1.1 SCOPE OF PHYSICS

1.1.1 Describe the importance of physics in science, technology and society.(COGNITIVE LEVEL:U)

IMPORTANCE OF PHYSICS IN SCIENCE:

1. Physics in relation to chemistry

The study of structure of atoms, radioactivity, X-ray, diffraction, etc., in physics has enabled chemists to rearrange elements in the periodic table and to have a better understanding of chemical bonding and complex chemical structures.

2. Physics in relation to Biological science

The optical microscopes developed in physics are extensively used in the study of biological samples. Electron microscope X-rays and radio isotopes are used widely in medical sciences.

3. Physics in relation to astronomy

The giant astronomical telescopes and radio telescopes have enabled the astronomers to observe planets and other heavenly objects.

4. Physics related to other sciences

The other sciences like Biophysics, Geology, Meteorology and Oceanography and Seismology use some of the laws of physics.

IMPORTANCE OF PHYSICS IN SOCIETY AND TECHNOLOGY

The development of telephone, telegraph and telex enables us to transmit messages instantly. The development of radio and television satellites has revolutionized the means of communication. Advances in electronics (computers, calculators and lasers) have greatly enriched the society. Rapid means of transport are important for the society. Generation of power from nuclear reactors is based on the phenomenon of controlled nuclear chain reaction. Digital electronics is widely used in modern technological developments.

1.2 S.I. UNITS

1.2.1 Describe S.I base units, derived units and supplementary units for various measurements. .(COGNITIVE LEVEL:U)

BASE UNITS:

There are seven base units for various physical quantities namely: length, mass, time, temperature, electric current, luminous intensity and amount of a substance (with special reference to the number of particles).

The names of base units for these physical quantities together with symbols are given below.

FUNDAMENTAL UNITS		
Quantity	Unit	Symbol
1. Length	meter	m
2. Mass	kilogram	kg
3. Time	second	s
4. Electric Current	ampere	A
5. Temperature	kelvin	K
6. Luminious Intensity	candela	Cd
7. Amount of Substance	mole	mol

DERIVED UNITS:

The units that require two or more basic measurements of same units or different fundamental units for its definition are called derived units.SI units for measuring all other physical quantities are derived from the base and supplementary units. Some of the derived units are given below.

DERIVED UNITS		
Quantity	Unit	Symbol
1. Area	square meter	m^2
2. Volume	cubic meter	m^3
3. Density	kilogram/ cubic meter	kg/m^3
4. Velocity	meter/second	m/s
5. Angular Velocity	radian/ second	r/s
6. Acceleration	meter/second square	m/s^2
7. Angular Accleration	radian/second square	rad/s^2
8. Frequency	hertz	Hz
9. Force	newton	N
10. Work energy	joule	J

SUPPLEMENTARY UNITS:

The general conference on weights and measures has not yet classified certain units of the SI under either base units or derived units. These SI units are called supplementary units. For the time being this class contains only two units of purely geometrical quantities, which are plane angle and the solid angle.

Quantity	unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

1.2.2 Show the derived units as products or quotients of the base units. .(COGNITIVE LEVEL:U)

Derived	Quantities Equation	Derived Units
Area (A)	$A = L^2$	m^2
Volume (V)	$V = L^3$	m^3
Density (ρ)	$\rho = m / V$	$kg\ m^{-3}$
Velocity (v)	$v = L / t$	ms^{-1}
Acceleration (a)	$a = \Delta v / t$	$ms^{-1} / s = ms^{-2}$
Momentum (p)	$p = m \times v$	$(kg)(m^{s-1}) = kg\ m\ s^{-1}$

Derived Quantities	Equation	Derived Unit		Derived Units
		Special Name	Symbol	
Force (F)	$F = \Delta p / t$	Newton	N	$[(kg\ m\ s^{-1}) / s = kg\ m\ s^{-2}$
Pressure (p)	$p = F / A$	Pascal	Pa	$(kg\ m\ s^{-2}) / m^2 = kg\ m^{-1}\ s^{-2}$
Energy (E)	$E = F \times d$	joule	J	$(kg\ m\ s^{-2})(m) = kg\ m^2\ s^{-2}$
Power (P)	$P = E / t$	watt	W	$(kg\ m^2\ s^{-2}) / s = kg\ m^2\ s^{-3}$
Frequency (f)	$f = 1 / t$	hertz	Hz	$1 / s = s^{-1}$
Charge (Q)	$Q = I \times t$	coulomb	C	A s
Potential Difference (V)	$V = E / Q$	volt	V	$(kg\ m^2\ s^{-2}) / A\ s = kg\ m^2\ s^{-3}\ A^{-1}$
Resistance (R)	$R = V / I$	ohm	Ω	$(kg\ m^2\ s^{-3}\ A^{-1}) / A = kg\ m^2\ s^{-3}\ A^{-2}$

1.3 ERRORS AND UNCERTAINTY

1.3.1 Differentiate between systematic and random errors. (COGNITIVE LEVEL:U)

SYSTEMATIC ERROR:

Systematic error (also called systematic bias) is consistent, repeatable error associated with faulty equipment or a flawed experiment design. These errors are usually caused by measuring instruments that are incorrectly calibrated or are used incorrectly. However, they can creep into your experiment from many sources, including:

1. A worn out instrument. For example, a plastic tape measure becomes slightly stretched over the years, resulting in measurements that are slightly too high.

2. An incorrectly calibrated or tared instrument, like a scale that doesn't read zero when nothing is on it.

3. A person consistently takes an incorrect measurement. For example, they might think the 3/4" mark on a ruler is the 2/3" mark.

Systematic Errors produce consistent errors, either a fixed amount (like 1 lb) or a proportion (like 105% of the true value). If you repeat the experiment, you'll get the same error.

RANDOM ERROR:

Random error (also called unsystematic error, system noise or random variation) has no pattern. One minute your readings might be too small. The next they might be too large. You can't predict random error and these errors are usually unavoidable.

Random errors are (like the name suggests) completely random. They are unpredictable and can't be replicated by repeating the experiment again.

1.3.2 Measure the uncertainty in the derived quantity. (COGNITIVE LEVEL:A)

1. ADDITION AND SUBTRACTION:

When performing additions and subtractions we simply need to add together the absolute uncertainties.

Example:

Add the values 1.2 ± 0.1, 12.01 ± 0.01, 7.21 ± 0.01

1.2 + 12.01 + 7.21 = 20.42
0.1 + 0.01 + 0.01 = 0.12
20.42 ± 0.12

2. MULTIPLICATION, DIVISION AND POWERS:

When performing multiplications and divisions, or, dealing with powers, we simply add together the percentage uncertainties.

Example:

Multiply the values 1.2 ± 0.1, 12.01 ± 0.01

1.2 x 12.01 = 14
0.1 / 1.2 x 100 = 8.33 %
0.01 / 12.01 X 100 = 0.083%
8.33 + 0.083 = 8.413 %

14 ± 8.413 %

3. OTHER FUNCTIONS:

For other functions, such as trigonometric ones, we calculate the mean, highest and lowest value to determine the uncertainty range. To do this, we calculate a result using the given values as normal, with added error margin and subtracted error margin. We then check the difference between the best value and the ones with added and subtracted error margin and use the largest difference as the error margin in the result.

Example:

Calculate the area of a field if it's length is 12 ± 1 m and width is 7 ± 0.2 m.

Best value for area:
$12 \times 7 = 84\ m^2$

Highest value for area:
$13 \times 7.2 = 93.6\ m^2$

Lowest value for area:
$11 \times 6.8 = 74.8\ m^2$

If we round the values we get an area of:
$84 \pm 10\ m^2$

1.4 PRECISION AND ACCURACY

1.4.1 State differences between precision and accuracy. (COGNITIVE LEVEL:K)

S.No	Accuracy	Precision
1	Accuracy is a measure of rightness	Precision is a measure of exactness
2	Accurate means "capable of providing a correct reading or measurement."	Precise means "repeatable, reliable, getting the same measurement each time."
3	A measurement is accurate if it correctly reflects the size of the thing being measured	Precision refers to how closely individual measurements agree with each other.
4	If your scale gives you values of 49.8, 50.5, 51.0, 49.6, it is more accurate than the first balance, but not as precise.	If you take the measurements of the mass of a 50.0-gram standard sample and get values of 47.5, 47.6, 47.5, and 47.7 grams, your scale is precise, but not very accurate.
5	It depends on the measurement not the device used for measurement.	It depends on the measuring instrument.

1.5 SIGNIFICANT FIGURES

1.5.1 Calculate answers with correct scientific notations, number of significant figures in all numerical. (COGNITIVE LEVEL:A)

SIGNIFICANT FIGURES:

"All the accurately known digits in a value and the first doubtful digit are known as significant figures." In the measurement of any physical quantity the number of digits about which we are sure are called significant figures All physical measurements involve some degree of inaccuracy due to human error. instrumental error or due to both and therefore the knowledge of precision of a

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measurement is very important. A significant figure is that which is known to be reasonably reliable. The last figure being reasonably correct guarantees the certainty of the preceding figures.

RULES FOR COUNTING SIGNIFICANT FIGURES:

(i) In whole number values. all the digits except zeros at the right side m recognized as significant figures.

(ii) In decimal number values the zeros at the right side of the number are counted as significant figures but the zeros at the left side are not taken as significant figures.

(iii) Power or exponents to a certain base are not taken as significant figures.

(iv) In addition and subtraction process, the result should be rounded off to contain as many as decimal places as contained in the value of least number of decimal place.

(v) In multiplication and division process. the result should be rounded off to contain as many as significant figures as contained in the factor of least significant figures.

FOR EXAMPLE:

S.NO	Value	No. of significant figures
1	0.00045	2(4,5)
2	1.2000	5(1,2,0,0,0)
3	505	3(5,0,5)
4	34000	2(3,4)
5	6.67×10^{32}	3(6,6,7)

Converting to Scientific Notation:

The following rule can be used to convert numbers into scientific notation: **The exponent in scientific notation is equal to the number of times the decimal point must be moved to produce a number between 1 and 10.** In 1990 the population of Chicago was 6,070,000 . To convert this number to scientific notation we move the decimal point to the left six times.

$$6{,}070{,}000 = 6.070 \times 10^{6}$$

To translate 10,300,000,000,000,000,000,000 carbon atoms into scientific notation, we move the decimal point to the left 22 times.

$$10{,}300{,}000{,}000{,}000{,}000{,}000{,}000 = 1.03 \times 10^{22}$$

To convert numbers smaller than 1 into scientific notation, we have to move the decimal point to the right. The decimal point in 0.000985, for example, must be moved to the right four times.

$$0.000985 = 9.85 \times 10^{-4}$$

Converting 0.000,000,000,000,000,000,000,020 grams per carbon atom into scientific notation involves moving the decimal point to the right 23 times.

$$0.000,000,000,000,000,000,000,020 = 2.0 \times 10^{-23}$$

The primary reason for converting numbers into scientific notation is to make calculations with unusually large or small numbers less cumbersome. Because zeros are no longer used to set the decimal point, all of the digits in a number in scientific notation are significant, as shown by the following examples.

2.4×10^{22}	2 significant figures
9.80×10^{-4}	3 significant figures
1.055×10^{-22}	4 significant figures

1.5.2 Show that the least count (L.C) of an instrument is the smallest increment measurable by it. (COGNITIVE LEVEL:U)

Least Count tells you the minimum reading or value that can be measured with a measuring tool or device.

Generally, simply multiplying Least Count with the number of divisions (like in ruler) or fraction of divisions (like in Vernier Calipers), we get our answer in the units specified. For Example, 21 divisions in a Ruler would mean 2.1 cm or 21 mm. Least count of a ruler is 0.1 cm or 1 mm (we'll understand how to find it, later in this article).

HOW TO FIND LEAST COUNT:

I've seen many people confused about how to find Least Count. The method used by them might be slightly different, tough to remember, so even if they understand it once, the next time they try to do the same, they forget about it, which is not good.

The way I like to make it understandable is related to the definition of Least Count itself. Remember, Least Count gives you the minimum value that can be measured by by the instrument/device/tool. So considering that, Least Count will be:

You can take any number of divisions for finding Least Count, but those have to be the smallest ones. Let us take "n" small divisions.

$$LC = \frac{\text{Value measured in "n" divisions}}{n}$$

So overall, Least Count is based on the concept of Unitary Method.

FOR EXAMPLE: THE RULER

So for a ruler, that is, the scale, we use in daily life, we can find the Least Count, by the definition formula only, which we did.

Let us take 20 divisions for it (the value of "n". We know that a ruler measures 20 mm or 2 cm, 20 divisions.

$$LC = \frac{\text{Value measured in 20 divisions}}{20}$$

$$= 2\text{ cm}/20 = 0.1\text{ cm}$$

Therefore Least Count of a Ruler comes out to be 0.1 cm or 1 mm. Remember, you could even take other values like { 1 cm / 10 }.

Now what is the importance of this value (0.1 cm)?

While calculating, we used 20 divisions. Now 10, 20, 30, 40, etc. are numbers that can be easily dealt with practically, rather than numbers like 13, 17, 27, etc.

What if we want to calculate the value measured by 23 divisions of a ruler. Here Least Count becomes handy. You can simply multiply 23 with 0.1 cm (the Least Count) & get the answer 2.3 cm.

Therefore, 2.3 cm is the value measured by 23 divisions of a Ruler.

1.6 DIMENSIONS

1.6.1 Measure the homogeneity of physical equations by using dimension and basic units. (COGNITIVE LEVEL:A)

DIMENSION:

Dimension is a philosophical word. In literature it means a line or direction. In mathematics it means an axis but in physics it is used to denote the nature of a physical quantity) which comes from the involvement of fundamental quantities in that particular quantity. So each of the fundamental quantities is called Dimension. Hence the dimensions of physics are mass (M), length (L) and time (T). These are the fundamental quantities on which physics is based upon.

EXAMPLES:

S.No	Physical Quantity	Formula	Dimension	S.I Unit
1	Area	Length x breadth	L^2	m^2
2	Volume	Length x breadth x height	L^3	m^3
3	Density	Mass / Volume	$M L^{-3}$	$Kg\ m^{-3}$

4	Speed or Velocity	Distance/ Time	LT^{-1}	$m\ s^{-1}$
5	Acceleration	Velocity/Time	LT^{-2}	$m\ s^{-2}$
6	Force	Mass x acceleration	MLT^{-2}	$kgm\ s^{-2}$= N
7	Pressure	Force/Area	$ML^{-1}T^{-2}$	$kg\ m^{-1}\ s^{-2}$=Pa
8	Momentum	Mass/ Velocity	MLT^{-1}	$kqms^{-1}$
9	Work	Force x Displacement	$ML^{2}T^{-2}$	$kg\ m^{-2}\ s^{-2}$=J
10	Energy	Work	$ML^{2}T^{-2}$	$kg\ m^{-2}\ s^{-2}$=J
11	Power	Work / Time	$ML^{2}T^{-3}$	$kg\ m^{-2}\ s^{-3}$=W
12	Gravitational Constant	Force x $Distance^{2}/Mass^{2}$	$M^{-1}L^{3}T^{-2}$	$kg^{-1}\ m^{-3}\ s^{-2}$
13	Torque or couple	Force x perpendicular distance	$ML^{2}T^{-2}$	N.m
14	Angular Momentum	mass x velocity x radius	$ML^{2}T^{-1}$	$kgm^{2}s^{-1}$
15	Angle	Arc length \ radius	dimension less	radian

Q. Prove that $v_f^2 - v_i^2 = 2as$ is dimensionally correct.

Ans. $v_f^2 - v_i^2 = 2as$, can be written as $v_f^2 = 2as + v_i^2$

L.H.S

$[v_f]=LT^{-1}$

R.H.S:

$[v_i]=LT^{-1}$

[2]= No dimension

[s]=L

$[a]= LT^{-2}$

$\Rightarrow [LT^{-1}]^2=[LT^{-2}][L] +[LT^{-1}]^2$

$L^2T^{-2} = L^2T^{-2} + L^2T^{-2}$

$L^2T^{-2} = 2\,L^2T^{-2}$

Since 2 has no dimension,therefore,

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

L.H.S=R.H.S, hence proved.

Q.Verify that modulus of elasticity and pressure have same dimesions.

Ans. A/c definition of modulus of elesticity

Modulus of elasticity =stress / strain

$= \frac{F}{A} / \frac{\Delta L}{L}$, putting the dimensions

$= \frac{MLT^{-2}}{L^2} / \frac{L}{L}$

$= \frac{MT^{-2}}{L}$

$= ML^{-1}T^{-2}$ -----(i)

A/c definition of pressure

Pressure =Force / Area, putting the dimensions

$= \frac{MLT^{-2}}{L^2}$

$= ML^{-1}T^{-2}$ ------(ii)

eq(i) and eq(ii) verify that pressure and modulus of elasticity have same dimension.

Q. Find the dimensions of G. If $F = G\frac{m_1 m_2}{r^2}$

Ans. Rearranging the formula we get,

$$G = F\frac{r^2}{m_1 m_2}$$

putting the dimensions

$= \frac{MLT^{-2}L^2}{M^2}$

$= M^{-1}L^3T^{-2}$, is the dimension of G.

1.6.2 Derive formula for physical quantities by using dimensions. (COGNITIVE LEVEL:U)

There is one more benefit of learning to dimensional analysis techniques. They can often help us to quickly re-derive an important formula.

Example: You we taking a test on circular motion, when we come upon a problem involving the "centripetal force" acting on a body. In order to find the formula for centripetal force let us solve by dimensional analysis. Mass has dimension [M], speed has dimension [L/T], and radius has dimension [L]. All you have to do is to figure out a way to put the variables m, v, and r together in a way that makes their combined dimension come out to be that of force.

The force is given by

$$F = M^a L^b T^c$$

$$MLT^{-2} = m^a v^b r^c$$

Where, a, b, and c are unknown integers. They are found by requiring the dimensions of both sides of the equation to match:

$$MLT^{-2} = [M]^a \left[\frac{L}{T}\right]^b [L]^c$$

- If we match mass units [M] on each side, we see that the integer a must equal 1.

- If we match time units [T] on each side, we see that the integer b must equal 2.

If we match length units [L] on each side, we see that the sum b + c must equal 1.

Since b = 2, c must equal –1. We have deduced that the only possible set of values for a, b, and c that will result in an expression with dimension of force are: (a, b, c) = (1, 2, –1). So, we have:

$$F_C = m^1 v^2 r^{-1}$$

or

$$\boxed{F_C = \frac{mv^2}{r}}$$

Thus, we have managed to reproduce the required formula from our incomplete memory, just by making sure that the variables combine together in a way to give units of force.

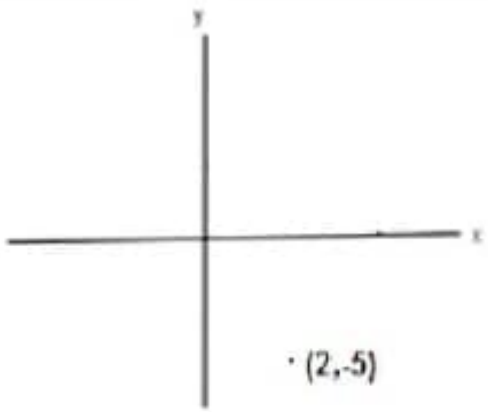
2.1 CARTESIAN COORDINATE SYSTEM

2.1.1 Describe the Cartesian coordinate system in two and three dimension systems. (COGNITIVE LEVEL:U)

Cartesian coordinates, also called rectangular coordinates, provide a method of rendering graphs and indicating the positions of points on a two-dimensional (2D) surface or in three-dimensional (3D) space.

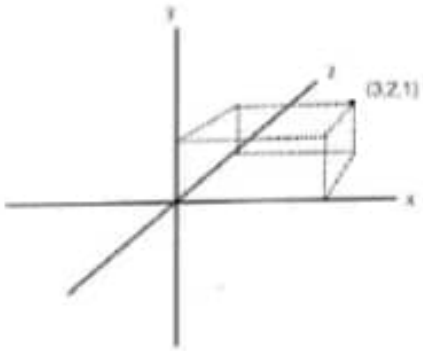
TWO DIMENSION SYSTEM:

The Cartesian plane consists of two perpendicular axes that cross at a central point called the origin. Positions or coordinates are determined according to the *east/west* and *north/south* displacements from the origin. The east/west axis is often called the *x* axis, and the north/south axis is called the *y*axis. For this reason, the Cartesian plane is also known as the *xy* -plane. The x and y axes are linear number lines, meaning that each division on a given axis always represents the same increment. However, the increments on different axes can differ. Points or coordinates are indicated by writing an opening parenthesis, the *x* value, a comma, the *y* value, and a closing parenthesis in that order. An example is (*x,y*) = (2,-5). The origin is usually, but not always, assigned the value (0,0).



THREE DIMENSION SYSTEM:

Cartesian three-space, also called *xyz* -space, has a third axis, oriented at right angles to the *xy* plane. This axis, usually called the *z* axis, passes through the origin of the *xy* -plane. Positions or coordinates are determined according to the east/west (*x*), north/south (*y*), and *up/down* (*z*) displacements from the origin. As is the case with the *x* and *y* axes, the *z* axis is a linear number line.Points or coordinates are indicated by writing an opening parenthesis, the *x* value, a comma, the *y* value, another comma, the *z* value, and a closing parenthesis in that order. An example is (*x,y,z*) = (3,2,1). The origin is usually, but not always, assigned the value (0,0,0).



2.2 ADDITION OF VECTORS BY HEAD TO TAIL RULE

2.2.1 Explain the sum of vectors using head to tail rule. (COGNITIVE LEVEL:U)

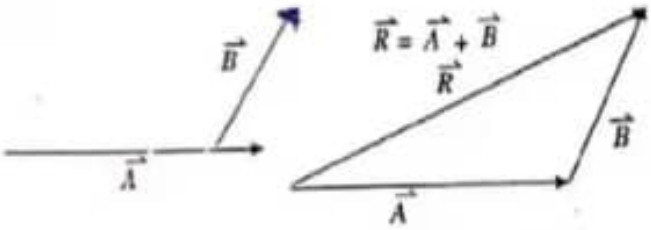
HEAD - TO - TAIL RULE:

Suppose we have two vector A and B having the different magnitude and direction.

1, First of all chose a suitable scale and representation of all the vector have been drawn on the paper.
2, Put all the vector for finding the resultant of given vector such that the head of the first vector join the tail of the second vector.
3, Now join the tail of the first vector with tail of the second vector such that it join the two vector with head to head and tail to tail by another.
4, The new vector R will be the resultant of the given vector.
5, It can be measured by the Dee or any suitable mean. This method is called the head and tail or tip to tail rule.

$$\boxed{\vec{R} = \vec{A} + \vec{B}}$$

This equation gives resultant vector and it is also known as "Triangle Law of Vector Addition".

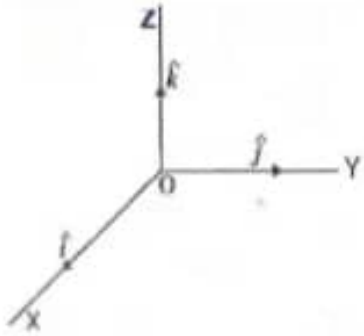


2.2.2 Define resultant, negative, unit, null, position and equal vectors. (COGNITIVE LEVEL:K)

RESULTANT VECTOR:

The process of combining of two or more vector to produce a signal vector having the combined effect of all the vector is called the resultant of the vector and this process is known as the addition of a vector

UNIT VECTOR:



A vector whose magnitude equals to "one" is called unit vector and it just represents direction of vector. In three dimensional space the unit vectors along x,y and z axis are i, j and k respectively.

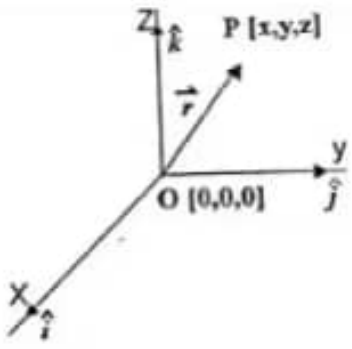
Mathematically a vector quantity $\vec{A}$ is defined through the equation.

$\vec{A} = |\vec{A}|\hat{a}$ or $\vec{A} = A\hat{a}$

Where $|\vec{A}|$represents magnitude or length of vector, $\hat{a}$ is the unit vector which represents direction

of vector $\vec{A}$ e.g. If Force on a body 8 N along x - axis, then $\vec{F} = 8\hat{i}\ N$

POSITION VECTOR



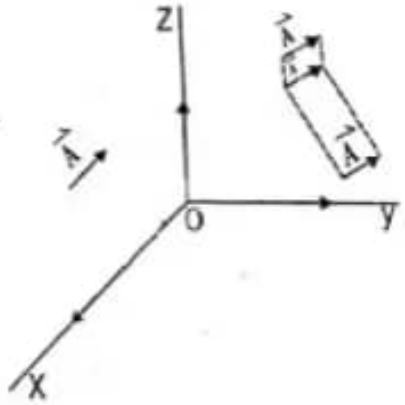
A vector which starts from origin or fixed point is called position vector. In three dimensional space it is usually written as $\vec{r}$ and in component form,

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

The magnitude of this position vector is represented by

$$r = \sqrt{x^2 + y^2 + z^2}$$

FREE VECTOR :



Such vector which can be displaced anywhere in space parallel to itself is called Free Vector. In this case magnitude and direction remain same. All vectors except positions are free vectors.

NULL VECTOR:

A vector whose magnitude equals to zero and has no direction and it may have any direction is called Null Vector. This vector always appears as resultant of addition of two equal but opposite vectors i.e.If A and B are equal in magnitudes and parallel but in opposite direction then

$$\vec{A} + \vec{B} = \vec{0}$$

Here $\vec{0}$ is null vector, and it may be written as

$$\vec{0} = 0\hat{i} + 0\hat{j} + 0\hat{k}$$

EQUAL VECTORS:

Two vectors are said to be equal vectors if and only if both have the same magnitude and as well as same direction.

2.2.3 Solve a vector into its rectangular components. (COGNITIVE LEVEL:A)

Vectors can be resolved in two or more components. Thus, splitting of a vector into components is termed as "Resolution of Vectors".

RECTANGULAR COMPONENTS:

If the components of a vector are perpendicular to each, other then these usually these components are called:

i) The Horizontal component on X-Component
ii) The Vertical component on Y- Component.
iii)

PROCEDURE OF RESOLUTION:

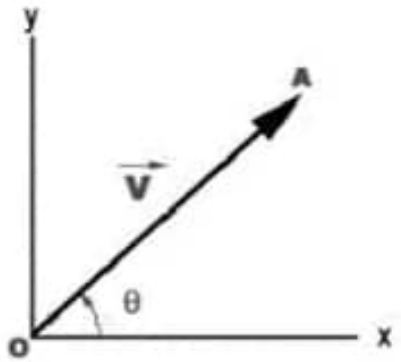


figure 01

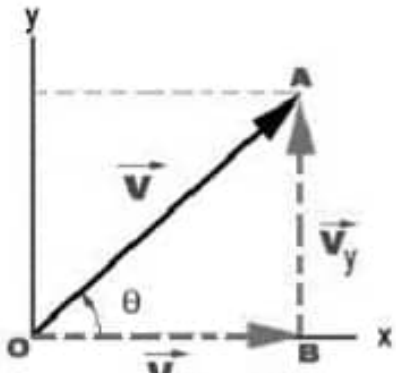


figure 02

Consider a vector $\vec{V}$ acting at a point making an angle **q** with positive X-axis. Vector $\vec{V}$ is represented by a line OA.From point A draw a perpendicular AB on X-axis.Suppose OB and BA represents two vectors.Vector OA is parallel to X-axis and vector BA is parallel to Y-axis.Magnitude of these vectors are V_x and V_y respectively.By the method of head to tail we notice that the sum of these vectors is equal to vector .Thus Vx and Vy are the rectangular components of vector .

Now,

$\vec{V_x}$ = Horizontal Component

$\vec{V_y}$ = Vertical Component

From figure, $\overrightarrow{OA} = \overrightarrow{OB} + \overrightarrow{AB}$

$$\vec{V} = \vec{V_x} + \vec{V_y}$$

$$\boxed{\vec{V} = \vec{V_x}\,\hat{i} + \vec{V_y}\hat{j}}$$

In ΔOAB

$$Cos\theta = \frac{\overrightarrow{OB}}{\overrightarrow{OA}} \quad \text{or} \quad Cos\theta = \frac{\vec{V_x}}{\vec{V}}$$

or $\boxed{V_x = VCos\theta}$ ----------(i)

and

$$Sin\theta = \frac{\overrightarrow{AB}}{\overline{OA}} \quad \text{or } Sin\theta = \frac{\overrightarrow{V_y}}{\vec{V}}$$

or $$\boxed{V_y = VSin\theta} \text{ ----------(ii)}$$

MAGNITUDE:

Squaring eq(i) and eq(ii) and then adding

$$V_x{}^2 + V_y^2 = V^2Cos^2\theta + V^2Sin^2\theta$$

or $$V_x{}^2 + V_y^2 = V^2(Cos^2\theta + Sin^2\theta)$$ Since $Cos^2\theta + Sin^2\theta = 1$

or $$V^2 = V_x{}^2 + V_y^2$$

or

$$\boxed{V = \sqrt{V_x{}^2 + V_y^2}}$$

DIRECTION:

Dividing Eq(i) by Eq(ii)

$$\frac{V_x}{V_y} = \frac{VSin\theta}{VCos\theta}$$

or $$\frac{V_x}{V_y} = Tan\theta$$

or $$\boxed{\theta = Tan^{-1}\frac{V_x}{V_y}}$$

2.3 ADDITION OF VECTORS BY RECTANGULAR COMPONENT METHOD

2.3.1 Determine the sum of vectors using perpendicular components. (COGNITIVE LEVEL:U)

Rectangular Components Method:

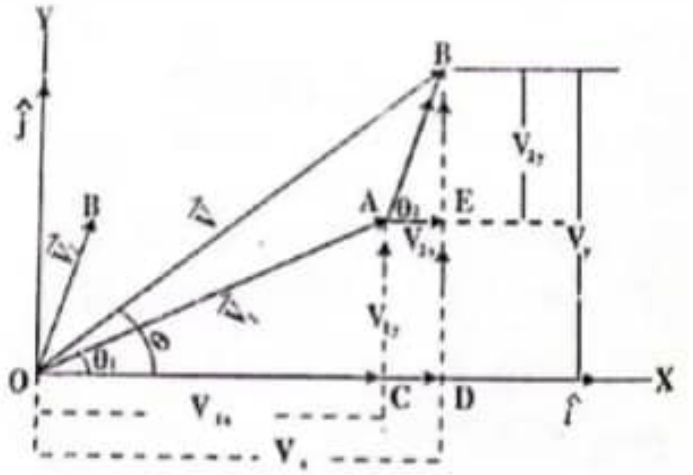
The way of adding vectors with the help of their rectangular components is called addition of vectors by rectangular components method.

Suppose two Position vectors $\vec{V_1}$, and $\vec{V_2}$ having lengths or magnitudes V_1 and V_2 and making angles θ_1 and θ_2 respectively are to be added. For this purpose we first adopt head-to-tail rule and then we draw perpendiculars form their heads on x and y axes to get their rectangular components as shown in fig

The rectangular components of V_1 are

$$V_{1x} = V_1 Cos\theta_1$$

$$V_{1y} = V_1 Sin\theta_1$$



The rectangular components of V_2 are

$$V_{2x} = V_2 Cos\theta_2$$

$$V_{2y} = V_2 Sin\theta_2$$

It is clear from the figure that

$$\overrightarrow{V_{1x}} = \overrightarrow{OC}$$

$$\overrightarrow{V_{2x}} = \overrightarrow{AE}$$

$$\overrightarrow{V_x} = \overrightarrow{OD}$$

and

$$\overrightarrow{OD} = \overrightarrow{OC} + \overrightarrow{CD}$$

or $$\overrightarrow{OD} = \overrightarrow{OC} + \overrightarrow{AE}$$

$$\vec{V_x} = \overrightarrow{V_{1x}} + \overrightarrow{V_{2x}}$$

$$\vec{V_x}\hat{i} = \overrightarrow{V_{1x}}\hat{i} + \overrightarrow{V_{2x}}\hat{i}$$

$$\vec{V_x}\hat{i} = (\overrightarrow{V_{1x}} + \overrightarrow{V_{2x}})\hat{i}$$

$$\vec{V_x} = \overrightarrow{V_{1x}} + \overrightarrow{V_{2x}}$$

or $$\boxed{\vec{V_x} = V_1 Cos\theta_1 + V_2 Cos\theta_2}$$

Similarly for y component

$$\overrightarrow{V_{1y}} = \overrightarrow{CA}$$

$$\overrightarrow{V_{2y}} = \overrightarrow{EB}$$

$$\overrightarrow{V_y} = \overrightarrow{DB}$$

and

$$\overrightarrow{DB} = \overrightarrow{DE} + \overrightarrow{EB}$$

or $$\overrightarrow{OD} = \overrightarrow{CA} + \overrightarrow{AE}$$

$$\overrightarrow{V_y} = \overrightarrow{V_{1y}} + \overrightarrow{V_{2y}}$$

$$\overrightarrow{V_y}\hat{j} = \overrightarrow{V_{1y}}\hat{j} + \overrightarrow{V_{2y}}\hat{j}$$

$$\overrightarrow{V_y}\hat{j} = (\overrightarrow{V_{1y}} + \overrightarrow{V_{2y}})\hat{j}$$

$$\overrightarrow{V_y} = \overrightarrow{V_{1y}} + \overrightarrow{V_{2y}}$$

or $$\boxed{\overrightarrow{V_y} = V_1 Sin\theta_1 \ + V_2 Sin\theta_2}$$

Now , the resultant can be calculated by the formula

$$\boxed{V = \sqrt{V_x{}^2 + V_y^2}}$$

2.4 SCALAR PRODUCT OF TWO VECTORS

2.4.1 Define scalar product of two vectors. (COGNITIVE LEVEL:K)

SCALAR PRODUCT

"The multiplication of two vectors to give a scalar."

Or in other words,

"It involves the multiplication of two vectors in such a way that their product is a scalar quantity".

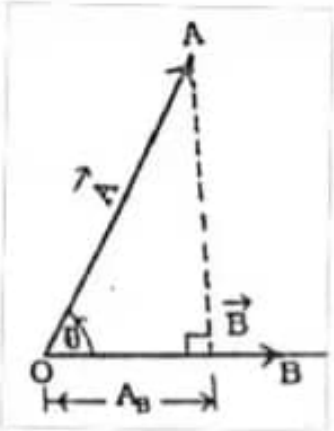
2.4.2 Describe the scalar product of two vectors in terms of angle between them. (COGNITIVE LEVEL:U)

DESCRIPTION:

Scalar product of two vectors A and B is the product of magnitudes of two vectors and the cosine of the angle between them.

Let vector A and B. Draw a perpendicular form head of B on x axis.

According to the definition of scalar product , it is equal to the product of magnitude of first vector with the length of projection of second vector onto first vector.



Thus,

$$\vec{A}.\vec{B} = ABCos\theta$$

2.4.3 Discuss properties of scalar product of two vectors.

(COGNITIVE LEVEL:U)

PROPERTIES OF SCALAR PRODUCT:

1) Commutative Law:

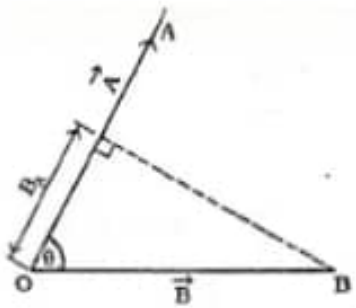
$$\vec{A}.\vec{B} = \vec{B}.\vec{A}$$

Proof:

Let vector A and B. Draw a perpendicular form head of B on x axis.According to the definition of scalar product , it is equal to the product of magnitude of first vector with the length of projection of second vector onto first vector.

Thus,

$$\vec{A}.\vec{B} = ABCos\theta = A(BCos\theta)$$



In the same way, when

$ACos\theta$ = Magnitude of component of A onto B,

$$\vec{B}.\vec{A} = B(ACos\theta) = BACos\theta$$

Hence, it is clear that

$$ABCos\theta = BACos\theta$$

$$\boxed{\vec{A}.\vec{B} = \vec{B}.\vec{A}}$$

2) Distributive Law:

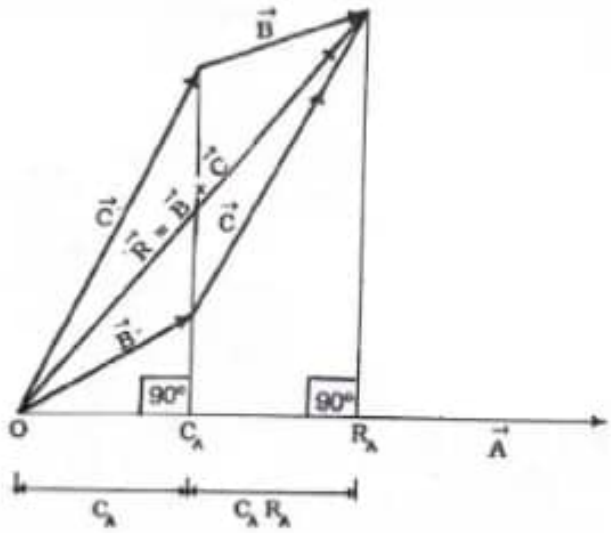
$$\vec{A}.(\vec{B}+\vec{C}) = \vec{A}.\vec{B}+\vec{A}.\vec{C}$$

Proof:

Let us consider Vector $\vec{A}$, $\vec{B}$ and $\vec{C}$ in different directions.let us first add B and C to get resultant vector $\vec{R}$,i.e.

$$\vec{R} = \vec{B} + \vec{C}$$

Now



$$\vec{A}.\vec{R} = A(R_A)$$

$$\vec{A}.\vec{R} = A(\overrightarrow{ON})$$

$$\vec{A}.\vec{R} = A(\overrightarrow{OM} + \overrightarrow{MN})$$

$$\vec{A}.\vec{R} = A(B_A + C_A)$$

$$\vec{A}.\vec{R} = AB_A + AC_A$$

or

$$\boxed{\vec{A}.(\vec{B} + \vec{C}) = \vec{A}.\vec{B} + \vec{A}.\vec{C}}$$

3. If $\vec{A}$ is parallel to $\vec{B}$ i.e. θ = 0° then

$$\vec{A}.\vec{B} = AB$$

4. If $\vec{A}$ =$\vec{B}$ i.e. $\vec{A}$ is parallel and equal to B then

$$\vec{A}.\vec{A} = (A)\ (A)\ (\cos 0°) = A^2$$

5. If $\vec{A}$ is perpendicular to $\vec{B}$ i.e. θ = 90° or one of the vector is null vector then

$$\vec{A}.\vec{B} = 0$$

6. The unit vectors i, j and $\hat{k}$ are perpendicular to each other therefore,

$$\hat{i}.\hat{i} = \hat{j}.\hat{j} = \hat{k}.\hat{k} = 1$$

$$\hat{i}.\hat{j} = \hat{j}.\hat{k} = \hat{k}.\hat{i} = 0$$

2.5 VECTOR PRODUCT OF TWO VECTORS

2.5.1 Define vector product of two vectors. (COGNITIVE LEVEL:K)

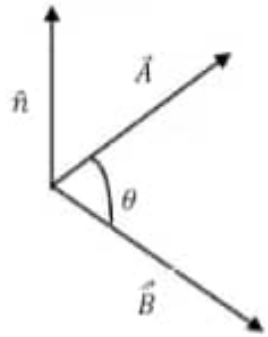
VECTOR PRODUCT:

It is the multiplication of two Vectors to give vectors

Or,

"It involves the multiplication of two vectors in such a way that the produ ct is also a vector.

