo dynamic state of a gas we use any two of three physical quantities P, V & T. Following ratio is always constant

$$\frac{PV}{T} = R \quad \text{(constant)}$$

So, if we change P & V, T will automatically change itself to make the ratio constant.

5. **(b)** We know that for first law of thermodynamics, equation is

$$Q = \Delta E + \Delta W$$

Here, $Q = 2240;\ \Delta E = ?\ \Delta W = 168$

$$\Delta E = Q - \Delta W = 2240 - 168 = 2072\text{J}$$

6. **(a)** For adiabatic change, the equation is

$$TV^{\gamma-1} = \text{constant}$$

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$(27+273)V_1^{\gamma-1} = T_2\left(\frac{V_1}{4}\right)^{\gamma-1}$$

$$300 \times V_1^{\gamma-1} = \frac{T_2 \times V_1^{\gamma-1}}{4^{\gamma-1}} \Rightarrow T_2 = 300 \times 4^{\gamma-1}$$

$$T_2 = 300 \times 4^{1.4-1} = 300 \times 4^{0.4}\ \text{K}$$

7. **(b)** Heat absorbed = Work done by gas at constant pressure

$$= 2P_0(2V_0 - V_0) = 2P_0V_0$$

Net work done by the gas
= Workdone by the gas
– Workdone on the gas

$= 2P_0V_0 - P_0V_0$ [Net work done in a cyclic process is area of the loop]

$= P_0V_0$

So, efficiency $= \dfrac{P_0V_0}{2P_0V_0} \times 100 = 50\%$

8. **(c)** $dS = \dfrac{dQ}{T}$

In freezing process dQ is negative so entropy decreases.

9. **(b)** In adiabatic process, $P^{\gamma-1} \propto T^{\gamma}$ where $\gamma = \dfrac{5}{3}$ for monoatomic gas $\therefore P \propto T^{\gamma/(\gamma-1)}$

$$\therefore\ C = \frac{\gamma}{\gamma-1} = \frac{5/3}{5/3-1} = \frac{5/3}{2/3} = \frac{5}{2}$$

10. **(c)** Heat lost by He = Heat gained by N_2

$$n_1C_{v_1}\Delta T_1 = n_2C_{v_2}\Delta T_2$$

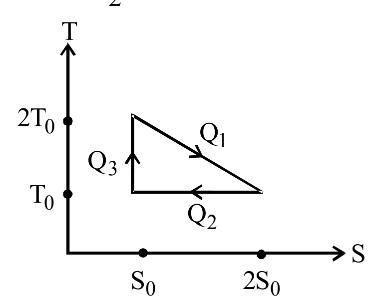
$$\frac{3}{2}R\left[\frac{7}{3}T_0 - T_f\right] = \frac{5}{2}R\left[T_f - T_0\right]$$

$$7T_0 - 3T_f = 5T_f - 5T_0$$

$$\Rightarrow 12T_0 = 8T_f \Rightarrow T_f = \frac{12}{8}T_0$$

$$\Rightarrow T_f = \frac{3}{2}T_0$$

11. **(d)**



$$Q_1 = T_0S_0 + \frac{1}{2}T_0S_0 = \frac{3}{2}T_0S_0$$

$$Q_2 = T_0(2S_0 - S_0) = T_0S_0 \text{ and } Q_3 = 0$$

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0S_0}{\frac{3}{2}T_0S_0} = \frac{1}{3}$$

12. **(b)** For path **iaf**
$Q = 50$ cal.
$W = 20$ cal.
According ot I law of thermodynamics,
$dQ = dU + dW$
or $dU = dQ - dW = 50 - 20 = 30$ cal.

(i) For path **iaf**
$Q = 36$ cal.
$W = ?$
$dU = 30$ cal (since internal energy depends only on the initial and final positions of the system).
$\therefore\ W = Q - dU = 36 - 30 = 6$ cal.

(ii) $W = -13$ cal.
$dU = -30$ cal.
$Q = ?$
$\therefore Q = dU + W = -43$ cal.

(iii) $E_{int,\,f} = E_{int,\,i} + \Delta U = 10$ cal $+ 30$ cal. $= 40$ cal.

13. **(d)** Workdone by n moles of a gas when its volume changes from V_1 to V_2 is,
$$W = nRT\log_e\frac{V_2}{V_1}$$
For, $n = 1$
$$W = RT\ 1n\frac{V_2}{V_1}$$
For an isothermal process, $\Delta U = 0$
$$\therefore\ \Delta Q = \Delta U + W = 0 + RT1n\frac{V_2}{V_1}$$
$$\therefore\ \text{Entropy} = \frac{\Delta Q}{T} = R1n\frac{V_2}{V_1}.$$

14. **(d)** The work done in expansion of gas
$$W = nRT\,\ell n\frac{V_f}{V_i} = nRT\,\ell n\frac{P_i}{P_f}$$
The work done on the gas
$$= -nRT\,\ell n\left(\frac{P_f}{P_i}\right)$$

15. **(a)** $\Delta E = n\frac{3}{2}R\,\Delta T$
$$= 2\times\frac{3}{2}\times 8.31\times 10 = 250\text{ J}$$

16. **(b)** From FLOT $\Delta Q = \Delta U + \Delta W$
$\because$ Heat supplied to the system so $\Delta Q \to$ Positive
and work is done on the system so $\Delta W \to$ Negative
Hence $+\Delta Q = \Delta U - \Delta W$

17. **(b)** Change in internal energy do not depend upon the path followed by the process. It only depends on initial and final states i.e.,
$$\Delta U_1 = \Delta U_2$$

18. **(b)** In cyclic process ABCA
$Q_{cycle} = W_{cycle}$
$Q_{AB} + Q_{BC} + Q_{CA} =$ ar. of ΔABC
$$+400 + 100 + Q_{C\to A} = \frac{1}{2}(2\times 10^{-3})(4\times 10^4)$$
$\Rightarrow\quad Q_{C\to A} = -460$ J
$\Rightarrow\quad Q_{A\to C} = +460$ J

19. **(c)** According to first law of thermodynamics
$$Q = \Delta U + W$$
$$\Delta U = Q - W$$
$$= 2\times 4.2\times 1000 - 500$$
$$= 8400 - 500$$
$$= 7900\text{ J}$$

20. **(a)** Here, $T_1 = 500$ K, $T_2 = 375$ K
$Q_1 = 25\times 10^5$ J
$$\therefore\ \eta = 1 - \frac{T_2}{T_1} = 1 - \frac{375}{500} = 0.25$$
$W = \eta Q = 0.25\times 25\times 10^5 = 6.25\times 10^5$ J

Type B : Assertion Reason Questions

21. **(a)** $\Delta Q = \Delta U + P\Delta V$ $\quad$ $[PV = nRT$
$\Delta Q = \Delta U + nR\Delta T$ $\quad$ $P\Delta V = nR\Delta T$
For isothermal change $\quad$ $\Delta T = 0$
$\therefore \Delta Q = \Delta U$
In other words whole of heat supplied is converted into internal energy.

22. **(d)** Adiabatic compression is a fast process. There is rise in temperature and also increase in internal energy.
So, both are false.

23. **(e)** Isothermal curves have slope which is equal to $\frac{P}{V}$. It can be calculated as follows
$PV = RT$
Differentiating,
$PdV + VdP = 0$
$$-\frac{dP}{dV} = \frac{P}{V}$$

Now, if they cut each other at certain point, they will have different slope at the same point (for same value of P & V). So, they can not cut each other at some point.

Reason is true, slope is $\frac{P}{V}$.

For adiabatic curve slope is γ times $\frac{P}{V}$.

24. (a) In cold carbonated drink, gas is dissolved under pressure, when pressure is released expansion of gas occurs due to which gas cools down and temperature falls. Condensation of water vapour occurs.

25. (a) Most of the phenomenon in nature is irreversible. A process becomes irreversible in case some energy is converted into heat energy. This is known as dissipative effect. When there is dissipative effect, process becomes irreversible.

26. (a) In any process some energy is found to be converted into heat (dissipative in nature) due to which process becomes irreversible.

27. (a) Air cools down due to adiabatic expansion as air has to do work against external pressure at the cost of its internal energy.

28. (b) In an unisolated system, heat may enter into or escape from the system due to which entropy may increase or decrease but for isolated system we do not consider exchange of heat, so, in this case entropy will always increase as the process is spontaneous.

An adiabatic process involves no exchange of heat. We also define isolated system as having no exchange of heat with the surrounding so it process in an isolated system are adibatic.

The two statements are independently correct but not co-related.

29. (a) Carnot cycle represents process of an ideal heat engine which has maximum efficiency of conversion of heat energy into mechanical energy. So, A is right. The efficiency of a Carnot cycle depends only on the temperature of heat reservoirs is source and sink. So, reason is right and reason explains assertion.

30. (b) A body cools, its entropy decreases as

$dS = \frac{dQ}{T}$ and dQ is –ve, dS is also –ve.

R is also true. Second law states that entropy of the universe increases. Universe includes both system and surroundings. R does not explain A.

31. (c) In free expansion of an ideal gas, work done comes from internal energy of the gas and since randomness increases or Gibbs free energy increases so we can say entropy increases.

32. (d) As isothermal processes are very slow and so the different isothermal curves have different slopes, they cannot intersect each other.

33. (c)

34. (d) According to first law of thermodynamics, $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$. If heat is supplied in such a manner that volume does not change $\Delta V = 0$,i.e., isochoric process, then whole of the heat energy supplied to the system will increase internal energy only. But, in any other process it is not possible.

Also heat may be adsorbed or evolved when state of thermal equilibrium changes.

Chapter 12 Kinetic Theory

TYPE A : MULTIPLE CHOICE QUESTIONS

1. The average kinetic energy of a gas molecule at 27°C is 6.21×10^{-21} J, then its average kinetic energy at 227°C is : ***[1999]***

(a) 10.35×10^{-21} J (b) 11.35×10^{-21} J
(c) 52.2×10^{-21} J (d) 5.22×10^{-21} J

2. An ideal gas at 27°C is compressed adiabatically to $\frac{8}{27}$ its original volume [$TV^{\gamma-1}$ = constant] and $\gamma = \frac{5}{3}$, then the rise in temperature will be:

(a) 480°C (b) 450°C ***[1999]***
(c) 375°C (d) 225°C

3. v_{rma}, v_{av} and v_{mp} are root mean square, average and most probable speeds of molecules of a gas obeying Maxwellian velocity distribution. Which of the following statements is correct ? ***[2005]***

(a) $v_{rms} < v_{av} < v_{mp}$ (b) $v_{rms} > v_{av} > v_{mp}$
(c) $v_{mp} < v_{rms} < v_{av}$ (d) $v_{mp} > v_{rms} < v_{av}$

4. Let $\bar{v}, \bar{v}_{rms}$ and v_p respectively denote the mean speed, root mean square speed and most probable speed of the molecules in an ideal monoatomic gas at absolute temperature T. The mass of the molecule is m. Then ***[2010]***

(a) no molecule can have a speed greater than $(\sqrt{2}v_{rms})$
(b) no molecule can have a speed less than $\frac{v_p}{(\sqrt{2})}$
(c) $\bar{v} < v_p < v_{rms}$
(d) the average kinetic energy of the molecules is $\frac{3}{4}(mv_p^2)$

5. Two identical containers A and B with frictionless pistons contain the ideal gas at the same temperature and the same volume V. The mass of the gas in A is m_A and in B is m_B. The gas in each cylinder is now allowed to expand isothermally to the same final volume $2V$. The changes in pressure in A and B are found to be Δp and $1.5\Delta P$ respectively. Then ***[2010]***

(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$
(c) $3m_A = 2m_B$ (d) $9m_A = 4m_B$

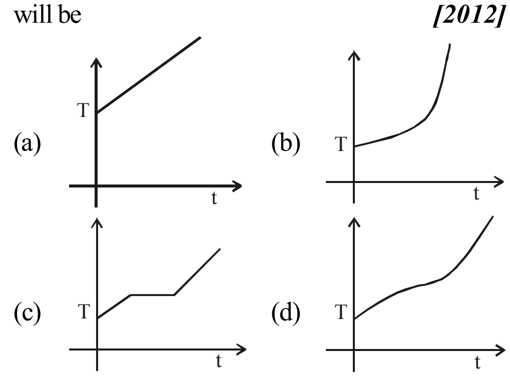
6. N_1 molecules of a gas at temperature T_1 are mixed with N_2 molecules at temperature T_2. The resulting temperature of the mixture gas is ***[2010]***

(a) $\frac{(T_1 - T_2)}{2}$
(b) $\frac{(N_1T_1 - N_2T_2)}{(N_1 + N_2)}$
(c) $\frac{(N_1T_1 + N_2T_2)}{(N_1 + N_2)}$
(d) $\left\{\frac{(N_1 + N_2)}{2}\right\}\left\{\frac{T_1 + T_2}{2}\right\}$

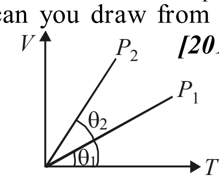
7. At what temperature the molecules of nitrogen will have the same rms velocity as the molecules of oxygen at 127° C ***[2011]***

(a) 457° C (b) 273° C
(c) 350° C (d) 77° C

8. If liquefied oxygen at 1 atmospheric pressure is heated from 50 K to 300 K by supplying heat at constant rate. The graph of temperature vs time will be ***[2012]***



9. The figure shows the volume V versus temperature T graphs for a certain mass of a perfect gas at two constant pressures of P_1 and P_2. What inference can you draw from the graphs? ***[2014]***



(a) $P_1 > P_2$
(b) $P_1 < P_2$
(c) $P_1 = P_2$
(d) No inference can be drawn due to insufficient information.

10. A gas mixture consists of molecules of type 1, 2 and 3, with molar masses $m_1 > m_2 > m_3$. v_{rms} and $\bar{K}$ are the r.m.s. speed and average kinetic energy of the gases. Which of the following is true? ***[2015]***

(a) $(v_{rms})_1 < (v_{rms})_2 < (v_{rms})_3$ and $(\bar{K})_1 = (\bar{K})_2 = (\bar{K})_3$

(b) $(v_{rms})_1 = (v_{rms})_2 = (v_{rms})_3$ and $(\bar{K})_1 = (\bar{K})_2 > (\bar{K})_3$

(c) $(v_{rms})_1 > (v_{rms})_2 > (v_{rms})_3$ and $(\bar{K})_1 < (\bar{K})_2 > (\bar{K})_3$

(d) $(v_{rms})_1 > (v_{rms})_2 > (v_{rms})_3$ and $(\bar{K})_1 < (\bar{K})_2 < (\bar{K})_3$

11. A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats γ. It is moving with speed v and its suddenly brought to rest. Assuming no heat is lost to the surroundings, its temperature` increases by

(a) $\frac{(\gamma-1)}{2\gamma R}Mv^2K$ (b) $\frac{\gamma Mv^2}{2R}K$ ***[2016]***

(c) $\frac{(\gamma-1)}{2R}Mv^2K$ (d) $\frac{(\gamma-1)}{2(\gamma+1)R}Mv^2K$

12. If the root mean square velocity of the molecules of hydrogen at NTP is 1.84 km/s. Calculate the root mean square velocity of oxygen molecule at NTP, molecular weight of hydrogen and oxygen are 2 and 32 respectively ***[2017]***

(a) 1.47 km/sec (b) 0.94 km/s

(c) 1.84 km/s (d) 0.47 km/sec

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 13-14) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

13. **Assertion :** For a gas atom the number of degrees of freedom is 3.

Reason : $\frac{C_p}{C_v} = \gamma$ ***[2000]***

14. **Assertion :** The root mean square and most probable speeds of the molecules in a gas are the same.

Reason : The Maxwell distribution for the speed of molecules in a gas in symmetrical. ***[2006]***

Directions for (Qs. 15-20) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

15. **Assertion :** The ratio of $\frac{C_p}{C_v}$ for an ideal diatomic gas is less than that for an ideal monoatomic gas (where C_p and C_v have usual meaning).

Reason : The atoms of a monoatomic gas have less degrees of freedom as compared to molecules of the diatomic gas. ***[2009]***

16. **Assertion :** The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume.

Reason : The molecules of a gas collide with each other and the velocities of the molecules change due to the collision. ***[2013]***

17. **Assertion :** Mean free path of a gas molecules varies inversely as density of the gas.

Reason : Mean free path varies inversely as pressure of the gas. ***[2014]***

18. **Assertion :** At a given temperature the specific heat of a gas at constant volume is always greater than its specific heat at constant pressure.

Reason : When a gas is heated at constant volume some extra heat is needed compared to that at constant pressure for doing work in expansion. ***[2015]***

19. **Assertion :** One mole of any substance at any temperature or volume always contains 6.02×10^{23} molecules.

Reason : One mole of a substance always refers to S.T.P. conditions. ***[2016]***

20. **Assertion :** Air pressure in a car tyre increases during driving.

Reason : Absolute zero temperature is not zero energy temperature. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (a) Average kinetic energy of gas molecules $\propto$ Temperature (Absolute)

$$\frac{\text{K.E.(at } 227°\text{C)}}{\text{K.E.(at } 27°\text{C)}} = \frac{273+227}{273+27} = \frac{500}{300} = \frac{5}{3}$$

$$\text{K.E. } (227°) = \frac{5}{3} \times 6.21 \times 10^{-21} \text{ J}$$

$$= 10.35 \times 10^{-21} \text{ J}$$

2. (c) Applying the formula

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$\left(\Rightarrow \frac{27+273}{T_2}\right) = \left(\frac{8}{27}\right)^{\gamma-1} = \left(\frac{8}{27}\right)^{5/3-1}$$

$$\text{or, } \frac{300}{T_2} = \left(\frac{2}{3}\right)^{\frac{2}{3}\times 3} = \frac{4}{9}$$

$$T_2 = \frac{9 \times 300}{4} = 675°\text{K}$$

$$t°C = 675 - 273 = 402°C$$

Rise in temperature = 402 – 27 = 375°C

3. (b) $v_{rms} = \sqrt{\frac{3kT}{m}}$; $v_{mp} = \sqrt{\frac{2kT}{m}}$

$$v_{av} = \sqrt{\frac{8kT}{\pi m}}$$

So, $v_{rms} > v_{av} > v_{mp}$

4. (d) $v_{rms} = \sqrt{\frac{3RT}{m}}$

$$\bar{v} = \sqrt{\frac{8RT}{\pi m}} = \sqrt{\frac{2.5RT}{m}}$$

and $v_p = \sqrt{\frac{2RT}{m}}$

From these expressions, we can see that

$v_p < \bar{v} < v_{rms}$

Again, $v_{rms} = v_p \frac{\sqrt{3}}{2}$

and average kinetic energy of a gas molecule

$$E_k = \frac{1}{2} m v_{rms}^2$$

$$E_k = \frac{1}{2} m \left(\sqrt{\frac{3}{2}} v_y\right)^2 = \frac{1}{2} m \times \frac{3}{2} v_p^2 = \frac{3}{4} m v_p^2$$

5. (c) The initial pressure in the two containers will be

$$P_A = \frac{n_A RT}{V} = m_A \left(\frac{RT}{MV}\right)$$

$$P_B = \frac{n_B RT}{V} = m_B \left(\frac{RT}{MV}\right)$$

After isothermal expansion, pressure will be

$$P_A' = \frac{n_A RT}{2V} = m_A \left(\frac{RT}{2MV}\right)$$

$$P_B' = \frac{n_B RT}{2V} = m_B \left(\frac{RT}{2MV}\right)$$

$$\therefore -\Delta P_A = P_A - P_A' = m_A \left(\frac{RT}{2MV}\right)$$

$$\therefore -\Delta P_B = P_B - P_B' = m_B \left(\frac{RT}{2MV}\right)$$

But $\Delta P_A = \Delta P$ and $-\Delta P_B = 1.5\Delta P$

$$\text{So, } \frac{-\Delta P_A}{-\Delta P_B} = \frac{1}{1.5} \Rightarrow -\Delta P_A = \frac{-\Delta P_B}{1.5}$$

$$m_A \left(\frac{RT}{2MV}\right) = \frac{m_B}{1.5}\left(\frac{RT}{2MV}\right)$$

$$\text{or } \quad m_A = \frac{10 m_B}{15}$$

$$\therefore \quad 3m_A = 2m_B$$

6. (c) $\left(\frac{3}{2} kT_1\right) \times N_1 + \left(\frac{3}{2} kT_2\right) \times N_2$

$$= (N_1 + N_2) \times \frac{3}{2} kT$$

$$T_1 N_1 + T_2 N_2 = (N_1 + N_2) T$$

$$\therefore \quad T = \frac{N_1 T_1 + N_2 T_2}{N_1 + N_2}$$

7. (d) Rms velocity of gas is

$$v_{rms} = 1.73\left(\frac{RT}{M}\right)^{\frac{1}{2}};$$

M = molecular mass
For oxygen, $M = 16 \times 2$,
$T = 127°C = 127 + 273 = 400\,K$
For nitrogen, $M = 17 \times 2$, $T = ?$

$$\Rightarrow 1.73\left(\frac{RT}{M}\right)_{O_2}^{\frac{1}{2}} = 1.73\left(\frac{RT}{M}\right)_{N_2}^{\frac{1}{2}}$$

$$\Rightarrow \left(\frac{T}{M}\right)_{O_2}^{\frac{1}{2}} = \left(\frac{T}{M}\right)_{N_2}^{\frac{1}{2}}$$

$$\Rightarrow \sqrt{T_{N_2}} = \sqrt{\frac{M_{N_2}}{M_{O_2}}T_{O_2}} = \sqrt{\frac{28}{32}\times 400}$$

$$= \sqrt{\frac{7}{8}\times 400}$$

$$\Rightarrow T_{N_2} = \frac{7}{8}\times 400 = 350K$$

$$T_{N_2} = 350K - 273K = 77°C$$

8. (c) $Q = mc\Delta T$
$Q = mc(T - T_0)$ ......(i)
$Q = Kt$ whereas K is heating rate
$\therefore$ from 50 to boiling temperature, T increases linearly.
At vaporization, equation is $Q = mL$
so, temperature remains constant till vaporisation is complete
After that, again Eqn (i) is followed and temperature increases linearly

9. (b) $\because \theta_1 < \theta_2 \Rightarrow \tan\theta_1 < \tan\theta_2$

$$\Rightarrow \left(\frac{V}{T}\right)_1 < \left(\frac{V}{T}\right)_2$$

from $PV = \mu RT$; $\frac{V}{T} \propto \frac{1}{P}$

Hence $\left(\frac{1}{P}\right)_1 < \left(\frac{1}{P}\right)_2 \Rightarrow P_1 > P_2$.

10. (a) $v_{rms} \propto \frac{1}{\sqrt{M}} \Rightarrow (v_{rms})_1 < (v_{rms})_2 < (v_{rms})_3$
also in mixture temperature of each gas will be same, hence kinetic energy also remains same.

11. (c) As no heat is lost,
Loss of kinetic energy = gain of internal energy of gas

$$\frac{1}{2}mv^2 = nC_V\Delta T$$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{m}{M}\cdot\frac{R}{\gamma - 1}\Delta T$$

$$\Rightarrow \Delta T = \frac{mv^2(\gamma - 1)}{2R}K$$

12. (d) $(c_{rms})_{H_2} = 1.84$ km/s, $(c_{rms})_{O_2} = ?$
$M_{H_2} = 2$, $M_{O_2} = 32$
$\Rightarrow$ Rms velocity,

$$c_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\therefore \frac{c_{H_2}}{c_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}}$$

$$\Rightarrow \frac{1.84}{C_{O_2}} = \sqrt{\frac{32}{2}} = 4$$

$$\Rightarrow C_{O_2} = \frac{1.84}{4} = 0.46\text{ km/s}$$

Type B : Assertion Reason Questions

13. (b) For a gas atom no. of degree of freedom is 3 because it can have translatory motion in three directions, along X-axis, Y-axis, and Z-axis.

$\frac{C_p}{C_v} = \gamma$ is also correct but it is not the Reason for Assertion given.

14. (d) Both Assertion and Reason are incorrect.

15. (a) If f be the degree of freedom, then the ratio $\frac{C_p}{C_v}(=\gamma)$ is given by $\gamma = 1 + \frac{2}{f}$.
For monoatomic gas, $f = 3$;

$$\therefore \gamma = 1 + \frac{2}{3} = \frac{5}{3} = 1.67$$

For diatomic gas, $f = 5$

$$\therefore \gamma = 1 + \frac{2}{5} = \frac{7}{5} = 1.4.$$

$$\therefore \gamma_{diatomic} < \gamma_{monoatomic}$$

16. (b) Total translational kinetic energy

$$= \frac{3}{2} nRT = \frac{3}{2} PV$$

In an ideal gas all molecules moving randomly in all direction collide and their velocity changes after collision.

17. (a) The mean free path of a gas molecule is the averge distance between two successive collisions. It is represented by λ.

$$\lambda = \frac{1}{\sqrt{2}} \frac{kT}{\pi\sigma^2 P} \text{ and } \lambda = \frac{m}{\sqrt{2} \cdot \pi\sigma^2 d}$$

Here, $\sigma = 0$ diameter of molecule and

k = Boltzmann's constant.

$\Rightarrow \lambda \propto 1/d,\ \lambda \propto T$ and $\lambda \propto 1/P$.

Hence, mean free path varies inversely as density of the gas. It can easily proved that the mean free path varies directly as the temperature and inversely as the pressure of the gas.

18. (a)

19. (c) The number 6.02×10^{23} is Avogadro's number and one mole of a substance contains Avogadro's number of molecules.

20. (b) When a person is driving a car then the temperature of air inside the tyre is increased because of motion. From the Gay Lussac's law,

$P \propto T$

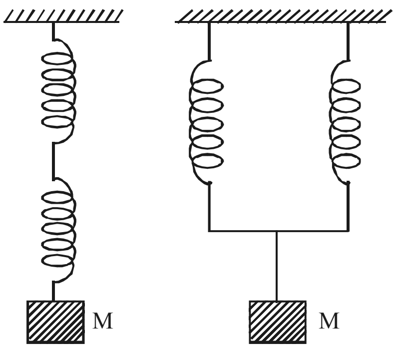
Hence, when temperature increases the pressure also increase.

Chapter 13

Oscillations

TYPE A : MULTIPLE CHOICE QUESTIONS

1. Two identical springs of spring constant k are connected in series and parallel as shown in figure. A mass M is suspended from them.



The ratio of their frequencies of vertical oscillation will be : ***[1997]***

(a) 1 : 2 (b) 2 : 1
(c) 4 : 1 (d) 1 : 4

2. If the metal bob of a simple pendulum is replaced by a wodden bob, then its time period will be : ***[1998]***

(a) decreased (b) the same
(c) increased (d) first (c) then (a)

3. If the time period of oscillation of mass m suspended from a spring is 2 sec, the time period of mass 4 m will be : ***[1998]***

(a) 2 sec (b) 3 sec
(c) 4 sec (d) T sec

4. If a simple pendulum oscillates with an amplitude of 50 mm and time period of 2 sec then its maximum velocity is ***[1998]***

(a) 0.6 m/s (b) 0.16 m/s
(c) 0.8 m/s (d) 0.32 m/s

5. A horizontal platform with an object placed on it is executing simple harmonic motion in the vertical direction. The amplitude of oscillation is 3.92×10^{-3} m. What should be the least period of these oscillations, so that the object is not detached from the platform ? ***[1999]***

(a) 0.145 sec (b) 0.1556 sec
(c) 0.1256 sec (d) 0.1356 sec

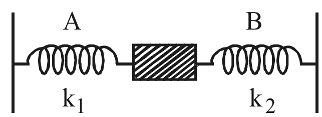
6. Which one of the following statement is not correct for a particle executing S.H.M.? ***[1999]***

(a) Acceleration of the particle is minimum at the mean position
(b) Restoring force is always directed towards a fixed point
(c) Total energy of the particle always remains the same
(d) Restoring force is maximum at the extreme position

7. A particle execute simple harmonic motion with an angular velocity of 3.5 rad/sec and maximum acceleration 7.5 m/s^2. The amplitude of oscillation will be: ***[1999]***

(a) 0.53 cm (b) 0.28 m
(c) 0.61 m (d) 0.36 m

8. In arrangement given in figure if the block of mass m is displaced, the frequency is given by: ***[1999]***



(a) $n = \frac{1}{2\pi}\sqrt{\left(\frac{k_1 + k_2}{m}\right)}$

(b) $n = \frac{1}{2\pi}\sqrt{\left(\frac{m}{k_1 + k_2}\right)}$

(c) $n = \frac{1}{2\pi}\sqrt{\left(\frac{m}{k_1 - k_2}\right)}$

(d) $n = \frac{1}{2\pi}\sqrt{\left(\frac{k_1 - k_2}{m}\right)}$

9. A spring is vibrating with frequency under same mass. If it is cut into two equal pieces and same mass is suspended then the new frequency will be: ***[1999]***

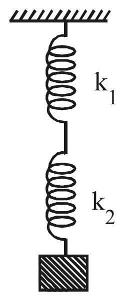
(a) $n\sqrt{2}$ (b) $\frac{n}{\sqrt{2}}$

(c) $\frac{n}{2}$ (d) n

10. Simple pendulum is executing simple harmonic motion with time period T. If the length of the pendulum is increased by 21 %, then the increase in the time period of the pendulum of the increased length is : ***[2001]***

(a) 22 % (b) 13 %
(c) 50 % (d) 10 %

11. The frequency of oscillator of the springs as shown in figure will be : ***[2001]***



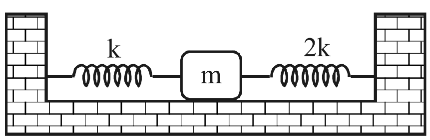
(a) $\frac{1}{2\pi}\sqrt{\frac{(k_1+k_2)m}{k_1k_2}}$

(b) $\frac{1}{2\pi}\sqrt{\frac{k_1k_2}{(k_1+k_2)m}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$

(d) $2\pi\sqrt{\frac{k}{m}}$

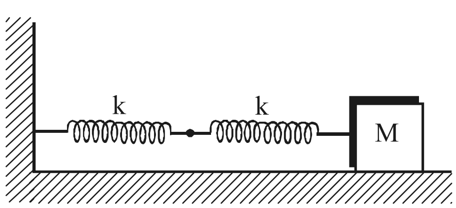
12. Two springs of force constant k and 2k are connected to a mass as shown below : The frequency of oscillation of the mass is : ***[2003]***



(a) $(1/2\pi)\sqrt{(k/m)}$ (b) $(1/2\pi)\sqrt{(2k/m)}$

(c) $(1/2\pi)\sqrt{(3k/m)}$ (d) $(1/2\pi)\sqrt{(m/k)}$

13. Two springs are connected to a block of mass M placed on a frictionless surface as shown below. If both the springs have a spring constant k, the frequency of oscillation of block is : ***[2004]***



(a) $\frac{1}{2\pi}\sqrt{\frac{k}{M}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{k}{2M}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{M}{k}}$

14. Which of the following functions represents a simple harmonic oscillation ? ***[2005]***

(a) $\sin\omega t - \cos\omega t$ (b) $\sin^2\omega t$

(c) $\sin\omega t + \sin 2\omega t$ (d) $\sin\omega t - \sin 2\omega t$

15. A large horizontal surface moves up and down in S.H.M. with an amplitude of 1 cm. If a mass of 10 kg (which is placed on the surface0 is to remain continuously in contact with it, the maximum frequency of S.H.M. will be ***[2007]***

(a) 5 Hz (b) 0.5 Hz
(c) 1.5 Hz (d) 10 Hz

16. A coin is placed on a horizontal platform which undergoes vertical simple harmonic motion of angular frequency ω. The amplitude of oscillation is gradually increased. The coin will leave contact with the platform for the first time ***[2008]***

(a) at the mean position of the platform

(b) for an amplitude of $\frac{g}{\omega^2}$

(c) for an amplitude of $\frac{g^2}{\omega^2}$

(d) at the highest position of the platform

17. The function $\sin^2(\omega t)$ represents ***[2008]***

(a) a periodic, but not simple harmonic motion with a period $\frac{\pi}{\omega}$

(b) a periodic, but not simple harmonic motion with a period $\frac{2\pi}{\omega}$

(c) a simple harmonic motion with a period $\frac{\pi}{\omega}$

(d) a simple harmonic motion with a period $\frac{2\pi}{\omega}$

18. A particle of mass is executing oscillations about the origin on the x-axis. Its potential energy is $V(x) = k|x|^3$, where k is a positive constant. If the amplitude of oscillation is a, then its time period T is ***[2008]***

(a) proportional to $\frac{1}{\sqrt{a}}$

(b) proportional to $\sqrt{a}$

(c) independent $a^{\frac{3}{2}}$

(d) none of these

19. The average speed of the bob of a simple pendulum oscillating with a small amplitude A and time period T is ***[2009]***

(a) $\frac{4A}{T}$ (b) $\frac{2\pi A}{T}$

(c) $\frac{4\pi A}{T}$ (d) $\frac{2A}{T}$

20. A pendulum is swinging in an elevator. Its period will be greatest when the elevator is ***[2010]***

(a) moving upwards at constant speed
(b) moving downwards
(c) moving downwards at constant speed
(d) accelerating downwards

21. If A is the area of cross-section of a spring L is its length E is the Young's modulus of the material of the spring then time period and force constant of the spring will be respectively: ***[2010]***

(a) $T = 2\pi\sqrt{\frac{EA}{ML}}, k = \frac{L}{EA}$

(b) $T = \frac{1}{2\pi}\sqrt{\frac{EA}{ML}}, k = \frac{A}{EL}$

(c) $T = \frac{1}{2\pi}\sqrt{\frac{EL}{MA}}, k = \sqrt{\frac{EA}{L}}$

(d) $T = 2\pi\sqrt{\frac{ML}{EA}}, k = \frac{EA}{L}$

22. The time period of a seconds pendulum is 2 sec. The spherical bob which is empty from inside has a mass 50 gram, this now is replaced by another solid of same radius but have different mass of 100 gram. The new time period will be

(a) 2 sec (b) 8 sec ***[2010]***
(c) 4 sec (d) 1 sec

23. A particle executes SHM of amplitude 25 cm and time period 3 s. What is the minimum time required for the particle to move between two points 12.5 cm on either side of the mean position? ***[2010]***

(a) 0.5 s (b) 1.0 s
(c) 1.5 s (d) 2.0 s

24. The displacement of a particle undergoing SHM of time period T is given by $x(t) = x_m \cos(\omega t + \phi)$. The particle is at $x = -x_m$ at time t = 0. The particle is at $x = +x_m$ when : ***[2011]***

(a) $t = 0.25\,T$ (b) $t = 0.50\,T$
(c) $t = 0.75\,T$ (d) $t = 1.00\,T$

25. The circular motion of a particle with constant speed is ***[2012]***

(a) periodic but not simple harmonic
(b) simple harmonic but not periodic
(c) periodic and simple harmonic
(d) neither periodic nor simple harmonic

26. A child swinging on a swing in sitting position, stands up, then the time period of the swing will

(a) increase ***[2012]***
(b) decrease
(c) remains same
(d) increases of the child is long and decreases if the child is short

27. A point particle of mass 0.1 kg is executing S.H.M. of amplitude of 0.1 m. When the particle passes through the mean position, its kinetic energy is 8×10^{-3} Joule. Obtain the equation of motion of this particle if this initial phase of oscillation is 45º. ***[2013]***

(a) $y = 0.1\sin\left(\pm 4t + \frac{\pi}{4}\right)$

(b) $y = 0.2\sin\left(\pm 4t + \frac{\pi}{4}\right)$

(c) $y = 0.1\sin\left(\pm 2t + \frac{\pi}{4}\right)$

(d) $y = 0.2\sin\left(\pm 2t + \frac{\pi}{4}\right)$

28. The bob of a simple pendulum is a spherical hollow ball filled with water. A plugged hole near the bottom of the oscillating bob gets suddenly unplugged. During observation, till water is coming out, the time period of oscillation would ***[2013]***

(a) first decrease and then increase to the original value
(b) first increase and then decrease to the original value
(c) increase towards a saturation value
(d) remain unchanged

29. $y = 2\text{ (cm)} \sin\left[\frac{\pi t}{2} + \phi\right]$ what is the maximum acceleration of the particle doing the S.H.M. ***[2014]***

(a) $\frac{\pi}{2}\text{ cm/s}^2$ (b) $\frac{\pi^2}{2}\text{ cm/s}^2$

(c) $\frac{\pi^2}{4}\text{ cm/s}^2$ (d) $\frac{\pi}{4}\text{ cm/s}^2$

30. Resonance is an example of ***[2014]***

(a) tuning fork (b) forced vibration
(c) free vibration (d) damped vibration

31. Two particles are executing S.H.M. of same amplitude and frequency along the same straight line path. They pass each other when going in opposite directions, each time their displacement is half of their amplitude. What is the phase difference between them ? ***[2015]***
(a) $5\pi/6$ (b) $2\pi/3$
(c) $\pi/3$ (d) $\pi/6$

32. The period of oscillation of a mass M suspended from a spring of negligible mass is T. If along with it another mass M is also suspended, the period of oscillation will now be ***[2016]***
(a) T (b) $T/\sqrt{2}$
(c) 2T (d) $\sqrt{2}\,T$

33. Two, spring *P* and *Q* of force constants k_p and $k_Q\left(k_Q = \dfrac{k_p}{2}\right)$ are stretched by applying forces of equal magnitude. If the energy stored in *Q* is E, then the energy stored in *P* is ***[2016]***
(a) E (b) 2E
(c) E/2 (d) E/4

34. A particle moves with simple harmonic motion in a straight line. In first τ s, after starting from rest, it travels a distance a, and in next τ s, it travels 2a in same direction then ***[2016]***
(a) amplitude of motion is 3a
(b) time period of oscillations is 8τ.
(c) amplitude of motion is 4a.
(d) time period of oscillations is 6τ.

35. The amplitude of a damped oscillator decreases to 0.9 times its original magnitude in 5s. In another 10s it will decrease to α times its original magnitude, where α equals ***[2017]***
(a) 0.7 (b) 0.81
(c) 0.729 (d) 0.6

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 36-38) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

36. **Assertion :** In simple harmonic motion, the motion is to and fro and periodic
Reason : Velocity of the particle $(v) = \omega\sqrt{k^2 - x^2}$ (where x is the displacement). ***[2002]***

37. **Assertion :** The time-period of pendulum, on a satellite orbiting the earth is infinity.
Reason : Time-period of a pendulum is inversely proportional to $\sqrt{g}$. ***[2002]***

38. **Assertion :** The amplitude of an oscillating pendulum decreases gradually with time
Reason : The frequency of the pendulum decreases with time. ***[2003]***

Directions for (Qs. 39-42) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

39. **Assertion :** In SHM, acceleration is always directed towards the mean position.
Reason : In SHM, the body has to stop momentary at the extreme position and move back to mean position. ***[2009]***

40. **Assertion :** For a particle performing SHM, its speed decreases as it goes away from the mean position.
Reason : In SHM, the acceleration is always opposite to the velocity of the particle. ***[2009]***

41. **Assertion :** Resonance is a special case of forced vibration in which the natural frequency of vibration of the body is the same as the impressed frequency of external periodic force and the amplitude of forced vibration is maximum.
Reason : The amplitude of forced vibrations of a body increases with an increase in the frequency of the externally impressed periodic force. ***[2010]***

42. **Assertion :** In simple harmonic motion, the velocity is maximum when the acceleration is minimum.
Reason : Displacement and velocity of S.H.M. differ in phase by $\dfrac{\pi}{2}$. ***[2014]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (a) We know that

$$T = 2\pi\sqrt{\frac{m}{K}} \Rightarrow n = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

For a spring mass system.
In **case I** if K is the resultant spring constant, then

$$\frac{1}{K} = \frac{1}{k} + \frac{1}{k} = \frac{2}{k} \Rightarrow K = \frac{k}{2}$$

In **case II**, $K = k + k = 2k$
If n_1 & n_2 be frequencies in two cases, then

$$n_1 = \frac{1}{2\pi}\sqrt{\frac{k}{2m}};\ n_2 = \frac{1}{2\pi}\sqrt{\frac{2k}{m}};$$

$$\Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{1}{4}} \Rightarrow \frac{n_1}{n_2} = \frac{1}{2}$$

2. (b) The expression of time period

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

This formula contains nothing which depends upon the nature of material from which bob is made of. So time period will remain the same.

3. (c) $T = 2\pi\sqrt{\frac{m}{K}} \Rightarrow 2 = 2\pi\sqrt{\frac{m}{K}}$

$$T' = 2\pi\sqrt{\frac{4m}{K}} \Rightarrow T' = 2 \times 2\pi\sqrt{\frac{m}{K}}$$

$T' = 2 \times 2 = 4$ sec

4. (b) $v = \omega\sqrt{a^2 - u^2}$; when $u = 0$, $v = v_{max}$.
So, $v_{max} = \omega a$
[where ω is angular velocity and a is amplitude]

$$v_{max.} = \frac{2\pi}{T} \times a = \frac{2\pi}{2} \times \frac{50}{1000} = 0.16\ m/sec$$

5. (c) The possibility of the object to be detached from the platform is at the highest point when the platform starts going down. If it is less than g then object will not get away from the platform. So, maximum acceleration of platform under SHM is g.
From formula, maximum acceleration under SHM $= \omega^2 a$

$$\omega^2 a = g \Rightarrow \left(\frac{2\pi}{T}\right)^2 \times 3.92 \times 10^{-3} = 10$$

$$T = 2\pi\sqrt{\frac{3.92 \times 10^{-3}}{10}} = 2\pi\sqrt{3.92 \times 10^{-4}}$$

$= 0.1256$ secs.

6. (a) For a particle under SHM.
acceleration $= \omega^2 x$
If $x = 0$ (at mean position), acceleration $= 0$
So, acceleration at the mean position is zero.

7. (c) $\omega = 3.5$ radian/sec
maximum acceleration of a particle under SHM $= \omega^2 a$ where a is amplitude of oscillation.

$$\omega^2 a = 7.5 \Rightarrow (3.5)^2 a = 7.5$$

$$\Rightarrow a = \frac{7.5}{3.5 \times 3.5} \Rightarrow = \frac{30}{49} = 0.61\ m$$

8. (a) This is case of spring in series, so $K = k_1 + k_2$

$$T = 2\pi\sqrt{\frac{m}{(k_1 + k_2)}}$$

$$\Rightarrow n(\text{frequency}) = \frac{1}{2\pi}\sqrt{\frac{k_1 + k_2}{m}}$$

9. (a) For a vibrating spring $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Now spring is cut into two pieces, so new spring constant $K' = 2k$

$$n' = \frac{1}{2\pi}\sqrt{\frac{2k}{m}} = n\sqrt{2}$$

10. (d) $T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow T^2 = 4\pi^2\frac{\ell}{g}$

Taking log on both sides,

$2 \log T = \log 4\pi^2 + \log \ell - \log g$,

Differentiating on both sides,

$$\frac{2}{T}dT = 0 + \frac{1}{\ell}d\ell - 0$$

$$\frac{dT}{T} = \frac{1}{2}.\frac{d\ell}{\ell} \Rightarrow \frac{dT}{T} \times 100 = \frac{1}{2}.\frac{d\ell}{\ell} \times 100$$

Percent increase in time period

$$= \frac{1}{2}\% \text{ increase in length}$$

$$= \frac{1}{2} \times 21 = 10.5\%$$

Percent increase in time period $\cong 10\%$

11. (b) $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

As springs are in parallel, total spring constant k of system of spring

$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} = \frac{k_1 + k_2}{k_1 k_2}$$

$$k = \frac{k_1 k_2}{(k_1 + k_2)}$$

$$n = \frac{1}{2\pi}\sqrt{\frac{k_1 k_2}{(k_1 + k_2)m}}$$

12. (c) For any spring-mass system time period of oscillation,

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

In the present case total spring constt. $= k + 2k = 3k$.

$$n = \frac{1}{2\pi}\sqrt{\frac{3k}{m}}$$

13. (b) For spring block system, $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Here two springs are joined in series so,

total spring constant, $k_R = \frac{k_1 k_2}{k_1 + k_2}$

$$k_R = \frac{k.k}{2k} = \frac{k}{2}$$

So, $n = \frac{1}{2\pi}\sqrt{\frac{k}{2m}}$

14. (a) $\sin\omega t - \cos\omega t = \sqrt{2}\left[\frac{1}{\sqrt{2}}\sin\omega t - \frac{1}{\sqrt{2}}\cos\omega t\right]$

$$= \sqrt{2}\left[\cos\frac{\pi}{4}.\sin\omega t - \sin\frac{\pi}{4}\cos\omega t\right]$$

$$= \sqrt{2}\sin(\omega t - \pi/4)$$

which represents simple harmonic motion.

15. (a) Frequency of SHM,

$$\nu = \frac{1}{2\pi}\sqrt{\frac{\text{acceleration}}{\text{displacement}}} = \frac{1}{2\pi}\sqrt{\frac{a}{x}}$$

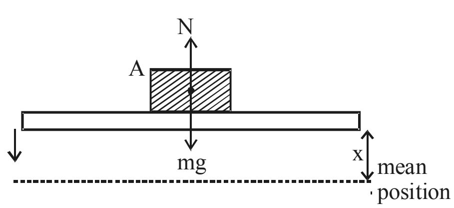
$$\Rightarrow \nu = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$\Rightarrow \frac{k}{m} = \frac{a}{x} \Rightarrow \frac{k}{a} = \frac{m}{x} \Rightarrow \nu = \frac{1}{2\pi}\sqrt{\frac{m}{x}}$$

$$\nu = \frac{1}{2\pi}\sqrt{\frac{10}{10^{-2}}} = \sqrt{\frac{10^3}{2\pi}} = \frac{10\sqrt{10}}{2\pi}$$

$$= \frac{10 \times 3.16}{2 \times 3.14} = 5 \text{ Hz}$$

16. (b) For block A to move in SHM.



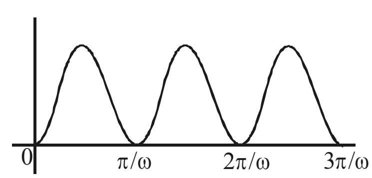
$mg - N = m\omega^2 x$

where x is the distance from mean position

For block to leave contact N = 0

$$\Rightarrow mg = m\omega^2 x \Rightarrow x = \frac{g}{\omega^2}$$

17. (a) Clearly $\sin^2\omega t$ is a periodic function as $\sin\omega t$ is periodic with period π/ω



For SHM $\frac{d^2y}{dt^2} \propto -y$

$\frac{dy}{dt} = 2\omega \sin \omega t \cos \omega t = \omega \sin 2\omega t$

$\frac{d^2y}{dt^2} = 2\omega^2 \cos 2\omega t$ which is not proportional to $-y$. Hence it is not in SHM.

18. (a) $V(x) = k|x|^3$

since, $F = -\frac{dV(x)}{dx} = -3k|x|^2$ ...(1)

$x = a \sin(\omega t)$

This equation always fits to the differential equation

$\frac{d^2x}{dt^2} = -\omega^2 x$ or $m\frac{d^2x}{dt} = -m\omega^2 x$

$\Rightarrow F = -m\omega^2 x$ ...(2)

Equation (1) and (2) give

$-3k|x|^2 = -m\omega^2 x$

$\Rightarrow \omega = \sqrt{\frac{3kx}{m}} = \sqrt{\frac{3ka}{m}}[\sin(\omega t)]^{1/2}$

$\Rightarrow \omega \propto \sqrt{a} \Rightarrow T \propto \frac{1}{\sqrt{a}}$

19. (a) $x = A \sin\left(\frac{2\pi}{T}t\right)$

$\Rightarrow$ distance covered in time $t = \frac{T}{4} = A$

$\Rightarrow$ average speed $= \frac{A}{T/4} = \frac{4A}{T}$

20. (d) Time period of a simple pendulum is given by

$T = 2\pi\sqrt{\frac{l}{g}}$ or $T \propto \sqrt{\frac{l}{g}}$

when the elevator is accelerating downwards, the net gravitational acceleration is $(g - a)$, so, the time period when elevation is accelerating downwards, is greatest.

21. (d) According to the formula of Young's Modulus

$E = \frac{FL}{A.\Delta L}$

where ΔL is the extension in the spring.

$F = \frac{EA\,\Delta L}{L}$ ...(1)

Now, according to Hooke's law

$F = k\,\Delta L$ ...(2)

where k is the spring constant

By comparing (1) and (2)

$k\,\Delta L = \frac{EA\,\Delta L}{L}$

$k = \frac{EA}{L}$

Time period, $T = 2\pi\sqrt{\frac{M}{k}}$

$T = 2\pi\sqrt{\frac{ML}{EA}}$

22. (a) $T = 2\pi\sqrt{\frac{L}{g}}$

i.e., time period of a simple pendulum depends upon effective length and acceleration due to gravity, not on mass.

So, $T = 2$ sec.

23. (a) $y = r \sin \omega t$

$12.5 = 25 \sin\frac{2\pi}{3} \times t \quad \left(\because \omega = \frac{2\pi}{T}\right)$

$\frac{\pi}{6} = \frac{2\pi}{3}t$

$t = \frac{1}{4}\text{sec} = 0.25$ sec

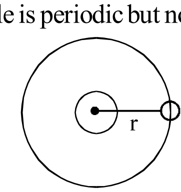
$t' = 2t$

$= 2 \times 0.25 = 0.5$ sec

for either side

24. (b) The time taken by particle from left extreme to right extreme $= 0.5$ T.

25. (a) In circular motion of a particle with constant speed, particle repeats its motion after a regular interval of time but does not oscillate about a fixed point. So, motion of particle is periodic but not simple harmonic.



26. **(b)** $T = 2\pi\sqrt{l_{eff}/g}$; l_{eff} decreases when the child stands up.

27. **(a)** The displacement of a particle in S.H.M. is given by

$y = a \sin(\omega t + \phi)$

velocity $= \frac{dy}{dt} = \omega a \cos(\omega t + \phi)$

The velocity is maximum when the particle passes through the mean position i.e.,

$$\left(\frac{dy}{dt}\right)_{max} = \omega a$$

The kinetic energy at this instant is given by

$$\frac{1}{2}m\left(\frac{dy}{dt}\right)^2_{max} = \frac{1}{2}m\omega^2 a^2 = 8 \times 10^{-3} \text{ joule}$$

or $\frac{1}{2} \times (0.1)\,\omega^2 \times (0.1)^2 = 8 \times 10^{-3}$

Solving we get $\omega = \pm 4$

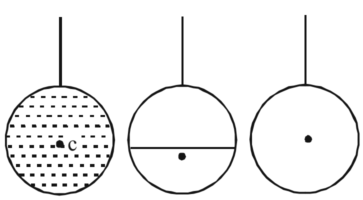
Substituting the values of a, ω and ϕ in the equation of S.H.M., we get

$y = 0.1 \sin(\pm 4t + \pi/4)$ metre.

28. **(b)** Centre of mass of combination of liquid and hollow portion (at position ℓ), first goes down (to $\ell + \Delta\ell$) and when total water is drained out, centre of mass regain its original position (to ℓ),

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$\therefore$ 'T' first increases and then decreases to original value.



29. **(b)** $y = 2\sin\left(\frac{\pi t}{2} + \phi\right)$

velocity of particle $\frac{dy}{dt} = 2 \times \frac{\pi}{2}\cos\left(\frac{\pi t}{2} + \phi\right)$

acceleration $\frac{d^2y}{dt} = -\frac{\pi^2}{2}\sin\left(\frac{\pi t}{2} + \phi\right)$

Thus $a_{max} = \frac{\pi^2}{2}$

30. **(b)**

31. **(b)** $y = a \sin(\omega t + \phi)$; when $y = a/2$,

then $\frac{a}{2} = a\sin(\omega t + \phi)$

or $\sin(\omega t + \phi) = \frac{1}{2} = \sin\frac{\pi}{6}$ or $\sin\frac{5\pi}{6}$

So phase of two particles is $\pi/6$ and $5\pi/6$ radians

Hence phase difference $= (5\pi/6) - \pi/6 = 2\pi/3$

32. **(d)** $T = 2\pi\sqrt{\frac{m}{K}}$ $\quad \therefore \frac{T_1}{T_2} = \sqrt{\frac{M_1}{M_2}}$

$$T_2 = T_1\sqrt{\frac{M_2}{M_1}} = T_1\sqrt{\frac{2M}{M}}$$

$T_2 = T_1\sqrt{2} = \sqrt{2}\,T$ (where $T_1 = T$)

33. **(c)** Here, $k_Q = \frac{k_p}{2}$

According to Hooke's law

$\therefore \quad F_p = -k_p x_p$

$$F_Q = -k_Q x_Q \Rightarrow \frac{F_p}{F_Q} = \frac{k_p x_p}{k_Q x_Q}$$

$F_p = F_Q$ [Given]

$$\therefore \quad \frac{x_p}{x_Q} = \frac{k_Q}{k_p} \qquad \text{...(i)}$$

Energy stored in a spring is $U = \frac{1}{2}kx^2$

$$\therefore \quad \frac{U_p}{U_Q} = \frac{k_p x_p^2}{k_Q x_Q^2} = \frac{k_p}{k_Q} \times \frac{k_Q^2}{k_p^2} = \frac{1}{2}\left[\because k_Q = \frac{k_p}{2}\right]$$

$$\Rightarrow \quad U_p = \frac{U_Q}{2} = \frac{E}{2} \qquad [\therefore U_Q = E]$$

34. **(d)** As it starts from rest, we have,

$x = A\cos\omega t$. At $t = 0$, $x = A$

When $t = \tau$, $x = A - a$ and

when $t = 2\tau$, $x = A - 3a$

$\Rightarrow \quad A - a = A \times \cos \times \omega\tau$ and .... (i)

$A - 3a = A \times \cos \times 2\omega\tau$ .... (ii)

As, $\cos 2\omega\tau = 2\cos^2\omega\tau - 1$,

$$\Rightarrow \frac{A-3a}{A} = 2\left(\frac{A-a}{A}\right)^2 - 1$$

$$\therefore \frac{A-3a}{A} = \frac{2A^2+2a^2-4Aa-A^2}{A^2}$$

$\therefore A^2 - 3aA = A^2 + 2a^2 - 4Aa$

$\therefore a^2 = 2aA \Rightarrow A = 2a$

Now, $A - a = A \times \cos \times \omega\tau$ ..... [From (i)]

$$\Rightarrow \cos \times \omega\tau = \frac{1}{2}$$

$$\therefore \frac{2\pi}{T}\tau = \frac{\pi}{3} \Rightarrow T = 6\tau$$

35. (c) $\because A = A_0 e^{-\frac{bt}{2m}}$ (where, A_0 = maximum amplitude)

According to the questions, after 5 seconds,

$$0.9A_0 = A_0 e^{-\frac{b(5)}{2m}} \quad \ldots (i)$$

After 10 more seconds,

$$A = A_0 e^{-\frac{b(15)}{2m}} \quad \ldots (ii)$$

From equations (i) and (ii)

$A = 0.729\, A_0$

$\therefore \alpha = 0.729$

Type B : Assertion Reason Questions

36. (b) SHM is to and fro motion of an object and it is periodic.

$v = \omega\sqrt{k^2 - x^2}$

If x = 0, v has maximum value. At x = k, v has minimum velocity. Similarly, when x = – k, v has zero value, all these indicate to & fro movement.

37. (a) Time period of pendulum in a satellite is infinity. It means it may not oscillate as apparent value of g is zero. So, time period being $\propto \sqrt{\frac{1}{g}} \propto \sqrt{\infty}$

38. (c) The amplitude of an oscillating pendulum decreases with time due to friction of air. In absence of air, its frequency and amplitude will remain constant.

39. (b) SHM is basically to and fro motion about the mean position. So when the body goes away from mean position an acceleration always try to return the body towards mean position. As the acceleration in SHM is always in opposite phase to that of displacement. The displacement of the particle in SHM at an instant is directed away from the mean position then acceleration at that instant is directed towards the mean position.