2.5.2 Describe vector product of two vectors in terms of angle between them. (COGNITIVE LEVEL:U)



DESCRIPTION:

Vector product is the product of magnitudes of two vectors and the sine of the angle between thEM

$$\boxed{\vec{A} \times \vec{B} = AB \sin\theta\ (\hat{n})}$$

2.5.3 Discuss properties of vector product.

PROPERTIES OF VECTOR PRODUCT:

1. **COMMUTATIVE LAW:**

$$\vec{A} \times \vec{B} = -\ \vec{A} \times \vec{B}$$

It means that vector product is not commutative.

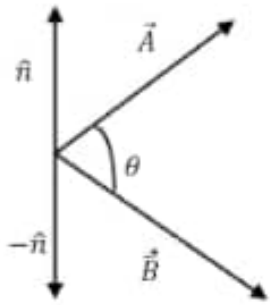
Proof:

By the definition of vector product,

$$\vec{A} \times \vec{B} = AB \sin\theta\ (\hat{n}) \text{----------(i)}$$

where $\hat{n}$ is the unit vector normal pointing outwards the plane of vector $\vec{A} and\ \vec{B}$.

Similarly,



$$\vec{B} \times \vec{A} = BA \sin(-\theta)\ (\hat{n})$$

or

$$\vec{B} \times \vec{A} = BA \sin(\theta)\ (-\hat{n}) \quad \text{Since } \sin(-\theta) = -\sin\theta$$

or

$$\vec{B} \times \vec{A} = -AB \sin(\theta)\ (\hat{n})$$

Using eq(i) we get,

$$\vec{B} \times \vec{A} = -\vec{A} \times \vec{B}$$

or

$$\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}$$

The above equation shows that vector product is **not** commutative.

2) Distributive Law:

$$\vec{A} \times (\vec{B} + \vec{C}) = \vec{A} \times \vec{B} + \vec{A} \times \vec{C}$$

or

$$(\vec{A} + \vec{B}) \times \vec{C} = \vec{A} \times \vec{C} + \vec{B} \times \vec{C}$$

3. If $\vec{A}$ is parallel to $\vec{B}$ i.e. $\theta = 0°$ then

$$\vec{A} \times \vec{B} = 0$$

4. If $\vec{A} = \vec{B}$ i.e. $\vec{A}$ is parallel and equal to B then

$$\vec{A} \times \vec{A} = (A)\,(A)\,(\sin 0°) = 0$$

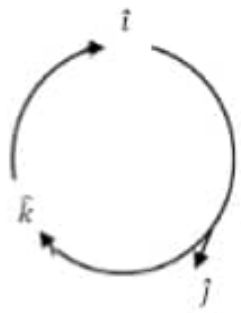
5. If $\vec{A}$ is perpendicular to $\vec{B}$ i.e. $\theta = 90°$ or one of the vector is null vector then

$$\vec{A} \times \vec{B} = AB\,\hat{n} \qquad \text{or} \qquad |\vec{A} \times \vec{B}| = AB$$

6. The unit vectors i, j and $\hat{k}$ are perpendicular to each other therefore,

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$$

$\hat{i} \times \hat{j} = \hat{k}$	$\hat{j} \times \hat{i} = = -\hat{k}$
$\hat{j} \times \hat{k} = \hat{i}$	$\hat{k} \times \hat{j} = -\hat{i}$
$\hat{k} \times \hat{i} = \hat{j}$	$\hat{i} \times \hat{k} = -\hat{j}$



2.6 TORQUE

2.6.1 Describe torque as a vector product of $\vec{r} \times \vec{F}$. (COGNITIVE LEVEL:U)

DEFINITION:

The turning effect of force is called torque Mathematically it is defined as the product of force and the force arm that is the perpendicular distance between the point of application of force and the fixed point or fulcrum about which body rotates.

EXPLANATION:

From above definition,

Torque = Force x Momemt arm

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{\tau} = rF\ Sin\ \theta$$

Where 'θ' is the angle between 'F' and 'r'

2.6.2 List applications of torque. (COGNITIVE LEVEL:K)

1. Opening or closing the door.	2. Opening the cap of bottle.
3. Using See-Saw.	4.Using steering wheel of a car.
5. Using a wrench.	6. Bending of arm.

2.7 EQUILIBRIUM OF FORCES

2.7.1 Define equilibrium and its types. (COGNITIVE LEVEL:K)

EQUILIBRIUM:

A body is said to be equilibrium if it is at rest or is moving with uniform velocity.

1) STATIC EQUILIBRIUM:

A body at rest is said to be in static equilibrium

2) DYNAMIC EQUILIBRIUM:

A body in uniform motion along a straight line is said to be in dynamic equilibrium.

In both the cases the bodies do not posses any acceleration neither linear nor angular.

2.7.2 Describe first and second conditions of equilibrium with the help of examples from daily life. (COGNITIVE LEVEL:U)

A)FIRST CONDITION OF EQUILIBRIUM: (TRANSLATION EQUILIBRIUM):

STATEMENT:

A body will be in equilibrium if the resultant of all the forces on it is equal to zero."

EXPLANATION:

Let $\vec{F_1}$, $\vec{F_2}$,....., $\vec{F_n}$ be the external forces acting on a body. Thus, according to the first condition.

$$\vec{F_1} + \vec{F_2} + ... + \vec{F_n} = 0$$

or

$$\boxed{\sum_{i=1}^{n} \vec{F_i} = 0}$$

For Example:

i. Car stopping at a signal.

ii. Body moving through a fluid.

iii. A person holding a dumbbell.

B) SECOND CONDITION OF EQUILIBRIUM:(ROTATIONAL EQUILIBRIUM)

STATEMENT:

"If the vector sum of the torques acting on a body is zero, the body is said to in rotational equilibrium."

EXPLANATION:

Let τ_1, τ_2 , ... , τ_n are the torques on the body then

$\tau_1 + \tau_2 + ... + \tau_n = 0$

or

$$\boxed{\sum_{i=1}^{n} \vec{\tau} = 0}$$

For Example:

i. Fan moving at constant speed.

ii. Acrobat making somersaults.

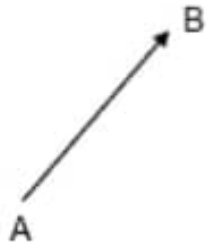
iii. Rope walker.

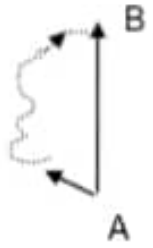
3.1 DISPLACEMENT

3.1.1 Define displacement with illustrations. (COGNITIVE LEVEL:K)

DISPLACEMENT:

"The change of position of a body in a particular direction is called displacement" .It is the maximum distance between two points. It is a vector quantity.



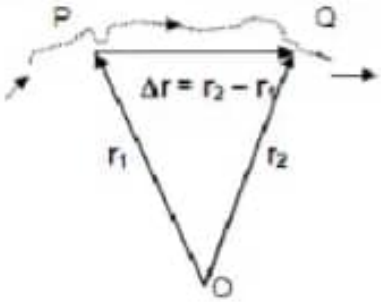


3.2 VELOCITY

3.2.1 Define velocity, average velocity and instantaneous velocity with illustrations. (COGNITIVE LEVEL:K)

VELOCITY: "It is the change in position (or displacement) with respect to time."

ILLUSTRATION:



From above definition,

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

Consider a body moves along the path AC. Let $\vec{r1}$ and $\vec{r2}$ position vectors from origin to the points 'P' ad 'Q'

As the body moves from 'P' to 'Q" in time $\Delta t = t_2 - t_1$ undergoes a change in position

$\vec{\Delta r} = \vec{r2} - \vec{r1}$.

AVERAGE VELOCITY: "The total distance travelled by a body divided y the time elapsed" is called average velocity.

The average velocity is given by

$$\vec{V}_{av} = \vec{\Delta r} / \Delta t = \text{Displacement / Time}$$

Hence rate of change of position of a body in the direction of displacement is called 'velocity'

INSTANTANEOUS VELOCITY:

"It is the change in position (or displacement) with respect to time when time is very small such that $\Delta t \rightarrow 0$, the velocity is called 'instantaneous velocity".

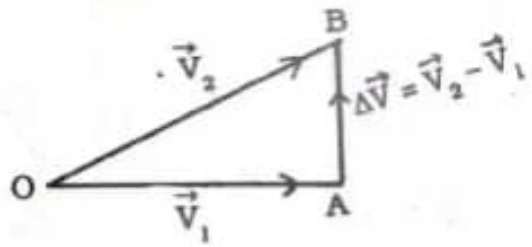
$$\vec{V}_{ins} = \lim_{\Delta t \rightarrow 0} \frac{\vec{\Delta r}}{\Delta t}$$

3.2.2 Define acceleration, average acceleration and instantaneous acceleration. (COGNITIVE LEVEL:K)

ACCELERATION: The rate of change of velocity of a body is called acceleration.

ILLUSTRATION:

It is a vector quantity and its direction is parallel to the direction of velocity.



ACCELERATION	**=**	**CHANGE OF VELOCITY / TIME**

Consider a body in motion let Vi be it velocity instant "t_1" and V_2 at instant t_2.

AVERAGE ACCELARATION: "The total change in velocity of a body divided y the time elapsed" is called average acceleration.

The average acceleration during this internal is given by

$$\vec{a}_{av} = \frac{\vec{V}_2 - \vec{V}_1}{t_2 - t_1} = \frac{\vec{\Delta V}}{\Delta t}$$

INSTANTANEOUS ACCELARATION: The rate of change of velocity of a body when Δt is very small then at $\Delta t \rightarrow 0$,

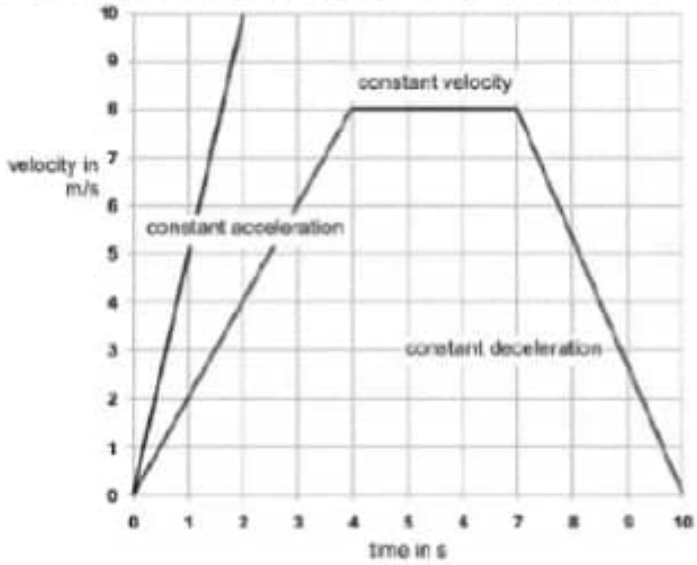
$$\vec{a}_{ins} = \lim_{\Delta t \rightarrow 0} \frac{\overrightarrow{\Delta V}}{\Delta t}$$

This acceleration is called instantaneous acceleration.

3.2.3 Interpret velocity-time graph for constant direction and understand significance of area under velocity-time graph. (COGNITIVE LEVEL:A)

VELOCITY-TIME GRAPH FOR CONSTANT DIRECTION:

When an object is moving with a constant velocity, the line on the graph is horizontal. When an object is moving with a steadily increasing velocity, or a steadily decreasing velocity, the line on the graph is straight, but sloped. The diagram shows some typical lines on a velocity-time graph.



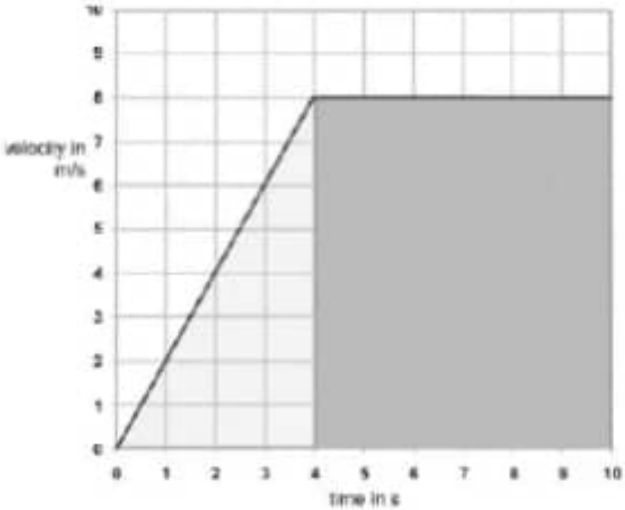
The steeper the line, the more rapidly the velocity of the object is changing. The blue line is steeper than the red line because it represents an object that is increasing in velocity much more quickly than the one represented by the red line.

Notice that the part of the red line between 7 and 10 seconds is a line sloping downwards (with a negative gradient). This represents an object that is steadily slowing down.

AREA UNDER VELOCITY-TIME GRAPH:

Study this velocity-time graph.

The area under the line in a velocity-time graph represents the distance travelled. To find the distance travelled in the graph above, we need to find the area of the light-gray triangle and the dark-gray rectangle.



1. **Area of light-gray triangle**
   - The width of the triangle is 4 seconds and the height is 8 metres per second. To find the area, you use the equation:
   - area of triangle = ½ × base × height
   - so the area of the light-gray triangle is ½ × 8 × 4 = 16 m.
2. **Area of dark-gray rectangle**
   - The width of the rectangle is 6 seconds and the height is 8 metres per second. So the area is 8 × 6 = 48 m.
3. **Area under the whole graph**

- The area of the light-gray triangle plus the area of the dark-gray rectangle is:
- 16 + 48 = 64 m
- This is the total area under the distance-time graph. This area represents the distance covered.

Summary

- The gradient of a velocity-time graph represents the acceleration
- The area under a velocity-time graph represents the distance covered

3.3 ACCELERATION

3.3.1 Summarize the equations of motion for uniformly accelerated bodies in a straight line and in uniform gravitational field in a non-resistive medium. (COGNITIVE LEVEL:U)

EQUATIONS OF UNIFORMLY ACCELERATED RECTILINEAR MOTION:

There are three fundamental equations about uniformly accelerated rectilinear motion,

1. $V_f = V_i + at$

2. $S = V_i t + \frac{1}{2} at^2$

3. $V_f^2 = V_i^2 + 2aS$

In case of motion under gravity with nearly constant a cceleration we just replace 'a' with 'g' i.e. acceleration due to gravity in equations of motion, as weight is always directed downwards.

1. $V_f = V_i + gt$

2. $h = V_i t + \frac{1}{2} gt^2$

3. $V_f^2 = V_i^2 + 2gh$

Where $g = 9.8\ m/s^2$

or $= 980\ cm/s^2$

$= 32 ft/s^2$

The most common example of motion with nearly constant acceleration is that of a body falling towards the earth. This acceleration is due to pull of earth (gravity).If the body moves towards earth, neglecting resistance and small changes in the acceleration with altitude, the body is referred to as free falling body and this motion is called Free Fall. Such type of vertical motion under the action of gravity is a good example of uniformly accelerated motion.

3.4 LAWS OF MOTION

3.4.1 State Newton's laws of motion. (COGNITIVE LEVEL:K)

(1) Newton's First Law of Motion:

Newton's first law of motion consists of two parts.

(i) The first part states that a body cannot change its state of rest or uniform motion in straight line itself unless it is acted upon by some unbalanced force to change its state. It can also be stated that a moving body when not acted upon by some net force would have free motion, that is uniform motion in straight line.

(ii) The second part states that force is an agent which changes or tends to change the state of rest or uniform motion i.e. it produces acceleration in the body. The first law of motion is also known as the law of inertia.

Inertia:

Everybody in this universe has a property that it always offers some resistance to the change of its state. This property is known as Inertia and it is because of the mass of body. Therefore we need force to overcome inertia for the change of its state, either rest or motion. Hence Newton's first law of motion is also known as inertia.

(2) Newton's Second Law of Motion:

Newton's second Law states that : "when a force acts upon a certain body, the acceleration produced is proportional to the force and it is in the direction of the force."

$$\vec{F} \propto \vec{a}$$

$$\vec{F} = m\vec{a}$$

where

F = Net force on the body

m = mass of the body

a = acceleration in the body

It is clear from the above equation that the acceleration for certain force on the body is inversely proportional to the mass of the body.

(3) Newton's Third Law of Motion:

Newton's third law can be stated as "To every action there is a an equal but opposite reaction".

The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs.

3.5 FORCE, MOMENTUM AND IMPULSE

3.5.1 Describe the relation between Newton's 2nd law of motion and the rate of change of momentum. (COGNITIVE LEVEL:U)

RELATION BETWEEN NEWTON'S 2ND LAW OF MOTION AND THE RATE OF CHANGE OF MOMENTUM:

Let mass of a body = m

Initial velocity of a body = v_i

Initial momentum of a body = $m\ v_i$

Final velocity of a body = v_f

Final momentum of a body = $m\ v_f$

Change in momentum of a body = $m\ v_f - m\ v_i$

Rate of change of a body = $m\ v_f - m\ v_i / \Delta t$

Rate of change of a body = $m\ (v_f - v_i)/\Delta t$

But $a = (v_f - v_i)/\Delta t$

Rate of change of momentum of a body = ma

According to Newton's second law of motion.

$$F = ma$$

Rate of change of momentum of a body = F

It shows that "Rate of change of momentum is equal to force"

3.5.2 Infer impulse as product of impulsive force and time. (COGNITIVE LEVEL:A)

IMPULSE:

Impulse is defined as the product of the force (F) acting on an object and the time of action (t).Impulse exerted on an object is equal to the momentum change of the object.

FORMULA OF IMPULSE:

Impulse is the product of force and time.

$$\boxed{Impulse = F \times t}$$

3.5.3 Describe law of conservation of momentum. (COGNITIVE LEVEL:U)

LAW OF CONSERVATION OF MOMENTUM

STATEMENT:

The law of conservation of momentum states that:

"When some bodies constituting an isolated system act upon one another, the total momentum of the system remains constant." OR

"The total momentum of an isolated system of interacting bodies remains constant."

OR

"Total momentum of an isolated system before collision is always equal to total momentum after collision."

EXPLANATION:

Consider an isolated system of the interacting bodies 'A' and 'B' of masses 'm_1' and 'm_2' colliding with velocities U_1 and U_2 after colliding they move with velocities V_1 and V_2

Therefore,

Total momentum of the system before collision = $m_1u_1 + m_2u_2$ and total momentum of the bodies collide with each other they come in contact for a time interval 's'. During the interval the average force exerted by the body 'A' on body 'B' is F.

According to the third law of motion, the body 'B' will also exert a force (-F) on the body 'A'.

The average force acting on the body 'B' is equal to the rate of change of its momentum.

$$\vec{F}_{A\ on\ B} = \frac{m_2v_2 - m_2u_2}{t}$$

Similarly the average force acting on body 'A' is,

$$\vec{F}_{B\ on\ A} = \frac{m_1v_1 - m_1u_1}{t}$$

Since,

$$\vec{F}_{B\ on\ A} = \vec{F}_{A\ on\ B}$$

$$m_2v_2 - m_2u_2 = m_1v_1 - m_1u_1$$

t t

$$\boxed{m_1u_1 + m_2u_2 = m_2v_1 + m_2v_2}$$

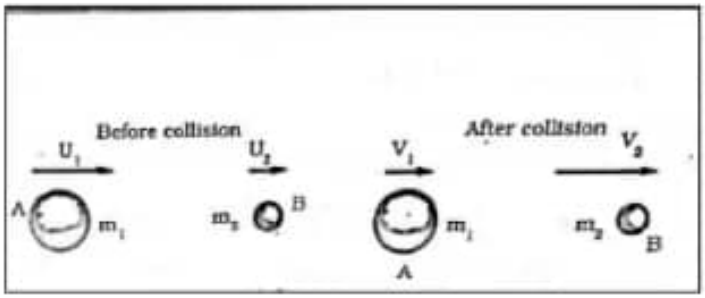
This proves that,

The total momentum of the system remains constant.

3.5.4 Apply law of conservation of momentum and study the special cases of elastic collision between two bodies in one dimension. (COGNITIVE LEVEL:A)

ELASTIC COLLISION IN ONE DIMENSION:

Consider two unequal, non rotating spheres of masses 'm_1' and 'm_2' moving with initial velocities 'u_1' and 'u_2'. If $u_1 > u_2$, the body 'A' will collide with body 'B" and both move s with velocities 'V_1' and 'V_2' in the line and direction as shown. According to the law of conservation of momentum,



Initial momentum of the system = Final momentum of the system.

$m_1u_1 + m_2 u_2 = m_1v_1 + m_2v_2$ ----------(1)

or $m_1u_1 - m_1v_1 = m_2v_2 - m_2u_2$

or $m_1(u_1 - v_1) = m_2(v_2 - u_2)$ ⟶ (2)

And for elastic collision,

Total K.E of the system = Total K.E of the system

Before collision after collision

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$m_1u_1^2 + m_2u_2^2 = m_1v_1^2 + m_2v_2^2$

$m_1u_1^2 - m_2u_2^2 = m_1v_1^2 - m_2v_2^2$

$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$

$m_1(u_1 + v_1)(u_1 - v_1) = m_2(v_2 + u_2)(v_2 - u_2)$ ⟶ (3)

Dividing eq (2) by eq (1),

$$\frac{\cancel{m_1}(u_1 + v_1)\cancel{(u_1 - v_1)}}{\cancel{m_1(u_1 - v_1)}} = \frac{\cancel{m_2}(v_2 + u_2)\cancel{(v_2 - u_2)}}{\cancel{m_2(v_2 - u_2)}}$$

$$u_1 + v_1 = v_2 + u_2 \longrightarrow (4)$$

FOR V_1:

From eq (3),

$$v_2 = u_1 + v_1 - u_2$$

putting the value of 'V_2' in eq (1),

$$m_1u_1 + m_2u_2 = m_2v_1 + m_2(u_1 + v_1 - u_2)$$

$$m_1u_1 + m_2u_2 = m_2v_1 + m_2u_1 + m_2 v_1 - m_2u_2$$

$$m_1u_1 + m_2u_2 - m_2u_1 + m_2u_2 = m_2v_1 + m_2 v_1$$

$$(m_1 - m_2) u_1 + 2 m_2u_2 = (m_2 + m_2) v_1$$

$$\boxed{\frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2u_2}{(m_1 + m_2)} = V_1} \longrightarrow (A)$$

FOR V_2:

From eq (3),

$$v_1 = v_2 + u_2 - u_1$$

putting the value of 'V_1' in eq (1),

$$m_1u_1 + m_2u_2 = m_1(v_2 + u_2 - u_1) + m_2v_2$$

$$m_1u_1 + m_2u_2 = m_1v_2 + m_1u_2 - m_1 u_1 + m_2v_2$$

$$m_1u_1 + m_1u_2 - m_1u_2 + m_1 u_1 = m_1v_2 + m_2v_2$$

$$2m_1u_1 + (m_1 - m_1) u_2 = (m_1 + m_2)v_2$$

$$\boxed{v_2 = \frac{2m_1u_1}{(m_1 + m_2)} + \frac{(m_1 - m_2)u_2}{(m_1 + m_2)}} \longrightarrow (B)$$

SPECIAL CASES OF ELASTIC COLLISIONS

Case I: if $m_1 = m_2$,

Let $m_1 = m_2 = m$

Then from equ (A)

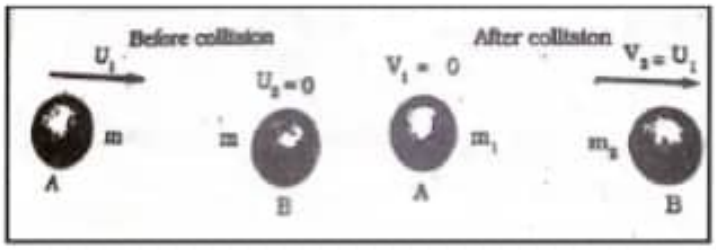
$$\frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2u_2}{(m_1 + m_2)} = V_1$$

Thus,

$$v_1 = \frac{(m - m)u_1}{(m + m)} + \frac{2mu_2}{(m + m)}$$

$$v_1 = o + \frac{2mu_2}{2m}$$

$$\boxed{v_1 = u_2}$$



And from eq (B),

$$v_2 = \frac{2m_1u_1}{(m_1 + m_2)} - \frac{(m_1 - m_2)u_2}{(m_1 + m_2)}$$

Thus,

$$v_2 = \frac{2m\,u_1}{(m + m)} - \frac{(m - m)u_2}{(m + m)}$$

$$v_2 = \frac{2mu_1}{2m}$$

$$\boxed{v_2 = u_1}$$

This shown that the bodies interchange their velocities after the collision.

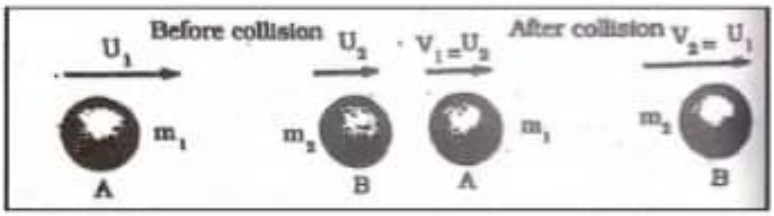
Case II: if $m_1 = m_2$, and $u_2 = 0$

let $m_1 = m_2 = m$, $u_2 = 0$

Then,

$$\frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2u_2}{(m_1 + m_2)} = V_1$$

$$\frac{(m - m)}{(m + m)} u_1 + \frac{2m(0)}{(m + m)} = V_1$$



$$\boxed{v_1 = 0}$$

And,

$$V_2 = \frac{2mu_1}{(m + m)} + \frac{(m - m)}{(m + m)} \times 0$$

$$\boxed{v_2 = u_1}$$

This means that body 'A' will stop after collision and 'B' will move with the initial velocity of A.

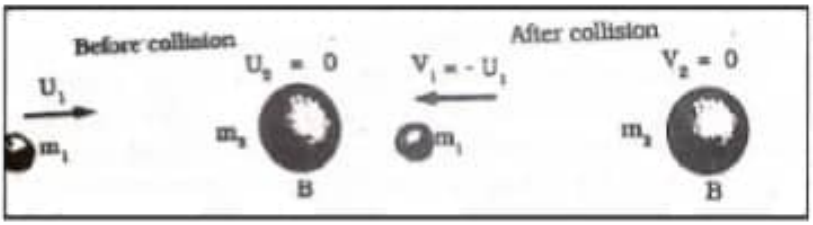
Case III: if $m_1 << m_2$ and $u_2 = O$ (Massive body at rest)

Now, m_1 can be neglected

Since,

$$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2u_2}{(m_1 + m_2)}$$

$$v_1 = \frac{(0 - m_2)}{(0 + m_2)} u_1 + \frac{2m_2(0)}{(0 + m_2)}$$



$$\boxed{v_1 = -u_1}$$

and

$$v_2 = \frac{2m_1u_1}{} + \frac{(m_1 - m_2)u_2}{}$$

$(m_1 + m_2) \qquad (m_1 + m_2)$

$$v_2 = \frac{2(0)\ u_1}{(0 + m_2)} + \frac{(0 - m_2)(0)}{(0 + m_2)}$$

thus

$$\boxed{v_2 = 0}$$

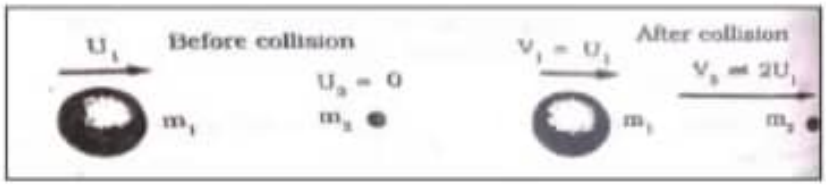
This means that body lighter body "A" will comes back with its in itial velocity and the massive body "B" will remain at rest.

Case IV: if $m_1 >> m_2$ and $u_2 = 0$

then m_2 can be neglected,

Thus

$$v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{2m_2u_2}{(m_1 + m_2)}$$



$$v_1 = \frac{(m_1 - 0)}{(m_1 + 0)} u_1 + \frac{2(0)(0)}{(m_1 + 0)}$$

$$\boxed{v_1 = u_1}$$

And,

$$v_2 = \frac{2m_1u_1}{(m_1 + m_2)} + \frac{(m_1 - m_2)u_2}{(m_1 + m_2)}$$

$$v_2 = \frac{2m_1u_1}{(m_1 + 0)} + \frac{(m_1 - 0)(0)}{(m_1 + 0)}$$

$$\boxed{V_2 = 2u_1}$$

This means that body 'A' will continues its motion with the same velocity and 'B' will move with double the velocity of body A.

3.5.5 Describe the force produced due to flow of water. (COGNITIVE LEVEL:U)

Force Due To Water Flow:

When water from a horizontal pipe strikes a wall normally, a force is exerted on the wall. Suppose the water strikes the wall normally with velocity v and comes to rest on striking the wall, the change in velocity is then

$$\Delta v = 0 - v = - v$$

From second law, the force equals the momentum change per second of water flow. If mass m of the water strikes the wall in time t then force F on the water is

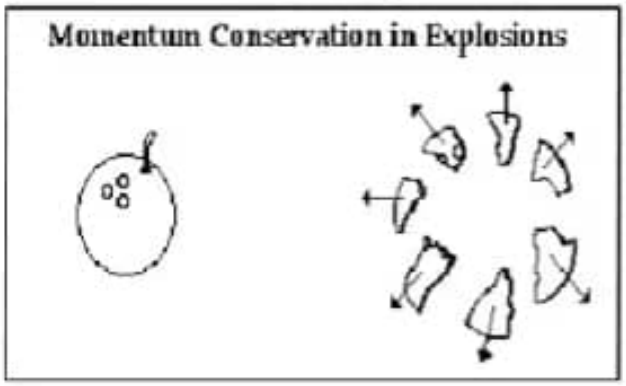
$$F = -\frac{m}{t} v = \text{- mass per second x change in velocity}$$

From third law of motion, the reaction force exerted by the water on the wall is equal but opposite.Hence,

$$\boxed{F = -\left(-\frac{m}{t} v\right) = \frac{m}{t} v}$$

3.5.6 Apply the law of conservation of momentum to study explosive forces. (COGNITIVE LEVEL:A)

As we know that total system momentum is conserved for collisions between objects in an isolated system. For collisions occurring in isolated systems, there are no exceptions to this law. This same principle of momentum conservation can be applied to explosions. In an explosion, an internal impulse acts in order to propel the parts of a system (often a single object) into a variety of directions. After the explosion, the individual parts of the system (that is often a collection of fragments from the original object) have momentum. If the vector sum of all individual parts of the system could be added together to determine the total momentum after the explosion, then it should be the same as the total momentum before the explosion. Just like in collisions, total system momentum is conserved.



Momentum conservation is often demonstrated in a Physics class with a homemade cannon demonstration. A homemade cannon is placed upon a cart and loaded with a tennis ball. The cannon is equipped with a reaction chamber into which a small amount of fuel is inserted. The fuel is ignited, setting off an explosion that propels the tennis ball through the muzzle of the cannon. The impulse of the explosion changes the momentum of the tennis ball as it exits the muzzle at high speed. The cannon experienced the same impulse, changing its momentum from zero to a final value as it recoils backwards. Due to the relatively larger mass of the cannon, its backwards recoil speed is considerably less than the forward speed of the tennis ball.

3.5.7 Explain forces applied on the process of rocket propulsion. (COGNITIVE LEVEL:U)

ROCKET PROPULSION :

The propulsion of all rockets works on the Newton's third law of motion. Matter is forcefully ejected from a system, producing an equal and opposite reaction on what remains. Another common example is the recoil of a gun. The gun exerts a force on a bullet to accelerate it and consequently experiences an equal and opposite force, causing the gun's recoil or kick.

Let us consider a rocket accelerating straight up. In part (a), the rocket has a mass m and a velocity v relative to Earth, and hence a momentum mv. In part (b), a time Δt has elapsed in which the rocket has ejected a mass Δm of hot gas at a velocity v_e relative to the rocket. The remainder of the mass (m−m) now has a greater velocity (v+Δv). The momentum of the enti re system (rocket plus expelled gas) has actually decreased because the force of gravity has acted for a time Δt, producing a negative impulse Δp=−mgΔt. (Remember that impulse is the net external force on a system multiplied by the time it acts, and it equals the change in momentum of the system.

So the center of mass of the system is in free fall but, by rapidly expelling mass, part of the system can accelerate upward. It is a commonly held misconception that the rocket exhaust pushes on the ground. If we consider thrust; that is, the force exerted on the rocket by the exhaust gases, then a rocket's thrust is greater in outer space than in the atmosphere or on the launch pad. In fact, gases are easier to expel into a vacuum.

ACCELARATION OF THE ROCKET:

If m is the mass of gases ejected per second fr om the rocket with velocity "v" w.r.t the rocket, then the rate of change of momentum of gases is "mv" which is equal to the trust produced by the engine "Ma", so acceleration "a" of the rocket is given by

$$\boxed{a = \frac{mv}{M}}$$

3.6 PROJECTILE

3.6.1 Define projectile, projectile motion and trajectory of projectile. (COGNITIVE LEVEL:K)

PROJECTILE

An object falling freely in a gravitational field, having been projected with a velocity 'v' and at an angle of elevation 'θ' with the horizontal is called projectile.

PROJECTILE MOTION:

When an object is projected with a velocity 'v' it will move in a semi -parabolic path then its motion is called projectile motion.

TRAJECTORY OF PROJECTILE:

The path followed by the projectile is known as its trajectory.

3.6.2 Describe projectile motion in non-resistive medium. (COGNITIVE LEVEL:U)

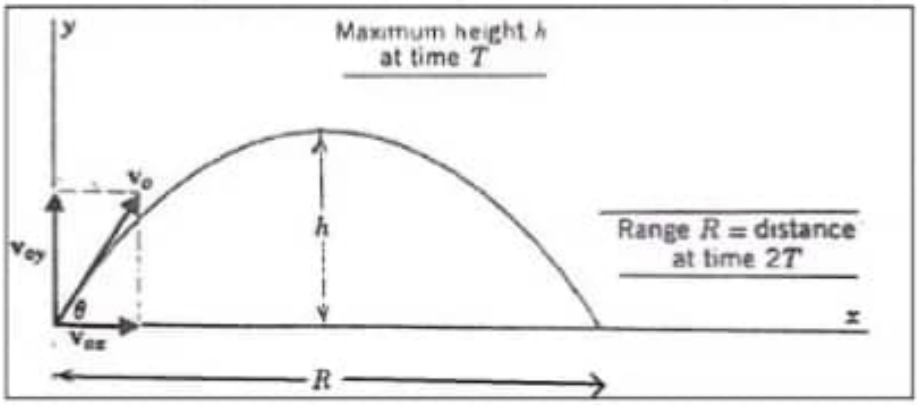
Suppose a ball is projected towards the sky (in XY-plane) with an initial velocity Vo in a direction making an angle q with the horizontal. To study the motion of the ball, it is convenient to resolve the velocity of the projectile along x and y plane. These components are Vocos θ and Vosinθ .

As the ball starts moving, it is subjected to a vertically downward force due to gravity. This causes a retardation in the motion of the ball along y-plane. However, there is no force acting on it along horizontal direction. Hence, the horizontal component of velocity (Vocos θ) remains constant throughout its flight. The retardation along vertical direction continues till the body reaches to point B, the highest point on its trajectory. At this point the vertical component of velocity is reduced to zero

and the body momentarily moves along horizontal direction with a velocity Vocos θ. Beyond point B, there is acceleration due to gravity along the vertically downward direction. Hence, the vertical component of the velocity gradually increases in the downward direction until the body strikes the ground at point 'C' and instead of a straight line the trajectory of projectile becomes curved.

Another correct result is that the body strikes the ground at point 'C' with its initial velocity, Vo again making the same angle q with the horizontal direction.

3.6.3 Derive the relation for time of flight, maximum height and horizontal range of a projectile and use these relations in solving numerical. (COGNITIVE LEVEL:A)



A) <u>TIME TO REACH MAXIMUM HEIGHT:</u>

Initial Velocity = V_{oy} = $V_o Sin\theta$

Final Velocity = V_y = 0

Time = T

Acceleration = -g

We know that

$V_f = V_i + at$

$V_y = V_o y + (-g)T$

$0 = V_o Sin\theta - gT$

$gT = V_o Sin\theta$

$$T = \frac{V_o Sin\theta}{g}$$

B) <u>TIME OF FLIGHT:</u>

Total time of flight = T

$T' = 2T$

$$\boxed{T' = \frac{2V_o \sin\theta}{g}}$$

C) MAXIMUM HEIGHT:

Distance = Height = $y = h_{max}$

Initial Velocity = $V_{oy} = V_o \sin\theta$

Acceleration = $a = -g$

Time = $T = \frac{V_o \sin\theta}{g}$

We know that,

$S = Vit + 1/2\ at^2$

$Y = V_{oy}T + 1/2\ (-g)\ T^2$

$h_{max} = V_o\sin\theta \times \frac{V_o\sin\theta}{g} - 1/2g \left(\frac{V_o\sin\theta}{g}\right)^2$

$h_{max} = \frac{V_o^2\sin^2\theta}{g} - \frac{V_o^2\sin^2\theta}{g}$

$h_{max} = \frac{2Vo^2\sin^2\theta - Vo^2\sin^2\theta}{2g}$

$$\boxed{h_{max} = \frac{Vo^2\sin^2\theta}{2g}}$$

D) RANGE:

The maximum horizontal distance traveled by a projectile is called ' rang ".

Distance = X = R

Velocity = $V_{ox} = V_o\cos\theta$

Time = T'

Since,

$S = V \times t$

$X = V_o \times T$

$R = V_o Cos\theta \times \frac{2 V_o Sin\theta}{g}$

$R = \frac{V_o^2 2Cos\theta \ Sin\theta}{g}$

$$\boxed{R = \frac{V_o^2 Sin2\theta}{g}} \qquad \left(Sin\ 2\theta = 2Sin\theta\ Cos\theta \right)$$

E) MAXIMUM RANGE:

Horizontal Range is given as,

$$R = \frac{V_o^2 sin2\theta}{g}$$

Above expression shows that, for constant velocity of projection (V0) and gravitational acceleration (g), horizontal range depends on the factor sin2θ and it will be maximum at the maximum value of sin2θ. The maximum value of sin is 1.

$Sin\ 2\theta = 1$

or $2\theta = Sin^{-1}(1)$

or $2\theta = 90^0$

or $\theta = 45^0$

It shows that, "when a projectile is projected with 45^0, its horizontal range will be maximum."

PROBLEM 1: A ball kicked from ground level at an initial velocity of 60 m/s and an angle θ with ground reaches a horizontal distance of 200 meters.

a) What is the size of angle ?

b) What is time of flight of the ball?

SOLUTION:

a) Let T be the time of flight.

$$T = \frac{2 V_0 sin\theta}{g} \quad \text{-------(i)}$$

Also

T= Range / Horizontal component of velocity

$$T = \frac{R}{V_0 cos\theta} \text{ --------(ii)}$$

Equate the two expressions

$$\frac{R}{V_0 cos\theta} = \frac{2\,V_0 sin\theta}{g}$$

which gives

$$\frac{200}{60\ cos\theta} = \frac{2\,60\ sin\theta}{9.8}$$

$$sin(2\theta) = 200 \times \frac{9.8}{(60)^2} \qquad \{sin(2\theta) = 2sin\theta\ cos\theta\}$$

$$\theta = 16.5^\circ$$

b) Time of flight = $\frac{2\,V_0 sin\theta}{g} = 2 \times 60 \times \sin(16.5)\,/9.8$ = 3.48 s

<u>PROBLEM 2:</u> A cannon is fired with muzzle velocity of 150 m/s at an angle of elevation = 45°.

a) What is the maximum height the projectile reaches?

b) What is the total time of flight?

c) How far away did the projectile land?

<u>SOLUTION:</u>

a) Maximum Height attained: $H_{max} = \frac{V_0^2 \sin^2\theta}{2g}$

$$H_{max} = \frac{(150)^2(\sin(45))^2}{2\times 9.8} = 574.4\ m$$

b) Total Time of flight: $T = \frac{2\,V_0 sin\theta}{g} = \frac{2\times 150\times \sin(45)}{9.8} = 21.6\ s$

c) Range of projectile: $R = \frac{V_0^2 \sin(2\theta)}{g} = \frac{(150)^2 \sin(2\times 45)}{9.8} = 2295.8m$

<u>PROBLEM 3:</u> In a game of cricket a shot is played at an angle of 55 ^{0} and the ball covered the distance of 80 m. Find the velocity by which the shot was played.

<u>SOLUTION:</u> In this problem we have to find the initial velocity. The range of projectile is given by

$$R = \frac{V_0^2 \sin\ (2\theta)}{g}$$

$$V_0^2 = \frac{Rg}{\sin(2\theta)}$$

$$V_0^2 = \frac{80 \times 9.8}{\sin(2(55))} = \frac{784}{0.939} = 834.9$$

or

$$V_0 = \sqrt{834.9} = 28.8\, m/s$$

3.6.4 Relate the motion of ballistic missiles with projectile motion. (COGNITIVE LEVEL:U)

APPLICATION TO BALLISTIC MISSILES:

A ballistic flight is that in which a projectile is given an initial push and is then allowed to move freely due to inertia and under the action of gravity. An un-powered and un-guided missile is called a ballistic missile and the path followed by it is called ballistic trajectory.

As discussed before, a ballistic missile moves in a way that is the result of the superposition of two independent motion: a straight line inertial flight in the direction of the launch and a vertical gravity fall. By law of inertia, an object should sail straight off in the direction thrown, at constant speed equal to its initial speed particularly in empty space. But the downward force of gravity will alter straight path into a curved trajectory. For short ranges and flat Earth approximation, the trajectory is parabolic but the drag less ballistic trajectory for spherical Earth should actually be elliptical. At high speed and for long trajectories the air friction is not negligible and sometimes the force of air friction is more than gravity. It affects both horizontal as well as vertical motions. Therefore, it is completely unrealistic to neglect the aerodynamic forces.

The shooting of a missile on a selected distant spot is a major element of warfare. It undergoes complicated motions due to air friction and wind etc. consequently the angle of projection can not be found by the geometry of the situation at the moment of launching. The actual flights of missiles are worked out to high degrees of precision and the result were contained in tabular form. The modified equation of trajectory is too complicated to be discussed here. The ballistic missiles are useful only for short ranges. For long ranges and greater precision, powered and remote control guided missiles are used.

4.1 WORK

4.1.1 Define work. (COGNITIVE LEVEL:K)

DEFINITION:

"Work is said to be done if a force causes a displacement in a body in the direction of force".

OR

" The work done by a constant force is defined as the product of the co mponent of the force and the displacement in the direction of displacement".

4.1.2 Describe work when force and displacement are acting at an angle (θ). (COGNITIVE LEVEL:U)

DESCRIPTION:

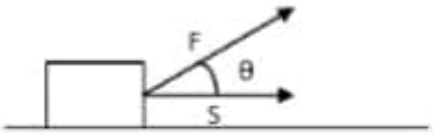
Work is the scalar product or dot product of the force and displ acement".

$$W = \vec{F}.\vec{S} = FS\cos\theta = (F\cos\theta)S \text{------(I)}$$

Where, F= Magnitide of Force

S= Magnitude of Displacement

θ= Angle between $\vec{F}$ and $\vec{S}$



or eq(i) can also be written as,

$$W = F(S\cos\theta)$$

Where $S\cos\theta$ is the component of Displacement in the direction of Force.

4.1.3 List different units of work. (COGNITIVE LEVEL:K)

UNITS OF WORK:

- In S.I system: Joule (j)
- In C.G.S. system: Erg
- In F.P.S system: ft X lb
-

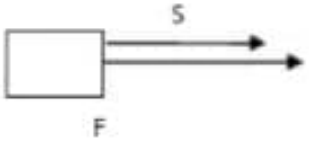
4.1.4 Distinguish between positive, negative and zero work with examples. (COGNITIVE LEVEL:U)

SPECIAL CASES OF WORK :

(i) **POSITIVE WORK:** if force and displacement are in the same direction , work will be positive or if $\theta > 0$ or $\theta < 90^\circ$

Let $\theta = 0^\circ$

As



Work = FS Cos θ

Work = FS Cos 0°

Work = (F) (S) (1)

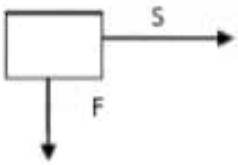
$\boxed{\text{Work} = FS}$

For Example: Pushing a car, pulling a door.

(ii) **ZERO WORK:** if force and displacement are perpendicular to each other, work will be zero. I.e

Since $\theta = 90^\circ$

As



Work = FS Cos θ

Work = FS Cos 90°

Work = (F) (S) (0)

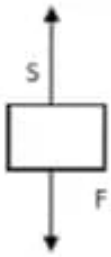
$\boxed{\text{Work} = 0}$

For Example: walk with a bucket in hand, walk with holding a book.

iii) **NEGATIVE WORK:** If force and displacement are in the opposite direction, work will be negative.

Since $\theta = 180^\circ$

As



Work = FS Cos θ

Work = FS Cos 180°

Work = (F) (S) (-1)

$\boxed{\text{Work} = -FS}$

For Example: Lifting a brick, weight lifting.

4.1.5 Describe work done by variable and constant forces. (COGNITIVE LEVEL:U)

<u>WORK DONE BY CONSTANT FORCE:</u>

The work done by constant force can be found by the following formula.

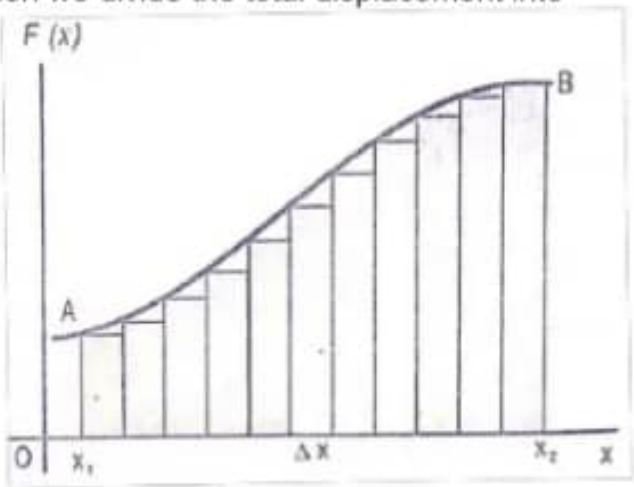
$$W = \vec{F}.\vec{S} = FS\cos\theta = (F\cos\theta)S$$

WORK DONE BY VARIABLE FORCE:

According to the definition of work done, we have,

-> W = F . S

This cannot be used directly in case of variable force over displacement S because the force is continuously changing with displacement 'S'. In this situation we divide the total displacement into large number of small intervals or patches each of equal width. Δx.



An approximately constant force is supposed to act throughout the small patch and this force is different for different patches as shown in fig.

As the force varies with position then it may be represented as F(x), where x represents position coordinate.

Now the work done by the force F (x) acting in the interval Δx will be

$$\Delta W = \vec{F}(x) . \Delta\vec{x}$$

In the same manner calculate work clone by the force for each interval. The total work done in displacing the body from x_1 to x_2 is equal to the algebraic sum of all ΔW. i.e

$$\Delta W = \Delta W_1 + \Delta W_2 + \cdots + \Delta W_n$$

$$\Delta W = \sum_{i=1}^{n} W_i$$

$$\boxed{\Delta W = \sum_{i=1}^{n} \vec{F_i}(x) . \Delta\vec{x_i}}$$

Now if the variation of force is very rapid then we make the patches small enough so that the force may not change significantly during the interval of displacement.

4.2 WORK DONE IN A GRAVITATIONAL FIELD

4.2.1 Explain the work done in a gravitational field. (COGNITIVE LEVEL:U)

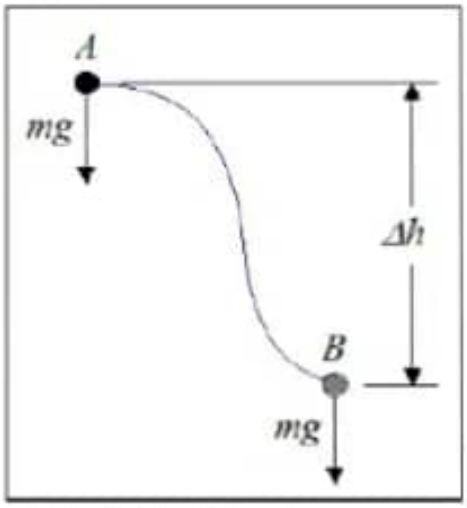
WORK DONE IN A GRAVITATIONAL FIELD:

The space around the earth in which its gravitational force acts on a body is called the gravitational field. When an object is moved in the gravitational field, the work is done by the gravitational force. If displacement is in the direction of gravitational force, the work is positive. If the displacement. Is against the gravitational force, the work is negative.

Let us consider an object of mass m being displaced with constant velocity from point A to B along various paths in the presence of a gravitational force ,in this case the gravitational force is equal to the weight mg of the object.

The work done by the gravitational force along the path ADB can be split into two parts. The work done along AD is zero, because the weight mg is perpendicular to this path, the work done along DB is (-mgh) because the direction of mg is opposite to that of the displacement i.e. $\theta = 180^{\circ}$. Hence, the work done in displacing a body from A to B through path 1 is

$$W_{ADB} = 0 + (-mgh) = -mgh$$



If we consider the path ACB, the work done along AC is also (-mgh). Since the work done along CB is zero, therefore,

$$W_{ACB} = -mgh + 0 = -mgh$$

Let us now consider path 3, i.e. a curved one. Imagine the curved path, the be broken down into a series of horizontal and vertical steps as shown in Fig. 4.9. there is no work done along the horizontal steps, because mg is perpendicular to the displacement for these steps. Work is done by the force of gravity only along the vertical displacements.A smooth path may be replaced by a series of infinitesimal x and y displacements. work is done only during the y displacements.

The net amount of work done along AB path is still (-mgh).We conclude from the above discussion that.Work done in the earth's gravitational field is independent of the path followed.

The field in which the work done be independent of the path followed or work down in a closed path be zero, is called a conservative filed.

4.3 POWER

4.3.1 Define power and give its dimension. (COGNITIVE LEVEL:K)

DEFINITION:" The rate of work done of a body is called power"

AVERAGE POWER:

Average power of a body doing work is numerically equal to the total work done divided by the time taken to perform the work.

MATHEMATICALLY:

Power = Work done / time

Power = W / Δt

As we know that

$$W = \vec{F}.\vec{S}$$

Therefore,

$$P = \vec{F}.\vec{S} / \Delta t$$

DIMENSION AND NATURE:

Power is a scalar quantity and its dimension is $ML^{2}T^{-3}$

4.3.2 List different units of power. (COGNITIVE LEVEL:K)

UNITS OF POWER:

1. Watt [1 watt = 1joule / sec]
2. Kilo watt [1 Kw = 1000 watt]
3. Mega watt (Mw) [1Mw = 10^6 watt]
4. Horse Power [1 Hp = 746]

4.3.3 Derive the formula of power in terms of force and velocity and use it in solving numerical. (COGNITIVE LEVEL:A)

As we know that

$$W = \vec{F}.\vec{S}$$

Therefore,

$$P = \vec{F}.\vec{S} / \Delta t$$

According to the definition of Velocity,

$$v = \vec{S}/\Delta t$$

Therefore,Eq(i)=>

$$P = \vec{F}.\vec{v}$$

or

$$P = \vec{F}.\vec{v} = Fv\cos\theta$$

PROBLEM 1: During the Powerhouse lab, Khizar runs up the stairs, elevating his 70 kg body a vertical distance of 2.29 meters in a time of 1.32 seconds at a constant speed. Determine the power generated by Khizar.

SOLUTION:

$$P = Fv$$

so first we find v.

$$v = \frac{s}{t} = \frac{2.29}{1.32} = 1.73\, m/s$$

and $F = W = mg = 70 \times 9.8 = 686\ N$

Now using $P = Fv = 686 \times 1.73 = 1186.8\ watt$

PROBLEM 2: A 500N force is applied to an object. If the object travels with a constant velocity of 20 meters per second, calculate the power expended on the object.

SOLUTION:

$$P = Fv = 500 \times 20 = 10000\ watt$$

4.4 ENERGY

4.4.1 Define energy. (COGNITIVE LEVEL:K)

DEFINITION:

" The ability of a body to perform work is called Energy". A body cannot perform work if it does not possess energy. A body cannot perform work more than the amount of energy.

4.4.2 Differentiate between potential and kinetic energy. (COGNITIVE LEVEL:U)

	Kinetic Energy	Potential Energy
Definition	The energy of a body or a system with respect to the motion of the body or of the particles in the system.	Potential Energy is the stored energy in an object or system because of its position or configuration.
Relation to environment	Kinetic energy of an object is relative to other moving and stationary objects in its immediate environment.	Potential energy is not relative to the environment of an object.
Transferability	Kinetic energy can be transferred from one moving object to another, say, in collisions.	Potential energy cannot be transferred.
Determining factors	Speed/velocity and mass	Height or distance and mass
Examples	Flowing water, such as when falling from a waterfall	Water at the top of a waterfall, before the precipice.

4.4.3 List units of energy. (COGNITIVE LEVEL:K)

UNITS OF ENERGY:

(i) Joule
(ii) Calorie [1 Calorie =4.2 joule]
(iii) Kilo Watt Hour [1Kwh=3.6 x 10^6 J]

4.5 WORK-ENERGY RELATION

4.5.1 Deduce how energy is related with work

(i) when friction is present

(ii) when friction is not present; (COGNITIVE LEVEL:A)

WORK ENERGY EQUATION

DERIVATION:

Let us consider a body of mass "m" is placed at point A at a height h from the surface of earth.At this point the body possesses gravitational potential energy equal to mgh w.r.t point C lying on the ground.

Now consider a point B at a distance x below the point A during downward motion of body.At this stage the height of the body becomes (h-x).

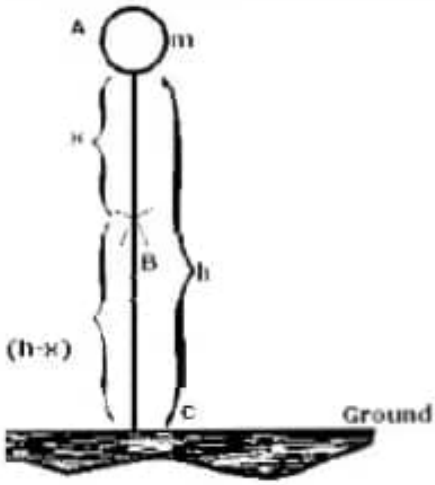
so, potential energy at point B becomes,

$$P.E=mg(h-x)$$

As we know that potential energy at point B is less than the potential energy at point A,i.e.

$$mg(h-x) < mgh$$

or $$mgh - mgx < mgh$$



The loss in potential energy at point B is mgx.

The Kinetic Energy at point A is equal to zero because the body is at rest.During its downward motion its velocity increases ,so its kinetic energy also increases.If there is no air friction then the loss of P.E is equal to the gain in K.E, means P.E is converted into K.E.

When the body reaches at point C its P.E becomes zero which means all of its P.E is converted into K.E,so we can write as

Loss in P.E = Gain in K.E

Practically there is always a force of friction which opposes the downward motion of the body.Let if friction f is present in this case then some amount of P.E is lost in work done against friction.Now, the modified equation can be written as,

Loss in P.E = Gain in K.E + Work done against friction

$$mgx = 1/2\, mv^2 + fx$$

or $$1/2\, mv^2 = mgx - fx$$

In terms of "h"

$$\boxed{1/2\, mv^2 = mgh - fh}$$

The above equation is known as "Work Energy Equation".

4.6 ABSOLUTE GRAVITATIONAL ENERGY

4.6.1 Analyze the absolute gravitational energy. (COGNITIVE LEVEL:A)

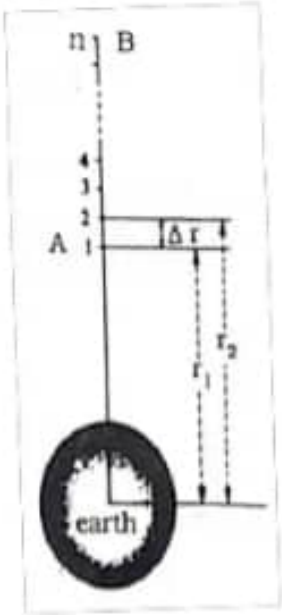
The potential energy of a body at height "h" from centre of earth w. r.t. a point at which the gravitational field is zero i.e. a point which has no potential is called absolute gravitational potential energy.

$$P.E(abs) = U = -\frac{GmM_e}{R_E}$$

Where R_E is the radius of earth.The minus sign indicates that the potent ial energy is "negative" at any finite distance that is the potential energy is zero at infinity and decreases as the separation distance decreases. This is due to the fact that the gravitational force acting on the particle by earth is attractive. As the particle moves in from infinity the Work is positive which means U is negative.

4.6.2 Derive an expression for absolute P.E . (COGNITIVE LEVEL:U)

Gravitational Potential Energy(G.P.E.):



In order to derive formula for gravitational potential energy ,we have assumed that throughout the displacement of the body from the initial position to the final position force of gravity remains constant. But for large displacements (height h) as measured from the surface of the earth. e.g in space flights we cannot take the gravitational force as constant. In fact. it decreases with the increase of height. Hence to calculate the work done (which is a measure of R_e) against the force of gravity the simple formula F .S cannot be applied.

To overcome this difficulty we divide the entire displacement into a large number of small displacement intervals and applying Newton's Law of Gravitation.

A point B is situated at large distance from the surface of earth. In order to find work done in bringing the mass "m" fro initia l position A or 1 to final position B or n. We divide the distance between A and B into large number say, n of intervals of equal width Δreach.

Since Δr is small,the force of gravity throughout this in can be assumed to be constant. This value of constant force may taken as the average of the forces acting at the two ends of an interval. The magnitude F_1, of the force $\vec{F}_1$ acting at the point 1 (first end of the first interval) is given by

$$F_1 = \frac{GmM_e}{{r_1}^2}$$

Here M_e is the mass of earth. G is universal gravitational constant and r_1 is the distance of the point 1 from the centre of the earth.Similarly the magnitude F_2 of the force F_2 acting at point 2 is given by

$$F_2 = \frac{GmM_e}{{r_2}^2}$$

The average force acting throughout the first interval

$$F = \frac{F_1 + F_2}{2}$$

where F represents the magnitude of the average force ,therefore

$$F = \frac{GmM_e}{2}\left[\frac{1}{{r_1}^2} + \frac{1}{{r_2}^2}\right]$$

$$F = \frac{GmM_e}{2}\left[\frac{{r_2}^2 + {r_1}^2}{{r_1}^2\ {r_2}^2}\right]$$

$$F = \frac{GmM_e}{2}\left[\frac{(r_1+\Delta r)^2 + {r_1}^2}{{r_1}^2\ {r_2}^2}\right] \qquad [\because r_2 = r_1 + \Delta r]$$

$$F = \frac{GmM_e}{2}\left[\frac{{r_1}^2 + 2r_1\Delta r + \Delta r^2 + {r_1}^2}{{r_1}^2\ {r_2}^2}\right]$$

as Δr is very small, Δr^2 is negligibly small,

$$F = \frac{GmM_e}{2}\left[\frac{2{r_1}^2 + 2r_1\Delta r}{{r_1}^2\ {r_2}^2}\right] = F = \frac{GmM_e}{2}\left[\frac{2r_1(r_1+\Delta r)}{{r_1}^2\ {r_2}^2}\right]$$

$$F = \frac{GmM_e}{r_1 r_2}$$

The work done in lifting the body from point 1 (position A) to point 2 by an applied force. which is equal and opposite to the average gravitational force is given by

$$W_{12} = \vec{F}.\overrightarrow{\Delta r}$$

Since the applied force F and displacement Δr are in the same direction.

$$W_{12} = F\Delta r$$

substituting for F, Δr in the above equation. we get

$$W_{12} = \frac{GmM_e}{r_1 r_2}(r_2 - r_1)$$

$$W_{12} = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Similarly the work done in lifting the body from point 2 to 3, 3 to 4,…and so on

$$W_{23} = GmM_e\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$$

$$W_{(n-1)n} = GmM_e\left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

Hence the total work done by the applied force in lifting the body from initial position A to final position B,we get

$$W = W_{12} + W_{23} \ldots + W_{(n-1)n}$$

$$W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right) + GmM_e\left(\frac{1}{r_2} - \frac{1}{r_3}\right) \ldots + GmM_e\left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

$$W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_3} - \frac{1}{r_4} \ldots + \frac{1}{r_{n-2}} - \frac{1}{r_{n-1}} + \frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

$$\boxed{W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_n}\right)}$$

This is the P.E represented by U of the body at the point B with respect to the point A. Hence the potential energy of the body at the point A with respect to that at the point B is $\Delta U = -W$

$$\Delta U = -GmM_e\left(\frac{1}{r_1} - \frac{1}{r_n}\right)$$

or $$\boxed{\Delta U = GmM_e\left(\frac{1}{r_n} - \frac{1}{r_1}\right)}$$ => Gravitational Potential Energy

When the point B lies at an infinite distance i.e. r_n the P.E. at that point is zero (this point becomes reference point) then a

$$U = -\frac{GmM_e}{r_1}$$

or $$U = -\frac{GmM_e}{r_1}$$

Therefore the absolute P.E of a body of mass m lying at the surface of the earth is given by

$$\boxed{P.E(abs) = U = -\frac{GmM_e}{R_E}}$$

4.7 ESCAPE VELOCITY

4.7.1 Describe the concept of escape velocity. (COGNITIVE LEVEL:U)

ESCAPE VELOCITY:

If you throw an object straight up, it will rise until the the negative acceleration of gravity stops it, then returns it to Earth. Gravity's force diminishes as distance from the center of the Earth increases, however. So if you can throw the object with enough initial upward velocity so that gravity's decreasing force can never quite slow it to a complete stop, its decreasing velocity can always be just high enough to overcome gravity's pull. The initial velocity needed to achieve that condition is called escape velocity.

4.7.2 Derive the formula for escape velocity. (COGNITIVE LEVEL:U)

DERIVATION:

In order to escape from the gravitational pull the body should be thrown with a energy which is equal to the absolute gravitational potential energy. Let us consider a body of mass "m" is thrown with velocity "v".If "M" is the mass of earth and "R" is the radius of earth then we can write as

$$\frac{1}{2}mv^2 = \frac{GMm}{R}$$

$$\boxed{v = \sqrt{\frac{2GM}{R}}}$$

As we know that

$$g = \frac{GM}{R^2}$$

therefore,

$$\boxed{v = \sqrt{2gR}}$$

4.7.3 Calculate escape velocity for the moon and the earth when mass and radius of the bodies are given and use this formula for solving numerical. (COGNITIVE LEVEL:A)

ESCAPE VELOCITY FOR THE MOON:

Mass of Moon= 7.35 x10^{22} kg

Radius of Moon=1.738 x 10^6 km

According to the definition of Escape Velocity,

$$v = \sqrt{\frac{2GM}{R}}$$

Putting the values in above formula, we get

$$v = \sqrt{\frac{2(6.67\times10^{-11})(7.35\text{ x}10^{22})}{1.738\text{ x }10^6}}$$

$$v = 2.38\ \times 10^3 \frac{m}{s}$$

or $$\boxed{v = 2.38\ \frac{km}{s}}$$

ESCAPE VELOCITY FOR THE EARTH:

Mass of Earth= 7.35 x10^{22} kg

Radius of Earth=1.738 x 10^6 km

According to the definition of Escape Velocity,

$$v = \sqrt{\frac{2GM}{R}}$$

Putting the values in above formula, we get

$$v = \sqrt{\frac{2(6.67\times10^{-11})(5.98\,\text{x}10^{24})}{6.38\,\text{x}\,10^{6}}}$$

$$v = 11.2 \times 10^{3}\,\frac{m}{s}$$

or $$\boxed{v = 11.2\,\frac{km}{s}}$$

4.8 CONSERVATION OF ENERGY

4.8.1 Explain the law of conservation of energy. (COGNITIVE LEVEL:U)

LAW OF CONSERVATION OF ENERGY

STATEMENT:

According to the law of conservation of energy
" Energy can neither be created nor it is destroyed, however energy can be converted from one from energy to any other form of energy".

Explanation:

Consider a body of mass "m" at height h above the ground. Its kinetic energy at that point A is:

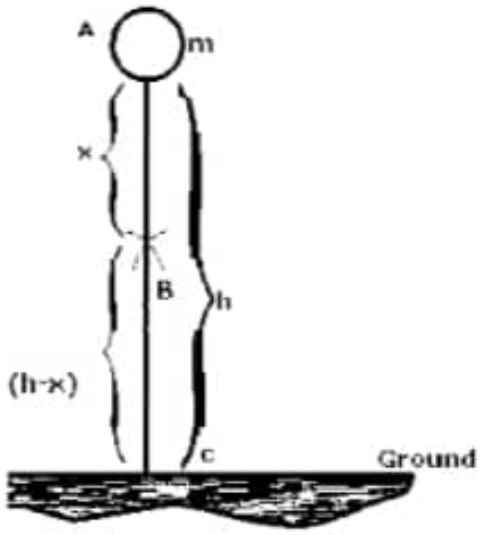
1. At Point A:

A/c to the definition of Kinetic Energy

K.E = 1/2(mv^2)

K.E = 1/2 m * (0) (At point A body is at rest)

K.E = 0 ..... (i)



The potential Energy at point A is :

P.E = mgh .....(ii)

So the total energy at point A will be :

T.E = K.E + P.E

E(A) = 0 + mgh

$\boxed{E(A) = mgh}$ ----------(A)

2. At Point B:

Suppose the body is released from this height and falls through a distance x. Its new height will be (h-x). The velocity with which it reaches point B is calculated by using the third equation of motion:

$$2gs = V_f^2 - Vi^2$$

As we know:

* $Vi = 0$
* $S = x$

Therefore,

$$2gx = V_f^2 - 0$$

$$2gx = v^2$$

The kinetic energy at point B is:

$$K.E. = 1/2\ mv^2$$

Substituting the value of v^2:

$$K.E. = 1/2 \times m \times 2gx$$

$$K.E = mgx$$

The Potential Energy at point B is:

$$P.E = mgh$$

The height of the body is (h-x):

$$P.E. = mg(h-x)$$

The total energy at point B is :

$$E(B) = P.E + K.E.$$

$$E(B) = mgx + mg(h-x)$$

$$E(B) = mgx + mgh - mgx$$

$$\boxed{E(B) = mgh} \text{---------(B)}$$

3. At Point C:

Now the body reaches at point "C" which is just before striking the ground.

The Potential Energy at point C is:

$$P.E = 0 \qquad (h=0)$$

The velocity with which it reaches point C is calculated by using the third equation of motion:

$$2gs = V_f^2 - Vi^2$$

As we know:

* $Vi = 0$
* $S = h$

Therefore,

$$2gh = V_f^2 - 0$$

$$2gh = v^2$$

The kinetic energy at point B is:

$$K.E. = 1/2\ mv^2$$

Substituting the value of v^2:

$$K.E. = 1/2 \times m \times 2gh$$

$$K.E = mgh$$

The total energy at point B is :

$$E(C) = P.E + K.E.$$

$$E(C) = 0 + mgh$$

$$\boxed{E(C) = mgh} \text{ ----------(C)}$$

Hence, the total energy at point A ,B and C are same. It means that the total value of energy remains constant.That is, Law of conservation of energy.

4.8.2 Demonstrate potential energy and kinetic energy in a resistive medium. (COGNITIVE LEVEL:U)

Practically there is always a force of friction which opposes the downward motion of the body.Let if friction f is present in this case then some amount of P.E is lost in work done against friction.Now, the modified equation can be written as,

Loss in P.E = Gain in K.E + Work done against friction

$$mgx = 1/2\ mv^2 + fx$$

or $$1/2\ mv^2 = mgx - fx$$

In terms of "h"

$$\boxed{1/2\ mv^2 = mgh - fh}$$

4.9 TYPES OF ENERGY SOURCES

4.9.1 List the conventional and non-conventional energies. (COGNITIVE LEVEL:K)

(A) CONVENTIONAL ENERGY SOURCES:

1. Coal
2. Petroleum and natural gases
3. Fuel woods
4. Hydropower
5. Nuclear energy

(B) NON CONVENTIONAL ENERGY SOURCES:

1. Solar energy
2. Wind energy
3. Tidal energy
4. Geothermal energy
5. Bio-mass based energy
6. Biogas

4.9.2 Describe the uses of energy. (COGNITIVE LEVEL:U)

General uses of energy are divided into three economic sectors; they are:

1. RESIDENTIAL USES OF ENERGY:

When we talk about residential uses of energy, these are the most basic uses of energy. They include watching television, washing clothes, heating and lighting the home, taking a shower, working from home on your laptop or computer, flushing the toilet and cooking. Residential uses of energy account for almost forty percent of total energy use globally.

Wastage In this category of use is also the highest globally. This can be attributed to the lack of education offered to the public on how to conserve the energy they use daily, or to the lack of inventions available in the market. Most people are ignorant to the fact that there are avenues or

companies and innovations available that can help them monitor and reduce the amount of energy they use.

2. COMMERCIAL USES OF ENERGY:

Commercial use of energy is what energy is used for in the commercial sector. This includes lighting of commercial buildings and spaces, power used by companies and business throughout our cities for computers, fax machines, workstations, copiers just to name but a few.

The uses of energy in the commercial space is more or less similar to the uses in the industrial space save for personal uses. Energy saving here though, is targeted at the corporate world rather than at individuals. Players in the sector of energy conservation should introduce energy saving campaigns in order to curb the culture of wastage present at our places of work.

3. TRANSPORTATION:

Transportation is one hundred percent dependent on energy. Over seventy percent of petroleum used goes into the transport sector. The transport sector includes all vehicles from personal cars to trucks to buses and motorcycles. It also includes aircrafts, trains, ship and pipelines.

The transportation sector can be very vital in the overall quest for energy conservation. Innovations such as the introduction of more fuel efficient vehicles and development of alternative sources of energy for our transport system can greatly help in the saving of energy

Efforts at energy conservation can be made on a global scale if we factor in the uses and deal with them one by one. If we focus on them as individual uses rather than trying to find a solution as a whole, we will make much bigger strides in conservation.

5.1 ANGULAR MOTION

5.1.1 Define angular displacement, angular velocity and angular acceleration.(COGNITIVE LEVEL:K)

ANGULAR DISPLACEMENT:

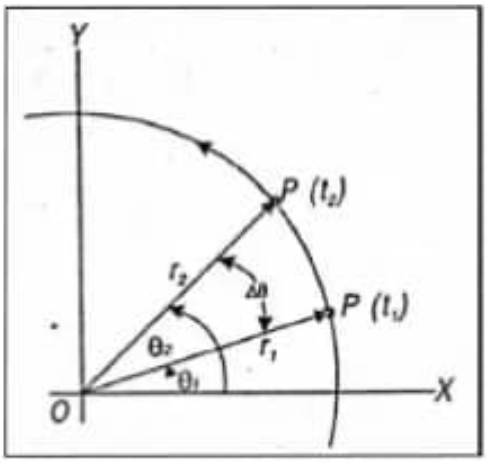
The angle, through which a body moves while moving along a circular path, is called as angular displacement. It is the angle subtended at the center during angular motion. Angular displacement is measured in degree and radian.

ANGULAR VELOCITY:

In circular motion of a particle P the rate of change of angular displacement is called angular velocity and it is denoted by "(i)". If 'AB' is the change in angular displacement during time interval Δt due to the motion of particle P along a circular path then average angular velocity will be

$$\omega_{av} = \frac{\Delta\theta}{\Delta t}$$

$$\omega_{av} = \frac{\theta_2 - \theta_1}{t_2 - t_1}$$



If the interval Δt is very small i.e., Δt → 0 then angular velocity during such a short time interval will be called instantaneous angular velocity. i.e.

$$\omega_{ins} = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$$

ANGULAR ACCELARATION:

The rate of change of angular velocity is called angular acceleration and it is denoted by ' ∝'. If $\Delta\omega$ is the change in angular velocity during time interval Δt due to the motion of a point along circular path then average angular acceleration will be,

$$\propto_{av} = \frac{\Delta\omega}{\Delta t}$$

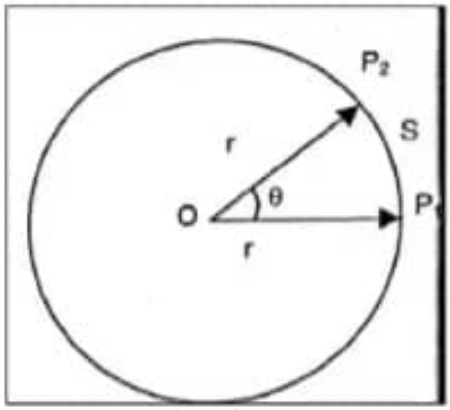
$$\propto_{av} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$$

Now if the time interval for this change is very small then angular acceleration on during such a short time interval is called instantaneous angular acceleration.i.e.

$$\propto_{ins} = \lim_{\Delta t \to 0} \frac{\Delta \omega}{\Delta t}$$

5.1.2 Investigate the relation between linear and angular displacement, velocity and acceleration.(COGNITIVE LEVEL:U)

RELATION BETWEEN LINEAR AND ANGULAR DISPLACEMENT:



It is clear from the figure that the arc length is directly proportional to the angle subtended at the center.

Mathematically we can write as,

$$S \propto \theta$$

or

$$\boxed{S = r\theta}$$

Where, r is the radius of circle and angle is measured in Radian.

RELATION BETWEEN LINEAR AND ANGULAR VELOCITIES:

We know that

$$S = r\theta$$

But in case of small angular displacement due to circular motion of particle P along circle of radius r, we may write this equation

$$\Delta S = r\Delta\theta$$

Divide both sides by Δt

$$\frac{\Delta S}{\Delta t} = r\frac{\Delta\theta}{\Delta t}$$

Taking limits on both sides

$$\lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t} = r \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} \text{ ------(i)}$$

As we know that

$$v = \lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t}$$

And

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$$

Therefore eq(i) , becomes

$$\boxed{V = r\omega}$$

or

$$\vec{V} = \vec{r} \times \vec{\omega}$$

RELATION BETWEEN LINEAR AND ANGULAR ACCELERATION:

We have the relation between linear and angular velocities as $V = r\omega$. Suppose an object rotating about a fixed axis, changes it angular velocity by $\Delta\omega$ in a time change Δt then the change in tangential velocity.

$$V_t = r\omega$$

Divide both sides by Δt

$$\frac{\Delta V_t}{\Delta t} = r\frac{\Delta\omega}{\Delta t}$$

Taking limits on both sides

$$\lim_{\Delta t \to 0} \frac{\Delta V_t}{\Delta t} = r \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} \text{ ------(i)}$$

As we know that

$$a_t = \lim_{\Delta t \to 0} \frac{\Delta V_t}{\Delta t}$$

And $\propto = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t}$

Therefore eq(i) , becomes

$$\boxed{a_t = r \propto}$$

or

$$\boxed{\vec{a_t} = \vec{r} \times \vec{\propto}}$$

5.2 CENTRIPETAL FORCE AND CENTRIPETAL ACCELERATION

5.2.1 Define centripetal force and centripetal acceleration. (COGNITIVE LEVEL:K)

CENTRIPETAL ACCELARATION

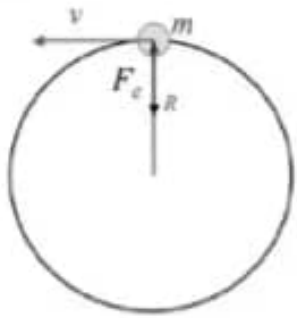
The acceleration in the motion of a body only due to the rate of change in direction of velocity is called centripetal acceleration as it is always directed towards centre of the circle or centre of curvature of the track.

FORMULA:

$$a_c = \frac{v^2}{r}$$

CENTRIPETAL FORCE:

"The force that causes an object to move along a curve (or a curved path) is called centripetal force."



FORMULA:

We know that the magnitude of centripetal acceleration of a body in a uniform circular motions is directly proportional to the square of velocity and inversely proportional to the radius of the path. Newton's Second Law of Motion:

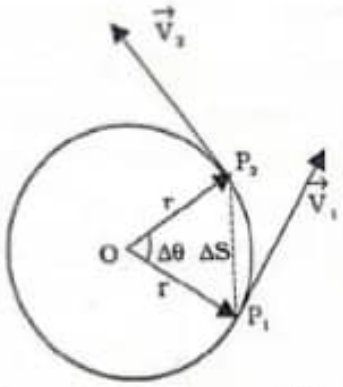
$$F = ma$$

$$\Rightarrow F_c = mv^2/r$$

5.2.2 Derive centripetal acceleration when velocity is uniform. (COGNITIVE LEVEL:U)

DERIVATION:

Let us consider a particle of mass m moving with uniform speed 'v' along a circular path of radius 'r'. Suppose its linear velocity vector at P_1 is $\vec{v_1}$ at time t_1 whereas velocity vector at P_2 is $\vec{v_2}$ at time t_2 , as shown in the figure.