40. (c) Speed = $\omega\sqrt{A^2 - x^2}$

as $|x|$ increases $\Rightarrow$ speed decreases

Acceleration is in direction of speed as it comes towards mean position.

41. (c) The amplitude become large when the frequency of the driving force (ω) is near the natural frequency of oscillation or when $\omega \simeq \omega_0$. This frequency is known as resonance frequency. Amplitude of oscillation for a forced, damped oscillator is

$$A = \frac{F_0/m}{\sqrt{(\omega^2-\omega_0^2) + (b\omega/m)^2}}$$

where b is constant related to the strength of the resistive force, $\omega_0 = \sqrt{k/m}$ is natural frequency of undamped oscillator (b = 0).

42. (b) At the middle point velocity of the particle under SHM is maximum but acceleration is zero since displacement is zero. So Assertion is true.

We know that x = a sin ωt ...(1)

Where x is displacement and a is amplitude.

$$\text{Velocity} = \frac{dx}{dt} = a\omega\cos\omega t$$

$$= a\omega\cos(-\omega t) = a\omega\sin\left(\frac{\pi}{2} - (-\omega t)\right)$$

$$= a\omega\sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{...(2)}$$

From equation (i) and (ii) it is clear that Velocity is ahead of displacement (x) by $\frac{\pi}{2}$ angle.

Chapter 14

Waves

TYPE A : MULTIPLE CHOICE QUESTIONS

1. At which temperature velocity of sound (at 27°C) doubles? ***[1997, 2002]***

(a) 327°C (b) 927°C
(c) 54°C (d) –123 °C

2. The wave equation is y = 0.30 sin (314t – 1.57x) where t, x and y are in second, metre and centimetre respectively. The speed of the wave is ***[1997]***

(a) 400 m/s (b) 100 m/s
(c) 200 m/s (d) 50 m/s

3. An object producing a pitch of 1200 Hz is moving with a velocity of 50 m/s towards a stationary person. The velocity of sound is 350 m/s. The frequency of sound heard by the stationary person is : ***[1997]***

(a) 1250 Hz (b) 1050 Hz
(c) 700 Hz (d) 1400 Hz

4. The air column in a pipe which is closed at one end will be in resonance with a vibrating tuning fork at a frequency 260 Hz. The length of the air column is : ***[1997]***

(a) 12.5 cm (b) 35.75 cm
(c) 31.92 cm (d) 62.5 cm

5. Standing waves are produced in 10 m long stretched string. If the string vibrates in 5 segments and wave velocity is 20 m/s, then its frequency will be : ***[1998]***

(a) 5 Hz (b) 2 Hz
(c) 10 Hz (d) 2 Hz

6. Newton's formula for the velocity of sound in gas is : ***[1998]***

(a) $v = \sqrt{\frac{P}{\rho}}$ (b) $v = \frac{2}{3}\sqrt{\frac{P}{\rho}}$

(c) $v = \sqrt{\frac{\rho}{P}}$ (d) $v = \sqrt{\frac{2P}{\rho}}$

7. The equation of a travelling wave is $y = 60\cos(1800t - 6x)$ where y is in microns, t in second and x in metre. The ratio of maximum particle velocity to the velocity of wave propagation is : ***[1998]***

(a) 3.6×10^{-4} (b) 3.6×10^{-6}
(c) 3.6×10^{-8} (d) none of these

8. The waves in which the particles of the medium vibrate in a direction perpendicular to the direction of wave motion is known as : ***[1998]***

(a) longitudinal waves (b) propagated waves
(c) transverse wave (d) none of these

9. Energy is not carried by which of the following wave? ***[1999]***

(a) Progressive (b) Electromagnetic
(c) Transverse (d) Stationary

10. If the vibrations of a string are to be increased by a factor of two, then tension in the string should be made : ***[1999]***

(a) Twice (b) Four times
(c) Eight times (d) Half

11. A resonance in air column of length 20 cm resonates with a tuning fork of frequency 450 Hz. Ignoring end correction, the velocity of sound in air is: ***[1999]***

(a) 1020 m/s (b) 720 m/s
(c) 620 m/s (d) 820 m/s

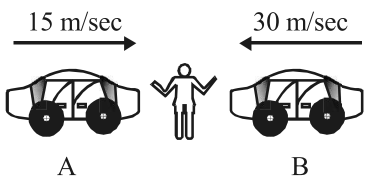
12. A transverse wave passes through a string with the equation : $y = 10\sin\pi(0.02x - 2.00t)$ where x is in metre and t in second. The maximum velocity of the particle in wave motion is : ***[2000]***

(a) 100 m/s (b) 63 m/s
(c) 120 m/s (d) 161 m/s

13. A wave is represented by the equation $y = a\sin(0.01x - 2t)$ where a and x are in cm and t in second. Velocity of propagation of the wave is : ***[2000]***

(a) 200 cm/sec (b) 10 cm/sec
(c) 25 cm/sec (d) 50 cm/sec

14. Two cars A and B approach a stationary observer from opposite sides as shown in fig. Observer hears no beats. If the frequency of the horn of the car B is 504 Hz, the frequency of horn of car A will be :



(a) 529.2 Hz (b) 295.2 Hz ***[2000]***
(c) 440.5 Hz (d) none of these

15. The tension in a piano wire is 10 N. The tension in a piano wire to produce a node of double frequency is : ***[2001]***
(a) 20 N (b) 40 N
(c) 10 N (d) 120 N

16. Two sound waves have phase difference of 60°, then they will have the path difference of : ***[2001]***
(a) 3λ (b) $\frac{\lambda}{3}$
(c) $\frac{\lambda}{6}$ (d) λ

17. A sings with a frequency (n) and B sings with a frequency 1/8 that of A. If the energy remains the same and the amplitude of A is a, then amplitude of B will be : ***[2001]***
(a) 2a (b) 8a
(c) 4a (d) a

18. If equation of sound wave is y = 0.0015 sin (62.4 x + 316t), then its wavelength will be ***[2002]***
(a) 2 unit (b) 0.3 unit
(c) 0.1 unit (d) 0.2 unit

19. A siren emitting sound of frequency 800 Hz is gong away from a static listener with a speed of 30 m/s. Frequency of the sound to be heard by the listener is (Take velocity of sound = 300 m/s)
(a) 286.5 Hz (b) 481.2 Hz ***[2002]***
(c) 733.3 Hz (d) 644.8 Hz

20. The velocities of sound at the same temperature in two monoatomic gases of densities ρ_1 and ρ_2 are v_1 and v_2 respectively. If $\rho_1/\rho_2 = 4$, then the value of v_1/v_2 is ***[2002]***
(a) 4 (b) 2
(c) $\frac{1}{2}$ (d) $\frac{1}{4}$

21. A string in a musical instrument is 50 cm long and its fundamental frequency is 800 Hz. If a frequency of 1000 Hz is to be produced, then required length of string is ***[2002]***
(a) 37.5 cm (b) 40 cm
(c) 50 cm (d) 62.5 cm

22. An earthquake generates both transverse (S) and longitudinal (P) sound waves in the earth. The speed of S waves is about 4.5 km/s and that of P waves about 8.0 km/s. A seismograph records P and S waves from an earthquake. The first P wave arrives 4.0 min. before the first S wave. The epicenter of the earthquake is located at a distance of about : ***[2003]***
(a) 25 km (b) 250 km
(c) 2500 km (d) 5000 km

23. An organ pipe closed at one end has fundamental frequency of 1500 Hz. The maximum number of overtones generated by this pipe which a normal person can hear is ***[2004]***
(a) 4 (b) 13
(c) 6 (d) 9

24. The wave produced by a motor boat sailing in water are ***[2004]***
(a) transverse
(b) longitudinal
(c) longitudinal and transverse
(d) stationary

25. A boat at anchor is rocked by waves whose crests are 100 m apart and velocity is 25 m/sec. The boat bounces up once in every: ***[2006]***
(a) 2500 s (b) 75 s
(c) 4s (d) 0.25 s

26. A stone thrown into still water, creates a circular wave pattern moving radially outwards. If r is the distance measured from the centre of the pattern. the amplitude of the wave aries as : ***[2006]***
(a) $r^{-1/2}$ (b) r^{-1}
(c) r^{-2} (d) $r^{-3/2}$

27. When a guitar string is sounded with a 440 Hz tuning fork, a beat frequency of 5 Hz is heard. If the experiment is repeated with a tuning fork of 437Hz, the beat frequency is 8 Hz. The string frequency (Hz) is : ***[2006]***
(a) 445 (b) 435
(c) 429 (d) 448

28. For a wave propagating in a medium, identity the property that is independent of the others: *[2006]*

(a) velocity
(b) wavelength
(c) frequency
(d) all these depend on each other

29. A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. Then, the lowest resonant frequency for this string is *[2008]*

(a) 105 Hz (b) 1.05 Hz
(c) 1050 Hz (d) 10.5 Hz

30. A person speaking normally produces a sound intensity of 40 dB at a distance of 1 m. If the threshold intensity for reasonable audibility is 20 dB, the maximum distance at which he can be heard clearly is *[2008]*

(a) 4m (b) 5m
(c) 10m (d) 20m

31. A wave on a string is travelling and the displacement of particles on it is given by $x = A\sin(2t - 0.1\,x)$. Then the wavelength of the wave is *[2009]*

(a) 10π (b) 20π
(c) 40π (d) 20

32. A tuning fork of frequency 340 Hz is vibrated just above the tube of 120 cm height. Water is poured slowly in the tube. What is the minimum height of water necessary for the resonance? (speed of sound in air = 340 m/s) *[2009]*

(a) 45 cm (b) 30 cm
(c) 40 cm (d) 25 cm

33. The velocity of sound in a gas at pressure P and density d is *[2009]*

(a) $v = \sqrt{\frac{\gamma P}{d}}$ (b) $v = \sqrt{\frac{P}{\gamma d}}$

(c) $v = \gamma\sqrt{\frac{P}{d}}$ (d) $v = \sqrt{\frac{2P}{d}}$

34. The expression $y = a\sin bx \sin \omega t$ represents a stationary wave. The distance between the consecutive nodes is equal to : *[2011]*

(a) π/b (b) $2\pi/b$
(c) $\pi/2b$ (d) $1/b$

35. An open and closed organ pipe have the same length. The ratio of pth mode of frequency of vibration of two pipes is *[2012]*

(a) 1 (b) p
(c) $p(2p+1)$ (d) $\frac{2p}{(2p-1)}$

36. When two tuning forks (fork 1 and fork 2) are sounded simultaneously, 4 beats per second are heard. Now, some tape is attached on the prong of the fork 2. When the tuning forks are sounded again, 6 beats per second are heard. If the frequency of fork 1 is 200 Hz, then what was the original frequency of fork 2? *[2012]*

(a) 202 Hz (b) 200 Hz
(c) 204 Hz (d) 196 Hz

37. A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of *[2012]*

(a) 100 (b) 1000
(c) 10000 (d) 10

38. A fork of frequency 256 Hz resonates with a closed organ pipe of length 25.4 cm. If the length of pipe be increased by 2 mm, the number of beats/sec. will be *[2014]*

(a) 4 (b) 1
(c) 2 (d) 3

39. The equation of a progressive wave is

$$y = 0.02\sin 2\pi\left[\frac{t}{0.01} - \frac{x}{0.30}\right]$$

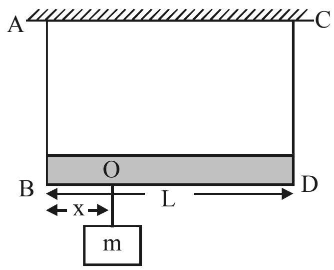
Here x and y are in metre and t is in second. The velocity of propagation of the wave is *[2014]*

(a) $300\ m\ s^{-1}$ (b) $30\ m\ s^{-1}$
(c) $400\ m\ s^{-1}$ (d) $40\ m\ s^{-1}$

40. Two waves of wavelengths 99 cm and 100 cm both travelling with velocity 396 m/s are made to interfere. The number of beats produced by them per second is *[2015]*

(a) 1 (b) 2
(c) 4 (d) 8

41. A massless rod of length L is suspended by two identical strings AB and CD of equal length. A block of mass m is suspended from point O such that BO is equal to 'x'. Further it is observed that the frequency of 1st harmonic in AB is equal to 2nd harmonic frequency in CD. 'x' is **[2016]**



(a) $\frac{L}{5}$ (b) $\frac{4L}{5}$

(c) $\frac{3L}{4}$ (d) $\frac{L}{4}$

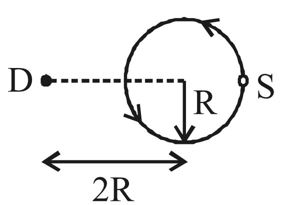
42. Two similar open organ pipe of length 50 cm and 50.5 cm produce 3 beats per second when sounded together. The velocity of sound in air is **[2016]**

(a) 303 m/s (b) 330 m/s

(c) 151.5 m/s (d) 603 m/s

43. A whistle S of frequency f revolves in a circle of radius R at a constant speed v. What is the ratio of largest and smallest frequency detected by a detector D at rest at a distance 2R from the centre of circle as shown in figure ?

(take c as speed of sound) **[2016]**



(a) $\left(\frac{c+v}{c-v}\right)$ (b) $\sqrt{2}\left(\frac{c+v}{c-v}\right)$

(c) $\sqrt{2}$ (d) $\frac{(c+v)}{c\sqrt{2}}$

44. A train moving at a speed of 220 ms^{-1} towards a stationary object, emits a sound of frequency 1000 Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is (speed of sound in air is 330 ms^{-1}) **[2017]**

(a) 3500 Hz (b) 4000 Hz

(c) 5000 Hz (d) 3000 Hz

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 45-49) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

45. **Assertion :** Sound travels faster in solids than gases.

Reason : Solids possess greater density than gases. **[2000]**

46. **Assertion :** Speed of wave $=\frac{\text{wavelength}}{\text{time period}}$

Reason : Wavelength is the distance between two nearest particles in phase. **[2002]**

47. **Assertion :** When a beetle moves along the sand within a few tens of centimeters of a sand scorpion, the scorpion immediately turns towards the beetle and dashes towards it

Reason : When a beetle disturbs the sand, it sends pulses along the sand's surface. One set of pulses is longitudinal while the other set is transverse. **[2003]**

48. **Assertion :** Sound waves cannot travel in vacuum but light can travel in vacuum.

Reason : Sound waves are longitudinal waves and they cannot be polarised but electromagentic waves are transverse and they can be polarised. **[2007]**

49. **Assertion :** The change in air pressure affects the speed of sound.

Reason : The speed of sound in gases is proportional to the square of pressure. ***[2008]***

Directions for (Qs. 50-56) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

50. **Assertion :** The pitch of wind instruments rises and that of string instruments falls as an orchestra warms up.

Reason : When temperature rises, speed of sound increases but speed of wave in a string fixed at both ends decreases. ***[2009]***

51. **Assertion :** For the formation of stationary waves the medium must be bounded having definite boundaries.

Reason : In the stationary wave, some particles of the medium remain permanently at rest. ***[2010]***

52. **Assertion :** A transverse waves are produced in a very long string fixed at one end. Only progressive wave is observed near the free end.

Reason : Energy of reflected wave does not reach the free end. ***[2013]***

53. **Assertion :** Doppler formula for sound wave is symmetric with respect to the speed of source and speed of observer.

Reason : Motion of source with respect to stationary observer is not equivalent to the motion of an observer with respect to stationary source. ***[2014]***

54. **Assertion :** Two waves moving in a uniform string having uniform tension cannot have different velocities.

Reason : Elastic and inertial properties of string are same for all waves in same string. Moreover speed of wave in a string depends on its elastic and inertial properties only. ***[2015]***

55. **Assertion :** The base of Laplace correction was that exchange of heat between the region of compression and rarefaction in air is negligible.

Reason : Air is bad conductor of heat and velocity of sound in air is quite large. ***[2016]***

56. **Assertion :** The fundemental frequency of an open organ pipe increases as the temperature is increased.

Reason : As the temperature increses, the velocity of sound increases more rapidly than length of the pipe. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** Velocity of sound $\propto \sqrt{T}$ (where T is temperature of body in absolute scale).

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{2v}{v} = \sqrt{\frac{t+273}{27+273}}$$

$$4 = \frac{t+273}{300} \Rightarrow t + 273 = 1200$$

$$\Rightarrow t = 927°C$$

2. **(c)** Given equation $y = 0.30\sin(314t - 1.57x)$

Comparing it with standard equation of wave,

$$y = a\sin(\omega t - kx)$$

$$\omega = 314;\ k = 1.57$$

$$v = \frac{\omega}{k} \Rightarrow v = \frac{314}{1.57} = 200\ m/sec$$

3. **(d)** If n_a be the apparent frequency, then

$$n_a = n \times \frac{v_s}{(v_s - v_0)} = \frac{1200 \times 350}{(350-50)}$$

$$= \frac{1200 \times 350}{300} = 1400\,Hz$$

4. **(c)** For fundamental frequency

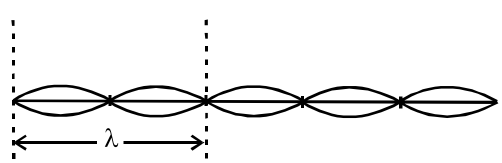
$$n = \frac{v}{\lambda}\ \&\ \frac{\lambda}{4} = \ell \Rightarrow \lambda = 4\ell$$

$$n = \frac{v}{4\ell} \Rightarrow 260 = \frac{330}{4\ell}$$

$$\Rightarrow \ell = \frac{330}{260 \times 4} = 0.3173\,m$$

$\ell = 31.73$ cm ~ 31.92 cm (given in option)

5. **(a)**



There are 5 loops in 10 metre.
Length of one loop = 2 m
Length of two loops = 2 × 2 = 4 m

Now, $\lambda = 4m$; $v = 20$ m/sec
From formula

$$v = \nu\lambda \Rightarrow 20 = \nu \times 4 \Rightarrow \nu = 5Hz$$

6. **(a)** Newton's formula for velocity of sound in gas

$$v = \sqrt{\frac{P}{\rho}}$$ where P is pressure & ρ is density of gas.

7. **(a)** $y = 60\cos(1800t - 6x)$, y is in microns.

$$y = 60\cos(1800t - 6x) \times 10^{-6}$$

$$v = \frac{dy}{dt} = \text{particle velocity}$$

$$= 60 \times 10^{-6} \times 1800\sin(1800t - 6x)$$

$$v_{max} = 6 \times 18 \times 10^{-3}$$

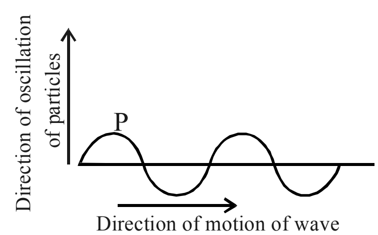
$$v_{wave} = \frac{\omega}{k};\ \omega = 1800; K = 6$$

$$v_{wave} = \frac{1800}{6} = 300$$

$$\frac{v_{max}}{v_{wave}} = \frac{6 \times 18 \times 10^{-3}}{300}$$

$$= 36 \times 10^{-5} = 3.6 \times 10^{-4}$$

8. **(c)** Transverse waves have particles oscillating perpendicular to the direction of motion of wave. Ripple in the surface of water is transverse in nature.



9. **(d)** Stationary waves do not carry energy with it as it is stationary or does not change position.

10. **(b)** We know that, $n = \frac{1}{2}\sqrt{\frac{T}{m}} \Rightarrow n \propto \sqrt{T}$

If tension is increased four times, the frequency will become twice.

11. (b) Let the air column be closed one.
In closed organ pipe for fundamental node of vibration , $\frac{\lambda}{4} = 0.2 \Rightarrow \lambda = 0.8m$,
$v = n\lambda$
If we take the frequency of air column to be equal to tuning fork then,
$v = 450 \times 0.8 = 360 \text{ m/sec}$
If we take the frequency of air column to be twice that of tuning fork then,
$v = 900 \times 0.8 = 720 \text{ m/sec}$
This matches with alternative (b).

12. (b) The equation of wave
$y = 10 \sin \pi(0.02x - 2t)$
Particle velocity,
$\frac{dy}{dt} = 10 \cos \pi(0.02x - 2t) \times \pi \times 0.2$
$= 0.63 \cos \pi(0.02x - 2t)$
Maximum value of velocity = 63 m/sec.

13. (a) In the wave of the form
$y = \sin(\omega t - kx)$
Velocity $v = \frac{\omega}{k}$
Here $\omega = 2$; $k = 0.01$
$v = \frac{\omega}{k} = \frac{2}{0.01} = 200 \text{ cm/sec}$

14. (a) Since, the person hears no beats therefore their apparent frequency are the same.
So, $n \times \frac{330}{330-15} = 504 \times \frac{330}{330-30}$
$n = \frac{504 \times 315}{300} = 529.2 \text{ Hz}$

15. (b) For frequency of oscillation of wire.
$n \propto \sqrt{T}$, Here T is tension in the wire.
In order to increase frequency twice, tension needs to be made 4 times. So, new tension must be $4 \times 10 = 40$ N

16. (c) Path diff. $= \frac{\lambda}{2\pi} \times$ phase difference
$= \frac{\lambda}{2\pi} \times \frac{\pi}{3} = \frac{\lambda}{6}$

17. (b) Energy of sound wave $= 2\pi^2 \nu^2 a^2 v\rho$
ν is frequency and v is velocity of sound; ρ is density of air or any other medium.
Now, $E_1 = 2\pi^2 \nu^2 a^2 v\rho$
$E_2 = 2\pi^2 \left(\frac{\nu}{8}\right)^2 A^2 v\rho \quad E_1 = E_2$
$2\pi^2 \nu^2 a^2 v\rho = 2\pi^2 \frac{\nu^2}{64} A^2 v\rho$
$A^2 = 64a^2 \; A = 8a$

18. (c) $y = 0.0015 \sin(62.8x + 314t)$
Comparing it with the equation
$y = a \sin(\omega t + kx)$
$\omega = 314, k = 62.8$
$k = \frac{2\pi}{\lambda} = 62.8 \Rightarrow \lambda = \frac{2\pi}{62.8} = 0.1$ unit.

19. (c) Since, the source is going away from listener $n' = n \times \frac{v}{v+u} = 800 \times \frac{330}{(330+30)}$
$n' = 800 \times \frac{330}{360} = 733.33 \text{ Hz}$

20. (c) For velocity of sound in gas
$v = \sqrt{\frac{\gamma P}{\rho}}$
[P is pressure and ρ is density of gas, γ is C_p/C_v]
Here, $v_1 = \sqrt{\frac{\gamma P}{\rho_1}}$ and $v_2 = \sqrt{\frac{\gamma P}{\rho_2}}$
$\frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

21. (b) We know that for frequency of sound in string the formula is, $\nu = \frac{1}{2\ell}\sqrt{\frac{T}{m}}$ or $\nu = \frac{1}{\ell}$
$\frac{\nu_1}{\nu_2} = \frac{\ell_2}{\ell_1} \Rightarrow \frac{800}{1000} = \frac{\ell_2}{50}$
$\ell_2 = 50 \times \frac{800}{1000} = 40 \text{ cm}$

22. (c) Let d be the distance of epicenter.
Time taken by S-wave $= \frac{d}{4.5}$

Time taken by P-wave $= \dfrac{d}{8}$

Now $\dfrac{d}{4.5} - \dfrac{d}{8} = 4 \times 60$

$d\left[\dfrac{10}{45} - \dfrac{1}{8}\right] = 4 \times 60$

$\Rightarrow d = \dfrac{4 \times 60 \times 8 \times 45}{35}$

$= \dfrac{240 \times 72}{7} = \dfrac{17280}{7} = 2468.5 \approx 2500\,\text{km}.$

23. (c) In an organ pipe only odd harmonics are found. So, frequency equal to odd multiple of 1500 Hz may be found in this case. Maximum audible frequency is 20,000 Hz. So, possible frequency are 1500 Hz, 4500 Hz, 7500 Hz, 10500 Hz, 13500 Hz, 16500 Hz, 19500 Hz. 19500 Hz will be sixth overtone as 4500 will be first overtone.

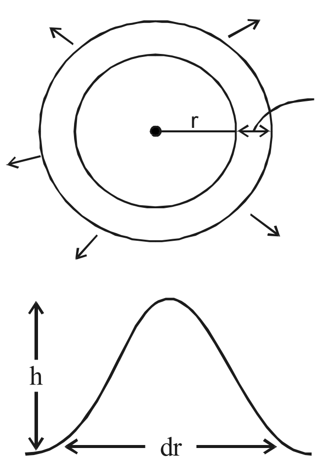
24. (c) The waves produced by a motorboat sailing in water are of both transverse and longitudinal type. Transverse waves are produced on the surface and longitudinal waves are produced deep inside the water.

25. (c) Wavelength is distance between two crest. $\lambda = 100\,\text{m}$; $v = 25$

$n = \dfrac{25}{100}$

$T = \dfrac{1}{n} = \dfrac{100}{25} = 4\,\text{sec}$

26. (a)



Energy of crest (P.E) $= (2\pi r.dr \times h \times \rho) \times g \times h$

Now, as crest spread, this energy E remains constant. So,

$2\pi r dr h^2 \rho g = E$

$\Rightarrow h = \sqrt{\dfrac{E}{2\pi r dr \rho g}}$ or $h \propto r^{-1/2}$

27. (a) If we decrease the frequency of tuning fork no. of beat is increased i.e., difference of frequency is increased. It means unknown frequency is more than 440 Hz.

So it is $440 + 5 = 445$ Hz.

28. (c) In a medium velocity and wavelength are dependent on refractive index of the medium but frequency remains unchanged.

29. (a) Given $\dfrac{nv}{2\ell} = 315$ and $(n+1)\dfrac{v}{2\ell} = 420$

$\Rightarrow \dfrac{n+1}{n} = \dfrac{420}{315} \Rightarrow n = 3$

Hence $3 \times \dfrac{v}{2\ell} = 315 \Rightarrow \dfrac{v}{2\ell} = 105$ Hz

The lowest resonant frequency is when $n = 1$

Therefore lowest resonant frequency $= 105$ Hz.

30. (c) We have, $\beta = 10\log_{10}\left(\dfrac{I}{I_0}\right)$

Where $I_0 =$ threshold intensity of sound $= 10^{-12}\,W/m^2$

i.e., $40 = 10\log_{10}\left(\dfrac{I_1}{I_0}\right)$ ...(i)

and $20 = 10\log_{10}\left(\dfrac{I_2}{I_0}\right)$ ...(ii)

$\dfrac{(i)}{(ii)} \Rightarrow \dfrac{40}{20} = \log_{10}\left(\dfrac{I_1}{I_2}\right)$

$2 = \log_{10}\left(\dfrac{I_1}{I_2}\right)$ or $\dfrac{I_1}{I_2} = 10^2$

$\therefore \dfrac{r_2^2}{r_1^2} = 10^2$ (since $I \propto \dfrac{1}{r^2}$)

$r_2^2 = 10^2 r_1^2$ or $r_2 = 10 r_1 = 10 \times 1 = 10\,\text{m}$

31. (b) $x = A\sin(2t - 0.1x)$

also $x = A\sin\left(\frac{2\pi t}{T} - \frac{2\pi}{\lambda}x\right)$

$\Rightarrow \frac{2\pi}{\lambda} = 0.1 \Rightarrow \lambda = 20\pi$

32. (a) We have $v = \nu\lambda$.

or $\lambda = \frac{v}{\nu} = \frac{340 m/s}{340 Hz} = 1m$

First resonating length,

$l_1 = \frac{\lambda}{4} = \frac{1}{4} m = 25 cm$

Second resonating length,

$l_2 = \frac{3\lambda}{4} = \frac{3 \times 1m}{4} = 75 cm.$

Third resonating length,

$l_3 = \frac{5\lambda}{4} = \frac{5 \times 1m}{4} = 125 cm.$

So third resonance is not possible since the length of the tube is 120 cm.

$\therefore$ Minimum height of water necessary for resonance $= 120 - 75 = 45$ cm.

33. (a) $v = \sqrt{\frac{\gamma RT}{M}}$

$PV = RT$

$P\frac{M}{d} = RT$

$\frac{P}{d} = \frac{RT}{M}$

$v = \sqrt{\frac{\gamma P}{d}}$

34. (a) $y = a \sin bx \sin \omega t$

on comparing with standard equation of stationary wave

$y = R \sin \frac{2\pi x}{\lambda} . \sin \omega t$, we get

$\frac{2\pi x}{\lambda} = bx$,

$\therefore \lambda = \frac{2\pi}{b}$

The distance between constructive nodes

$= \frac{\lambda}{2} = \frac{2\pi / b}{2} = \frac{\pi}{b}$

35. (d) For open pipe, $n = p\frac{v}{2\ell}$

For closed pipe $n' = (2p-1)\frac{v}{4\ell}$

$\therefore \frac{n}{n'} = \frac{2p}{(2p-1)}$

36. (d) Frequency of fork $1 = 200$ Hz $= n_0$

No. of beats heard when fork 2 is sounded with fork $1 = \Delta n = 4$

Now we know that if on loading (attaching tape) an unknown fork, the beat frequency increases (from 4 to 6 in this case) then the frequency of the unknown fork 2 is given by, $n = n_0 - \Delta n = 200 - 4 = 196$ Hz

37. (a) We have, $L_1 = 10\log\left(\frac{I_1}{I_0}\right)$

$L_2 = 10\log\left(\frac{I_2}{I_0}\right)$

$\therefore \quad L_1 - L_2 = 10\log\left(\frac{I_1}{I_0}\right) - 10\log\left(\frac{I_2}{I_0}\right)$

or, $\Delta L = 10\log\left(\frac{I_1}{I_0} \times \frac{I_0}{I_2}\right)$

or, $\Delta L = 10\log\left(\frac{I_1}{I_2}\right)$

or, $20 = 10\log\left(\frac{I_1}{I_2}\right)$

or, $2 = \log\left(\frac{I_1}{I_2}\right)$

or, $\frac{I_1}{I_2} = 10^2$

or, $I_2 = \frac{I_1}{100}$.

$\Rightarrow$ Intensity decreases by a factor 100.

38. (c) $n_1 = 256 = \frac{v}{4\ell_1} = \frac{v}{4 \times 25.4}$

$\therefore v = 256 \times 101.6$ cm/s

$n_2 = \frac{v}{4\ell_2} = \frac{256 \times 101.6}{4 \times 25.6} = 254$ Hz

No. of beats/sec $= n_1 - n_2 = 256 - 254 = 2$

39. (b) $\omega = \dfrac{2\pi}{0.01}$ and $k = \dfrac{2\pi}{0.30}$

$$v = \frac{\omega}{k} = \frac{2\pi}{0.01} \times \frac{0.30}{2\pi} = 30 \text{ m s}^{-1}$$

40. (c) Velocity of wave $v = n\lambda$

where n = frequency of wave $\Rightarrow n = \dfrac{v}{\lambda}$

$$n_2 = \frac{v_2}{\lambda_2} = \frac{396}{100 \times 10^{-2}} = 396\,\text{Hz}$$

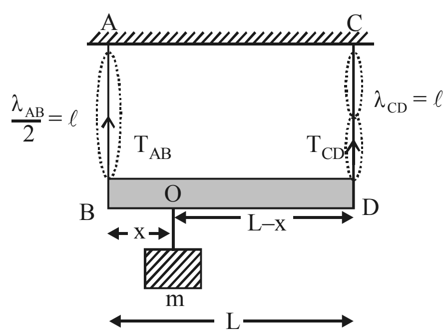
no. of beats = $n_1 - n_2 = 4$

41. (a) Frequency of 1st harmonic of AB

$$= \frac{1}{2\ell}\sqrt{\frac{T_{AB}}{m}}$$

Frequency of 2nd harmonic of CD

$$= \frac{1}{\ell}\sqrt{\frac{T_{CD}}{m}}$$



Given that the two frequencies are equal.

$$\therefore \frac{1}{2\ell}\sqrt{\frac{T_{AB}}{m}} = \frac{1}{\ell}\sqrt{\frac{T_{CD}}{m}}$$

$$\Rightarrow \frac{T_{AB}}{4} = T_{CD} \Rightarrow T_{AB} = 4T_{CD} \qquad \text{....(i)}$$

For rotational equilibrium of massless rod, taking torque about point O,

$$T_{AB} \times x = T_{CD}(L - x) \qquad \text{....(ii)}$$

For translational equilibrium,

$$T_{AB} + T_{CD} = mg \qquad \text{....(iii)}$$

On solving, (i) & (iii) we get, $T_{CD} = \dfrac{mg}{5}$;

$$\therefore T_{AB} = \frac{4mg}{5}$$

Substituting these values in (ii) we get

$$\frac{4mg}{5} \times x = \frac{mg}{5}(L - x)$$

$$\Rightarrow \; 4x = L - x \Rightarrow x = \frac{L}{5}$$

42. (a) $L_1 = 50$ cm, $L_2 = 50.5$ cm
as $L_2 > L_1$, so $n_2 < n_1$
For open pipe,

$$n = \frac{v}{2L}$$

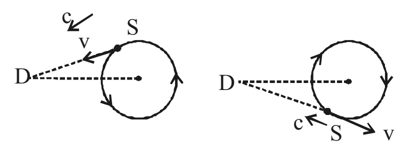
$n_1 - n_2 = 3$ beats/s

$$\therefore \; \frac{v}{2}\left(\frac{1}{L_1} - \frac{1}{L_2}\right) = 3$$

$$\therefore \; \frac{v}{10^{-2}}\left(\frac{1}{50} - \frac{1}{50.5}\right) = 6$$

$$\therefore \; v = \frac{6 \times 50 \times 50.5 \times 10^{-2}}{0.5} = 303 \text{ m/s}$$

43. (a)



Largest frequency (f_1) Lowest frequency (f_2)

Largest frequency will be detected when the source approaches detector along the line joining and the smallest frequency will be detected when the source recedes the detector along the line joining them

$$\frac{f_1}{f_2} = \frac{\left(\dfrac{c}{c - v}\right)f}{\left(\dfrac{c}{c + v}\right)f} = \frac{c + v}{c - v}$$

44. (c) Frequency of the echo detected by the driver of the train is
(According to Doppler effect in sound)

$$f' = \left(\frac{v + u}{v - u}\right)f$$

where f = original frequency of source of sound
f' = Apparent frequency of source because of the relative motion between source and observer.

$$f' = \left(\frac{330 + 220}{330 - 220}\right)1000 = 5000\,\text{Hz}$$

Type B : Assertion Reason Questions

45. (b) Sound travels faster in solids than gases. It is because the elasticity of solid is more than that of gases. Solids posses greater density than gases. Though density has effect on the velocity of sound in the medium as follows

$$v \propto \frac{1}{\sqrt{\rho}}$$

In case of solid, its elasticity far exceeds that of gas so its effect far exceeds the effect of density.

46. (a) Since wavelength is distance between two nearest particles in phase and time period is time required by a wave to cover this distance.

$$\text{So speed of wave} = \frac{\text{wavelength}}{\text{time period}}$$

47. (a) When beettle moves along the sand it sends two sets of pulses, one longitudinal and the other transverse. Scorpion has the capacity to intercept the waves. By getting a sense of time interval between receipt of these two waves, it can determine the distance of bettle also.

48. (b) Longitudinal waves travel or propagate by compression and rarefaction of the medium particles hence in absence of a medium they cannot propagate.
Light waves are made of perpendicular electric and magnetic field vectors normal to direction of motion. Hence, they are transverse waves and if plane of vibration is same for a wave then it is polarised but this is not so for sound waves.

49. (d) Speed of sound in cases is independent of pressure because $v = \sqrt{\frac{\gamma P}{\rho}}$

At constant temperature, if P changes then ρ also changes in such a way that the ratio $\frac{P}{\rho}$ remains constant. Hence there is no effect of the pressure change on the speed of sound.

50. (a) Pitch is related to frequency and $f = \frac{v}{\lambda}$

51. (b) For the formation of stationary waves, it is necessary that the medium should not be unlimited but it should have a boundary. The wave propagating in such a medium will reflect at the boundary and produce a wave of the same kind travelling in the opposite direction. The position of two waves will give rise to a stationary wave. At free end, transverse wave is reflected without change of phase. Hence as essential requirement for the formation of stationary wave is that the medium must be bounded having definite boundaries. In stationary waves, there are certain points of the medium, which are permanently at rest *i.e.*, their displacement is zero throughout. These points are called nodes. Similarly, there are some other points which vibrate about their mean position with largest amplitude. These points are called antinodes.

52. (a)

53. (d) Reason is correct, Assertion is incorrect. In doppler for sound wave effect due to observer and source motion are different.

54. (d) Two waves moving in uniform string with uniform tension shall have same speed and may be moving in opposite directions. Hence both waves may have velocities in opposite direction. Hence Assertion is incorrect.

55. (c) Laplace assumed adiabatic process during sound propagation.

56. (a) As $f = \frac{v}{2l}$; and so with increase in temperature v increases more than l.

Also $v = \sqrt{\frac{\gamma RT}{M}}$

Chapter 15

Electric Charges and Fields

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A body can be negatively charged by : ***[1998]***
(a) removing some neutrons from it
(b) giving excess electrons to it
(c) removing some protons from it
(d) removing some electrons from it

2. The number of electrons for one coulomb of charge are: ***[1999]***
(a) 6.25×10^{23} (b) 6.25×10^{21}
(c) 6.25×10^{18} (d) 6.25×10^{19}

3. Let E_a be the electric field due to a dipole in its axial plane distant ℓ and E_q be the field in the equatorial plane distant ℓ', then the relation between E_a and E_q will be : ***[2000]***
(a) $E_a = 4E_q$ (b) $E_q = 2E_a$
(c) $E_a = 2E_q$ (d) $E_q = 3E_a$

4. A particle of mass 2g and charge 1μC is held at a distance of 1m from a fixed charge 1mC. If the particle is released it will be repelled. The speed of particle when it is at a distance of 10 metre from the fixed charge is ***[2000]***
(a) 90 m/s (b) 100 m/s
(c) 45 m/s (d) 55 m/s

5. What is the electric flux associated with one of faces of a cube, when a charge (q) is enclosed in the cube ? ***[2001]***
(a) $\dfrac{6q}{\varepsilon_0}$ (b) $\dfrac{q}{6\varepsilon_0}$
(c) $\dfrac{q}{3\varepsilon_0}$ (d) $\dfrac{3q}{\varepsilon_0}$

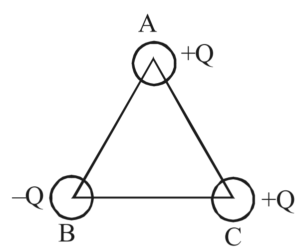
6. The point charges Q and –2Q are placed at some distance apart. If the electric field at the location of Q is E. The electric field at the location of Q is E. The electric field at the location of –2Q will be ***[2001]***
(a) $-\dfrac{3E}{2}$ (b) $-E$
(c) $-\dfrac{E}{2}$ (d) $-2E$

7. How many electrons make up a charge of 20 μC. ***[2002]***
(a) 1.25×10^{14} (b) 2.23×10^{14}
(c) 3.25×10^{14} (d) 5.25×10^{14}

8. A conducting sphere of radius 10 cm is charged with 10 μC. Another uncharged sphere of radius 20 cm is allowed to touch it for some time. After that if the spheres are separated, then surface density of charges on the spheres will be in the ratio of ***[2002]***
(a) 1 : 1 (b) 2 : 1
(c) 1 : 3 (d) 4 : 1

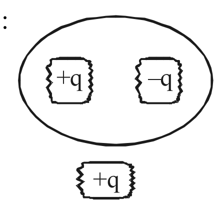
9. An electric dipole placed in a non-uniform electric field experiences : ***[2003]***
(a) both, a torque and a net force
(b) only a force but no torque
(c) only a torque but no net force
(d) no torque and no net force

10. Three charges are placed at the vertices of an equilateral triangle of side 'a' as shown in the following figure. The force experienced by the charge placed at the vertex A in a direction normal to BC is : ***[2003]***



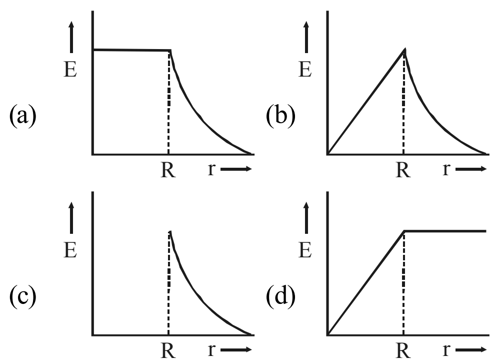
(a) $Q^2/(4\pi\varepsilon_0 a^2)$ (b) $-Q^2/(4\pi\varepsilon_0 a^2)$
(c) zero (d) $Q^2/(2\pi\varepsilon_0 a^2)$

11. Shown below is a distribution of charges. The flux of electric field due to these charges through the surfaces S is : ***[2003]***

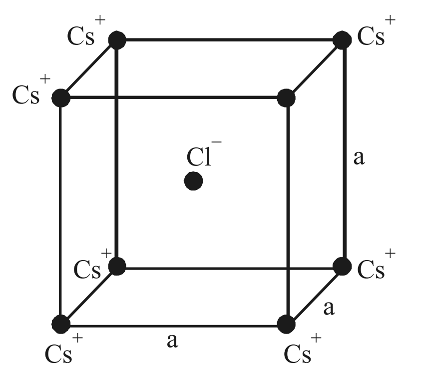


(a) $3q/\varepsilon_0$
(b) $2q/\varepsilon_0$
(c) q/ε_0
(d) zero

12. The electric field due to a uniformly charged non-conducting sphere of radius R as a function of the distance from its centre is represented graphically by ***[2004]***



13. In the basic CsCl crystal structure, Cs^+ and Cl^- ions are arranged in a bcc configuration as shown in the figure. The net electrostatic force exerted by the eight Cs^+ ions on the Cl^- ion is : ***[2004]***



(a) $\frac{1}{4\pi\varepsilon_0}\frac{4e^2}{3a^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{16e^2}{3a^2}$

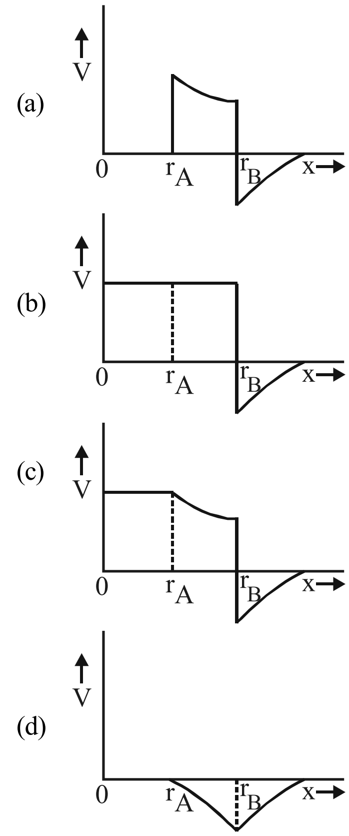
(c) $\frac{1}{4\pi\varepsilon_0}\frac{32e^2}{3a^2}$ (d) zero

14. Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum then the electric field in the region between the plates is : ***[2005]***

(a) 0 volt/m (b) $\sigma/2\varepsilon_0$ volt/m

(c) σ/ε_0 volt/m (d) $2\sigma/\varepsilon_0$ volt/m

15. Two concentric conducting thin spherical shells A and B having radii r_A and r_B ($r_B > r_A$) are charged to Q_A and $-Q_B$ ($|Q_B| > |Q_A|$). The electrical field along a line, (passing through the centre) is: ***[2005]***



16. A particle having charge q and mass m is projected with velocity $\vec{v} = 2\hat{i} - 3\hat{j}$ in a uniform electric field $\vec{E} = E_0.\hat{j}$. Change in momentum $|\Delta\vec{p}|$ during any time interval t is given by : ***[2005]***

(a) $\sqrt{qE_0t}$ (b) qE_0t

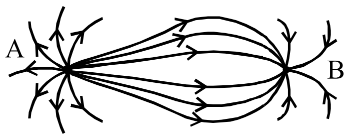
(c) $\frac{qE_0t}{m}$ (d) zero

17. Two parallel large thin metal sheets have equal surface charge densities ($\sigma = 26.4 \times 10^{-12}$ c/m^2) of opposite signs. The electric field between these sheets is : ***[2006]***

(a) 1.5 N/C (b) 1.5×10^{-10} N/C

(c) 3 N/C (d) 3×10^{-10} N/C

18. The spatial distribution of the electric field due to two charges (A, B) is shown in figure. Which one of the following statements is correct ? ***[2006]***

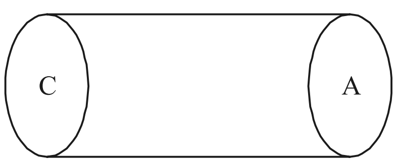


(a) A is +ve and B –ve; |A| > |B|
(b) A is –ve and B +ve; |A| = |B| :
(c) Both are +ve but A > B
(d) Both are –ve but A > B

19. Three point charges +q, –2q and +q are placed at point (x = 0, y = a, z = 0), (x = 0, y = 0, z = 0) and (x = a, y = 0, z = 0) respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are ***[2008]***

(a) $\sqrt{2}qa$ along + y direction
(b) $\sqrt{2}qa$ along the line joining points (x = 0, y = 0, z = 0) and (x = a, y = a, z = 0)
(c) qa along the line joining points (x = 0, y = 0, z = 0) and (x = a, y = a, z = 0)
(d) $\sqrt{2}$qa along + x direction

20. A hollow cylinder has charge q C within it. If ϕ is the electric flux in unit of voltmeter associated with the curved surface B, the flux linked with the plane surface A in unit of voltmeter will be ***[2008]***



(a) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$ (b) $\frac{q}{2\varepsilon_0}$
(c) $\frac{q}{\varepsilon_0}$ (d) $\frac{q}{\varepsilon_0} - \phi$

21. Charge q is uniformly distributed over a thin half ring of radius R. The electric field at the centre of the ring is ***[2008]***

(a) $\frac{q}{2\pi^2\varepsilon_0 R^2}$ (b) $\frac{q}{4\pi^2\varepsilon_0 R^2}$
(c) $\frac{q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{q}{2\pi\varepsilon_0 R^2}$

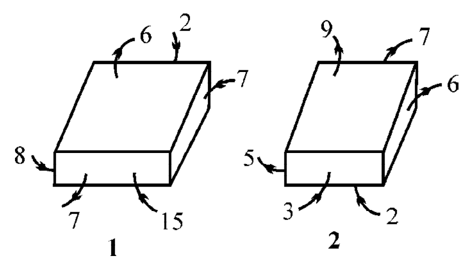
22. The electric field at a distance r from the centre in the space between two concentric metallic spherical shells of radii r_1 and r_2 carrying charge Q_1 and Q_2 is $(r_1 < r < r_2)$ ***[2009]***

(a) $\frac{Q_1 + Q_2}{4\pi \epsilon_0 (r_1 + r_2)^2}$ (b) $\frac{Q_1 + Q_2}{4\pi \epsilon_0 r^2}$
(c) $\frac{Q_1}{4\pi \epsilon_0 r^2}$ (d) $\frac{Q_2}{4\pi \epsilon_0 r^2}$

23. The potential at a point *P* due to an electric dipole is 1.8×10^5V. If *P* is at a distance of 50 cm apart from the centre *O* of the dipole and if *CP* makes an angle 60° with the positive side of the axial line of the dipole, what is the moment of the dipole? ***[2010]***

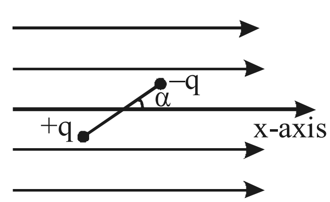
(a) 10 C–m (b) 10^{-3} C–m
(c) 10^{-4} C–m (d) 10^{-5} C–m

24. The figure shows two situations in which a Gaussian cube sits in an electric field. The arrows and values indicate the directions and magnitudes (in N–m^2/C) of the electric fields. What is the net charge (in the two situations) inside the cube? ***[2011]***



(a) (1) negative (2) positive
(b) (1) negative (2) zero
(c) (1) positive (2) positive
(d) (1) positive (2) zero

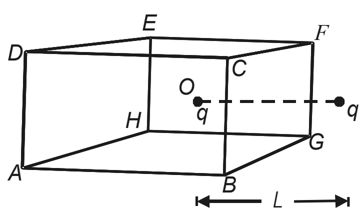
25. There exists a non-uniform electric field along x-axis as shown in the figure below. The field increases at a uniform rate along +ve x-axis. A dipole is placed inside the field as shown. Which one of the following is correct for the dipole? ***[2012]***



(a) Dipole moves along positive x-axis and undergoes a clockwise rotation
(b) Dipole moves along negative x-axis and undergoes a clockwise rotation
(c) Dipole moves along positive x-axis and undergoes a anticlockwise rotation
(d) Dipole moves along negative x-axis and undergoes a anticlockwise rotation

26. Two point charges +q and –q are held fixed at (–d, 0) and (d, 0) respectively of a x – y coordinate system. Then ***[2013]***
(a) the electric field E at all points on the axis has the same direction
(b) work has to be done in bringing a test charge from ∞ to the orgin
(c) electric field at all points on y-axis is along x-axis
(d) the dipole moment is 2qd along the x-axis

27. A charged particle q is placed at the centre O of cube of length L ($A\ B\ C\ D\ E\ F\ G\ H$). Another same charge q is placed at a distance L from O. Then the electric flux through $ABCD$ is ***[2013]***



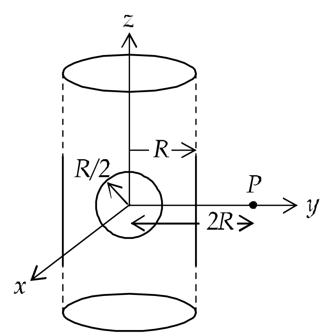
(a) $q/4\pi\epsilon_0 L$ (b) zero
(c) $q/2\pi\epsilon_0 L$ (d) $q/3\pi\epsilon_0 L$

28. In a medium of dielectric constant K, the electric field is $\vec{E}$. If ϵ_0 is permittivity of the free space, the electric displacement vector is ***[2014]***
(a) $\frac{K\vec{E}}{\epsilon_0}$ (b) $\frac{\vec{E}}{K\epsilon_0}$
(c) $\frac{\epsilon_0\vec{E}}{K}$ (d) $K\epsilon_0\vec{E}$

29. Three charge q, Q and 4q are placed in a straight line of length l at points distant 0, $\frac{1}{2}$ and l respectively from one end. In order to make the net froce on q zero, the charge Q must be equal to ***[2015]***
(a) –q (b) – 2q
(c) $\frac{-q}{2}$ (d) q

30. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre a, b are constants. Then the charge density inside the ball is ***[2015]***
(a) $-6a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0$
(c) $-6a\varepsilon_0$ (d) $-24\pi a\varepsilon_0 r$

31. An infinitely long solid cylinder of radius R has a uniform volume charge density ρ. It has a spherical cavity of radius $R/2$ with its centre on the axis of the cylinder, as shown in the figure. The magnitude of the electric field at the point P, which is at a distance $2R$ from the axis of the cylinder, is given by the expression $\frac{23\rho R}{16K\varepsilon_0}$. The value of k is ***[2016]***



(a) 6 (b) 5
(c) 7 (d) 4

32. An electric dipole of moment $\vec{P}$ is placed in a uniform electric field $\vec{E}$ such that $\vec{P}$ points along $\vec{E}$. If the dipole is slightly rotated about an axis perpendicular to the plane containing $\vec{E}$ and $\vec{P}$ and passing through the centre of the dipole, the dipole executes simple harmonic motion. Consider I to be the moment of inertia of the dipole about the axis of rotation. What is the time period of such oscillation? ***[2016]***
(a) $\sqrt{(pE/I)}$ (b) $2\pi\sqrt{(I/pE)}$
(c) $2\pi\sqrt{(I/2pE)}$ (d) None of these

33. A hollow insulated conduction sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere if its radius is 2 m? ***[2017]***
(a) Zero (b) 5 μCm^{-2}
(c) 20 μCm^{-2} (d) 8 μCm^{-2}

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 34-38) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

34. **Assertion:** Electron move away from a region of higher potential to a region of lower potential.
Reason: An electron has a negative charge. ***[1999]***

35. **Assertion :** A metallic shield in form of a hollow shell may be built to block an electric field.
Reason : In a hollow spherical shield, the electric field inside it is zero at every point. ***[2001]***

36. **Assertion :** Electric lines of force never cross each other.
Reason : Electric field at a point superimpose to give one resultant electric field. ***[2002]***

37. **Assertion :** The Coulomb force is the dominating force in the universe.
Reason : The Coulomb force is weaker than the gravitational force. ***[2003]***

38. **Assertion :** In a cavity within a conductor, the electric field is zero.
Reason : Charges in a conductor reside only at its surface. ***[2007]***

Directions for (Qs. 39-43) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

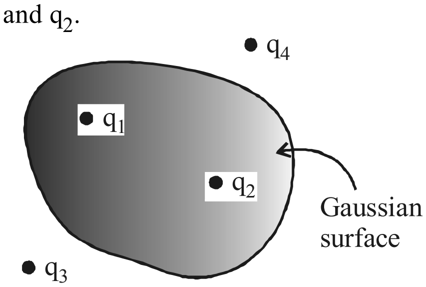
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

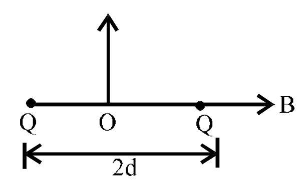
(d) If both the Assertion and Reason are incorrect.

39. **Assertion :** Four point charges q_1, q_2, q_3 and q_4 are as shown in figure. The flux over the shown Gaussian surface depends only on charges q_1 and q_2.



Reason : Electric field at all points on Gaussian surface depends only on charges q_1 and q_2. ***[2012]***

40. **Assertion :** Consider two identical charges placed distance 2d apart, along x-axis.



The equilibrium of a positive test charge placed at the point O midway between them is stable for displacements along the x-axis.
Reason: Force on test charge is zero. ***[2013]***

41. **Assertion :** A deuteron and an α-particle are placed in an electric field. If F_1 and F_2 be the forces acting on them and a_1 and a_2 be their accelerations respectively then, $a_1 = a_2$.
Reason : Forces will be same in electric field. ***[2015]***

42. **Assertion :** In the absence of an external electric field, the dipole moment per unit volume of a polar dielectric is zero.
Reason : The dipoles of a polar dielectric are randomly oriented. ***[2016]***

43. **Assertion :** The positive charge particle is placed in front of a spherical uncharged conductor. The number of lines of forces terminating on the sphere will be more than those emerging from it.
Reason : The surface charge density at a point on the sphere nearest to the point charge will be negative and maximum in magnitude compared to other points on the sphere. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** A body can be negatively charged by adding some excess electron to it.