In case of uniform motion

$$|v_1| = |v_2|$$

but from the figure

$$\vec{V_1} + \Delta\vec{V} = \vec{V_2}$$

$$\Delta\vec{V} = \vec{V_2} - \vec{V_1}$$

This change in velocity is only because of the change in its direction. So its rate of change will be called centripetal acceleration. As we know that the angle between perpendiculars to the two lines is same as the angle between these two lines, therefore, the angle between V_1 and V_2 is $\Delta\theta$ as the angle between radial lines is $\Delta\theta$.

It is clear from fig (i) and (ii) that the isosceles triangle ΔP_1OP_2 and ΔBAC are congruent. Then according to geometry,

$$\frac{\Delta S}{r} = \frac{\Delta V}{V}$$

$$\Delta V = \frac{V\Delta S}{r}$$

Divide both sides by Δt

$$\frac{\Delta V}{\Delta t} = \frac{V\Delta S}{r\Delta t}$$

Taking limit both sides as $\Delta t \rightarrow 0$

$$\lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t} = \frac{V}{r} \lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t} \text{----------(i)}$$

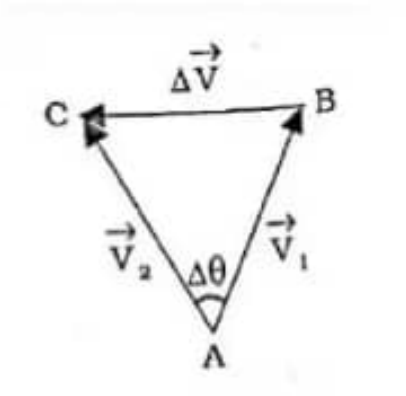
As we know that

$$V = \lim_{\Delta t \to 0} \frac{\Delta S}{\Delta t}$$

and $$a_c = \lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t}$$

Then eq (i) becomes

$$\boxed{a_c = \frac{v^2}{r}}$$



5.2.3 Relate centripetal acceleration with the angular velocity. (COGNITIVE LEVEL:U)

According to the definition of c3entripetal acceleration

$$a_c = \frac{v^2}{r} \text{------(i)}$$

As we know that

$$V = r\omega$$

putting in eq(i)

$$a_c = \frac{(r\omega)^2}{r}$$

$$\boxed{a_c = r\omega^2}$$

5.3 MOMENT OF INERTIA

5.3.1 Define moment of inertia and its formula. (COGNITIVE LEVEL:K)

MOMENT OF INERTIA:

The moment of inertia is a value that measures how difficult it is to change the state of an object's rotation. The moment of inertia depends on the mass and shape of an object, and the axis around which it rotates.

FORMULA:

$$\boxed{I = mr^2}$$

Where ,I = Moment of inertia

m= Mass of Body

r= Radius

5.4 ANGULAR MOMENTUM

5.4.1 Define angular momentum and state its S.I. unit with dimension. (COGNITIVE LEVEL:K)

DEFINITION: Angular momentum of an object moving in a circle is the cross product of linear momentum and position vector from the origin."

EXPLANATION:

A body having rotatory motion possesses angular velocity and angular momentum.

Consider a particle of mass 'm' let r be its position vector and P be the linear momentum with respect to origin.

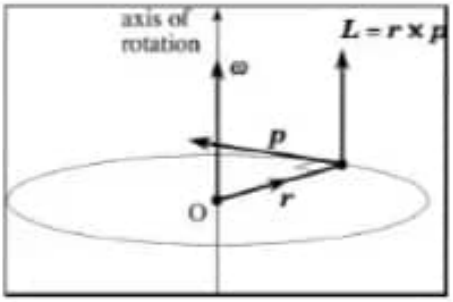
From Definition,

Angular momentum = Position Vector X Linear Momentum

$$\vec{l} = \vec{r} \times \vec{P}$$

$$\vec{l} = \vec{r} \times m\vec{v} \quad [P = mv]$$

$$\vec{l} = m\vec{r} \times \vec{v}$$



where, $\vec{v}$ be the velocity of the particle.

DIMENSION AND UNIT:

The dimension of angular momentum is

$$[l] = [r]\,[p] = [r]\,[m]\,[v] = L.M.L/T = L^2MT^{-1}$$

In S.I system its units is NmS = J.S.

5.4.2 Explain the law of conservation of angular momentum. (COGNITIVE LEVEL:U)

LAW OF CONSERVATION OF ANGULAR MOMENTUM

STATEMENT:

The angular momentum of a particle is conserved (constant) if the torque acting on it is zero."

EXPLANATION:

If F is the force acting on a particle of mass 'm' moving with velocity V and P is the linear momentum, then,

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$= \vec{r} \times \frac{\vec{P_f} - \vec{P_i}}{\Delta t} \quad \because \text{Force is the rate of change of momentum}$$

$$= \frac{\vec{r} \times \vec{P_f} - \vec{r} \times \vec{P_i}}{\Delta t}$$

$$= \frac{\vec{L_f} - \vec{L_i}}{\Delta t} \qquad \because \vec{L} = \vec{r} \times \vec{P}$$

$$\vec{\tau} = \frac{\Delta \vec{L}}{\Delta t}$$

This equation states that the torque acting on a particle is the time rate of change of its angular momentum.

If net torque acting on the particle is zero, Then,

$$\frac{\Delta \vec{L}}{\Delta t} = 0$$

or $\quad \Delta \vec{L} = 0 \quad \Rightarrow \quad \boxed{\vec{L} = Constant}$

thus, angular momentum of a particle is conserved, i.e. law of conservation of angular momentum.

5.5 ROTATIONAL KINETIC ENERGY

5.5.1 Define rotational kinetic energy. (COGNITIVE LEVEL:K)

ROTATIONAL KINETIC ENERGY:

The kinetic energy of a rotating object is analogous to linear kinetic energy and can be expressed in terms of the moment of inertia and angular velocity. The total kinetic energy of an extended object can be expressed as the sum of the translational kinetic energy of the center of mass and the rotational kinetic energy about the center of mass. For a given fixed axis of rotation, the rotational kinetic energy can be expressed in the form

$$\boxed{K.E_{rotational} = \frac{1}{2} I\omega^2}$$

5.5.2 Derive an expression for rotational kinetic energy and use this expression for solving numerical. (COGNITIVE LEVEL:A)

DERIVATION:

According to the definition of Kinetic Energy

$$K.E = \frac{1}{2} mv^2 \text{ ---------(i)}$$

The relation between linear and angular velocity is given by

$$v = r\omega$$

putting in eq(i), we get

$$K.E_{rotational} = \frac{1}{2} m(r\omega)^2$$

$$K.E_{rotational} = \frac{1}{2} mr^2\omega^2$$

As we know that

$$I = mr^2$$

then Rotational Kinetic Energy is given by

$$\boxed{K.E_{rotational} = \frac{1}{2} I\omega^2}$$

PROBLEM 1: Khizar rolls a bowling ball of mass 7 kg and radius 10.9 cm down a lane with a velocity of 6 m/s. Find the rotational kinetic energy of the bowling ball, assuming it does not slip.(For Sphere=I=2/5 mr^2).

SOLUTION:

First we have to find moment of inertia

$$I = \frac{2}{5}mr^2 = \frac{2\times7\times(0.109)^2}{5} = 0.033\ kg-m^2$$

Now we will find the value of ω,

$$\omega = \frac{V}{r} = \frac{6}{0.109} = 55\ rad/s$$

Now,

$$K.E_{rotational} = \frac{1}{2}I\omega^2 = \frac{1}{2}\times 0.033 \times (55)^2$$

$$K.E_{rotational} = 50.4\,J$$

PROBLEM 2: A typical ten-pound car wheel has a moment of inertia of about 0.35 kg m^2. The wheel rotates about the axle at a constant angular speed making 50 full revolutions in a time interval of 7 s.What is the rotational kinetic energy of the rotating wheel?

SOLUTION: For constant angular speed

$$\omega = \frac{\theta}{t} = \frac{2\times\pi\times50}{7} = 48.9\frac{rad}{s}$$

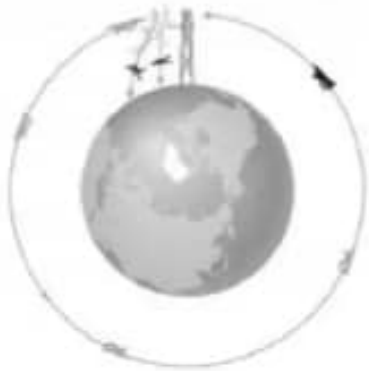
Now, $K.E_{rotational} = \frac{1}{2}I\omega^2 = \frac{1}{2}\times 0.35 \times (48.9)^2 = 352\,J$

5.6 ARTIFICIAL SATELLITES AND WEIGHTLESSNESS

5.6.1 Define weightlessness in artificial satellites. (COGNITIVE LEVEL:K)

WEIGHTLESSNESS IN ARTIFICIAL SATELLITES:

Weight is the manifestation of the Earth's gravitational attraction of you to it. When a satellite is orbiting the Earth, it is falling towards the Earth because of its weight and it is also moving forward at some speed. When the forward speed and the falling tendency are balanced, the satellite never loses altitude. It remains the same height off the surface of the Earth. Due to the free fall motion of satellite the objects or people in the satellite will feel zero gravity and this is weightlessness in satellites.



5.6.2 Classify different types of satellites. (COGNITIVE LEVEL:U)

1. ASTRONOMICAL SATELLITES:

Astronomical satellites are satellites used for observation of distant planets, galaxies, and other outer space objects.

2.BIOSATELLITES:

Biosatellites are satellites designed to carry living organisms, generally for scientific experimentation.

3.COMMUNICATIONS SATELLITES:

Communications satellites are satellites stationed in space for the purpose of telecommunications. Modern communications satellites typically use geosynchronous orbits, Molniya orbits or Low Earth orbits.

4.NAVIGATIONAL SATELLITES:

Navigational satellites are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracy on the order of a few meters in real time.

5. RECONNAISSANCE SATELLITES:

Reconnaissance satellites are Earth observation satellite or communications satellite deployed for military or intelligence applications. Very little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.

6. EARTH OBSERVATION SATELLITES:

Earth observation satellites are satellites intended for non-military uses such as environmental monitoring,meteorology, map making etc. (See especially Earth Observing System.)

7. TETHER SATELLITES:

Tether satellites are satellites which are connected to another satellite by a thin cable called a tether.Weather satellites are primarily used to monitor Earth's weather and climate.

8. RECOVERY SATELLITES:

Recovery satellites are satellites that provide a recovery of reconnaissance, biological, space-production and other payloads from orbit to Earth.

9. MANNED SPACECRAFT (SPACESHIPS):

Manned spacecraft (spaceships) are large satellites able to put humans into (and beyond) an orbit, and return them to Earth. Spacecraft including space planes of reusable systems have major propulsion or landing facilities. They can be used as transport to and from the orbital stations.

5.6.3 Define geostationary orbits. (COGNITIVE LEVEL:K)

GEOSTATIONARY ORBIT:

A geostationary orbit, geostationary Earth orbit or geosynchronous equatorial orbit (GEO) is a circular orbit 35,786 kilometers (22,236 mi) above the Earth's equator and following the direction of the Earth's rotation. An object in such an orbit has an orbital period equal to the Earth's rotational period (one sidereal day) and thus appears motionless, at a fixed position in the sky, to ground observers. Communications satellites and weather satellites are often placed in geostationary orbits, so that the satellite antennas (located on Earth) that communicate with them do not have to rotate to track them, but can be pointed permanently at the position in the sky where the satellites are located.

A geostationary orbit is a particular type of geosynchronous orbit, the distinction being that while an object in geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position.

5.6.4 Derive expression for geostationary orbits altitudes. (COGNITIVE LEVEL:U)

DERIVATION FOR GEOSTATIONARY ORBITS:

In case of circular orbit the centripetal force is provided by the gravitational force on satellite.

Therefore $F_C = F_g$

$$\frac{mv^2}{r} = \frac{GM_e m}{r^2}$$

where m is the mass of satellite, M_e is the mass of earth, v is the orbital velocity,r is the altitude of satellite.Now,

$$v^2 = \frac{GM_e}{r} \text{ ------(i)}$$

As we know that the relation between linear and angular velocity is given by

$$v = r\omega$$

Putting in eq(i), we get

$$(r\omega)^2 = \frac{GM_e}{r}$$

$$r^2\omega^2 = \frac{GM_e}{r}$$

$$r^3 = \frac{GM_e}{\omega^2}$$

or $r^3 = \frac{GM_e T}{4\pi^2}$ (b/c $\omega = \frac{2\pi}{T}$)

$$\boxed{r = \sqrt[3]{\frac{GM_e T}{4\pi^2}}}$$

In case of geostationary satellites the time period T=24 hours.

5.6.5 Explain how artificial gravity can be produced when a satellite revolves around the earth. (COGNITIVE LEVEL:U)

ARTIFICIAL GRAVITY

INTRODUCTION:

All orbiting satellites along with their astronauts and other objects are in a state of free fall and consequently will be in a state of weightlessness. Weightlessness in space craft is highly inconvenient to an astronaut in a number of ways.

For example he cannot pour liquid into a glass, neither he can drink properly. In order to overcome this problem, artificial gravity is produced in the spacecrafts.

EXPLANATION:

In order to produce an artificial gravity in the space craft, the laboratory of space craft is rotated with suitable frequency about its own axis. The rotation is so maintained that the astronaut do not feel weightlessness. The frequency of rotation depends on the length of laboratory of space craft.

Consider a space craft whose laboratory is 'L' meter long consisting of two chambers connected by a tunnel. Let us see how many revolutions per second must the space craft make in order to supply artificial gravity for the astronauts.

Let 'T' be the time for one revolution and 'f' be the frequency of rotation.

When the laboratory revolves, a centripetal accelaration is experienced by the astronauts.

$a_c = \frac{v^2}{r}$

Where a_c is the centripetal acceleration

Since radius of laboratory is R , therefore,

$a_c = \frac{v^2}{R}$ --------(iv)

Now we will determine the linear speed of the laboratory.

As we know that V= $R\omega$

$a_c = \frac{(R\omega)^2}{R}$

Now, $\omega = 2\pi f$

so,

$a_c = \frac{R^2(2\pi f)^2}{R}$

$a_c = 4\pi^2 f^2 R$

or $f^2 = \frac{a_c}{4\pi^2 R}$

Taking square roots on both sides

$$f = \sqrt{\frac{a_c}{4\pi^2 R}}$$

or

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{a_c}{R}}}$$

Let, R=10 m and a_c=g=9.8 m/s^2

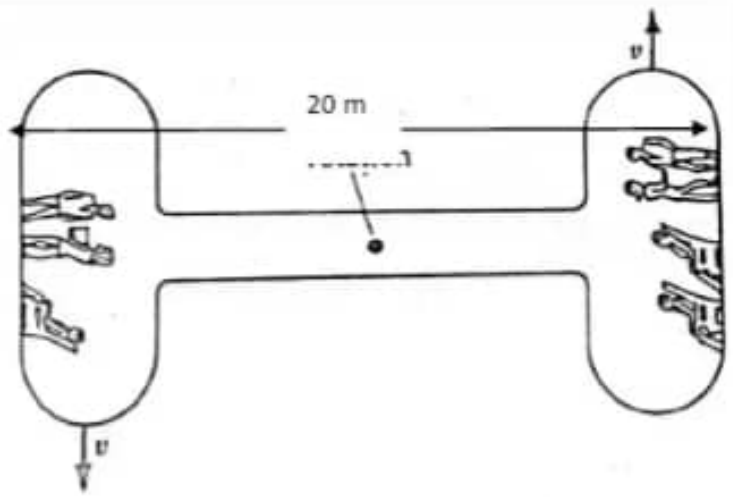
now, f becomes => $f = \frac{1}{2(3.14)}\sqrt{\frac{9.8}{10}}$

$$f = 0.158\, rev/sec$$

or

$$f = 9.5\, rev/min$$

So, in order to produce artificial gravity on a satellite of length 20m it should be rotated at a rate of 9.5 rev/min.



5.7 ORBITAL VELOCITY

5.7.1 Define orbital velocity. (COGNITIVE LEVEL:K)

DEFINITION:

Objects that travel in uniform circular motion around the Earth are said to be "in orbit". The velocity of this orbit depends on the distance from the object to the center of the Earth. The velocity has to be just right, so that the distance to the center of the Earth is always the same.This velocity is called orbital velocity.

5.7.2 Derive a relation for orbital velocity and use this relation for solving numerical. (COGNITIVE LEVEL:A)

DERIVATION FOR ORBITAL VELOCITY:

In case of circular orbit the centripetal force is provided by the gravitational force on satellite.

Therefore $F_C = F_g$

$$\frac{mv^2}{r} = \frac{GM_e m}{r^2}$$

where m is the mass of satellite, M_e is the mass of earth, v is the orbital velocity,r is the altitude of satellite.Now,

$$v^2 = \frac{GM_e}{r}$$

$$\boxed{v = \sqrt{\frac{GM_e}{r}}} \text{ ---------(i)}$$

As we know that

$$g = \frac{GM_e}{r^2}$$

so, $G = gr^2/M_e$

putting in eq(i), we get

$$v = \sqrt{\frac{\frac{gr^2}{M_e}M_e}{r}}$$

or $\boxed{v = \sqrt{gr}}$ --------(ii)

Equations (i) and (ii) gives the value of orbital velocity.

PROBLEM 1: A satellite orbits Earth at an altitude of 400 kilometers above the planet's surface. What is its speed in meters per second?

SOLUTION: First we convert altitude in meters

h =400 x 1000 = 4 x 10^5 m

Now using the fact that r = Re +h = 6.38 x 10^6 +4 x 10^5

r =6.78 x 10^6 m

Now, $v = \sqrt{\frac{GM_e}{r}}$

$$v = \sqrt{\frac{(6.67 \times 10^{-11}(5.98 \times 10^{24})}{6.78 \times 10^6}}$$

$$v = \sqrt{5.883 \times 10^7}$$

$$\boxed{v = 6.76 \times 10^3 m/s}$$

PROBLEM 2: The GMVX satellite is "pulled" along by the force of Earth's gravity at a speed of 1,200 meters per second. How many kilometers from Earth's center is the GMVX located?

SOLUTION: Using the formula $v = \sqrt{\frac{GM_E}{r}}$

$$1200 = \sqrt{\frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{r}}$$

S.O.B.S.

$$(1200)^2 = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{r}$$

$$r = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{1.44 \times 10^{6}}$$

$$\boxed{r = 2.8 \times 10^{8} m}$$

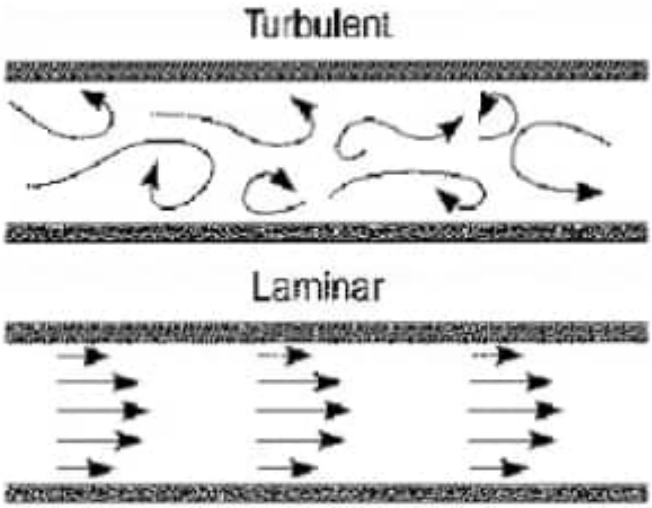
CHAPTER 6- FLUID DYNAMICS

6.1 STREAMLINE AND TURBULENT FLOW

6.1.1 Define streamline and turbulent flow and state the conditions for turbulent flow. (COGNITIVE LEVEL:K)

STREAMLINE FLOW:

The flow of a fluid is said to be streamline (also known as steady flow or laminar flow), if every particle of the fluid follows exactly the path of its preceding particle and has the same velocity as that of its preceding particle when crossing a fixed point of reference.



TURBULENT FLOW:

The flow of a fluid is said to be turbulent or disorderly, if its velocity is greater than its critical velocity. Critical velocity of a fluid is that velocity up to which the fluid flow is streamlined and above which its flow becomes turbulent. When the velocity of a fluid exceeds the critical velocity, the paths and velocities of the fluid particles begin to change continuously and haphazardly. The flow loses all its orderliness and is called turbulent flow.

CONDITIONS FOR TURBULENT FLOW:

1. The fluid should have large velocity.
2. The fluid should be less viscous.
3. The area of flow should be large.

6.2 EQUATION OF CONTINUITY

6.2.1 Derive the equation of continuity. (COGNITIVE LEVEL:U)

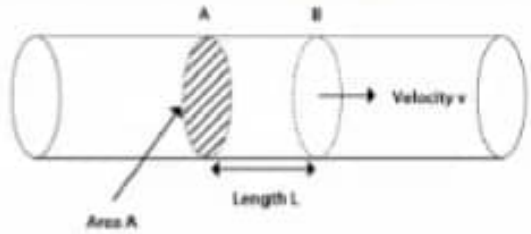
DERIVATION:

Consider an incompressible fluid (water is almost incompressible) flowing along a pipe, as in Figure 1. An incompressible fluid flowing along a pipe.

Its volume (V) is given by:

$$V = A.L \text{ ----------(i)}$$

Therefore the volume passing per second (the volumetric flow rate Q) is given by:



$$Q = V/t = A.L/t$$

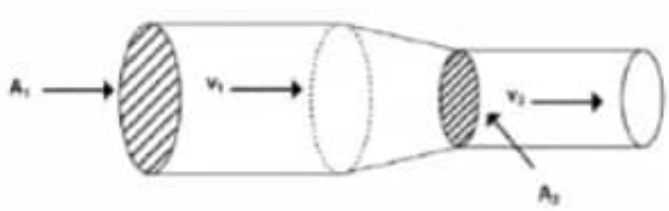
But we can write velocity as distance moved/time (see Equation (1)), so we can replace L/t by v:

$$Q = A.v$$

This is the Flow Equation.

Now consider pipes of different areas A_1 and A_2 as shown in Figure 2. The volumetric flow rate (Q) must be the same for both pipes, because we cannot gain or lose any fluid.

Therefore from Equation (1) above:



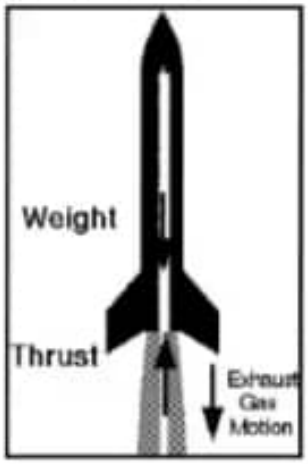
$$Q = A_1 v_1 = A_2 v_2$$

or

$$\boxed{A_1 v_1 = A_2 v_2}$$

This is the EQUATION OF CONTINUITY.

6.2.2 Describe the motion of a rocket on the basis of the equation of continuity. (COGNITIVE LEVEL:U)



Motion of the rocket is based of Newton's 3rd law of motion, which states that "for every action there is equal but opposite reaction". Hot gases are exhausted through nozzle of the rocket and produce the action force .The reaction force acting in the opposite direction is called the thrust. The thrust causes the rocket acceleration .rocket are propelled by the momentum reaction of the exhaust gases expelled from the tail. Since these gases arise from the reaction of the fuels carried in the rocket, the mass of the rocket is not constant but decreases as the fuel expended.

According to equation of continuity the net rate of flow of mass outwards across any closed surface is equal to the rate of decrease of the mass within the surface. Rocket works by rocket engine push in forward direction by simply throwing their exhaust backward very fast. The engine take in large volume of air that in compressed by the compressor. The air enters a combustion chamber where at mixes with the combustion gases. This increases the temperature of the air and its volume will increase many times than its original state.

As this air is expelled through the rear nozzles of the engine the tremendous thrust of the exhaust gases pushes against the atmosphere and the resultant equal and opposite force moves the rocket forwards. As it gain speed, the air intake flow and pressure increases the fuel accordingly and

the thrust in both directions increases the rocket's speed, Speed is then controlled by the fuel supply to the combustion chambers.

In rockets the area of crossection for the ejection of gases is made small, so according to the equation of continuity the speed of gases increases,this leads to raise the speed (and momentum) of the rocket, and change in momentum becomes rapid.As change in momentum gives force, the force on the rocket increases and it flies fast.

6.2.3 Solve problems by using this equation. (COGNITIVE LEVEL:A)

PROBLEM #1: On a circular conduit there are different diameters: diameter D_1 = 2 m changes into D_2 = 3 m. The velocity in the entrance profile was measured: v_1 = 3 ms^{-1}.Calculate the discharge velocity.

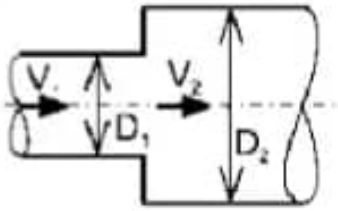


Figure 1

Solution:

$$Q = A_1 v_1 = \frac{\pi d_1^2}{4} v_1 = \frac{(3.14)(2)^2}{4} \times 3 = 9425\ m^3/sec$$

Now the discharge velocity can be found by using equation of continuity.

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{Q}{A_2} = 9425/\ \frac{\pi d_2^2}{4}$$

$$v_2 = \frac{9425}{\frac{(3.14)(3)^2}{4}} = 1333\frac{m}{s}$$

$\boxed{v_2 = 1333\frac{m}{s}}$ (Answer)

6.3 BERNOULLI'S EQUATION

6.3.1 Derive Bernoulli's equation. (COGNITIVE LEVEL:U)

DERIVATION:

Consider the case of water flowing though a smooth pipe. Such a situation is depicted in the figure below. We will use this as our working model and obtain Bernoulli's equation employing the work-energy theorem and energy conservation.

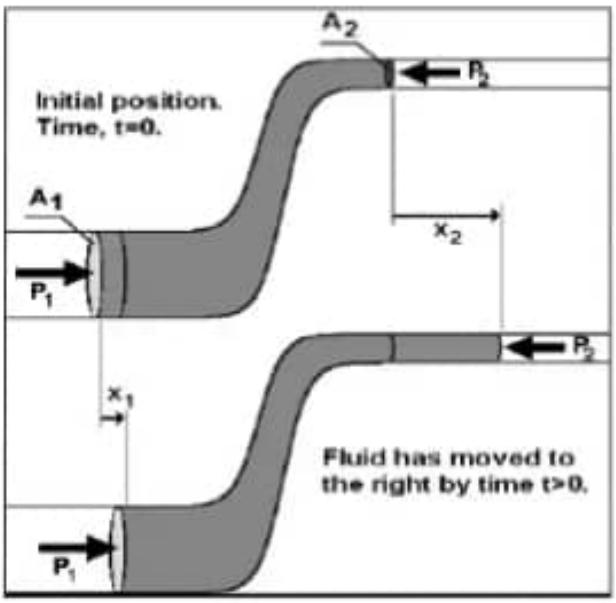
We examine a fluid section of mass m traveling to the right as shown in the schematic above. The net work done in moving the fluid is

$$Net\ work\ done\ = W_1 - W_2$$

$$W = F_1 x_1 - F_2 x_2 \text{ ------eq(1)}$$

where F denotes a force and an x a displacement. The second term picked up its negative sign because the force and displacement are in opposite directions.Pressure is the force exerted over the cross-sectional area, or P = F/A. Rewriting this as F = PA and substituting into Eq.(1) we find that

$$W = P_1A_1x_1 - P_2A_2x_2 \text{ ----------eq(2)}$$



The displaced fluid volume V is the cross-sectional area A times the thickness x. This volume remains constant for an incompressible fluid, so

$$V = A_1x_1 = A_2x_2 \text{ ----------eq(3)}$$

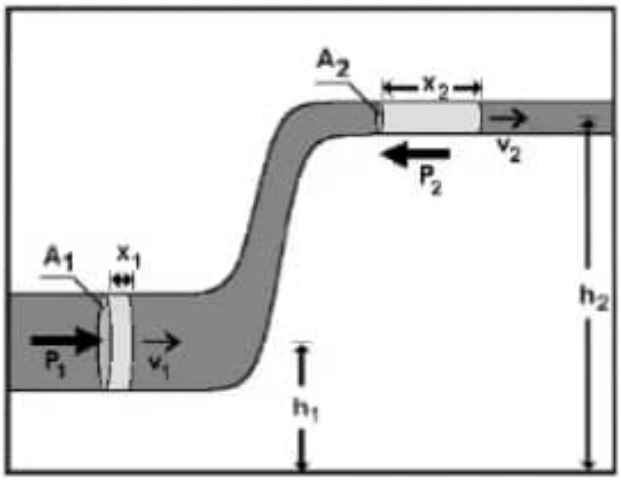
Volume is constant for an incompressible fluid. Using Eq.(3) in Eq.(2) we have

$$W = (P_1 - P_2)V \text{ -----eq(4)}$$

Since work has been done, there has been a change in the mechanical energy of the fluid segment. This energy change is found with the help of the next diagram.The energy change between the initial and final positions is given by

$$Energy\ change = \Delta E = E_2 - E_1$$

$$\Delta E = (mgh_2 + \frac{1}{2}mv_2^2) - (mgh_1 + \frac{1}{2}mv_1^2) \text{---------eq(5)}$$



Here, the kinetic energy K =1/2 mv² where m is the fluid mass and v is the speed of the fluid. The potential energy U = mgh where g is the acceleration of gravity, and h is average fluid height.The work-energy theorem says that the net work done is equal to the change in the system energy. This can be written as

$$\Delta E = W$$

Substitution of Eq.(4) and Eq.(5) into above equation

$$(P_1 - P_2)V = (mgh_2 + \frac{1}{2}mv_2^2) - (mgh_1 + \frac{1}{2}mv_1^2)$$

Dividing by the fluid volume, V gives us

$$(P_1 - P_2) = (\frac{m}{V}gh_2 + \frac{1}{2}\frac{m}{V}v_2^2) - (\frac{m}{V}gh_1 + \frac{1}{2}\frac{m}{V}v_1^2)$$

As we know that Density = mass / volume

Therefore, $(P_1 - P_2) = (\rho g h_2 + \frac{1}{2}\rho\, v_2^2) - (\rho g h_1 + \frac{1}{2}\rho v_1^2)$

or $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho\, v_2^2$

or $\boxed{P + \rho g h + \frac{1}{2}\rho v^2 = Constant}$

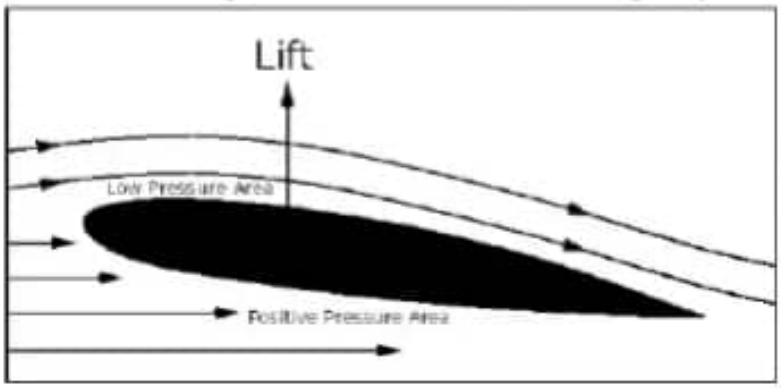
This equation is commonly referred to as Bernoulli's equation. Keep in mind that this expression was restricted to incompressible fluids and smooth fluid flows.

6.3.2 Interpret and apply Bernoulli effect in the flow of air over an aerofoil, venturi meter and atomizers. (COGNITIVE LEVEL:A)

1. BERNOULLI EFFECT IN THE FLOW OF AIR OVER AN AEROFOIL:

An airfoil is a device which gets a useful reaction from air moving over its surface. When an airfoil is moved through the air, it is capable of producing lift. Wings, horizontal tail surfaces, vertical tails surfaces, and propellers are all examples of airfoils.

Generally the wing of small aircraft will look like the cross-section of the figure. The forward part of an airfoil is rounded and is called the leading edge. The aft part is narrow and tapered and is called the trailing edge. A reference line often used in discussing airfoils is the chord, an imaginary straight line joining the extremities of the leading and trailing edges.

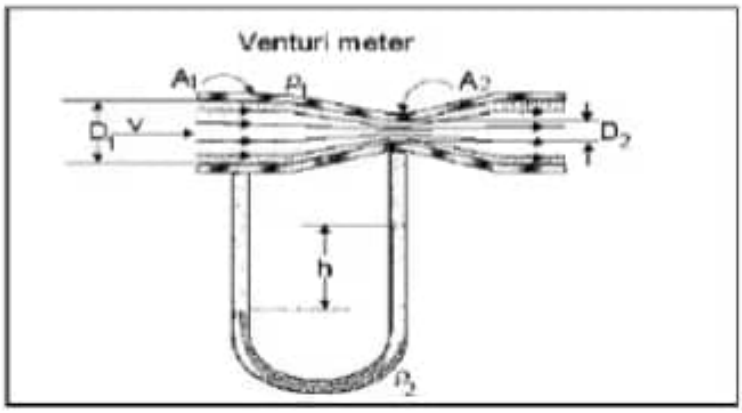


To understand how lift is produced, we must examine a phenomenon discovered many years ago by the scientist Bernoulli and later called Bernoulli's Principle: The pressure of a fluid (liquid or gas) decreases at points where the speed of the fluid increases. In other words, Bernoulli found that within the same fluid, in this case air, high speed flow is associated with low pressure, and low speed flow with high pressure. This principle was first used to explain changes in the pressure of fluid flowing within a pipe whose cross-sectional area varied. In the wide section of the gradually narrowing pipe, the fluid moves at low speed, producing high pressure. As the pipe narrows it must contain the same amount of fluid. In this narrow section, the fluid moves at high speed, producing low pressure.

The airfoil is designed to increase the velocity of the airflow above its surface, thereby decreasing pressure above the airfoil. Simultaneously, the impact of the air on the lower surface of the airfoil increases the pressure below. This combination of pressure decrease above and increase below produces lift.

2. BERNOULLI EFFECT IN VENTURI METER:

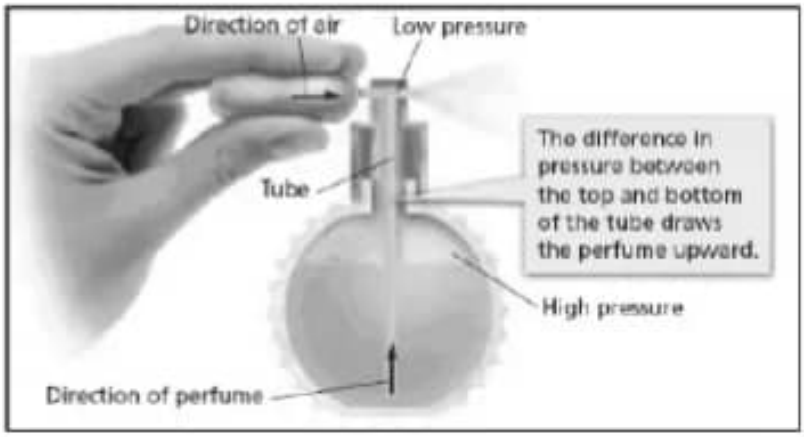
Venturimeter is the most widely used device to measure the discharge through the pipe. A venturi is a converging-Diverging nozzle of circular cross-section.



The principle of venturimeter is that when a fluid flows through the venturimeter, it accelerates in the convergent section and decelerates in the divergent section, resulting in a drop in the static pressure followed by a pressure recovery in the flow direction. By measuring the difference in the pressures at an axial station upstream of the convergent section and at the throat, the volumetric flow rate can be estimated.

3. BERNOULLI EFFECT IN ATOMIZERS:

Bernoulli's principle can help you understand how the perfume atomizer shown in Figure works. When you squeeze the rubber bulb, air moves quickly past the top of the tube. The moving air lowers the pressure at the top of the tube. The greater pressure in the flask pushes the liquid up into the tube. The air stream breaks the liquid into small drops, and the liquid comes out as a fine mist.



6.3.3 Solve problems by the help of Bernoulli's equation. (COGNITIVE LEVEL:A)

PROBLEM 1:A hose lying on the ground has water coming out of it at a speed of 5.4 meters per second. You lift the nozzle of the hose to a height of 1.3 meters above the ground. At what speed does the water now come out of the hose?

SOLUTION:

Use Bernoulli's equation:

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho\, v_2^2$$

In this case, let point 1 be on the ground and point 2 be at 1.3 meters above the ground. At both points, the pressure is atmospheric pressure, so

$$P_1 = P_2 = 1.01 \times 10^5 Pa$$

The difference in heights between points 1 and 2 is $h_2 - h_1 = 1.3\,m$.Using these equations, you can solve Bernoulli's equation for the speed

$$\cancel{P_1} + \rho g h_1 + \frac{1}{2}\rho v_1^2 = \cancel{P_2} + \rho g h_2 + \frac{1}{2}\rho\, v_2^2$$

$$\rho g h_1 + \frac{1}{2}\rho v_1^2 - \rho g h_2 = \frac{1}{2}\rho\, v_2^2$$

or $$2gh_1 + v_1^2 - 2gh_2 = v_2^2$$

$$v_2^2 = v_1^2 + 2g(h_1 - h_2)$$

$$v_2 = \sqrt{v_1^2 + 2g(h_1 - h_2)}$$

$$v_2 = \sqrt{(5.4)^2 + 2 \times 9.8(-1.3)} = 1.9\,m/s \text{ (Answer)}$$

<u>PROBLEM 2:</u>Water at a gauge pressure of 3.8 atm at street level flows in to an office building at a speed of 0.06 m/s through a pipe 5.0 cm in diameter. The pipes taper down to 2.6cm in diameter by the top floor, 20 m above with flow velocity 2.2 m/s. Calculate the gauge pressure in such a pipe on the top floor. Assume no branch pipe and ignore viscosity.

<u>SOLUTION:</u>

Converting P_1 in Pascals: $3.8 \times 1.01 \times 10^5 = 3.83 \times 10^5 Pa$

By Bernoulli's Equation:

$$P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho\, v_2^2$$

$$P_2 = P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 - \rho g h_2 - \frac{1}{2}\rho\, v_2^2$$

$$P_2 = 3.83 \times 10^5 + \rho g(h_1 - h_2) + \frac{1}{2}\rho(v_1^2 - v_2^2)$$

$$P_2 = 3.83 \times 10^5 + 1000 \times 9.8 \times 20 + \frac{1}{2} \times 1000 \times [(0.06)^2 - (2.2)^2]$$

$$P_2 = 2.8 \times 10^5 Pa \text{ (Answer)}$$

<u>6.4 VISCOUS FLUIDS</u>

6.4.1 Define viscous and non-viscous fluids. (COGNITIVE LEVEL:K)

<u>VISCOUS FLUID:</u>

A viscous fluid is one which resists movement or the movement of an object through the fluid. All fluids, liquid, gas, or plasma, have some measure of viscosity which can be compared using mathematical formulas or direct measurements of movement. Though all fluids have viscosity, a viscous fluid, in the everyday sense of the term, is one that has a high level of viscosity. These types of fluid may move slowly or not at all, depending on how viscous they are.

NON VISCOUS FLUID:

A non viscous fluid is one which does not resist movement or the movement of an object through the fluid. Generally speaking, any fluid having a viscosity less than water's viscosity is non - viscous fluid.

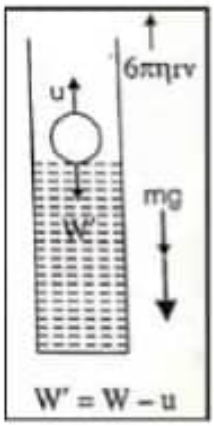
6.4.2 Describe that viscous force in a fluid causes a retarding force on an object moving through it. (COGNITIVE LEVEL:U)

VISCOUS FORCE:

When bodies are allowed to move through liquid or gases, they experience force which opposes their motion. This opposing force offered by liquid or gases is called viscous drag or fluid friction.

Stoke studied the effect of viscous drag on small spheres falling through liquids. He found that sphere of radius "r" falling through liquids of viscosity η with velocity v experience retarding force "F" given by,

$$F = 6\pi\eta r v$$



This is called Stoke's law. This equation shows that retarding force on sphere depends upon velocity "v". Forces acting on the falling sphere in liquid are mg downward and retarding force $6\pi\eta r v$ upward.Net force with which spheres falls in liquid is mg - $6\pi\eta r v$.

Retarding $6\pi\eta r v$ increases with increase in velocity. After falling through some distance, velocity of sphere attains such a value that force ($6\pi\eta r v$ becomes equal to mg).Under this condition sphere starts falling down with constant velocity. This constant velocity of sphere in a given liquid at which mg becomes equal to retarding force is called terminal velocity denoted by V_t.

6.5 FLUID FRICTION

6.5.1 Define fluid friction. (COGNITIVE LEVEL:K)

FLUID FRICTION:

A thick layer of liquid consists of large number of microscopic layers of molecules. When liquid flows each of its layers slides over the other, experiences force which opposes their motion. This internal friction between layers of same liquid, which makes it to flow slowly or resists in flow is called Viscosity. This force is called fluid friction. This property is found in all fluids. It is found that opposing tangential force between last stationary layer and any upper layer of given liquid is directly proportional to area of contact, velocity of layer and inversely proportional to distance of layer from stationary layer.

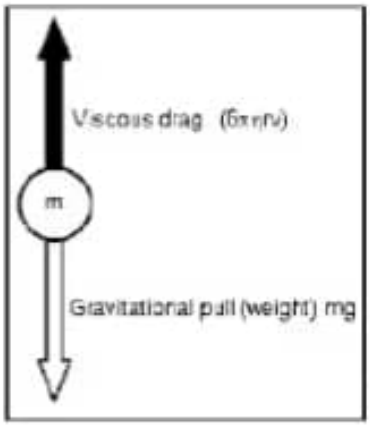
$$F \propto \frac{Av}{d}$$

$$F = \eta \frac{Av}{d}$$

Where η the constant of proportionality is called co-efficient of viscosity of given liquid.

6.5.2 Apply dimensional analysis to confirm the form of the Stoke's law. (COGNITIVE LEVEL:A)

PROOF:



On the basis of experimental observations proof George stokes law concluded that the viscous force on a small sphere in a liquid depends upon:

1. Viscosity of liquid(η)
2. Radius of sphere (r)
3. Speed of spherical body(v)

Mathematically we can write as,

$$F = 6\,\pi\,\eta\,r\,v$$

Putting the dimensions of physical quantities

$$MLT^{-2} = [ML^{-1}T^{-1}][L][LT^{-1}]$$

Where $6\,\pi$ is dimensionless constants.

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

$$\boxed{MLT^{-2} = MLT^{-2}}$$

Hence proved.

6.5.3 Apply Stoke's law to derive an expression for terminal velocity of spherical body falling through viscous fluids. (COGNITIVE LEVEL:A)

DERIVATION FOR TERMINAL VELOCITY:

According to the definition of terminal velocity force $(6\,\pi\,\eta\,r\,v)$ becomes equal to mg.

Therefore, $$6\,\pi\,\eta\,r\,v_t = mg$$

$$v_t = \frac{mg}{6\pi\,\eta\,r} \text{ -------(i)}$$

According to the definition of density

$$\rho = \frac{m}{V}$$

For Sphere $V = \frac{4}{3}\pi r^3$

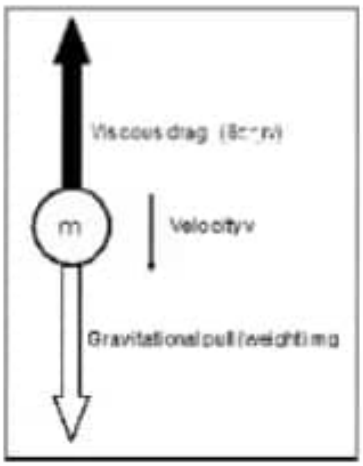
Therefore, $\rho = \frac{m}{\frac{4}{3}\pi r^3}$

or $m = \frac{4}{3}\pi \rho r^3$

Putting in eq(i), weget

$$v_t = \frac{(\frac{4}{3}\pi \rho r^3)g}{6\pi \eta r}$$

$$\boxed{v_t = \frac{2g\rho r^2}{9\eta}}$$



6.6 TERMINAL VELOCITY

6.6.1 Define terminal velocity. (COGNITIVE LEVEL:K)

TERMINAL VELOCITY:

A sphere falling through a viscous fluid. As the sphere falls so its velocity increases until it reaches a velocity known as the terminal velocity. At this velocity the frictional drag due to viscous forces is just balanced by the gravitational force and the velocity is constant.

6.6.2 Describe the factors on which it depends. (COGNITIVE LEVEL:U)

FACTORS OF TERMINAL VELOCITY:

According to the formula for terminal velocity $v_t = \frac{2g\rho r^2}{9\eta}$,it depends on four factors.

1. Acceleration due to gravity: More acceleration due to gravity, greater will be the terminal velocity.

2. Density of the falling body: High density will have a greater terminal velocity.

3. Radius of the sphere: Sphere with greater radius will have a greater terminal velocity.

4. Viscosity of the medium through which it is falling: More viscosity means the drag force will become equal to weight very soon, so the less will be terminal velocity.

CHAPTER 7- OSCILLATIONS

7.1 SIMPLE HARMONIC MOTION (SHM)

7.1.1 Define the terms, oscillatory motion, periodic motion, time period, frequency and amplitude. (COGNITIVE LEVEL:K)

OSCILLATORY MOTION:

The to and fro motion of a body about a fixed point is known as oscillatory motion.For example; Motion of pendulum, motion of spring, motion of string of guitar.

PERIODIC MOTION:

The motion which repeats its self after a certain interval of time is called periodic motion.For example; The motion of satellites, the motion of simple pendulum,heart beat of a person.

TIME PERIOD:

The time required to complete one oscillation about a fixed point is known as time period. It is denoted by "T". Its S.I. unit is second.

FREQUENCY :

The number of oscillations in one second is known as frequency. It is denoted by ν (nu).Its S.I. unit is Hertz(cycles per second).

AMPLITUDE:

The maximum displacement from mean position of a vibrating body is known as amplitude.It is denoted by x_0.

7.1.2 State Hook's law. (COGNITIVE LEVEL:K)

STATEMENT:

If a mass 'm' is attached to one end of a spring placed on horizontal smooth surface, the other end of which is rigidly fixed. If the mass 'm' is pulled to the right through a distance x and then released, the mass 'm' will vibrate about its mean position."Th e force exerted on the spring will be proportional to the displacement from mean position."

7.1.3 Derive Hook's law. (COGNITIVE LEVEL:U)

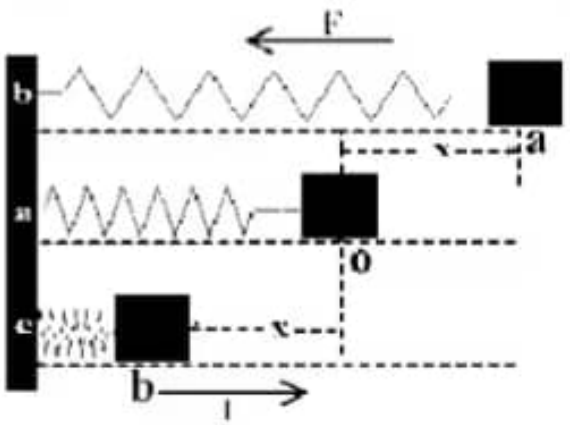
DERIVATION:

As shown in the figure a mass 'm' is attached to one end of a spring placed on horizontal smooth surface, the other end of which is rigidly fixed. If the mass 'm' is pulled to the right through a distance x and then released, the mass 'm' will vibrate about its mean position. The force exerted on the spring will be proportional to the displacement.

$$F \propto x$$

or

$$F = kx$$



This is known as Hook's law.

Where k is a constant of proportionality, called force constant of spring. The spring also exerts an equal and opposite force to restore its shape. This force is called restoring force.

Restoring force = - Kx

7.1.4 Derive an expression for acceleration of a body vibrating under elastic restoring force. (COGNITIVE LEVEL:U)

EXPRESSION FOR ACCELERATION:

Consider the motion of mass 'm' in fig (a) there is no force on the mass 'm' because spring suffers no extension. In fig (b), the spring is pulled to the right through a distance x_o the restoring force of the spring is F = - Kx

The work done in pulling the spring through a distance x_o is stored in the form of potential energy of the spring. In return the spring applies a force to restore its position and the mass 'm' moves to the left. Thus potential energy changes into kinetic energy. At its mean position, the mass 'm' has a maximum speed and because of inertia the mass moves to the left. The spring then compresses and the motion of the mass 'm' retards. At its extreme left position all the energy is potential. This process repeats and the energy of the spring oscillates between potential and kinetic energy.

Let x be the displacement of the mass 'm' at any instant then.

$$F = -Kx$$

From Newton's second law of motion

$$F = ma$$

where a = acceleration

Hence

Or **a = - (K/m) x**

7.2 UNIFORM CIRCULAR MOTION AND SHM

7.2.1 Discuss SHM on the basis of uniform circular motion. (COGNITIVE LEVEL:U)

CONNECTION BETWEEN S.H.M. AND UNIFORM CIRCULAR MOTION

Let us consider a particle of mass 'm' moving around a vertical circle of radius 'x_0' with constant angular velocity "ω". If 'θ' is the angular displacement swept during time 't' then $\theta = \omega t$

The projection 'Q' of particle 'P' on the diameter AB of the circle vibrates to and fro about the centre of the circle as 'P' moves along circular path. It is also observed that the projection 'Q' speeds up when it moves towards the centre 'O' and slows down when it moves away from the centre.Thus the instantaneous acceleration of projection 'Q' is directed towards the centre and it is in vibratory motion.

The motion of 'Q' is associated with the motion of 'P' hence the acceleration of 'Q' must be a component of the acceleration of the motion of particle P.The acceleration of the particle P is Centripetal acceleration i.e. directed towards centre of the circle along the line PO and it given by,

$$a_c = \frac{v^2}{r}$$

or $$a_c = -\frac{{v_p}^2}{x_o}$$ (x_0 and a_c are in opposite direction)

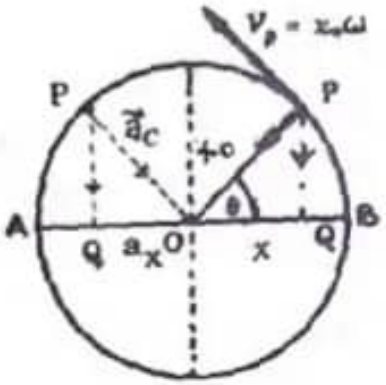
$$a_c = -\frac{(x_o\omega)^2}{x_o} \qquad \because v = r\omega$$

or $$a_c = -x_0\omega^2 \text{-------(i)} \quad \therefore v_p = x_0\omega$$

The acceleration of projection Q is equal to the component of acceleration of particle P along x axis .i.e.

$$a_x = a_c \cos\theta \text{ --------(ii)}$$

In triangle POQ



$$\cos\theta = \frac{\overline{OQ}}{\overline{OP}}$$

$$\cos\theta = \frac{x}{x_o} \text{ -------(iii)}$$

putting values from eq(i) and (iii) in eq(ii) we get ,

$$a_x = -x_0\omega^2\frac{x}{x_o}$$

or $$a_x = -\omega^2 x$$

As we know that ω is constant, Therefore,

$$\boxed{a \propto -x}$$

Hence it is proved that the motion of projection Q of particle p executing uniform circular motion is S.H.M.

7.2.2 Derive expression for displacement, instantaneous velocity and acceleration in terms of (ω). (COGNITIVE LEVEL:U)

EQUATION OF DISPLACEMENT:

At some instant of time t, the angle between OP and x axis is ω t+ φ , where φ is the angle which OP makes with the x axis at time t=0.This angle is known as initial phase angle.

In right angled triangle OPQ

$$\cos\theta = \frac{\overline{OQ}}{\overline{OP}}$$

$$\cos(\omega t + \varphi) = \frac{x}{x_o} \qquad \because \theta = \varphi + \omega t$$

or $$\boxed{x = x_o \cos(\omega t + \varphi)}$$

Where x_0=amplitude of S.H.M of Q and x =instantaneous displacement.

EQUATION FOR ACCELERATION:

As shown in the figure, a particle p is moving along the circumference of a circle of radius 'r; with its linear velocity V_p, its angular velocity ω is given by

$$\omega = \frac{V_p}{r}$$

or $$v_p = r\omega \qquad \text{---------- (1)}$$

let the particle starts from 'A' and in time 't' it sweeps and angle θ then

$$\theta = \omega t$$

When the particle 'P' is at 'B' its projection 'Q' is at O. As the particle moves and reaches 'C', the projection of P (i.e.Q) along reaches C. When the particle is at D,Q again at O. And when P is at A, Q is also at A. Thus when the particle P moves along circular path. Q moves along AOC and back to COA. Hence the motion of O is along a straight line.
Since the particle P is moving along a circular path it centripetal acceleration a_c is given by

$$a_c = -r\omega^2$$

The acceleration of Q is along AOC, hence the component a_c along AOC will give the acceleration of O.The competent of a_c along AOC is given by

$$a_o = a_c \cos\theta = \omega^2 r \cos\theta$$

From figure r cosθ = x

$$\boxed{a_0 = -\omega^2 x}$$

The negative sing shows that the acceleration of Q is directed towards the center and is proportional to x.

EQUATION OF VELOCITY:

The velocity of Q is equal to the X component of the velocity of P directed along AOC. Let Vo be the velocity of Q along AOC and Vp that of P along the tangent at any point on the circumference of the circle then

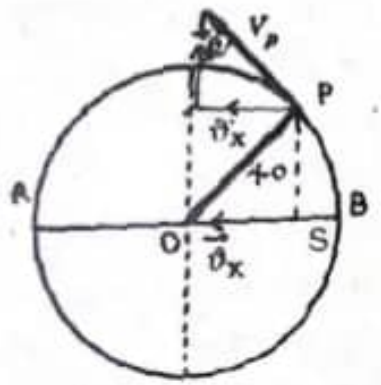
$V_Q = V_p \sin\theta = x_o\, \omega \sin\theta$ --------- (1)

From the relation $\sin^2\theta + \cos^2\theta = 1$, we get

$\sin^2\theta = 1 - \cos^2\theta$

$$\sin\theta = \sqrt{1 - \cos^2\theta}$$

putting in equation (i)



$$V_Q = x_0\omega\sqrt{1 - \left(\frac{x}{x_0}\right)^2}$$

$$V_Q = x_0\omega\sqrt{\frac{x_0^2 - x^2}{x_0^2}}$$

$$V_Q = \frac{x_0\omega}{x_0}\sqrt{x_0^2 - x^2}$$

so, $\boxed{V_Q = \omega\sqrt{x_0^2 - x^2}}$ ---------(ii)

i) At Extreme Position:

$x = x_0$, putting in eq (ii)

$$V_Q = \omega\sqrt{x_0^2 - x_0^2}$$

$$V_Q = \omega\sqrt{0}$$

$$V_Q = 0$$

The velocity of projection at the extreme position is equal to zero.

ii) At Mean Position:

x=0,putting in eq (ii)

$$V_Q = \omega\sqrt{x_0^2 - 0}$$

$$V_Q = \omega\sqrt{x_0^2}$$

$$V_Q = \omega x_0$$

The velocity of projection at the extreme position is Maximum.

7.3 PHASE

7.3.1 Define phase angle. (COGNITIVE LEVEL:K)

PHASE ANGLE:

"Phase (in SHM) is defined as the state of a particle pertaining to its position and direction of motion."The angle $\theta = \omega$ t is known as phase angle.

7.3.2 Derive an expression for the displacement "x". (COGNITIVE LEVEL:U)

EQUATION OF DISPLACEMENT:

At some instant of time t, the angle between OP and x axis is ω t+ φ , where φ is the angle which OP makes with the x axis at time t=0.This angle is known as initial phase angle.

In right angled triangle OPQ

$$\cos\theta = \frac{\overline{OQ}}{\overline{OP}}$$

$$\cos(\omega\,\mathrm{t} + \varphi) = \frac{x}{x_o} \qquad \because \theta = \varphi + \omega t$$

or $$\boxed{x = x_o \cos(\omega\,\mathrm{t} + \varphi)}$$

Where x_0=amplitude of S.H.M of Q and x =instantaneous displacement.

7.4 A HORIZONTAL MASS-SPRING SYSTEM

7.4.1 Derive an expression for instantaneous velocity in case of horizontal mass-spring system. (COGNITIVE LEVEL:U)

DERIVATION:

In case of horizontal spring system

$$a = -\left(\frac{K}{m}\right) x \text{ --------(i)}$$

In case of uniform circular motion

$$a = -\omega^2 x \text{ ----------(ii)}$$

comparing eq(i) and eq(ii) we get

$$\boxed{\omega = \sqrt{\frac{k}{m}}}$$

The instantaneous velocity is given by

$$v = \omega\sqrt{x_0^2 - x^2}$$

putting the value $\omega = \sqrt{\frac{k}{m}}$,we get

$$\boxed{v = \sqrt{\frac{k}{m}}\sqrt{x_0^2 - x^2}}$$

This is the expression for instantaneous velocity in case of horizontal mass-spring system.

7.5 SIMPLE PENDULUM

7.5.1 Show that the motion of a simple pendulum is SHM. (COGNITIVE LEVEL:U)

When the bob is slightly displaced from its mean position, it beings to perform oscillatory motion. Let us see the motion of the bob.

The bob of the pendulum is under the action of two force.

(i) The gravitational force W = mg acting vertically downwards

(ii) The tension T acts along the string.

The net force acting on the bob is $F_{Net} = W - T$

Resolving W into two components

(i) along the length of string (parallel) and

(ii) perpendicular to the string.

$W_{\parallel} = mg\cos\theta$ and $W_{\perp} = mg\sin\theta$

Since there is no motion of the bob along the string, a net force in the direction of string is zero. in this case.

$$mg\cos\theta = T$$

Hence the magnitude of the net force is $F_{Net} = mg\sin\theta$ brings the bob to its mean position.

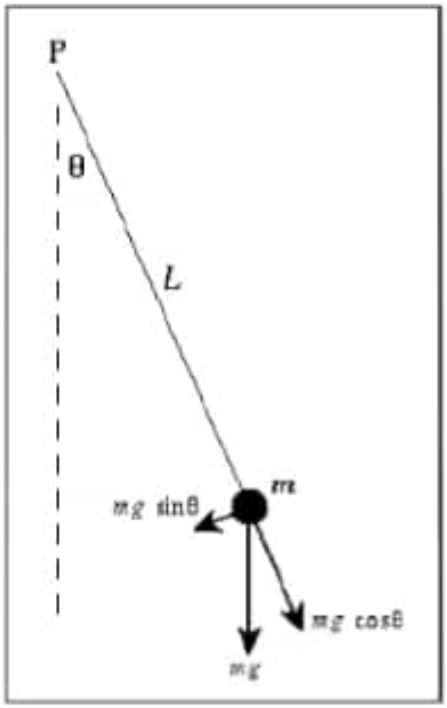
From Newton's second law of motion $F_{Net} = ma$

$\cancel{m}a = \cancel{m}g \sin\theta$ (since the force is directed towards mean position, hence,)

$a = -g \sin\theta$

If θ is small $\sin\theta \approx \theta$

then $a = -g\theta$ ----------(i)



As we know that

$S = r\theta$ => $\theta = S/r$

In this case S=x and r=l (length of string)

so, $\theta = x/l$

Putting in eq(i)

$a = -g(x/l)$

or $a = -(g/l)x$

where g and l are constant,therefore,

$$\boxed{a \propto -x}$$

Hence it is proved that the motion of pendulum is S.H.M.The acceleration of the simple pendulum is directly proportional to the displacement and directed towards the mean position. Thus the motion of simple pendulum is simple harmonic.

7.5.2 Derive an expression for the time period of simple pendulum and use this expression for solving numerical. (COGNITIVE LEVEL:A)

TIME PERIOD:

The time required to complete one cycle of motion is called time period. Denoted by "T".

A/c to the definition of angular velocity ω

$$\omega = \frac{\Delta\theta}{\Delta t}$$

For one complete cycle, $\Delta\theta = 360^0 = 2\pi, \Delta t = T$

$$\omega = \frac{2\pi}{T}$$

or $$\boxed{T = \frac{2\pi}{\omega}}$$ -------(A)

In case of simple pendulum

$$a = -\left(\frac{g}{l}\right) x$$ ------(i)

In case of uniform circular motion

$$a = -\omega^2 x$$ ----------(ii)

comparing eq(i) and eq(ii) we get

$$\boxed{\omega = \sqrt{\frac{g}{l}}}$$

so, the time period is given by

$$T = \frac{2\pi}{\sqrt{\frac{g}{l}}}$$

or $$\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$$

PROBLEM 1:What is the acceleration due to gravity in a region where a simple pendulum having a length 75 cm has a period of 1.7 s?

SOLUTION:

As we know that $T = 2\pi\sqrt{\frac{l}{g}}$

Putting the values in above formula

$$1.7 = 2 \times 3.14\sqrt{\frac{0.75}{g}}$$

S.O.B.S.

$$(1.7)^2 = (6.28)^2\left(\frac{0.75}{g}\right)$$

$$g = \frac{(6.28)^2 \times 0.75}{(1.7)^2} = 10.2\ m/s^2$$ (Answer)

PROBLEM 2: Khizar wishes to make a simple pendulum that serves as a timing device. She plans to make it such that its period is 1.00 second. What length must the pendulum have?

SOLUTION:

As we know that $T = 2\pi\sqrt{\frac{l}{g}}$

Putting the values in above formula

$$1 = 2 \times 3.14\sqrt{\frac{l}{9.8}}$$

S.O.B.S.

$$(1)^2 = (6.28)^2\left(\frac{l}{9.8}\right)$$

$$l = \frac{(1)^2(9.8)}{(6.28)^2} = 0.25\,m \text{ (Answer)}$$

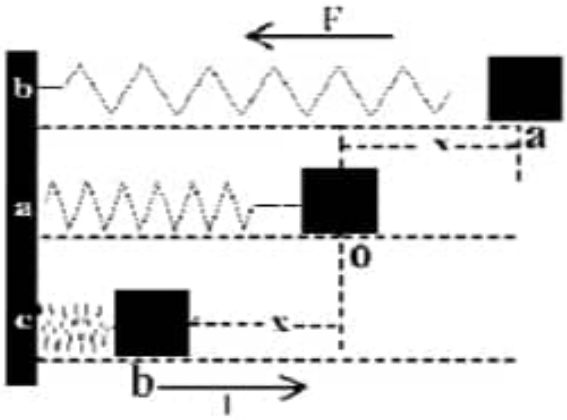
7.6 ENERGY CONSERVATION IN SHM

7.6.1 Relate between P.E, K.E and total energy for a body oscillating with SHM. (COGNITIVE LEVEL:U)

Let us consider a mass "m" connected with one end of a string whose other end is connected with a rigid wall and it can execute SHM on friction less surface as shown in fig.

(I) KINETIC ENERGY:

The instantaneous velocity of the body when its displacement is x is given by,



$$V = \omega\sqrt{x_0^2 - x^2}$$

In case of Spring mass system $\omega = \sqrt{\frac{K}{m}}$

$$\Rightarrow V = \sqrt{\frac{K}{m}}\sqrt{x_0^2 - x^2}$$

As we know that ,

K.E =1/2 mv^2

K.E =1/2 m$\left(\sqrt{\frac{K}{m}}\sqrt{x_0^2 - x^2}\right)^2$

K.E =1/2 m $\frac{K}{m}(x_0^2 - x^2)$

$\boxed{\text{K.E =1/2 K } (x_0^2 - x^2)}$ ---------(i)

(I) POTENTIAL ENERGY:

A/c to Hooke's law

F=Kx

At mean Position=> F=0

At extreme position => F=kx

Therefore the average force on mass "m" during the displacement x is

$$F = \frac{0+Kx}{2}$$

$$F = \frac{1}{2}kx$$

Now, A/c definition of P.E

P.E=avg. force x displacement

$$P.E = \frac{1}{2}kx \times x$$

$$\boxed{P.E = \frac{1}{2}kx^2} \text{----------(ii)}$$

(III) TOTAL ENERGY:

The energy of a body executing simple harmonic motion is the sum of potential energy and kinetic energy at that instant at a displacement x from the mean position.

E=K.E + P.E

putting values from eq(i) and eq(ii)

$$E = 1/2\, K\, (x_0^2 - x^2) + \frac{1}{2}kx^2$$

$$E = \frac{1}{2}kx^2 + \frac{1}{2}kx_0{}^2 - \frac{1}{2}kx^2$$

$$\boxed{E = \frac{1}{2}kx_0{}^2}$$

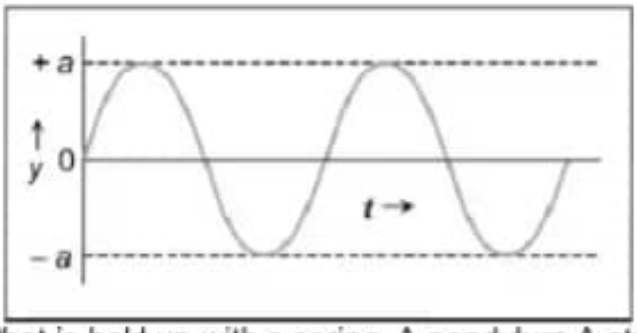
The above equation shows that the total energy of a particle executing simple harmonic motion is proportional to the square of its amplitude of vibration.

7.7 FREE AND FORCED OSCILLATION

7.7.1 Explain free and forced oscillation with examples. (COGNITIVE LEVEL:U)

FREE OSCILLATION:

The oscillation of a particle with fundamental frequency under the influence of restoring force is defined as free oscillation. In this type of oscillation the amplitude, energy and frequency of the oscillation remains constant. The frequency of this type of oscillation is called Natural frequency because it depends upon the nature and structure of the body.



For Example: A mass that is held up with a spring, A pendulum,A string of a guitar.

FORCED OSCILLATION:

The oscillation in which the body oscillates under the influence on an external periodic force is known as forced oscillation. These are vibrations that are driven by an external force.

For Example: Loud Speaker, Vibration of body of bus due to vibration of engine, Vibration of glass due to nearby speaker.

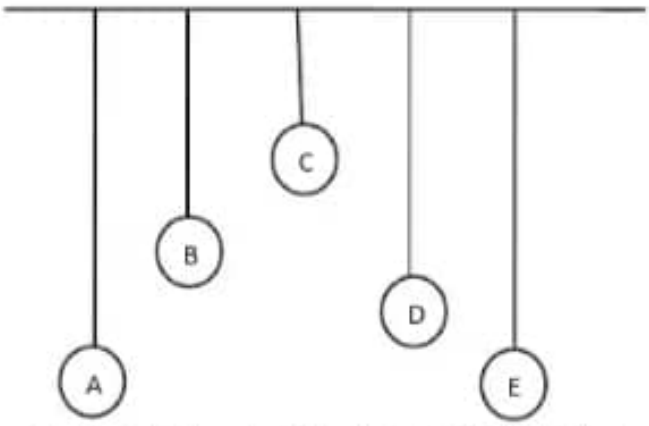
7.8 RESONANCE

7.8.1 Explain the phenomenon of resonance with examples. (COGNITIVE LEVEL:U)

Definition:

"The large amplitude vibration of an object wh en given impulses at its natural frequency is known as Resonance."

EXAMPLES:



1. Consider a long string stretched tightly between two pegs. Four pendulums A, B, C and D of different lengths are fastened to the string. Another pendulum E of same length as A is also fastened.

When pendulum E is set to vibrate, it will be observed that all the pendulums start to swing but pendulum A begins to vibrate with larger amplitude, as pendulum E is set into vibration. It imparts its motion to the string. This string in turn imparts the same periodic

motion to the pendulums. The natural frequency of all other pendulums except A is different. Due to the same natural frequency only A vibrates as the same vibration of E. This phenomenon under which pendulum A begin to vibrate is called resonance.

2. March of Soldiers while Crossing the Bridge: Each bridge has its own natural frequency and marching of soldiers is another vibrating system. So there may occur a force on vibration in bridge. This may damage the bridge. So, for safely precautions, it is written that soldiers must march out of stop while crossing the bridge.

3. Reception of Mobile call.

4. Breaking of glass by an Oprah singer.

7.9 DAMPED OSCILLATIONS

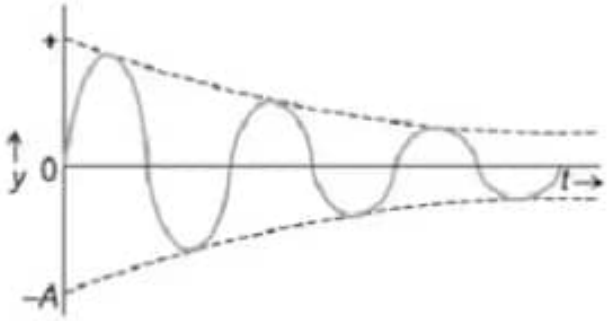
7.9.1 Define damped oscillation and list down its different applications. (COGNITIVE LEVEL:K)

DAMPED OSCILLATION:

The oscillation of a body in which the amplitude decreases with respect to time is called damped oscillation. In these oscillations the amplitude decreases exponentially due to damping forces like friction or viscous force. Due to decrease in amplitude its energy also decreases exponentially.

APPLICATIONS:

1. Suspension system of car (Shock Absorbers)
2. Earthquake protection for buildings
3. Door (with automatic closing arrangements)



8.1 WAVE MOTION

8.1.1 Define wave motion with the help of examples. (COGNITIVE LEVEL:K)

DEFINITION:

The mechanism by which energy transfers from one point to another is known as wave motion. Wave motion is a form of disturbance, which travels through a medium due to periodic motion of particles of the medium about their mean position.

EXAMPLES:

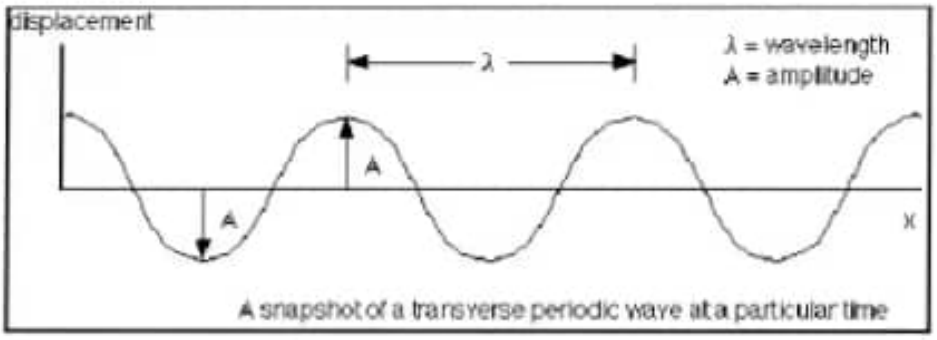
1. We see that if we dip a pencil into a tap of water and take it out a pronounced circular ripple is set up on the water surface and travels towards the edges of the tub. However if we dip the pencil and take it out many times, a number of ripples will be formed one after the other.

2. Waves can also be produced on very long ropes. If one end of the rope is fixed and the other end is given sudden up and down jerk, a pulse-shaped wave is formed which travels along the rope.

8.1.2 Define periodic waves. (COGNITIVE LEVEL:K)

PERIODIC WAVES:

A periodic wave is a wave in which the particles of the medium oscillate continuously repeating their vibratory motion regularly at fixed intervals of time. A periodic wave generally follows a sine wave pattern, as shown in the diagram.



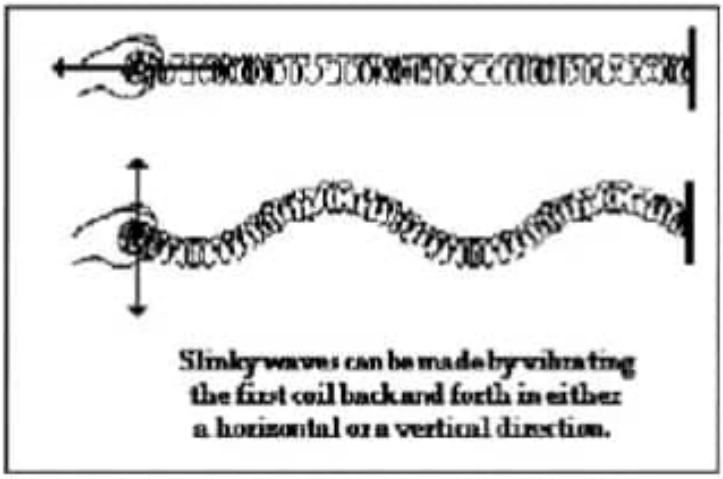
A snapshot of a transverse periodic wave at a particular time

8.1.3 Describe the propagation of waves with an example. (COGNITIVE LEVEL:U)

PROPAGATION OF WAVES:

Wave motion, propagation of disturbances that is, deviations from a state of rest or equilibrium from place to place in a regular and organized way. Most familiar are surface waves on water, but both sound and light travel as wavelike disturbances, and the motion of all subatomic particles exhibits wavelike properties.

Let us consider the movement of a slinky or similar set of coils. If a slinky is stretched out from end to end, a wave can be introduced into the slinky by either vibrating the first coil up and down vertically or back and forth horizontally. A wave will subsequently be seen traveling from one end of the slinky to the other. As the wave moves along the slinky, each individual coil is seen to move out of place and then return to its original position. The coils always move in the same direction that the first coil was vibrated. A continued vibration of the first coil results in a continued back and forth motion of the other coils. If looked at closely, one notices that the wave does not stop when it reaches the end of the slinky; rather it seems to bounce off the end and head back from where it started.



8.1.4 Define progressive waves. (COGNITIVE LEVEL:K)

DEFINITION:

A progressive wave distributes energy from a point source to the surrounding area. They move energy in the form of vibrating particles or fields.

8.1.5 Explain how energy is transferred through a progressive wave. (COGNITIVE LEVEL:U)

ENERGY IN WAVES

Let a harmonic wave travelling along a string. The points P,Q and R represent various segments of the string which move vertically. The wave moves a distance equal to one wavelength ' λ' in time period 'T'. We know that every point of the string moves vertically up or down.Thus every segment of equal mass has the same total energy. The energy of the segment P is entirely potential energy since the segment is momentarily stationary. The energy of the segment Q is entirely kinetic energy and segment R has both kinetic & potential energies. Suppose at point Q, the mass of the segment of the string is Δm and it has maximum transverse velocity $V_{y\,MAX}$. Then the total energy of the segment is.

$$\Delta E = K.E$$

$$\Delta E = \tfrac{1}{2}\,\Delta m\,(V_{y\,MAX})^2$$

$$\Delta E = \tfrac{1}{2}\,\Delta m\,(y_0\omega)^2$$

$$\Delta E = \tfrac{1}{2}\,\Delta m\,y_0^2\omega^2$$

Now , power is defined as

$$P = \frac{\Delta E}{T}$$

$$P = \frac{\frac{1}{2}\Delta m\, y_0^2 \omega^2}{T}$$

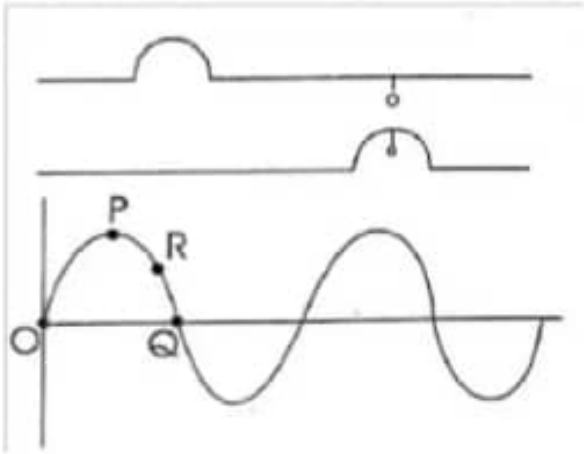
$$P = \frac{1}{T} \times \frac{1}{2}\, \Delta m\, y_0^2 \omega^2$$

$$P = \frac{\lambda}{T} \times \frac{1}{2}\frac{\Delta m}{\lambda}\, y_0^2 \omega^2$$

$$P = \lambda v \times \frac{1}{2}\frac{\Delta m}{\lambda}\, y_0^2 \omega^2 \qquad \because v = \frac{1}{T}$$

$$P = v \times \frac{1}{2}\frac{\Delta m}{\lambda}\, y_0^2 \omega^2 \qquad \because v = \lambda v$$

$$P = v \times \frac{1}{2}\mu\, y_0^2 \omega^2 \qquad \because \mu = \frac{\Delta m}{\lambda}$$



or $$\boxed{P = \frac{1}{2} v\, \mu\, y_0^2 \omega^2}$$

This result shows that the power transmitted by harmonic waves produced by string is proportional to,

(i) The Velocity of the waves 'V'

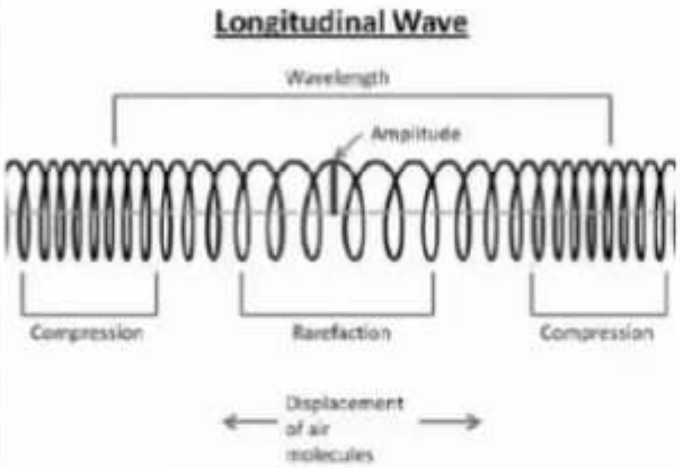
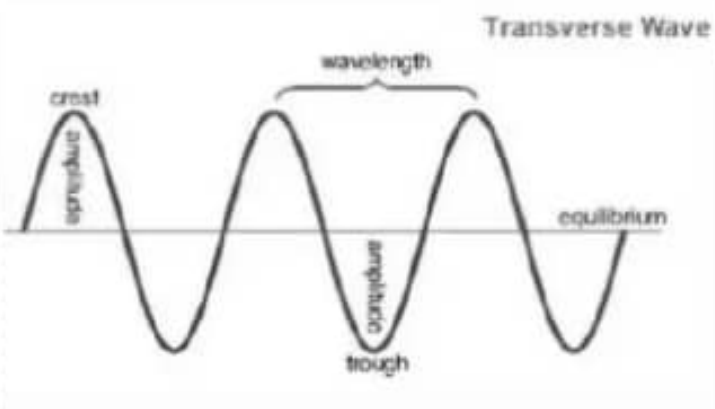
(ii) The square of the frequency ω

(iii) The square of the amplitude y_o

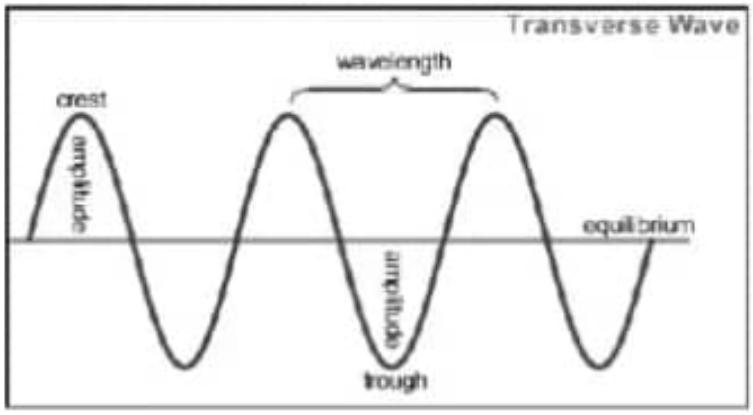
(iv) The linear density of the medium (String) μ

8.1.6 Differentiate between transverse and longitudinal waves. (COGNITIVE LEVEL:U)

Transverse Waves	Longitudinal Waves
Displacement of the medium is perpendicular to the direction of propagation of the wave.	Displacement of the medium is parallel to the direction of propagation of the wave.
To understand this it is good to think of a rope being held still by person B and being moved up and down by person A. The direction of propagation is from person A to B, so you will see the waves move along this way. But the displacement will be up and down.	A good example for this is a slinky being pushed along the table, the propagation will be along the table and so will the displacement of all the 'rings'.