2. **(c)** 1 electron carries a charge of 1.6×10^{-19} coulomb.
No. of electron in one coulomb

$$= \frac{1}{1.6 \times 10^{-19}}$$

$$= \frac{10^{19}}{1.6} = \frac{10}{1.6} \times 10^{18} = 6.25 \times 10^{18}.$$

3. **(c)** We know that for short dipole,

field at axial point, $E_a = \frac{2p}{d^3}$

and field at equatorial point, $E_q = \frac{p}{d^3}$

So, $E_a = 2E_q$

4. **(a)** Potential at 1 m from the charge

$$V_A = \frac{K.10^{-6}}{1} = K \times 10^{-6}$$

Potential at 10 m from the charge

$$V_B = \frac{K.10^{-6}}{10} = K \times 10^{-7}$$

Potential diff.$= V_A - V_B = K(10^{-6} - 10^{-7})$

Its velocity at 10 m is V, then

$$\frac{1}{2} \times mv^2 = (V_A - V_B) \times q$$

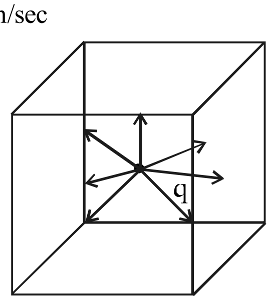
$$\frac{1}{2} \times 2 \times 10^{-3} \times v^2 = K \times 10^{-6}\left(1 - \frac{1}{10}\right) \times 10^{-3}$$

$$v^2 = \frac{K \times 10^{-9} \times 9}{10^{-3} \times 10} = K \times \frac{9}{10} \times 10^{-6}$$

$$= 9 \times 10^9 \times \frac{9}{10} \times 10^{-6} = 81 \times 100$$

v = 90 m/sec

5. **(b)**



Charge q is lying inside the cube. Flux coming out of it $= \frac{q}{\epsilon_0}$. It is now distributed evenly over six faces. So, flux passing through one face

$$= \frac{q}{\epsilon_0} \times \frac{1}{6} = \frac{q}{6\epsilon_0}$$

6. **(c)** Field at Q is E. So, force on Q = QE
This force will be applied on –2Q. Also according to Coulomb's law. So, field at –2Q is $\frac{QE}{-2Q} = \frac{E}{2}$.

7. **(a)** Charge on an electron
$= 1.6 \times 10^{-19}$ coulomb

No. of electrons required $= \frac{20 \times 10^{-6}}{1.6 \times 10^{-19}}$

$$= \frac{20}{1.6} \times 10^{13} = 1.25 \times 10^{14}$$

8. **(b)** Let the common potential after the touch is V. So, applying conservation of charge
$10 \times 10^{-6} = V \times C_1 + V \times C_2$

$$V = \frac{10 \times 10^{-6}}{(C_1 + C_2)}$$

Charge on first sphere

$$= C_1V = \frac{10 \times 10^{-6}}{(C_1 + C_2)} \times C_1$$

Charge on second sphere

$$= C_2V = \frac{10 \times 10^{-6}}{(C_1 + C_2)} \times C_2$$

Charge densities are,

$$= \frac{10 \times 10^{-6} \times C_1}{(C_1 + C_2)4\pi r_1^2} \ \& \ \frac{10 \times 10^{-6} \times C_2}{(C_1 + C_2)4\pi r_2^2}$$

and their ratio $= \frac{C_1}{C_2} \times \frac{r_2^2}{r_1^2}$

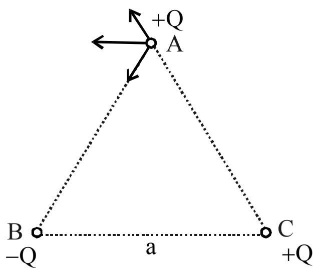
$$= \frac{4\pi \epsilon_0 r_1}{4\pi \epsilon_0 r_2} \times \frac{r_2^2}{r_1^2}$$

$$= \frac{r_2}{r_1} = \frac{20}{10} = 2 : 1$$

[Capacity of spherical capacitor $= 4\pi\epsilon_0 R$]

9. **(a)** An electric dipole placed in a non-uniform electric field experiences a torque and a net force. In a uniform field it experiences only torque.

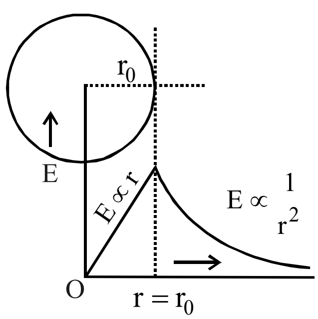
10. **(c)**



From the figure it is clear that force on Q due to charges on B and C will be as shown in the figure. Their resultant will be parallel to BC. So, their component perpendicular to BC will be zero.

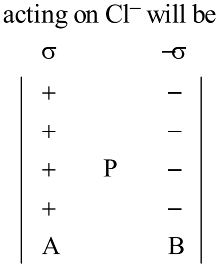
11. **(d)** Net charge inside the surface is zero. So, flux through the surface is zero.

12. **(b)** Inside a uniformly charged non-conducting sphere, charge is uniformly distributed. So, field is there. In such cases electric field is directly proportional to the distance from the centre. Outside the sphere, field is inversely proportional to (distance)^2. So, graph is as follows



13. **(d)** All Cs ions are symmetrically distributed around Cl^- so, resultant of all the forces acting on Cl^- will be zero.

14. **(c)**



Field at P due to plate, $A = \dfrac{\sigma}{2\varepsilon_0}$

Field at P due to plate, $B = \dfrac{\sigma}{2\varepsilon_0}$

Both are acting in the same direction so,

Total field $= \dfrac{2\sigma}{2\varepsilon_0} = \dfrac{\sigma}{\varepsilon_0}$

15. **(c)** Electric field inside sphere A is zero. Potential inside is uniform. If we move out of the sphere starting from centre, we find potential dropping to –ve value at the surface of B. After that it becomes zero at infinity as we take potential at infinity to be zero.

16. **(b)** Impulse = mv – mu = Change in momentum

= force × time $qE_0 \times t = qE_0 t$

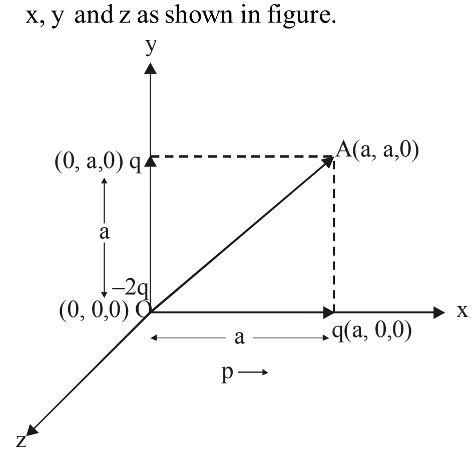
= Change in momentum

17. **(c)** Field between two parallel sheet

$$= \frac{\sigma}{\epsilon_0} = \frac{26.4 \times 10^{-12}}{8.85 \times 10^{-12}} = 3 \text{ N/C}$$

18. **(a)** A is positive as electric lines are coming out of it. B is negative as electric lines are entering into it.

19. **(b)** The given charge assembly can be represented using the three co-ordinate axes x, y and z as shown in figure.



The charge –2q is placed at the origin O. One +q charge is place at (a, 0, 0) and the other +q charge is placed at (0, a, 0). Thus the system has two dipoles along x-axis and y-axis respectively.

As the electric dipole moment is directed from the negative to the positive charge hence the resultant dipole moment will be along $\overrightarrow{OA}$ where co-ordinates of point A are (a, a, 0). The magnitude of each dipolemoment,

$p = qa$

So, the magnitude of resultant dipole moment is

$$P_R = \sqrt{p^2 + p^2} = \sqrt{(qa)^2 + (qa)^2}$$

$$= \sqrt{2}\,qa$$

20. (a) Let electric flux linked with surfaces A, B, and C are ϕ_A, ϕ_B and ϕ_C respectively.

Thus $\phi_{total} = \phi_A + \phi_B + \phi_C$

$\because \phi_A = \phi_C$

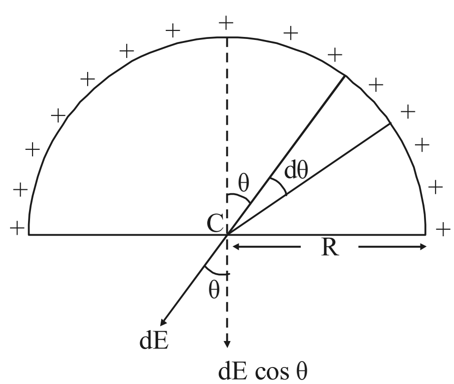
and $\phi_{total} = \dfrac{q}{\epsilon_0}$ (From Gauss's Law)

$$\therefore \frac{q}{\epsilon_0} = 2\phi_A + \phi_B \quad \text{But } \phi_B = \phi \text{ (given)}$$

Hence, $\dfrac{q}{\epsilon_0} = 2\phi_A + \phi$

or $\dfrac{q}{\epsilon_0} - \phi = 2\phi_A$ or $\phi_A = \dfrac{1}{2}\left(\dfrac{q}{\epsilon_0} - \phi\right)$

21. (a)



From figure, $d\ell = Rd\theta$

Charge on $d\ell = \lambda R d\theta$,

where λ = linear charge density.

Electric field at centre due to $d\ell$

$$dE = k.\frac{\lambda R d\theta}{R^2}$$

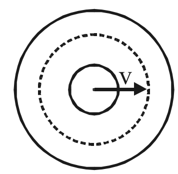
We need to consider only the component dE cos θ, as the component dE sin θ will cancel out.

$$\therefore \text{Total field at centre} = 2\int_0^{\pi/2} dE\cos\theta$$

$$= 2\int_0^{\pi/2} \frac{k\lambda R\cos\theta}{R^2}d\theta = \frac{2k\lambda}{R}\int_0^{\pi/2}\cos\theta d\theta$$

$$= \frac{q}{2\pi^2 \epsilon_0 R^2} \qquad \left(\text{since } \lambda = \frac{q}{\pi R}\right)$$

22. (c) $\int E.dx = \dfrac{Q_1}{\epsilon_0} \Rightarrow E = \dfrac{Q_1}{4\pi r^2 \epsilon_0}$



23. (d) $V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{p\cos\theta}{r^2}$

Here, $V = 1.8 \times 10^5 V$, $\theta = 60°$,

$r = 50 \times 10^{-2} = 0.5$ m

$$\therefore 1.8\times10^5 = 9\times10^9 \times \frac{p\cos 60°}{(0.5)^2}$$

$$\text{or } p = \frac{1.8\times10^5\times0.25\times2}{9\times10^9} = 10^{-5}\text{C–m}$$

24. (a) The field lines in 1 are :

(6 + 7)out – (2 + 7+ 15 + 8)in = 19 (in)

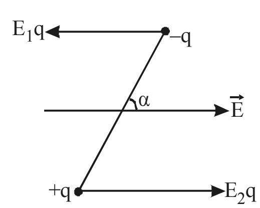
It represents negative charge.

The field lines in 2 are :

(9 + 5 + 6) out – (7+ 3 + 2) in = 8 (out)

It represents positive charge.

25. (d) The dipole is placed in a non-uniform field, therefore a force as well as a couple acts on it. The force on the negative charge is more ($F \propto E$) and is directed along negative x-axis. Thus the dipole moves along negative x-axis and rotates in an anticlockwise direction.



26. **(c)** If we take a point M on the X-axis as shown in the figure, then the net electric field is in X-direction.

$\therefore$ Option (a) is incorrect.

If we take a point N on Y-axis, we find net electric field along +X direction. The same will be true for any point on Y-axis. (c) is a correct option.

$$W_{\infty 0} = q(V_{\infty} - V_0) = q(0-0) = 0$$

$\therefore$ (b) is incorrect. The direction of dipole moment is from –ve to +ve. Therefore (d) is incorrect.

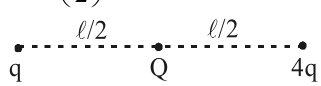
27. **(b)** The flux for both the charges exactly cancels the effect of each other.

28. **(d)** Electric displacement vector, $\vec{D} = \varepsilon\vec{E}$

As, $\varepsilon = \varepsilon_0 K$ $\quad\therefore\ \vec{D} = \varepsilon_0 K\vec{E}$

29. **(a)** $(F_{net})_q = 0$

$$\Rightarrow k\frac{Qq}{\left(\frac{\ell}{2}\right)^2} + k\frac{4q^2}{\ell^2} = 0$$



where $k = \dfrac{1}{4\pi\varepsilon_0}$

$\Rightarrow 4Qq + 4q^2 = 0$

$\Rightarrow Q = -q$

30. **(c)** Electric field, $E = -\dfrac{d\phi}{dt} = -2ar$

By Gauss's theorem $E(4\pi r^2) = \dfrac{q}{\varepsilon_0}$

$$\Rightarrow q = -8\pi\varepsilon_0 ar^3$$

$$\rho = \frac{dq}{dV} = \frac{dq}{dr} \times \frac{dr}{dV}$$

$$= (-24\pi\varepsilon_0 ar^2)\left(\frac{1}{4\pi r^2}\right) = -6\varepsilon_0 a$$

31. **(a)** We suppose that the cavity is filled up by a positive as well as negative volume charge of ρ. So the electric field now produced at P is the superposition of two electric fields.

(i) The electric field created due to the infinitely long solid cylinder is

$E_1 = \dfrac{\rho R}{4\varepsilon_0}$ directed towards the $+Y$ direction

(ii) The electric field created due to the spherical negative charge density

$E_2 = \dfrac{\rho R}{96\varepsilon_0}$ directed towards the $-Y$ direction.

$\therefore$ The net electric field is

$$E = E_1 - E_2 = \frac{1}{6}\left[\frac{23\rho R}{16\varepsilon_0}\right]$$

32. **(b)** The dipole experiences a torque pE sin θ tending to bring itself back in the direction of field.

Therefore, on being released (i.e. rotated) the dipole oscillates about an axis through its centre of mass and perpendicular to the field. If I is the moment of inertia of the dipole about the axis of rotation, then the equation of motion is

$I.d^2\theta/dt^2 = -\,pE\sin\theta$

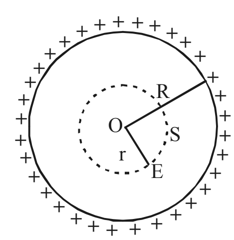
For small amplitude $\sin\theta \approx \theta$

Thus $d^2\theta/dt^2 = -(pE/I).\theta = -\omega^2\theta$

where $\omega = \sqrt{(pE/I)}$.

This is a S.H.M., whose period of oscillation is $T = 2\pi/\omega = 2\pi\sqrt{(I/pE)}$.

33. **(a)** Charge resides on the outer surface of a conducting hollow sphere of radius R. We consider a spherical surface of radius r < R. By Gauss theorem



$\int_s \vec{E}.\vec{ds} = \dfrac{1}{\varepsilon_0} \times$ charge enclosed or

$$E \times 4\pi r^2 = \frac{1}{\varepsilon_0} \times 0 \Rightarrow E = 0$$

i.e., electric field inside a hollow sphere is zero.

Type B : Assertion Reason Questions

34. (e) Direction of electric field is from region of high potential to low potential & electron or any -ve charged particle will move against the field or lower potential to higher potential.

35. (a) A metallic shield may be used to block an electric field because field inside a metallic shield is zero.

36. (b) Electric lines of force never cross each other. Electric field at a point add up vectorally to give one resultant electric field. So, they do not have independent existence at the point of superposition so, electric lines of force do not cross each other (crossing of electric lines of force at a point means at a point two fields are having independent existence).

37. (d) Gravitational force is the dominating force in the universe so Assertion is incorrect. Gravitational force is weaker than Coulombic force so, Reason is incorrect.

38. (a) Net field inside the conductor is zero because by virtue of induced charges, applied and induced electric fields are equal and opposite thus the net charge resides on surface only. If any cavity is there inside the conductor, electric field will be zero in it.

39. (d) Electric field at any point depends on presence of all charges.

40. (b) If +ve charge is displaced along x-axis, then net force will always act in a direction opposite to that of displacement and the test charge will always come back to its original position.

41. (c) $q_d = e,\ m_d = 2m_p = 2m$

$q_\alpha = 2e,\ m_\alpha = 4m_p = 4m$

$F_1 = F_\alpha = eE,\ F_2 = F_\alpha = 2eE \neq F_1$

Further, $a_1 = \dfrac{F_1}{2m} = \dfrac{eE}{2m}$

and $a_2 = \dfrac{F_2}{2m} = \dfrac{2eE}{4m} = \dfrac{eE}{2m} = a_1$

42. (a)

43. (d) No. of lines entering the surface = No. of lines leaving the surface.

Chapter 16

Electrostatic Potential and Capacitance

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A condenser of capacitor $50\mu F$ is charged to 10 volt, the energy stored is : ***[1997]***

(a) 5×10^{-3} J (b) 2.5×10^{-3} J

(c) 3.75×10^{-3} J (d) 1.25×10^{-3} J

2. If the sep aration between the plates of a capacitor is 5 mm, then the area of the plate of a 3F parallel plate capacitor is : ***[1998]***

(a) $4.259\times10^{9}\ m^2$ (b) $1.964\times10^{9}\ m^2$

(c) $12.81\times10^{9}\ m^2$ (d) $1.964\times10^{9}\ m^2$

3. Minimum numbers of $8\mu F$ and 250 V capacitors are used to make a combination of $16\mu F$ and 1000V are: ***[2000]***

(a) 4 (b) 32

(c) 8 (d) 3

4. An insulated charged sphere of radius 5 cm has a potential of 10 V at the surface. The potential at the centre will be ***[2000]***

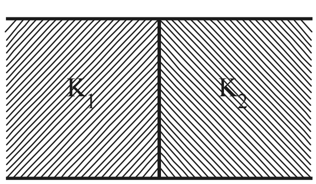
(a) same as that at 5 cm from the surface

(b) same as that at 25 cm from the surface

(c) 10 V

(d) zero

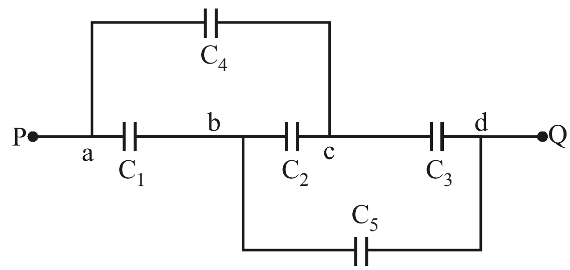
5. Two materials having the dielectric constants K_1 and K_2 are filled between two parallel plates of a capacitor, which is shown in figure. The capacity of the capacitor is : ***[2001]***



(a) $\dfrac{A\varepsilon_0(K_1\times K_2)}{d(K_1+K_2)}$ A (b) $\dfrac{A\varepsilon_0(K_1-K_2)}{d}$

(c) $\dfrac{A\varepsilon_0K_1K_2}{(K_1+K_2)}$ (d) $\dfrac{A\varepsilon_0(K_1+K_2)}{d}$

6. The capacitors C_1, C_3, C_4, C_5 have a capacitance $4\mu F$ each and C_2 has capacitance $10\mu F$. The effective capacitance between P and Q will be :



(a) $8\ \mu F$ (b) $6\ \mu F$ ***[2002]***

(c) $4\ \mu F$ (d) $2\ \mu F$

7. A $40\ \mu F$ capacitor in a defibrillator is charged to 3000 V. The energy stored in the capacitor is set through the patient during a pulse of duration 2 ms. The power delivered to the patient is : ***[2004]***

(a) 45 kW (b) 90 kW

(c) 180 kW (d) 360 kW

8. Equipotential surfaces associated with an electric field which is increasing in magnitude along the x-direction are : ***[2004]***

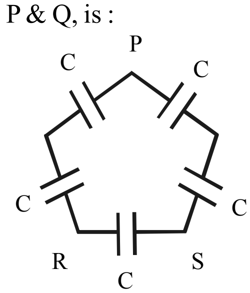
(a) planes parallel to yz-plane

(b) planes parallel to xy-plane

(c) planes parallel to xz -plane

(d) coaxial cylinders of increasing radii around the x-axis

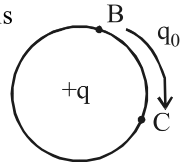
9. Five capacitors, each of capacitance value C are connected as shown in the figure. The ratio of capacitance between P & R, and the capacitance between P & Q, is : ***[2006]***



(a) 3 : 1 (b) 5 : 2

(c) 2 : 3 (4) 1 : 1

10. A circle of radius R is drawn with charge + q at the centre. A charge q_0 is brought from point B to C, then work done is ***[2009]***



(a) positive
(b) negative
(c) zero
(d) infinite

11. A parallel plate air capacitor has a capacitance *C*. When it is half filled with a dielectric of dielectric constant 5, the percentage increase in the capacitance will be ***[2009]***

(a) 400% (b) 66.6%
(c) 33.3% (d) 200%

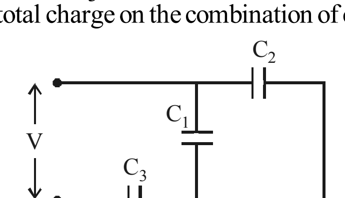
12. A capacitor is charged by using a battery which is then disconnected. A dielectric slab is introduced between the plates which results in

(a) increase in the potential difference across the plates and reduction in stored energy but no change in the charge on the plates
(b) decrease in the potential difference across the plates and reduction in the stored energy but no change in the charge on the plates
(c) reduction of charge on the plates and increase of potential difference across the plates
(d) increase in stored energy but no change in potential difference across the plates ***[2010]***

13. The maximum electric field that can be held in air without producing ionisation of air is 10^7 V/m. The maximum potential therefore, to which a conducting sphere of radius 0.10 m can be charged in air is ***[2010]***

(a) 10^9 V (b) 10^8 V
(c) 10^7 V (d) 10^6 V

14. Three capacitors C_1, C_2 and C_3 are connected as shown in the figure to a battery of V volt. If the capacitor C_3 breaks down electrically the change in total charge on the combination of capacitors is ***[2010]***



(a) $(C_1 + C_2)$ V $[1 - C_3/(C_1 + C_2 + C_3)]$
(b) $(C_1 + C_2)$ V $[1-(C_1 + C_2)/(C_1 + C_2 + C_3)]$
(c) $(C_1 + C_2)$ V $[1+ C_3/(C_1 + C_2 + C_3)]$
(d) $(C_1 + C_2)$ V $[1- C_2/(C_1 + C_2 + C_3)]$

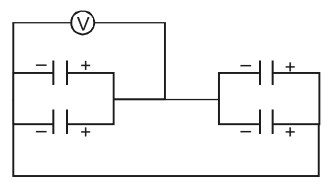
15. Two charges of magnitude + q and – 3q are placed 100 cm apart. The distance from + q between the charges where the electrostatic potential is zero is : ***[2011]***

(a) 25 cm (b) 50 cm
(c) 75 cm (d) 80 cm

16. If a dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$, then torque acting on it is given by ***[2012]***

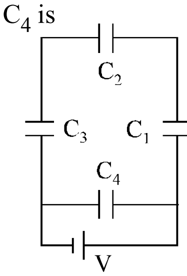
(a) $\vec{\tau} = \vec{p}.\vec{E}$ (b) $\vec{\tau} = \vec{p} \times \vec{E}$
(c) $\vec{\tau} = \vec{p} + \vec{E}$ (d) $\vec{\tau} = \vec{p} - \vec{E}$

17. The four capacitors, each of 25 μ F are connected as shown in Fig. The dc voltmeter reads 200 V. The charge on each plate of capacitor is ***[2012]***



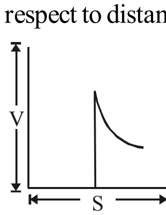
(a) $\pm 2 \times 10^{-3}$ C (b) $\pm 5 \times 10^{-3}$ C
(c) $\pm 2 \times 10^{-2}$ C (d) $\pm 5 \times 10^{-2}$ C

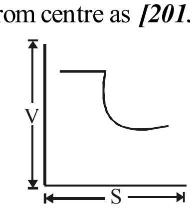
18. A network of four capacitors of capacity equal to $C_1 = C, C_2 = 2C, C_3 = 3C$ and $C_4 = 4C$ are conducted to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is ***[2012]***

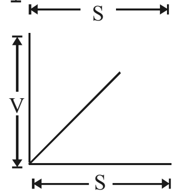


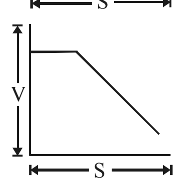
(a) 4/7
(b) 3/22
(c) 7/4
(d) 22/3

19. In a hollow spherical shell, potential (V) changes with respect to distance (s) from centre as ***[2013]***

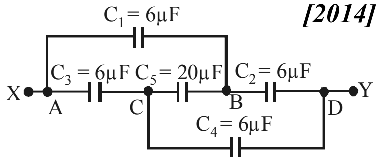
(a)


(b)


(c)


(d)


20. What is the effective capacitance between points X and Y? *[2014]*



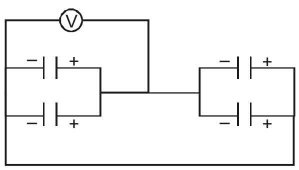
(a) 24 μF

(b) 18 μF

(c) 12 μF

(d) 6 μF

21. The four capacitors, each of 25 m F are connected as shown in fig. The dc voltmeter reads 200 V. The charge on each plate of capacitor is *[2015]*



(a) $\pm 2 \times 10^{-3}$C (b) $\pm 5 \times 10^{-3}$C

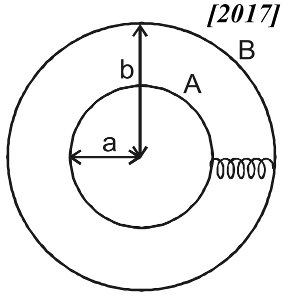
(c) $\pm 2 \times 10^{-2}$C (d) $\pm 5 \times 10^{-2}$C

22. A charge +q is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$, ... upto ∞ on X-axis and charge –q is fixed on each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$, ... upto ∞. Here x_0 is a positive constant. Take the potential at a point due to a charge Q at a distance r from it to be $\frac{Q}{4\pi\varepsilon_0 r}$. Then the potential at the origin due to above system of charges will be *[2016]*

(a) zero (b) $\frac{q}{8\pi\varepsilon_0 x_0 \log_e 2}$

(c) infinity (d) $\frac{q \log_e 2}{4\pi\varepsilon_0 x_0}$

23. Two spherical conductors A and B of radii a and b (b>a) are placed concentrically in air. The two are connected by a copper wire as shown in figure. Then the equivalent capacitance of the system is *[2017]*



(a) $4\pi\varepsilon_0 \frac{ab}{b-a}$

(b) $4\pi\varepsilon_0 (a+b)$

(c) $4\pi\varepsilon_0 b$

(d) $4\pi\varepsilon_0 a$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 24-26) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

24. **Assertion :** If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.

Reason : Capacity of the capacitor does not depend upon the nature of the material. *[1997]*

25. **Assertion :** If three capacitors of capacitances $C_1 < C_2 < C_3$ are connected in parallel then their equivalent capacitance $C_P > C_S$.

Reason : $\frac{1}{C_p} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ *[2002]*

26. **Assertion :** A parallel plate capacitor is connected across battery through a key. A dielectric slab of dielectric constant K is introduced between the plates. The energy which is stored becomes K times. *[2008]*

Reason : The surface density of charge onthe plate remains constant or unchanged.

Directions for (Qs. 27-33) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

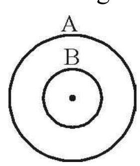
27. **Assertion :** The total charge stored in a capacitor is zero.

Reason : The field just outside the capacitor is $\frac{\sigma}{\varepsilon_0}$. ($\sigma$ is the charge density). ***[2009]***

28. **Assertion :** The electrostatic force between the plates of a charged isolated capacitor decreases when dielectric fills whole space between plates.

Reason : The electric field between the plates of a charged isolated capacitance increases when dielectric fills whole space between plates. ***[2009]***

29. **Assertion :** Two concentric charged shells are given. The potential difference between the shells depends on charge of inner shell.

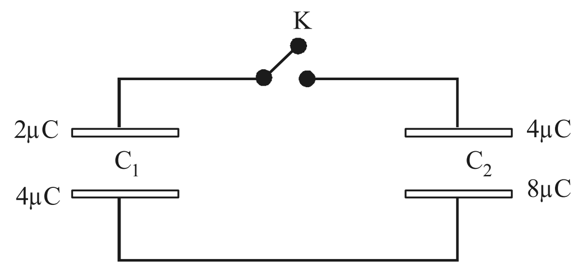


Reason : Potential due to charge of outer shell remains same at every point inside the sphere. ***[2010]***

30. **Assertion :** Two equipotential surfaces cannot cut each other.

Reason : Two equipotential surfaces are parallel to each other. ***[2011]***

31. **Assertion :** Charges are given to plates of two plane parallel plate capacitors C_1 and C_2 (such that $C_2 = 2C_1$) as shown in figure. Then the key K is pressed to complete the circuit. Finally the net charge on upper plate and net charge the circuit. Finally the net charge on upper plate and net charge on lower plate of capacitor C_1 is positive.



Reason : In a parallel plate capacitor both plates always carry equal and opposite charge. ***[2012]***

32. **Assertion :** For a non-uniformly charged thin circular ring with net charge is zero, the electric field at any point on axis of the ring is zero.

Reason : For a non-uniformly charged thin circular ring with net charge zero, the electric potential at each point on axis of the ring is zero. ***[2015]***

33. **Assertion :** Electric potential and electric potential energy are different quantities.

Reason : For a system of positive test charge and point charge electric potential energy = electric potential. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** Energy of condenser $= \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times CV^2$

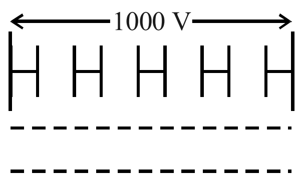
$= \frac{1}{2} \times 50 \times 10^{-6} \times 10 \times 10 = 2.5 \times 10^{-3}$ joule

2. **(d)** $C = \frac{A \in_0}{d} \Rightarrow 3 = \frac{A \times 8.85 \times 10^{-12}}{0.005}$

$A = \frac{0.015}{8.85 \times 10^{-12}} = \frac{15 \times 10^{-3} \times 10^{12}}{8.85}$

$= 1.694 \times 10^9\ m^2$

3. **(b)**



To create 1000 V, we need to combine 4 capacitors in series. Total capacity becomes $= \frac{8\mu F}{4} = 2\mu F$. In order to obtain capacity of $16\mu F$, 8 rows of this combination will be needed in parallel.

Total capacity $= 2\mu F \times 8 = 16\mu F$

Total number of capacitor $= 4 \times 8 = 32$

4. **(c)** We know that in case of hollow sphere potential at the surface is equal to potential at the centre. So potential at the centre will be 10 V.

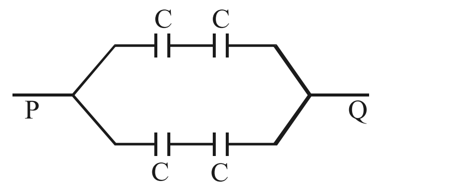
5. **(d)** Capacity of Ist capacitor, $C_1 = \frac{\in_0 AK_1}{d}$

Capacity of 2nd capacitor, $C_2 = \frac{\in_0 AK_2}{d}$

Both of these capacitors are parallel so, total capacity, $C = C_1 + C_2 = \frac{\in_0 A}{d}(K_1 + K_2)$

6. **(c)** The combination forms Wheatstone bridge as $\frac{C_1}{C_4} = \frac{C_5}{C_3}$

So, central capacitor, that is C_2 becomes ineffective. Now equivalent circuit will become as follows.



Now, two C are in series, their equivalent capacity

$= \frac{C^2}{2C} = \frac{C}{2}$ and then two $\frac{C}{2}$ are in parallel so their equivalent capacity will be

$= \frac{C}{2} + \frac{C}{2} = C$

So, total capacity $= C = 4\mu F$

7. **(b)** Energy given during this time period

$= \frac{1}{2}CV^2 = \frac{1}{2} \times 40 \times 10^{-6} \times 3000 \times 3000$

$= 2 \times 9 \times 10$ joule

Power $= \frac{\text{Work}}{\text{Time}} = \frac{90 \times 2}{2 \times 10^{-3}} = 90 \times 10^3$ W

$= 90$ kW

8. **(a)** Equipotential surface is always perpendicular to the direction of electric field. As the field is along x-direction, equipotential surface must be parallel to yz-plane.

9. **(c)** In the first case, 3C and 2C are parallel. Equivalent capacitance is,

$\frac{C}{3} + \frac{C}{2} = \frac{5C}{6}$

In the second case 1C & 4C are parallel.

Equivalent capacitance $= \frac{C}{1} + \frac{C}{4} = \frac{5C}{4}$

Ratio $= \frac{5C}{6} \times \frac{4}{5C} = 2:3$

10. **(c)** Circle represents equipotential surface

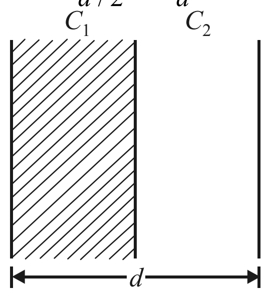
$\therefore$ work done around it $= 0$

11. **(b)** Initial capacitance $= \frac{\in_0 A}{d}$

When it is half filled by a dielectric of dielectric constant K, then

$$C_1 = \frac{K\varepsilon_0 A}{d/2} = 2K\frac{\varepsilon_0 A}{d}$$

and $C_2 = \dfrac{\varepsilon_0 A}{d/2} = \dfrac{2\varepsilon_0 A}{d}$



$$\therefore\ \frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K}+1\right)$$

$$= \frac{d}{2\varepsilon_0 A}\left(\frac{1}{5}+1\right) = \frac{6}{10}\frac{d}{\varepsilon_0 A}$$

$$C' = \frac{5\varepsilon_0 A}{3d}$$

Hence, % increase in capacitance

$$= \left(\frac{\frac{5}{3}\frac{\varepsilon_0 A}{d} - \frac{\varepsilon_0 A}{d}}{\frac{\varepsilon_0 A}{d}}\right) \times 100$$

$$= \left(\frac{5}{3} - 1\right) \times 100 = \frac{2}{3} \times 100 = 66.6\%$$

12. **(b)** If a dielectric slab of dielectric constant K is filled in between the plates of a capacitor after charging the capacitor (i.e., after removing the connection of battery with the plates of capacitor) the potential difference between the plates reduces to $\frac{1}{K}$ times and the potential energy of capacitor reduces to $\frac{1}{K}$ times but there is no change in the charge on the plates.

13. **(d)** $E = 10^7$ V/m

$r = 0.10$ m

$$E = \frac{V}{r}$$

$$V = Er = 10^7 \times \frac{10}{100}$$

$$V = 10^6 \text{ V}$$

14. **(a)** Equivalent capacitance of circuit,

$$\frac{1}{C_{eq}} = \frac{1}{C_3} + \frac{1}{C_1 + C_2}$$

(Since C_1 and C_2 are in parallel and which is in series with C_3).

$$\text{ie, } \frac{1}{C_{eq}} = \frac{C_1 + C_2 + C_3}{C_3(C_1 + C_2)}$$

$$\therefore\ C_{eq} = \frac{C_3(C_1 + C_2)}{C_1 + C_2 + C_3}$$

Since V is the voltage of battery,

charge, $q = C_{eq}V$

$$= \frac{C_3(C_1 + C_2)V}{C_1 + C_2 + C_3}$$

If the capacitor C_3 breaks down, then effective capacitance,

$$C'_{eq} = C_1 + C_2$$

$\therefore$ New charge q' =

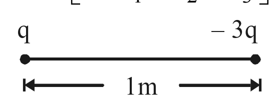
$$C'_{eq}V = (C_1 + C_2)V$$

Change in total charge = q' – q

$$= (C_1 + C_2)V - \frac{C_3(C_1 + C_2)V}{C_1 + C_2 + C_3}$$

$$= (C_1 + C_2)V\left[1 - \frac{C_3}{C_1 + C_2 + C_3}\right]$$

15. **(a)**



Suppose x is the required distance from q, then

$$\frac{1}{4\pi\varepsilon_0}\left[\frac{9}{x} + \frac{(-3q)}{1-x}\right] = 0$$

After solving for x, we get $x = \frac{1}{4}$ m

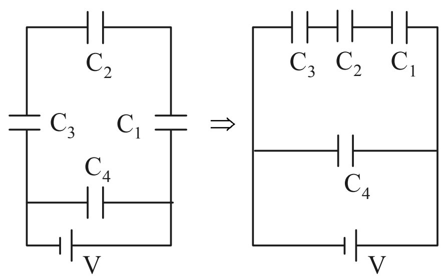
16. **(b)** **Given :** Dipole moment of the dipole = $\vec{p}$ and uniform electric field = $\vec{E}$. We know that dipole moment (p) = q.a (where q is the charge and a is dipole length). And when a dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$, then Torque (τ) = Either force × perpendicular distance between the two forces = qaEsinθ or $\tau = pE\sin\theta$ or $\vec{\tau} = \vec{p} \times \vec{E}$ (vector form)

17. (b) Charge on each plate of each capacitor

$Q = \pm CV = \pm 25 \times 10^6 \times 200$

$= \pm 5 \times 10^{-3}\,C$

18. (b)



Equivalent capacitance for three capacitors (C_1, C_2 & C_3) in series is given by

$$\frac{1}{C_{eq.}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{C_2C_3 + C_3C_1 + C_1C_2}{C_1C_2C_3}$$

$\Rightarrow$

$$C_{eq.} = \frac{C_1C_2C_3}{C_1C_2 + C_2C_3 + C_3C_1}$$

$$\Rightarrow C_{eq.} = \frac{C(2C)(3C)}{C(2C) + (2C)(3C) + (3C)C} = \frac{6}{11}C$$

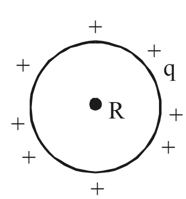
$\Rightarrow$ Charge on capacitors (C_1, C_2 & C_3)

in series $= C_{eq}V = \frac{6C}{11}V$

Charge on capacitor $C_4 = C_4V = 4C\,V$

$$\frac{\text{Charge on } C_2}{\text{Charge on } C_4} = \frac{\frac{6C}{11}V}{4CV} = \frac{6}{11} \times \frac{1}{4} = \frac{3}{22}$$

19. (b) In shell, q charge is uniformly distributed over its surface, it behaves as a conductor.

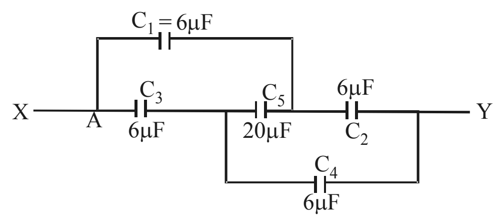


V= potential at surface $= \frac{q}{4\pi\varepsilon_0 R}$ and

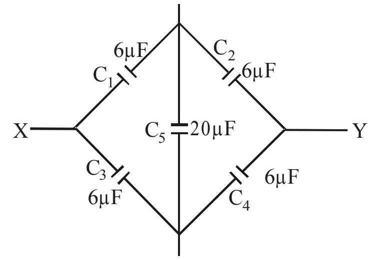
inside $V = \frac{q}{4\pi\varepsilon_0 R}$

Because of this it behaves as an equipotential surface.

20. (d)

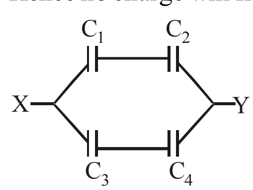


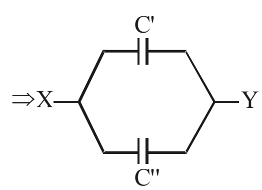
Equivalent circuit



As $\frac{C_1}{C_3} = \frac{C_2}{C_4}$

Hence no charge will flow through $20\mu F$





C_1 and C_2 are in series, also C_3 and C_4 are in series.

Hence $C' = 3\ \mu F$, $C'' = 3\ \mu F$

C' and C'' are in parallel hence net capacitance

$= C' + C'' = 3 + 3 = 6\ \mu F$

21. (b) Charge on each plate of each capacitor

$Q = \pm CV = \pm 25 \times 10^6 \times 200$

$= \pm 5 \times 10^{-3}\,C$

22. (d) Potential at origin

$= (V_1 + V_3 + V_5 + ...) - (V_2 + V_4 + V_6 + ...)$

$$\Rightarrow \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x_0} - \frac{1}{2x_0} + \frac{1}{3x_0} .....\infty\right]$$

$$\Rightarrow \frac{q}{4\pi\varepsilon_0 x_0}\left[1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}.....\infty\right]$$

$$\Rightarrow \frac{q}{4\pi\varepsilon_0 x_0}\log_e(1+1) \Rightarrow \frac{q}{4\pi\varepsilon_0 x_0}\log_e 2$$

23. **(c)** All the charge given to inner sphere will pass on to the outer one. So capacitance that of outer one is $4\pi \in_0 b$.

Type B : Assertion Reason Questions

24. **(c)** We know that capacity of capacitor is directly proportional to dielectric constant and inversely proportional to distance. So, the net effect of making distance halved & making dielectric constant three times will be capacity becoming six times.
As nature of the material (dielectric constant) is a factor influencing the capacity, therefore, Reason is incorrect.

25. **(c)** If three capacitors are joined in parallel then their equivalent capacitor will be less than the least value of capacitor so

$C_p > C_s$

$\frac{1}{C_p} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ is incorrect.

26. **(c)** In the given cases, $V = V_0$ (remains constant).

Energy stored inthe capacitor $U = \frac{1}{2}CV^2$

When a dielectric slab of dielectric constant K is introduced between the plates of the condenser, then $C \longrightarrow KC$

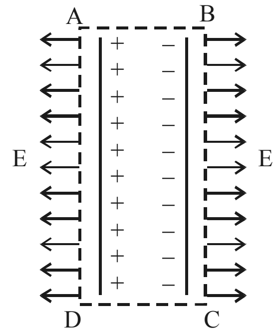
So energy stored will become K times .

Since $Q = CV$, So Q will become K times

$\therefore$ Surface charge density

$$\sigma' = \frac{KQ}{A} = K\sigma_0$$

27. **(c)** Charge stored on the two plates are + Q and –Q $\Rightarrow Q + (-Q) = 0$ and hence Assertion is correct. The field however, outside the plates is zero.



Draw a Gaussian surface ABCD as shown.

The field $\vec{E}$ is uniform on faces AD and BC

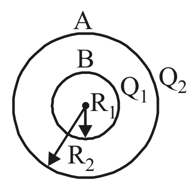
$\Rightarrow \oint \vec{E}.ds = 0$ yields $\vec{E} = 0$.

28. **(d)** For isolated capacitor Q = constant, F = constant.

But $E = \frac{\sigma}{K \in_0}$, hence E decreases.

$\therefore$ Assertion is incorrect and Reason is correct.

29. **(a)**



$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{Q_1+Q_2}{R_2}$$

$$V_B = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{R_1}+\frac{Q_2}{R_2}\right)$$

$$V_B - V_A = \frac{1}{4\pi\varepsilon_0}Q_1\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

30. **(c)** Two equipotential surfaces are not necessarily parallel to each other.

31. **(d)** Charge distribution on each surface makes both capacitor of same potential difference hence charge will not flow.

32. **(d)** For a non-uniformly charged thin circular ring with net zero charge, electric potential at each point on its axis is zero. Hence electric field at each point on its axis must be perpendicular to the axis. Therefore Assertion is incorrect and Reason is correct.

33. **(c)** Potential and potential energy are different quantities and cannot be equated.

Chapter **17**

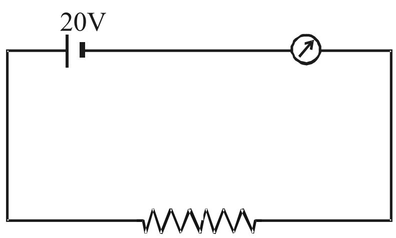
Current Electricity

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A wire of radius r has resistance R. If it is stretched to a radius $\frac{r}{2}$, its resistance will be : ***[1997]***

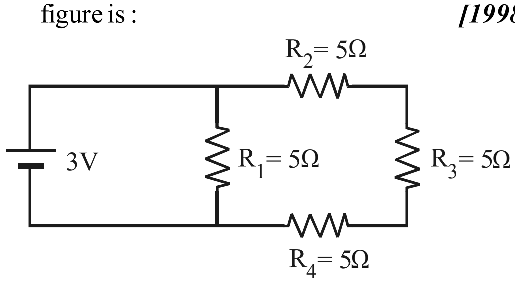
(a) 16R (b) 2R
(c) 4R (d) zero

2. A battery of e.m.f. 20 V and internal resistance 6Ω is connected to a resistor as shown in figure. If the current in the circuit is 1 amp, the resistance of the resistor will be : ***[1997]***



(a) 14Ω (b) 16Ω
(c) 28Ω (d) 7Ω

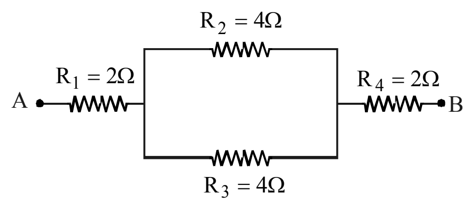
3. The value of current i in the circuit as shown in figure is : ***[1998]***



(a) 1.8 A (b) 0.8 A
(c) 0.2 A (d) 1.6 A

4. Electroplating is not provided to be used for ***[1998]***
(a) shinning appearance
(b) protection of metal against corrosion
(c) fine finishing to the surface
(d) hardening the metals

5. In the given figure, the equivalent resistance between two points A and B will be: ***[1999]***

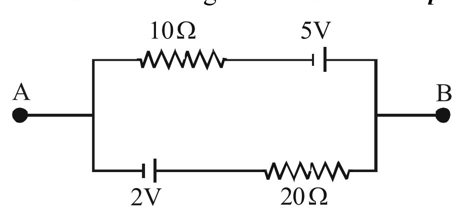


(a) 4 Ω (b) 2 Ω
(c) 8 Ω (d) 6 Ω

6. Two filaments of same length are connected first in series then in parallel. For the same amount of main current flowing, the ratio of the heat produced is: ***[1999]***
(a) 1 : 2 (b) 4 : 1
(c) 1 : 4 (d) 2 : 1

7. Given a current carrying wire of non-uniform cross-section. Which one of the following is constant throughout the length of wire ? ***[2000]***
(a) current only
(b) current and drift speed
(c) drift speed only
(d) current, electric field and drift speed

8. The current in the given circuit is : ***[2000]***



(a) 0.3 amp (b) 0.4 amp
(c) 0.1 amp (d) 0.2 amp

9. Same length of two identical wires are first connected is series and then in parallel, then the amount of heat produced in both the conditions are in the ratio : ***[2000]***
(a) 1 : 4 (b) 4 : 1
(c) 3 : 1 (d) 1 : 2

10. The temperature of the cold junction of a thermocouple is 0°C and the temperature of the hot junction is T°C. The relation for the thermo emf is given by; $E = AT - \frac{1}{2}BT^2$

(when A = 16 and B = 0.08). The temperature of inversion will be : ***[2001]***

(a) 500°C (b) 460°C
(c) 600°C (d) 400°C

11. The cell has an emf of 2V and the internal resistance of this cell is 0.1Ω, it is connected to a resistance of 3.9Ω. The voltage across the cell will be : ***[2001]***

(a) 1.95 V (b) 1.5 V
(c) 2 V (d) 1.8 V

12. The internal resistance of a cell is the resistance of:

(a) electrolyte used in the cell ***[2001]***
(b) electrodes of the cell
(c) vessel of the cell
(d) none of these

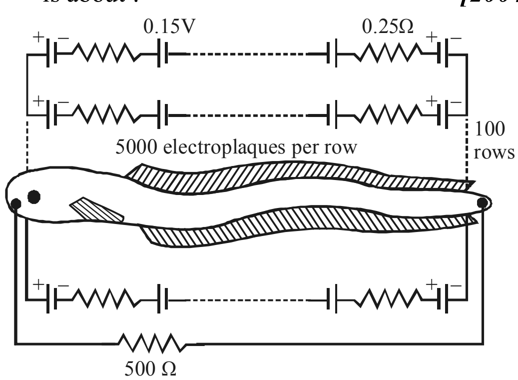
13. An electric bulb marked 40 W and 200V, is used in a circuit of supply voltage 100V. Now its power is ***[2002]***

(a) 10 W (b) 20 W
(c) 40 W (d) 100 W

14. A wire of length L is drawn such that its diameter is reduced to half of its original diameter. If the initial resistance of the wire were 10 Ω, its new resistance would be : ***[2003]***

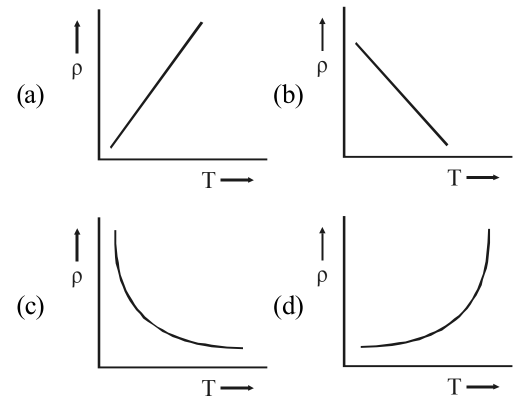
(a) 40 Ω (b) 80 Ω
(c) 120 Ω (d) 160 Ω

15. Eels are able to generate current with biological cells called electroplaques. The electroplaques is an eel are arranged in 100 rows, each row stretching horizontally along the body of the fish containing 5000 electroplaques. The arrangement is suggestively shown below. Each electroplaque has an emf of 0.15 V and internal resistance of 0.25 Ω. The water surrounding the eel completes a circuit between the head and its tail. If the water surrounding it has a resistance of 500 Ω, the current an eel can produce in water is about : ***[2004]***

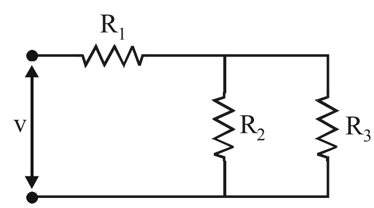


(a) 1.5 A (b) 3.0 A
(c) 15 A (d) 300 A

16. The temperature (T) dependence of resistivity (ρ) of a semi-conductor is represented by : ***[2004]***



17. For ensuring dissipation of same energy in all three resistors (R_1, R_2, R_3) connected as shown in figure, their values must be related as ***[2005]***



(a) $R_1 = R_2 = R_3$
(b) $R_2 = R_3$ and $R_1 = 4R_2$
(c) $R_2 = R_3$ and $R_1 = (1/4)R_2$
(d) $R_1 = R_2 + R_3$

18. The voltage of clouds is 4×10^6 volt with respect to round. In a lighteing strike lasting 100 m sec, a charge of 4 coulombs is delivered to the ground. The power of lightening strike is : ***[2006]***

(a) 160 MW (b) 80 MW
(c) 20 MW (d) 500 KW

19. Faraday law of electrolysis indirectly shows

(a) quantisation of charge ***[2007]***
(b) quantisation of angular momentum
(c) quantisation of current
(d) quantisation of viscosity

20. Two sources of equal emf are connected to an external resistance R. The internal resistance of the two sources are R_1 and R_2 ($R_2 > R_1$). If the potential difference across the source having internal resistance R_2 is zero, then ***[2008]***

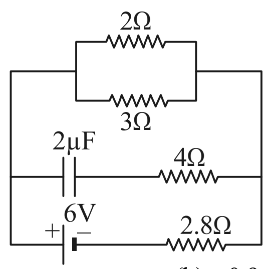
(a) $R = R_2 - R_1$

(b) $R = R_2 \times (R_1 + R_2)/(R_2 - R_1)$

(c) $R = R_1R_2/(R_2 - R_1)$

(d) $R = R_1R_2/(R_1 - R_2)$

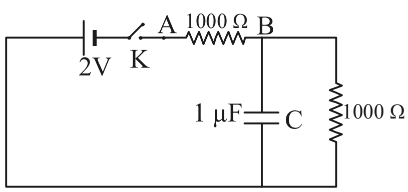
21. In the figure shown, the capacity of the condenser C is 2μF. The current in 2Ω resistance is ***[2008]***



(a) 9A (b) 0.9 A

(c) $\frac{1}{9}$A (d) $\frac{1}{0.9}$A

22. When the key K is passed at t = 0, which of the following statements about the current I in the resistor AB of the given circuit is ture? ***[2008]***



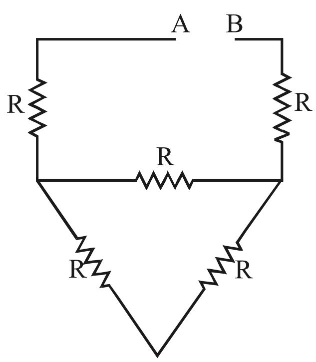
(a) I = 2 mA at all t

(b) I oscillates between 1 m A and 2 mA

(c) I = 1 mA at all t

(d) At t = 0, I = 2mA and with time it goes to 1 mA

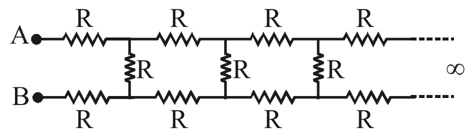
23. What is the equivalent resistance across A and B in the figure shown, if R = 3Ω? ***[2009]***



(a) 9Ω (b) 12Ω

(c) 15Ω (d) 8Ω

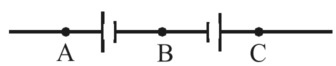
24. The resistance between points A and B is ***[2009]***



(a) $\left(\sqrt{3}+1\right)R$ (b) $\left(\sqrt{3}-1\right)R$

(c) 4R (d) $\left(\sqrt{3}+2\right)R$

25. A potentiometer is connected between A and B and the balance point is obtained at 203. 6 cm. When the end of the potentiometer connected to B is shifted to C, then the balance point is obtained at 24.6 cm. If now the potentiometer be connected between B and C, the balance point will be at



(a) 179. 0 cm (b) 197.2 cm ***[2010]***

(c) 212.0 cm (d) 228.0 cm

26. Four wires of the same diameter are connected in turn between two points, maintained at a constant potential difference. Their resistivities are; ρ and L (wire 1)., 1.2ρ and 1.2 L (wire 2), 0.9 ρ and 0.9L (wire 3) and ρ and 1.5 L (wire 4). Rank the wires according to the rates at which energy is dissipated as heat, greatest first ***[2010]***

(a) 4 > 3 > 1 > 2 (b) 4 > 2 > 1 > 3

(c) 1 > 2 > 3 > 4 (d) 3 > 1 > 2 > 4

27. The resistance of a galvanometer is 50 Ω and current required to give full scale deflection is 100 μA in order to convert it into an ammeter for reading upto 10 A. It is necessary to put an resistance of ***[2010]***

(a) $3.5 \times 10^{-4}\,\Omega$ (b) $10 \times 10^{-4}\,\Omega$

(c) $2.5 \times 10^{-4}\,\Omega$ (d) $5 \times 10^{-4}\,\Omega$

28. Two resistances equal at 0° C with temperature coefficient of resistance α_1 and α_2 joined in series act as a single resistance in a circuit. The temperature coefficient of their single resistance will be : ***[2011]***

(a) $\alpha_1 + \alpha_2$ (b) $\dfrac{\alpha_1\alpha_2}{\alpha_1 + \alpha_2}$

(c) $\dfrac{\alpha_1 - \alpha_2}{2}$ (d) $\dfrac{\alpha_1 + \alpha_2}{2}$

29. When the power delivered by a 100 volt battery is 40 watts the equivalent resistance of the circuit is : *[2011]*

(a) 100 ohms (b) 250 ohms
(c) 300 ohms (d) 350 ohms

30. The electro-chemical equivalent of a substance is numerically equal to the mass of the substance deposited if a current I flows through the electrolyte for 0.25 seconds. The value of I is : *[2011]*

(a) 1 A (b) 2 A
(c) 3 A (d) 4 A

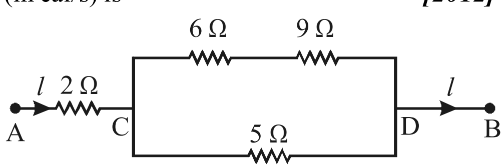
31. Two wires of same metal have the same length but their cross sections are in the ratio 3 : 1. They are joined in series. The resistance of the thicker wire is 10 Ω. The total resistance of the combination is *[2012]*

(a) 5/2 Ω (b) 40/3 Ω
(c) 40 Ω (d) 100 Ω

32. A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is developed in it. The heat developed is double if *[2012]*

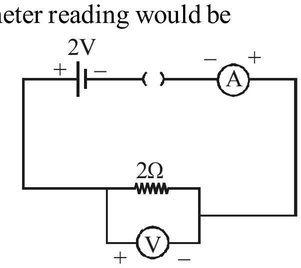
(a) both the length and radius of wire are halved
(b) both length and radius of wire are doubled
(c) the radius of wire is doubled
(d) the length of the wire is doubled

33. In the circuit shown in figure, the 5Ω resistance develops 20.00 cal/s due to the current flowing through it. The heat developed in 2Ω resistance (in cal/s) is *[2012]*

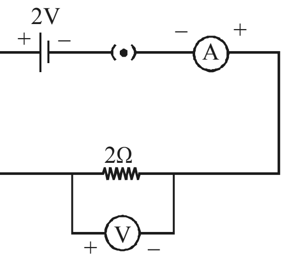


(a) 23.8 (b) 14.2
(c) 11.9 (d) 7.1

34. For the circuits shown in figures I and II, the voltmeter reading would be *[2012]*



(I)



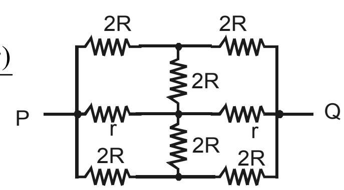
(II)

(a) 2 V in circuit I and 0 V in circuit II
(b) 0 V in both circuits
(c) 2 V in both circuits
(d) 0 V in circuit I and 2 V in circuit II

35. Three copper wires of lengths and cross sectional areas are (ℓ, A), (2 ℓ, A/2) and (ℓ/2, 2A). Resistance is minimum in *[2013, 2017]*

(a) wire of cross-sectional area A/2
(b) wire of cross-sectional area A
(c) wire of cross-sectional area 2A
(d) same in all the three cases

36. The effective resistance between points P and Q of the electrical circuit shown in the figure is *[2013]*



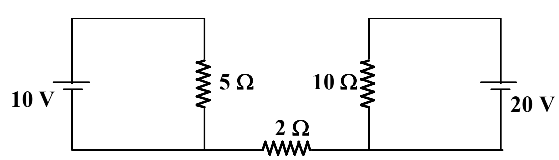
(a) $\dfrac{2Rr}{R+r}$

(b) $\dfrac{8R(R+r)}{3R+r}$

(c) $2r+4R$

(d) $\dfrac{5R}{2}+2r$

37. Find out the value of current through 2Ω resistance for the given circuit *[2014]*

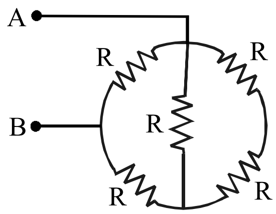


(a) zero (b) 2 A
(c) 5 A (d) 4 A

38. The cold junction of a thermocouple is maintained at 10ºC. No thermo e.m.f. is developed when the hot junction is maintained at 530ºC. The neutral temperature is *[2014]*

(a) 260ºC (b) 265ºC
(c) 270ºC (d) 520ºC

39. The equivalent resistance between A and B is **[2015]**



(a) $\frac{8R}{5}$ (b) $\frac{5R}{8}$

(c) $\frac{3R}{8}$ (d) $\frac{7R}{8}$

40. A potentiometer wire, 10 m long, has a resistance of 40Ω. It is connected in series with a resistance box and a 2 V storage cell. If the potential gradient along the wire is 0.1 m V/cm, the resistance unplugged in the box is **[2015]**

(a) 260 Ω (b) 760 Ω

(c) 960 Ω (d) 1060 Ω

41. A current source drives a current in a coil of resistance R_1 for a time t. The same source drives current in another coil of resistance R_2 for same time. If heat generated is same, find internal resistance of source. **[2016]**

(a) $\frac{R_1R_2}{R_1+R_2}$ (b) R_1+R_2

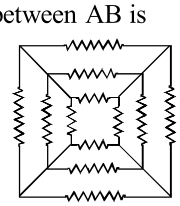
(c) zero (d) $\sqrt{R_1R_2}$

42. Two long conductors, separated by a distance d carry current I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to 3d. The new value of the force between them is **[2016]**

(a) $-\frac{2F}{3}$ (b) $\frac{F}{3}$

(c) –2 F (d) $-\frac{F}{3}$

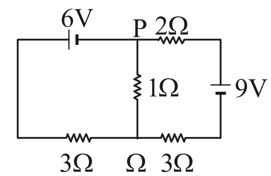
43. Twelve resistors each of resistance 16 Ω are connected in the circuit as shown. The net resistance between AB is **[2016]**



(a) 1Ω (b) 2Ω

(c) 3Ω (d) 4Ω

44. In the circuit shown, the current in the 1Ω resistor is : **[2017]**



(a) 0.13 A, from Q to P

(b) 0.13 A, from P to Q

(c) 1.3A from P to Q

(d) 0A

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 45-50) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

45. **Assertion :** In a simple battery circuit, the point of the lowest potential is positive terminal of the battery.

Reason : The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal. **[2002]**

46. **Assertion :** A larger dry cell has higher emf.

Reason : The emf of a dry cell is proportional to its size. **[2004]**

47. **Assertion :** A current continues to flow in superconducting coil even after switch is off.

Reason : Superconducting coils show Meissner effect. **[2007]**

48. **Assertion :** Voltmeter is connected in parallel with the circuit.

Reason : Resistance of a voltmeter is very large. **[2007]**

49. **Assertion :** Ohm's law is applicable for all conducting elements.

Reason : Ohm's law is a fundamental law. ***[2007]***

50. **Assertion :** An electric bulb becomes dim, when the electric heater in parallel circuit is switched on.

Reason : Dimness decreases after sometime. ***[2008]***

Directions for (Qs. 51-59) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

51. **Assertion :** The electric bulbs glows immediately when switch is on.

Reason : The drift velocity of electrons in a metallic wire is very high. ***[2009]***

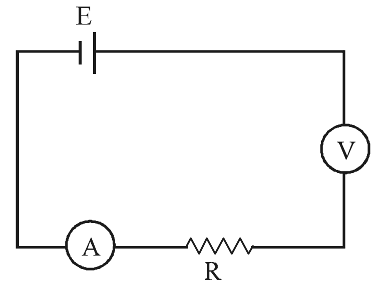
52. **Assertion :** In a simple battery circuit, the point of the lowest potential is negative terminal of the battery.

Reason : The current flows towards the point of the higher potential, as it does in such a circuit from the negative to the positive terminal. ***[2010]***

53. **Assertion :** Free electrons always keep on moving in a conductor even then no magnetic force act on them in magnetic field unless a current is passed through it.

Reason : The average velocity of free electron is zero. ***[2011]***

54. **Assertion :** All electric devices shown in the circuit are ideal. The reading of each of ammeter (a) and voltmeter (V) is zero.



Reason : An ideal voltmeter draws almost no current due to very large resistance, and hence (V) and (a) will read zero. ***[2012]***

55. **Assertion :** Long distance power transmission is done at high voltage.

Reason : At high voltage supply power losses are less. ***[2014]***

56. **Assertion :** When current through a bulb decreases by 0.5%, the glow of bulb decreases by 1%.

Reason : Glow (Power) which is directly proportional to square of current. ***[2015]***

57. **Assertion :** The current density $\vec{j}$ at any point in ohmic resistor is in direction of electric field $\vec{E}$ at that point.

Reason : A point charge when released from rest in a region having only electrostatic field always moves along electric lines of force. ***[2016]***

58. **Assertion :** Bending a wire does not effect electrical resistance.

Reason : Resistance of wire is proportional ot resistivity of material. ***[2016]***

59. **Assertion :** Kirchoff's junction rule follows from conservation of charge.

Reason : Kirchoff's loop rule follows from conservation of momentum. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (a) Let length & cross sectional area of wire be ℓ & a respectively. ρ be the specific resistance, then

$$R = \rho\frac{\ell}{a}$$

If radius becomes half, area becomes $\frac{1}{4}$th or cross sectional area after the stretch $= \frac{a}{4}$. Let its length increases to ℓ'. Since volume remains the same in the process,

$$\ell a = \ell' \times \frac{a}{4} \Rightarrow \ell' = 4\ell$$

Let R' be the resistance of streched wire,

$$R' = \rho\frac{4\ell}{a/4} = 16 \times \rho\frac{\ell}{a} = 16R$$

2. (a) $\frac{20}{R+6} = 1 \Rightarrow 20 = R + 6 \Rightarrow R = 14\ \Omega$

3. (b) Three 5Ω resistors are in series. Their total resistance = 15Ω. Now it is in parallel with 5Ω resistor, so total resistance,

$$\frac{1}{R} = \frac{1}{5} + \frac{1}{15} = \frac{3+1}{15} = \frac{4}{15}$$

$$R = \frac{15}{4}$$

$$\therefore\ I = \frac{V}{R} = \frac{3}{15/4} = \frac{3\times 4}{15} = 0.8A$$

4. (d) Electroplating is a process which uses the process of electrolysis to form a thin layer of a metal on any other metal. It is not used for hardening purpose.

6. (d) Two 4Ω resistors are in parallel so, their total resistance = 2Ω. Now three 2Ω resistors are in series. Their total resistance will be 6 Ω.

7. (b) Let main current be I & let the resistance of each wire be R.
In the first case heat produced
$= I^2 Rt + I^2Rt = 2I^2Rt$
In the second case heat produced

$$= \left(\frac{I}{2}\right)^2 Rt \times 2 = \frac{I^2Rt}{2}$$

$$\text{Ratio} = \frac{2I^2Rt}{\frac{I^2Rt}{2}} = 4:1$$

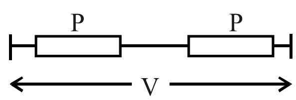
7. (a) Current is uniform throughout the wire even if it is of non-uniform thickness. This is because charge passing through every cross sectional area per unit time remains the same throughout the wire. So, current remains the same.

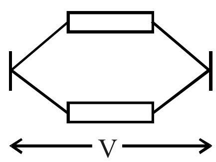
8. (c) Two batteries are joined with opposite polarity so, total e.m.f. = 5 – 2 = 3V

Total resistance $= 10 + 20 = 30\Omega$

$$\text{Current} = \frac{3}{30} = 0.1A$$

9. (b)





Let the resistances be r for each wire.
Heat generated $= I^2(2r) = 2I^2r$,
where I is current through both of them. When they are connected in parallel each will have current $= \frac{I}{2}$.

$$\text{Heat generated} = \left(\frac{I}{2}\right)^2 rt \times 2 = \frac{I^2rt}{2}$$

Ratio of heat generated in two cases

$$= \frac{2I^2rt}{\frac{I^2rt}{2}} = \frac{4\times I^2rt}{I^2rt} = 4:1$$

10. (d) Since, $E = AT - \frac{1}{2}BT^2$

$$E = 16T - \frac{1}{2}0.08T^2 = 16T - 0.04T^2$$

At temperature of inversion, E = 0
So, $16T - 0.04T^2 = 0 \Rightarrow T = 0$
or $16 - 0.04T = 0$

$$T = \frac{16}{0.04} = 400°C$$

11. **(a)** Current $= \frac{2}{3.9+0.1} = \frac{2}{4} = 0.5$

Voltage across the cell

$= 2 - 0.5 \times 0.1 = 2 - 0.05 = 1.95$ V

12. **(a)** Internal resistance of a cell is the resistance of electrolyte used in the cell. That is why when it is heated its conductivity is increased due to mobility of ions.

13. **(a)** Resistance of bulb

$= \frac{V^2}{P} = \frac{200 \times 200}{40} = 1000\Omega$

New power $= \frac{V^2}{R} = \frac{100 \times 100}{1000} = 10W$.

14. **(d)** Let the new length be ℓ_1, keeping volume constant,

$\pi r^2 L = \pi\left(\frac{r}{2}\right)^2 \ell_1$

$\Rightarrow \ \ell_1 = 4L$

Now, $10 = \frac{\rho L}{\pi r^2}$; $R = \frac{\rho \ell_1}{\pi\left(\frac{r}{2}\right)^2}$

$\frac{R}{10} = \frac{\rho \ell_1 \times 4}{\pi r^2} \times \frac{\pi r^2}{\rho L} = \frac{4L \times 4 \times r^2}{r^2 \times L} = \frac{16}{1}$

R = 160

15. **(a)** It is an example of mixed arrangement.

Total potential = 0.15 × 5000 = 750 V.

Resistance per row = 0.25 × 5000 = 1250 Ω

There are 100 rows, so

Total resistance $= \frac{1250}{100} = 12.5\ \Omega$

It is connected with external resistance of 500Ω, so

Total resistance = 500 + 12.5 = 512.5 Ω

Current $= \frac{750}{512.5} = 1.5$ A

16. **(c)** In a semiconductor when temperature increases conductivity increases so resistivity decreases i.e.

$T \propto \frac{1}{\rho}$

$\rho\, T = \text{constant} \Rightarrow \rho = K\frac{1}{T}$

$d\rho = -K\frac{1}{T^2}dT \Rightarrow \frac{d\rho}{dT} = -\frac{K}{T^2}$

So, slope of $\rho - T$ curve is negative & it is dependent upon T i.e. it is not constant. So, alternative (c) is right choice.

17. **(c)** Let i_1, i_2 & i_3 be current in R_1, R_2 & R_3.

Now, power consumed are same so,

$i_1^2R_1 = i_2^2R_2 = i_3^2R_3$ .....(i)

$i_1R_2 = i_3R_3$ [volt over them are same] .....(ii)

Dividing (i) with (ii), $i_2 = i_3 \Rightarrow R_2 = R_3$

$i_1 = 2i_2$ [i_1 is equally being divided]

$i_1^2R_1 = i_2^2R_2 = \frac{i_1^2}{4}R_2$

$R_2 = 4R_1$

18. **(a)** Energy delivered to the ground = V.Q.

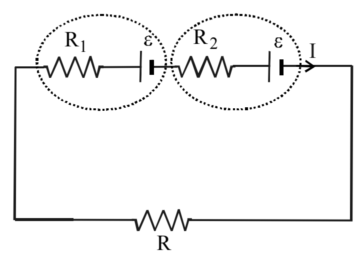
$= 4 \times 10^6 \times 4 = 16 \times 10^6$ joule

Power $= \frac{16 \times 10^6}{\text{time}} = \frac{16 \times 10^6}{100 \times 10^{-3}} = 16 \times 10^7$

= 160 MW

19. **(a)** Faraday's law says that amount of substance liberated or deposited at an electrode is proportional to quantity of charge passed through it. Thus, mass ∝ charge. Since mass is quantised hence indirectly charge is quantised.

20. **(a)** $I = \frac{2\varepsilon}{R + R_1 + R_2}$



Pot. difference across second cell

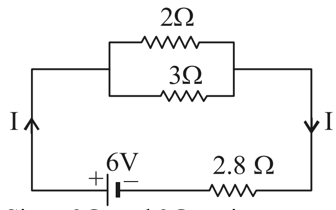
$= V = \varepsilon - IR_2 = 0$

$\varepsilon = \frac{2\varepsilon}{R + R_1 + R_2}.R_2 = 0$

$R + R_1 + R_2 - 2R_2 = 0$

$R + R_1 - R_2 = 0 \quad \therefore \quad R = R_2 - R_1$

21. **(b)** At the steady state, the branch containing capacitor will be in effective as no current will be flowing through it



Since 2Ω and 3Ω resistors are in parallel, equivalent resistance,

$$R' = \frac{2\times 3}{2+3} = 1.2\Omega$$

Total current throgh the battery,

$$I = \frac{6}{1.2+2.8} = 1.5A$$

$\therefore$ Current flowing through 2Ω resistor

$$I_{(2\Omega)} = \frac{3}{5}\times 1.5 = 0.9A$$

22. (d) At time t = 0 i.e., when the capacitor is charging, then current through the circuit,

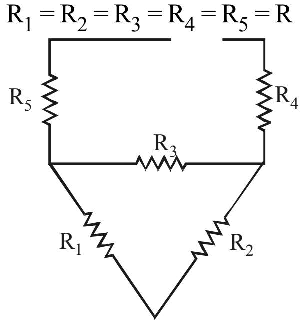
$$I = \frac{2}{1000} = 2mA$$

When capacitor is fully charged, no current will pass through it.

Hence current through the circuit

$$I = \frac{2}{2000} = 1mA$$

23. (d) $R_1 = R_2 = R_3 = R_4 = R_5 = R$



R' & R_2 are in series

Their equivalent resistance,

$R' = R_1 + R_2 = 2R$

Now R' & R_3 in are parallel

Their equivalent resitance R" is given by

$$\frac{1}{R''} = \frac{1}{R'} + \frac{1}{R_3} = \frac{1}{2R} + \frac{1}{R}$$

$$\frac{1}{R''} = \frac{1+2}{2R}$$

$$R'' = \frac{2R}{3}$$

R", R_5 & R_4 are in series

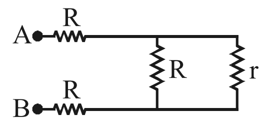
$\therefore$ $R_f = R'' + R_5 + R_4 = R + R + 2R/3 = 8R/3$,

Since $R = 3\Omega$

$$\therefore \quad R_f = 8\times\frac{3}{3} = 8\Omega.$$

24. (a) Let resistance between A and B be r.

$$\therefore\ r = 2R + \frac{R\times r}{r+R}$$



$$\Rightarrow r = (\sqrt{3}+1)R$$

25. (a) $e_1 = 203.6$ ....(i)

$e_1 - e_2 = 24.6$ ...(ii)

(i) - (ii) gives $e_2 = 179.0$ cm

26. (d) $R_1 = \dfrac{\rho L}{A}$,

$$R_2 = \frac{(1.2\rho)(1.2L)}{A} = \frac{1.44\rho L}{A},$$

$$R_3 = \frac{(0.9\rho)(0.9L)}{A} = \frac{0.81\rho L}{A},$$

$$R_4 = \frac{\rho(1.5L)}{A} = \frac{1.5\rho L}{A}$$

$\therefore$ $R_3 < R_1 < R_2 < R_4$

For constant potential, $P \propto \dfrac{1}{R}$,

$\therefore$ $P_3 < P_1 < P_2 < P_4$

27. (d) $G = 50\,\Omega, I_G = 100\mu A, I = 10\,A$

$$\text{Shunt, } S = \left(\frac{I_G}{I-I_G}\right)G$$

$$\Rightarrow \quad S = \left(\frac{100\times10^{-6}}{10-100\times10^{-6}}\right)\times 50$$

$$= \frac{10^{-4}}{10}\times 50 = 5\times10^{-4}\,\Omega$$

28. (d) $R_1 = R_0(1+\alpha_1 t) + R_0(1+\alpha_2 t)$

$$= 2R_0\left(1+\frac{\alpha_1+\alpha_2}{2}t\right)$$

$$= R'_0\left(1+\frac{\alpha_1+\alpha_2}{2}t\right)$$

Comparing with $R = R_0(1+\alpha t)$

$$\alpha = \frac{\alpha_1+\alpha_2}{2}$$

29. **(b)** $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$

30. **(d)** We have, $m = Zq$

or $\quad Z = \frac{m}{q}$

For $q = 1C, Z = m$

So, for 1 coulomb of charge, $q = i\,t$

or $\quad 1 = i \times 0.25$ or $i = 4\,A$

31. **(c)** Resistance of a wire $= \rho l/A$.

For the same length and same material,

$$\frac{R_2}{R_1} = \frac{A_1}{A_2} = \frac{3}{1} \text{ or, } R_2 = 3R_1$$

The resistance of thick wire, $R_1 = 10\,\Omega$

The resistance of thin wire $= 3R_1 = 3 \times 10 = 30\,\Omega$.

Total resistance $= 10 + 30 = 40\Omega$.

32. **(b)** $R = \frac{\rho\ell}{\pi r^2}$

When ℓ is $\frac{\ell}{2}$ and radius is $\frac{r}{2}$,

$$\therefore \quad R' = \frac{\rho\ell 4}{\pi 2r^2} = \frac{2\rho\ell}{\pi r^2}$$

So, $R' = 2R$. So, heat is doubled according to $H = I^2RT$.

33. **(b)** Let I_1 be the current throug $5\,\Omega$ resistance, I_2 through $(6 + 9)\,\Omega$ resistance. Then as per question,

$$I_1^2 \times 5 = 20 \text{ or, } I_1 = 2A.$$

Potential difference across C and D $= 2 \times 5 = 10V$

Current $I_2 = \frac{10}{6+9} = \frac{2}{3}A.$

Heat produced per second in 2Ω

$$= I^2R\left(\frac{8}{3}\right)^2 \times 2 = 14.2\,\text{cal/s}.$$

34. **(d)** In the circuit I, the key is open so current in the circuit is zero. Therefore the voltmeter gives 0V reading. In the circuit II, the reading of the voltmeter is 2V.

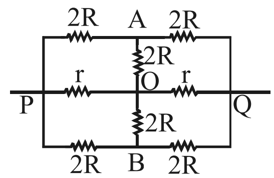
35. **(c)** $R \propto \frac{\ell}{A}$;

So, the resistance of the wire will be minimum when the area of cross-section is maximum and length is minimum.

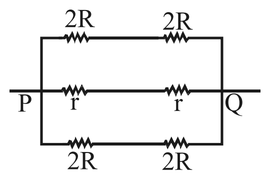
36. **(a)** The circuit is symmetrical about axis POQ. Therefore the equivalent circuit is drawn

$$\therefore \frac{1}{R_{PQ}} = \frac{1}{4R} + \frac{1}{4R} + \frac{1}{2r} = \frac{1}{2R} + \frac{1}{2r} = \frac{R+r}{2Rr}$$

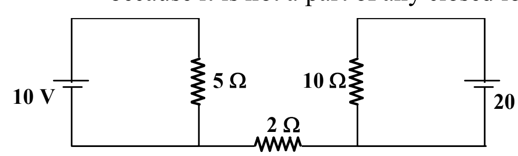
$$\Rightarrow R_{PQ} = \frac{2Rr}{R+r}$$



If a potential difference is applied across P and Q, there will be no currents in arms AO and OB. So these resistance will be ineffective.



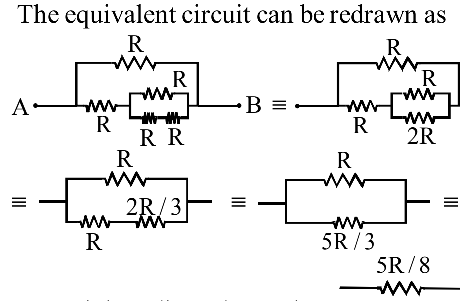
37. **(a)** The current in 2Ω resistor will be zero because it is not a part of any closed loop.



38. **(c)** Neutral temperature,

$$\theta_n = \frac{\theta_i + \theta_0}{2} = \frac{530+10}{2} = 270°C.$$

39. **(b)** The equivalent circuit can be redrawn as



40. **(b)** Potential gradient along wire

$$= \frac{\text{potential difference along wire}}{\text{length of wire}}$$

or, $0.1 \times 10^{-3} = \frac{I \times 40}{1000}$ V/cm

or, Current in wire, $I = \frac{1}{400}$ A

or, $\frac{2}{40+R} = \frac{1}{400}$ or $R = 800 - 40 = 760\,\Omega$

41. (d) Let internal resistance of source = R

Current in coil of resistance

$R_1 = I_1 = \frac{V}{R+R_1}$

Current in coil of resistance

$R_2 = I_2 = \frac{V}{R+R_2}$

Further, as heat generated is same, so

$I_1^2R_1t = I_2^2R_2t$

or $\left(\frac{V}{R+R_1}\right)^2 R_1 = \left(\frac{V}{R+R_2}\right)^2 R_2$

$\Rightarrow R_1(R+R_2)^2 = R_2(R+R_1)^2$

$\Rightarrow R^2R_1 + R_1R_2^2 + 2RR_1R_2$

$= R^2R_2 + R_1^2R_2 + 2RR_1R_2?$

$\Rightarrow R^2(R_1 - R_2) = R_1R_2(R_1 - R_2)$

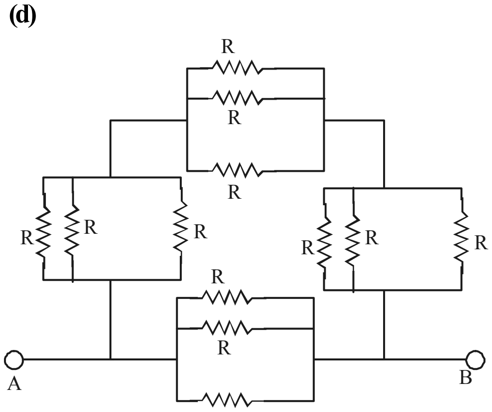
$\Rightarrow R = \sqrt{R_1R_2}$

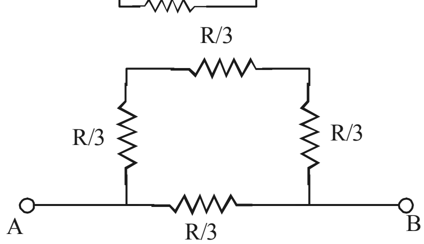
42. (a) $F = \left(\frac{\mu_0 I_1}{2\pi r}\right)\ell I_2$ When I, = – 2I, and r =3r,

then $F' = -\frac{\mu_0 - 2I_1\ell I_2}{2\pi.3r}$

$= \left(\frac{\mu_0 I_1 I_2 \ell}{2\pi r}\right)\left(-\frac{2}{3}\right) = -\frac{2}{3}F$

43. (d)

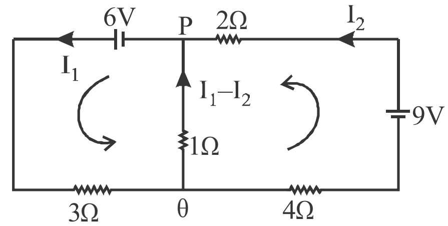




R_{net} between AB $= \frac{\frac{3R}{3}\times\frac{R}{3}}{\frac{3R}{3}+\frac{R}{3}} = \frac{R^2}{4R} = 4\Omega$

44. (a) From KVL

$-6 + 3I_1 + 1\,(I_i - I_2) = 0$



$6 = 3I_1 + I_1 - I_2$

$4I_1 - I_2 = 6$ ...(1)

$-9 + 2I_2 - (I_1 - I_2) + 3I_2 = 0$

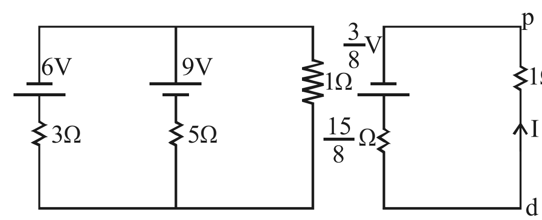
$-I_1 + 6I_2 = 9$ ...(2)

On solving (1) and (2)

$I_1 = 0.13A$

Direction Q to P, since $I_1 > I_2$.

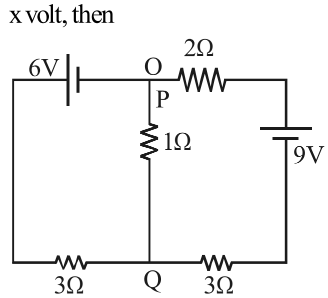
Alternatively



$$Eq = \frac{\frac{E_1}{r_1}+\frac{E_2}{r_2}}{\frac{1}{r_1}+\frac{1}{r_2}} = \frac{\frac{6}{3}-\frac{9}{5}}{\frac{1}{3}+\frac{1}{5}} = \frac{3}{8V}$$

$$\therefore\quad I = \frac{\frac{3}{8}}{\frac{15}{8}+1} = \frac{3}{23} = 0.13A$$

Considering potential at P as 0V and at Q as x volt, then



$$\frac{x-6}{3} + \frac{x-0}{1} + \frac{x+9}{5} = 0$$

$\therefore \quad x = \frac{2}{23}$

$\therefore \quad i = \frac{x-0}{1} = \frac{2}{23} = 0.13A$

From Q to P

Type B : Assertion Reason Questions

45. (d) Positive terminal of a battery is point of highest potential and current flows from highest to lowest potential i.e. from +ve to –ve potential.

46. (d) The e.m.f. of a dry cell is dependent upon the electrode potential of cathode and anode which in turn is dependent upon the reaction involved as well as concentration of the electrolyte. It has nothing to do with size of the cell.
So, both assertion & reason are wrong.

47. (b) Current continues to flow in a super conducting coil even after switch off because at critical temperature, its resistance is zero so there is no hinderance to current flow.
Meissner effect says that at critical temperature magnetic field inside the conductor is zero i.e, B = 0 but this does not explain assertion.

48. (b) Voltmeter is a galvanometer with high resistance. It measures potential drop across any part of an electrical circuit. It is connected in parallel so that it does not draw any current itself (due to high resistance) and does not affect net resistance of the circuit.

49. (c) A conducting device obeys ohm's law when the resistance of device is independent of the magnitude and polarity of the applied potential difference which happens in metallic conductors. Reason is false as ohm's law is not true for non-ohmic conductors such as junction diodes etc.

50. (b) The electric power of a heater is more than that of a bulb. As $P \propto \frac{1}{R}$, the resistance of heater is less than that of the electric bulb. When a heater connected in parallel to the bulb is switched on, it draws more current due to its lesser resistance, consequently, the current through the bulb decreases and so it becomes dim.
When the heater coil becomes sufficient hot, its resistance becomes more and hence it draws a little lesser current. Consequently, the current through the electric bulb recovers.

51. (c) In a conductor there are large number of free electrons. When we close the circuit, the electric field is established instantly with the speed of electromagnetic wave which cause electron drift at every portion of the circuit. Due to which the current is set up in the entire circuit instantly. The current which is set up does not wait for the electrons flow from one end of the conductor to the another end. It is due to this reason, the electric bulb glows immediatly when switch is on.

52. (c) Positive terminal of a battery is point of highest potential and current flows from highest to lowest potential i.e. from +ve to –ve potential.

53. (a) In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecule in a gas. Their average velocity is zero. i.e. they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

54. (a)

55. (a) Power loss $= i^2R = \left(\frac{P}{V}\right)^2 R$
[P = Transmitted power]

56. (a) Glow = Power (P) = I^2R

$\therefore \frac{dP}{P} = 2\left(\frac{dI}{I}\right) = 2 \times 0.5 = 1\%$

57. (c) From relation $\vec{J} = \sigma\,\vec{E}$, the current density $\vec{J}$ at any point in ohmic resistor is in direction of electric field $\vec{E}$ at that point. In space having non-uniform electric field, charges released from rest may not move along ELOF. Hence Assertion is correct while Reason is incorrect.

58. (a) Resistance wire $R = \rho\frac{l}{A}$, where ρ is resistivity of material which does not depend on the geometry of wire. Since when wire is bent resistivity, length and area of cross-section do not change, therefore resistance of wire also remain same.

59. (c) Kirchoff's loop rule follows from conservation of energy.

Chapter

18 Moving Charges and Magnetism

TYPE A : MULTIPLE CHOICE QUESTIONS

1. An electron moving with kinetic energy 6.6×10^{-14} J enters in a magnetic field of 4×10^{-3} T at right angles to it. The radius of its circular path will be nearest to : ***[1997]***
(a) 100 cm (b) 75 cm
(c) 25 cm (d) 50 cm

2. A charged particle enters a magnetic field H with its initial velocity making an angle of 45° with H. Then the path of the particle will be: ***[1999]***
(a) circle (b) helical
(c) a straight line (d) a circle

3. What should be amount of current through the ring of radius of 5 cm so that field at the centre equal to the magnetic field of 7×10^{-5} Wb/m^2, is
(a) 0.28 amp (b) 5.57 amp ***[2000]***
(c) 2.8 amp (d) none of these

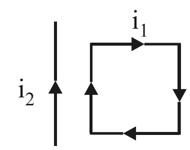
4. A closely wound flat circular coil of 25 turns of wire has diameter of 10 cm which carries current of 4 amperes, the magnetic field at the centre of a coil will be : ***[2001]***
(a) 1.256×10^{-3} tesla
(b) 1.679×10^{-5} tesla
(c) 1.512×10^{-5} tesla
(d) 2.28×10^{-4} tesla

5. Cyclotron is used to accelerate : ***[2001]***
(a) positive ion (b) negative ion
(c) electron (d) none of these

6. The magnetic field at a given point is 0.5×10^{-5} Wb m^{-2}. This field is to be annulled by magnetic induction at the centre of a circular conducting loop of radius 5.0 cm . The current required to be flown in the loop is nearly ***[2002]***
(a) 0.2 A (b) 0.4 A
(c) 4A (d) 40 A

7. An electron is travelling along the x-direction. It encounters a magnetic field in the y-direction. Its subsequent motion will be : ***[2002]***
(a) straight line along the x-direction
(b) a circle in the xz-plane
(c) a circle in the yz-plane
(d) a circle in the xy-plane

8. A rectangular loop carrying a current i_1 , is situated near a long straight wire carrying a steady current i_2. The wire is parallel to one of the sides of the loop and is in the plane of the loop as shown in the figure. Then the current loop will : ***[2003]***



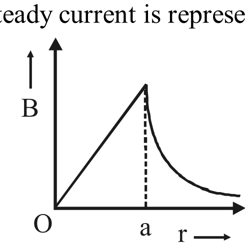
(a) move away from the wire
(b) move towards the wire
(c) remain stationary
(d) rotate about an axis parallel to the wire

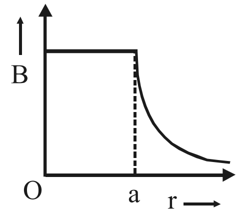
9. The cyclotron frequency of an electrons gyrating in a magnetic field of 1 T is approximately:
(a) 28 MHz (b) 280 MHz ***[2003]***
(c) 2.8 MHz (d) 28 GHz

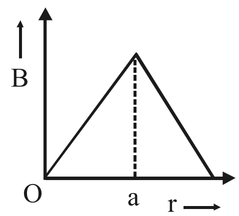
10. The magnetic moment of current (I) carrying circular coil of radius (r) and number of turns (n) varies as : ***[2004]***
(a) $1/r^2$ (b) $1/r$
(c) r (d) r^2

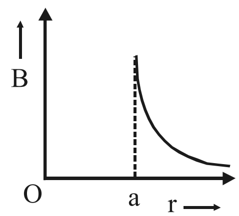
11. A circular coil of radius R carries an electric current. The magnetic field due to the coil at a point on the axis of the coil located at a distance r from the centre of the coil, such that r > > R, varies as ***[2004]***
(a) $1/r$ (b) $1/r^{3/2}$
(c) $1/r^2$ (d) $1/r^3$

12. The magnetic field due to a straight conductor of uniform cross-section of radius a and carrying a steady current is represented by : ***[2004]***

(a)


(b) 

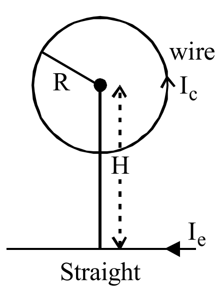
(c) 

(d) 

13. Two parallel beams of positrons moving in the same direction will : ***[2004]***
(a) repel each other
(b) will not interact with each other
(c) attract each other
(d) be deflected normal to the plane containing the two beams

14. A proton and an α-particle, moving with the same velocity, enter a uniform magnetic field, acting normal to the plane of their motion. The ratio of the radii of the circular paths described by the proton and α-particle is : ***[2004]***
(a) 1 : 2 (b) 1 : 4
(c) 4 : 1 (d) 1 : 16

15. Circular loop of a wire and a long straight wire carry currents I_c and I_e, respectively as shown in figure. Assuming that these are placed in the same plane, the magnetic fields will be zero at the centre of the loop when the separation H is : ***[2006]***



(a) $\dfrac{I_eR}{I_c\pi}$ (b) $\dfrac{I_cR}{I_e\pi}$
(c) $\dfrac{\pi I_c}{I_eR}$ (d) $\dfrac{I_e\pi}{I_cR}$

16. What is the magnetic field at a distance R from a coil of radius r carrying current I? ***[2007]***
(a) $\dfrac{\mu_0 IR^2}{2(R^2+r^2)^{\frac{3}{2}}}$ (b) $\dfrac{\mu_0 Ir^2}{2(R^2+r^2)^{\frac{3}{2}}}$
(c) $\dfrac{\mu_0 I}{2r}$ (d) $\dfrac{\mu_0 I}{2R}$

17. A long straight wire of radius *a* carries a steady current i. The current is uniformly distributed across its cross section. The ratio of the magnetic field at a/2 and 2a is ***[2007]***
(a) 1/2 (b) 1/4
(c) 4 (d) 1

18. In a mass spectrometer used for measuring the masses of ions, the ions are initially accelerated by an electric potential V and then made to describe semicircular paths of radius R using a magnetic field B. If V and B are kept constant, the ratio $\left(\dfrac{\text{charge on the ion}}{\text{mass of the ion}}\right)$ will be proportional to ***[2008]***
(a) $\dfrac{1}{R}$ (b) $\dfrac{1}{R^2}$
(c) R^2 (d) R

19. Two concentric coils each of radius equal to 2π cm are placed at right angles to each other. 3 ampere and 4 ampere are the currents flowing in each coil respectively. The magnetic induction in Weber/m^2 at the centre of the coils will be $\left(\mu_0 = 4\pi\times10^{-7}\,\text{Wb/A.m}\right)$ ***[2008]***
(a) 10^{-5} (b) 12×10^{-5}
(c) 7×10^{-5} (d) 5×10^{-5}

20. The magnetic field due to a square loop of side a carrying a current I at its centre is ***[2009]***
(a) $\dfrac{\mu_0 i}{2a}$ (b) $\dfrac{\mu_0 i}{\sqrt{2}\pi a}$
(c) $\dfrac{\mu_0 i}{2\pi a}$ (d) $\sqrt{2}\dfrac{\mu_0 i}{\pi a}$

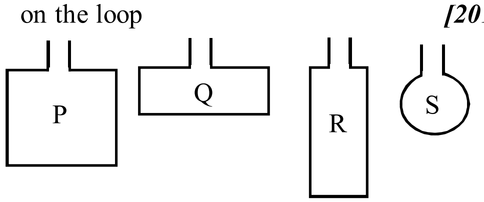
21. Electron of mass m and charge q is travelling with a speed along a circular path of radius r at right angles to a uniform magnetic field of intensity B. If the speed of the electron is doubled and the magnetic field is halved the resulting path would have a radius ***[2009]***
(a) $2r$ (b) $4r$
(c) $\frac{r}{4}$ (d) $\frac{r}{2}$

22. Electron moves at right angles to a magnetic field of 1.5×10^{-2} tesla with speed of 6×10^7 m/s. If the specific charge of the electron is 1.7×10^{11} C/kg. The radius of circular path will be ***[2010]***
(a) 3.31 cm (b) 4.31cm
(c) 1.31 cm (d) 2.35 cm

23. An electron beam passes through a magnetic field of 2×10^{-3} Wb/m^2 and an electric field of 1.0×10^4 V/m both acting simultaneously. The path of electron remains undeviated. The speed of electron if the electric field is removed, and the radius of electron path will be respectively ***[2011]***
(a) 10×10^6 m/s, 2.43 cm
(b) 2.5×10^6 m/s, 0.43 cm
(c) 5×10^6 m/s, 1.43 cm
(d) none of these

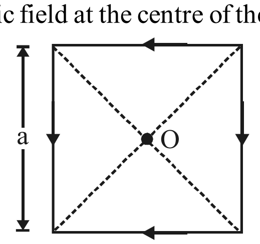
24. A charged particle is released from rest in a region of uniform electric and magnetic fields which are parallel to each other. The particle will move on a:
(a) straight line (b) circle ***[2011]***
(c) helix (d) cycloid

25. Four wires, each of length 2.0 m, are bent into four loops P, Q, R and S and then suspended in a uniform magnetic field. If the same current is passed in each, then the torque will be maximum on the loop ***[2012]***



(a) P (b) Q
(c) R (d) S

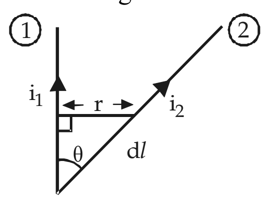
26. A square coil of side a carries a current I. The magnetic field at the centre of the coil is ***[2012]***



(a) $\frac{\mu_0 I}{a\pi}$ (b) $\frac{\sqrt{2}\mu_0 I}{a\pi}$
(c) $\frac{\mu_0 I}{\sqrt{2}\, a\pi}$ (d) $\frac{2\sqrt{2}\,\mu_0 I}{a\pi}$

27. A charged particle moves through a magnetic field in a direction perpendicular to it. Then the
(a) velocity remains unchanged ***[2013]***
(b) speed of the particle remains unchanged
(c) direction of the particle remains unchanged
(d) acceleration remains unchanged

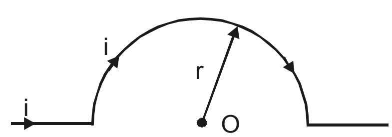
28. Wires 1 and 2 carrying currents i_1 and i_2 respectively are inclined at an angle θ to each other. What is the force on a small element dl of wire 2 at a distance of r from wire 1 (as shown in figure) due to the magnetic field of wire 1? ***[2013]***



(a) $\frac{\mu_0}{2\pi r} i_1 i_2\, dl \tan\theta$ (b) $\frac{\mu_0}{2\pi r} i_1 i_2\, dl \sin\theta$
(c) $\frac{\mu_0}{2\pi r} i_1 i_2\, dl \cos\theta$ (d) $\frac{\mu_0}{4\pi r} i_1 i_2\, dl \sin\theta$

29. If we double the radius of a coil keeping the current through it unchanged, then the magnetic field at any point at a large distance from the centre becomes approximately ***[2014]***
(a) double (b) three times
(c) four times (d) one-fourth

30. A portion of a conductive wire is bent in the form of a semicircle of radius r as shown below in fig. At the centre of semicircle, the magnetic induction will be ***[2015]***



(a) zero (b) infinite
(c) $\frac{\mu_0}{4\pi}.\frac{\pi i}{r}$ gauss (d) $\frac{\mu_0}{4\pi}.\frac{\pi i}{r}$ tesla

31. A coil of circular cross-section having 1000 turns and 4 cm^2 face area is placed with its axis parallel to a magnetic field which decreases by 10^{-2} Wb m^{-2} in 0.01 s. The e.m.f. induced in the coil is:
(a) 400mV (b) 200mV **[2017]**
(c) 4mV (d) 0.4mV

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 32-35) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

32. Assertion : Cyclotron is a device which is used to accelerate the positive ion.
Reason : Cyclotron frequency depends upon the velocity. ***[1997]***

33. Assertion : Cyclotron does not accelerate electron.
Reason : Mass of the electrons is very small. ***[2000]***

34. Assertion : In electric circuits, wires carrying currents in opposite directions are often twisted together
Reason : If the wires are not twisted together, the combination of the wires forms a current loop, the magnetic field generated by the loop might affect adjacent circuits or components. ***[2008]***

35. Assertion : The magnetic field produced by a current carrying solenoid is independent of its length and cross-sectional area.
Reason : The magnetic field inside the solenoid is uniform. ***[2008]***

Directions for (Qs. 36-42) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

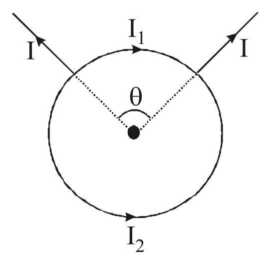
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

36. Assertion : A charge, whether stationary or in motion produces a magnetic field around it.
Reason : Moving charges produce only electric field in the surrounding space. ***[2009]***

37. Assertion : A proton and an alpha particle having the same kinetic energy are moving in circular paths in a uniform magnetic field. The radii of their circular paths will be equal.
Reason : Any two charged particles having equal kinetic energies and entering a region of uniform magnetic field $\vec{B}$ in a direction perpendicular to $\vec{B}$, will describe circular trajectories of equal radii. ***[2009]***

38. Assertion : If the current in a solenoid is reversed in direction while keeping the same magnitude, the magnetic field energy stored in the solenoid remains unchanged.
Reason : Magnetic field energy density is proportional to the magnetic field. ***[2010, 2017]***

39. Assertion : The magnetic field at the centre of the circular coil in the following figure due to the currents I_1 and I_2 is zero.



Reason : $I_1 = I_2$ implies that the fields due to the current I_1 and I_2 will be balanced. ***[2013]***

40. Assertion : If the current in a solenoid is reversed in direction while keeping the same magnitude, the magnetic field energy stored in the solenoid decreases.
Reason : Magnetic field energy density is proportional to square of current. ***[2015]***

41. Assertion : Free electrons always keep on moving in a conductor even then no magnetic force act on them in magnetic field unless a current is passed through it.
Reason : The average velocity of free electron is zero. ***[2016]***

42. Assertion: To convert a galvanometer into an ammeter a small resistance is connected in parallel with it.
Reason: The small resistance increases the combined resistance of the combination. ***[2016]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(d)** When a charged particle enters a magnetic field, its path becomes circular whose radius can be found out from the relation.

$$\frac{mv^2}{r} = Bqv \Rightarrow r = \frac{mv}{Bq}$$

$$E = \frac{1}{2}mv^2 = 6.6\times10^{-14}$$

$$\frac{1}{2}\frac{m^2v^2}{m} = 6.6\times10^{-14}$$

$$\Rightarrow m^2v^2 = 2m\times6.6\times10^{-14}$$

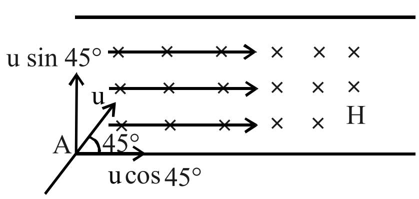
$$mv = \sqrt{2m\times6.6\times10^{-14}}$$

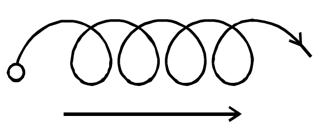
$$= \sqrt{2\times9.1\times10^{-31}\times6.6\times10^{-14}}$$

$$r = \frac{\sqrt{2\times9.1\times10^{-31}\times6.6\times10^{-14}}}{4\times10^{-3}\times1.6\times10^{-19}}$$

= 50 cm. approx.

2. **(b)**

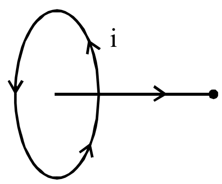




Helical Path

At point A, charge is entering in a magnetic field in which direction of field is shown in the figure. The velocity of particle is u making an angle of 45° with field. We resolve it in two directions, one along the field and other perpendicular to it. Since u sin45° is perpendicular to H, it will create a rotatory effect on the charge. So charge particle will start rotating with axis along the direction of H. At the same time it will move forward with velocity u cos 45°. Under both these motions, it will have helical path as shown in the figure.

3. **(b)**



Magnetic field at the centre of a coil carrying current.

$$B = \frac{\mu_0 i}{2r}$$

$$7\times10^{-5} = \frac{4\pi\times10^{-7}i}{2\times5\times10^{-2}}$$

$$i = \frac{70\times10^{-7}}{4\pi\times10^{-7}} = 5.57\,\text{amp}$$

4. **(a)** Flux density, $B = \frac{\mu_0 i}{2r}\times n$

$$= \frac{4\pi\times10^{-7}\times4\times25}{2\times5/100} = \frac{4\pi\times10^{-7}\times(100)^2}{10}$$

$= 1.256\times10^{-3}$ tesla.

5. **(a)** Cyclotron is used to accelerate positive ions. Electron can not be used as its velocity increases appreciably resulting into its mass becoming very large. It creates problem in synchronisation.

6. **(b)** Fields created at the centre

$= 0.5\times10^{-5}$ Wb/m^2

Due to current in circular loop, field created

in the centre $= \frac{\mu_0 i}{2r}$

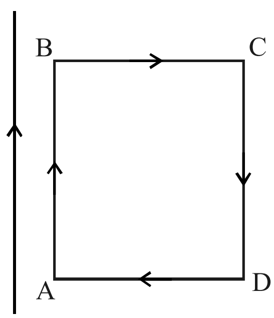
$$= \frac{4\pi\times10^{-7}\times i}{2\times5\times10^{-2}} = 0.5\times10^{-5}$$

$$i = \frac{0.5\times10^{-5}\times10\times10^{-2}}{4\pi\times10^{-7}} = \frac{5}{4\pi} = \frac{35}{88}$$

$= 0.3980 = 0.4\,A$

7. **(b)** When a charged particle enters a magnetic field, it experiences a force which is always directed perpendicular to its direction of motion. In that case the path of the charged particle becomes circular and the plane of the circle is perpendicular to the plane containing the magnetic field and velocity vector of the charged particle.

8. **(b)**



Current in AB is same as that current in straight wire so it will be attracted. CD portion will be repelled. Net force in the loop will be attractive. Force on BC and AD will be opposite to each other so energy will cancel out each other.

9. **(d)** For an electron gyrating in a magnetic field

$$\frac{mv^2}{r} = Bqv$$

$$r = \frac{mv}{Bq} \Rightarrow \frac{v}{r} = \frac{Bq}{m}$$

$$T = \frac{2\pi r}{v}; \quad n = \frac{1}{T} = \frac{v}{2\pi r} = \frac{Bq}{2\pi m}$$

$$n = \frac{1 \times 1.6 \times 10^{-19}}{2 \times \pi \times 9.1 \times 10^{-31}}$$

$$= \frac{1.6 \times 10^{12}}{2\pi \times 9.1} = 28 \text{ GHz}$$

10. **(d)** Magnetic moment of a coil of radius r carrying current i is equal to
M = iAn [A is area of the coil, x is no. of turns]

$$= ni\pi r^2$$

So, $M \propto r^2$

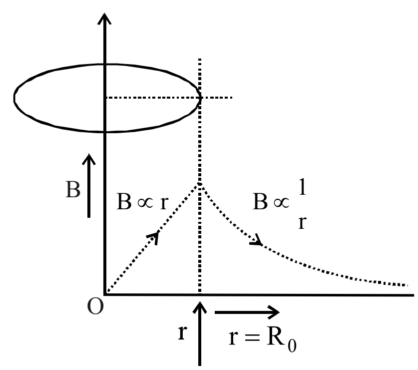
11. **(d)** Magnetic field on the axis of the coil is

$$B = \frac{1}{4\pi \in_0} \frac{\pi a^2 nix}{(x^2 + a^2)^{3/2}}$$

If $x >> a$

$$B = \frac{1}{4\pi \in_0} \frac{\pi a^2 ni}{x^3} \text{ or } B \propto \frac{1}{x^3}$$

12. **(a)** Inside the wire magnetic field will be directly proportional to the distance from the axis. Outside the wire, field is inversely proportional to distance.



13. **(c)** Two parallel beams of positron moving in same direction is equivalent to two current carrying conductor, carrying current in same direction. They will attract each other.

14. **(a)** When a charged particle enters a field, it takes a circular path. The radius of circular path is given by the relation

$$r = \frac{mv}{Bq}$$

For proton, $r_1 = \frac{mv}{Bq}$

For α-particle, $r_2 = \frac{4m \times v}{B \times 2q} = \frac{2mv}{Bq}$

$\Rightarrow r_1 : r_2 : : 1 : 2$

15. **(a)** Magnetic field due to straight wire $= \frac{\mu_0 I_e}{2\pi H}$

Magnetic field due to circular wire $= \frac{\mu_0 I_c}{2R}$

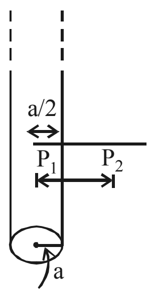
Now $\dfrac{\mu_0 I_e}{2\pi H} = \dfrac{\mu_0 I_c}{2R}$

$\Rightarrow \quad H = \dfrac{R\, I_e}{\pi I_c}$

16. (b) The magnetic field is $B = \dfrac{\mu_0 I r^2}{2(R^2 + r^2)^{3/2}}$

(see application of Biot-Savart law to magnetic field at a point along axis of coil)

17. (d) Here, current is uniformly distributed across the cross-section of the wire, therefore, current enclosed in the amperean path formed at a distance $r_1 \left(= \dfrac{a}{2}\right)$



$= \left(\dfrac{\pi r_1^2}{\pi a^2}\right) \times I$, where I is total current

$\therefore$ Magnetic field at

$$P_1(B_1) = \frac{\mu_0 \times \text{current enclosed}}{\text{Path}}$$

$$= \frac{\mu_0 \times \left(\dfrac{\pi r_1^2}{\pi a^2}\right) \times I}{2\pi r_1} = \frac{\mu_0 \times I r_1}{2\pi a^2}$$

Now, magnetic field at point P_2,

$$(B_2) = \frac{\mu_0}{2\pi} \cdot \frac{I}{(2a)} = \frac{\mu_0 I}{4\pi a}.$$

$\therefore$ Required Ratio $= \dfrac{B_1}{B_2} = \dfrac{\mu_0 I r_1}{2\pi a^2} \times \dfrac{4\pi a}{\mu_0 I}$

$$= \frac{2r_1}{a} = \frac{2 \times \dfrac{a}{2}}{a} = 1.$$

18. (b) The centripetal force is provided by the magnetic force.

i.e., $\dfrac{mv^2}{R} = qvB \qquad \ldots(1)$

where m = mass of the ion, v = velocity, q = charge of ion, B = flux density of the magnetic field.

we have, $v = R\omega$

or $\omega = \dfrac{v}{R} = \dfrac{qB}{m} \qquad$ (From (1))

Energy of ion is given by,

$$E = \frac{1}{2}mv^2 = \frac{1}{2}m(R\omega)^2 = \frac{1}{2}mR^2\frac{q^2B^2}{m^2}$$

or $E = \dfrac{1}{2}\dfrac{R^2B^2q^2}{m} \qquad \ldots(2)$

If ions are accelerated by electric potential V, the energy attained by ions,

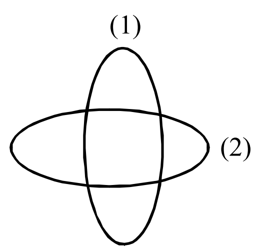
$E = qV \qquad \ldots(3)$

From eqns (2) and (3)

$qV = \dfrac{1}{2}\dfrac{R^2B^2q^2}{m}$ or $\left(\dfrac{q}{m}\right) = \dfrac{2V}{R^2B^2}$

i.e., $\left(\dfrac{q}{m}\right) \propto \dfrac{1}{R^2}$ (If V and B are const.)

19. (d)



$$B_1 = \frac{\mu_0 i_1}{2(2\pi)} = \frac{\mu_0 \times 3}{4\pi}$$

$$B_2 = \frac{\mu_0 i_2}{2(2\pi)} = \frac{\mu_0 \times 4}{4\pi}$$

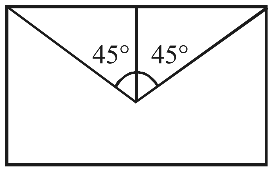
$$B = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0}{4\pi}.5$$

$\Rightarrow B = 10^{-7} \times 5 \times 10^2$

$\Rightarrow B = 5 \times 10^{-5}\, Wb/m^2$

20. **(d)** $B = \left[\dfrac{\mu_0 i}{4\pi a}(\cos 45° - \cos 135°)\right] \times 4$

$= \dfrac{\mu_0 i}{\pi a}\dfrac{2}{\sqrt{2}}$



$= \sqrt{2}\dfrac{\mu_0 i}{\pi a}$

21. **(b)** Radius of path is given by $r = \dfrac{mv}{Bq}$

Here, m and q remain unchanged

So, $\dfrac{r_1}{r_2} = \dfrac{v_1}{v_2}\cdot\dfrac{B_2}{B_1} = \dfrac{v}{2v}\cdot\dfrac{B/2}{B} = \dfrac{1}{4}$

$\Rightarrow r_2 = 4r$

22. **(d)** $B = 1.5 \times 10^{-2}$ T,

$\theta = 90°$, $\sin\theta = 1$, $v = 6 \times 10^7$ m/s,

$\dfrac{e}{m} = 1.7 \times 10^{11}$ C/kg

$r = \dfrac{mv}{Be} = \dfrac{6 \times 10^7}{1.5 \times 10^{-2} \times 1.7 \times 10^{11}}$

$= 2.35 \times 10^{-2}$ m $= 2.35$ cm

23. **(c)** $B = 2 \times 10^{-3}$ Wb/m^2,

$E = 1 \times 10^4$ V/m^2

Since the path of electron remains undeviated, $qvB = qE$ or

$v = \dfrac{E}{B} = \dfrac{1 \times 10^{+4}}{2 \times 10^{-3}} = 0.5 \times 10^7$

$= 5 \times 10^6$ m/s

If the electricfield is removed, the path of the charged particle is circular and magnetic field provides the necessary centripetal force. i.e.,

$\dfrac{mv^2}{r} = Bev \Rightarrow \quad r = \dfrac{mv}{Be}$

$= \dfrac{9.1 \times 10^{-31} \times 5 \times 10^6}{2 \times 10^{-3} \times 1.6 \times 10^{-19}}$

$= 14.3 \times 10^{-3}$ m $= 1.43$ cm

24. **(a)**

The magnetic force on charged particle is zero.