Can travel in solids, but not in liquids and gas.	Can travel through all states of matter.
eg. Electromagnetic radiation	eg. Sound waves
	

8.1.7 Derive the relation $v = \nu\lambda$ and use it in solving numerical. (COGNITIVE LEVEL:A)



DERIVATION:

Let us consider a transverse wave having wavelength , frequency ν, speed v and time period T, as shown in figure.

According to the definition of speed

$$v = \frac{displacement}{time}$$

As we know that the displacement covered by the wave in time equal to its time period is wavelength. Therefore,

$$v = \frac{\lambda}{T}$$

According to the definition of Frequency, it is the reciprocal of time period. so,

$$\nu = \frac{1}{T}$$

Therefore, the speed of wave is given by

$$\boxed{v = \nu\lambda}$$

PROBLEM 1: A fisherman notices that wave crests pass the bow of his anchored boat every 3.0 seconds. He measures the distance between two crests to be 7.5 meters. How fast are the waves traveling?

SOLUTION:

Since the wave crests pass the boat once every 3.0 seconds, we know that the frequency of the water waves is f = 1 / 3.0 seconds = 0.33 Hz. The distance between wave crests (at a fixed time) is the wavelength. The fisherman's observation says that the wavelength is 7.5 m. Then we know that

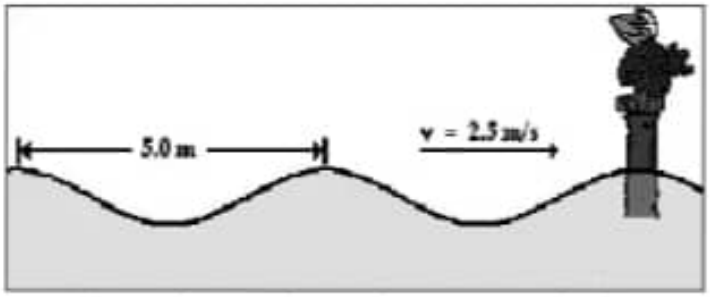
$$v = \nu \lambda$$

$$v = (7.5\,\text{m}) \times (0.33\,\text{Hz}) = 2.5\,\text{m/s}$$

Note, the fisherman could observe different wavelength water waves as well. Those waves would also travel with a speed of 2.5 m/s, since the wave speed is a property of the *medium*. Longer wavelength water waves would have smaller frequencies and shorter wavelength water waves would have higher frequencies to keep the wave speed constant at 2.5 m/s.

PROBLEM 2: The water waves below are traveling along the surface of the ocean at a speed of 2.5 m/s and splashing periodically against Wilbert's perch. Each adjacent crest is 5 meters apart. The crests splash Wilbert's feet upon reaching his perch. How much time passes between each successive drenching?

SOLUTION:



The wave speed is given by

$$v = \nu \lambda$$

$$2.5 = \nu (5)$$

$$\nu = \frac{2.5}{5} = 0.5\,Hertz$$

Now, we have to find the time, so

$$T = \frac{1}{\nu}$$

$$\boxed{T = \frac{1}{0.5} = 2\,sec}$$

8.2 SPEED OF SOUND

8.2.1 Show that the speed of sound depends on the properties of medium in which it propagates. (COGNITIVE LEVEL:U)

In case of mechanical waves, the velocity of propagation depends upon the ratio between the elastic property of the medium (bulk modulus), and the inertial property of the medium (density).

Sound waves are compression waves which propagate through compressible medium such as air. For compression waves, the elastic property describes how the medium responds to changes in pressure with a change in volume. This is known as bulk modulus B .

$$B = \frac{-\Delta P}{\Delta V/V}$$

Where ΔP is the change in pressure and Δv is the change in volume V. The negative sign ensures that an increase in pressure ($\Delta P > 0$) causes a decreases in volume ($\Delta v < o$).

The inertial property of a medium is gives by its density " ρ" .Hence the speed of sound wave in a medium is given by

$$\boxed{v = \sqrt{\frac{B}{\rho}}}$$

8.2.2 Describe Newton's formula for speed of sound. (COGNITIVE LEVEL:U)

NEWTON'S FORMULA FOR SPEED OF SOUND:

Newton's formula was based on the assumption that when compressions and refractions travel through medium (air or gas), the temperature of the air remains constant and Boyle 's law is obtained under this isothermal process. So the Bulk modulus B is equal to the pressure P.

$$\boxed{v = \sqrt{\frac{P}{\rho}}}$$

The above formula is known as Newton's formula for the speed of sound. The speed of sound in air as obtained by Newton's formula was not in good agreement with the experimental results. Theoretical value was less than the experimental value

8.2.3 Discuss Laplace's correction in Newton's formula. (COGNITIVE LEVEL:U)

LAPLACE CORRECTION:-

Laplace suggested that when compressions and rarefaction travel through air, the temperature falls. Therefore, the compression and rarefactions occur adiabatically.

In such a case the bulk modulus of the gas is not equal to the pressure of the gas but, ' γ' times the pressure of the gas. Where, ' γ' is the ratio of the specific heat of the gas at constant pressure to the specific heat at constant volume, For air, γ = 1.4.

$$\boxed{v = \sqrt{\frac{\gamma P}{\rho}}}$$

This is known as Laplace correction.

For an ideal gas PV = nRT

$$v = \sqrt{\frac{\gamma nRT}{V\rho}}$$

As we know that, $V\rho$=m (mass of gas)

so, $$v = \sqrt{\frac{\gamma nRT}{m}}$$

or, $$v = \sqrt{\frac{\gamma RT}{M}}$$ ∵M=n/m

The speed of sound wave is directly proportional to the square root of the temperature in Kelvin Scale.

8.2.4 Demonstrate the effects of pressure, density and temperature on the speed of sound in air. (COGNITIVE LEVEL:U)

1. EFFECT OF PRESSURE ON THE SPEED OF SOUND IN AIR:

Air pressure has no effect at all in an ideal gas approximation. This is because pressure and density both contribute to sound velocity equally, and in an ideal gas the two effects cancel out, leaving only the effect of temperature.

2. EFFECT OF DENSITY ON THE SPEED OF SOUND IN AIR:

The density of a medium is the second factor that affects the speed of sound. Density describes the mass of a substance per volume. A substance that is denser per volume has more mass per volume. Usually, larger molecules have more mass. If a material is denser because its molecules are larger, it will transmit sound slower. Sound waves are made up of kinetic energy. It takes more energy to make large molecules vibrate than it does to make smaller molecules vibrate. Thus, sound will travel at a slower rate in the more dense object if they have the same elastic properties

3. EFFECT OF TEMPERATURE ON THE SPEED OF SOUND IN AIR:

Temperature is a condition that affects the speed of sound. Heat, like sound, is a form of kinetic energy. Molecules at higher temperatures have more energy, thus they can vibrate faster. Since the molecules vibrate faster, sound waves can travel more quickly. The speed of sound in room temperature air is 346 meters per second. This is faster than 331 meters per second, which is the speed of sound in air at freezing temperatures.

The formula to find the speed of sound in air is as follows:

$$V = V_o + 0.61\,t$$

8.2.5 Show the expression $V = V_o + 0.61\,t$. (COGNITIVE LEVEL:U)

PROOF:

As we know that

$$v \propto \sqrt{T}$$

So, The speed of sound at a temperature is given by,

$$\frac{v}{v_0} = \sqrt{\frac{T}{T_0}} \qquad (using\ v = \sqrt{\frac{\gamma RT}{M}})$$

where v is the speed at a temperature T, v_o is the speed of sound at 0^0C.

or in Kelvin scale we can write as,

$$\frac{v}{v_0} = \sqrt{\frac{t+273}{273}}$$

$$v = v_0\sqrt{1+\frac{t}{273}}$$

Where speed of sound at 0^0C is 332 m/s then,

$$v = 332\left(1+\frac{t}{273}\right)^{\frac{1}{2}}$$

Using Binomial expansion we can write as,

$$v = 332\left(1+\frac{\frac{1}{2}\frac{t}{273}}{1!}+\frac{\frac{1}{2}\left(\frac{1}{2}-1\right)\left(\frac{t}{273}\right)^2}{2!}+\cdots\right)$$

Neglecting higher powers of $\frac{t}{273}$, we get

$$v = 332\left(1+\frac{t}{546}\right)$$

or

$$v = 332+\frac{332\,t}{546}$$

or

$$\boxed{v = v_0 + 0.61\,t}$$

Hence, proved.

8.3 SUPERPOSITION OF WAVES

8.3.1 State the principle of superposition of two waves. (COGNITIVE LEVEL:K)

PRINCIPLE:

When two or more than two waves overlap each other, then a resultant wave is formed. The net wave displacement caused by the resultant wave is found equal to the algebraic sum of the individual wave displacements of all given waves. Mathematically we can write as,

$$\boxed{Y = y_1 + y_2 + y_3 + \cdots + y_n}$$

8.3.2 Describe the phenomenon of interference of sound waves. (COGNITIVE LEVEL:U)

INTERFERENCE OF SOUND WAVES:

Sound is a pressure wave that consists of compressions and rarefactions. As a compression passes through a section of a medium, it tends to pull particles together into a small region of space, thus creating a high-pressure region. And as a rarefaction passes through a section of a medium, it tends to push particles apart, thus creating a low-pressure region. The interference of sound waves causes the particles of the medium to behave in a manner that reflects the net effect of the two individual waves upon the particles.

For example, if a compression (high pressure) of one wave meets up with a compression (high pressure) of a second wave at the same location in the medium, then the net effect is that that particular location will experience an even greater pressure. This is a form of constructive interference. If two rarefactions (two low-pressure disturbances) from two different sound waves meet up at the same location, then the net effect is that that particular location will experience an even lower pressure. This is also an example of constructive interference. Now if a particular location along the medium repeatedly experiences the interference of two compressions followed up by the interference of two rarefactions, then the two sound waves will continually reinforce each other and produce a very loud sound. The loudness of the sound is the result of the particles at that location of the medium undergoing oscillations from very high to very low pressures. As mentioned in a previous unit, locations along the medium where constructive interference continually occurs are known as anti-nodes. The animation below shows two sound waves interfering constructively in order to produce very large oscillations in pressure at a variety of anti-nodal locations.

Now if two sound waves interfere at a given location in such a way that the compression of one wave meets up with the rarefaction of a second wave, destructive interference results. The net effect of a compression (which pushes particles together) and a rarefaction (which pulls particles apart) upon the particles in a given region of the medium is to not even cause a displacement of the particles. The tendency of the compression to push particles together is canceled by the tendency of the rarefactions to pull particles apart; the particles would remain at their rest position as though there wasn't even a disturbance passing through them. This is a form of destructive interference. Now if a particular location along the medium repeatedly experiences the interference of a compression and rarefaction followed up by the interference of a rarefaction and a compression, then the two sound waves will continually cancel each other and no sound is heard. The absence of sound is the result of

the particles remaining at rest and behaving as though there were no disturbance passing through it. Amazingly, in a situation such as this, two sound waves would combine to produce no sound.

8.3.3 Classify the formation of beats giving an illustration. (COGNITIVE LEVEL:U)

The periodic alternation of sound between a maximum and minimum loudness caused by the super position of two waves of nearly the same frequency are called beats.

PRODUCTION OF BEATS:

Take two tuning forks A and B of nearly the same frequencies say 32 and 30 hz. Respectively place them at equal distance from the ear. Let at time t = 0, the two forks are in phase and the right hand prongs of both the forks are sending compressions towards right. There two compressions will arrive at the ear together and thus a loud sound in heard.

As time goes on the fork B, vibrating at slightly lower frequency than A will begin to fall behind. After ¼ second the fork A will complete 8 vibrations and will just be sending out compressions. On the other hand the fork B will complete 71/2 vibrations and will sending out a rarefaction from B will reach the ear at the same time. They will cancel each other. Hence no sound will be heard.

As time passes the fork B will still fall behind A. After half a second the fork A will complete 16 vibrations while the fork B will complete 15 vibrations. Both the forks will be sending out compressions together and thus again a loud sound will be heard.

After ¾ second – fork A will complete 24 vibrations and fork B will complete 22½ vibrations. At this compression and fork B will be sending a rarefaction. B will be sending a rarefaction. Thus no sound will be heard.

After 1 second the fork A will complete 32 vibrations. Both the forks will be sending out compressions together and thus again a loud sound will be heard.

We have seen that in one second two beat are produced. The difference between the frequencies is also two. Thus we conclude that the number of beats per second is equal to the difference between the frequencies of the forks. The maximum beat frequency that the human ear can detect is 7 beats per second. When the beat frequency is number of beats produced per second) is greater than 7 we cannot hear them clearly.

8.4 STATIONARY WAVES

8.4.1 Define stationary waves. (COGNITIVE LEVEL:K)

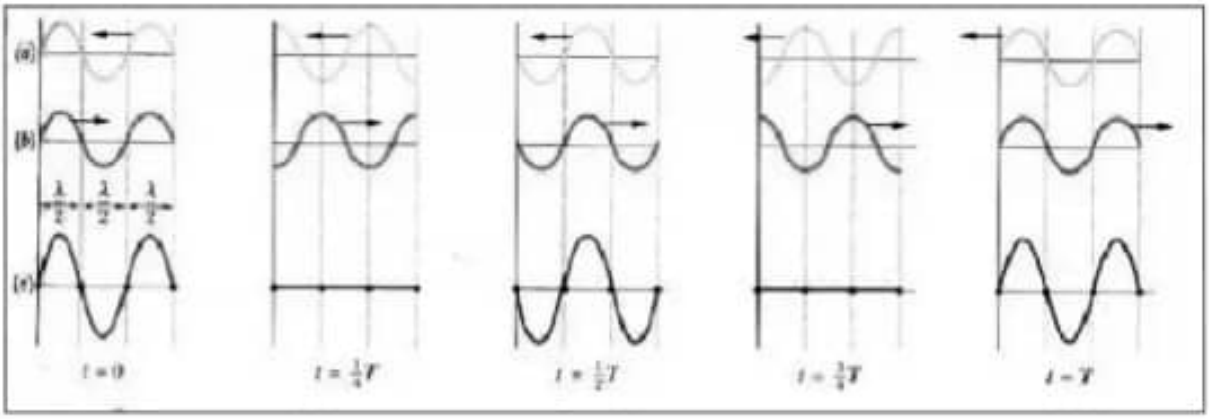
STANDING OR STATIONARY WAVES IN A STRING:

When a stretched is fixed between two supports and is then plucked from the middle, the crest extends the whole length between the supports. At each end, the wave reflects from the denser medium and hence it suffers a phase change. The crest returns as a crest. Thus a wave is set up between two fixed points which lasts for a long time. At the end P and Q, the incident and reflected waves are always equal in amplitude and opposite in phase and hence the ends are stationery. Such waves are called stationery waves.

8.4.2 Describe the formation stationary waves using graphical approach. (COGNITIVE LEVEL:U)

The modes of vibration associated with resonance in extended objects like strings and air columns have characteristic patterns called standing waves. These standing wave modes arise from the combination of reflection and interference such that the reflected waves interfere constructively with the incident waves. An important part of the condition for this constructive interference for stretched strings is the fact that the waves change phase upon reflection from a fixed end. Under these conditions, the medium appears to vibrate in segments or regions and the fact that these vibrations are made up of traveling waves is not apparent - hence the term "standing wave".

The behavior of the waves at the points of minimum and maximum vibrations (nodes and antinodes) contributes to the constructive interference which forms the resonant standing waves. The illustration above involves the transverse waves on a string, but standing waves also occur with the longitudinal waves in an air column. Standing waves in air columns also form nodes and antinodes, but the phase changes involved must be separately examined for the case of air columns.



8.4.3 Define the terms nodes and antinodes. (COGNITIVE LEVEL:K)

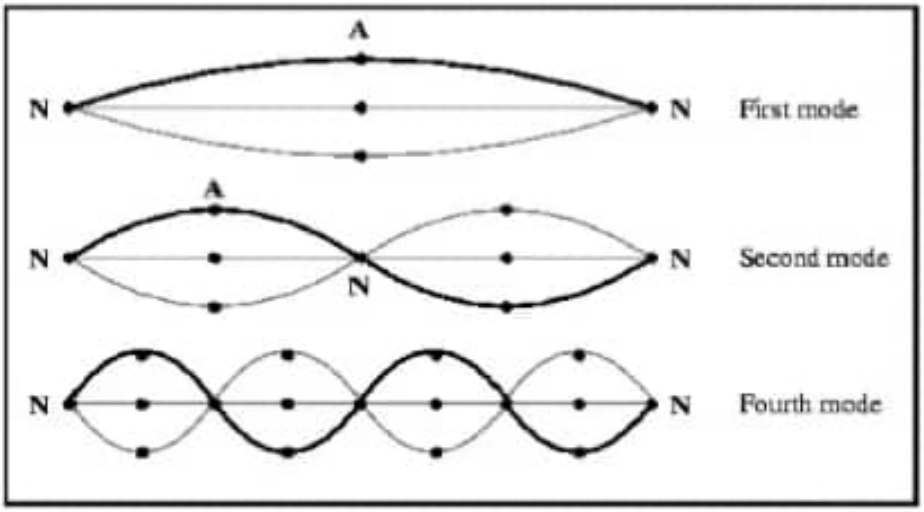
NODES: In a stationery waves, the points of minimum displacement are called NODES (N)

ANTI NODES: In stationary waves, the points of maximum displacement are called ANTI NODES (A).

8.4.4 Classify with illustration the formation of stationary waves in a string. (COGNITIVE LEVEL:U)

Let's consider a string stretched across the room. If an upward displaced pulse is introduced at the left end of the string, it will travel rightward across the string until it reaches the fixed end on the right side of the string. Upon reaching the fixed end, the single pulse will reflect and undergo inversion. That is, the upward displaced pulse will become a downward displaced pulse.

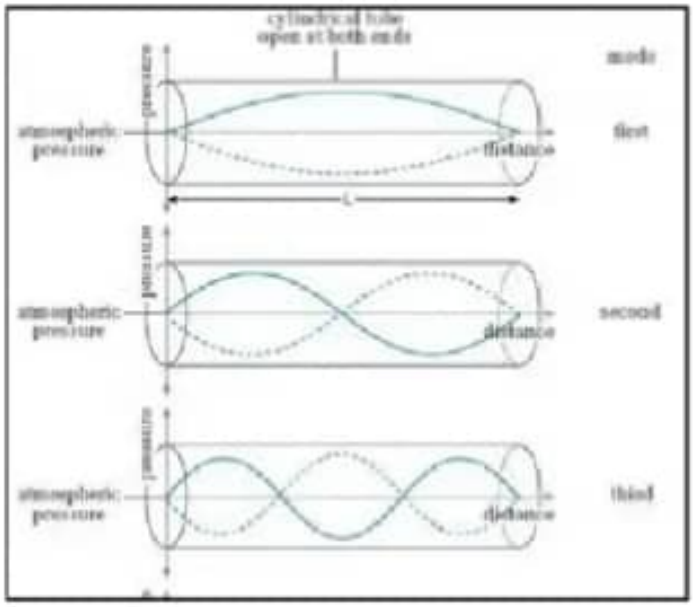
Now suppose that a second upward displaced pulse is introduced into the string at the precise moment that the first crest undergoes its fixed end reflection. If this is done with perfect timing, a rightward moving, upward displaced pulse will meet up with a leftward moving, downward displaced pulse in the exact middle of the string. As the two pulses pass through each other, they will undergo destructive interference. Thus, a point of no displacement in the exact middle of the string will be produced. The animation below shows several snapshots of the meeting of the two pulses at various stages in their interference. An upward displaced pulse introduced at one end will destructively interfere in the exact middle of the string with a second upward displaced pulse introduced from the same end if the introduction of the second pulse is performed with perfect timing. The same rationale could be applied to two downward displaced pulses introduced from the same end. If the second pulse is introduced at precisely the moment that the first pulse is reflecting from the fixed end, then destructive interference will occur in the exact middle of the string.



8.4.5 Recognize the formation of stationary waves in a vibrating air column. (COGNITIVE LEVEL:K)

STATIONARY WAVES IN A VIBRATING AIR COLUMN:

In the case of air columns, a closed end in a column of air is analogous to the fixed end on a vibrating string. That is, at the closed end of an air column, air is not free to undergo movement and thus is forced into assuming the nodal positions of the standing wave pattern. Conversely, air is free to undergo its back-and-forth longitudinal motion at the open end of an air column; and as such, the standing wave patterns will depict antinodes at the open ends of air columns.



So the basis for drawing the standing wave patterns for air columns is that vibrational antinodes will be present at any open end and vibrational nodes will be present at any closed end. If this principle is applied to open-end air columns, then the pattern for

the fundamental frequency (the lowest frequency and longest wavelength pattern) will have antinodes at the two open ends and a single node in between.

The distance between antinodes on a standing wave pattern is equivalent to one-half of a wavelength. A careful analysis of the diagram above shows that adjacent antinodes are positioned at the two ends of the air column. Thus, the length of the air column is equal to one-half of the wavelength for the first harmonic.

The standing wave pattern for the second harmonic of an open-end air column could be produced if another antinode and node was added to the pattern. This would result in a total of three antinodes and two nodes. This pattern is shown in the diagram below. Observe in the pattern that there is one full wave in the length of the air column. One full wave is twice the number of waves that were present in the first harmonic. For this reason, the frequency of the second harmonic is two times the frequency of the first harmonic.

The standing wave pattern for the third harmonic of an open-end air column could be produced if still another antinode and node were added to the pattern. This would result in a total of four antinodes and three nodes. This pattern is shown in the diagram below. Observe in the pattern that there are one and one-half waves present in the length of the air column. One and one-half waves is three times the number of waves that were present in the first harmonic. For this reason, the frequency of the third harmonic is three times the frequency of the first harmonic.

8.4.6 Describe modes of vibration in a string and explain them by using L = n λ / 2. (COGNITIVE LEVEL:U)

MODES OF VIBRATION IN A STRING:

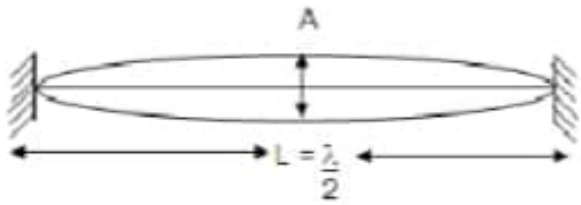
When a stretched string is fixed between two ends and then plucked, stationery waves are produced due to superposition of wave's incident and reflected from the ends. The string can vibrate into several segments. There vibrations are called normal modes. Each mode has its characteristic frequency.

(i) **For ONE loop:**

When the string is plucked from the center it vibrates in one loop. The frequency of such a vibration is called fundamental frequency or first fundamental frequency or first harmonics and it is the lowest frequency with which the string can vibrate. In this case.

$L = \frac{\lambda}{2}$ or $\lambda = 2L$

Let ν_1, the frequency of first harmonics is given by



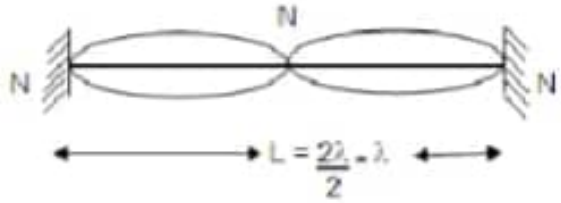
$$\because V = \nu\lambda \quad \text{or } \nu = \frac{V}{\lambda}$$

or

$$\boxed{v_1 = \frac{V}{2L}}$$

(ii) **For TWO loops:** When the string vibrates in two loops, the frequency is called second harmonics, In this case.

$\lambda = L$



Let v_2, the frequency of second harmonics is given by

$$\because V = v\,\lambda \quad \text{or } v = \frac{V}{\lambda}$$

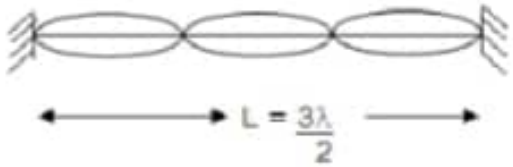
or

$$\boxed{v_2 = \frac{V}{L}}$$

(iii) **For THREE loops:** When the string vibrates in two loops, the frequency is called second harmonics, In this case.

$$L = 3\frac{\lambda}{2} \;\; or\; \lambda = \frac{2L}{3}$$

Let v_3, the frequency of third harmonics is given by



$$\because V = v\,\lambda \quad \text{or } v = \frac{V}{\lambda}$$

or

$$\boxed{v_3 = \frac{3V}{2L}}$$

(iv) **For "n" loops:** When the string vibrates in two loops, the frequency is called second harmonics, In this case.

$$L = n\frac{\lambda}{2} \;\; or\; \lambda = \frac{2L}{n}$$

Let v_3, the frequency of third harmonics is given by

$$\because V = v\,\lambda \quad \text{or } v = \frac{V}{\lambda}$$

or

$$\boxed{v_n = \frac{nV}{2L}}$$

$$\because v_1 = \frac{V}{2L}$$

so,

$$\boxed{\nu_n = n\nu_1}$$

Thus we see that in case of a string fixed at both ends the harmonics are integral multiple of the fundamental frequency.

8.5 DOPPLER'S EFFECT

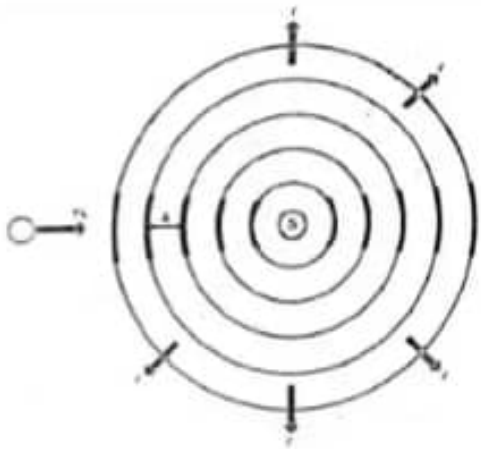
8.5.1 Define Doppler's effect. (COGNITIVE LEVEL:K)

DOPPLER'S EFFECT

The change in the pitch (frequency) of sound caused by the relative motion between the source and observer is called Doppler's Effect.

8.5.2 Derive the relation between the original frequency of source of sound and the apparent frequency detected by the listener in four different conditions and use these relations for solving numerical. (COGNITIVE LEVEL:A)

CASE 1(A): When listener moves towards the stationary source of sound.



Let us consider the listener is moving towards the stationary source of sound emitting sound of frequency ν ,with velocity V_L.The speed of sound is V.In this case the apparent frequency heard by listener is ν'.

As we know that

$$V = \nu\,\lambda \qquad \Rightarrow \lambda = \frac{V}{\nu} \text{ ----(i)}$$

and

$$\nu = \frac{V}{\lambda} \text{ (Real Frequency)}$$

But the relative velocity of sound for the listener will be $V+V_L$, then apparent frequency will be

$$\nu' = \frac{V+V_L}{\lambda}$$

putting the value of λ from eq(i),we get

$$\nu' = \frac{V+V_L}{\frac{V}{\nu}}$$

or

$$\boxed{\nu' = \left(\frac{V+V_L}{V}\right)\nu}$$

This expression shows that the apparent frequency will be greater than real frequency.

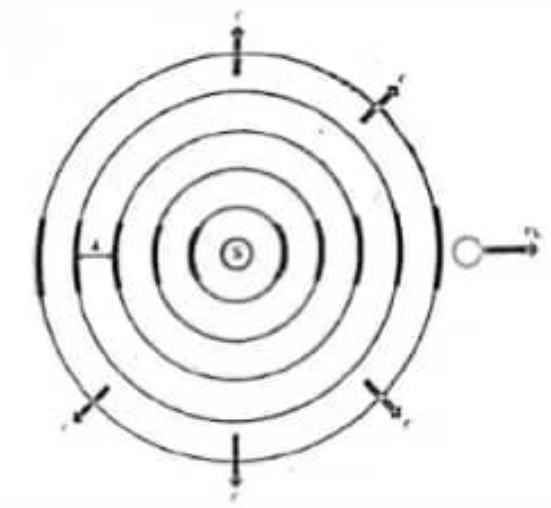
CASE 1(B): When listener moves away from the stationary source of sound.

Let us consider the listener is moving towards the stationary source of sound emitting sound of frequency ν ,with velocity V_L.The speed of sound is V.In this case the apparent frequency heard by listener is ν'.

As we know that

$$V = \nu\,\lambda \qquad \Rightarrow \lambda = \frac{V}{\nu} \text{ ----(ii)}$$

and $\nu = \frac{V}{\lambda}$ (Real Frequency)



But the relative velocity of sound for the listener will be $V-V_L$, then apparent frequency will be

$$\nu' = \frac{V-V_L}{\lambda}$$

putting the value of λ from eq(ii),we get

$$\nu' = \frac{V-V_L}{\frac{V}{\nu}}$$

or $$\boxed{\nu' = \left(\frac{V-V_L}{V}\right)\nu}$$

This expression shows that the apparent frequency will be less than real frequency.

CASE 2(A): When source of sound moves towards the stationary listener.

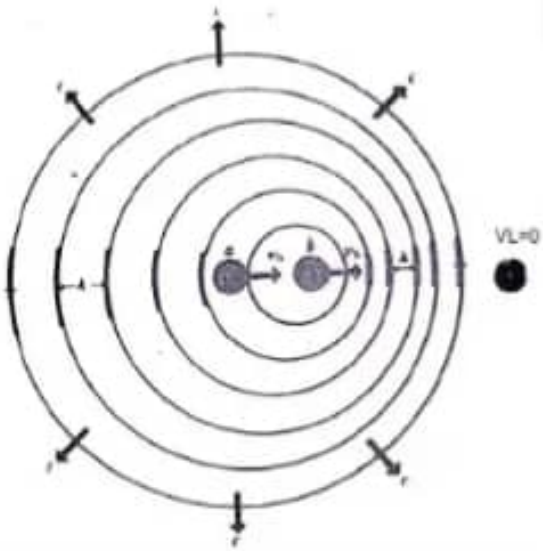
Let us consider a source of sound moving with velocity Vs towards stationary listener. The wave crests detected by the listener are closer together because the source is moving in the direction of outgoing wave resulting the shortening of wavelength.

As we know that

$$V = \nu\,\lambda \qquad \Rightarrow \lambda = \frac{V}{\nu} \text{ (Distance occupied by one wave)}$$

and $\nu = \frac{V}{\lambda}$ (Real Frequency) ------(i)

During each vibration source travels a distance equal to $\frac{V_S}{\nu}$ towards the listener then apparent wavelength is shortened.



$$\lambda' = \frac{V}{\nu} - \frac{V_S}{\nu}$$

or $$\lambda' = \frac{V - V_S}{\nu} \text{ ----------(ii)}$$

The apparent frequency from eq(i) is given as,

$$\nu' = \frac{V}{\lambda'}$$

Putting value of λ' from eq(ii),we get

$$\nu' = \frac{V}{\frac{V - V_S}{\nu}}$$

or $$\boxed{\nu' = \left(\frac{V}{V - V_S}\right)\nu}$$

This expression shows that the apparent frequency will be greater than real frequency.

<u>CASE 2(B):</u> When source of sound moves away from the stationary listener.

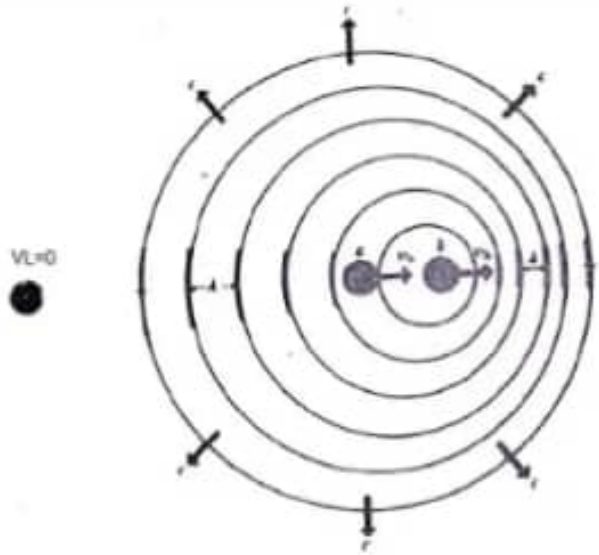
Let us consider a source of sound moving with velocity Vs away from stationary listener. The wave crests detected by the listener are farther together because the source is moving in the opposite direction of outgoing wave resulting the increasing of wavelength.

As we know that

$V = \nu\,\lambda$ => $\lambda = \frac{V}{\nu}$ (Distance occupied by one wave)

and $\nu = \frac{V}{\lambda}$ (Real Frequency) ------(i)

During each vibration source travels a distance equal to $\frac{V_S}{\nu}$ away from the listener then apparent wavelength is increased.



$$\lambda' = \frac{V}{\nu} + \frac{V_S}{\nu}$$

or $$\lambda' = \frac{V + V_S}{\nu} \text{ ----------(ii)}$$

The apparent frequency from eq(i) is given as,

$$\nu' = \frac{V}{\lambda'}$$

Putting value of λ' from eq(ii),we get

$$\nu' = \frac{V}{\frac{V+V_S}{\nu}}$$

or $$\boxed{\nu' = \left(\frac{V}{V+V_S}\right)\nu}$$

This expression shows that the apparent frequency will be less than real frequency.

PROBLEM 1: A person sits beside a highway when a car traveling toward the observer at 35.0 m/s blows its horn with a frequency of 320 Hz. What frequency of sound does the observer hear when (a) the car is approaching? (b) the car is right next to him? (c) the car is moving away? (Speed of sound=344 m/s)

SOLUTION:

(a) When source of sound approaches the listener

$$\nu' = \left(\frac{V}{V-V_S}\right)\nu$$

$$\nu' = \left(\frac{344}{344-35}\right)320$$

$$\boxed{\nu' = 356Hz}$$

(b) When source of sound is next to the listener

$$\nu' = \boxed{\nu = 320\ Hz}$$

(a) When source of sound moving away from the listener

$$\nu' = \left(\frac{V}{V+V_S}\right)\nu$$

$$\nu' = \left(\frac{344}{344+35}\right)320$$

$$\boxed{\nu' = 290.4Hz}$$

PROBLEM 2: A certain dog whistle has a frequency of 35.1 kHz. A person blows the whistle while standing on bus stop. With what minimum velocity must a person in a car in order for the sound to be shifted into the audible frequency range? (speed of sound in air is 338 m/s).

SOLUTION:

As 35.1 KHz is greater than the audible frequency range, therefore the second plane has to move away so that the frequency will decrease and shift in audible frequency range.When listener moves away the apparent frequency is given by

$$v' = \left(\frac{V - V_L}{V}\right) v$$

$$20000 = \left(\frac{338 - V_L}{338}\right) 35100$$

$$192.6 = 338 - V_L$$

$$V_L = 192.6 + 338$$

$$\boxed{V_L = 530.6\, m/s}$$

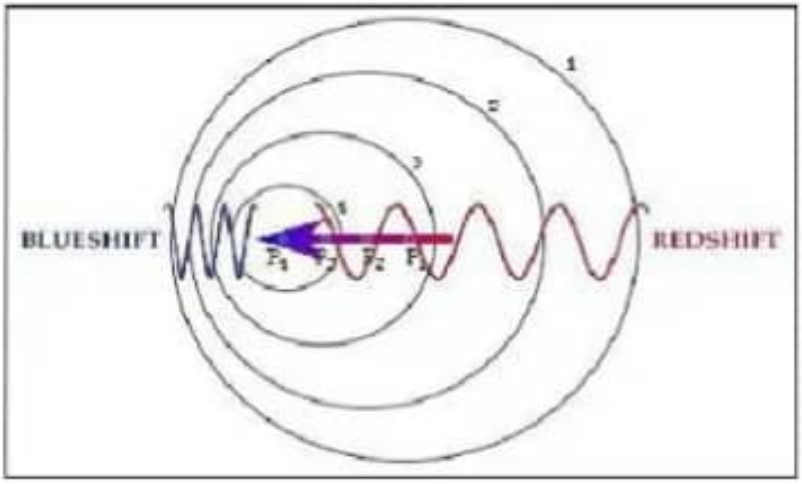
8.5.3 Explain the application of Doppler's effect in electromagnetic waves. (COGNITIVE LEVEL:U)

As we know that electromagnetic waves do not need a medium, the Doppler effect for EM waves

is simply a relative-velocity phenomenon. The shift in frequency observed by an observer depends only on the relative velocity, between the source and the observer. If the source emits EM waves that have a frequency f, the observed frequency f ' is given by

$$f' = f\left(1 \pm \frac{v}{c}\right)$$ (The Doppler effect for electromagnetic waves)

where v is the magnitude of the relative velocity between the source and the observer. As with the Doppler effect for sound, we use the top (+) sign when the source and observer are moving toward one another, and the bottom (−) sign when the source and observer are moving farther apart.