25. **(d)** For a given perimeter the area of circle is maximum. So magnetic moment of (S) is greatest.

26. **(d)** $B_{total} = 4B_{side}$

$B_{total} = 4\dfrac{\mu_0 I}{2\pi\left(\dfrac{a}{2}\right)}\left[\sin\dfrac{\pi}{4} + \sin\dfrac{\pi}{4}\right]$

$B_{total} = \dfrac{2\sqrt{2}\mu_0 I}{a\pi}$

27. **(b)** Magnetic force acts perpendicular to the velocity. Hence speed remains constant.

28. **(c)**

29. **(c)** $B_{axis} = \left(\dfrac{\mu_0 NI}{2x^3}\right)R^2$

$B \propto R^2$

So, when radius is doubled, magnetic field becomes four times.

30. **(d)** The straight part will not contribute magnetic field at the centre of the semicircle because every element of the straight part will be 0º or 180º with the line joining the centre and the element

Due to circular portion, the field is

$\dfrac{1}{2}\dfrac{\mu_0 i}{2r} = \dfrac{\mu_0 i}{4r}$

Hence total field at O $= \dfrac{\mu_0 i}{4r}$ tesla

31. **(a)** **Given:** No. of turns $N = 1000$

Face area, $A = 4$ cm$^2 = 4 \times 10^{-4}$ m^2

Change in magnetic field,

$\Delta B = 10^{-2}$ wbm^{-2}

Time taken, $t = 0.01$ s $= 10^{-2}$ sec

Emf induced in the coil $e = ?$

Applying formula,

Induced emf, $e = \dfrac{-d\phi}{dt}$

$= N\left(\dfrac{\Delta B}{\Delta t}\right)A\cos\theta$

$= \dfrac{1000 \times 10^{-2} \times 4 \times 10^{-4}}{10^{-2}} = 400$ mV

Type B : Assertion Reason Questions

32. **(c)** Cyclotron is used to accelerate charged particles. So Assertion is correct.

We know that time period of a particle

$$T = \frac{2\pi r}{v_0};\ \frac{mv_0^2}{r} = Bqv_0 \Rightarrow v_0 = \frac{Bqr}{m}$$

$$T = \frac{2\pi r}{Bqr} \times m = \frac{2\pi}{Bq} m$$

$$\text{Frequency} = \frac{1}{T} = \frac{Bq}{2\pi m}$$

This does not dpeend upon velocity so Reason is incorrect.

33. **(c)** Cyclotron does not accelerate electron because mass of electron is very small. It gets accelerated very appreciably as a result of which its mass increases. It result is mismatch between frequency of a.c. used and frequency of rotation of electron in the Dee's. So cyclotron stops accelerating electrons after some time.

34. **(a)** If the wires are twisted together, they can be formed as a single wire carrying currents in opposite directions. In this pattern, in wires no magnetic field is induced which does not affect adjacent circuits.

35. **(b)** Magnetic field inside the solenoid at point P is given by,

$$B = \frac{\mu_0}{4\pi}(2\pi ni)[\sin\alpha + \sin\beta]$$

where n = no. of turns per unit length $= N/\ell$

Thus it is clear that mangetic field is independent of length and cross sectional area.

Also the magnetic field with in the solenoid is uniform and parallel to the axis of the solenoid.

36. **(d)** A charge, whether stationary or in motion, produces an electric field around it. If it is in motion, then in addition to the electric field, it also produces a magnetic field, because moving charges produces magnetic field in the surrounding space.

37. **(c)** The radius of the circular path is given by

$$r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB};\quad \text{where } K = \frac{1}{2}mv^2$$

Since K and B are the same for the two particles, $r \propto \frac{\sqrt{m}}{q}$. Now, the charge of an alpha particle is twice that of a proton and its mass is four times the mass of a proton, $\sqrt{m}/q$ will be the same for both particles. Hence, r will be the same for both particles.

38. **(c)**

39. **(d)** $\frac{I_1}{I_2} = \frac{2\pi - \theta}{\theta} \Rightarrow I_1\theta = I_2(2\pi - \theta)$ .... (1)

$$B_1 = \frac{\theta}{2\pi}.\frac{\mu_0 I_1}{2R} \text{ and } B_2 = \frac{2\pi - \theta}{2\pi}.\frac{\mu_0 I_2}{2R}$$

Using (1), we get $B_1 = B_2$.

40. **(d)** Reversing the direction of the current reverses the direction of the magnetic field. However, it has no effect on the magnetic-field energy density, which is proportional to the square of the magnitude of the magnetic field.

41. **(b)** In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecule in a gas. Their average velocity is zero. i.e. they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

42. **(c)** An ammeter should have a low resistance which we get when we connect low resistance in parallel with galvanometer.

Chapter 19

Magnetism and Matter

TYPE A : MULTIPLE CHOICE QUESTIONS

1. Domain formation is the necessary feature of : ***[1998]***

(a) ferromagnetism (b) diamagnetism
(c) paramagnetism (d) all of these

2. The best material for the core of a transformer is

(a) mild steel (b) stainless steel
(c) soft iron (d) hard steel ***[1998]***

3. The north pole of a magnet is brought near a metallic ring. Then the direction of the induced current in the ring will be: ***[1999]***

(a) Towards north (b) Towards south
(c) Anticlockwise (d) Clockwise

4. Angle of dip is 90° at: ***[1999]***

(a) Equator (b) Middle point
(c) Poles (d) None of these

5. What happens, when a magnetic substance is heated ? ***[1999]***

(a) It loses its magnetism
(b) It becomes a strong magnet
(c) Does not effect the magnetism
(d) Either (b) and (c)

6. A magnet 10 cm long and having a pole strength 2 amp m is deflected through 30° from the magnetic meridian. The horizontal component of earth's induction is 0.32×10^{-4} tesla then the value of deflecting couple is: ***[1999]***

(a) 32×10^{-7} Nm (b) 16×10^{-7} Nm
(c) 64×10^{-7} Nm (d) 48×10^{-7} Nm

7. Which one of the following statement is not correct about the magnetic field ? ***[2000]***

(a) Inside the magnet the lines go from north pole to south pole of the magnet
(b) Tangents to the magnetic lines give the direction of the magnetic field
(c) The magnetic lines form a closed loop
(d) Magnetic lines of force do not cut each other

8. Which one of the following are used to express intensity of magnetic field in vacuum ? ***[2000]***

(a) oersted (b) tesla
(c) gauss (d) none of these

9. A frog can be levitated in a magnetic field produced by a current in a vertical solenoid placed below the frog. This is possible because the body of the frog behaves as : ***[2003]***

(a) paramagnetic (b) diamagnetic
(c) ferromagnetic (d) antiferromagnetic

10. Liquid oxygen remains suspended between two pole forces of a magnet because it is : ***[2004]***

(a) diamagnetic (b) paramagnetic
(c) ferromagnetic (d) antiferromagnetic

11. The magnetic susceptibility of an ideal diamagnetic substance is ***[2007]***

(a) –1 (b) 0
(c) +1 (d) ∞

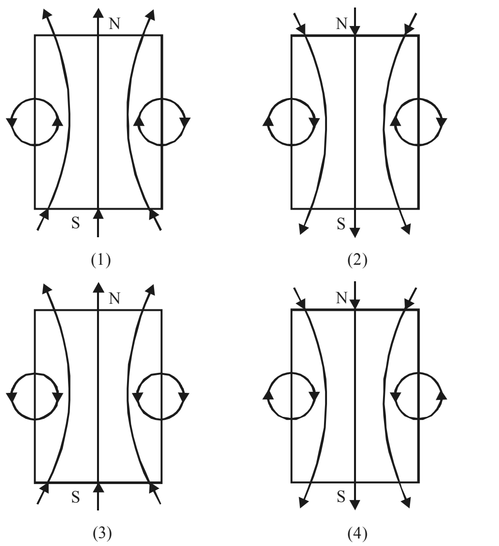
12. A magnet makes 40 oscillation per minute at a place having magnetic intensity of 0.1×10^{-5} tesla. At another place it takes 2.5 sec to complete one oscillation. The value of earth's horizontal field at that place is ***[2011]***

(a) 0.76×10^{-6} tesla (b) 0.18×10^{-6} tesla
(c) 0.09×10^{-6} tesla (d) 0.36×10^{-6} tesla

13. Curie temperature is the temperature above which ***[2012]***

(a) a ferromagnetic material becomes paramagnetic
(b) a paramagnetic material becomes diamagnetic
(c) a ferromagnetic material becomes diamagnetic
(d) a paramagnetic material becomes ferromagnetic

14. Of the following Fig., the lines of magnetic induction due to a magnet SN, are given by



(a) 1 (b) 2 ***[2012]***
(c) 3 (d) 4

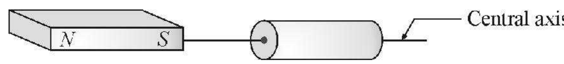
15. The materials suitable for making electromagnets should have ***[2013]***
(a) high retentivity and low coercivity
(b) low retentivity and low coercivity
(c) high retentivity and high coercivity
(d) low retentivity and high coercivity

16. Magnetic lines of force due to a bar magnet do not intersect because ***[2014]***
(a) a point always has a single net magnetic field
(b) the lines have similar charges and so repel each other
(c) the lines always diverge from a single force
(d) the lines need magnetic lenses to be made to interest

17. At a temperatur of 30°C, the susceptibility of a ferromagnetic material is found to be χ. Its susceptibility at 333°C is ***[2015]***
(a) χ (b) 0.5χ
(c) 2χ (d) 11.1χ

18. Two points A and B are situated at a distance x and 2x respectively from the nearer pole of a magnet 2 cm long. The ratio of magnetic field at A and B is ***[2016]***
(a) 4 : 1 exactly (b) 4 : 1 approximately
(c) 8 : 1 approximately (d) 1 : 1 approximately

19. Imagine rolling a sheet of paper into a cylinder and placing a bar magnet near its end as shown in figure. What can you say about the sign of $\vec{B}.d\vec{A}$ for every area $d\vec{A}$ on the surface? ***[2017]***



(a) Positive
(b) Negative
(c) No sign
(d) Can be positive or negative

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 20-27) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

20. **Assertion :** We cannot think of a magnetic field configuration with three poles
Reason : A bar magnet does exert a torque on itself due to its own field. ***[2002]***

21. **Assertion :** In high latitudes one sees colourful curtains of light hanging down from high altitudes
Reason : The high energy charged particles from the sun are deflected to polar regions by the magnetic field of the earth. ***[2003]***

22. **Assertion :** The true geographic north direction is found by using a compass needle.
Reason : The magnetic meridian of the earth is along the axis of rotation of the earth. ***[2004]***

23. **Assertion :** A disc-shaped magnet is deviated above a superconducting material that has been cooled by liquid nitrogen.
Reason : Superconductors repel a magnet. ***[2005]***

24. **Assertion :** Magnetic Resonance Imaging (MRI) is a useful diagnostic tool for producing images of various parts of human body.

    Reason : Protons of various tissues of the human body play a role in MRI. ***[2006]***

25. **Assertion :** Diamagnetic materials can exhibit magnetism.

    Reason : Diamagnetic materials have permanent magnetic dipole moment. ***[2006]***

26. **Assertion :** Ferro-magnetic substances become paramegnetic above Curie temp.

    Reason : Domains are destroyed at high temperature. ***[2007]***

27. **Assertion :** If a compass needle be kept at magnetic north pole of the earth the compass needle may stay in any direction.

    Reason : Dip needle will stay vertical at the north pole of earth ***[2008]***

Directions for (Qs. 28-33) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

28. **Assertion :** The ferromagnetic substance do not obey Curie's law.

    Reason : At Curie point a ferromagnetic substance start behaving as a paramagnetic substance. ***[2011]***

29. **Assertion** : The ferromagnetic substance do not obey Curie's law.

    Reason : At Curie point a ferromagnetic substance start behaving as a paramagnetic substance. ***[2014]***

30. **Assertion :** A paramagnetic sample display greater magnetisation (for the same magnetic field) when cooled.

    Reason : The magnetisation does not depend on temperature. ***[2015]***

31. **Assertion :** Electromagnetic are made of soft iron.

    Reason : Coercivity of soft iron is small. ***[2016]***

32. **Assertion :** The sensitivity of a moving coil galvanometer is increased by placing a suitable magnetic material as a core inside the coil.

    Reason : Soft iron has high magnetic permeability and cannot be easily magnetized or demagnetized. ***[2016]***

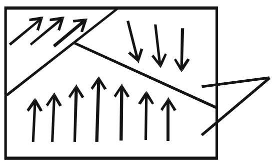
33. **Assertion :** The poles of magnet can not be separated by breaking into two pieces.

    Reason : The magnetic moment will be reduced to half when a magnet is broken into two equal pieces. ***[2017]***

HINTS & SOLUTIONS

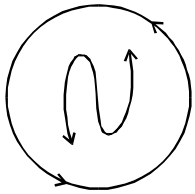
Type A : Multiple Choice Questions

1. (a) In ferromagnetic material atomic magnets of a substance form domain in which magnetic moment of all the tiny magnets are oriented in the same direction.



2. (c) Soft iorn provides the best material for the core of a transformer as its permeability (μ) is very high. Its hysteresis curve is of small area and its coercivity is very low.

3. (c)



When we bring a north pole near a metallic ring applying Lenz's law the ring will behave as north pole so that repulsion occurs. So direction of current induced in it will be anti-clockwise as depicted above.

4. (c) At poles angle of dip will be 90° because earth's magnetic field will be almost vertical there.

5. (a) When a magnetic substance is heated it loses its magnetic property. It is because all the atomic magnet becomes randomly oriented due to heat.

6. (a) $M = 2 \times \frac{10}{100} = 0.2$

Value of restoring couple = $MH \sin\phi$

$= 0.2 \times 0.32 \times 10^{-4} \sin 30°$

$= 0.2 \times 0.32 \times 10^{-4} \times \frac{1}{2} = 32 \times 10^{-7}\,\text{Nm}$

7. (a) Inside the magnet, lines go from south pole to north pole. So, option (a) is correct.

8. (a) Intensity of magnetic field in vacuum is expressed in oersted in c.g.s. system and Am^{-1} in S.I. system. In the formula, $B = \mu H$

H is known as intensity of magnetic field.

9. (c) The frog will levitate in the magnetic field due to repulsion. It suggests that the body of frog is acting as ferromagnetic material.

10. (b) Oxygen is paramagnetic in nature. So if it will be attracted both by North pole or South pole. When it is placed exactly between two magnetic poles, the forces acting on it due to magnetic poles will be equal & opposite. Hence it will remain suspended between them.

11. (a) Magnetic susceptibility χ is related to permeability μ by $\mu = 1 + 4\pi\chi_m$. For diamagnetic substances χ_m is negative and $\mu<1$ (negative). Ideal diamagnet should expel all magnetic field lines inside it i.e. $\chi_m < 0$ or $\chi_m = -1$

12. (d) Time period of vibration of a magnet is

$$T = 2\pi\sqrt{\frac{I}{MH}}$$

For the same magnet, I and M are constant where M = magnetic moment,

I = moment of inertia of magnet.

$$\Rightarrow T \propto \frac{1}{\sqrt{H}}.$$

First case

$$T_1 = \frac{60}{40} = \frac{3}{2} = 1.5 \text{ sec.}$$

$H_1 = 0.1 \times 10^{-5}\text{T}, T_2 = 2.5 \text{ sec}, H_2 = ?$

$$\Rightarrow \frac{1.5}{2.5} = \sqrt{\frac{H_2}{H_1}}$$

$$\Rightarrow \frac{15}{25} = \sqrt{\frac{H_2}{10^{-6}}}$$

$$\Rightarrow H_2 = \left(\frac{3}{5}\right)^2 \times 10^{-6}$$

$$\Rightarrow H_2 = \frac{9}{25} \times 10^{-6} = 0.36 \times 10^{-6} T$$

13. **(a)**

14. **(a)** As lines of magnetic induction B are continuous curves, they run continuously through the bar and outside, as shown in Fig. (1).

15. **(b)** Electro magnet should be amenable to magnetisation and demagnetization
$\therefore$ retentivity should be low and coercivity should be low.

16. **(a)**

17. **(b)** According to Curie's law, $\chi_m = \frac{\mu_0 C}{T}$
where C is Curie constant, T = temperature

$$\therefore \chi_m \alpha \frac{1}{T}$$

$$\frac{\chi_{m_1}}{\chi_{m_2}} = \frac{T_2}{T_1} = \frac{273+333}{273+30} = \frac{606}{303} = 2$$

$$\therefore \chi_{m_2} = \chi_{m_1}/2 = 0.5\chi_{m_1} = 0.5\chi$$

$$(\because \chi_{m_1} = \chi)$$

18. **(c)** Taking distances from the centre of the magnet,

$$\frac{B_1}{B_2} = \left(\frac{x_2}{x_1}\right)^3 = \left(\frac{2x+1}{x+1}\right)^3 = 8:1, \text{ approximately.}$$

19. **(b)** The field is entering into the surface so flux is negative.

Type B : Assertion Reason Questions

20. **(d)** Magnetic field may be formed with the help of three poles. A bar magnet does not exert a torque on itself due to its own field.

21. **(a)** In polar region like north pole and south pole one sees colourful curtains of light hanging down from light altitude. It results from high energy charged particles from the sun being attracted by the poles of the earth. In northern hemisphere it is known Aure Boreali's and in southern hemisphere it is known as Aura Australi's.

22. **(d)** The true geographic north-south direction is inclined at an angle with magnetic north-south direction. The angle between them is known as declination. Compass needle gives us direction of north-south (magnetic) direction. Magnetic meridian to pass through magnetic north-south direction. Axis of rotation of the earth gives us geographic north-south direction. So, both Assertion and Reason are incorrect.

23. **(a)** Superconductors are actually diamagnetic in nature so when it is placed above a magnet it will be repelled by magnet or it will tend to move from higher field to lower field. This is the principle behind leviation of a superconducting material above magnet.

24. **(a)** MRI is useful diagnostic tool for producing images of various parts of human body because it makes use of magnetic property of spinning proton inside the nucleus.

25. **(c)** Diamagnetic material exhibits magnetism in reverse direction. R is a wrong statement. Because due to absence of unpaired electron in diamagnetic material it does not exhibit permanent magnet dipole moment.

26. **(a)** Susceptibility of ferro magnets decreases with increase of temperature. At a transition temperature called Curie temperature they pass over to paramagnets. When temperature is increased, dipoles acquire kinetic energy and are disoriented, hence domain internal interaction called exchange coupling disappears.

27. **(b)** The earth has only vertical component of its magnetic field at the magnetic poles. Since compass needle is only free to rotate in horizontal plane where H = 0, hence the compass needle may stay in any direction. The dip needle rotates in a vertical plane and angle of dip at poles is 90°. So it will stand vertical.

28. **(b)** The susceptibility of ferromagnetic substance decreases with the rise of temperature in a complicated manner. After Curie point in the susceptibility of ferromagnetic substance varies inversely with its absolute temperarture. Ferromagnetic substance obey's Curie's law only above its Curie point.

29. (c) The susceptibility of ferromagnetic substance decreases with the rise of temperature in a complicated manner. After Curies point in the susceptibility of ferromagnetic substance varies inversely with its absolute tempearture. Ferromagnetic substance obey's Curie's law only above its Curie point.

30. (d) A paramagnetic sample display greater magnetisation when cooled, this is because at lower temperature, the tendency to disrupt the alignment of dipoles (due to magnetising field) decreases on account of reduced random thermal motion.

31. (b) Electromagnets are magnets, which can be turnd on and off by switching the current on and off.

As the material in electromagnets is subjected to cyclic changes (magnification and demangetisation), the hysteresis loss of the material must be small. The material should attain high value of I and B with low value of magnetising field intensity H. As soft iron has small coercivity, so it is a best choice for this purpose.

32. (c) Sensitivity of galvanometer,

$$s = \frac{\theta}{i} \simeq \frac{\tan\theta}{i} = \frac{\mu_0 N}{2RB_H}.$$

If a magnetic material is placed inside coil of galvanometer, then

$$s' = \frac{\mu_r \mu_0 N}{2RB_H}.$$

33. (b) When a magnet is cut into pieces, each piece becomes new magnet. $M' = \frac{m\ell}{2} = \frac{M}{2}$.

Chapter 20

Electromagnetic Induction

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A coil of copper having 1000 turns is placed in a magnetic field ($B = 4 \times 10^{-5}$) perpendicular to its axis. The cross sectional area of the coil is 0.05 m^2. If it turns through 180° in 0.01 second, then the e.m.f. induced in the coil will be ; ***[1997]***

(a) 4V (b) 0.04V
(c) 0.4V (d) 0.2V

2. In a coil of self inductance of 5 henry, the rate of change of current is 2 ampere per second, the e.m.f. induced in the coil is : ***[1997]***

(a) 5V (b) – 5V
(c) – 10 V (d) 10V

3. According to Lenz's law there is a conversion of:

(a) momentum (b) collision ***[1997]***
(c) voltage (d) energy

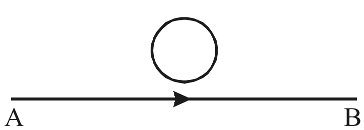
4. A 50 turn circular coil has a radius of 3 cm, it is kept in a magnetic field acting normal to the area of the coil. The magnetic field B is increased from 0.10 T to 0.35 T in 2 milli second, the average induced emf will be: ***[1999]***

(a) 177V (b) 1.77V
(c) 0.177V (d) 17.7V

5. A solenoid is 1.5 m long and its inner diameter is 4.0 cm. It has 3 layers of windings of 1000 turns each and carries a current of 2.0 amperes. The magnetic flux for a cross-section of the solenoid is nearly ***[2000]***

(a) 4.1×10^{-5} weber (b) 5.2×10^{-5} weber
(c) 6.31×10^{-3} weber (d) 2.5×10^{-7} weber

6. The current flows from A to B as shown in figure, then the direction of the induced current in the loop will be : ***[2001]***

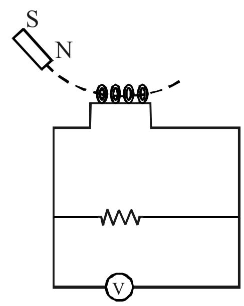


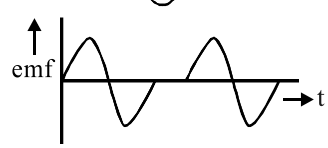
(a) straight line (b) anti-clockwise
(c) clockwise (d) none of these

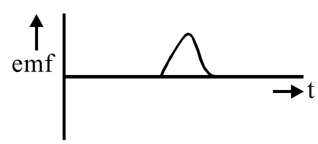
7. A conducting ring of radius 1 metre is placed in an uniform magnetic field B of 0.01 tesla oscillating with frequency 100 Hz with its plane at right angle to B. What will be the induced electric field ? ***[2005]***

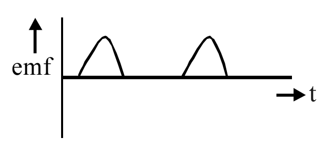
(a) π volt / m (b) 2volt / m
(c) 10 volt/m (d) 62 volt/m

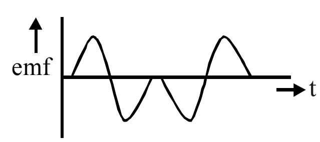
8. A magnet is made to oscillate with a particular frequency, passing through a coil as shown in figure. The time variation of the magnitude of emf generated across the coil during on cycle is ***[2005]***



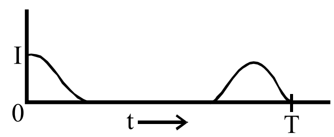
(a) 

(b) 

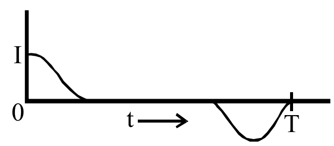
(c) 

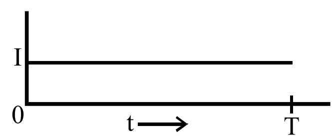
(d) 

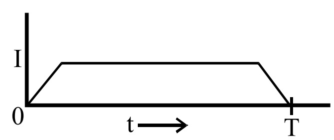
9. A metallic ring is dropped down, keeping its plane perpendicular to a constant and horizontal magnetic field. The ring enters the region of magnetic field at t = 0 and completely emerges out at t = T sec. The current in the ring varies as

(a) 

[2006]

(b) 

(c) 

(d) 

10. Which of the following conclusion can be drawn from the result ***[2010]***

$$\oint \vec{B}.d\vec{A} = 0$$

(a) magnetic field is zero everywhere
(b) magnetic monopole cannot exist
(c) magnetic lines of force do not intersect each other
(d) a current produces magnetic field

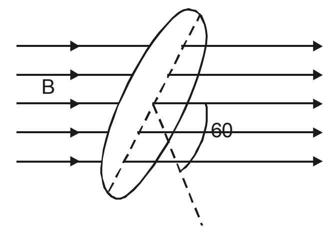
11. A wheel with ten metallic spokes each 0.50m long is rotated with a speed of 120 rev/min in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.40 G, the induced emf between the axle and the rim of the wheel is equal to ***[2010]***

(a) 1.256×10^{-3} V (b) 6.28×10^{-4} V
(c) 1.256×10^{-4} V (d) 6.28×10^{-5} V

12. The magnetic flux through a circuit carrying a current of 2.0 A is 0.8 weber. If the current reduces to 1.5 A in 0.1 s, the induced emf be : ***[2011]***

(a) 2.0 V (b) 4.0 V
(c) 8.0 V (d) none of the above

13. Fig represents an area A = 0.5 m^2 situated in a uniform magnetic field ***[2012]***



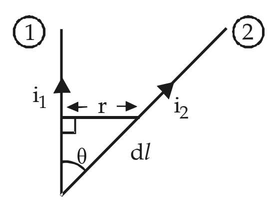
B = 2.0 weber/m^2 and making an angle of 60º with respect to magnetic field. The value of the magnetic flux through the area would be equal to

(a) 2.0 weber (b) $\sqrt{3}$ weber
(c) $\sqrt{3}/2$ weber (d) 0.5 weber

14. A charged particle moves through a magnetic field in a direction perpendicular to it. Then the

(a) velocity remains unchanged ***[2013]***
(b) speed of the particle remains unchanged
(c) direction of the particle remains unchanged
(d) acceleration remains unchanged

15. Wires 1 and 2 carrying currents i_1 and i_2 respectively are inclined at an angle θ to each other. What is the force on a small element d*l* of wire 2 at a distance of r from wire 1 (as shown in figure) due to the magnetic field of wire 1?



[2013]

(a) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \tan\theta$ (b) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \sin\theta$

(c) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \cos\theta$ (d) $\frac{\mu_0}{4\pi r} i_1 i_2 \, dl \sin\theta$

16. The flux linked with a coil at any instant 't' is given by

$\phi = 10t^2 - 50t + 250$. The induced emf at t = 3s is

(a) –190 V (b) –10 V ***[2014]***
(c) 10 V (d) 190 V

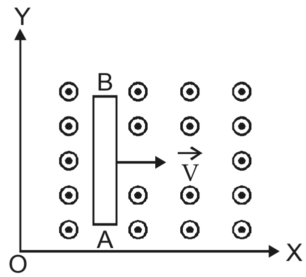
17. In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. The maximum value of emf generated in the coil is ***[2015]***

(a) N.A.B.R.ω (b) N.A.B.
(c) N.A.B.R. (d) N.A.B.ω

18. In an inductor of self-inductance L = 2 mH, current changes with time according to relation $i = t^2e^{-t}$. At what time emf is zero? ***(2016)***

(a) 4s (b) 3s
(c) 2s (d) 1s

19. A conducting rod AB moves parallel to X-axis in a uniform magnetic field, pointing in the positive X-direction. The end A of the rod gets ***(2017)***



(a) positively charged
(b) negatively charged
(c) neutral
(d) first positively charged and then negatively charged

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 20-21) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

20. **Assertion :** An emf $\vec{E}$ is induced in a closed loop where magnetic flux is varied. The induced $\vec{E}$ is not a conservative field.

Reason : The line integral $\vec{E}.d\vec{l}$ around the closed loop is nonzero. ***[2006]***

21. **Assertion :** An electric motor will have maximum efficiency when back emf becomes equal to half of applied emf.

Reason : Efficiency of electric motor depends only on magnitude of back emf. ***[2008]***

Directions for (Qs. 22-24) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

22. **Assertion :** An induced current has a direction such that the magnetic field due to the current opposes the change in the magnetic flux that induces the current.

Reason : Above statement is in accordance with conservation of energy. ***[2011]***

23. **Assertion :** Lenz's law violates the principle of conservation of energy.

Reason : Induced emf always opposes the change in magnetic flux responsible for its production. ***[2014]***

24. **Assertion :** Faraday's laws are consequence of conservation of energy.

Reason : In a purely resistive ac circuit, the current legs behind the emf in phase. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(c)** Flux passing through the coil,

$= 1000 \times 4 \times 10^{-5} = 2 \times 10^{-3}$ Weber

Change in flux when the coil turns by 180°.

$= 2 \times 10^{-3} - (-2 \times 10^{-3})$

$\Delta\phi = 4 \times 10^{-3}$

$$\text{e.m.f.} = \frac{d\phi}{dt} = \frac{4 \times 10^{-3}}{0.01} = 0.4\text{V}$$

2. **(c)** $\text{e.m.f.} = -L\frac{di}{dt} = -5 \times 2 = -10\text{V}$

3. **(d)** Lenz's law deals with conversion of mechanical energy into electromagnetic energy in case of electromagnetic induction.

4. **(b)** Average flux in the beginning $= \pi r^2 n B_1$

Average flux in the final $= \pi r^2 n B_2$

Increase in flux $d\phi = \pi r^2 n(B_2 - B_1)$

$= 3.14 \times (0.03)^2 \times 50\,(0.35 - 0.10)$

$= 314 \times 45 \times 25 \times 10^{-7}$

Given time $dt = 2 \times 10^{-3}$

$$e = -\frac{d\phi}{dt} = \frac{314 \times 45 \times 25 \times 10^{-7}}{2 \times 10^{-3}}$$

$= 1.77$ V (approx.)

5. **(c)** Magnetic flux $(\phi) = nBA$

where n is number of turns, B is magnetic field and A is area

Given, $n = 1000$, $i = 2$ amp $r = 0.02$

and $l = 1.5$ m

Magnetic field of solenoid of length ℓ is

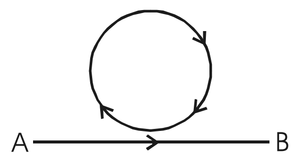
$$B = \frac{\mu_0 i}{l}$$

$$\therefore\ \phi = \frac{\mu_0 n i A}{l}$$

$$\phi = \frac{3 \times 10^{-7} \times 4\pi \times (1000)^2 \times 2 \times \pi(2 \times 10^{-2})^2}{1.5}$$

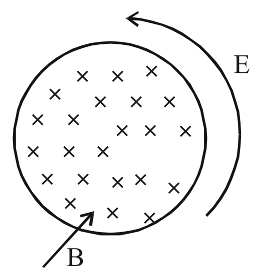
$= 6.31 \times 10^{-3}$ Wb

6. **(c)**



Direction of magnetic field due to indicated current will be in upward direction passing through the coil. So, a current in coil will be induced so that it decreases the flux in the coil. So, current in the clockwise direction will be induced.

7. **(b)** A changing magnetic field gives rise to electric field as shown in the figure.



The relation between electric field and changing magnetic field is

$$\oint E\,d\ell = \frac{d\phi}{dt} = \frac{dBA}{dt}$$

$$2\pi r E = \frac{\pi r^2 dB}{dt} \Rightarrow E = \frac{r}{2}\frac{dB}{dt}$$

Here $dB = 0.01 - (-0.01) = 0.02$

$$dt = \frac{T}{2} = \frac{1}{2 \times 100}$$

$$E = \frac{1}{2} \times \frac{0.02}{\frac{1}{2 \times 100}} = \frac{2 \times 100 \times 0.02}{2} = 2\text{ volt}$$

8. **(a)** We know that electromagnetic e.m.f. induced,

$$e = -\frac{d\phi}{dt}$$

Initially, $d\phi$ will be positive (during first $\frac{T}{4}$ time period) then it becomes negative during the period from $\frac{T}{4}$ to $\frac{T}{2}$.

During the period $\frac{T}{2}$ to $\frac{3T}{4}$ it is again positive and in the last $\frac{T}{4}$ time it is negative. Accordingly sign of emf produced will be changed. Figure (a) fits exactly in this change pattern. So this figure represents the answer.

9. **(b)** When ring enters the field an emf is induced due to change in flux. Once with the magnetic field, there is no change in flux in the ring so there is no emf. When it emerges out of the field, once again there is a flux change which creates emf in reverse direction. Graph (b) shows this result.

10. **(b)** Flux of certain closed surface is zero and so it tells that net magnetic charge is equal to zero. This is possible when there are two equal and opposite poles.

11. **(d)** $e = \frac{B\omega\ell^2}{2}$

$$= \frac{(0.4\times10^4)\times\left(2\pi\times\frac{120}{60}\right)\times(0.5)^2}{2}$$

$= 0.628\times10^{-4}V$

12. **(a)** flux corresponds to 2A is = 0.8 weber
flux corresponds to 1.5 A is = 0.6 weber

$$|e| = \frac{\Delta\phi}{\Delta t} = \frac{0.2}{0.1} = 2.0V$$

13. **(d)** $\phi = BA\cos\theta = 2.0\times0.5\times\cos60^\circ$

$$= \frac{2.0\times0.5}{2} = 0.5 \text{ Weber.}$$

14. **(b)** Magnetic force acts perpendicular to the velocity. Hence speed remains constant.

15. **(c)**

16. **(b)** $\phi = 10t^2 - 50t + 250$

$$e = -\frac{d\phi}{dt} = -(20t - 50)$$

$e_{t=3} = -10$ V

17. **(d)** $e = -\frac{d\phi}{dt} = -\frac{d(N\vec{B}.\vec{A})}{dt}$

$$= -N\frac{d}{dt}(BA\cos\omega t) = NBA\omega\sin\omega t$$

$\Rightarrow e_{max} = NBA\omega$

18. **(c)** $L = 2mH,\ i = t^2e^{-t}$

$$E = -L\frac{di}{dt} = -L[-t^2e^{-t} + 2te^{-t}]$$

when $E = 0$
$-e^{-t}t^2 + 2te^{-t} = 0$
$2t\,e^{-t} = e^{-t}t^2$
$t = 2$ sec.

19. **(a)** According to right hand palm rule, the Lorentz force on free electrons in the conductor will be directed towards end B. Hence, the end A gets positively charged.

Type B : Assertion Reason Questions

20. **(a)** Assertion and Reason is correct and Reason explains Assertion. According to Faraday's law of electromagnetic induction

$$\int\vec{E}.d\vec{\ell} = -\frac{d\phi}{dt}$$

So, (E) is non-conservative field as in conservative field line integral over a closed loop is zero.

21. **(c)** Efficiency of an electric motor is maximum when the back emf setup in the armature is half the value of the applied battery emf

$$\text{Efficiency, } \eta = \frac{P_{out}}{P_{in}} = \frac{e}{E} = \frac{\text{Back emf}}{\text{Supply voltage}}$$

22. **(a)**

23. **(a)** Lenz's law (that the direction of induced emf is always such as to oppose the change that cause it) is direct consequence of the law of conservation of energy.

24. **(c)** In purely resistive circuit, the current and emf are in the same phase.

Chapter 21

Alternating Current

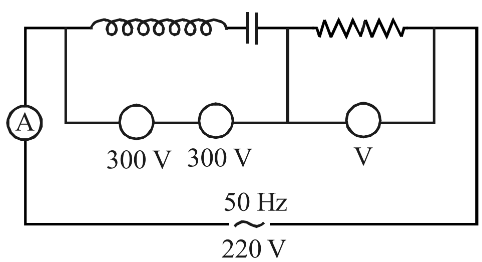
TYPE A : MULTIPLE CHOICE QUESTIONS

1. An A.C. circuit containing only capacitance, the current : *[1997]*
(a) lags the voltage by 90°
(b) leads the voltage by 90°
(c) remains in phase with voltage
(d) leads the voltage in 180°

2. A choke coil has: *[1999]*
(a) Low inductance and low resistance
(b) High inductance and high resistance
(c) Low inductance and high resistance
(d) High inductance and low resistance

3. Turn ratio in a step up transformer is 1 : 2 if a Lechlanche cell of 1.5 V is connected across the input, then the voltage across the output will be
(a) 0.1 V (b) 1.5 V *[2000]*
(c) 0.75 V (d) zero

4. In the circuit shown below what will be the reading of the voltmeter and ammeter ? *[2000]*
(Total impedance of circuit $Z = 100\Omega$)



(a) 200 V, 1A (b) 800 V, 2A
(c) 100 V, 2A (d) 220 V, 2.2 A

5. In a circuit the coil of a choke : *[2001]*
(a) decreases the current
(b) increases the current
(c) has high resistance to D. C. circuit
(d) no effect with the current

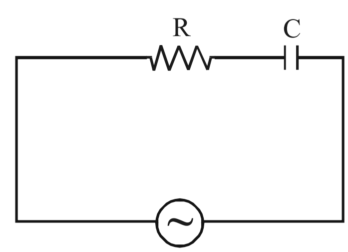
6. In a circuit, the current lags behind the voltage by a phase difference of $\pi/2$, the circuit will contain which of the following : *[2001]*
(a) only R (b) only C
(c) R and C (d) only L

7. The coefficient of mutual inductance, when magnetic flux changes by 2×10^{-2} Wb and current changes by 0.01 A is *[2002]*
(a) 8 henry (b) 4 henry
(c) 3 henry (d) 2 henry

8. In an ideal parallel LC circuit, the capacitor is charged by connecting it to a D.C. source which is then disconnected. The current in the circuit
(a) becomes zero instantaneously *[2003]*
(b) grows monotonically
(c) decays monotonically
(d) oscillates instantaneously

9. A capacitor of capacitance 2μF is connected in the tank circuit of an oscillator oscillating with a frequency of 1 kHz. If the current flowing in the circuit is 2 m A, the voltage across the capacitor will be : *[2003]*
(a) 0.16 V (b) 0.32 V
(c) 79.5 V (d) 159 V

10. A 50 Hz a.c. source of 20 volt is connected across R and C as shown in figure. The voltage across R is 12 volt. The voltage across C is : *[2004]*



(a) 8 V
(b) 16 V
(c) 10 V
(d) not possible to determine unless values of R and C are given

11. In an AC circuit the potential differences across an inductance and resistance joined in series are respectively 16 V and 20 V. The total potential difference of the source is *[2007]*
(a) 20.0 V (b) 25.6 V
(c) 31.9 V (d) 53.5 V

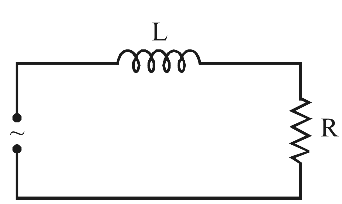
12. With the decrease of current in the primary coil from 2 amperes to zero value in 0.01s the emf generated in the secondary coil is 1000 volts. The mutual inductance of the two coils is
(a) 1.25 H (b) 2.50 H *[2007]*
(c) 5.00 H (d) 10.00 H

13. An AC source of angular frequency ω is fed across a resistor R and a capacitor C in series. The current registered is I. If now the frequency of source is changed to ω/3 (but maintaining the same voltage), the current in the circuit is found to be halved. Calculate the ratio of reactance to resistance at the original frequency ω *[2008]*
(a) $\sqrt{\frac{3}{5}}$ (b) $\sqrt{\frac{2}{5}}$
(c) $\sqrt{\frac{1}{5}}$ (d) $\sqrt{\frac{4}{5}}$

14. If an AC main supply is given to be 220 V. The average emf during a positive half cycle will be
(a) 198 V (b) 220 V *[2009]*
(c) 240 V (d) $220\sqrt{2}$ V

15. A coil has an inductance of 0.7 henry and is joined in series with a resistance of 220 Ω. When the alternating emf of 220 V at 50 Hz is applied to it then the phase through which current lags behind the applied emf and the wattless component of current in the circuit will be respectively *[2010]*
(a) 30°, 1 A (b) 45°, 0.5 A
(c) 60°, 1.5 A (d) none of these

16. An inductor and a resistor in series are connected to an A.C. supply of variable frequency. As the frequency of the source is increased, the phase angle between current and the potential difference across L will: *[2010]*



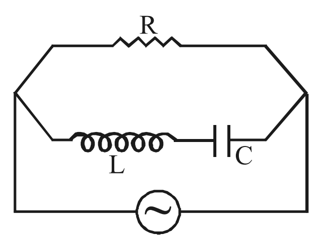
(a) first increase and then decrease
(b) first decrease and then increase
(c) go on decreasing
(d) go on increasing

17. In a AC circuit the voltage and current are described by $V = 200\sin\left(319t - \frac{\pi}{6}\right)$ volts *[2010]* and $i = 50\sin\left(314t + \frac{\pi}{6}\right)$ mA respectively. The average power dissipated in the circuit is : *[2011]*
(a) 2.5 watts (b) 5.0 watts
(c) 10.0 watts (d) 50.0 watts

18. If we decrease the frequency of the applied A.C. with a purely capacitive load, do (1) the amplitude of V_c and (2) amplitude of I_c increase, decrease of remain the same. *[2011]*
(a) (1) increase (2) same
(b) (1) same (2) increase
(c) (1) same (2) decrease
(d) (1) decrease (2) same

19. An inductor coil of inductance L is cut into two equal parts and both the parts are connected in parallel. The net inductance is : *[2011]*
(a) L (b) L/2
(c) L/4 (d) 2 L.

20. The current in resistance R at resonance is



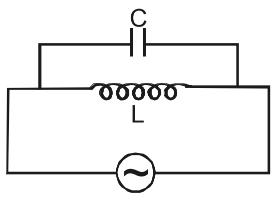
$V = V_0 \sin \omega t$

(a) zero *[2012]*
(b) minimum but finite
(c) maximum but finite
(d) infinite

21. An inductance L having a resistance R is connected to an alternating source of angular frequency ω. The Quality factor Q of inductance is *[2012]*
(a) R/ωL (b) $(\omega L/R)^2$
(c) $(R/\omega L)^{1/2}$ (d) ωL/R

22. In an A.C. circuit, the current flowing in inductance is $I = 5\sin(100t - \pi/2)$ amperes and the potential difference is $V = 200\sin(100t)$ volts. The power consumption is equal to *[2013]*
(a) 1000 watt (b) 40 watt
(c) 20 watt (d) zero

23. For the circuit shown in the fig., the current through the inductor is 0.9 A while the current through the condenser is 0.4 A. Then *(2013)*



$V = V_0 \sin \omega t$

(a) current drawn from generator I = 1.13 A
(b) $\omega = 1/(1.5\,LC)$
(c) I = 0.5 A
(d) I = 0.6 A

24. L, C, R represent physical quantities inductance, capacitance and resistance respectively. The combinations which have the dimensions of frequency are *[2013]*

(a) 1/RC (b) R/L
(c) $1/\sqrt{LC}$ (d) C/L

25. An inductance L having a resistance R is connected to an alternating source of angular frequency ω. The Quality factor Q of inductance is *[2014]*

(a) $R/\omega L$ (b) $(\omega L/R)^2$
(c) $(R/\omega L)^{1/2}$ (d) $\omega L/R$

26. A step down transformer is connected to 2400 volts line and 80 amperes of current is found to flow in output load. The ratio of the turns in primary and secondary coil is 20 : 1. If transformer efficiency is 100%, then the current flowing in the primary coil will be *[2015]*

(a) 1600 amp (b) 20 amp
(c) 4 amp (d) 1.5 amp

27. The mutual inductance of a pair of coils, each of N turns, is M henry. If a current of I ampere in one of the coils is brought to zero in t second, the emf induced per turn in the other coil, in volt, will be *[2015]*

(a) $\frac{MI}{t}$ (b) $\frac{NMI}{t}$
(c) $\frac{MN}{It}$ (d) $\frac{MI}{Nt}$

28. The tuning circuit of a radio receiver has a resistance of 50Ω, an inductor of 10 mH and a variable capacitor. A 1 MHz radio wave produces a potential difference of 0.1 mV. The values of the capacitor to produce resonance is (Take $\pi^2 = 10$) *[2015]*

(a) 2.5 pF (b) 5.0 pF
(c) 25 pF (d) 50 pF

29. A coil has resistance 30 ohm and inductive reactance 20 ohm at 50 Hz frequency. If an ac source, of 200 volt, 100 Hz, is connected across the coil, the current in the coil will be *[2016]*

(a) 4.0 A (b) 8.0 A
(c) $\frac{20}{\sqrt{13}}$ A (d) 2.0 A

30. An ideal coil of 10H is connected in series with a resistance of 5Ω and a battery of 5V. After 2 sec the connection is made, the current flowing in ampere in the circuit is *[2016]*

(a) $(1 - e^{-1})$ (b) $(1 - e)$
(c) e (d) e^{-1}

31. An inductor, a resistor and a capacitor are joined in series with an AC source. As the frequency of the source is slightly increased from a very low value, the reactance of the *[2017]*

(a) inductor increases
(b) resistor increases
(c) capacitor increases
(d) circuit increases

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 32-34) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

32. **Assertion :** In series LCR circuit resonance can take place.
Reason : Resonance takes place if inductance and capacitive reactances are equal and opposite. *[1998]*

33. **Assertion :** Faraday's laws are consequences of conservation of energy.

    Reason : In a purely resistive A.C. circuit, the current lags behind the e.m.f. in phase. *[2002]*

34. **Assertion :** No power loss associated with pure capacitor in ac circuit.

    Reason : No current is flowing in this circuit. *[2007]*

Directions for (Qs. 35-41) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

35. **Assertion :** Ohm's law cannot be applied to a.c circuit.

    Reason : Resistance offered by capacitor for a.c source depends upon the frequency of the source. *[2009]*

36. **Assertion :** The resistance offered by an inductor in a d.c circuit is always constant.

    Reason : The resistance of inductor in steady state is non-zero. *[2010]*

37. **Assertion :** Long distance power transmission is done at high voltage.

    Reason : At high voltage supply power losses are less. *[2011, 2013]*

38. **Assertion :** A capacitor blocks direct current in the steady state.

    Reason : The capacitive reactance of the capacitor is inversely proportional to frequency f of the source of emf. *[2011]*

39. **Assertion :** In the purely resistive element of a series LCR, AC circuit the maximum value of rms current increases with increase in the angular frequency of the applied e.m.f.

    Reason :

    $$I_{max} = \frac{\varepsilon_{max}}{z},\ z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2},$$

    where I_{max} is the peak current in a cycle. *[2012]*

40. **Assertion :** In the purely resistive element of a series LCR, AC circuit the maximum value of rms current increases with increase in the angular frequency of the applied emf.

    Reason :

    $$I_{max} = \frac{\varepsilon_{max}}{z},\ z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2},$$

    where I_{max} is the peak current in a cycle. *[2016]*

41. **Assertion :** A laminated core is used in transformers to increase eddy currents.

    Reason : The efficiency of a transformer increases with increase in eddy currents. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (b) In an a.c. circuit containing resistance only voltage & current remain in the same phase. If circuit contains inductance only, voltage remains ahead of current by phase difference of 90°.

If circuit contains capacitance only, current remains ahead of voltage by a phase difference of 90°.

2. (d) A choke coil has high inductance and low resistance so, it is capable of producing very high induced e.m.f. which produces discharge in the tube.

3. (d) A transformer can not step up a d.c. input so output potential here will be zero. No potential will be induced in the secondary coil.

4. (d) Total impedence of the circuit = 100Ω

$$\text{Current} = \frac{220}{100} = 2.2\text{A}$$

Potential drop over inductance and capacitance is 300 V. As they are in opposite phase they will sum up to zero. So whole of 220 volt (external source) will come over the resistance.

$$(V_L - V_C)^2 + {V_R}^2 = (220)^2$$

As $V_L = V_C$ so $V_R = 220$ volt

5. (a) In a circuit with a.c. source, choke coil which is essentially an inductor with high reactance, is used to decrease the current without loss of energy. No heat is generated so no loss of energy. When we use resistance to reduce current, there is loss of electrical energy in the form of heat generated.

6. (d) If a circuit contains L, voltage leads current by a phase angle of $\frac{\pi}{2}$.

7. (d) We know that

$\phi = Mi$

$d\phi = Mdi$

$$M = \frac{d\phi}{di} = \frac{2\times10^{-2}}{1\times10^{-2}} = 2 \text{ henry}$$

8. (d) In an LC circuit current oscillates between maximum and minimum value. So, LC circuit needs oscillations (electrical). It occurs due to discharging and charging of capacitor and magnetisation and demagnetisation of inductor.

9. (a) Here, oscillating frequency

$= 1 \text{ kHz} = 10^3 \text{ Hz}$

Reactance of capacitor $= \frac{1}{\omega C}$

$$= \frac{1}{2\pi\times10^3\times2\times10^{-6}} = \frac{10^3}{4\pi}$$

Potential over capacitance

$$\frac{1}{\omega C}\times i = \frac{10^3}{4\pi}\times2\times10^{-3} = \frac{2}{4\pi} = \frac{7}{44} = 0.16\text{ V}$$

10. (b) $$E^2 = {V_R}^2 + \left(\frac{1}{\omega C}\right)^2 = {V_R}^2 + {V_C}^2$$

[Phase difference between V_R & V_C is 90°]

$(20)^2 = (12)^2 + {V_C}^2$

$\Rightarrow {V_C}^2 = 400 - 144 = 256$

$\Rightarrow V_C = 16$

11. (b) In any ac (LR) circuit, total potential is given by $V = \sqrt{V_R^2 + V_L^2}$ where V_R and V_L are potential across resistance and inductance respectively.

$$\text{Hence } V = \sqrt{(16)^2 + (20)^2} = \sqrt{256 + 400} = 25.6\text{ V}$$

12. (c) The emf induced in secondary is given by

$$e = \frac{-MdI}{dt} \Rightarrow 1000 = M\left(\frac{2-0}{0.01}\right)$$

(since current is reduced dI = – ve)

$$\Rightarrow M = \frac{1000\times0.01}{2} = 5.00\text{ H.}$$

13. (a) At angular frequency ω, current through RC circuit is given by

$$I_{rms} = \frac{V_{rms}}{\sqrt{R^2 + {X_C}^2}} = \frac{V_{rms}}{\sqrt{R^2 + (1/\omega C)^2}} \quad \ldots(1)$$

When angular frequency is changed to $\frac{\omega}{3}$, then the current becomes,

$$\frac{I_{rms}}{2} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{1}{\left(\frac{\omega}{3}\right)C}\right)^2}} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{3}{\omega C}\right)^2}} \quad \ldots (2)$$

Dividing (i) by (ii)

$$2 = \frac{\sqrt{R^2 + (3/\omega C)^2}}{\sqrt{R^2 + (1/\omega C)^2}}$$

or $4\left[R^2 + \left(\frac{1}{\omega C}\right)^2\right] = R^2 + \left(\frac{3}{\omega C}\right)^2$

$$3R^2 = \frac{5}{\omega^2 C^2} \Rightarrow \frac{1/\omega C}{R} = \sqrt{\frac{3}{5}}$$

$$\Rightarrow \frac{X_C}{R} = \sqrt{\frac{3}{5}}$$

14. (a) $E_{rms} = 220$ V

$\therefore E_{rms} = \frac{E_0}{\sqrt{2}} \Rightarrow E_0 = \sqrt{2}\, E_{rms}$

Average e.m.f over half cycle

$= \frac{2}{\pi} E_0 = 0.637 \times 1.41 \times 220 = 198.15$ V

15. (b) $L = 0.7$H, $R = 220\Omega$, $E_0 = 220$V, $v = 50$ Hz.

This is an L – R circuit

Phase difference,

$$\tan\phi = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{2\pi v L}{R}$$

$$[X_L = 2\pi v L = 2 \times \frac{22}{7} \times 50 \times 0.7 = 220\Omega]$$

$= \frac{220}{220} = 1$ or, $\phi = 45°$

Wattless component of current

$$= I_0 \sin\phi = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}} \cdot \frac{E_0}{Z}$$

$$= \frac{1}{\sqrt{2}} \frac{220}{\sqrt{X_L^2 + R^2}} = \frac{1}{\sqrt{2}} \cdot \frac{220}{\sqrt{220^2 + 220^2}}$$

$$= \frac{1}{2} = 0.5\text{ A}$$

16. (d) $\tan\theta = \frac{X_L}{R}$

17. (a) $P = \frac{V_0 i_0 \cos\phi}{2} = \frac{200 \times 50 \times 10^3}{2} \cos\frac{\pi}{3}$

18. (c) $X_c = \frac{1}{\omega c}$ and $i_c = \frac{Vc}{Xc}$

With decrease in frequency, X_c increases and hence i_c decreases.

19. (c) The inductance is proportional to the length of the coil. So each part will have inductance $\frac{L}{2}$. In parallel their equivalent becomes $\frac{L_1 L_2}{L_1 + L_2} = \frac{L}{4}$.

20. (c) At resonance $X_L = X_C$

$\Rightarrow$ R & current is maximum but finite, which is $I_{max} = \frac{E}{R}$, where E is applied voltage.

21. (d)

$$Q = \frac{\text{Potential drop across capacitor or inductor}}{\text{Potential drop across R.}}$$

$$= \frac{\omega L}{R}$$

22. (d) Power, $P = \mathbf{I}_{r.m.s.} \times V_{r.m.s.} \times \cos\phi$

In the given problem, the phase difference between voltage and current is p/2. Hence $P = \mathbf{I}_{r.m.s.} \times V_{r.m.s.} \times \cos(\pi/2) = 0$.

23. (c) The current drawn by inductor and capacitor will be in opposite phase. Hence net current drawn from generator $= I_L - I_C = 0.9 - 0.4 = 0.5$ amp.

24. (c) $\frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(ML^2T^{-2}A^{-2}) \times (M^{-1}L^{-2}T^4A^2)}}$

$$= \frac{1}{\sqrt{T^2}} = T^{-1}$$

25. (d)

$$Q = \frac{\text{Potential drop across capacitor or inductor}}{\text{Potential drop across R.}}$$

$$= \frac{\omega L}{R}$$

26. (c) $\frac{\mathbf{I}_s}{\mathbf{I}_p} = \frac{n_p}{n_s}$; $\frac{80}{\mathbf{I}_p} = \frac{20}{1}$ or $\mathbf{I}_p = 4$ amp.

27. (a) $E = \frac{d}{dt}(NMI) \Rightarrow E = NM\frac{dI}{dt} \Rightarrow E = \frac{NMI}{t}$

emf induced per unit turn $= \frac{E}{N} = \frac{MI}{t}$

28. **(a)** $L = 10\,mHz = 10^{-2}\,Hz$
$f = 1MHz = 10^6\,Hz$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f^2 = \frac{1}{4\pi^2 LC}$$

$$\Rightarrow C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\times10\times10^{-2}\times10^{12}}$$

$$= \frac{10^{-12}}{4} = 2.5\ pF$$

29. **(a)** If $\omega = 50 \times 2\pi$ then $\omega L = 20\Omega$
If $\omega' = 100 \times 2\pi$ then $\omega' L = 40\Omega$
Current flowing in the coil is

$$I = \frac{200}{Z} = \frac{200}{\sqrt{R^2 + (\omega' L)^2}} = \frac{200}{\sqrt{(30)^2 + (40)^2}}$$

$I = 4A.$

30. **(a)** We have, $I = I_0\left(1 - e^{-\frac{R}{L}t}\right)$
(When current is in growth in LR circuit)

$$= \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right) = \frac{5}{5}\left(1 - e^{-\frac{5}{10}\times 2}\right)$$

$= (1 - e^{-1})$

31. **(c)** The phase angle is given by

$$\tan\phi = \frac{\omega L}{R} = \frac{2\pi\times50\times0.21}{12} = 5.5$$

$$\phi = \tan^{-1} 5.5 = 80^\circ$$

Type B : Assertion Reason Questions

32. **(a)** In series resonance circuit, current becomes maximum because total impedence becomes zero. In case of LC circuit,

$$\text{Total impedence} = \omega L - \frac{1}{\omega C} = 0$$

$$\Rightarrow \omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC}$$

33. **(c)** Faraday's laws of electromagnetic induction are consequences of conservation of energy. It involves only transformation of energy into electrical energy.

In purely resistive circuit, current and voltage are in the same phase.

34. **(c)** For a pure capacitor circuit average power is given by $P_{av} = E_v I_v \cos(-\pi/2)$,

(as $\phi = -\pi/2$)

$\therefore\ E_v I_v (0) = 0 \Rightarrow P_{av} = 0$

thus no power loss occurs. A pure capacitor acts as a block of direct current (d.c) and easy path to a.c since reactance

$X_C = \dfrac{1}{2\pi f_c} = \infty$ for d.c (f = 0 for d.c). Hence we can say no d.c. flows but a.c part is there hence reason is false.

35. **(d)** Assertion is false and Reason is false.

36. **(d)** Resistance offered by an inductor in a d.c. circuit at t = 0 is infinity, which decreases to zero at steady state.

37. **(a)** Power loss $= I^2 R = \left(\dfrac{P}{V}\right)^2 R$

[P = Transmitted power]

38. **(a)**

39. **(c)**

40. **(c)**

41. **(d)** Large eddy currents are produced in non-laminated iron core of the transformer by the induced emf, as the resistance of bulk iron core is very small. By using thin iron sheets as core the resistance is increased. Laminating the core substantially reduces the eddy currents. Eddy current heats up the core of the transformer. More the eddy currents greater is the loss of energy and the efficiency goes down.

Chapter

22 Electromagnetic Waves

TYPE A : MULTIPLE CHOICE QUESTIONS

1. According to Maxwell's hypothesis, changing of electric field give rise to : *[1998]*
(a) magnetic field (b) pressure gradient
(c) charge (d) voltage

2. Frequency of infrared wave is approximately: *[1999]*
(a) 10^{18} Hz (b) 10^{14} Hz
(c) 10^{9} Hz (d) 10^{16} Hz

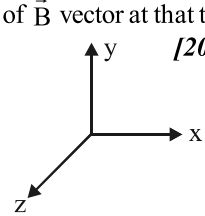
3. Which wavelength of sun is used finally as electric energy? *[2007]*
(a) Radio waves (b) Infra red waves
(c) Visible light (d) Micro waves

4. If the magnetic field of a light wave oscillates parallel to y-axis and is given by $B_y = B_m \sin(kz - \omega t)$, the direction of wave travel and the axis along which the electric vector oscillates is : *[2011]*
(a) + ve y – axis, z – axis
(b) – ve z – axis, x – axis
(c) – ve x – axis, y – axis
(d) – ve x – axis, z – axis

5. The energy of electromagnetic wave in vacuum is given by the relation *(2013)*
(a) $\dfrac{E^2}{2\varepsilon_0} + \dfrac{B^2}{2\mu_0}$ (b) $\dfrac{1}{2}\varepsilon_0 E^2 + \dfrac{1}{2}\mu_0 B^2$
(c) $\dfrac{E^2 + B^2}{c}$ (d) $\dfrac{1}{2}\varepsilon_0 E^2 + \dfrac{B^2}{2\mu_0}$

6. Which of the following are not electromagnetic waves? *[2014]*
(a) cosmic rays (b) γ–rays
(c) β-rays (d) X-rays.

7. Light wave is travelling along y-direction. If the corresponding $\vec{E}$ vector at any time is along the x-axis, the direction of $\vec{B}$ vector at that time is along *[2015]*
(a) y-axis
(b) x-axis
(c) + z-axis
(d) – z-axis



8. Electromagnetic wave consists of periodically oscillating electric and magnetic vectors
(a) in mutually perpendicular planes but vibrating with a phase difference of π
(b) in mutually perpendicular planes but vibrating with a phase difference of $\dfrac{\pi}{2}$
(c) in randomly oriented planes but vibrating in phase
(d) in mutually perpendicular planes but vibrating in phase *[2017]*

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 9-10) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

9. **Assertion :** X-ray travel with the speed of light.
Reason : X-rays are electromagnetic rays. *[2001]*

10. **Assertion :** Dipole oscillations produce electromagentic waves.
Reason : Accelerated charge produces electromagnetic waves. *[2007]*

Directions for (Qs. 11-13) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

11. **Assertion :** Environmental damage has increased the amount of ozone in the atmosphere.
Reason : Increase of ozone increases the amount of ultraviolet radiation on earth. ***[2014]***

12. **Assertion :** Radio waves can be polarised.
Reason : Sound waves in air are longitudinal in nature. ***[2016]***

13. **Assertion :** Microwaves are better carrier of signals than optical waves.
Reason : Microwaves move faster than optical waves. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** Changing of electric field produces displacement current which produces magnetic field. So, changing electric field produces magnetic field.

2. **(b)** We know that visible light has wavelength in the region of 4000Å-7000Å. If we take infrared as approximately having wavelength of 7000Å then applying $\nu\lambda = c$

$$\nu \times 7000 \times 10^{-10} = 3 \times 10^8$$

$$\nu = \frac{3 \times 10^8}{7 \times 10^{-7}} = \frac{3}{7} \times 10^{15}\,\text{Hz}$$

$$= 4.3 \times 10^{14}\,\text{Hz}$$

3. **(b)** The heating property of Infra red waves is used in solar heater and solar cells. Hence option (b) is correct.

4. **(b)** Given $B_y = B_m \sin(kz - \omega t)$. According to this equation the direction of propagation is along z axis. The direction of electric vector must be perpendicular both y and z-axis. So it is along x-axis.

5. **(d)** $\frac{1}{2}\varepsilon_0 E_0^2$ is electric energy density.

$\frac{B^2}{2\mu_0}$ is magnetic energy density.

So, total energy $= \frac{1}{2}\varepsilon_0 E_0^2 + \frac{B_0^2}{2\mu_0}$

6. **(c)** β-rays are the beam of fast moving electrons.

7. **(c)** Light wave is an electromagnetic wave in which $\vec{E}$ and $\vec{B}$ are at right angles to each other as well as at right angles to the direction of wave propagation.

8. **(d)** Electromagnetic wave consists of periodically oscillating electric and magnetic vectors in mutually perpendicular planes but vibrating in phase.

Type B : Assertion Reason Questions

9. **(a)** All electromagnetic waves have same speed in vacuum. X-ray is a high energy electromagnetic wave.

10. **(b)** Hertz produced em waves by oscillating charge between dipolar electric field.

A charge moving with non-zero acceleration where both magnetic and electric field are varying emits em waves but this does not explain assertion.

11. **(a)** Ozone layer in the stratosphere helps in protecting life of organism form ultraviolet radiation on earth. Ozone layer is depleted due to of several factors like use of chlorofluoro carbon (CFC) which is the cause of environmental damages.

12. **(c)** Radio waves can be polarised because they are transverse in nature. Sound waves in air are longitudinal in nature.

13. **(d)** The optical waves used in optical fibre communication are better carrier of signals than microwaves. The speed of microwave and optical wave is the same in vacuum.

Chapter 23

Ray Optics and Optical Instruments

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If two mirrors are kept at 45° to each other and a body is placed in the middle then total number of images formed is : ***[1997]***

(a) 7 (b) 8
(c) 14 (d) 4

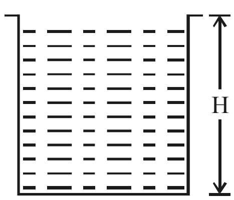
2. An astronomical telescope of ten fold angular magnification has a length of 44 cm. The focal length of the objective is : ***[1997]***

(a) 44 cm (b) 440 cm
(c) 40 cm (d) 4 cm

3. The refractive index of diamond is 2.0, velocity of light in diamond in cm per second is approximately: ***[1997]***

(a) 1.5×10^{10} (b) 2.0×10^{10}
(c) 6×10^{10} (d) 3×10^{10}

4. A cylindrical vessel is filled with water ($\mu = 4/3$) as shown in figure. A coin placed in water at the bottom appears upto maximum distance of : ***[1997]***



(a) $\frac{3H}{4}$ from the surface
(b) $\frac{H}{4}$ from the surface
(c) H from the surface
(d) $\frac{H}{2}$ from the surface

5. The critical angle for the material of a prism is 45° and its refracting angle is 30°. A monochromatic ray goes out perpendicular to the surface of emergence from the prism. Then the angle of incidence on the prism will be : ***[1997]***

(a) 60° (b) 75°
(c) 45° (d) 30°

6. How can the chromatic aberration be corrected ***[1997]***

(a) By providing different suitable curvature to its two surface
(b) By combining it with another lens of opposite nature
(c) By reducing its aperture
(d) By providing proper polishing of its two surfaces

7. When a beam of light from air enters into the water, the characteristics of light will not be changed, is : ***[1997]***

(a) frequency (b) speed
(c) colour (d) amplitude

8. Mirage is a phenomenon due to : ***[1998]***

(a) refraction of light
(b) diffraction of light
(c) total internal reflection of light
(d) none of these

9. In an astronomical microscope, the focal length of the objective is made : ***[1998]***

(a) shorter than that of the eye piece
(b) greater than that of the eye piece
(c) half of the eye piece
(d) equal to that of the eye piece

10. Light appears to travel in a straight line, because ***[1998]***

(a) its wavelength is very small
(b) its velocity is large
(c) it is not absorbed by surroundings
(d) it is reflected by surroundings

11. Sky appears to be blue in clear atmosphere due to which property of light : ***[1999]***

(a) Scattering (b) Polarization
(c) Diffraction (d) Dispersion

12. A doctor prescribes spectacles to a patient with a combination of a convex lens of focal length 40 cm, and concave lens of focal length 25 cm then the power of spectacles will be : ***[2000]***

(a) – 6.5 D (b) 1.5 D
(c) – 1.5 D (d) – 8.5 D

13. Match the items in list-1 with items in list-II and collect the correct answers from the codes given below the lists ***[2000]***

	List-I		**List-II**
I.	Myopia	A.	Bifocal lens
II.	Hyper-metropia	B.	Cylindrical lens
III.	Presbyopia	C.	Concave lens
IV.	Astigmation	D.	Convex lens

(a) I-D, II-C, III-A, IV-B
(b) I-C, II-D, III-A, IV-B
(c) I-B, II-D, III-A, IV-C
(d) I-A, II-B, III-C, IV-D

14. When a ray of light enters a glass slab, then ***[2000]***
(a) its frequency and wavelength changes
(b) its frequency does not change
(c) only frequency changes
(d) its frequency and velocity changes

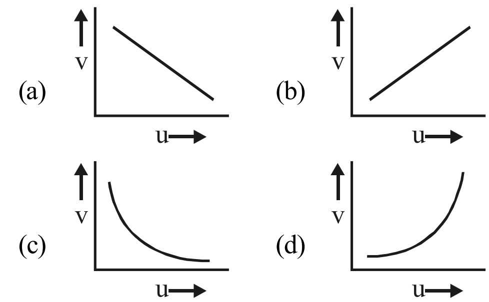
15. An equilateral prism is made of a material of refractive index $\sqrt{3}$. The angle of minimum deviation for the prism is ***[2000]***
(a) 90°   (b) 60°
(c) 45°   (d) 30°

16. A concave mirror having the focal length 15 cm, forms an image having twice of the linear dimensions of the object. If the image is virtual, then the position of the object will be : ***[2001]***
(a) 7.5 cm   (b) 22.5 cm
(c) 40 cm   (d) 30 cm

17. Four lenses having the focal length of + 15 cm, 20 cm, +150 cm, and +250 cm respectively are provided to make an astronomical telescope. The focal length of the eyepiece to produce the largest magnification, should be : ***[2001]***
(a) + 250 cm   (b) + 155 cm
(c) 25 cm   (d) + 15 cm

18. The Cauchy's dispersion formula is ***[2002]***
(a) $h = A + B\lambda^2 + C\lambda^4$
(b) $\mu = A + B\lambda^{-2} + C\lambda^4$
(c) $\mu = A + B\lambda^2 + C\lambda^{-4}$
(d) $\mu = A + B\lambda^{-2} + C\lambda^{-4}$

19. In an experiment to find the focal length of a concave mirror, a graph is drawn between the magnitudes of u and v. The graph looks like : ***[2003]***



20. An object is immersed in a fluid. In order that the object becomes invisible, it should : ***[2004]***
(a) behave as a perfect reflector
(b) absorb all light falling on it
(c) have refractive index one
(d) have refractive index exactly matching with that of the surrounding fluid

21. Sodium lamps are used in foggy conditions because : ***[2004]***
(a) yellow light is scattered less by the fog particles
(b) yellow light is scattered more by the fog particles
(c) yellow light is unaffected during its passage through the fog
(d) Wavelength of yellow light is the mean of the visible part of the spectrum

22. An endoscope is employed by a physician to view the internal parts of a body organ. It is based on the principle of : ***[2004]***
(a) refraction
(b) reflection
(c) total internal reflection
(d) dispersion

23. A telescope has an objective lens of focal length 200 cm and an eye piece with focal length 2 cm. If this telescope is used to see a 50 metre tall building at a distance of 2 km, what is the height of the image of the building formed by the objective lens? ***[2005]***
(a) 5 cm   (b) 10 cm
(c) 1 cm   (d) 2 cm

24. In refraction, light waves are bent on passing from one medium to the second medium, because, in the second medium: ***[2006]***
(a) the frequency is different
(b) the coefficient of elasticity is different
(c) the speed is different
(d) the amplitude is smaller

25. 1 wire mesh consisting of very small squares is viewed at a distance of S cm through a magnifying converging lens of focal length 10 cm, kept close to the eye. The magnification produced by the lens is: ***[2006]***

(a) 5 (b) 8
(c) 10 (d) 20

26. A lens is made of flint glass (refractive index = 1.5). When the lens is immersed in a liquid of refractive index 1.25, the focal length: ***[2006]***

(a) increases by a factor of 1.25
(b) increases by a factor of 2.5
(c) increases by a factor of 1.2
(d) decreases by a factor of 1.2

27. A leaf which contains only green pigments, is illuminated by a laser light of wavelength 0.6328 μm. It wound appear to be: ***[2006]***

(a) brown (b) black
(c) red (d) green

28. The focal length of the objective and eye lenses of a microscope are 1.6 cm and 2.5 cm respectively. The distance between the two lenses is 21.7 cm. If the final image is formed at infinity, what is the linear magnification? ***[2007]***

(a) 11 (b) 110
(c) 1.1 (d) 44

29. The camera lens has an aperture of f and the exposure time is (1/60)s. What will be the new exposure time if the aperture become 1.4 f ? ***[2007]***

(a) $\frac{1}{42}$ (b) $\frac{1}{56}$
(c) $\frac{1}{72}$ (d) $\frac{1}{31}$

30. A thin glass (refractive index 1.5) lens has optical power of – 5 D in air. Its optical power in a liquid medium with refractive index 1.6 will be ***[2008]***

(a) – 1D (b) 1 D
(c) – 25 D (d) 25 D

31. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 cm below the surface, the radius of this circle in cm is ***[2008]***

(a) $\frac{36}{\sqrt{7}}$ (b) $36\sqrt{7}$
(c) $4\sqrt{5}$ (d) $36\sqrt{5}$

32. A fish in an aquarium, 30 cm deep in water can see a light bulb kept 50 cm above the surface of water. The fish can also see the image of this bulb in the reflecting bottom surface of the aquarium. Total depth of water is 60 cm. Then the apparent distance between the two images seen by the fish is ($\mu_w = 4/3$) ***[2009]***

(a) 140 cm (b) $\frac{760}{3}$ cm
(c) $\frac{280}{3}$ cm (d) $\frac{380}{3}$ cm

33. The focal length of the objective and eye piece of a telescope are respectively 200 cm and 5 cm. The maximum magnifying power of the telescope will be ***[2010]***

(a) – 100 (b) – 60
(c) – 48 (d) – 40

34. A thin prism P_1 with angle 6° and made from glass of refractive index 1.54 is combined with another thin prism P_2 of refractive index 1.72 to produce dispersion without deviation. The angle of prism P_2 will be ***[2011]***

(a) 4° 30' (b) 8.5°
(c) 6.5° (d) none of these

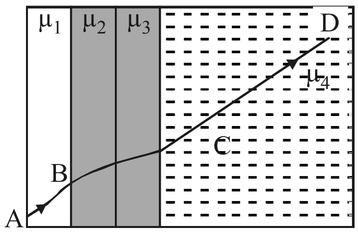
35. The focal length of a converging lens are f_V and f_R for violet and red light respectively. Then ***[2012]***

(a) $f_V > f_R$ (b) $f_V = f_R$
(c) $f_V < f_R$ (d) any of the three is possible depending on the value of the average refractive index μ

36. A plano-convex lens of focal length 30 cm has its plane surface silvered. An object is placed 40 cm from the lens on the convex side. The distance of the image from the lens is ***[2013]***

(a) 18 cm (b) 24 cm
(c) 30 cm (d) 40 cm

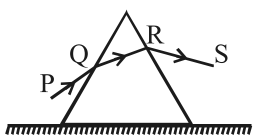
37. A ray of light passes through four transparent media with refractive indices μ_1, μ_2, μ_3 and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray CD is parallel to the incident ray AB, we must have ***[2013]***



(a) $\mu_1 = \mu_2$ (b) $\mu_2 = \mu_3$

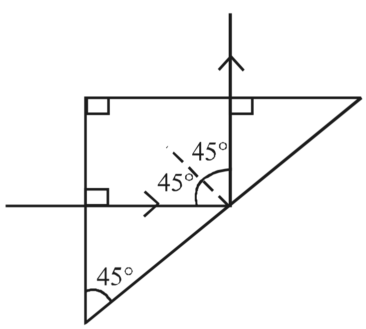
(c) $\mu_3 = \mu_4$ (d) $\mu_4 = \mu_1$

38. An equilateral prism is placed on a horizontal surface. A ray PQ is incident onto it. For minimum deviation *[2014]*



(a) PQ is horizontal
(b) QR is horizontal
(c) RS is horizontal
(d) Any one will be horizontal

39. A light ray is incident perpendicularly to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index *[2014]*



(a) $n > \frac{1}{\sqrt{2}}$ (b) $n > \sqrt{2}$

(c) $n < \frac{1}{\sqrt{2}}$ (d) $n < \sqrt{2}$

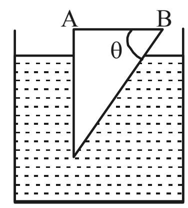
40. A man 160 cm high stands in front of a plane mirror. His eyes are at a height of 150 cm from the floor. Then the minimum length of the plane mirror for him to see his full length image is *[2015]*

(a) 85 cm (b) 170 cm
(c) 80 cm (d) 340 cm

41. An achromatic convergent lens of focal length 20 cms is made of two lenses (in contact) of materials having dispersive powers in the ratio of 1 : 2 and having focal lengths f_1 and f_2. Which of the following is true ? *[2015]*

(a) $f_1 = 10$ cms, $f_2 = -20$ cms
(b) $f_1 = 20$ cms, $f_2 = 10$ cms
(c) $f_1 = -10$ cms, $f_2 = -20$ cms
(d) $f_1 = 20$ cms, $f_2 = -20$ cms

42. A glass prism of refractive index 1.5 is immersed in water (refractive index 4/3). A light beam incident normally on the face AB is totally reflected to reach on the face BC if *[2016]*



(a) $\sin\theta \geq \frac{8}{9}$

(b) $\frac{2}{3} < \sin\theta < \frac{8}{9}$

(c) $\sin\theta \leq \frac{2}{3}$

(d) None of these

43. A ray of light is incident at an angle of incidence, *i*, on one face of prism of angle *A* (assumed to be small) and emerges normally from the opposite face. If the refractive index of the prism is μ, the angle of incidence *i*, is nearly equal to *[2016]*

(a) μA (b) $\frac{\mu A}{2}$

(c) $\frac{A}{\mu}$ (d) $\frac{A}{2\mu}$

44. A green light is incident from the water to the air - water interface at the critical angle (θ). Select the correct statement. *[2017]*

(a) The entire spectrum of visible light will come out of the water at an angle of 90º to the normal.
(b) The spectrum of visible light whose frequency is less than that of green light will come out to the air medium.
(c) The spectrum of visible light whose frequency is more than that of green light will come out to the air medium.
(d) The entire spectrum of visible light will come out of the water at various angles to the normal.

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 45-61) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

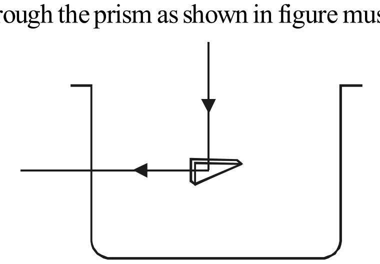
45. **Assertion :** The colour of the green flower seen through red glass appears to be dark.
Reason : Red glass transmits only red light. ***[1997]***

46. **Assertion :** Newton's rings are formed in the reflected system when the space between the lens and the glass plate is filled with a liquid of refracitve index greater than that of glass, the central spot of the pattern is bright.
Reason : This is because the reflection in these cases will be from a denser to rarer medium and the two interfering rays are reflected under similar conditions. ***[1998]***

47. **Assertion :** Corpuscular theory fails in explaining the velocities of light in air and water.
Reason : According to corpuscular theory, light should travel faster in denser medium than in rarer medium. ***[1998]***

48. **Assertion :** Different colours travel with different speed in vacuum.
Reason : Wavelength of light depends on refractive index of medium. ***[1998]***

49. **Assertion :** The maximum refractive index of liquid for total internal reflection of the ray passing through the prism as shown in figure must be $\sqrt{2}$.



Reason: Here, critical angle is 45° ***[1999]***

50. **Assertion:** A double convex lens ($\mu = 1.5$) has focal length 10 cm. When the lens is immersed in water ($\mu = 4/3$) its focal length becomes 40 cm.

Reason: $\frac{1}{f} = \frac{\mu_1 - \mu_m}{\mu_m} = \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ ***[1999]***

51. **Assertion :** The refractive index of diamond is $\sqrt{6}$ and that of liquid is $\sqrt{3}$. If the light travels from diamond to the liquid, it will totally reflected when the angle of incidence is 30°.

Reason : $\mu = \frac{1}{\sin C}$, where μ is the refractive index of diamond with respect to liquid ***[2000]***

52. **Assertion :** The setting sun appears to be red.
Reason : Scattering of light is directly proportional to the wavelength. ***[2000]***

53. **Assertion :** In a movie, ordinarily 24 frames are projected per second from one end to the other of the complete film.
Reason : The image formed on retina of eye is sustained upto 1/10 second after the removal of stimulus. ***[2001]***

54. **Assertion :** Blue colour of sky appears due to scattering of blue colour.
Reason : Blue colour has shortest wave length in visible spectrum. ***[2001]***

55. **Assertion :** The air bubble shines in water.
Reason : Air bubble in water shines due to refraction of light. ***[2002]***

56. **Assertion :** The stars twinkle while the planets do not.
Reason : The stars are much bigger in size than the planets. ***[2003]***

57. **Assertion :** A red object appears dark in the yellow light.
Reason : The red colour is scattered less. ***[2004]***

58. **Assertion :** By roughening the surface of a glass sheet its transparency can be reduced.
Reason : Glass sheet with rough surface absorbs more light. ***[2005]***

59. **Assertion :** Diamond glitters brilliantly.
Reason : Diamond does not absorb sunlight. ***[2005]***

60. **Assertion :** In optical fibre, the diameter of the core is kept small.
Reason : This smaller diameter of the core ensures that the fibre should have incident angle more than the critical angle required for total internal reflection. ***[2006]***

61. **Assertion :** A concave mirror and convex lens both have the same focal length in air. When they are submerged in water, they will have same focal length.

Reason : The refractive index of water is smaller than the refractive index of air. ***[2008]***

Directions for (Qs. 62-70) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

62. **Assertion :** The image of a virtual object due to a plane mirror is real.

Reason : If the rays seem to be converging at a point behind a plane mirror, they are reflected and they actually meet in front of the mirror. ***[2009]***

63. **Assertion :** The formula connecting u, v and f for a spherical mirror is valid only for mirrors whose sizes are very small compared to their radii of curvature.

Reason : Laws of reflection are strictly valid for plane surfaces, but not for large spherical surface. ***[2009]***

64. **Assertion :** Position of image approaches focus of a lens, only when object approaches infinity.

Reason : Paraxial rays incident parallel to principal axis intersect at the focus after refraction from lens. ***[2010]***

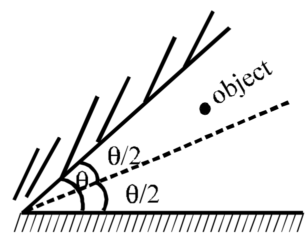
65. **Assertion :** There exists two angles of incidence for the same magnitude of deviation (except minimum deviation) by a prism kept in air.

Reason : In a prism kept in air, a ray is incident on first surface and emerges out of second surface. Now if another ray is incident on second surface (of prism) along the previous emergent ray, then this ray emerges out of first surface along the previous incident ray. This particle is called principle of reversibility of light. ***[2011]***

66. **Assertion :** A point object is placed at a distance of 26 cm from a convex mirror of focal length 26 cm. The image will not form at infinity.

Reason : For above given system the equation $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ gives $v=\infty$. ***[2012]***

67. **Assertion :** If the angle between the two plane mirror is 72° and the object is asymmetrically placed between the two mirrors, then 5 images of the object will be formed. ***[2012]***



Reason : For given system of mirror the total number of images formed due to successive reflection is equal to either $\frac{360°}{\theta}$ or $\frac{360°}{\theta}-1$ accordingly as $\frac{360°}{\theta}$ is odd or even respectively.

68. **Assertion:** Two convex lenses joined together cannot produce an achromatic combination.

Reason : The condition for achromatism is $\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=0$ where symbols have their usual meaning. ***[2013]***

69. **Assertion:** Critical angle is minimum for violet colour.

Reason : Because critical angle $\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ and $\mu \propto \frac{1}{\lambda}$. ***[2014]***

70. **Assertion :** Plane mirror may form real image.

Reason : Plane mirror forms virtual image, if object is real. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** No. of images $= \frac{360}{\theta} - 1 = \frac{360}{45} - 1 = 7$

2. **(c)** In case of telescope, in normal adjustment,

$$m = \frac{f_o}{f_e} = 10$$

and $f_o + f_e =$ length of tube $= 44$

$f_o = 10 f_e \qquad 10f_e + f_e = 44 \Rightarrow f_e = 4$

$f_o = 10 \times 4 = 40\text{cm}$

3. **(a)** $\mu = \frac{\text{velocity of light in air}}{\text{velocity of light in diamond}}$

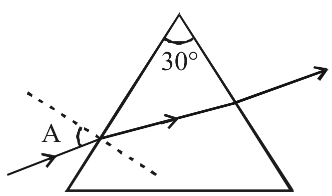
$$2 = \frac{3 \times 10^{10}\,\text{cm/sec}}{v}$$

$$\Rightarrow v = \frac{3}{2} \times 10^{10}\ \text{cm/sec}$$

$= 1.5 \times 10^{10}\,\text{cm/sec}$

4. **(b)**

5. **(c)**



In this case

$r + r' = A \Rightarrow r + 0 = 30° \Rightarrow r = 30°$

$$\mu = \frac{1}{\sin C} \Rightarrow \mu = \frac{1}{\sin 45°} \Rightarrow \mu = \sqrt{2}$$

Now, $\frac{\sin A}{\sin r} = \mu \Rightarrow \frac{\sin A}{\sin 30°} = \sqrt{2}$

$$\sin A = \sin 30°.\sqrt{2} = \frac{1}{2} \times \sqrt{2} = \frac{1}{\sqrt{2}}\ A = 45°$$

6. **(b)** Chromatic aberration takes place when white light is used as source. We get a series of images overlapping each other and made by a lens. By using combination of lenses of opposite nature (convex & concave) we can reduce this aberration.

7. **(a)** When electromagnetic wave enters into any other medium, its electric component induces dipole in the molecule of the medium. These dipoles have oscillating dipole moment and its time period is the same as inducing electric field of incoming wave. These dipole in turn radiates electromagnetic wave having same time period. So, in this phenomenon, time period or frequency of the wave remains unaltered.

8. **(c)** Mirage is a phenomenon in which we see an inverted image of plants and trees on the surface and it gives the impression that there is water around the trees. It occurs due to total internal reflection of light.

9. **(b)** In astronomical telescope the focal length of objective is larger in comparision.

10. **(a)** Light appears to travel in a straight line because diffraction (or deviation from the path) is least in light. Diffraction is least because of small wavelength of light. So small wave length of light causes the light to travel almost in straight line.

11. **(a)** Sky appears blue due to scattering of light.

12. **(c)** For combination of lenses, power

$$P = P_1 + P_2 = \frac{100}{40} - \frac{100}{25} = -1.5D$$

13. **(b)** In myopia, we use concave lens. In hyper metropia we use convex lens. In presbyopia we use bifocal lens and in astigmatism we use cylindrical lens.

14. **(b)** When an electromagnetic wave enters a medium (new), it undergoes change in velocity. $\qquad v = n\lambda$

This change in velocity is due to change in wave-length. The frequency remains constant.

15. **(b)** $A = 60°$

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\frac{A}{2}} \Rightarrow \sqrt{3} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin 30°}$$

$$\sin\left(\frac{60° + \delta_m}{2}\right) = \sqrt{3} \times \frac{1}{2} = \frac{\sqrt{3}}{2} = \sin 60°$$

$60° + \delta_m = 120° \Rightarrow \delta_m = 120° - 60° = 60°$

16. (a) Since, image is virtual v is +ve
f = – 15 cm, u = ?,

$m = 2 = \frac{v}{u}$ v = 2u

Applying mirror formula

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{2u}-\frac{1}{u}=-\frac{1}{15} \Rightarrow \frac{1-2}{2u}=-\frac{1}{15}$$

$$-\frac{1}{2u}=-\frac{1}{15} \Rightarrow u = 7.5\text{ cm}$$

or

We know that virtual and erect image is formed when we place an object within focal length of the mirror. As focal length given = 15 cm. So, object distance must be less than 15 cm out of four given option only one option is correct.

17. (d) In case of astronomical telescope, magnification $=\frac{f_o}{f_e}$

For maximum magnification, f_e should be least. So, f_e should be 15 cm.

18. (d) The Cauchy's formula is based on the relation between wavelength of light and the refractive index. It is as follows

$$\mu = A+\frac{B}{\lambda^2}+\frac{C}{\lambda^4}$$

19. (c) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ is the formula which relates u & v.

$$\frac{1}{u}=\frac{1}{f}-\frac{1}{v}$$

Slope of this curve can be found by differentiation $-\frac{1}{u^2}du = 0+\frac{dv}{v^2}$

$$\Rightarrow \frac{dv}{du}=-\frac{v^2}{u^2}$$

$\frac{dv}{du}$ is the slope which is negative so either curve (c) or curve (a) is right. Now the slope depends upon the value of u & v i.e. it keeps changing at every point as per the equation above. So figure (c) is the answer.

20. (d) If the refractive index of the body becomes equal to surrounding liquid, there will not be any deviation in the direction of light neither will any light get reflected from its surface. So, the object becomes invisible.

21. (a) The higher the wavelength the lesser the scattering. Yellow light has higher wavelength so it is least likely to be scattered among all colours in the visible region (except red & orange). So this light is visible from long distance ever when there is foggy weather.

22. (c) In endoscopy a fine thread of hollow glass tube is send into the body cavity. Light from the interior enters the tube & through internal reflector comes out at desired angle. These rays are picked up by microscopy to take a view of internal parts.

23. (a) u = – 2000 m, v = ?, f = 200 cm = 2 m

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}+\frac{1}{2000}=\frac{1}{2}$$

$$\frac{1}{v}=\frac{1}{2}-\frac{1}{2000}=\frac{1000-1}{2000}=\frac{999}{2000}$$

$$v=\frac{2000}{999};\ \frac{v}{u}=m=\frac{2000}{999\times 2000}=\frac{1}{999}$$

$$\text{Size of image}=\frac{1}{999}\times 50\times 100\text{ cm}\approx 5\text{ cm}$$

24. (c) Since the speed of light changes in the second medium, its direction also changes.

25. (a) Using $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$\frac{1}{v}+\frac{1}{8}=\frac{1}{10}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{8}=\frac{4-5}{40}=-\frac{1}{40}$$

v = –40 cm

$$m=\frac{v}{u}=\frac{40}{8}=5.$$

26. (b) $\frac{1}{f}=(\mu-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$

$$\frac{1}{f_a}=(1.5-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$

$$\frac{1}{f_\ell} = (\mu_g - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$^{\ell}\mu_g = \frac{\mu_g}{\mu_\ell} = \frac{1.5}{1.25} = \frac{6}{5}$$

$$\frac{1}{f_\ell} = \left(\frac{6}{5} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{1}{5}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\frac{1/f_a}{1/f_\ell} = \frac{0.5}{1/5}$$

$$\Rightarrow \frac{f_\ell}{f_a} = 0.5 \times 5 = 2.5$$

$$f_\ell = 2.5 \times f_a$$

27. **(b)** $0.6328\ \mu m = 6328 Å$
This is wave length of Red colour. So this light will be absorbed by green pigments. The leaf will appear black.

28. **(b)** In normal adjustment, object lies close to focus of objective and image is formed at infinity, magnification, $m = \dfrac{Ld}{f_e f_0}$.
Where $f_0 = 1.6$ cm, $f_e = 2.5$ cm, $d = 21.7$ cm, $L = d - f_0 = 21.7 - 1.6 = 20.1$ cm (approx.)

$$\Rightarrow m = \frac{21.7 \times 20.1}{1.6 \times 2.5} = \frac{436.17}{4} = 109.1 \simeq 110$$

29. **(d)** aperture = f, exposure time $\dfrac{1}{60}$ sec.

area of aperture = f^2, area $\propto \dfrac{1}{\text{exposure time}}$
New aperture = 1.4f area = 1.96 f^2
Ratio of areas = 1.96. Since area of aperture has increased thus exposure time will decrease in same proportion, i.e.,

$$\text{new time} = \frac{1}{(60/1.96)} = \frac{1}{31}\ \text{sec.}$$

30. **(b)** $$\frac{1}{f_a} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ...(i)$$

$$\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_m} = \left(\frac{1.5}{1.6} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ...(ii)$$

Dividing (i) by (ii), $$\frac{f_m}{f_a} = \left(\frac{1.5 - 1}{\frac{1.5}{1.6} - 1}\right) = -8$$

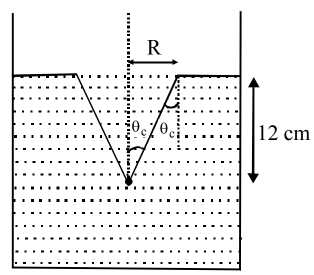
$$P_a = -5 = \frac{\mu}{f_a} = \frac{1}{f_a} \qquad \Rightarrow f_a = -\frac{1}{5}$$

$$\Rightarrow f_m = -8 \times f_a = -8 \times -\frac{1}{5} = \frac{8}{5}$$

$$P_m = \frac{\mu}{f_m} = \frac{1.6}{8} \times 5 = 1\,D$$

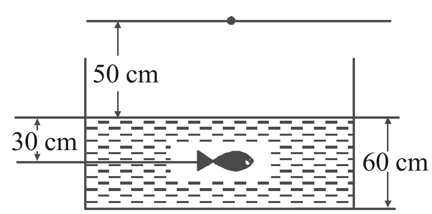
31. **(a)** $$\sin\theta_c = \frac{1}{\mu} = \frac{3}{4}$$

$$\text{or } \tan\theta_c = \frac{3}{\sqrt{16-9}} = \frac{3}{\sqrt{7}} = \frac{R}{12}$$



$$\Rightarrow \qquad R = \frac{36}{\sqrt{7}}\ \text{cm}$$

32. **(b)** Apparent distance of the bulb from the fish
$d_1 = 50\mu + 30$



apparent distance of the image
$d_2 = 50\mu + 60 + 30$
$\therefore d_1 + d_2 = 100\mu + 120$

$$= \frac{400}{3} + 120 = \frac{760}{3}\ \text{cm}$$
$$= 253.3\ \text{cm}$$

33. **(c)** Magnifying power $M = \dfrac{f_0}{f_e}\left(1 + \dfrac{f_e}{d}\right)$
Least distance of distinct vision, d = 25cm

$$M = -\frac{200}{5}\left(1+\frac{5}{25}\right) = -40\left(1+\frac{1}{5}\right)$$

$$= -40\left(\frac{6}{5}\right) = -48\,\text{cm}.$$

34. (a) For dispersion without deviation, the necessary condition is

$$\frac{A_2}{A_1} = -\frac{\mu_1 - 1}{\mu_2 - 1} = -\frac{(1.54-1)}{(1.72-1)} = -\frac{0.54}{0.72}$$

or, $A_2 = \frac{0.54}{0.72} \times 6° = 4.5° \approx 4°30'$

35. (c) Since $\lambda_R > \lambda_V \quad \mu_R < \mu_V$

$$\left(\because \mu \propto \frac{1}{\lambda}\right) \Rightarrow f_V < f_R \left(\because \frac{1}{f} \propto (\mu - 1)\right)$$

36. (b)

37. (d)

38. (b) For minimum deviation, incident angle is equal to emerging angle.

$\therefore$ QR is horizontal.

39. (b) The incident angle is 45° incident angle > critical angle, $i > i_c$

$\therefore \sin i > \sin i_c$ or $\sin 45 > \sin i_c$

$$\sin i_c = \frac{1}{n}$$

$$\therefore \sin 45° > \frac{1}{n} \text{ or } \frac{1}{\sqrt{2}} > \frac{1}{n} \Rightarrow n > \sqrt{2}$$

40. (c) The minimum length of the mirror is half the length of the man. This can be proved from the fact that $\angle i = \angle r$.

41. (a) $\frac{f_1}{f_2} = -\frac{\omega_1}{\omega_2} = -\frac{1}{2} \quad \therefore f_2 = -2f_1$

As $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

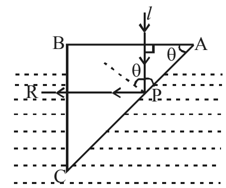
$\therefore \frac{1}{20} = \frac{1}{f_1} - \frac{1}{2f_1} = \frac{1}{2f_1} \qquad \therefore f_1 = 10\,\text{cm}$

$f_2 = -20$ cm

42. (a) The phenomenon of total internal reflection takes place during reflection at P.

$$\sin\theta = \frac{1}{{}_g^{\omega}\mu} \qquad \ldots(i)$$

When θ is the angle of incidence at P



Now, ${}_g^{\omega}\mu = \frac{{}_g^{a}h}{{}_g^{\omega}\mu} = \frac{1.5}{4/3} = 1.125$

Putting in (i), $\sin\theta = \frac{1}{1.125} = \frac{8}{9}$

$\therefore \sin\theta$ should be greater than or equal to $\frac{8}{9}$

43. (a) For normally emerge $e = 0$

Therefore $r_2 = 0$ and $r_1 = A$

Snell's Law for Incident ray's

$1\sin i = \mu \sin r_1 = \mu \sin A$

For small angle

$i = \mu A$

44. (b) For critical angle θ_c,

$$\sin\theta_c = \frac{1}{\mu}$$

For greater wavelength or lesser frequency μ is less. So, critical angle would be more. So, they will not suffer reflection and come out at angles less then 90°.

Type B : Assertion Reason Questions

45. (a) A green flower absorbs all the light except green coloured light. So when red glass transmits only red light and falls on green flower, it absorbs all the light. Therefore, colour of the green flower becomes dark.

46. (a) Newton's rings are formed in reflected system and if the refractive index of the first medium is more than the second medium, there is no reversal of phase in reflected ray so, central fringe remains bright.

47. (a) Corpuscular theory fails to explain the velocityof light in air and water because it predicted light to have more velocity in denser medium where as the fact is just the opposite.

So option (a) is correct.

48. (e) In vacuum all the colours have same velocity but their velocity changes when they enter in a medium. In the medium their velocity changes due to change in their wavelength.

$$v = n\lambda$$

If λ changes, v also changes for a particular colour therefore, different colours have different wavelength (λ).

49. (a) We know that in case of total internal reflection, the minimum refractive index is given by the relation.

$$\mu = \frac{1}{\sin c} = \frac{1}{\sin 45°} = \frac{1}{1/\sqrt{2}} = \sqrt{2}$$

$$\mu = \sqrt{2}$$

50. (a) Using the given relation,

$$\frac{1}{10} = \left(\frac{1.5-1}{1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{10} = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{..........(i)}$$

In the second case, $\mu = \frac{4}{3}$;

$$\frac{1}{f} = \left(\frac{1.5 - \frac{4}{3}}{4/3}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \text{.........(ii)}$$

Dividing (ii) from (i),

$$\frac{f}{10} = \frac{0.5}{0.5/4} = \frac{4 \times 0.5}{0.5}$$

$f = 4 \times 10 = 40$ cm

51. (e) ${}^a\mu_d = \sqrt{6}, \quad {}^a\mu_\ell = \sqrt{3},$

${}^\ell\mu_d = ?\ ;\ {}^a\mu_d \times {}^d\mu_\ell \times {}^\ell\mu_a = 1$

$$\sqrt{6} \times {}^d\mu_\ell \times \frac{1}{\sqrt{3}} = 1$$

$${}^d\mu_\ell = \frac{\sqrt{3}}{\sqrt{6}} = \frac{1}{\sqrt{2}};\ {}^\ell\mu_d = \sqrt{2}$$

If C be the critical angle, then

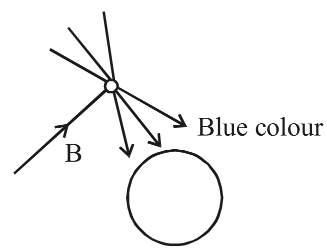
$$\sin C = \frac{1}{\mu} = \frac{1}{\sqrt{2}}$$

C = 45°. As angle of incidence < 45°, it will not be internally reflected. So Assertion is incorrect Reason is correct.

52. (c) Setting sun appears to be red because red light which has greatest wavelength is least scattered and reaches our eyes the most. Other wavelength are scattered to the longest extent. So, reason given is wrong.

53. (c) The image formed on retina of eye is sustained upto $\frac{1}{16}$ th second after removal of stimulus. So, number of frames to be projected on the screen must be at most 16 per second.

54. (a) Blue colour of sky is due to scattering of blue colour to the maximum extent by dust particles. Blue colour appears to be coming from the sky. Blue colour has the least wave-length.



55. (c) Air bubble shines in water due to total internal reflection from the surface of the bubble.
So, Assertion is correct and Reason is incorrect.

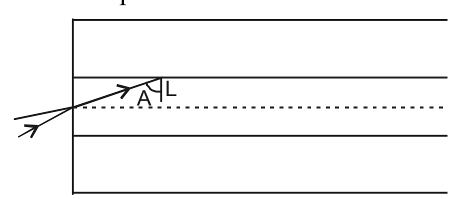
56. (b) Stars twinkle because of changing refractive index of atmosphere. As the apparent size of stars are small, the effect of this change on the direction of rays coming from star is more pronounced.

57. (b) A red object appears dark in the yellow light because red object absorbs all the light falling on it except red. The Reason which is a fact can not be assigned to the Assertion.

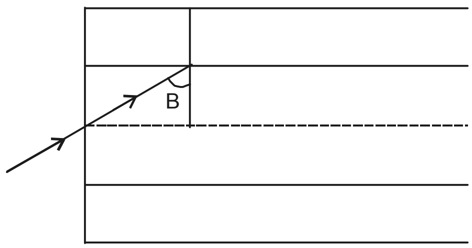
58. (c) The transparency of rough glass is reduced due to scattering of light.

59. (b) Diamond glitters brilliantly because of high refractive index and less critical angle.

60. (a) Assertion and Reason are correct and Reason explains Assertion.



Small diameter core, angle A is larger



Large diameter core, angle B is smaller. In the former case ∠A is large so the possibility of this angle becoming greater than critical angle is more. Hence, the chance of internal reflection is more.

61. **(d)** If a mirror is placed in a medium other than air, its focal length does not change as f = R/2. But for the lens,

$$\frac{1}{f_g} = ({}_a n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

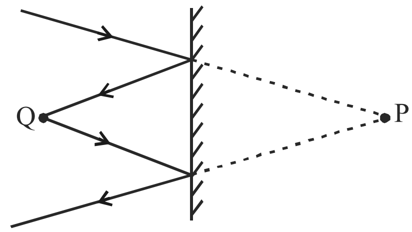
and $\frac{1}{f_w} = ({}_w n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

As ${}_w n_g < {}_a n_g$, hence focal length of lens in water increase.

The refractive index of water is 4/3 and that of air is 1

Hence, refractive index of water is greater than that of air.

62. **(a)**



The image of a real object is virtual while that of a virtual object (as shown) is real.

63. **(c)** Assertion is correct. Laws of reflection can be applied to any type of surface.

64. **(b)** Assertion is correct, Reason is correct.

65. **(a)** Reason is correct explanation of Assertion.

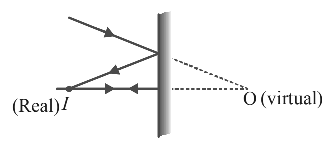
66. **(c)**

67. **(a)**

68. **(a)**

69. **(b)**

70. **(b)** Plane mirror may form real image, if object is virtual.



Chapter 24

Wave Optics

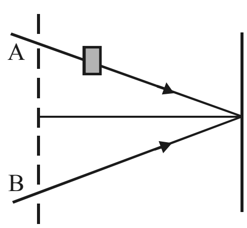
TYPE A : MULTIPLE CHOICE QUESTIONS

1. Two waves of intensities I and 4I superimposes. Then the maximum and minimum intensities are:
(a) 9I and I (b) 3I and I ***[1997]***
(c) 9I and 3I (d) 6I and I

2. On a rainy day, if there is an oil drop on tar road, coloured rings are seen around this drop. This is because of : ***[1997]***
(a) total internal reflection of light
(b) polarisation
(c) diffraction pattern
(d) interference pattern produced due to thin films

3. Interference occurs in which of the following waves? ***[1999]***
(a) Transverse (b) Electromagnetic
(c) Longitudinal (d) All of these

4. In young's experiment the monochromatic light is used to illuminate two slits A and B as shown in figure. Interference fringes are observed on a screen placed in front of the slits. Now a thin glass plate is placed normally in the path of beam coming from the slit A, then : ***[1999, 2004]***



(a) There will be no change in fringe width
(b) Fringe width will decrease
(c) Fringe width will increase
(d) Fringes will disappear

5. The ratio of intensities of two waves is 9 : 1. If they superimpose, the ratio of maximum to minimum intensity will be : ***[2000]***
(a) 3 : 1 (b) 4 : 9
(c) 4 : 1 (d) 1 : 9

6. A light of intensity I_0 passes through a material of thickness d, then the intensity will be
(a) $I = I_0 e^{-d\lambda}$ (b) $I = I_0 e^{d\lambda}$ ***[2000]***
(c) $I = I_0(1 - e^{-\lambda d})$ (d) none of these

7. Light of wavelength 589.3 nm is incident normally on a slit of width 0.01 mm. The angular width of the central diffraction maximum at a distance of 1 m from the slit, is : ***[2000]***
(a) 0.68° (b) 0.34°
(c) 2.05° (d) none of these

8. In an electron microscope the accelerating voltage is increased from 20 kV to 80 kV, the resolving power of the microscope will become
(a) 2R (b) $\frac{R}{2}$ ***[2000]***
(c) 4R (d) 3R

9. How does the red shift confirm that the universe is expanding ? ***[2001]***
(a) wavelength of light emitted by galaxies appears to decrease
(b) wavelength of light emitted by galaxies appears to be the same
(c) wavelength of light emitted by galaxies appears to increase
(d) none of these

10. What change occurs, if the monochromatic light used in Young's double slit experiment is replaced by white light ? ***[2001]***
(a) only the central fringe is white and all other fringes are observed coloured.
(b) no fringes are observed.
(c) all the bright fringes become white.
(d) all the bright fringes are coloured between violet and red.

11. Light of wavelength 6000Å is reflected at nearly normal incidence from a soap films of refractive index 1.4. The least thickness of the film that will appear black is : ***[2002]***
(a) infinity (b) 200 Å
(c) 2000 Å (d) 1000 Å

12. A ray of light is incident on the surface of plate of glass of refractive index 1.5 at the polarising angle. The angle of refraction of the ray will be : ***[2002]***
(a) 33.7º (b) 43.7º
(c) 23.7º (d) 53.7º

13. When a beam of light is used to determine the position of an object, the maximum accuracy is achieved if the light is : ***[2003]***
(a) polarised
(b) of longer wavelength
(c) of shorter wavelength
(d) of high intensity

14. A double slit experiment is performed with light of wavelength 500 nm. A this film of thickness 2 μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will : ***[2003]***
(a) remain unshifted
(b) shift downward by nearly two fringes
(c) shift upward by nearly two fringes
(d) shift downward by ten fringes

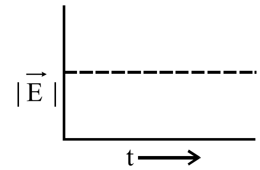
15. An astronaut is looking down on earth's surface from a space shuttle an altitude of 400 km. Assuming that the astronaut's pupil diameter is 5 mm and the wavelength of visible light is 500 nm, the astronaut will be able to resolve linear objects of the size of about : ***[2003]***
(a) 0.5m (b) 5m
(c) 50m (d) 500m

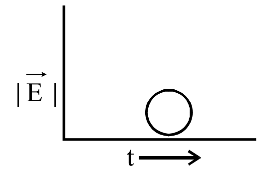
16. When a compact disc is illuminated by a source of white light, coloured lines are observed. This is due to : ***[2004]***
(a) dispersion (b) diffraction
(c) interference (d) refraction

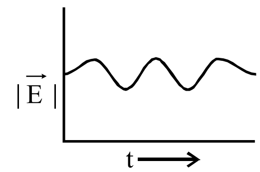
17. In case of linearly polarised light, the magnitude of the electric field vector : ***[2005]***
(a) does not change with time
(b) varies periodically with time
(c) increases and decreases linearly with time
(d) is parallel to the direction of propagation

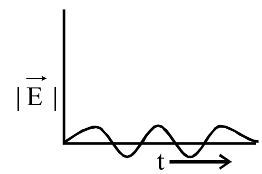
18. When exposed to sunlight, thin films of oil on water often exhibit brilliant colours due to the phenomenon of : ***[2005]***
(a) interference (b) diffraction
(c) dispersion (d) polarisation

19. Which of the following diagrams represents the variation of electric field vector with time for a circulatory polarized light? ***[2006]***

(a) 

(b) 

(c) 

(d) 

20. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye? [Take wavelength of light = 500 nm] ***[2008]***
(a) 1m (b) 5m
(c) 3m (d) 6m

21. What happens to fringe width in Young's double slit experiment if it is performed in glycerine instead of air ***[2009]***
(a) shrinks (b) disappears
(c) unchanged (d) enlarged

22. If a polaroid is kept in the path of an uniformly unpolarised light, the intensity of the transmitted light to the intensity of the light when the polaroid was not kept in its path is ***[2009]***
(a) 1 (b) $\frac{1}{2}$
(c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{2\sqrt{2}}$

23. In a single slit diffraction experiment, the width of the slit is made double its original width. Then the central maximum of the diffraction pattern will become ***[2009]***
(a) narrower and fainter
(b) narrower and brighter
(c) broader and fainter
(d) broader and brighter

24. If the source of light used in a Young's double slit experiment is changed from red to violet: *[2011]*
(a) the fringes will become brighter
(b) consecutive fringes will comes closer
(c) the intensity of minima will increase
(d) the central fringe- will became a dark fringe

25. Wavelength of light used in an optical instrument are $\lambda_1 = 4000\ \mathring{A}$ and $\lambda_2 = 5000\ \mathring{A}$, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is *[2012]*
(a) 16 : 25 (b) 9 : 1
(c) 4 : 5 (d) 5 : 4

26. The correct formula for fringe visibility is *[2012]*
(a) $V = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$
(b) $V = \dfrac{I_{max} + I_{min}}{I_{max} - I_{min}}$
(c) $V = \dfrac{I_{max}}{I_{min}}$
(d) $V = \dfrac{I_{min}}{I_{max}}$

27. In Young's expt., the distance between two slits is $\frac{d}{3}$ and the distance between the screen and the slits is 3 D. The number of fringes in $\frac{1}{3}$m on the screen, formed by monochromatic light of wavelength 3λ, will be *[2012]*
(a) $\dfrac{d}{9D\lambda}$ (b) $\dfrac{d}{27D\lambda}$
(c) $\dfrac{d}{81\,D\lambda}$ (d) $\dfrac{d}{D\lambda}$

28. To demonstrate the phenomenon of interference, we require two sources which emit radiation of *[2013]*
(a) nearly the same frequency
(b) the same frequency
(c) different wavelengths
(d) the same frequency and having a definite phase relationship

29. Two sources of light of wavelengths 2500 Å and 3500 Å are used in Young's double slit expt. simultaneously. Which orders of fringes of two wavelength patterns coincide? *[2013]*
(a) 3rd order of 1st source and 5th of the 2nd
(b) 7th order of 1st and 5th order of 2nd
(c) 5th order of 1st and 3rd order of 2nd
(d) 5th order of 1st and 7th order of 2nd

30. In Young's double slit experiment, we get 10 fringes in the field of view of monochromatic light of wavelength 4000Å. If we use monochromatic light of wavelength 5000Å, then the number of fringes obtained in the same field of view is *[2014]*
(a) 8 (b) 10
(c) 40 (d) 50

31. The condition for obtaining secondary maxima in the diffraction pattern due to single slit is *[2014]*
(a) $a\sin\theta = n\lambda$
(b) $a\sin\theta = (2n-1)\dfrac{\lambda}{2}$
(c) $a\sin\theta = (2n-1)\lambda$
(d) $a\sin\theta = \dfrac{n\lambda}{2}$

32. The Fraunhoffer 'diffraction' pattern of a single slit is formed in the focal plane of a lens of focal length 1 m. The width of slit is 0.3 mm. If third minimum is formed at a distance of 5 mm from central maximum, then wavelength of light will be *[2015]*
(a) 5000 Å (b) 2500 Å
(c) 7500 Å (d) 8500 Å

33. A parallel beam of monochromatic unpolarised light is incident on a transparent dielectric plate of refractive index $\frac{1}{\sqrt{3}}$. The reflected beam is completely polarised. Then the angle of incidence is *[2015]*
(a) 30º (b) 60º
(c) 45º (d) 75º

34. A single slit Fraunhoffer diffraction pattern is formed with white light. For what wavelength of light the third secondary maximum in the diffraction pattern coincides with the second secondary maximum in the pattern for red light of wavelength 6500 Å? *[2016]*
(a) 4400 Å (b) 4100 Å
(c) 4642.8 Å (d) 9100 Å

35. A diffraction pattern is obtained by using beam of red. light what will happen, if red light is replced by the blue light? ***[2017]***
(a) Bands disappear.
(b) Bands become broader and farther apart.
(c) No change will take place.
(d) Diffraction bands become narrow and crowded together.