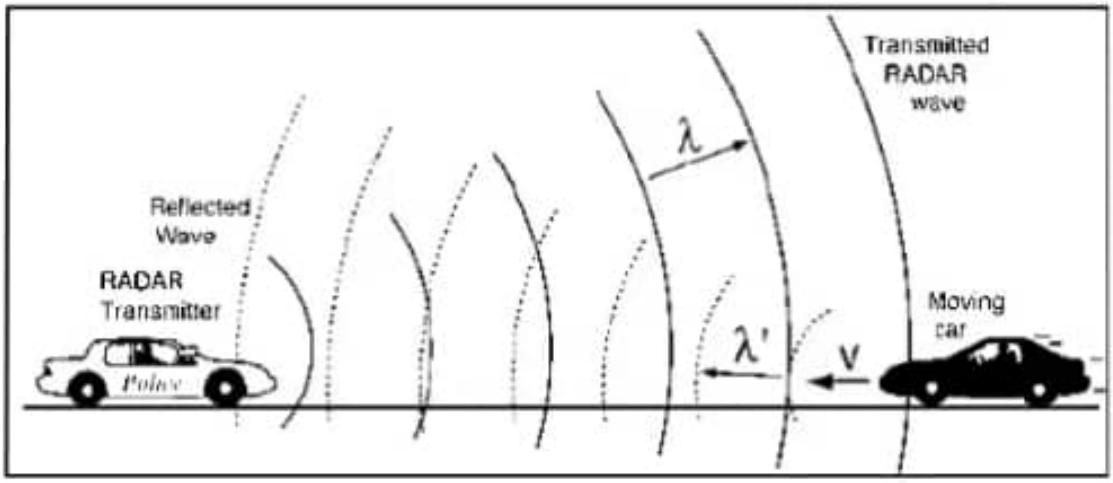


A common application in which the Doppler Effect is exploited by astrophysicists is to determine how fast, and in what direction, distant stars or galaxies are moving with respect to us here on Earth. At the bottom is the spectrum received on Earth from the Sun. The dark lines at specific wavelengths correspond to light that is absorbed by hydrogen atoms in the Sun. These same lines are seen in the spectrum received from a distant source, at the top, except all the lines are Doppler-shifted toward the red end (the right end) of the spectrum, indicating that the source is moving away from the Earth. It was data such as this that was used by Edwin Hubble (1889 – 1953) to show that the universe is expanding.

8.5.4 Apply Doppler's effect to understand the working of radar, sonar and satellites. (COGNITIVE LEVEL:A)

WORKING OF RADAR:

The Doppler Effect is used in some types of radar, to measure the velocity of detected objects. A radar beam is fired at a moving target e.g. a motor car, as police use radar to detect speeding motorists as it approaches or recedes from the radar source. Each successive radar wave has to travel farther to reach the car, before being reflected and re-detected near the source. As each wave has to move farther, the gap between each wave increases, increasing the wavelength. In some situations, the radar beam is fired at the moving car as it approaches, in which case each successive wave travels a lesser distance, decreasing the wavelength. In either situation, calculations from the Doppler Effect accurately determine the car's velocity. Moreover, the proximity fuze, developed during World War II, relies upon Doppler radar to detonate explosives at the correct time, height, distance, etc.



Because the Doppler shift affects the wave incident upon the target as well as the wave reflected back to the radar, the change in frequency observed by radar due to a target moving at relative velocity Δv is twice that from the same target emitting a wave :

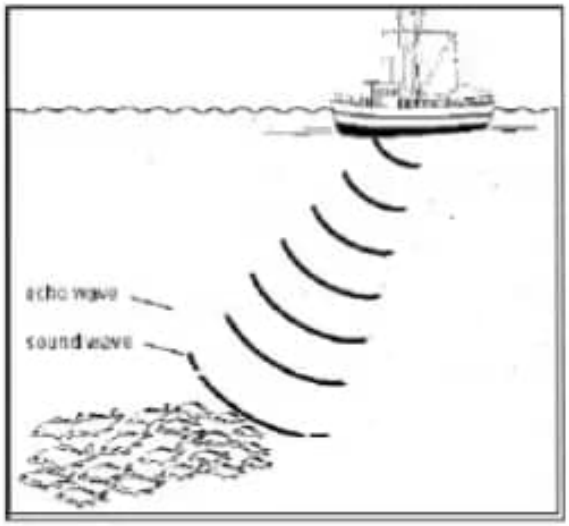
$$\boxed{\Delta f = f_0\left(\frac{2\Delta v}{c}\right)}$$

WORKING OF SONAR:

Sonar stands for Sound Navigation And Ranging, is a technique that uses sound propagation (usually underwater, as in submarine navigation) to navigate, communicate with or detect objects on or under the surface of the water, such as other vessels.

Active sonar creates a pulse of sound, often called a "ping", and then listens for reflections (echo) of the pulse. To measure the distance to an object, the time from transmission of a pulse to

reception is measured and converted into a range by knowing the speed of sound. Particularly when single frequency transmissions are used, the Doppler effect can be used to measure the radial speed of a target. The difference in frequency between the transmitted and received signal is measured and converted into a velocity. Since Doppler shifts can be introduced by either receiver or target motion, allowance has to be made for the radial speed of the searching platform.



WORKING OF SATELLITES:

The Doppler Effect allows the distance between a satellite transmitting from space and a radio receiver on the ground to be measured by observing how the frequency received from the satellite transmitter changes as the satellite approaches, passes overhead, and moves away.

1. As a satellite approaches, the frequency of its transmitter appears to be higher than the actual transmission frequency.

2. Overhead is the time of closest approach when the transmitted frequency and the received frequency are the same.

3. As a satellite moves away, the frequency appears to be lower than the actual transmission frequency.

The frequency received can be displayed on a Doppler Curve graph relating frequency to time. As a satellite approaches and passes overhead, the received frequency appears to fall. However, the rate of change in frequency is not constant. At first, the frequency changes slowly. Then the change increases to its greatest rate at the time of closest approach. After passing overhead, the rate of frequency change slows as the satellite moves away.

9.1 NATURE OF LIGHT

9.1.1 Discuss different points of view about nature of light. (COGNITIVE LEVEL:U)

NATURE OF LIGHT:

In the seventeenth century two rival theories of the nature of light were proposed, the wave theory and the corpuscular theory.

The Dutch astronomer Huygens (1629-1695) proposed a wave theory of light. He believed that light was a longitudinal wave, and that this wave was propagated through a material called the 'aether'. Since light can pass through a vacuum and travels very fast Huygens had to propose some rather strange properties for the aether: for example; it must fill all space and be weightless and invisible. For this reason scientists were sceptical of his theory.

In 1690 Newton proposed the corpuscular theory of light. He believed that light was shot out from a source in small particles, and this view was accepted for over a hundred years.

The quantum theory put forward by Max Planck in 1900 combined the wave theory and the particle theory, and showed that light can sometimes behave like a particle and sometimes like a wave. You can find a much fuller consideration of this in the section on the quantum theory.

WAVE THEORY OF HUYGENS:

As we have seen, Huygens considered that light was propagated in longitudinal waves through a material called the ether. We will now look at his ideas more closely.

Huygens published his theory in 1690, having compared the behaviour of light not with that of water waves but with that of sound. Sound cannot travel through a vacuum but light does, and so Huygens proposed that the aether must fill all space, be transparent and of zero inertia. Clearly a very strange material!

There are however at least two problems with this idea and these led Newton and others to reject it:

(a) the secondary waves are propagated in the forward direction only, and

(b) they are assumed to destroy each other except where they form the new wavefront.

Huygens' theory also failed to explain the rectilinear propagation of light.

CORPUSCULAR THEORY OF NEWTON:

Newton proposed that light is shot out from a source as a stream of particles. He argued that light could not be a wave because although we can hear sound from behind an obstacle we cannot see

light - that is, light shows no diffraction. He stated that particles of different colours should be of different sizes, the red particles being larger than the blue.

Since these particles are shot out all the time, according to Newton's theory, the mass of the source of light must get less! .A problem of the corpuscular theory was that temperature has no effect on the velocity of light, although on the basis of this theory we would expect the particles to be shot out at greater velocities as the temperature rises.

CLASSICAL AND MODERN THEORIES OF LIGHT:

It is interesting to compare the two classical theories of light and see which phenomena can be explained by each theory. The following table does this.

Wave theory	Corpuscular theory
Reflection	Reflection
Refraction	Photoelectric effect
Diffraction	
Interference	

Notice that neither theory can account for polarization, since for polarization to occur the waves must be transverse in nature.

MODEM THEORIES:

Twentieth-century ideas have led us to believe that light is:

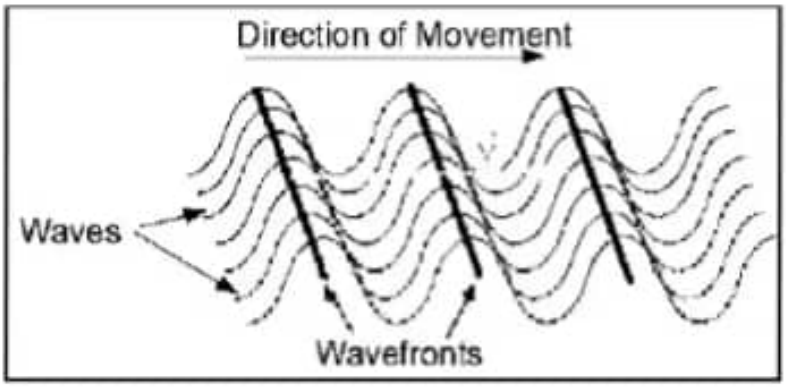
(a) a transverse electromagnetic wave with a small wavelength, and

(b) emitted in quanta or packets of radiation of about 10-8 s duration with abrupt phase changes between successive pulses.

9.1.2 Discuss the concept of wave-front. (COGNITIVE LEVEL:U)

WAVE FRONT:

Whenever a wave passes through a certain medium, its particles execute simple harmonic motion. The focus of at the points in the medium having same phase of vibrations is called a wave front.



In case of a point source of light in a certain homogenous medium the wave front will be concentric spheres with center as the source S. such a wave front is known as

spherical a Wave Front.

At a very large distance from source, a small portion of a spherical wave front is nearly a plane, Such a portion of the wave front is called a plane wave front.

In case of light, a Ray is known as the direction in which a wave propagates and it is always normal to the wave front. Thus a please wave front represents a parallel pencil of rays.

9.1.3 Describe Huygens principle and use it to explain linear superposition of light. (COGNITIVE LEVEL:U)

HUYGEN'S PRINCIPLE:

Huygens principle consists of two parts:-

(i) The first part states that every point on a wave front can be considered as a source of secondary spherical wave-lets.

(ii) The secondary wavelets travels with the speed equal to the source of wavelets.

In figure AB represents the position of a spherical front at a particular instant. To get the position of the new wave front after t second we take some points on the wave front AB, according to the first principle. If the wave travels a distance vt in time t sec, then draw the secondary wavelets with radius v t. By the second part of the principle draw a plane CD tangential to these wavelets, then CD will be the new wave front after time t.

INTERFERENCE OF WAVES:

When two waves superpose one another they either enhance the effect of one another or they reduce their effect at that point. This phenomenon is called interference of waves.

CONSTRUCTIVE INTERFERENCE:-

When two waves meet such that the crest of one wave coincides with the crest of other wave, and the trough of one wave coincides with the trough other wave, the resulting crests and troughs are enhanced. Such interference is called constructive interference. For constructive interference the path difference between them must be integral multiple of λ i.e.

$$\boxed{Path\ difference = m\lambda}$$

where m = 0: $\pm$ 1; $\pm$ 2; $\pm$3,...

DESTRUCTIVE INTERFERENCE:

When two waves meet such that the crest of one wave coincides with the trough of the other wave and the trough of one wave coincides with the crest of the other wave, the resulting crests and

troughs are reduced. Such interference is called destructive interference. For destructive interference the path difference between them must be odd multiple of $\lambda/2$ i.e.

$$\boxed{Path\ difference\ =\ (m\ +\frac{1}{2})\lambda}$$

Where m = 0; ± 1; ± 2; ± 3 ...

9.2 INTERFERENCE OF LIGHT

9.2.1 Define interference of light and state conditions necessary for it. (COGNITIVE LEVEL:K)

INTERFERENCE OF LIGHT:

When two light waves superpose one another they either enhance the effect of one another or they reduce their effect at that point. This phenomenon is called interference of light.

CONDITIONS OF INTERFERENCE OF LIGHT:

For interference of light the following conditions must be observed.

1. The sources of light must be monochromatic and coherent.
2. The slits must be narrow of the order of wavelength of light.
3. The slits must be separated by a small distance.

9.2.2 Explain Young's double slit experiment. (COGNITIVE LEVEL:U)

YOUNG'S DOUBLE SLIT EXPERIMENT

The fringes obtained by Young's double slit experiment are the result of interference of light waves. The conditions for interference are:

(i) Monochromatic light must be used.

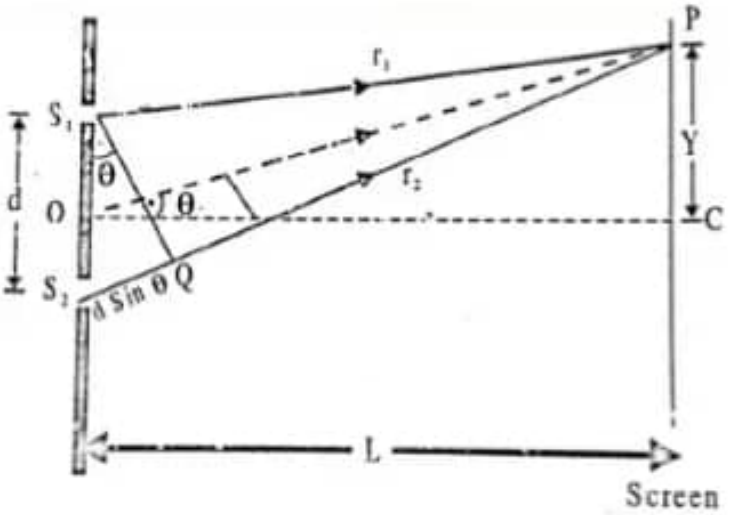
(ii) The slits must be narrow of the order of wavelength of light and two sources of light must be coherent.

(iii) The two sources must be very close to each other is the wavelength of light is very small, otherwise the bright and dark pattern in front of the source would be two fine to see and interference pattern will be visible.

Light from a monochromatic source falls on the slits S and illuminate the two slits S_1 and S_2 separated by a small distance d. Since the light diverging from the slit S_1 has exactly the same frequency as the light diverging from S_2 act as two close coherent sources interference takes places at the screen placed at a distance L form the double slits.

9.2.3 Derive relation for fringe spacing and use the relation in solving numerical. (COGNITIVE LEVEL:A)

Waves traveling from the slit S_2 to any point P on the screen travel a distance $S_2P = r_2$ and from the slit S_1 travel a distance $S_1P = r_1$ the intensity of light at P will be the result of the superposition of the waves coming from S_1 and S_2. The path difference



Between the waves from S1 and S_2 is given by

Path difference = $PS_2 - PS_1$

= $(r_2 - r_1)$

= $d \sin\theta$

IN CONSTRUCTIVE INTERFERENCE:

If the path difference is an integral multiple of λ, Constructive interference will take place at P. Hence for constructive interference.

$$d \sin\theta = m\lambda \text{ (Maxima)}$$

Where λ is the wave length of light used and m is the order of the fringe that is

$$m = 0, +1, +2, +3, +4, \ldots$$

The central bright fringe at $\theta = 0$ ($m = 0$) is called zero order maximum.

IN DESTRUCTIVE INTERFERENCE:

If the path difference is an odd multiple of λ, the waves arriving at P will be out of phase and hence Destructive interference will take place at P. for destructive interference.

$$d \sin\theta = (m + \tfrac{1}{2})\lambda \text{ (Minimum)}$$

$$m = 0, +1, +2, +3, +4, \ldots$$

The position of bright and dark fringes is measured from the central bright fringe. Since the distance L is very large from the slits as compared to the distance between the slits, hence the angle θ is very small. Thus for small angles.

$\sin\theta \cong \tan\theta = Y/L$ (From the triangle ΔOQP)

Now,

Path diff. = $d\,Y/L$

POSITION OF BRIGHT FRINGES:

For bright fringes the path difference is given by

$$d \sin\theta = m\lambda$$

or $$d\, Y/L = m\lambda$$

or $$\boxed{Y = \frac{m\lambda L}{d}}$$

=> $$Y = 0, \frac{\lambda L}{d}, 2\frac{\lambda L}{d}, 3\frac{\lambda L}{d}, 4\frac{\lambda L}{d}, \ldots$$

These are the positions of bright fringes

POSITION OF DARK FRINGES:

For dark fringes the path difference is given by

$$d \sin\theta = (m+1/2)\lambda$$

or $$d\, Y/L = (m+1/2)\lambda$$

or $$\boxed{Y = \frac{(m+\frac{1}{2})\lambda L}{d}}$$

=> $$Y = \frac{\lambda L}{2d}, 3\frac{\lambda L}{2d}, 5\frac{\lambda L}{2d}, \ldots$$

These are the positions of dark fringes

FRINGE SPACING:

The distance between two dark or two bright fringes is called Fringe spacing. The fringe spacing Δx is given by.

The position of 1st bright fringe =0

The position of 2nd bright fringe $= \frac{\lambda L}{d}$

$$\Delta x = \frac{\lambda L}{d} - 0$$

or

$$\boxed{\Delta x = \frac{\lambda L}{d}}$$

If L, d and Δx are known the value of the wavelength λ can be calculated. The fringe spacing depends upon the wavelength of light used as L and d are constant for a given experiment.

PROBLEM 1: In a double slit interference experiment, the distance between the slits is 0.0005m and the screen is 2 meters from the slits. Yellow light from a sodium lamp is used and it has a wavelength of 5.89 x 10^{-7} m. Find the distance between the first and second fringes on the screen.

SOLUTION:

The distance between two adjacent bright or dark fringes is known as fringe spacing, which is given by,

$$\Delta x = \frac{\lambda L}{d}$$

$$\Delta x = \frac{(5.89 \times 10^{-7})(2)}{(5 \times 10^{-4})} = 0.00235$$

or $$\boxed{\Delta x = 2.35 \times 10^{-3} m}$$ (Answer)

PROBLEM 2: With two slits spaced 0.2mm apart, and a screen at a distance of l=1m, the third bright fringe is found to be displaced h=7.5mm from the central fringe. Find the wavelength of the light used ?

SOLUTION:

The distance between 3 fringes is 7.5 mm, so the fringe spacing is given by,

$$\Delta x = \frac{\Delta x_3}{3} = \frac{7.5}{3} = 2.5mm = 2.5 \times 10^{-3} \text{ m}$$

Now, using the formula for fringe spacing,

$$2.5 \times 10^{-3} = \frac{\lambda(1)}{0.2 \times 10^{-3}}$$

$$\lambda = 2.5 \times 10^{-3} \times 0.2 \times 10^{-3}$$

$$\boxed{\lambda = 5 \times 10^{-7} m}$$ (Answer)

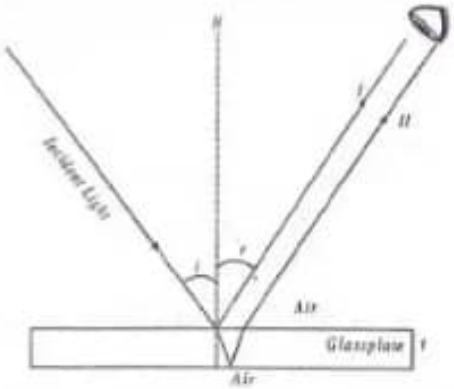
9.3 INTERFERENCE IN THIN FILMS

9.3.1 State basic concept of interference in thin films. (COGNITIVE LEVEL:K)

INTERFERENCE IN THIN FILM

Constructive and destructive interference of light waves is also the reason why thin films, such as soap bubbles, show colorful patterns. This is known as thin-film interference, because it is the interference of light waves reflecting off the top surface of a film with the waves reflecting from the bottom surface. To obtain a nice colored pattern, the thickness of the film has to be on the order of the wavelength of light.

Reflection of light waves, when light waves (transverse waves) strike at the boundary of a denser medium, the crest returns as a trough and the trough returns as a crest. There is a change in its phase by a or 180 ° or a path difference of ½ λ. On the contrary when it strikes at the boundary of rarer medium, the crest returns as a crest and trough returns as a trough. There is no change in its phase. The wave length of light in a medium is changed by a factor. I/n if λ be the wavelength of light in air and λ_n be its wavelength in a medium of refractive index n, then.



$$\lambda_n = \frac{\lambda}{n}$$

When light falls on a film of a transparent medium of thickness then a part of the light is reflected from the upper surface of the film and the change in the path difference of ½ λt akes place (phase is reversed) Some of the light is refracted into the medium of the film, which is reflected from the lower surface of the film. Since it is reflected from the rare medium, hence there is no change is its phase (ray 1 and 2)If the light rays are normal incident on the film, then the path difference between ray 1 and 2 is "2t". where t is the thickness of the film.

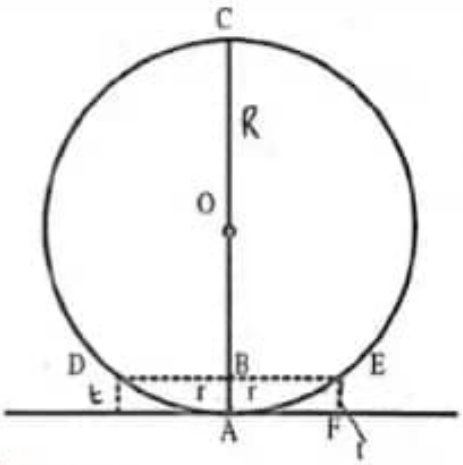
9.4 NEWTON'S RING

9.4.1 Explain the phenomenon of formation of Newton's rings with examples. (COGNITIVE LEVEL:U)

NEWTON'S RINGS

DEFINITION:-

The principle of Newton's rings is based on the interference of wedg e shaped film. A plano-convex lens is placed on a plane and smooth glass plate. An air film is enclosed between the lens and the glass plate. The thickness of the air film is zero at the point of contact 'A' and increase as we move outward.



$\overline{(AO)} = \overline{(OC)} = R$
$\overline{(DB)} = \overline{(BE)} = r$
$\overline{(FE)} = \overline{(AB)} = t$

Light is allowed to fall on the glass plate which is inclined at an angle of 45^0. The light is reflected from lower surface of the glass, plate and falls normally on the lens. After passing through the lens the light is reflected from the upper and lower surface of the air film. The light reflected from the upper surface of the air

film, does not suffer while light reflected from the lower surface of the air film (upper surface of the glass) suffers a phase change of 180° (if the thickness of the air film is such that the path difference between ray No. 1 and Ray No.2 is an integral multiple of λ., destructive interference will take place at those points. If the thickness of the air film is such that the path difference between ray No.1 and Ray No.2 is an integral multiple of λ destructive interference will take place at those points. If the thickness of the film is such that the path difference between ray No.1 and Ray No.2 is an integral multiple of λ., destructive interference will take place at those points. If the thickness of the film is such that the path difference between ray No.1 and Ray No.2 is odd multiple of λ/2 constructive interference will take place at those point of contact, hence the interference fringes will be circular, (dark and bright circles) when seen through the reflected light, the center will be dark. These circles are called Newton's rings.

9.5 MICHELSON'S INTERFEROMETER

9.5.1 Describe the working and use of Michelson's interferometer. (COGNITIVE LEVEL:U)

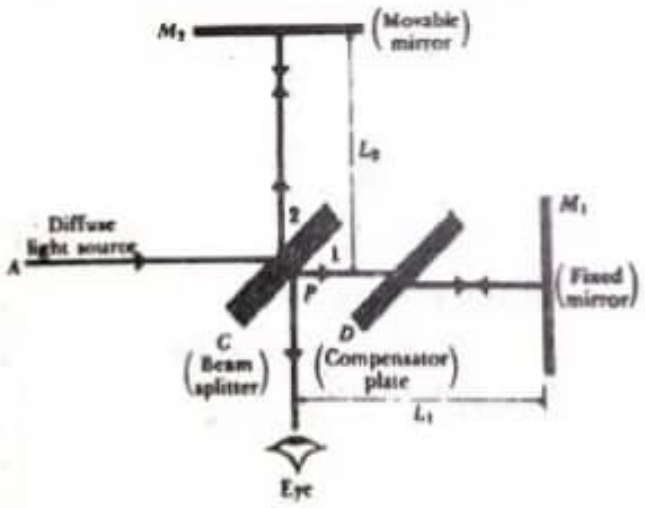
MICHELSON'S INTERFEROMETER

INTRODUCTION:

Michelson's interferometer was invented by and American physicist A.A Michelson.In case of a Michelson's interferometer we use an extended source of monochromatic light in comparison with Young's double slit experiment where we use two narrow slits.Figure shows the princi ple diagram of Michelson's interferometer.

PROCEDURE:

Light from an extended source strikes the glass plate C the right side of which has a thin coating of silver. Part of this light is reflected from the silvered surface at P to the mirror M_2 and back through the silvered surface to the observer's eye. The remainder of the light passes through the silvered surface and through the compensator plate D and is reflected from the mirror M_2. It then returns through D and I reflected from the silvered surface of C to the observer eye. Both the plates C and D are of early same thickness so that the rays 1 and 2 through the same thickness of glass. The plate C is called beam splitters.



If the distances L_1 and L_2 are exactly equal and the mirrors M_1 and M_2 are not perpendicular then a wedge film will be obtained under this conditions the virtual image of M_1 and mirror M_2 behave as the two surface of a wedge shaped film. The interference fringes are obtained in the same way as in case of thin wedge shaped film.

CALCULATION OF WAVELENGTH :

Let the extended source be monochromatic of wavelength λ and the mirror M_2 is moved through $\lambda/4$, the path difference is changed by $\lambda/2$, and a dark fringe will appear in place of bright fringe. If now the mirror M_2 is moved through $\lambda/2$, the path difference is changed by λ and a dark fringe will replace a bright fringe. If the fringes are seen, through a telescope, and 'm' bright fringes pass through the cross wire when the mirror M_2 is moved through X then

$$x = m\frac{\lambda}{2}$$

Or $\boxed{\lambda = \frac{2x}{m}}$

If m is large then X is also large and can be measured with good precision and hence a precise value of λ can be obtained.

9.6 DIFFRACTION OF LIGHT

9.6.1 Define diffraction of light. (COGNITIVE LEVEL:K)

DIFFRACTION OF LIGHT

According to geometrical optics when light falls on an opaque body it casts it shadow of the same shape, and

1. No light enters into the region of shadow and
2. Outside the shadow, the screen in uniformly illuminated

However, it is found when light falls on sharp edges and narrow slits, the light bends into the shadow showing that light can bend inside the geometrical shadows. "The bending of waves around the corners of obstacles, sharp edges or narrow slits is called diffraction".

9.6.2 Describe diffraction of light by diffraction grating. (COGNITIVE LEVEL:U)

DIFFRACTION GRATING

DEFINITION:

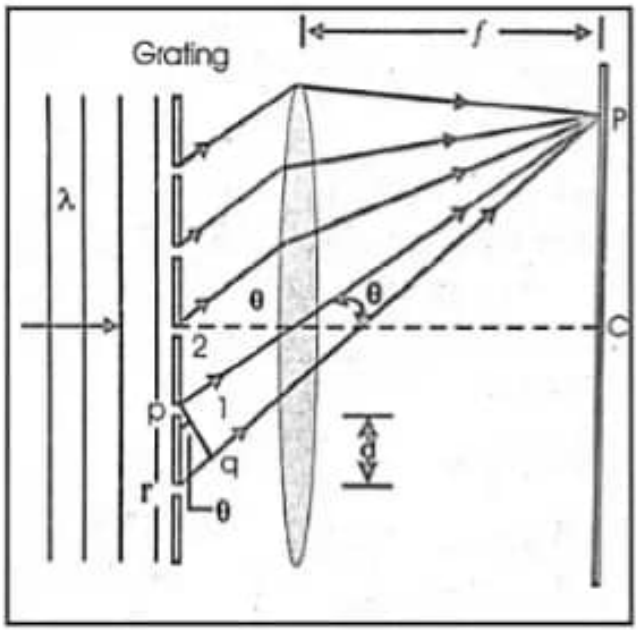
If instead of a single slit there are large number of slits parallel to one another with equal width, such an arrangement is called diffraction grating.A diffraction grating consists of a glass piece with a number of parallel opaque lines marked on it there is transparent portion which acts as slit. The distance between two lines on a grating is called grating element it is equal to the length of the grating divided by the number of lines on it, th e grating element 'd' is given by

$$d = \frac{length\ of\ grating}{number\ \ of\ opaque\ \ lies}$$

In the figure if 'n' width of the opaque line and 'b' is width of the opening then grating element is given by.

$$d = (a + b)$$

EXPLANATION:



A diffraction grating is shown in the figure. A parallel beam of monochromatic light is normal incident upon it, which sends out waves from each slit. A convex lens is placed in the path of diffracted waves which bring them together at a point on the screen in a certain direction waves of particular wavelength which are in phase reinforce each other and focus at a point in chase of white light.

If the parallel rays of light after diffraction differ in path difference by λ, they will interfere constructively at P.For constructive interference the path difference between any two adjacent rays must be zero or an integral multiple of λ.

Path difference = m λ

$(a + b) \sin\theta = m\lambda$

or $d \sin\theta = m\lambda$

The central maximum has a path difference equal to zero, hence it is called zero order.

The first order maximum occurs when ..... $d \sin\theta = 1\lambda$

The second order maximum occurs when ..... $d \sin\theta = 2\lambda$

The third order maximum occurs when..... $d \sin\theta = 3\lambda$

The mth order diffraction occurs when

$$\boxed{d \sin\theta = m\lambda}$$

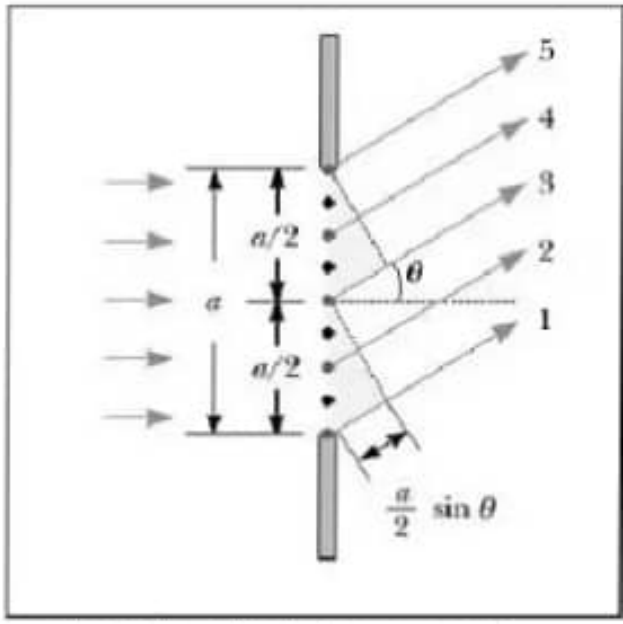
Where m called the order of spectrum and has values

$m = 0, \pm, \pm 1, \pm 2, \pm 3, ..$

9.6.3 Describe diffraction in a narrow slit. (COGNITIVE LEVEL:U)

DIFFRACTION IN A NARROW SLIT:

As Fresnel predicted, when light passes near the edge of an opaque object and then onto a screen, there appears to be some illumination in the area of the geometric shadow. In other words, light fails to travel in straight lines when passing sharp edges. This phenomenon is known as diffraction, and occurs because of the wave nature of light. This means that there are many different path lengths from the object to the screen. If there is sufficient difference in the path length, two waves reaching the same point may be 180° out of phase, resulting in destructive interference. In the same way, constructive interference may also occur.



If we consider how planes waves of light of wavelength λ are diffracted by a single long narrow slit of width a in an otherwise opaque screen, as shown in Figure 1. When the diffracted light reaches a viewing screen, waves from different points within the slit undergo interference and produce a diffraction pattern of bright and dark fringes on the screen. To locate the dark fringes, we shall us a clever strategy that involves pairing up all the rays coming through the slit and finding what conditions cause the waves of the rays in each pair to cancel each other. First, we divide the slit into two zones of equal widths a/2. Then we extend a light ray from the top point of the top zone, and another from the top point of the bottom zone, to the same point on the screen.

The waves of the pair of rays are in phase within the slit because they originate from the same wavefront passing through the slit. However, tto produce he first dark fringe they must be out of phase by λ/2 when they reach the viewing screen. This phase difference is due to their path length difference. To display this path length difference, we find a point b on the second ray such that the distance from that point to the screen is the same as the path length for the first ray. Then the phase difference is the distance from b to the center of the slit. The two rays are approximately parallel if the distance to the screen is much greater than the slit with, a. This makes the triangle formed by the top of the slit, the center of the slit and point b a right triangle. Therefore, using a little geometry, we find that one of the angles of this triangle is θ. The path length difference between the two rays is then equal to (a/2)sinθ.

This will be true for any pair of rays originating from corresponding points in these two regions going to the same point. Setting this common path length difference equal to λ/2, we have

$$a/2 \sin\theta = \lambda/2,$$

giving us

$$a \sin\theta = \lambda \text{ (first minimum).} \qquad (1)$$

Given the slit width a and the wavelength λ, this tells us the angle θ of the first dark fringe above and (by symmetry) below the central axis.

We can find the second dark fringes above and below the central axis in the same way, except that we now divide the slit into *four* zones of equal widths a/4. and extend these four rays to the same point on the screen. To produce a dark fringe, the path length difference between adjacent pairs of rays must be $\lambda/2$. So we now have

$$a/4 \sin\theta = \lambda/2,$$

giving us

$$a \sin\theta = 2\lambda \text{ (second minimum)} \qquad (2)$$

We can continue to locate dark fringes in the diffraction pattern by splitting up the slit into more zones of equal width. We would always choose an even number of zones so that the waves could be paired as we have been doing. In this way we would find that the dark fringes can be located with the following general equation:

$$a \sin\theta = m\lambda \text{ for } m = 1, 2, 3, \ldots \text{ (minima – dark fringes).} \qquad (3)$$

9.6.4 Describe X-rays diffraction through crystals. (COGNITIVE LEVEL:U)

DIFFRACTION OF X-RAYS

X rays have very Short wavelength less than that of visible and ultraviolet light. Therefore diffraction of X - rays cannot be observed with the help of common grating as X-rays pass through the slits of grating. However it is possible to obtain it rays diffraction by making use of crystals such as rock salt in which the atoms are uniformly spaced planes and separated by a distance of the order of 2 -5 A°. Therefore the diffraction of X - rays takes place when they incident on the crystals.

Crystals are regular arrays of atoms, and X-rays can be considered waves of electromagnetic radiation. Atoms scatter X-ray waves, primarily through the atoms' electrons. Just as an ocean wave striking a lighthouse produces secondary circular waves emanating from the lighthouse, so an X-ray striking an electron produces secondary spherical waves emanating from the electron. This phenomenon is known as elastic scattering, and the electron (or lighthouse) is known as the scatterer. A regular array of scatterers produces a regular array of spherical waves. Although these waves cancel one another out in most directions through destructive interference, they add constructively in a few specific directions, determined by Bragg's law:

$$\boxed{dSin\,\theta = m\lambda}$$

9.7 BRAGG'S LAW

9.7.1 Define Bragg's law. (COGNITIVE LEVEL:K)

BRAGG'S LAW:

It is law in physics which states that there is a definite relationship between the angle at which a beam of X rays must fall on the parallel planes of atoms in a crystal in order that there be strong reflection, the wavelength of the X rays, and the distance between the crystal planes

$$dSin\,\theta = m\lambda$$

where θ is the angle between the incident or the reflected beam and the crystal plane, λ is the X-ray wavelength, d is the crystal plane separation, and m is any integer

9.7.2 Derive the equation 2 d sin θ = m λ and use this equation for solving numerical. (COGNITIVE LEVEL:A)

Suppose parallel Lattice planes having spacing 'd' between each other. It is clear from figure that 2 nd ray covers more distance as compared to 1st ray and the path difference between two reflected rays is,

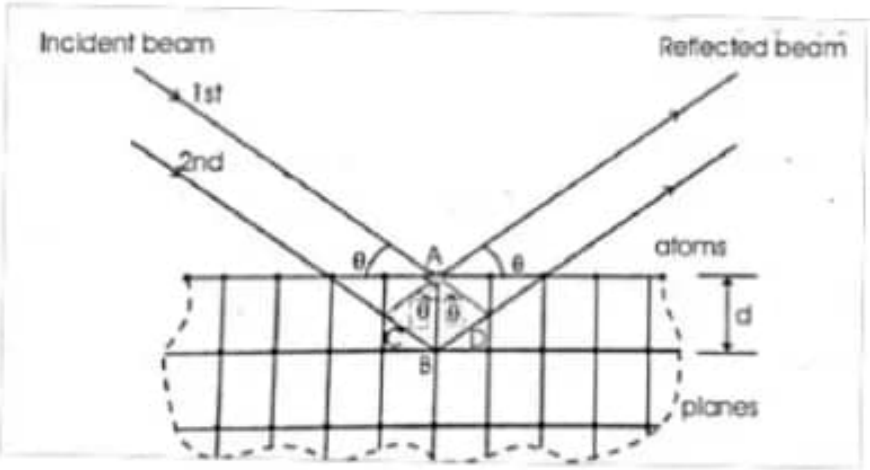
Path diff = BC + BD - (i)

In right angled Δ BAC,

$$Sin\,\theta = \frac{\overline{BC}}{\overline{AB}}$$

$$Sin\,\theta = \frac{\overline{BC}}{d}$$

$$\overline{BC} = dSin\,\theta$$



Similarly,

$$\overline{BD} = dSin\,\theta$$

Putting values in eq(i),we get

$$Path\ Diff = dSin\,\theta + dSin\,\theta$$

$$Path\ Diff = 2dSin\,\theta \text{ ---------(ii)}$$

Now, For constructive interference,

$$Path\ Diff = m\lambda \text{ ----------(iii)}$$

Comparing eq(ii) and eq(iii)

$$\boxed{dSin\,\theta = m\lambda}$$

This is known is Braw's Law.Now if 'd' the interplanar distance of crystal is known where 'm' and "θ" are experimentally measured then wave length of x ray light used can be calculated with the help of this equation.

9.8 POLARIZATION

9.8.1 Define polarization. (COGNITIVE LEVEL:K)

POLARIZATION:

A light wave that is vibrating in more than one plane is referred to as unpolarized light. Light emitted by the sun, by a lamp in the classroom, or by a candle flame is unpolarized light. Such light waves are created by electric charges that vibrate in a variety of directions, thus creating an electromagnetic wave that vibrates in a variety of directions. This concept of unpolarized light is rather difficult to visualize. In general, it is helpful to picture unpolarized light as a wave that has an average of half its vibrations in a horizontal plane and half of its vibrations in a vertical plane.

It is possible to transform unpolarized light into polarized light. Polarized light waves are light waves in which the vibrations occur in a single plane. The process of transforming unpolarized light into polarized light is known as polarization.