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 36-48) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

36. **Assertion :** The colour of the green flower seen through red glass appears to be dark.
Reason : Red glass transmits only red light. ***[1997]***

37. **Assertion :** In Young's experiment, the fringe width for dark fringes is different from that for white fringes.
Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed. ***[2001]***

38. **Assertion :** Coloured spectrum is seen when we look through a muslin cloth.
Reason : It is due to the diffraction of white light on passing through fine slits ***[2002]***

39. **Assertion :** When tiny circular obstacle is placed in the path of light from some distance, a bright spot is seen at the centre of the shadow of the obstacle.
Reason : Destructive interference occurs at the centre of the shadow. ***[2002]***

40. **Assertion :** Thin films such a soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.
Reason : It happens due to the interference of light reflected from the upper surface of the thin film. ***[2002]***

41. **Assertion :** At the first glance, the top surface of the Morpho butterfly's wing appears a beautiful blue-green. If the wind moves the colour changes.
Reason : Different pigments in the wing reflect light at different angles. ***[2004]***

42. **Assertion :** A famous painting was painted by not using brush strokes in the usual manner, but rather a myriad of small colour dots. In this painting the colour you see at any given place on the painting changes as you move away.
Reason : The angular separation of adjacent dots changes with the distance from the painting. ***[2004]***

43. **Assertion :** The clouds in sky generally appear to be whitish.
Reason : Diffraction due to clouds is efficient in equal measure at all wavelengths. ***[2005]***

44. **Assertion :** The resolving power of a telescope is more if the diameter of the objective lens is more.
Reason : Objective lens of large diameter collects more light. ***[2005]***

45. **Assertion :** Standard optical diffraction gratings can not be used for discriminating between X-ray wavelengths.
Reason : The grating spacing is not of the order of X-ray wavelengths. ***[2006]***

46. **Assertion :** Goggles have zero power.
Reason : Radius of curvature of both sides of lens is same. ***[2007]***

47. **Assertion :** A white source of light during interference forms only white and black fringes.
Reason : Width of fringe is inversely proportional to the wavelength of the light used. ***[2007]***

48. **Assertion :** In Young's double slit experiment the two slits are at distance d apart. Interference pattern is observed on a screen at distance D from the slits. At a point onthe screen when it is directly opposite to one of the slits, a dark fringe is observed. Then, the wavelength of wave is proportional to square of distance of two slits
Reason : For a dark fringe intensity is zero. ***[2008]***

Directions for (Qs. 49-51) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

49. **Assertion :** No interference pattern is detected when two coherent sources are infinitely close to each other.

Reason : The fringe width is inversely proportional to the distance between the two slits. ***[2009]***

50. **Assertion :** In Young's double slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringe on the screen will increase.

Reason : Maximum number of bright fringe on the screen is directly proportional to the wavelength of light used. ***[2015]***

51. **Assertion :** Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.

Reason : Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** Ratio of amplitudes $= \sqrt{\frac{4}{1}} = \frac{2}{1}$

$$\frac{\text{maximum amplitude}}{\text{minimum amplitude}} = \frac{2+1}{2-1} = \frac{3}{1}$$

$$\frac{\text{maximum intensity}}{\text{minimum intensity}} = \left(\frac{3}{1}\right)^2 = \frac{9}{1}$$

2. **(d)** When a thin layer of oil floats on the water level, interference takes place between ray of light reflected from upper interface and from lower interface. Due to interference coloured fringes are formed in oil film.

3. **(d)** Since, interference occurs both in sound and light waves so it will occur in all the forms of waves given.

4. **(a)** When we put a glass plate in the path of one of the beams interfering with each other then there is change of place of fringes on the screen. All the fringes including central fringe are shifted. It does not result in change of fringe width.

5. **(c)** $\frac{I_1}{I_2} = \frac{9}{1} \Rightarrow \frac{A_1}{A_2} = \sqrt{\frac{9}{1}} = \frac{3}{1}$

[Here A_1 & A_2 are amplitudes]

Maximum amplitude $= A_1 + A_2$

Minimum amplitude $= A_1 - A_2$

$$\frac{A_1 + A_2}{A_1 - A_2} = \frac{4}{2} = \frac{2}{1}$$

$$\frac{\text{maximum intensity}}{\text{minimum intensity}} = \frac{4}{1}$$

[Intensity $\propto$ (amplitude)^2]

6. **(a)** When a light passes through a material its intensity goes on decreasing. First equation given represents exponentially decreasing intensity. Option (b) and (c) represents increasing intensity.

7. **(a)** In case of diffraction,

Angular width of central fringe $= \frac{2\lambda}{a}$

$$= \frac{2 \times 589.3 \times 10^{-9}}{1 \times 10^{-5}} = 2 \times 589.3 \times 10^{-4}$$

$= 1178.6 \times 10^{-5}$ rad.

$$= 1178.6 \times 10^{-5} \times \frac{180}{11} = 67563 \times 10^{-5}$$

$= 0.68°$

8. **(a)** We know that wavelength and accelerating voltage for an electron is related to each other as follows

$\lambda \propto \frac{1}{\sqrt{V}}$ [V is potential applied]

and resolving power $\propto \frac{1}{\lambda}$

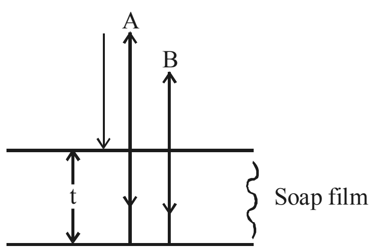
So, resolving power $\propto \sqrt{V}$

Now, if potential used is increased 4 times, resolving power will be increased 2 times. So, if resolving power earlier is R. It becomes 2R.

9. (c) Red shift means shifting of colours in the spectrum of a moving star towards the red end of the spectrum. It happens when the radiation emitting source goes away from the earth. It is due to Doppler's effect as we observe in case of sound. The apparent frequency decreases or wavelength increases for a receding source.

10. (a) When we use white light in place of monochromatic light then only central fringe looks white and other fringes of different colour are observed. It is because central fringe for all the colours are formed at central point so it becomes white after mixing up. As fringes of others colours fall at different places we see fringes of all colours on the central bright fringe.

11. (c)



Interference occurs between two reflected rays A and B. A is reflected from upper surface and B is reflected from lower surface.

The path difference between the two becomes $2\mu t + \frac{\lambda}{2}$

If it is equal to $\frac{3\lambda}{2}$ then destructive interference occurs and we see dark fringes from above. So, the equation $2\mu t + \frac{\lambda}{2} = \frac{3\lambda}{2}$ gives the least value of t for which we see dark fringes.

$$2\mu t = \lambda \Rightarrow t = \frac{\lambda}{2\mu} = \frac{6000}{2\times 1.4} \cong 2000 \text{Å}$$

12. (a) If i_p be the polarising angle, then

$\tan i_p = \mu = 1.5$

$i_p = 56.3°$

Angle of refraction, $r = 90° - i_p$

$= 90° - 56.3° = 33.7°$

13. (c) The resolving power of an instrument depends upon the wave length of light used. The lower the wavelength of light higher is the accuracy in vision.

$$\left(\text{Resolving power} \propto \frac{1}{\lambda}\right)$$

14. (c) When we introduce a thin film of some thickness in the path of upper beam actually we are increasing the optical path of the upper beam. Now for the same path difference lower beam will shift upwards so that it is elongated so that path difference remains unchanged.

15. (c) The resolving power of an instrument is given by the formula, $1.22 = \frac{\lambda D}{d}$

Here, d is aperture of the instrument, D is distance of satellite from the earth. Here eye is the optical instrument.

$$R.P = \frac{1.22 \times 500 \times 10^{-9}}{5 \times 10^{-3}} \times 400 \times 1000$$

$$= 1.22 \times \frac{10^{-2}}{10^{-3}} \times 4 = 1.22 \times 40 = 50 \text{ m}$$

16. (b) A compact disc contains many fine circular lines on it so it acts as diffraction grating. When white light falls upon it, it is diffracted as a result of which different colours are diffracted at different angles. We see different colours when we look at it through different angles.

17. (b) In any type of light whether polarised or unpolarised, the magnitude of electric field vector always varies periodically with time. Actually the change in electric field vector gives rise to periodically changing magnetic field.

18. (a) We see spectrum of colours when thin films of oil on water is exposed to sunlight due to phenomenon of interference.

19. (a) In circularly polarised light the magnitude of electric vector remains constant with respect to time.

20. (b) $\frac{y}{D} \geq 1.22\frac{\lambda}{d}$

$$\Rightarrow D \leq \frac{yd}{(1.22)\lambda} = \frac{10^{-3}\times 3\times 10^{-3}}{(1.22)\times 5\times 10^{-7}}$$

$$= \frac{30}{6.1} \approx 5\text{m}$$

$\therefore D_{max} = 5\text{m}$

21. (a) $\beta = \frac{D\lambda}{d}$

if it be performed in glycerine then

$\lambda' = \lambda / \mu$

$\beta' = \dfrac{D\lambda}{\mu d}$ Since $\mu > 1$

So, $\beta' < \beta$ (shrinks)

22. **(b)** The component of the Electric vector of all the electric vectors of unpolarised light in one direction only $= \dfrac{E_0}{\sqrt{2}}$

and $I \propto E^2 \Rightarrow I = \dfrac{I_0}{2}$

23. **(b)** $\sin\theta = \dfrac{\lambda}{d}$ $\quad \therefore \theta \propto \dfrac{1}{d}$

24. **(b)** The distance of n^{th} fringe is given by $y_n = \dfrac{nD\lambda}{d}$

As $\lambda_{violet} < \lambda_{red,}$

$\therefore$ fringes will come closer.

25. **(d)** Resolving power α $(1/\lambda)$.

Hence, $\dfrac{(R.P)_1}{(R.P)_2} = \dfrac{\lambda_2}{\lambda_1} = \dfrac{5}{4}$.

26. **(a)** Fringe visibility (V) is given by

$V = \dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$.

27. **(c)** $\beta = \dfrac{\lambda' D'}{d'} = \dfrac{3\lambda 3D}{d/3} = 27\dfrac{\lambda D}{d}$.

No. of fringes $= \dfrac{1/3}{\beta} = \dfrac{d}{81\lambda D}$.

28. **(d)**

29. **(b)** Let nth fringe of 2500 Å coincide with (n – 2)th fringe of 3500Å.

$\therefore\ 3500\,(n-2) = 2500 \times n$

$1000\,n = 7000, n = 7$

$\therefore$ 7th order fringe of 1st source will coincide with 5th order fringe of 2nd source.

30. **(a)** As $\beta \propto \lambda$

$\therefore$ fringe width becomes $\dfrac{5}{4}$ times,

No, of fringes $= \dfrac{4}{5} \times 10 = 8$

31. **(b)**

32. **(a)** $a \sin\theta = n\lambda$

$\dfrac{ax}{f} = 3\lambda$

(since θ is very small so $\sin\theta \approx \tan\theta \approx \theta = x/f$)

or $\lambda = \dfrac{ax}{3f} = \dfrac{0.3 \times 10^{-3} \times 5 \times 10^{-3}}{3 \times 1}$

$= 5 \times 10^{-7}\,m = 5000\text{Å}$.

33. **(a)** When angle of incidence i is equal to angle of polarisation i.e, then reflected light is completely plane-polarised whose vibration is perpendicular to plane of incidence.

34. **(c)** $x = \dfrac{(2n+1)\lambda\ D}{2a}$

For red light, $x = \dfrac{(4+1)D}{2a} \times 6500\text{Å}$

For other light, $x = \dfrac{(6+1)D}{2a} \times \lambda\text{Å}$

x is same for each.

$\therefore\ 5 \times 6500 = 7 \times \lambda$

$\Rightarrow \lambda = \dfrac{5}{7} \times 6500 = 4642.8\,\text{Å}$

35. **(d)** When red light is replaced by blue light the diffraction bands become narrow and crowded.

Type B : Assertion Reason Questions

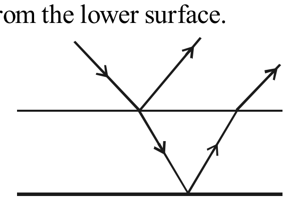
36. **(b)**

37. **(d)** In Young's experiments, fringe width of dark and white fringes are equal. If white light is used as source, coloured fringes are observed representing bright band of different colours.

38. **(a)** Porous muslin cloth has holes comparable to the wavelength of light falling on it. So, it get diffracted there forming fringes of different colours. We see it as colour spectrum.

39. **(c)** A bright spot is found at the centre of circular fringe patterns formed due to diffraction of light at the edge of circular obstacles. This bright spot is due to constructive interference there by secondary wavelets.

40. **(c)** Interference in between two rays, one is reflected from the upper surface & second from the lower surface.



41. (c) The Assertion is correct. When wind moves the colour of the wing changes. The visible colour of the wing is different from its original colour due to interference of light. Interference occurs between incident ray and reflected ray. Due to wind the reflectivity of the upper surface of the wing changes (as it is covered by tiny hairs) which changes the reflected wave. The resultant colour due to interference also changes. This is the principle behind the change of colour of wings of Morpho Butterfly.
So, (c) is the answer.

42. (a) We see two closely situated very small dots separate when their angular separation for the viewer is more than that required by Rayleigh's criterion.

$$\theta_R = 1.22\frac{\lambda}{d}$$

Here, d is diameter of eye and λ is wavelength of light seen.
If distance between spot is D and L be the distance of observer from the painting then,

$$\theta = \frac{D}{L}\ ;\ \text{So, } 1.22\frac{\lambda}{d} = \frac{D}{L}$$

$$L = \frac{Dd}{1.22\lambda}$$

If for red light having greater λ, the value of L will be smaller and for violet colour, this distance is larger. If we move away from the painting, adjacent red dots become indistinguishable before adjacent blue dots do. So, to make two dots distinguishable we shall have to give distance of the observer (L) a minimum value. At a greater distance colours of adjacent dots blend together. In this way we can have different view of dots by looking at it from different distance (or changing L).
So, both assertion and reason are correct.

43. (c) The clouds in the sky appear white as the size of cloud particle is not small enough to permit diffraction. So all the wavelength gets reflected and it appears white.

44. (a) The resolving power of a telescope increases as diameter of objective lens increases.

$$\text{Resolving Power} = \frac{D}{1.22\lambda}$$

where D is diameter of objective and λ is wavelength of light used.
The Reason of this question is incorrect.

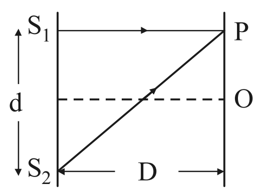
45. (a) For diffraction purpose, target should have size of the order of wavelength of light used. So, X-ray cannot be used in standard diffraction grating as target which is spacing between the lines in different grating is large as compared with very short wavelength of X-rays.

46. (b) Goggles protect from harmful UV light of sun rays and do not correct sight defects
$\therefore$ have zero power.
Both lens of goggles are identical hence have same curvature. The Reason does not explain Assertion.

47. (d) A white source of light during interference will form coloured fringes.

Fringe width is given by $\beta = \frac{\lambda D}{d}$ i.e., it is directly proportional to wavelength.

48. (b) When dark fringe is obtained at the point opposite to one of the slits then



$$S_1P = D$$

and $S_2P = \sqrt{D^2 + d^2} = D\left(1+\frac{d^2}{D^2}\right)^{1/2}$

$= D\left(1+\frac{d^2}{2D^2}\right)$ (By binomial theorem)

Path difference $= S_2P - S_1P$

$$= D\left(1+\frac{d^2}{2D^2}\right) - D = \frac{d^2}{2D} = \frac{\lambda}{2}$$

or $\lambda = \frac{d^2}{D} \Rightarrow \lambda \propto d^2$

Now, intensity of a dark fringe is zero.

49. (a) When *d* is negligibly small, fringe width β which is proportional to $1/d$ may become too large. Even a single fringe may occupy the whole screen. Hence the pattern cannot be detected.

50. (d) **51. (b)**

Chapter 25 Dual Nature of Radiation and Matter

TYPE A : MULTIPLE CHOICE QUESTIONS

1. X-ray will not show the phenomenon of : ***[1997]***
(a) interference
(b) deflection by electric field
(c) diffraction
(d) superposition

2. Which one of the following is not dependent on the intensity of incident photon in a photo-electric experiment ? ***[1998]***
(a) work function of the surface
(b) kinetic energy of photo-electron
(c) stopping potential
(d) amount of photo-electric current

3. The kinetic energy of an electron, which is accelerated in the potential difference of 100 V, is : ***[1998]***
(a) 1.6×10^{-10} J (b) 1.6×10^{8} J
(c) 1.6×10^{-17} J (d) 1.6×10^{-18} J

4. When cathode rays strike a metal target of high melting point with a very high velocity then which of the following are produced ? ***[1999]***
(a) γ-waves (b) Ultrasonic
(c) X-rays (d) α-rays

5. Particle nature and wave nature of electromagnetic waves and electrons can be represented by : ***[2000]***
(a) photoelectricity and electron microscopy
(b) light is refracted and diffracted
(c) X-rays is diffracted, reflected by thick metal sheet
(d) electrons have small mass, deflected by the metal sheet.

6. The surface of zone material is radiated in turn by waves of λ = 350 nm and 540 nm respectively. The ratio of the stopping potential in the two cases is 2 : 1. The work function of the material is
(a) 4.20 eV (b) 0.15 eV ***[2000]***
(c) 2.10 eV (d) 1.05 eV

7. Light of wavelength 4000 Å is incident on a metal plate whose work function is 2eV. What is maximum kinetic energy of emitted photoelectron? ***[2002]***
(a) 0.5 eV (b) 1.1 eV
(c) 2.0 eV (d) 1.5 eV

8. A laser beam is used for carrying out surgery because it ***[2003]***
(a) is highly monochromatic
(b) is highly coherent
(c) is highly directional
(d) can be sharply focussed

9. A proton is about 1840 times heavier than an electron. When it is accelerated by a potential difference of 1 kV, its kinetic energy will be ***[2003]***
(a) 1840 keV (b) 1/1840 keV
(c) 1keV (d) 920 V

10. If an electron and a photon propagate in the form of waves having the same wavelength, it implies that they have the same ***[2003]***
(a) energy
(b) momentum
(c) velocity
(d) angular momentum

11. Characteristic X-rays are produced due to ***[2003]***
(a) transfer of momentum in collision of electrons with target atoms
(b) transition of electrons from higher to lower electronic orbits of an atom
(c) heating of the target
(d) transfer of energy in collision of electrons with atoms in the target.

12. A photon of energy 4 eV is incident on a metal surface whose work function is 2eV. The minimum reverse potential to be applied for stopping the emission of electrons is ***[2004]***
(a) 2V (b) 4V
(c) 6V (d) 8V

13. Solid targets of different elements are bombarded by highly energetic electron beams. The frequency (f) of the characteristic X-rays emitted from different targets varies with atomic number Z as ***[2005, 2017]***

(a) $f \propto \sqrt{Z}$ (b) $f \propto Z^2$

(c) $f \propto Z$ (d) $f \propto Z^{3/2}$

14. Hard X-rays for the study of fractures in bones should have a minimum wavelength of 10^{11} m. The accelerating voltage for electrons in X-ray machine should be ***[2006]***

(a) < 124.2 kV

(b) > 124.2 kV

(c) Between 60 kV and 70 kV

(d) $= 100$ kV

15. In photoelectric effect, the electrons are ejected from metals if the incident light has a certain minimum ***[2006]***

(a) Wavelength

(b) Frequency

(c) Amplitude

(d) Angle of incidence

16. In a photoemissive cell with executing wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be

(a) $v(3/4)^{1/2}$ ***[2008]***

(b) $v\left(\frac{4}{3}\right)^{1/2}$

(c) less than $v\left(\frac{4}{3}\right)^{1/2}$

(d) greater than $v\left(\frac{4}{3}\right)^{1/2}$

17. The stopping potential doubles when the frequency of the incident light changes from ν to $\frac{3\nu}{2}$. Then the work function of the metal must be ***[2009]***

(a) $\frac{h\nu}{2}$ (b) $h\nu$

(c) $2h\nu$ (d) none of the above

18. The force on a hemisphere of radius 1 cm if a parallel beam of monochromatic light of wavelength 500 nm. falls on it with an intensity of 0.5 W/cm^2, striking the curved surface in a direction which is perpendicular to the flat face of the hemisphere is (assume the collisions to be perfectly inelastic) ***[2009]***

(a) 5.2×10^{-13} N (b) 5.2×10^{-12} N

(c) 5.22×10^{-9} N (d) zero

19. The energy of a photon of light with wavelength 5000 Å is approximately 2.5 eV. This way the energy of an X-ray photon with wavelength 1 Å would be ***[2010]***

(a) $\frac{2.5}{(5000)^2}$ eV (b) 2.5×5000 eV

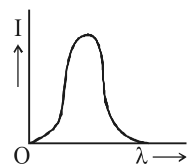
(c) $\frac{2.5}{(5000)^2}$ eV (d) $\frac{2.5}{5000}$ eV

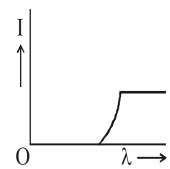
20. A 15.0 eV photon collides with and ionizes a hydrogen atom. If the atom was originally in the ground state (ionization potential = 13.6 eV), what is the kinetic energy of the ejected electron? ***[2014]***

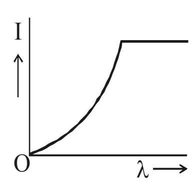
(a) 1.4 eV (b) 13.6 eV

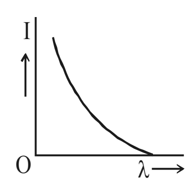
(c) 15.0 eV (d) 28.6 eV

21. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows ***[2017]***

(a)


(b)


(c)


(d)


TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 22-28) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

22. **Assertion :** Photosensitivity of a metal is high if its work function is small.

Reason : Work function = hf_0 where f_0 is the threshold frequency. *[1997]*

23. **Assertion:** Kinetic energy of photo electrons emitted by a photosensitive surface depends upon the intensity of incident photon.

Reason: The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency. *[1999]*

24. **Assertion :** If the speed of charged particle increases both the mass as well as charge increases.

Reason : If m_0 = rest mass and m be mass at velocity v then

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

where c = speed of light. *[2000]*

25. **Assertion :** Mass of moving photon varies inversely as the wavelength.

Reason : Energy of the particle *[2000]*
= mass × (speed of light)^2

26. **Assertion :** Photoelectric effect demonstrates the wave nature of light.

Reason : The number of photoelectrons is proportional to the frequency of light. *[2004]*

27. **Assertion :** The energy (E) and momentum (p) of a photon are related by p = E/c.

Reason : The photon behaves like a particle. *[2005]*

28. **Assertion :** The photoelectrons produced by a monochromatic light beam incident on a metal surface, have a spread in their kinetic energies.

Reason : The work function of the metal varies as a function of depth from the surface. *[2006]*

Directions for (Qs. 29-34) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

29. **Assertion :** Soft and hard *X*-rays differ in frequency as well as velocity.

Reason : The penetrating power of hard *X*–rays is more than the penetrating power of soft *X*–rays. *[2010]*

30. **Assertion :** In photoemissive cell inert gas is used.

Reason : Inert gas in the photoemissive cell gives greater current. *[2010]*

31. **Assertion :** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max} .When the ultraviolet light is replaced by *X*-rays, both V_0 and K_{max} increase.

Reason : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light. *[2013]*

32. **Assertion :** Photoelectric saturation current increases with the increase in frequency of incident light.

Reason : Energy of incident photons increases with increase in frequency and as a result photoelectric current increases. *[2015]*

33. **Assertion :** In process of photoelectric emission, all emitted electrons do not have same kinetic energy.

Reason : If radiation falling on photosensitive surface of a metal consists of different wavelength then energy acquired by electrons absorbing photons of different wavelengths shall be different. *[2015]*

34. **Assertion :** The phtoelectrons produced by a monochromatic light beam incident on a metal surface have a spread in their kinetic energies.

Reason : The work function of the metal is its characteristics property. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** X-rays are electromagnetic wave so it will remain undeflected in electric field.

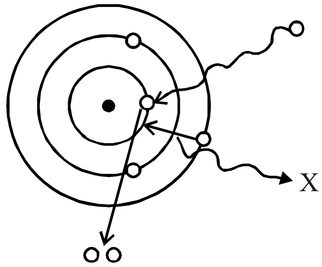
2. **(b)** The intensity of incident photon determines the no. of electrons being ejected from the surface. The kinetic energy of the photoelectron is determined by the frequency of incident photon.

3. **(c)** $\lambda = \frac{1.227}{\sqrt{V}}$ and $E = \frac{hc}{\lambda}$

   $h = 6.6 \times 10^{-34}$ JS, $C = 3 \times 10^8$ m/s

   and V = 100 volt.

4. **(c)** When electrons strike a metal target of high melting point with high velocity, it knocks out inner electrons of the atoms of the target material. To fill up this vacancy, electrons from higher energy level make transition to lower level resulting in emission of radiation. If target material has very high atomic number then the emitted radiation is X-ray.



5. **(a)** In photo electricity, photon is acting as particles which knocks out electron from the surface of the metal. In electron microscopy electron behaves as waves so we can take image of objects with the help of ray of electrons.

6. **(d)** Let the work function be ϕ.

   Einstein's equation in photo – electricity,

$$h\nu = \phi + \frac{1}{2}mv^2$$

$$h\frac{c}{\lambda} = \phi + \frac{1}{2}mv^2 = \phi + eV$$

$$[\,eV = \frac{1}{2}mv^2,\ V \text{ is stopping potential}]$$

$$h\left(\frac{c}{350 \times 10^{-9}}\right) = \phi + 2e.V \quad \text{.......(i)}$$

$$h\left(\frac{c}{540 \times 10^{-9}}\right) = \phi + eV \quad \text{......(ii)}$$

$$\frac{540}{350} = \frac{\phi + 2ev}{\phi + eV}$$

$$\Rightarrow 540\phi + 540\,eV = 350\phi + 700\,eV$$

$$\Rightarrow 190\phi = 160\,eV$$

$$\phi = \frac{16}{19}eV$$

$$\frac{6.6 \times 10^{-34} \times 3 \times 10^8}{350 \times 10^{-9}} = \phi + \frac{19 \times 2\phi}{16} = \frac{27}{8}\phi$$

$$\phi = \frac{8}{27} \times \frac{6.6 \times 3 \times 10^{-18}}{35}$$

$$= \frac{8}{27} \times \frac{6.6 \times 3 \times 10^{-18}}{35 \times 1.6 \times 10^{-19}} eV = 1.05\,eV$$

7. **(b)** Applying Einstein's equation,

$$h\nu = \phi + \frac{1}{2}mv^2 = \phi + K.E$$

$$6.6 \times 10^{-34} \times \frac{3 \times 10^8}{4000 \times 10^{-10}}$$

$$= 2 \times 1.6 \times 10^{-19} + K.E$$

$$\frac{6.6 \times 3}{4} \times 10^{-19} = 3.2 \times 10^{-19} + K.E$$

$$4.95 \times 10^{-19} = 3.2 \times 10^{-19} + K.E$$

$$K.E = (4.95 - 3.2) \times 10^{-19}$$

$$= 1.75 \times 10^{-19}\,J.$$

$$= \frac{1.75 \times 10^{-19}}{1.6 \times 10^{-19}} eV = 1.1\,eV$$

8. **(d)** A laser beam has great power to be focussed so energy density of radiation is greatly enhanced which may have cutting effect.

9. **(c)** When a charge q is accelerated by a potential difference of V, the energy imparted to it is qV. It does not depend upon

the mass. In the given problem potential diff = 1kV. Charge on the proton = charge on electron = 1.6×10^{-19} coulomb. The energy imparted = 1 keV.

[1eV is equal to energy acquired by an electron when it is accelerated under potential of 1eV]

10. (b) A photon and electron will have same momentum if their wavelength are equal.

For electron, momentum = $\frac{h}{\lambda}$.

For photon, momentum

$$= \frac{mc^2}{c} = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

11. (b) When we bombard electrons on a target consisting of heavier atoms, the electron of inner orbitals of target atoms get knocked out. So to fill their position, other electrons from the higher energy orbitals make transition to lower energy orbitals. Its results is emission of X-rays.

12. (a) From Einstein's equation of photoelectric effect

$$h\nu = \phi + \frac{1}{2}mv^2$$

$h\nu = \phi + Ve$ [V is stopping potential]

$4\,eV = 2\,eV + Ve$

$Ve = 2$ e volt

$V \times e = 2 \times e \times 1$ volt

V (Stopping potential) = 2 Volt

13. (b) From Mosley law,

$f = a\,(Z - b)^2$

$f \propto Z^2$

14. (a) $\frac{hc}{\lambda} = ev \Rightarrow v = \frac{hc}{e\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 10^{-11}}$

$$= \frac{33 \times 3}{8} \times 10^4 = 12.375 \times 10^4$$

$= 124 \times 10^3 V = 124$ kV

For minimum wavelength energy is 124 kV

$\therefore$ The accelerating voltage should be < 124 kV

15. (b) The incident wave must have a certain minimum frequency. This is known as threshold frequency.

16. (d) We have from Einsteins photo electric equation.

$$v_{max} = \sqrt{\frac{2hc}{m}\frac{(\lambda_0 - \lambda)}{\lambda\lambda_0}}$$

If wavelength is changed to $\left(\frac{3\lambda}{4}\right)$

then $v'_{max} = \sqrt{\frac{2hc}{m}\frac{(\lambda_0 - 3\lambda/4)}{\lambda_0(3\lambda/4)}}$

$$\frac{v'_{max}}{v_{max}} = \sqrt{\frac{(\lambda_0 - 3\lambda/4)}{\frac{3}{4}\lambda\lambda_0} \times \frac{\lambda\lambda_0}{\lambda_0 - \lambda}}$$

$$= \sqrt{\frac{4}{3}}\sqrt{\frac{(\lambda_0 - 3\lambda/4)}{\lambda_0 - \lambda}}$$

i.e., $v'_{max} = \sqrt{\frac{4}{3}} \times v \times \sqrt{\frac{\lambda_0 - 3\lambda/4}{\lambda_0 - \lambda}}$

$(\because v_{max} = v)$ i.e., $v'_{max} > \sqrt{\frac{4}{3}}\,v$

17. (a) $h\nu = \phi + V_s$ and $h\frac{3}{2}\nu = \phi + 2V_s$

$$\Rightarrow \phi = \frac{h\nu}{2}$$

18. (c) $p = \frac{h}{\lambda}$ of each photon

$$= \frac{6.63 \times 10^{-34}}{500 \times 10^{-9}} = 1.33 \times 10^{-27} \text{ kg-m/s}$$

and no. of photons

$$= \frac{0.5}{h\nu}/cm^2 = \frac{0.5\lambda}{hc}/cm^2$$

$$= \frac{0.5 \times 500}{1240 \times 1.6 \times 10^{-19}}/cm^2$$

$= 1.25 \times 10^{18}$ photons /cm^2

$\therefore$ force $= 1.25 \times 10^8 \times 1.33 \times 10^{-27} \times \pi \times 1^2$

$= 5.22 \times 10^{-9}$ N

19. (b) Energy of photon

$$E = \frac{hc}{\lambda}$$

$\Rightarrow 2.5\,eV = \frac{hc}{5000 \times 10^{-10}}$ (as $\lambda = 5000$Å)

$\Rightarrow hc = 2.5 \times 5 \times 10^{-7}$ eV

For X-ray photon, c = same, h = constant

$$\Rightarrow E = \frac{hc}{\lambda_{x-ray}}$$

$$= \frac{2.5 \times 5 \times 10^{-7}}{1 \times 10^{-10}} \text{eV}$$

$$= 2.5 \times 5000 \text{ eV}$$

20. (a) Conservation of energy requires that the 15.0 eV photon energy first provides the ionization energy to unbind the electron, and then allows any excess energy to become the electron's kinetic energy. The kinetic energy in this case is 15.0 eV – 13.6 eV = 1.4 eV.

21. (d) As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero. Hence (d) is correct answer.

Type B : Assertion Reason Questions

22. (b) The photosensitivity of a metal is high when its work function is small. Work function of a metal depends not on the threshold frequency but on the nature of the metal.

23. (d) Intensity of incident photon decides the number of electrons ejected and not the kinetic energy.

Ejection of electron from metallic surface is possible only when frequency of incident photon is more than threshold frequency.

24. (e) When speed of particle increases, the mass increases as

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$ charge does not alter

25. (b) We know that for photon , $mv = \frac{h}{\lambda}$

mass varies inversely as the wavelength. For particle $E = mc^2$, E is energy of particle if its mass is converted into energy. Both are uncorrelated.

26. (d) Photoelectric effect demonstrate the particle nature of light.

The number of photoelectrons is proportional to the intensity of light.

So, (d) is the answer.

27. (a) Photon when behaves as a particle carries momentum equal to $\frac{E}{c}$.

28. (a) Electrons being emitted as photoelectrons have different velocities. Actually all the electrons do not occupy the same level of energy but they occupy continuous band and levels. So, electrons being knocked off from different levels come out with different energies. Work function is the energy required to pull the electron out of metal surface. Naturally electrons on the surface will require less energy to be pulled out hence will have lesser work function as compared with those deep inside the metal. So, assertion and reason are correct and reason correctly explains the assertion.

29. (d) Soft and hard X–rays differ only in frequency. Soft X–rays have low frequency as compared to hard X–rays. But both types of X–ray travel with speed of light.

30. (a) The photoemissive cell contain two electrodes are enclosed in a glass bulb which may be evacuated or contain an inert gas at low pressure. An inert gas in the cell gives greater current but causes a time lag in the response of the cell to very rapid changes of radiation which may make it unsuitable for some purpose.

31. (c) We know that

$eV_0 = K_{max} = h\nu - \phi$

where, ϕ is the work function .

Hence, as ν increases (note that frequency of X-rays is greater than that of U.V. rays), both V_0 and K_{max} increase. So assertion is correct.

32. (d) Photoelectric saturation current is independent of frequency. It only depends on intensity of light.

33. (a) Both statement I and II are true; but even it radiation of single wavelength is incident on photosensitive surface, electrons of different KE will be emitted.

34. (b) The kinetic energy of emitted photoelectrons varies from zero to a maximum value. Work function depends on metal used.

Chapter

26 Atoms

TYPE A : MULTIPLE CHOICE QUESTIONS

1. If the electron in hydrogen orbit jumps from third orbit to second orbit, the wavelength of the emitted radiation is given by : ***[1997]***

(a) $\lambda = \frac{R}{6}$ (b) $\lambda = \frac{5}{R}$

(c) $\lambda = \frac{36}{5R}$ (d) $\lambda = \frac{5R}{36}$

2. The radius of hydrogen atom in the first excited level is : ***[1998]***

(a) twice (b) four times

(c) same (d) half

3. In Bohr's theory, relation between principal quantum number n and radius of orbit r is: ***[1999]***

(a) $r \propto \frac{1}{n^2}$ (b) $r \propto n$

(c) $r \propto \frac{1}{n}$ (d) $r \propto n^2$

4. For an electron in the second orbit of hydrogen, the moment of momentum as per Bohr's model is ***[2000]***

(a) $\frac{h}{\pi}$ (b) $\frac{2h}{\pi}$

(c) $\frac{h}{2\pi}$ (d) $2\pi h$

5. The speed of an electron having a wavelength of 10^{-10} m is ***[2002]***

(a) 4.24×10^6 m/s (b) 5.25×10^6 m/s

(c) 6.25×10^6 m/s (d) 7.25×10^6 m/s

6. We wish to seen inside an atom. Assuming the atom to have a diameter of 100 pm, this means that one must be able to resolve a width of say 10 pm. If an electron microscope is used, the minimum electron energy required is about

(a) 1.5 keV (b) 15 keV ***[2004]***

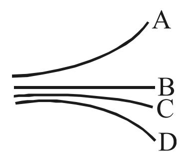
(c) 150 keV (d) 1.5 MeV

7. The ground state energy of hydrogen atom is – 13.6 eV. What is the potential energy of the electron in this state ? ***[2005]***

(a) 0 eV (b) –27.2 eV

(c) 1 eV (d) 2 eV

8. In the following diagram, which particle has highest e/m value? ***[2007]***



(a) A (b) B

(c) C (d) D

9. What is the energy of He^+ electron in first orbit?

(a) 40.8 eV (b) –27.2 eV ***[2007]***

(c) –54.4 eV (d) –13.6 eV

10. What is the energy of photon whose wavelength is 6840 Å? ***[2007]***

(a) 1.81 eV (b) 3.6 eV

(c) –13.6 eV (d) 12.1 eV

11. The ratio of the energy of the photon emitted by the k_α line to that of the k_β line is ***[2009]***

(a) greater than 1 (b) Less than 1

(c) 1 (d) indeterminate

12. The angular momentum of an electron in the 2^{nd} excited state of a Helium ion (He^+) is ***[2009]***

(a) $\frac{h}{2\pi}$ (b) $\frac{2h}{2\pi}$

(c) $\frac{3h}{2\pi}$ (d) $\frac{4h}{2\pi}$

13. What is the wavelength of the least energetic photon emitted in the Lyman series of the hydrogen atom spectrum ? ***[2011]***

(a) 150 nm (b) 122 nm

(c) 102 nm (d) 82 nm

14. The energy of electron in the nth orbit of hydrogen atom is expressed as $E_n = \frac{-13.6}{n^2} eV$. The shortest and longest wavelength of Lyman series will be ***[2013]***

(a) 910 Å, 1213 Å (b) 5463 Å, 7858 Å

(c) 1315 Å, 1530 Å (d) None of these

15. Which of the following statements are true regarding Bohr's model of hydrogen atom? ***[2015]***

(I) Orbiting speed of electron decreases as it shifts to discrete orbits away from the nucleus

(II) Radii of allowed orbits of electron are proportional to the principal quantum number

(III) Frequency with which electrons orbit around the nucleus in discrete orbits is inversely proportional to the cube of principal quantum number

(IV) Binding force with which the electron is bound to the nucleus increases as it shifts to outer orbits

Select correct answer using the codes given below.

Codes :

(a) I and II (b) II and IV

(c) I, II and III (d) II, III and IV

16. The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is ***[2016]***

(a) 3 (b) 4

(c) 1 (d) 2

17. Which one did Rutherford consider to be supported by the results of experiments in which α-particles were scattered by gold foil? ***[2017]***

(a) The nucleus of an atom is held together by forces which are much stronger than electrical or gravitational forces.

(b) The force of repulsion between an atomic nucleus and an α-particle varies with distance according to inverse square law.

(c) α-particles are nuclei of Helium atoms.

(d) Atoms can exist with a series of discrete energy levels

18. As an electron makes a transition from an excited state to the ground state of a hydrogen - like atom/ion ***[2017]***

(a) kinetic energy decreases, potential energy increases but total energy remains same

(b) kinetic energy and total energy decrease but potential energy increases

(c) its kinetic energy increases but potential energy and total energy decrease

(d) kinetic energy, potential energy and total energy decrease

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 19-21) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

19. **Assertion:** The specific charge of positive rays is not constant.

Reason: The mass of ions varies with speed.

[1999]

20. **Assertion :** Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

Reason : According to classical physics all moving electrons radiate. ***[2003]***

21. **Assertion :** Balmer series lies inthe visible region of the electromagnetic spectrum.

Reason : $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$, where n = 3, 4, 5

[2008]

Directions for (Qs. 22-25) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

22. **Assertion :** In Lyman series, the ratio of minimum and maximum wavelength is $\frac{3}{4}$.

Reason : Lyman series constitute spectral lines corresponding to transition from higher energy to ground state of hydrogen atom. ***[2011]***

23. **Assertion :** Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.

Reason : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it. ***[2015]***

24. **Assertion :** In Lyman series, the ratio of minimum and maximum wavelength is $\frac{3}{4}$.

Reason : Lyman series constitute spectral lines corresponding to transition from higher energy to ground state of hydrogen atom. ***[2016]***

25. **Assertion :** Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

Reason : According to classical physics all moving electrons radiate. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (c) We know that

$$\frac{1}{\lambda}=R\left(\frac{1}{n_1{}^2}-\frac{1}{n_2{}^2}\right)$$

$$\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{3^2}\right) \Rightarrow R\left(\frac{1}{4}-\frac{1}{9}\right)$$

$$\frac{1}{\lambda}=\left(\frac{9-4}{36}\right)R=\frac{5R}{36} \Rightarrow \lambda=\frac{36}{5R}$$

2. (b) Radius of H-atom $\propto n^2$
So for excitation from n = 1 to n = 2, radius becomes 4 times.

3. (d) Radius of Bohr's orbit $\propto n^2$, where n is principal quantum no.

4. (a) The moment of momentum is also known as angular momentum of electron.
We know from Bohr's theory that in an orbit

angular momentum $= n.\frac{h}{2\pi}$

For second orbit n = 2

So, angular momentum $= 2\times\frac{h}{2\pi}=\frac{h}{\pi}$ is the answer.

5. (d) We know that De-Broglie wavelength is

$$mv=\frac{h}{\lambda}\Rightarrow\lambda=\frac{h}{mv}$$

$$10^{-10}=\frac{6.6\times10^{-34}}{9.1\times10^{-31}\times v};$$

$$v=\frac{6.6\times10^{-34}}{9.1\times10^{-41}}=7.25\times10^6$$

6. (b) From the de-Broglie equation,

$$\lambda=\frac{h}{p}=\frac{h}{mv}$$

where l is wavelength, h is plank's constant and p is momentum and v is velocity

$$v=\frac{h}{m\lambda}=\frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^{-11}}=7.25\times10^7\,m/s$$

$\therefore$ Energy of electron $=\frac{1}{2}mv^2$

$$=\frac{1}{2}\times\frac{9.1\times10^{-31}\times(7.25\times10^7)^2}{1.6\times10^{-19}}=15\,keV$$

7. (b) In case of hydrogen atom
If –E = ground state energy (Total)
E is kinetic energy then –2E is potential energy.
Here E = 13.6 eV $\Rightarrow$ 2E = 27.2 eV
So, potential energy = – 27.2 eV

8. (d) The deflection of a particle along y-axis is electricfield is given by $y=\frac{Eex^2}{2mv^2}$

$\Rightarrow y\propto\frac{e}{m}$ for all other values to be constant. Since y is maximum for D, hence it has highest e/m ratio.

9. (c) $E=\frac{-13.6Z^2}{n^2}$ eV, for He^+, Z = 2, n = 1 (first orbit)

$$\therefore E=\frac{-13.6\times2}{1^2}=-54.4\text{ eV}$$

10. (a) Energy of photon

$$E=\frac{hc}{\lambda}=\frac{6.6\times10^{-34}\times3\times10^8}{6840\times10^{-10}}$$

$$=\frac{6.6\times3\times10^{-26}}{6.84\times10^{-7}}J$$

$$=\frac{6.6\times3\times10^{-26}}{6.84\times10^{-7}\times1.6\times10^{-19}}eV=1.8\,eV$$

11. (b) $\Delta E=E_0(Z-1)^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

for k_α, $n_1=1, n_2=2$

for k_β, $n_1=1, n_2=3$

so energy of the photon corresponding to k_α line is less than that of k_β line.

12. **(c)** Angular momentum in the ground state $= \frac{h}{2\pi}$

Angular momentum in the first excited state $= \frac{2h}{2\pi}$

Angular momentum in the second excited state $= \frac{3h}{2\pi}$

13. **(b)** The least energy is corresponding to longest wavelength, which is $\lambda = 1216\text{Å}$.

14. **(a)** $\frac{1}{\lambda_{max}} = R\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] \Rightarrow \lambda_{max} = \frac{4}{3R} \approx 1213\text{Å}$

and $\frac{1}{\lambda_{min}} = R\left[\frac{1}{(1)^2} - \frac{1}{\infty}\right] \Rightarrow \lambda_{min} = \frac{1}{R} \approx 910\text{Å}.$

15. **(a)** Orbital speed varies inversely as the radius of the orbit.

$v \propto \frac{1}{n}$

16. **(d)** For first line of Lyman series of hydrogen

$\frac{hc}{\lambda_1} = Rhc\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

For second line of Balmer series of hydrogen like ion

$\frac{hc}{\lambda_2} = Z^2 Rhc\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$

By question, $\lambda_1 = \lambda_2$

$\Rightarrow \left(\frac{1}{1} - \frac{1}{2}\right) = Z^2\left(\frac{1}{4} - \frac{1}{16}\right)$ or $Z = 2$

17. **(b)**

18. **(c)** $U = -K\frac{ze^2}{r}$; $T.E = -\frac{k}{2}\frac{ze^2}{r}$

$K.E = \frac{k}{2}\frac{ze^2}{r}$. Here r decreases

Type B : Assertion Reason Questions

19. **(a)** The specific charge $\frac{e}{m}$ of positive ray is not constant because for different velocities the rest mass of particles change i.e. mass of ions varies with speed. So $\frac{e}{m}$ will differ. Hence, Reason and Assertion both are correct and Reason explains Assertion.

20. **(b)** According to classical physics all moving electrons around the nucleus will radiate because an accelerated electron in electric field will radiate e.m. wave. So Reason is correct. But Reason does not explain the Assertion.

Bohr's postulates that the electron in stationary orbits do not radiate. His postulate was based not out of compulsion but on the quantum theory. So Assertion is also correct but Reason does not explain Assertion.

21. **(b)** Wavelength is Balmer series is,

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$; $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

or $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.097 \times 10^7} = 6563\text{Å}$

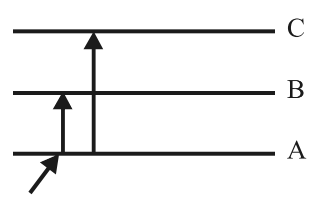
$1/\lambda_{min} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$

or $\lambda_{min} = \frac{4}{R} = \frac{4}{1.097 \times 10^7} = 3646\text{Å}$

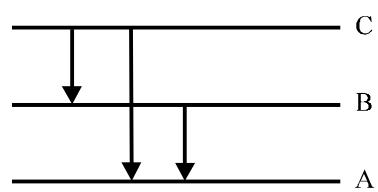
So it lies in the visible region.

22. **(b)**

23. **(a)** Absorption transition



Two possibilities in absorption transition.



Three possibilities in emission transition.

Therefore, absorption transition < emission.

24. **(b)**

25. **(b)** Bohr postulated that electrons in stationary orbits around the nucleus do not radiate. This is the one of Bohr's postulate. According to this the moving electrons radiates only when they go from one orbit to the next lower orbit.

Chapter 27

Nuclei

TYPE A : MULTIPLE CHOICE QUESTIONS

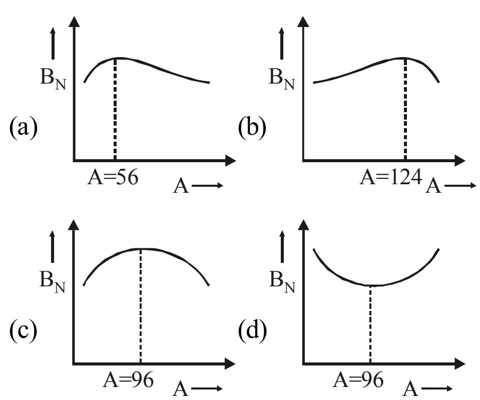
1. In the nuclear reaction, there is a conservation of:
   (a) momentum (b) mass ***[1997]***
   (c) energy (d) all of these
2. If the radioactive decay constant of radium is 1.07×10^{-4} per year. Then its half life period approximately is equal to : ***[1998]***
   (a) 5000 years (b) 6500 years
   (c) 7000 years (d) 8900 years
3. In $_{88}Ra^{226}$ nucleus there are : ***[1998]***
   (a) 226 protons and 88 electrons
   (b) 138 protons and 88 neutrons
   (c) 226 neutrons and 138 electrons
   (d) 138 neutrons and 88 protons
4. The activity of radioactive sample is measured as 9750 counts per minute at t = 0 and as 975 counts per minute at t = 5 minutes, the decay constant is approximately : ***[1998]***
   (a) 0.922 per minute (b) 0.270 per minute
   (c) 0.461 per minute (d) 0.39 per minute
5. The activity of a radioactive sample is 1.6 curie and its half life is 2.5 days. Then activity after 10 days will be : ***[1999]***
   (a) 0.16 curie (b) 0.8 curie
   (c) 0.1 curie (d) 0.4 curie
6. Which one of the following is used as a moderator in nuclear reaction ? ***[1999]***
   (a) Uranium (b) Heavy water
   (c) Cadmium (d) Plutonium
7. The reaction responsible for the production of light energy from the sun will be: ***[1999]***
   (a) fission (b) fusion
   (c) nuclear (d) none of these
8. Half life of a substance is 20 minutes, then the time between 33 % decay and 67 % decay will be
   (a) 20 minute (b) 40 minute ***[2000]***
   (c) 50 minute (d) 10 minute
9. Consider the following nuclear reaction
   $X^{200} \rightarrow A^{110} + B^{90} + \text{Energy}$
   If the binding energy per nucleon for X, A and B are 7.4 MeV, and 8.2 MeV and 8.2 MeV respectively, the energy released will be :***[2000]***
   (a) 90 MeV (b) 110 MeV
   (c) 200 MeV (d) 160 MeV
10. In each fission of $_{92}U^{235}$ releases 200 MeV, how many fissions must occur per second to produce power of 1 kW ? ***[2000]***
    (a) 1.25×10^{18} (b) 3.125×10^{13}
    (c) 3.2×10^{18} (d) 1.25×10^{13}
11. The function of heavy water in a nuclear reactor to
    (a) slow down the neutrons ***[2001]***
    (b) increase the neutrons
    (c) stop the electrons
    (d) none of these
12. Which one of the following has the highest neutrons ratio ? ***[2001]***
    (a) $_{92}U^{235}$ (b) $_{8}O^{16}$
    (c) $_{2}He^{4}$ (d) $_{26}Fe^{56}$
13. When radioactive substance emits an α-particle, then its position in the periodic table is lowered by ***[2001]***
    (a) two places (b) three places
    (c) five places (c) one place
14. In an atom bomb, the energy is released because of the : ***[2001]***
    (a) chain reaction of neutrons and $_{92}U^{238}$
    (b) chain reaction of neutrons and $_{92}U^{235}$
    (c) chain reaction of neutrons and $_{92}U^{236}$
    (d) chain reaction of neutrons and $_{92}U^{240}$
15. A radioactive substance decays to $1/16^{th}$ of its initial activity in 40 days. The half-life of the radioactive substance expressed in days is
    (a) 2.5 (b) 5 ***[2003]***
    (c) 10 (d) 20

16. Nuclear fusion is possible ***[2003]***
(a) only between light nuclei
(b) only between heavy nuclei
(c) between both light and heavy nuclei
(d) only between nuclei which are stable against β-decay

17. Radioactive nuclei that are injected into a potient collected at certain sites within its body, undergoing radioactive decay and emitting electromagnetic radiation. These radiations can then be recorded by a detector. This procedure provides an important diagnostic tools called
(a) Gamma camera ***[2003]***
(b) CAT can
(c) Radiotracer technique
(d) Gamma ray spectroscopy

18. In a material medium, when a positron meets an electron both the particles annihilate leading to the emission of two gamma ray photons. This process forms the basis of an important diagnostic procedure called ***[2003]***
(a) MRI (b) PET
(c) CAT (d) SPECT

19. The dependence of binding energy per nucleon, B_N, on the mass number A, is represented by ***[2004]***



20. Carbon dating is best suited for determining the age of fossils if their age in years is of the order of ***[2004]***
(a) 10^3 (b) 10^4
(c) 10^5 (d) 10^6

21. In nucleus of mass number A, originally at rest, emits an a-particle with speed v. The daughter nucleus recoils with a speed : ***[2004]***
(a) $\frac{2v}{A+4}$ (b) $\frac{4v}{A+4}$
(c) $\frac{4v}{A-4}$ (d) $\frac{2v}{A-4}$

22. When an electron-positron pair annihilates, the energy released is about ***[2004]***
(a) 0.8×10^{-13} J (b) 1.6×10^{-13} J
(c) 3.2×10^{-13} J (d) 4.8×10^{-13} J

23. A radioactive material has half-life of 10 days. What fraction of the material would remain after 30 days ? ***[2005]***
(a) 0.5 (b) 0.25
(c) 0.125 (d) 0.33

24. The operation of a nuclear reactor is said to be critical, if the multiplication factor (K) has a value
(a) 1 (b) 1.5 ***[2006]***
(c) 2.1 (d) 2.5

25. ^{238}U has 92 protons and 238 nucleons. It decays by emitting an Alpha particle and becomes
(a) $^{234}_{92}U$ (b) $^{234}_{90}Th$ ***[2006]***
(c) $^{235}_{92}U$ (d) $^{237}_{93}Np$

26. The fossil bone has a ^{14}C: ^{12}C ratio, which is $\left(\frac{1}{16}\right)$ of that in a living animal bone. If the half-life time of ^{14}C is 5730 years, then the age of the fossil bone is ***[2006]***
(a) 11460 years (b) 17190 years
(c) 22920 years (d) 45840 years

27. Which one of the following is a possible nuclear reaction ***[2006]***
(a) $^{10}_{5}B + ^{4}_{2}He \longrightarrow ^{13}_{7}N + ^{1}_{1}H$
(b) $^{23}_{11}Na + ^{1}_{1}H \longrightarrow ^{20}_{10}Ne + ^{4}_{2}He$
(c) $^{239}_{11}Np \longrightarrow ^{239}_{94}Pu + \beta^- + \bar{v}$
(d) $^{11}_{7}N + ^{1}_{1}H \longrightarrow ^{12}_{6}C + \beta^- + v$

28. If Alpha, Beta and Gamma rays carry same momentum, which has the longest wavelength
(a) Alpha rays ***[2006]***
(b) Beta rays
(c) Gamma rays
(d) None, all have some wavelength

29. What is the amount of energy released by deuterium and tritium fusion? ***[2007]***
(a) 60.6 eV (b) 123.6 eV
(c) 17.6 eV (d) 28.3 eV

30. Calculate power output of $^{235}_{92}U$ reactor, if it takes 30 days to use up 2 kg of fuel, and if each fission gives 185 MeV of useable energy. Avogadro's number = 6×10^{23} /mol? ***[2007]***

(a) 56.3 MW (b) 60.3 MW
(c) 58.3 MW (d) 54.3 MW

31. Starting with a sample of pure ^{66}Cu, $\frac{7}{8}$ of it decays into Zn in 15 minutes. The corresponding half life is ***[2008]***

(a) 15 minutes (b) 10 minutes
(c) $7\frac{1}{2}$ minutes (d) 5 minutes

32. A radioactive material decays by simultaneous emission of two particles with respective half-lives 1620 and 810 years. The time, in years, after which one-fourth of the material reamins is ***[2008]***

(a) 1080 (b) 2430
(c) 3240 (d) 4860

33. If the binding energy per nucleon of a nuclide is high then ***[2009]***

(a) It should be abundantly available in nature
(b) It will decay instantly
(c) It will have a large disintegration constant
(d) It will have a small half-life.

34. Activity of a radioactive sample decreases to $(1/3)^{rd}$ of its original value in 3 days. Then, in 9 days its activity will become ***[2009]***

(a) (1/27) of the original value
(b) (1/9) of the original value
(c) (1/18) of the original value
(d) (1/3) of the original value

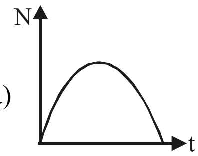
35. The half life of a radioactive substance against α -decay is 1.2×10^7 s. What is the decay rate for 4.0×10^{15} atoms of the substance ***[2010]***

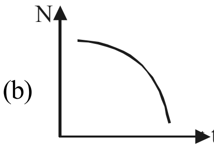
(a) 4.6×10^{12} atoms/s
(b) 2.3×10^{11} atoms/s
(c) 4.6×10^{10} atoms/s
(d) 2.3×10^{8} atoms/s

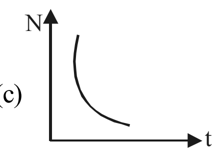
36. Actinium 231, $^{231}Ac_{89}$, emit in succession two β–particles, four alphas, one β and one alpha plus several γ rays. What is the resultant isotope: ***[2011]***

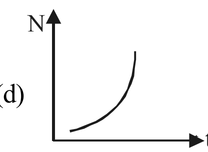
(a) $^{221}Au_{79}$ (b) $^{211}Au_{79}$
(c) $^{221}Pb_{82}$ (d) $^{211}Pb_{82}$

37. Radioactive element decays to form a stable nuclide, then the rate of decay of reactant is ***[2012]***

(a) 

(b) 

(c) 

(d) 

38. A nuclear reaction is given by ***[2012]***

$_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0} + \bar{v}$, represents

(a) fission (b) β-decay
(c) σ -decay (d) fusion

39. An archaeologist analyses the wood in a prehistoric structure and finds that C^{14} (Half life = 5700 years) to C^{12} is only one-fourth of that found in the cells of buried plants. The age of the wood is about ***[2013]***

(a) 5700 years (b) 2850 years
(c) 11,400 years (d) 22,800 years

40. A radioactive nuclide is produced at the constant rate of n per second (say, by bombarding a target with neutrons). The expected number N of nuclei in existence t seconds after the number is N_0 is given by ***[2014]***

(a) $N = N_0 e^{-\lambda t}$

(b) $N = \frac{n}{\lambda} + N_0 e^{-\lambda t}$

(c) $N = \frac{n}{\lambda} + \left(N_0 - \frac{n}{\lambda}\right)e^{-\lambda t}$

(d) $N = \frac{n}{\lambda} + \left(N_0 + \frac{n}{\lambda}\right)e^{-\lambda t}$

Where λ is the decay constant of the sample

41. The fossil bone has a ^{14}C : ^{12}C ratio, which is $\left[\frac{1}{16}\right]$ of that in a living animal bone. If the half-life of ^{14}C is 5730 years, then the age of the fossil bone is ***[2015]***

(a) 11460 years (b) 17190 years
(c) 22920 years (d) 45840 years

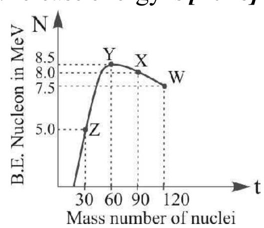
42. Binding energy per nucleon versus mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is ***[2016]***

(a) $Y \to 2Z$

(b) $W \to X + Z$

(c) $W \to 2Y$

(d) $X \to Y + Z$



43. The activity of a radioactive sample is measured as N_0 counts per minute at $t = 0$ and N_0/e counts per minute at $t = 5$ minutes. The time (in minutes) at which the activity reduces to half its value is ***[2017]***

(a) $\log_e 2/5$ (b) $\frac{5}{\log_e 2}$

(c) $5 \log_{10} 2$ (d) $5 \log_e 2$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 44-55) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

(e) If the Assertion is incorrect but the Reason is correct.

44. **Assertion :** Isobars are the elements having same mass number but different atomic number.

Reason : Neutrons and protons are present inside nucleus. ***[1997]***

45. **Assertion :** If the half life of a radioactive substance is 40 days then 25% substance decay in 20 days. ***[1998]***

Reason : $N = N_0\left(\frac{1}{2}\right)^n$

where, $n = \frac{\text{time elapsed}}{\text{half life period}}$

46. **Assertion:** Separation of isotope is possible because of the difference in electron numbers of isotope.

Reason: Isotope of an element can be separated by using a mass spectrometer. ***[1999]***

47. **Assertion:** ${}_ZX^A$ undergoes 2α-decays, 2β-decays and 2γ-decays and the daughter product is ${}_{Z-2}X^{A-8}$.

Reason : In α-decays the mass number decreases by 4 and atomic number decreases by 2. In 2β-decays the mass number remains unchanged, but atomic number increases by 1 only. ***[2001]***

48. **Assertion :** Radioactive nuclei emit β^- particles.

Reason : Electrons exist inside the nucleus. ***[2003]***

49. **Assertion :** Neutrons penetrate mater more readily as compared to protons.

Reason : Neutrons are slightly more massive than protons. ***[2003]***

50. **Assertion :** ^{90}Sr from the radioactive fall out from a nuclear bomb ends up in the bones of human beings through the milk consumed by them. It causes impairment of the production of red blood cells.

Reason : The energetic β-particles emitted in the decay of ^{90}Sr damage the bone marrow. ***[2004]***

51. **Assertion :** Energy is released in nuclear fission.

Reason : Total binding energy of the fission fragments is larger than the total binding energy of the parent nucleus. ***[2004]***

52. **Assertion :** It is not possible to use ^{35}Cl as the fuel for fusion energy.

Reason : The binding energy of ^{35}Cl is too small. ***[2005]***

53. **Assertion :** The binding energy per nucleon, for nuclei with atomic mass number A > 100, decreases with A.

Reason : The nuclear forces are weak for heavier nuclei. ***[2006, 2013]***

54. **Assertion :** Cobalt-60 is useful in cancer therapy.

Reason : Cobalt-60 is a source of γ-radiations capable of killing cancerous cells. ***[2006]***

55. **Assertion :** Heavy water is a better moderator than normal water.

Reason : Heavy water absorbs neutrons more efficiently than normal water. ***[2007]***

Directions for (Qs. 56-61) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

56. **Assertion :** In a decay process of a nucleus, the mass of products is less than that of the parent.

Reason : The rest mass energy of the products must be less than that of the parent. ***[2012]***

57. **Assertion :** Binding energy (or mass defect) of hydrogen nucleus is zero.

Reason : Hydrogen nucleus contain only one nucleon. ***[2012]***

58. **Assertion :** The ionising power of β-particle is less compared to α-particles but their penetrating power is more.

Reason : The mass of β-particle is less than the mass of α-particle. ***[2014]***

59. **Assertion :** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion and

Reason : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z. ***[2015]***

60. **Assertion :** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion and

Reason : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z. ***[2017]***

61. **Assertion :** Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.

Reason : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(a)** In a nuclear reaction, there may be conversion of some mass into energy. So, both mass and energy are not conserved. It is the momentum which is conserved.

2. **(b)** $\lambda = 1.07 \times 10^{-4}$

$$T_{1/2} = \frac{0.693}{1.07 \times 10^{-4}} = 6500 \text{ years}$$

3. **(d)** $_{88}Ra^{226}$

Number of protons = 88

Number of neutrons = 226 – 88 = 138

4. **(c)** We know that

$$\frac{dN}{dt} = \lambda N$$

Now, $\dfrac{dN_0}{dt} = \lambda N_0\,;\ \dfrac{dN_t}{dt} = \lambda N_t$

$9750 = \lambda N_0\,;\ 975 = \lambda N_t$

$$\frac{N_0}{N_t} = \frac{9750}{975} = \frac{10}{1} \Rightarrow N_0 = 10N_t$$

We know that

$N_t = N_0 e^{-\lambda t}$

$$\frac{N_t}{N_0} = e^{-\lambda t} \Rightarrow \frac{1}{10} = e^{-\lambda .5}$$

$10^{-1} = e^{-5\lambda}$

Taking log on both sides,

$$-1 = -5\lambda \times \frac{1}{2.303}$$

$$\lambda = \frac{1}{5} \times 2.303 = 0.461 \text{ per minute.}$$

5. **(c)** After every 2.5 days its activity reduces to half the value,

$$10\text{days} = \frac{10}{2.5} = 4 \text{ half lives}$$

$$\text{Reduced activity} = 1.6 \times \left(\frac{1}{2}\right)^4$$

$$= 1.6 \times \frac{1}{16} = 0.1 \text{ curie}$$

6. **(b)** Heavy water (D_2O) is used as a moderator in nuclear reaction.

7. **(b)** Fusion is the reaction responsible for the production of light energy from the Sun. In it two hydrogen molecules fuse to form helium.

$_1H^1 + {}_1H^1 \longrightarrow {}_2He^4 + \text{Energy}$

8. **(a)** When the body is already 33% decayed to be decayed to a further 33%, it will require a period equal to its half life. So achieve level of decay from 33% to 67% it takes time equal to half life or 20 minutes.

9. **(d)** Energy released = total binding energy of A and B less total binding energy of X.

$= (110 \times 8.2 + 90 \times 8.2)$

$\quad - (200 \times 7.4)\,(902 + 738) - 1480$

$= 160$ MeV

10. **(b)** Let n be number of fission per second

$n \times 200 \times 10^6$ eV is produced in one second

$= n \times 200 \times 10^6 \times 1.6 \times 10^{-19}$ Joule per second

$$= \frac{n \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{10^3} = 1(\text{given})$$

$$n = \frac{10^3}{2 \times 1.6 \times 10^{-11}} = \frac{10^{14}}{3.2}$$

$$= \frac{10}{3.2} \times 10^{13} = 3.125 \times 10^{13}$$

11. **(a)** In a nuclear reactor neutrons are needed for nuclear reactions. The product of nuclear reaction is also neutrons. But fast neutrons can not induce nuclear reactions. It requires to be slowed down. Fast neutrons cannot transfer its energy to the target atom effectively due to its high velocity. So, its velocity is reduced. For it we uses heavy water.

12. **(a)** Neutrons ratio that is $\dfrac{n}{p}$ determines the stability of nucleus. (Here, n is number of neutrons and p is number of protons).

Now, $n = 235 - 92 = 143$

$p = 92$

For $_{92}U^{235}$; Neutron ratio $= \dfrac{143}{92} = 1.55$

Which is the highest no. So, $_{92}U^{235}$ is most unstable.

13. (a) When radioactive substance emits an α-particle then the atomic number is reduced by 2. Naturally its position in periodic table will be reduced by 2 places.

14. (b) The nuclear reaction taking place in the atom is as follows

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow$$
$${}_{36}Ba^{141} + {}_{56}Kr^{92} + 3\,{}_{0}n^{1} + Q$$

Q = 200 MeV.

The three neutrons generated are capable of reacting with three atoms individually which leads to chain reaction.

15. (c) Let half life = T

$$40 \text{ days} = \frac{40}{T} \text{ Half life}$$

$$\text{Ratio of substance left} = \left(\frac{1}{2}\right)^{\frac{40}{T}}$$

$$\text{So, } \left(\frac{1}{2}\right)^{\frac{40}{T}} = \left(\frac{1}{2}\right)^{4}$$

$$\frac{40}{T} = 4 \Rightarrow T = \frac{40}{4} = 10 \text{ days}$$

16. (a) Nuclear fusion is possible only between light nuclei as they become more stable by acquiring greater atomic no.

17. (c) In radiotracer technique we trace the existence of an atom by detecting the radiation emitted by it if atom is a radioactive one. The case as stated in the question confirms to it so it is an example of radiotracer technique.

18. (b) Positron emission tomography (PET) is a nuclear medicine medical imaging technique which produces a three dimensional image are map of functional process in the body. The positron annihilates with an electron producing a pair of annihilation photons (gama rays) moving in opposite direction

19. (a) Binding energy per nucleon is maximum for atomic number (A) = 56, so figure (a) is correct alternative.

20. (b) Carbon dating is best suited for determining the age of fossils if their age in years is of the order of 10, 000 years. This is because fossil older than this are destroyed due to time factor. The tracks that are built by the rays are destroyed. For fossil earlier then this, the tracks are so small that it cannot be measured with accuracy.

21. (c) Applying law of conservation of momentum

$$MV = mv$$

Let mass of each proton = m

Mass of daughter nucleus = (Am – 4m)

Mass of α-particle = 4m

So, $(Am - 4m)\,V = 4m \times v$

$$V = \frac{4mv}{m(A-4)} = \frac{4v}{A-4}$$

22. (b) When electron-positron pair annihilates the energy released is due to conversion of mass into energy.

Total mass $= 2 \times 9 \times 10^{-31}$ kg

Energy produced

$$= 2 \times 9 \times 10^{-31} \times (3 \times 10^{8})^{2}$$

$$= 162 \times 10^{-15} = 1.62 \times 10^{-13}\text{ J}$$

23. (c) 30 days = 3 halflife

Fraction of material remained

$$= \left(\frac{1}{2}\right)^{3} = \frac{1}{8} = 0.125$$

24. (a) The operation of a nuclear reactor is said to be critical if the multiplication factor is

$$k = \frac{\text{rate of production of neutrons}}{\text{rate of loss of neutrons}}$$

If k > 1 explosion occurs

If k < 1 the chain reaction comes to half.

25. (b) $${}_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4}$$

26. (c) Let $\frac{p}{q}$ be the initial ratio of ${}^{14}C : {}^{12}C$. Let it is $\frac{1}{16}\frac{p}{q}$ in the fossil. As q remains constant, p must have reduced to $\frac{p}{16}$ during the period.

$$\frac{p}{q} = \frac{1}{16} = \frac{1}{(2)^{4}}$$

No. of half lives required = 4

Age of fossil = 4 × 5730 = 22920 years

27. (c)

28. (d) $\lambda = \frac{h}{mv}$

If they have same momentum (mv), they must have same wave length.

29. (c) ${}_1^2H + {}_1^3H \longrightarrow {}_2^4H + n + 17.59\,\text{MeV}$

(Controlled thermonuclear fission reaction)

30. (c) No. of ^{235}U atoms in 2 kg of fuel

$= \frac{6.023 \times 10^{23}}{235} \times 2000$

fission energy per atom = 185 MeV

$\therefore$ Energy for 2 kg of fuel

$= \frac{6.023 \times 10^{26} \times 2}{235} \times 185\,\text{MeV}$

$\text{Power} = \frac{\text{Energy released}}{\text{time}}$

$= \frac{6.023 \times 10^{26} \times 2 \times 185 \times 1.6 \times 10^{-13}\,\text{J}}{235 \times 30\,\text{days}}$

($\because$ 1 MeV = 1.6×10^{-13} J, 30 days = $30 \times 24 \times 60 \times 60$ sec)

$\therefore \text{Power} = \frac{6.023 \times 10^{26} \times 2 \times 185 \times 1.6 \times 10^{-13}}{235 \times 30 \times 24 \times 60 \times 60}$

$= \frac{3552 \times 10^{13}}{235 \times 3 \times 6 \times 6 \times 24 \times 10^{3}}\,\text{W}$

$= \frac{3552 \times 10^{10}}{235 \times 3 \times 6 \times 6 \times 24}$

$= \frac{3552 \times 10^{4}}{235 \times 18 \times 6 \times 24}\,\text{MW} = 58.3\,\text{MW}$

31. (d) $\frac{7}{8}$ days of Cu decays.

$\therefore$ Cu undecayed, $N = 1 - \frac{7}{8} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$

$\therefore$ No. of half lifes = 3

$n = \frac{t}{T}$ or $3 = \frac{15}{T}$

$\Rightarrow$ half life period, $T = \frac{15}{3} = 5$ minutes

32. (a) $\frac{-dN}{dt} = \lambda_1 N + \lambda_2 N \Rightarrow \log_e \frac{N}{N_0} = -(\lambda_1 + \lambda_2)t$

where N_0 is initial no. of atom

Here $\lambda_1 = \frac{0.693}{1620}$ and $\lambda_2 = \frac{0.693}{810}$

$\frac{N}{N_0} = \frac{1}{4} \Rightarrow \log_e \frac{1}{4} = -\left(\frac{0.693}{1620} + \frac{0.693}{810}\right)t$

$\Rightarrow 2.303[-2 \times (.3010)]$

$= -0.693\left(\frac{0.693}{1620} + \frac{0.693}{810}\right)t$

$\Rightarrow \frac{2 \times 1620 \times 810}{2430} = t = 1080$ year.

33. (a) High binding energy per nucleon ensures very high life of the nuclide. Hence they should be abundant in nature.

34. (a) $R = R_0 e^{-\lambda t}$

$\Rightarrow \frac{1}{3} = e^{-\lambda \times 3} = e^{-3\lambda}$ ...(1)

Let activity in 9 days be R'. Then

$\frac{R'}{R_0} = e^{-\lambda \times 9} = e^{-9\lambda}\ e^{-\lambda \times 3} = (e^{-3\lambda})^3$

$= \left(\frac{1}{3}\right)^3$, from (1)

$= \frac{1}{27} \Rightarrow R' = \frac{R_0}{27}$.

35. (d) We have, $\frac{dN}{dt} = \lambda N$

$\lambda = \frac{0.693}{T} = \frac{0.693}{1.2 \times 10^7}$

$\frac{dN}{dt} = \frac{0.693}{1.2 \times 10^7} \times 4 \times 10^{15}$

$= 2.3 \times 10^8$ atom/s

36. (d) Five alpha and three beta particles results

$^{231}AC_{89} \longrightarrow \underset{(89-5\times2+3\times1)=82}{\overset{231-5\times4=211}{Pb}}$

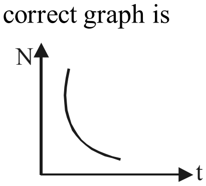
37. (c) No. of nuclide at time t is given by

$N = N_0 e^{-\lambda t}$

Where N_0 = initial nuclide

thus this equation is equivalent to $y = ae^{-kx}$

Thus correct graph is



38. (b) ${}_{-1}e^0$ is known as β^- particle & $\bar{\nu}$ is known as antineutrino. Since in this reaction $\bar{\nu}$ is emitted with ${}_{-1}e^0$ (β^- particle or electron), so it is known as β-decay.

39. (c) $\frac{C_{14}}{C_{12}} = \frac{1}{4} = \left(\frac{1}{2}\right)^{t/5700}$

$\Rightarrow \frac{t}{5700} = 2 \Rightarrow t = 11400$ years

40. (c) $\frac{dN}{dt} = n - \lambda N$

$dN = (n - \lambda N)dt$

$$\int_{N_0}^{N} \frac{dN}{n-\lambda N} = \int_0^t dt \Rightarrow -\frac{1}{\lambda}\int_{N_0}^{N} \frac{-\lambda dN}{n-\lambda N} = t$$

$$\Rightarrow -\frac{1}{\lambda}[\log_e(n-\lambda N)]_{N_0}^{N} = t$$

$$\Rightarrow -\frac{1}{\lambda}\left[\log_e\left(\frac{n-\lambda N}{n-\lambda N_0}\right)\right] = t$$

$$\Rightarrow \lambda t = \left[\log_e\left(\frac{n-\lambda N_0}{n-\lambda N}\right)\right]$$

$$e^{\lambda t} = \frac{n-\lambda N_0}{n-\lambda N}$$

$$n - \lambda N = (n - \lambda N_0)\, e^{-\lambda t}$$

$$\frac{n}{\lambda} - \left(\frac{n}{\lambda} - N_0\right)e^{-\lambda t} = N$$

41. (c) $\frac{{}^{14}C}{{}^{12}C} = \frac{1}{16} = \frac{N}{N_0}$

$\because \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

$\Rightarrow \quad \frac{1}{16} = \left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$

or, $\quad n = 4$

or $\quad \frac{t}{T} = 4$

or $\quad t = 4 \times T = 4 \times 5730 = 22920$ years

42. (c) Energy is released in a process when total binding energy (BE) of products is more than the reactants. By calculations we can see that this happens in option (c).

Given $\quad W = 2Y$

BE of reactants = 120 × 7.5 = 900 MeV

BE of products = 2 × (60 × 8.5) = 1020 MeV.

43. (d) $N = N_0 e^{-\lambda t}$

Here, $t = 5$ minutes

$$\frac{N_0}{e} = N_0 \cdot e^{-5\lambda}$$

$$\Rightarrow \quad 5\lambda = 1, \text{ or } \quad \lambda = \frac{1}{5},$$

Now, $T_{1/2} = \frac{\ell n2}{\lambda} = 5\ \ell n2$

Type B : Assertion Reason Questions

44. (b) By definition, isobars are elements having same mass number but different atomic number. Presence of neutron and proton inside nucleus has nothing to do with this definition.

45. (e) Half life of radioactive substance is 40 days. It means 50% substance decays in 40 days. During this period rate of decay is on decrease. So, 25% decay must have taken place is less than 20 days.

$$N = N_0\left(\frac{1}{2}\right)^n, \text{ where } n = \frac{\text{time elapsed}}{\text{half life period}}$$

46. (e) Isotope of an element can be separated by using a mass spectrometer because isotopes have different atomic mass. Alternative (e) is correct.

47. (a) The reason given is true. If we test the authenticity of assertion,

$${}_ZX^A \xrightarrow{\alpha-\text{decay}} {}_{Z-2}X^{A-4} \xrightarrow{\alpha-\text{rays}}$$

$${}_{Z-4}X^{A-8} \xrightarrow{(2\beta-\text{rays})} {}_{Z-2}X^{A-8}$$

47. (c) Radioactive nuclei emit β-particles. This β-particle comes from the splitting of neutron into β-particle and proton.

48. (b) Neturon is penetrate more readily as compared to protons because neutrons do not carry any change so there is no repulsion between nucleus and neutrons. So assertion is true reason is also true as mass of neutron is more than proton but reason does not explain assertion.

49. (a) RBC of blood are produced in the bone marrow. The radiation from the radioactive substances destroys of bone marrow which result in hampered production of RBC.

50. (a) Total binding energy of fragment nucleus is more than total binding energy of parent nucleus. Since, binding energy results in decrease of total energy. Hence there is great decrease in energy fragment nucleus because energy is released in nuclear fission.

$$\underset{(\text{Parent})}{A} \longrightarrow \underset{(\text{Fragment})}{B} + \underset{(\text{Energy})}{E}$$

Energy of B is decrease but the binding energy of B is increased due to release of energy from it. So, reason supports the assertion.

51. (a)

52. (c) Since, ^{35}Cl is stable so binding energy is high. So it is not capable of disintegration.

53. (a) Binding energy per nucleon decreases with A for nuclei with atomic mass number A > 100 due to weak nuclear forces. It can be explain as :

At short distances, the nuclear force is stronger than the Coulomb force; it can overcome the Coulomb repulsion of protons inside the nucleus. At typical nucleon separation (1.3 fm) it is a very strong attractive force (104 newtons). Beyond about 1.3 fm separation, the force exponentially dies off to zero. However, the Coulomb force between protons has a much larger range and becomes the only significant force between protons when their separation exceeds about (2.5 fm, A > 100).

54. (a) Cobalt 60 is radioactive isotope of cobalt. γ-radiation emitted by it is used in radiation therapy is cancer as it destroys cancerous cells.

So, assertion and reason is true and reason explains assertion.

55. (c) Heavy water has better ability to slow down neutrons by elastic collision between their protons and neutrons hence they are better moderators. Heavy water does not absorb neutrons.

56. (a)

57. (a)

58. (b) β-particles, being emitted with very high speed compared to α-particles, pass for very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

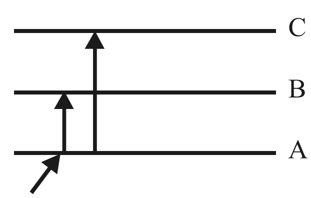
59. (c) We know that energy is released when heavy nuclei undergo fission or light nuclei undergo fusion. Therefore Assertion is correct.

The Reason is incorrect because for heavy nuclei the binding energy per nucleon decreases with increasing Z and for light nuclei, B.E/nucleon increases with increasing Z.

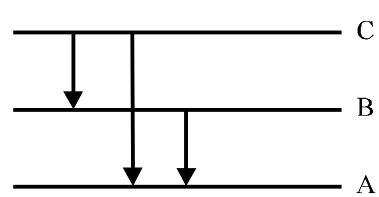
60. (d) We know that energy is released when heavy nuclei undergo fission or light nuclei undergo fusion. Therefore Assertion is correct.

The Reason is incorrect because for heavy nuclei the binding energy per nucleon decreases with increasing Z and for light nuclei, B.E/nucleon increases with increasing Z.

61. (a) Absorption transition



Two possibilities in absorption transition.



Three possibilities in emission transition.
Therefore, absorption transition < emission.

Chapter

28 Semi-Conductor, Electronics : Materials, Devices and Simple Circuits

TYPE A : MULTIPLE CHOICE QUESTIONS

1. In p-type semiconductor major current carriers are : *[1997]*
(a) negative ions (b) holes
(c) electrons (d) all of these

2. In a diode, when there is a saturation current, the plate resistance will be *[1997]*
(a) data insufficient
(b) zero
(c) some finite quantity
(d) infinite quantity

3. When the two semiconductors *p*- and *n*-type are brought into contact they form a *p-n* junction, which acts like a/an : *[1997]*
(a) rectifier (b) amplifier
(c) conductor (d) oscillator

4. The transfer ratio β of a transistor is 50. The input resistance of the transistor when used in the common emitter configuration is $1k\Omega$. The peak value of the collector A.C. current for an A.C. input voltage of 0.01 V, is *[1998]*
(a) $500\ \mu A$ (b) $0.25\ \mu A$
(c) $0.01\ \mu A$ (d) $100\ \mu A$

5. When n-p-n transistor is used as an amplifier, then *[1999]*
(a) electrons move from base to collector
(b) holes move from emitter to base
(c) electrons move from collector to base
(d) holes move from base to emitter

6. Boolean algebra is essentially based on: *[1999]*
(a) Numbers (b) Symbol
(c) Logic (d) Truth

7. A triode valve has an amplification factor of 20 and its plate is given a potential of 300 V. The grid voltage to reduce the plate current to zero, is *[1999]*
(a) 25 V (b) 15 V
(c) 12 V (d) 10 V

8. Diode is used as a/an *[1999]*
(a) modulator (b) rectifier
(c) oscillator (d) amplifier

9. In n-type semiconductor, majority charge carriers are *[1999]*
(a) electrons (b) neutrons
(c) holes (d) protons

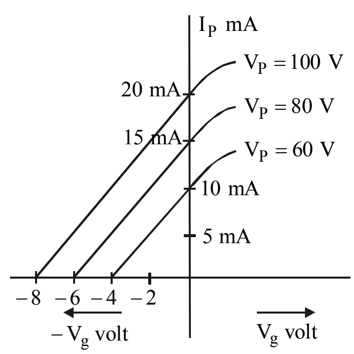
10. In a full wave rectifier circuit operating from 50 Hz mains frequency, what is the fundamental frequency in the ripple? *[2000]*
(a) 50 Hz (b) 100 Hz
(c) 70 Hz (d) 25 Hz

11.

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

The truth table given above for which of the following gates is correct *[2000]*
(a) NAND gate (b) OR gate
(c) AND gate (d) NOT gate

12. The variation of anode current in a triode valve corresponding to a change in grid potential at three different values of the plate potential is shown in the given figure. The mutual conductance of triode is *[2000]*



(a) 5×10^{-3} mho (b) 2.5×10^{-3} mho
(c) 7.5×10^{-3} mho (d) 9.5×10^{-3} mho

13. Which one of the following is true about the p-type and n-type semi-conductor ? *[2001]*
(a) n-type semi-conductor have holes in majority.

(b) the concentration of electrons and holes are equal in both n-type and p -type semi-conductors.
(c) n-type semi-conductors have free electrons in majority.
(d) p-type semi-conductor has excess negative charge.

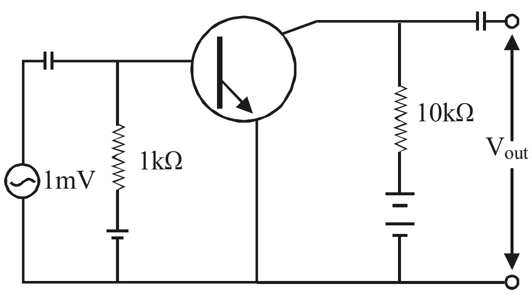
14. When added an impurity into the silicon which one of the following produces n-type of semi-conductors : *[2001]*
(a) iron (b) magnesium
(c) aluminium (d) phosphorous

15. At 0 K temperature, a p-type semiconductor *[2002]*
(a) has equal number of holes and free electrons
(b) has few holes but no free electrons
(c) has few holes and few free electrons
(d) does not have any charge carriers

16. The value of current gain α of a transistor is 0.98. The value of β will be *[2002]*
(a) 490 (b) 4.9
(c) 59 (d) 49

17. To a germanium sample, traces of gallium are added as an impurity. The resultant sample would behave like : *[2003]*
(a) a conductor
(b) a p-type semi-conductor
(c) an n-type sem-iconductor
(d) an insulator

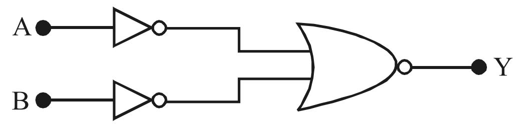
18. In the following common emitter configuration an npn transistor with current gain $\beta = 100$ is used. The output voltage of the amplifier will be : *[2003]*



(a) 10mV (b) 0.1 V
(c) 1.0 V (d) 10 V

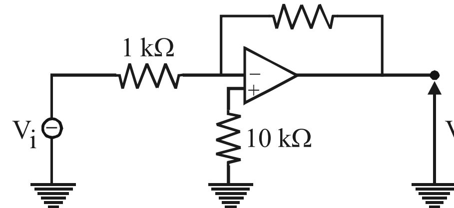
19. A Ge specimen is doped with Al. The concentration of acceptor atoms is ~10^{21} atoms/m^3. Given that the intrinsic concentration of electron-hole pairs is ~$10^{19}/m^3$, the concentration of electrons in the specimen is *[2004]*
(a) $10^{17}/m^3$ (b) $10^{15}/m^3$
(c) $10^4/m^3$ (d) $10^2/m^3$

20. Which logic gate is represented by the following combination of logic gates ? *[2004]*



(a) OR (b) NAND
(c) AND (d) NOR

21. The voltage gain of the following amplifier is *[2005]*



(a) 10 (b) 100
(c) 1000 (d) 9.9

22. Which of the following logic gates is an universal gate ? *[2005]*
(a) OR (b) NOT
(c) AND (d) NAND

23. Consider an n-p-n transistor amplifier in common emitter configuration. The current gain of the transistor is 100. If the collector current changes by 1mA, what will be the change in emitter current *[2005]*
(a) 1.1 mA (b) 1.01 mA
(c) 0.01 mA (d) 10 mA

24. In a semi-conducting material the mobilities of electrons and holes are μ_e and μ_h respectively. Which of the following is true ? *[2005]*
(a) $\mu_e > \mu_h$ (b) $\mu_e < \mu_h$
(c) $\mu_e = \mu_h$ (d) $\mu_e = 0; \mu_h > 0$

25. When a p-n diode is reverse biased, then *[2006]*
(a) no current flows
(b) the depletion region is increased
(c) the depletion region is reduced
(d) the height of the potential barrier is reduced

26. An amplifier has a voltage gain $A_v = 1000$. The voltage gain in dB is: *[2006]*
(a) 30 dB (b) 60 dB
(c) 3 dB (d) 20 dB

27. If the highest modulating frequency of the wave is 5 kHz, the number of stations that can be accomdated in a 150 kHz bandwidth are ***[2007]***
(a) 15 (b) 10
(c) 5 (d) none of these

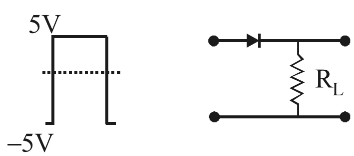
28. Zener diode acts as a/an ***[2007]***
(a) oscillator (b) regulator
(c) rectifier (d) filter

29. In the half wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be ***[2007]***
(a) 25 Hz (b) 50 Hz
(c) 70.7 Hz (d) 100 Hz

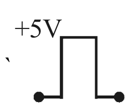
30. A transistor is a/an ***[2007]***
(a) chip (b) insulator
(c) semiconductor (d) metal

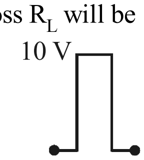
31. If collector current is 120 mA and base current is 2 mA and resistance gain is 3, what is power gain?
(a) 180 (b) 10800 ***[2007]***
(c) 1.8 (d) 18

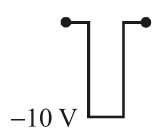
32. If in a p-n junction diode, a square input signal of 10 V is applied as shown ***[2008]***

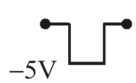


Then the output signal across R_L will be

(a) 

(b) 

(c) 

(d) 

33. The input resistance of a common emitter transistor amplifier, if the output resistance is 500 kΩ, the current gain $\alpha = 0.98$ and power gain is 6.0625×10^6, is ***[2008]***
(a) 198 Ω (b) 300 Ω
(c) 100 Ω (d) 400 Ω

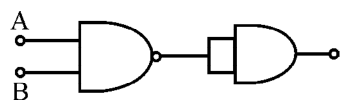
34. Mobilities of electrons and holes in a sample of intrinsic Ge at room temperature are $0.35 m^2/V–s$ and $0.18 m^2/V–s$ respectively. If the electron and hole densities are each equal to $2.5 \times 10^{19}/m^3$, the Ge conductivity will be ***[2010]***
(a) 3.12 S/m (b) 2.12 S/m
(c) 1.12 S/m (d) 4.12 S/m

35. An LED (Light Emitting Diode) is constructed from a *p–n* junction based on a certain Ga–As–P semi–conducting material whose energy gap is 1.9 eV. What is the wavelength of the emitted light? ***[2010]***
(a) 650 nm (b) 65Å
(c) 800 nm (d) 8000 Å

36. In n-p-n transistor circuit the collector current is 10 mA. If 90% of the electron reach the collector, then emitter current will be ***[2010]***
(a) 1 mA (b) 0.1 mA
(c) 2 mA (d) nearly 11 mA

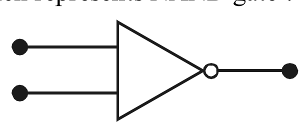
37. The cause of the potential barrier in a p-n junction diode is ***[2011]***
(a) depletion of positive charges near the junction
(b) concentration of positive charges near the junction
(c) depletion of negative charges near the junction
(d) concentration of positive and negative charges near the junction

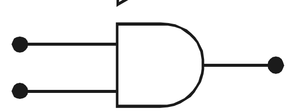
38. Identify the logic operation of the following logic circuit : ***[2011]***

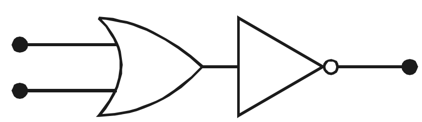


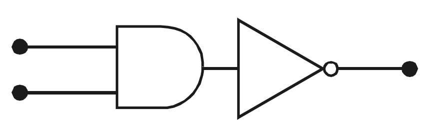
(a) NAND (b) AND
(c) NOR (d) OR

39. Which represents NAND gate ? ***[2012]***

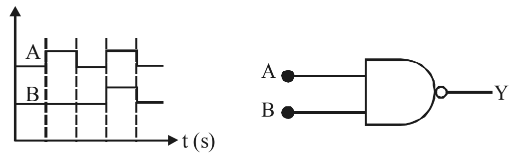
(a) 

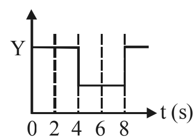
(b) 

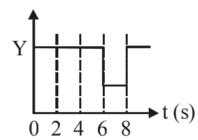
(c) 

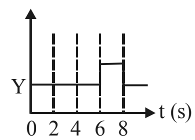
(d) 

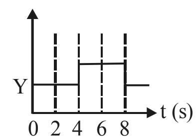
40. The real time variation of input signals A and B are as shown below. If the inputs are fed into NAND gate, then select the output signal from the following. *[2012]*



(a) 

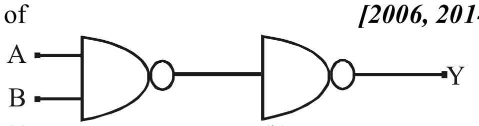
(b) 

(c) 

(d) 

41. An oscillator is nothing but an amplifier with
(a) positive feedback *[2013, 2014]*
(b) large gain
(c) no feedback
(d) negative feedback

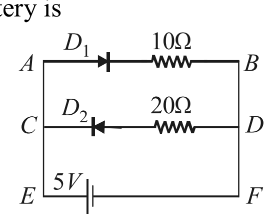
42. Following diagram performs the logic function of *[2006, 2014]*



(a) XOR gate (b) AND gate
(c) NAND gate (d) OR gate

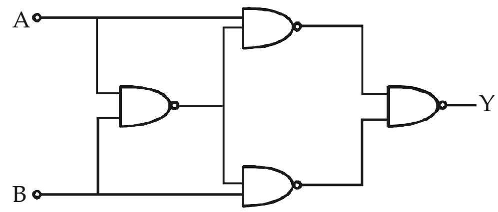
43. Carbon, Silicon and Germanium atoms have four valence electrons each. Their valence and conduction bands are separated by energy band gaps represented by $(E_g)_C$, $(E_g)_{Si}$ and $(E_g)_{Ge}$ respectively. Which one of the following relationship is true in their case? *[2015]*
(a) $(E_g)_C > (E_g)_{Si}$ (b) $(E_g)_C < (E_g)_{Si}$
(c) $(E_g)_C = (E_g)_{Si}$ (d) $(E_g)_C < (E_g)_{Ge}$

44. Two ideal diodes are connected to a battery as shown in the circuit. The current supplied by the battery is *[2017]*



(a) 0.75 A (b) 0.5 A
(c) 0.25 A (d) zero

45. Truth table for system of four NAND gates as shown in figure is *[2017]*



(a)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(b)

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

(c)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(d)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 46-52) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

46. **Assertion :** The resistivity of a semi-conductor increases with temperature.
Reason : The atoms of semi-conductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity. *[2003]*

47. **Assertion :** In a transition the base is made thin.
Reason : A thin base makes the transistor stable. *[2004]*

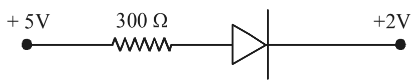
48. **Assertion :** The logic gate NOT can be built using diode.
Reason : The output voltage and the input voltage of the diode have 180° phase difference. *[2005]*

49. **Assertion :** The number of electrons in a p-type silicon semiconductor is less than the number of electrons in a pure silicon semiconductor at room temperature.
Reason : It is due to law of mass action. ***[2005]***

50. **Assertion :** In a common emitter transmitter amplifier the input current is much less than the out put current.
Reason : The common emitter transistor amplifier has very high input impedance. ***[2005]***

51. **Assertion :** In common base configuration. the current gain of the transistor is less than unity..
Reason : The collector terminal is reverse biased for amplification. ***[2006]***

52. **Assertion :** The value of current through p-n junction in the given figure will be 10 mA.



Reason : In the above figure, p-side is at higher potential than n-side. ***[2008]***

Directions for (Qs. 53-57) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

53. **Assertion :** NAND or NOR gates are called digital building blocks.
Reason : The repeated use of NAND (or NOR) gates can produce all the basis or complicated gates. ***[2011]***

54. **Assertion :** A p-n junction with reverse bias can be used as a photo-diode to measure light intensity.
Reason: In a reverse bias condition the current is small but is more sensitive to changes in incident light intensity. ***[2012]***

55. **Assertion :** If the temperature of a semiconductor is increased then it's resistance decreases.
Reason : The energy gap between conduction band and valence band is very small. ***[2015]***

56. **Assertion :** A transistor amplifier in common emitter configuration has a low input impedence.
Reason : The base to emitter region is forward biased. ***[2016]***

57. **Assertion :** Diode lasers are used as optical sources in optical communication.
Reason : Diode lasers consume less energy. ***[2017]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. **(b)** In p-type semiconductor, holes predominates, so, holes are major current carriers.

2. **(d)** Dynamic plate resistance $= \dfrac{\Delta V}{\Delta I}$

In case of saturation current, $\Delta I = 0$
Plate resistance $= \infty$

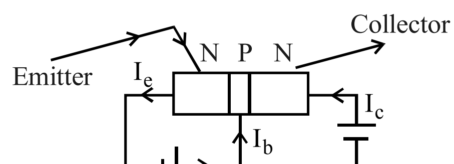
3. **(a)** In case of diode (formed by *p-n* junction) it acts as rectifier. It means it conducts only in case of forward biasing & not in reverse biasing.

4. **(a)** $\beta = \dfrac{I_c}{I_b} \Rightarrow I_b = \dfrac{0.01}{1\times10^3} = 10^{-5}$

or $50 = \dfrac{I_c}{10^{-5}} \Rightarrow I_c = 50\times10^{-5}$
$= 500\times10^{-6}$

$I_c = 500\,\mu A$

5. **(a)**



The connection in case of n-p-n transistor is shown in the figure. Current is flowing from collector to base so electrons will flow in reverse direction i.e., from base to collector.

6. **(c)** Boolean algebra is based on logic.

7. **(b)** Amplification factor $= 20 = \dfrac{\text{Plate potential}}{\text{Grid potential}}$

$$20 = \frac{300}{V} \Rightarrow V = \frac{300}{20} = 15V$$

8. **(b)** In diode, current can flow only in one direction. In reverse bias it does not work. So, it is used as rectifier.

9. **(a)** In n-type semiconductor we add pentavalent impurities so there is excess of electrons inside the material. So, majority charge carriers are electrons.

10. **(b)**

Frequency = 1 Unrectified wave — Frequency = 2 Rectified wave

In case of full wave rectification, frequency becomes twice.

So, new frequency $= 50 \times 2 = 100\text{Hz}$

11. **(b)** Given table represents 'OR' gate.

12. **(b)** Mutual conductance

$$= \frac{\Delta I_p}{\Delta V_g} = \frac{5 \times 10^{-3}}{2} = 2.5 \times 10^{-3}\,\text{mho}$$

13. **(c)** n-type semiconductors have free electrons in majority p-type semiconductors have holes in majority.

14. **(d)** Phosphorus which is pentavalent produces n-type semiconductor. Here only four electrons of phosphorus are used in making bonds with silicon crystal. The fifth electron remains free.

15. **(d)** At 0 K an electron hole pair is formed as all the electrons remain in the valence band. So we can say that there is no charge carrier at this temperature.

16. **(d)** $\alpha = \dfrac{I_c}{I_e}$ and $\beta = \dfrac{I_c}{I_b}$

[I_c, I_b and I_e are collector, base and emitter current]

$$I_e = I_c + I_b \Rightarrow \frac{I_e}{I_c} = 1 + \frac{I_b}{I_c}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta} \Rightarrow \beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98}$$

$$= \frac{0.98}{0.02} = 49$$

17. **(b)** Gallium is a trivalent atom so, the resultant sample will behave as p-type semi-conductor.

18. **(c)** $\beta = \dfrac{I_c}{I_b}$

Here, $I_c = \dfrac{V}{10 \times 10^3} = \dfrac{V}{10^4}$

$I_b = \dfrac{1 \times 10^{-3}}{10 \times 10^3} = 10^{-6}$; $\beta = 100$

Now, $100 = \dfrac{I_c}{I_b} = \dfrac{V}{10^4} \times 10^{-6}$

$V = 100 \times 10^4 \times 10^{-6} = 1$ volt.

19. **(a)** $n_e n_h = n_i^2$

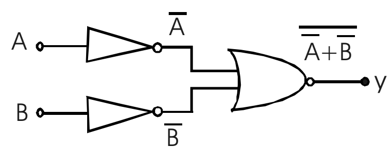
n_e is concentration of electron, n_h is concentration of holes and n_i is concentration of electron hole pairs in intrinsic semi-conductor.

Here $n_h = 10^{21}$, $n_e = ?$, $n_i = 10^{19}$

$10^{21} \times n_e = 10^{19} \times 10^{19}$

$$n_e = \frac{10^{38}}{10^{21}} = 10^{17}\,\text{m}^{-3}$$

20. **(c)** This is a case of AND gate. Input & output are shown below



$\therefore \quad y = \overline{\overline{A} + \overline{B}} = \overline{\overline{A}}\,.\,\overline{\overline{B}} = AB$ (since $\overline{A + B} = \overline{A}.\overline{B}$)

21. **(b)** Voltage gain $= \dfrac{\text{output voltage }(V_o)}{\text{input voltage}(V_i)}$

From Ohm's law $V = iR$

$\therefore$ Voltage gain, $A_v = \dfrac{R}{R_i} = \dfrac{100\text{k}\Omega}{1\text{k}\Omega} = 100$

22. **(d)** NAND gate is considered universal gate. As other gates can be formed from this gate.

23. **(b)** $100 = \dfrac{\Delta I_c}{\Delta I_b} \Rightarrow \Delta I_b = \dfrac{1}{100}\text{mA} = 0.01\text{mA}$

$\Delta I_e = \Delta I_c + \Delta I_b = 1 + 0.01 = 1.01\text{mA}$

24. **(a)** Mobility of electron is more than that of holes.

25. **(b)** When p-n junction is reverse biased, the depletion region is increased i.e., the potential barrier increased.

26. **(a)** Voltage gain = log 1000 Bel
$\log 10^3 = 3\text{Bel} = 30\text{ dB}$ [1 Bel = 10 dB]

27. **(a)** In case of complex audio signals, bandwidths (B.W) = 2 × maximum frequency of modulating signal = 2 × 5 kHz = 10 kHz. This is B.W for one channel.

$$\therefore \text{No. of stations} = \frac{\text{Total B.W}}{\text{B.W for each channel}}$$

$$= \frac{150\text{ kHz}}{10\text{ kHz}} = 15$$

28. **(b)** Zener diode is used to supply constant voltage in voltage regulator circuit hence option (b) is correct.

29. **(b)** In half wave rectifier, negative half of an a.c. cycle is removed from the sinusoidal pulse, but the time lag between two positive pulses is same, hence frequency remains same as the input (mains) frequency i.e., 50 Hz.

30. **(c)** As transistor is made of two p-types with n-type semiconductor in between or two n-types with p-type in between.

31. **(b)** $I_c = 120\text{ mA}, I_b = 2\text{mA} \Rightarrow I_e = I_b + I_c$ (emitter current)

$\Rightarrow I_e = 120 + 2 = 122\text{ mA}$

Resistance gain = 3

d.c power gain

= (current gain)^2 × resistance gain

$$= \left(\frac{I_c}{I_b}\right)^2 \times \text{resistance gain}$$

$$= \left(\frac{120}{2}\right)^2 \times 3$$

$= (60)^2 \times 3 = 3600 \times 3 = 10800$

32. **(a)** The current will flow through R_L when the diode is forward biased.

33. **(a)** $R_0 = 500\text{ k}\Omega; \alpha = 0.98$

Power gain = 6.0625×10^6

we have, voltage gain $A_V = \beta.\dfrac{R_0}{R_i}$

But current gain,

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = 49$$

$$\therefore A_V = 49 \times \frac{500\times10^3}{R_i} = \frac{24.5\times10^6}{R_i}$$

Given $6.0625 \times 10^6 = A_V \times \beta$

$$= \left(\frac{24.5\times10^6}{R_i}\right) \times 49$$

or $$R_i = \frac{24.5\times49}{6.0625} = 198\,\Omega$$

34. **(b)** Conductivity of Ge

$\sigma = e(n_e\mu_e + nh\,\mu_h)$

Here $n_e = n_h = 2.5 \times 10^{19}\text{ /m}^3$

$e = 1.6 \times 10^{-19}\text{C}$,

$\mu_e = 0.35\text{m}^2\text{/V–s}$, $\mu_h = 0.18\text{m}^2\text{/V–s}$

$\therefore \sigma = 1.6 \times 10^{-19}$

$(2.5\times10^{19}\times0.35 + 2.5\times10^{19}\times0.18)$

$= 1.6\times10^{-19}\times2.5\times10^{19}\times0.53$

$= 2.12\text{ S/m}$

35. **(a)** The wavelength of emitted light

$$\lambda = \frac{hc}{E_g}$$

where E_g = energy gap of semiconductor

$= 1.9\text{eV}$

$= 1.9\times1.6\times10^{-19}\text{V}$

$$\lambda = \frac{6.6\times10^{-34}\times3\times10^8}{1.9\times1.6\times10^{-19}}m$$

$= 6.5\times10^{-7}\text{ m}$

$= 650\times10^{-9}\text{ m}$

$= 650\text{ nm}$

36. **(d)** $I_c = 10\text{ mA}; I_e = I_c + I_b$

If $I_c = 90\%$ of I_e,

then $I_c = \dfrac{90}{100} \times I_e$

$\Rightarrow I_e = \dfrac{100}{90} I_c$

37. **(d)** During the formation of a junction diode, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electrons meets a hole, they cancel the effect at each other and as a result, a thin layer at the junction becomes free from any of charges carriers. This is called depletion layer. There is a potential gradient in the depletion layer, negative on the p-side, and positive on the n-side. The potential difference thus developed across the junction is called potential barrier.

38. **(b)** NAND + NAND
$\Rightarrow$ AND

39. **(d)** NAND is combination of AND gate and NOT gate.

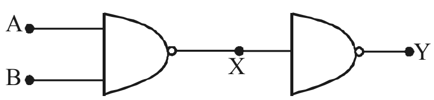
40. **(b)** From input signals, we have,

A	B	Output NAND gate
0	0	1
1	0	1
0	0	1
1	1	0
0	0	1

The output signal is shown at B.

41. **(a)**

42. **(b)**



$X = \overline{AB}$

$\therefore Y = \overline{X} = \overline{\overline{AB}}$

Y = AB by Demorgan theorem

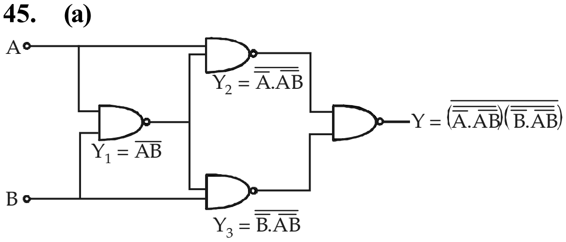
$\therefore$ This diagram performs the function of AND gate.

43. **(a)** Due to strong electronegativity of carbon.

44. **(b)** Here D_1 is in forward bias and D_2 is in reverse bias so, D_1 will conduct and D_2 will not conduct. Thus, no current will flow through *DC*.

$$I = \frac{V}{R} = \frac{5}{10} = \frac{1}{2}\text{A}$$

45. **(a)**



By expanding this Boolen expression

$$Y = A.\overline{B} + B.\overline{A}$$

Type B : Assertion Reason Questions

46. **(d)** The resistivity of semiconductor decreases with increase in temperature as more electrons jump into conduction band increasing its conductivity.

47. **(c)** In a transistor the base is made thin so that base current remains small and we can get output or collector current. We know that

$$I_c = I_e - I_b$$

Reason is incorrect.

48. **(d)** The diode is unidirectional it allows current to pass through it in a particular direction. It does not change the phase of input signal.

49. **(a)** We know that $n_e n_h = n_i^2$

This formula is based on law of mass action.

In p-type semiconductor $n_h > n_i$

So, $n_e < n_i$

50. **(c)** In an amplifier output current is always more than input current. Amplifier has low input impedance.

51. **(b)** For common base, Input is I_c and output is I_e.

Current gain $= \frac{I_c}{I_e} = \frac{I_c}{I_c + I_b}$ which is less than unity.

Collector terminal is reversed baised to increase the collector current. Both Assertion and Reason are correct but they are uncorrelated statements.

52. **(b)** The p-side of the junction diode is at a higher potential than the n-side. So p-n junction is forward biased. Hence a current flows through it and is given by

$$I = \frac{V}{R} = \frac{5-2}{300} = 10^{-2}\,\text{A} = 10\,\text{mA}$$

53. **(a)** These gates are called digital building blocks because using these gates only (either NAND or NOR) we can compile all other gates also (like OR, AND, NOT, XOR).

54. **(a)**

55. **(a)** In semiconductors the energy gap between conduction band and valence band is small ($\approx$1 eV). Due to temperature rise, electron in the valence band gain thermal energy and may jumpy across the small energy gap, (to the conduction band). Thus conductivity increases and hence resistance decreases.

56. **(a)** Input impedance of common emitter configuration.

$$= \left|\frac{\Delta V_{BE}}{\Delta i_B}\right|_{V_{CE} = \text{constant}}$$

where ΔV_{BE} = voltage across base and emitter (base emitter region is forward biased)

Δi_B = base current which is order of few microampere.

57. **(c)**

Chapter 29 Communication Systems

TYPE A : MULTIPLE CHOICE QUESTIONS

1. In communication with help of antenna if height is double then the range covered which was initially r would become ***[2007]***

(a) $\sqrt{2}r$ (b) 3r
(c) 4r (d) 5r

2. Communication on ground is through electromagnetic waves of wavelength ***[2010]***

(a) larger than 600 m
(b) between 200 and 600 m
(c) between 1 and 5 m
(d) between 10^{-3} and 0.1

3. 12 signals each band limited to 5 kHz are to be transmitted by frequency-division multiplexer. If AM-SSB modulation guard band of 1 kHz is used then the bandwidth of multiplexed signal is ***[2012]***

(a) 101 kHz (b) 99 kHz
(c) 84 kHz (d) 71 kHz

4. For 100% modulation (AM), the useful part of the total power radiated is ***[2013]***

(a) $\frac{1}{2}$ of the total power
(b) $\frac{1}{3}$ of the total power
(c) $\frac{1}{4}$ of the total power
(d) $\frac{2}{3}$ of the total power

5. Sky wave propagation is not possible for frequencies ***[2014]***

(a) equal to 30 MHz
(b) less than 30 MHz
(c) greater than 30 MHz
(d) None of these

6. For 100% modulation (AM), the useful part of the total power radiated is ***[2015]***

(a) $\frac{1}{2}$ of the total power
(b) $\frac{1}{3}$ of the total power
(c) $\frac{1}{4}$ of the total power
(d) $\frac{2}{3}$ of the total power

7. For transmission of e.m.wave of audible frequency, these waves are superimposed with waves of ***[2017]***

(a) frequency less than 20 Hz
(b) frequency between 20 Hz and 10 KHz
(c) frequency in the audible range
(d) radio-frequency

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 8) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

8. **Assertion :** Optical fibres are used for telecommunication.
Reason : Optical fibres are based on the phenomenon of total internal reflection. ***[2007]***

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (a) Range of antenna = $r\sqrt{2hr}$, h = height of antenna,
R = radius of earth
if h is doubled i.e., h' = 2h, then new range
$r' = \sqrt{2h'r}$
$\Rightarrow r' = \sqrt{2.2hr} = \sqrt{2}\sqrt{2hr} = \sqrt{2}\, r$

2. (d) The required wavelength should be from 10^{-3}m to 0.1m.

$$\Rightarrow I_e = \frac{100}{90} \times 10\,\text{mA} \simeq 11.1\,\text{mA}$$

3. (d) Total signal B.W = 12 × 5 = 60 kHz
11 guard band are required between 12 signal
∴ guard bandwidth = 11 × 1 kHz = 11 kHz
∴ total bandwidth = 60 + 11 = 71 kHz

4. (b) 100% modulation $\Rightarrow m_a = 1$

$$\frac{\text{useful power}}{\text{total power radiated}} = \frac{m_a^{\,2}}{2 + m_a^{\,2}}$$

$$= \frac{1}{2+1} = \frac{1}{3}$$

$\Rightarrow$ Useful power

$$= \frac{1}{3}(\text{total power radiated})$$

5. (c) Sky wave propagation is not possible for frequency > 30 MHz because they are not reflected by ionosphere.

6. (b) 100% modulation $\Rightarrow m_a = 1$

$$\frac{\text{useful power}}{\text{total power radiated}} = \frac{m_a^{\,2}}{2 + m_a^{\,2}}$$

$$= \frac{1}{2+1} = \frac{1}{3}$$

$\Rightarrow$ Useful power

$$= \frac{1}{3}(\text{total power radiated})$$

7. (d) Since radio frequency waves can travel long distances because these waves are of wave length of the order of 100 m and their energy content is quite large therefore e.m.wave of audible frequency are superimposed with radio frequency waves.

Type B : Assertion Reason Questions

8. (a) Both parts are true but optical fibres are used for telecommunication because they produce the same signal with the same intensity at the other end of the optical fibre even if fibre is several kilometre long i.e., total internal reflection. They have other advantages like being light weight, flexible, etc.