9.8.2 Evaluate polarization as a phenomenon associated with transverse waves. (COGNITIVE LEVEL:A)

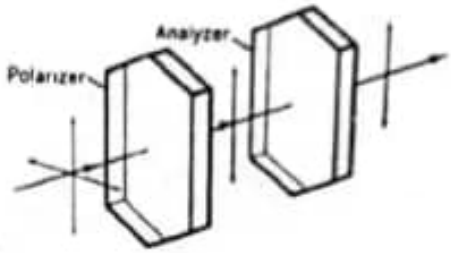
The interference and diffraction phenomena verify the wave nature of light but these phenomena do not provide any information about the type of light waves.

It is polarization phenomenon which tells us that light waves are transverse in nature.Actually, there is a periodic fluctuation in electric and magnetic fields along the propagation of light waves. These fields vary at right angles to the direction of the propagation of the light wave. so light wave is a transverse wave and this makes it possible to produce and detect polarized light.

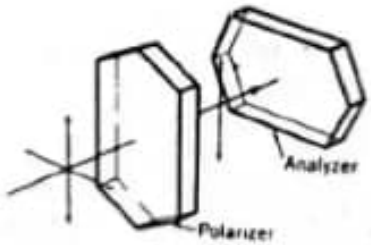
Unpolarized light means ordinary light whose waves have electric and magnetic vibrations in all directions in a plane perpendicular to the direction of propagation of light. Polarized light means light waves having vibrations in certain directions 'y' perpendicular to the direction of propagation of light. Tourmaline crystals are often used to polarize the light and to analyse the polarized light. A tourmaline crystal has its crystallographic axis parallel to its face and it transmits" only those vibrations of light waves which are parallel to the axis of crystal.

9.8.3 Express that polarization is a product by a Polaroid. (COGNITIVE LEVEL:U)

When unpolarized light is incident on two tourmaline crystals placed with their crystallographic axes parallel,the light beam is transmitted. If however, one of the crystal is rotated with respect to other the emergent beam becomes dimmer and ultimately light is totally cut off when the axes of the two crystals become perpendicular to each other. On further rotation, the light reappears and becomes brighter ,when the axes of crystals again parallel as shown in fig.



When a beam of light passes through crystal one component of the vibration is absorbed and the other component is transmitted.



Consequently the emerging beam differs from incident light in the sense that all the vibrations are in one direction. Such a beam is said to be plane polarized. When it falls on a second crystal, vibrations can only pass if they are parallel to the transmission direction of the crystal i.e. crystallographic axis of the crystal.It means that polarization of light is due to selective absorption by tourmaline of all light waves vibrating in one particular plane. The first crystal is known as polarizer ,where as the second crystal is known as analyzer.

9.8.4 Identify uses of polarization. (COGNITIVE LEVEL:K)

APPLICATIONS OF POLARIZATION OF LIGHT:

(i) The simplest application of polaroid is curtain less windows. An outer polarizing disc is fixed in position and an inner disc may be rotated to adjust the amount of light admitted.

(ii) In photography it is often desirable to enhance the effect of sky and clouds. Since light from the blue sky is partially polarized by scattering, suitable orientation polarization discs in front of the camera lens will serve as a sky filter.

(iii) Control of headlight glass in night driving is possible if each car has light polarizing viewer.

CHAPTER 10- THERMODYNAMICS

10.1 KINETIC THEORY OF GASES

10.1.1 State basic postulates of kinetic theory of gases. (COGNITIVE LEVEL:K)

POSTULATES OF KINETIC MOLECULAR THEORY:-

1. A gas consists of particles called molecules. Depending on the gas, each molecule will consist of an atom or a group of atoms. All the molecules of a gas in stable state are considered identical.

2. Any finite volume of a gas consists of very large number of these molecules. This assumption is justified by experiments. At standard conditions there are 3×10^{25} molecules in a cubic metre.

3. The molecules are separated by distance large as compared to their own dimensions. The diameter of a molecule considered as a sphere, is about 3×10^{-10} m

4. The molecules move in all directions and with various speeds making elastic collisions with one another and with the walls of the container. The walls of a container can be considered perfectly smooth.

5.Molecules exert no forces on one another except during collisions. Therefore in between collisions with other molecules or with the walls of the container and in the absence of the external forces they move freely in straight lines.

6. Newtonian mechanics is applicable to the motion of molecules.

10.1.2 Calculate pressure on a gas molecule inside a gas container. (COGNITIVE LEVEL:A)

INTERPRETATION OF PRESSURE ON KINETIC MOLECULAR THEORY OF GASES:

Let "N" number of molecules are present in a container whose Length, Breadth, and height is equal to L.Let mass of one molecule is "m" a nd the molecule is moving parallel to x axis with velocity V_x, We know that when this molecule collide with the opposite wall of the container them it will move back with velocity $-V_x$

Initial Momentum of gas molecule = $m V_x$

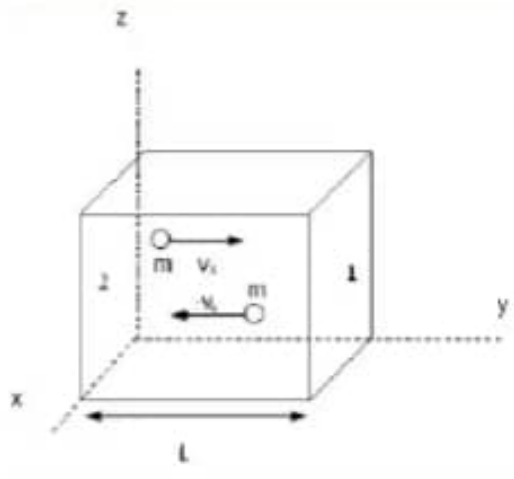
Final Momentum of gas molecule = $-(m V_x)$

Change in Momentum $= m V_x - (-m V_x)$

$= m V_x + m V_x$

Change in Momentum = 2mVx.

Rate of change of Momentum = $2m\,V_x / t$



According to the definition of force "Force is the rate of change of momentum, so

$$F = \frac{2m\,v_x}{t} \quad \text{----------(i)}$$

According to the definition of velocity

$$v = \frac{S}{t}$$

$$v_x = \frac{2L}{t} \quad \text{or} \quad t = \frac{2L}{v_x}$$

Putting the value of "t" in eq(i) we get,

$$F = 2m\,v_x \,/\, \frac{2L}{v_x}$$

or $$F = \frac{mv_x^2}{L}$$

Inside the container these are various molecular having velocities V_{1x}, V_{2x}, V_{3x}, V_{4x}...

Hence,

$$\text{Total Force} = F = \frac{m\,v_{1x}{}^2}{L} + \frac{m\,v_{2x}{}^2}{L} + \frac{m\,v_{3x}{}^2}{L} + \cdots + \frac{m\,v_{Nx}{}^2}{L}$$

$$F = \frac{m}{L}(v_{1x}{}^2 + v_{2x}{}^2 + v_{3x}{}^2 + \cdots + v_{Nx}{}^2)$$

We Know that

Pressure = Force/ Area

$$P = \frac{\frac{m}{L}(v_{1x}{}^2 + v_{2x}{}^2 + v_{3x}{}^2 + \cdots + v_{Nx}{}^2)}{L^2}$$

$$P = \frac{m}{L^3}(v_{1x}{}^2 + v_{2x}{}^2 + v_{3x}{}^2 + \cdots + v_{Nx}{}^2) \quad \text{----------(ii)}$$

Density = Mass / Volume

Let mass of one molecule = m

Mass of N molecule = mN

Mass / Volume = mN / L^3

If "ρ"represents the density of gas molecule them,

$$\rho = \frac{mN}{L_3}$$

$$\frac{\rho}{N} = \frac{m}{L_3}$$

Putting the value in eq(ii), we get

$$P = \frac{\rho}{N}(v_{1x}{}^2 + v_{2x}{}^2 + v_{3x}{}^2 + \cdots + v_{Nx}{}^2)$$

or $$P = \rho\frac{v_{1x}{}^2+v_{2x}{}^2+v_{3x}{}^2+\cdots+v_{Nx}{}^2}{N}$$

Where $\frac{v_{1x}{}^2+v_{2x}{}^2+v_{3x}{}^2+\cdots+v_{Nx}{}^2}{N}$ =Mean of square of velocity $=\overline{v_x{}^2}$

$$P = \rho\overline{v_x{}^2} \text{ ----------(iii)}$$

The term $\overline{v_x{}^2}$is the only one component of the total velocity ,since $\overline{v^2} = \overline{v_x{}^2} + \overline{v_y{}^2} + \overline{v_z{}^2}$.On the average $\overline{v_x{}^2} = \overline{v_y{}^2} = \overline{v_z{}^2}$, due to the randomness of motion, so

$$\overline{v^2} = \overline{v_x{}^2} + \overline{v_x{}^2} + \overline{v_x{}^2}$$

$$\overline{v^2} = 3\overline{v_x{}^2}$$

$$\frac{1}{3}\overline{v^2} = \overline{v_x{}^2}$$

Putting value in eq(iii),we get

$$\boxed{P = \frac{1}{3}\rho\overline{v^2}}$$

Where $\overline{v^2}$ is known as Root Mean Square Velocity.

10.1.3 Interpret temperature in terms of kinetic energy. (COGNITIVE LEVEL:A)

INTERPRETATION OF TEMPERATURE IN TERMS OF KINETIC ENERGY:

As we know that

$$P = \frac{1}{3}\rho\overline{v^2}$$

=> $$P = \frac{1}{3}\frac{mN}{V}\overline{v^2} \qquad \because \rho = \frac{mN}{V}$$

$$PV = \frac{1}{3}mN\overline{v^2} \text{ -------(i)}$$

also, $$PV = nRT \text{ ----------(ii)}$$

Comparing eq(i) and eq(ii), we get

$$nRT = \frac{1}{3} mN \ \overline{v^2}$$

=> $$T = \frac{1}{3}\frac{mN}{nR} \ \overline{v^2}$$

$$T = \frac{1}{3}\frac{mN_A}{R} \ \overline{v^2} \qquad \because N_A = \frac{N}{n} = \frac{No.of\ Molecule}{No.of\ Mole}$$

$$T = \frac{1}{3}\frac{m}{k} \ \overline{v^2} \qquad \because k = \frac{R}{N_A}$$

Multiply and divided by "2"

$$\boxed{T = \frac{2}{3k}\left(\frac{1}{2} m\overline{v^2}\right)}$$

or $$\boxed{T \propto \frac{1}{2} m\overline{v^2}}$$

Hence Proved that "The average Translational K-E of gas molecule is directly proportional to the absolute temperature."

10.2 GAS LAWS

10.2.1 Derive Boyle's and Charle's law with the help of kinetic theory. (COGNITIVE LEVEL:U)

BOYLE'S LAW:

As we know that

$$P = \frac{1}{3}\rho\overline{v^2}$$

=> $$P = \frac{1}{3}\frac{mN}{V} \ \overline{v^2} \qquad \because \rho = \frac{mN}{V}$$

$$PV = \frac{1}{3} mN \ \overline{v^2} \text{ -------(i)}$$

Multiply and divided by "2"

$$PV = \frac{2}{3} N\left(\frac{1}{2} m\overline{v^2}\right)$$

As we know that "In Boyle's Law the number of molecules "N" is constant and $\frac{1}{2} m\overline{v^2}$,which directly proportional to the temperature of gas "T" is also constant,Therefore,

$$\boxed{PV = Constant}$$ i.e. Boyle's Law.

CHARLES LAW:

As we know that

$$P = \frac{1}{3}\rho\overline{v^2}$$

=> $$P = \frac{1}{3}\frac{mN}{V}\ \overline{v^2}$$

$$V = \frac{1}{3}\frac{mN}{P}\ \overline{v^2}$$

Multiply and divided by "2"

$$V = \frac{2}{3}\frac{N}{P}\ (\frac{1}{2}m\ \overline{v^2})$$

Since, Number of molecules "N" and pressure of gas "P" is constant, therefore,

$$V = Constant\ (\frac{1}{2}m\ \overline{v^2})$$

$$V \propto \frac{1}{2}m\ \overline{v^2}$$ ----------(i)

But,

$$T \propto \frac{1}{2}m\overline{v^2}$$ ----------(ii)

By comparing eq(i) and eq(ii) we get,

$$\boxed{V \propto T}$$ i.e. Charle's Law

10.3 INTERNAL ENERGY

10.3.1 Explain that internal energy is function of 'state' and is independent of paths. (COGNITIVE LEVEL:U)

In thermodynamics, a state function or function of state is a function defined for a system relating several state variables or state quantities that depends only on the current equilibrium state of the system. State functions do not depend on the path by which the system arrived at its present state. A state function describes the equilibrium state of a system.

Internal energy, represented by E (or U a matter of preference), is essentially the thermal energy contained in a system (or particles making up the system). Unless change takes place, we usually have no way of evaluating it. A change in internal energy dE is due to the transfer of energy into or out of a system, but the volume stays constant. For example, energy transferred into the system, usually heat (q) and work (w), represents an increase of internal energy, dE, of the system. Thus,

$$dE = q + w.$$

In the case when heat or work is transferred from the system to its surroundings, the heat and work will be treated as negative quantities, resulting in a decrease in internal energy E.

The internal energy, E, does not depend on how energy is transferred and at what rate. It is purely an accounting of energy content of the system, and as such, the internal energy, E, is called a state function. The difference of a state function depends on the final and initial states, and we represent the change by,

$$dE = E_{final} - E_{initial}$$

As an illustration, lets put some air into a tire. All the air that will be put into the tire is the system. As we pump, the volume is reduced by the pumping (compression), and work is done onto the system, w. The internal energy E increase is equal to the amount of work done to the system, E.

$$dE = w \ (q = 0 \text{ in this case})$$

If the tire is heated, assuming the amount of heat transferred into it as q, additional increase E results in

$$dE = q + w$$

On the other hand, if the tire leaks, and the air is expanded, then work is done by the system (-w) resulting in a decrease in E.

$$dE = - w \ (q = 0 \text{ in this case})$$

If q amount of heat is transferred to the tire, and the tire does -w amount of work, then,

$$dE = q - w \ (q = 0 \text{ in this case})$$

This shows that internal energy is function of 'state' and is independent of path.

10.4 WORK AND HEAT

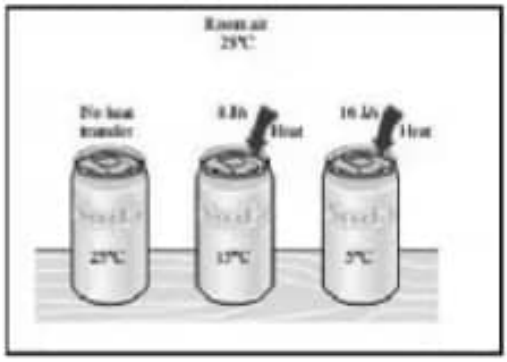
10.4.1 Describe that heat flow and work are two forms of energy transfer between systems. (COGNITIVE LEVEL:U)

The energy is transferred between two systems in two forms:

1. Heat Transfer

2. Work

1. HEAT TRANSFER:



Heat is the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of temperature difference. It is recognized only as it crosses the boundary of a system.Heat transfer between two states is denoted by Q.The rate of heat transfer is the amount of heat transfer per unit time.

2. ENERGY TRANSFER BY WORK:

Work is an energy interaction between a system and its surroundings.Work is the energy transfer associated with a force acting through a distance.

Examples: a rising piston, a rotating shaft, electric wire

Since work is a form of energy, it has the units J or kJ.Work done during a process between two states is denoted by W.

10.4.2 Calculate the heat being transferred. (COGNITIVE LEVEL:A)

HEAT TRANSFER FORMULA:

Heat, a measure of thermal energy, can be transferred from one point to another. Heat flows from the point of higher temperature to one of lower temperature. The heat content, Q, of an object depends upon its specific heat, c, and its mass, m. The Heat Transfer is the measurement of the thermal energy transferred when an object having a defined specific heat and mass undergoes a defined temperature change.

Heat transfer = (mass)(specific heat)(temperature change)

$$Q = mc\Delta T$$

Q = heat content in Joules

m = mass

c = specific heat, J/g °C

T = temperature

ΔT = change in temperature

10.4.3 Express work in terms of change in volume. (COGNITIVE LEVEL:U)

WORK DONE IN THERMODYNAMICS:

According to the definition of workdone

$$\Delta W = F.\ \Delta x \text{ -------(i)}$$

Also $P = F/A$

$$F = PA$$

Putting in eq(i), we get

$$\Delta W = PA.\ \Delta x$$

But,

$$A.\ \Delta x = \Delta V \quad \text{(change in volume)}$$

then wrok done is given by

$$\boxed{\Delta W = P\Delta V}$$

10.5 THERMODYNAMICS

10.5.1 Define thermodynamics and thermal equilibrium. (COGNITIVE LEVEL:K)

THERMODYNAMICS:

The branch of physical science that deals with the relations between heat and other forms of energy (such as mechanical, electrical, or chemical energy), and, by extension, of the relationships between all forms of energy.

THERMAL EQUILIBRIUM:

It is observed that a higher temperature object which is in contact with a lower temperature object will transfer heat to the lower temperature object. The objects will approach the same temperature, and in the absence of loss to other objects, they will then maintain a constant temperature. They are then said to be in thermal equilibrium.

10.5.2 Explain the 1st law of thermodynamics. (COGNITIVE LEVEL:U)

First Law of Thermodynamics

STATEMENT:

This law states that whenever heat energy is converted into another type of energy or

when other type of energy is converted into heat energy than the total amount of energy remains constant .In other words we can say that first law of thermodynamic is another form of law of conversation of energy. OR "When heat is provided to a system then it is converted into two parts i.e. Work done by the system (ΔW) and change in internal energy (ΔU)."

MATHEMATICALLY:

$$\boxed{\Delta Q = \Delta U + \Delta W}$$

ΔQ will be taken as positive when heat is sup plied to the system. ΔQ will be taken as negative when heat is rejected by the system. ΔW will be taken as positive when work in done by the system. ΔW will be taken as negative when work is done on the system.

10.5.3 Apply the 1st law of thermodynamics in (i) isothermal, (ii) adiabatic, (iii) isobaric, (iv) isochoric and 10.5.4 Calculate the 1st law of thermodynamics in terms of change in internal energy, work done on the system and work done by the system. (COGNITIVE LEVEL:A)

1) ISOBARIC PROCESS:

The process in which pressure (external pressure) is kept constant is knows as Isobaric process.In this process supplied amount of heat will utilize into following two types.

1) To increase the internal energy of the system
2) To work done in order to move, piston,

In this process first law of thermodynamics is given by,

$\Delta Q = \Delta U + \Delta W$ ----------(i)

But $\Delta W = F.\ \Delta x$

Also $P = F/A$

$F = PA$

$\Delta W = PA.\ \Delta x$

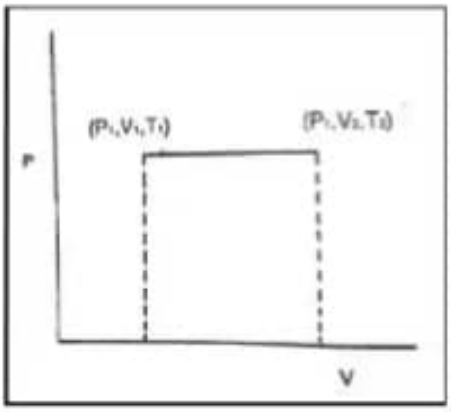
But, $A.\ \Delta x = \Delta V$ (change in volume)

$\Delta W = P\Delta V$

putting in eq(i) we get,

$$\boxed{\Delta Q = \Delta V + P\Delta V}$$

From above equation we can say that in case of isobaric process all the supplied amount of heat will increase to increase the enthalpy of the system. Isobaric process on P-V diagram can be represented as follows.



2) ISOCHORIC PROCESS:

The process in which volume is kept constant is known as Isochoric process.In this process all the supplied amount of heat will utilize to increase the internal energy of the system, no work will be done by the system because pistons remains fixed and there is no change in volume ($\Delta V=0$).

In this process first law of thermodynamic takes following form.

$\Delta Q = \Delta U + \Delta W.$

But, $\Delta W = P\Delta U$

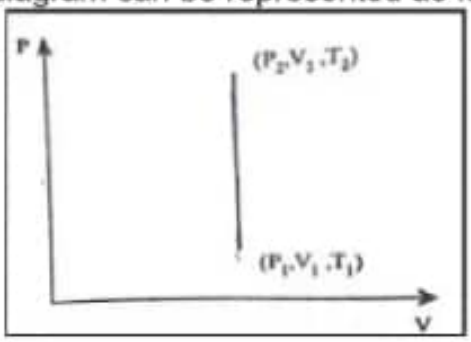
$\Delta Q = \Delta U + P\Delta V.$

$\Delta V = 0$ (for isochoric process)

$\Delta Q = \Delta U + P\text{x}0.$

so, $\boxed{\Delta Q = \Delta U}$

Isobaric process on P-V diagram can be represented as follows.



3) ISOTHERMAL PROCESS :-

The process is which temperature is kept constant is process as isothermal process. In this process volume of a given mass of a gas is inversely proportional to its applied pressure and the temp is kept constant so we can say that in this process Boyle's law holds good.

In case of isothermal expansion first law of thermodynamics takes the following form.

$$\Delta Q = \Delta U + \Delta W$$

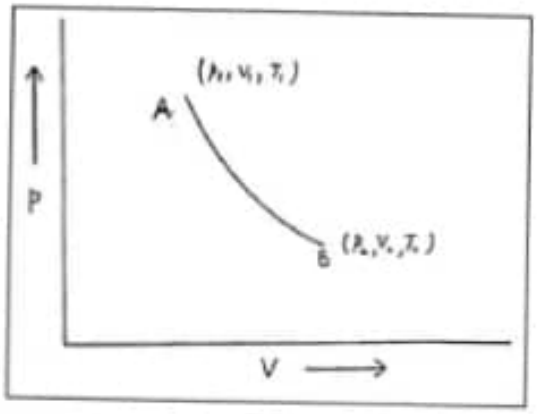
But, $\Delta U = 0$

then, $\Delta Q \quad 0 + \Delta W$

$$\Delta Q = \Delta W$$

$$\boxed{\Delta Q = P\Delta V}$$

Isothermal process on P-V diagram can be represented as follows.



4)ADIABATIC PROCESS:-

The process in which no heat is given on taken out from the surface is known as adiabatic process. In this process volume of a given mass of gas is inversely proportional to its applied pressure but the temp do not remains constant, so in this process Boyle's law modified as follows.

$$PV = \text{Constant}$$

Where γ = C_P/C_V

The value of "γ" for air is 1.4.

In case of adiabatic process first law of thermodynamics takes the following form.

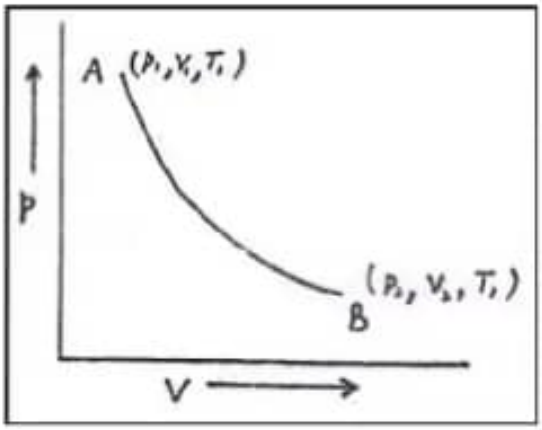
$$\Delta Q = \Delta U + \Delta W$$

But, $\Delta Q = 0$

then, $0 = \Delta U + \Delta W$

$\boxed{\Delta U = -\Delta W}$ or $\boxed{\Delta W = -\Delta U}$

Adiabatic process on P-V diagram can be represented as follows.



10.5.5 Explain the 1st law of thermodynamics in terms of conservation of energy. (COGNITIVE LEVEL:U)

1ST LAW OF THERMODYNAMICS IN TERMS OF CONSERVATION OF ENERGY:

The first law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic systems. The law of conservation of energy states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed. The first law is often formulated by stating that the change in the internal energy of a closed system is equal to the amount of heat supplied to the system, minus the amount of work done by the system on its surroundings

The First Law of Thermodynamics states that heat is a form of energy, and thermodynamic processes are therefore subject to the principle of conservation of energy. This means that heat energy cannot be created or destroyed. It can, however, be transferred from one location to another and converted to and from other forms of energy.

The First Law says that the internal energy of a system has to be equal to the work that is being done on the system, plus or minus the heat that flows in or out of the system and any other work that is done on the system,So, it's a restatement of conservation o f energy.

10.6 SPECIFIC AND MOLAR SPECIFIC HEAT OF GASES

10.6.1 Define the terms specific heat and molar specific heat. (COGNITIVE LEVEL:K)

SPECIFIC HEAT CAPACITY

DEFINITION:-

"It is defined as the amount of heat required to raise the temperature of unit mass of the substance to unit degree rise of temperature."

EXPLANATION:-

If a body or mass is heated so that its temperature rises from T to T + ΔT and it absorbs a small amount of heat ΔQ, then its heat capacity C is defined as

$$\boxed{C = \frac{\Delta Q}{\Delta T}}$$

whereas specific heat capacity $\boxed{c = \frac{C}{mass} = \frac{\Delta Q}{m\Delta T}}$ at temperature T.

Specific Heat is a characteristic of the material of which the substance is made of.

DEFINITION:-

Molar Specific Heat is defined as the quantity of heat required to raise the temperature of one mole of a substance through 1 K, Its units are J/mol-K.The molar specific heat of a gas depends upon whether or not the gas allowed to expand when it is heated.

EXPLANATION:-

As a matter of convenience mole is often used to describe the amount of substance. One mole of any substance is defined as the quantity of matter such that its

mass in gram is numerically equal to the molecular weight M. If n is the number of moles and m is the mass in gram of the substance, then

$$n = \frac{m}{M}$$

or $$m = Mn \text{ -------(i)}$$

For Specific heat we have the relation

$$c = \frac{\Delta Q}{m\Delta T}$$

Substituting the mass m from eq(i),we get

$$c = \frac{\Delta Q}{Mn\Delta T}$$

or $$Mc = \frac{\Delta Q}{n\Delta T}$$

The product Mc of molecular weight and specific heat is called Molar Specific Heat.

1.AT CONSTANT VOLUME (C_V)

When the volume of the gas is kept constant throughout heating we call it the molar specific heat at constant volume. It is defined as the amount of heat energy required to raise the temperature of one mole of a gas through 1 K at constant volume. It is designated by the symbol C_V.

2.AT CONSTANT PRESSURE(C_P):

When the volume of the gas is allowed to increase but its pressure is kept constant throughout heating, we speak of the molar specific heat at constant pressure. It is defined as the amount of heat energy required to raise the temperature of one mole of a gas through 1 K at constant pressure and it is denoted by the symbol C_p.

10.6.2 Show that $C_P - C_V = R$ and also explain $C_P > C_V$ by using 1st law of thermodynamics. (COGNITIVE LEVEL:U)

PROOF:

Let us consider a system at constant pressure, when it is heated then according to first law of thermodynamics

$$\Delta Q = \Delta U + \Delta W$$

In isobaric process we can write as

$$\Delta Q_p = \Delta U + P\Delta V \text{ -------(i)}$$

According to the definition of Molar Specific Heat at constant pressure

$$C_P = \frac{\Delta Q_P}{n\Delta T}$$

or $$\Delta Q_P = nC_P\Delta T$$

Putting in eq(i) we get

$$nC_P\Delta T = \Delta U + P\Delta V \text{ --------(ii)}$$

Now, consider the system at constant volume, when it is heated then according to first law of thermodynamics in isochoric process we can write as

$$\Delta Q_v = \Delta U \text{ ----- (iii)} \qquad (\text{Since } \Delta W = 0)$$

According to the definition of Molar Specific Heat at constant pressure volume

$$C_V = \frac{\Delta Q_V}{n\Delta T}$$

or $$\Delta Q_V = nC_V\Delta T$$

Putting in eq(iii) we get

$$nC_V\Delta T = \Delta U$$

Putting the value of "ΔU"in eq(ii)

$$nC_P\Delta T = nC_V\Delta T + P\Delta V$$

or $$nC_P\Delta T = nC_V\Delta T + nR\Delta T \qquad \text{(Since } P\Delta V = nR\Delta T\text{)}$$

$$\cancel{n}C_P\cancel{\Delta T} = \cancel{n}\cancel{\Delta T}\,(C_V + R)$$

$$C_P = C_V + R$$

or $$\boxed{C_P - C_V = R}$$

Where R= General Gas Constant=8.313 J/mol – K , Therefore we can write as

$$\boxed{C_P > C_V}$$

10.7 REVERSIBLE AND IRREVERSIBLE PROCESS

10.7.1 Define reversible and irreversible process. (COGNITIVE LEVEL:K)

IRREVERSIBLE PROCESS:

The process is said to be an irreversible process if it cannot return the system and the surroundings to their original conditions when the process is reversed. The irreversible process is not at equilibrium throughout the process.

For example; when we are driving the car uphill, it consumes a lot of fuel and this fuel is not returned when we are driving down hill. Many factors contribute in making any process irreversible. The most common of these are

1) Friction

2) Unrestrained expansion of a fluid

3) Heat transfer through a finite temperature difference

4) Mixing of two different substances.

REVERSIBLE PROCESS:

The basic concept is that most of the thermodynamic processes have a preferred direction just as Heat always flows from hotter object to colder object. Once a gas is released in a room, it expands in room and never contracts without indulgence of any external force etc.

But in some systems, the reverse occurs. Normally it happens when that system is close to thermal equilibrium. This equilibrium has to be inside the system itself and also within the system and its surroundings. When this stage is reached, even a small change can change the direction of the process and therefore such a reversible process is also known as an equilibrium process.

For Example: A very simple example can be of two metal jars A and B which are at a thermal equilibrium and are in contact with each other. Now when we heat jar A slightly, heat starts to flow from Jar A to Jar B. This is the direction of this process. Now this process can be reversed just by cooling Jar A slightly. When Jar A is cooled, heat flows from Jar B to Jar A till thermal equilibrium is reached.

10.8 SECOND LAW OF THERMODYNAMICS

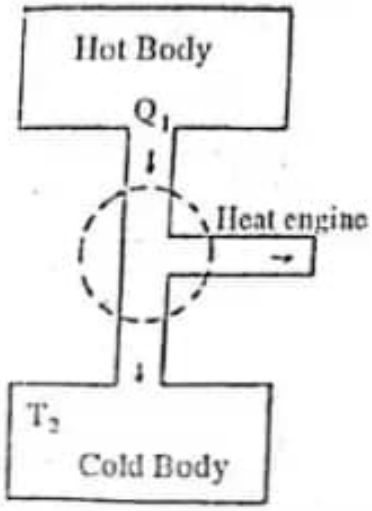
10.8.1 Explain the 2nd law of thermodynamics with the help of schematic diagram. (COGNITIVE LEVEL:U)

2ND LAW OF THERMODYNAMICS

There are following two statements of second law of thermodynamics.

1) Kelvin's statement 2) Clausius statement

1) KELVIN'S STATEMENT:-



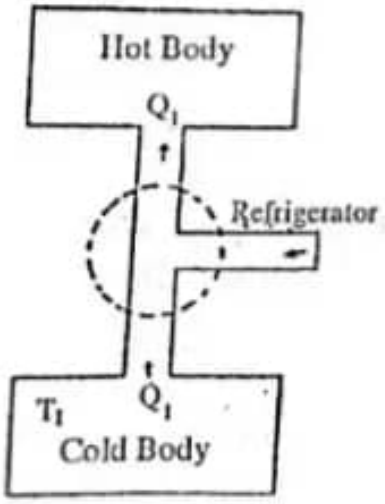
According to this statement "it is impossible to construct a heat engine, which is operating in a cycle and can convert all the available heat taken from source into Mechanical work, without rejecting a portion of heat into the sink"

From above statement we can say that according to Kelvin's statement without sink no heat engine can operate. From above statement we can easily understand the physical principle heat engine get heat from source, convert a portion of heat into Mechanical work and reject the rest of heat into the sink.

2. CLAUSIUS STATEMENT:-

According to this statement "it is impossible to convey the heat from a body at a lower temperature towards the body at a higher temperature without expenditure of external energy".

From the above statement we can easily understand the physical properties of Refrigerator / A.C External. In case of Refrigerator or Air Condition heat flows form low temperature towards high temperature but in order to do so we have to supply external (electrical engine).



10.9 CARNOT ENGINE

10.9.1 Define heat engine in terms of the 2nd law of thermodynamics. (COGNITIVE LEVEL:K)

HEAT ENGINE:

Heat engines which are devices that use heat to do work. A basic heat engine consists of a gas confined by a piston in a cylinder. If the gas is heated, it expands, moving the piston. This wouldn't be a particularly practical engine, though, because once the gas reaches equilibrium the motion would stop. A practical engine goes through cycles; the piston has to move back and forth. Once the gas is heated, moving the piston up, it can be cooled and the piston will move back down. A cycle of heating and cooling will move the piston up and down.

A necessary component of a heat engine, then, is that two temperatures are involved. At one stage the system is heated, at another it is cooled.

10.9.2 Explain the working principle of Carnot engine with its four processes with PV diagram. (COGNITIVE LEVEL:U)

CARNOT ENGINE

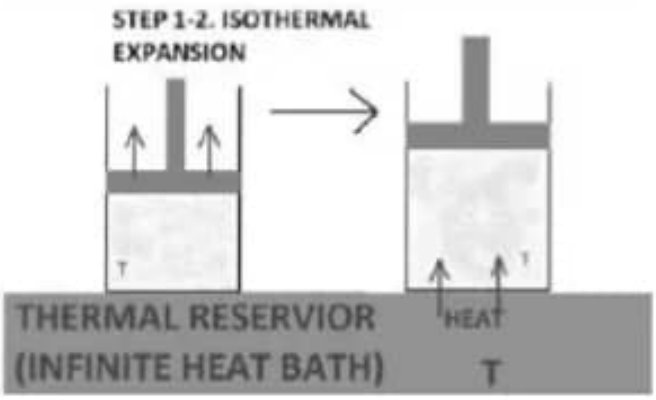
Carnot engine is an ideal heat engine (heat engine is a device which can convert heat energy into Mechanical energy which is free from heat losses and friction losses. Carnot engine is only theoretical heat engine; hence it is not available in market. Carnot engine consists of a cylinder whose walls are non-conducting and whose piston is also non conducting and frictionless whose bottom is conducting

one, an ideal gas is present inside the cylinder as a working substance. Carnot engine will operate on a cycle, which is known as Carnot cycle. The Carnot cycle consists of following four processes.

1) Isothermal expansion 2) Adiabatic expansion
3) Isothermal compression 4) Adiabatic compression.

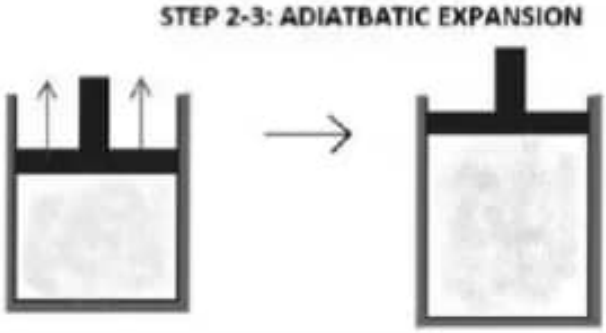
1) ISOTHERMAL EXPANSION:-

In this expansion cylinder is placed on a source and the piston is allowed to move upward when, we do so then the temperature of the working substance will decrease, pressure also decrease but volume will increase, the temp can be kept constant by Supplying the heat from the source since in this expansion in known as Isothermal expansion. Let Q_1 represents the amount of that supplied to the system in case of Isothermal expansion.



2) ADIABATIC EXPANSION:-

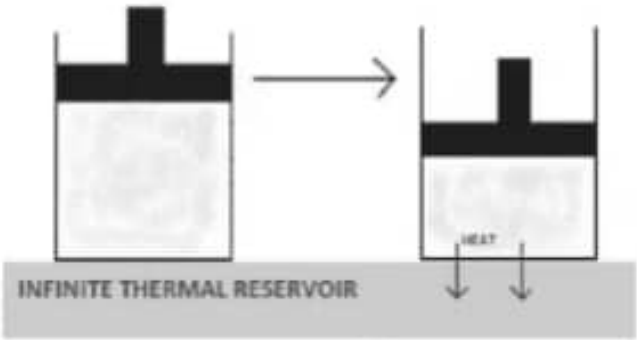
In this expansion cylinder is placed on an insulator and the piston is allowed to move upward, when we do so then the temp of the working substance will decrease, pressure also decrease but volume will increase since in this expansion no heat is given or taken out from the system. So this expansion is known as adiabatic expansion.



3) ISOTHERMAL COMPRESSION:-

In this compression cylinder is placed on a sink and the piston is allowed to move downward, so when we do so then the temp of the working substance will increase, pressure also increase but volume will decrease, the temp can be kept constant by rejecting the excess amount of heat through sink, since in this compression in known as isothermal compression. Let Q_2 represents the amount of heat rejected in case of isothermal compression.

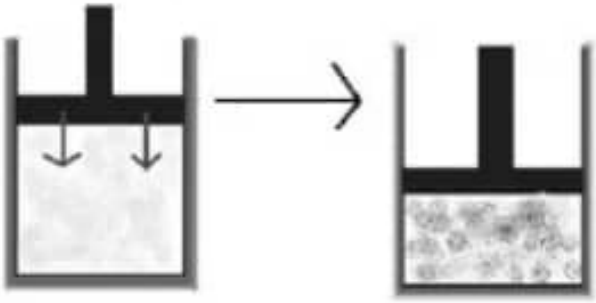
STEP 3-4: ISOTHERMAL COMPRESSION



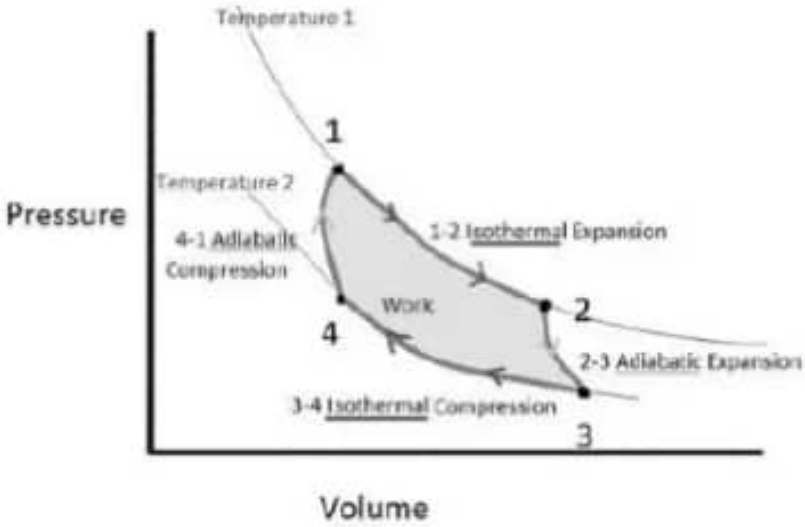
4) ADIABATIC COMPRESSION:-

In this compression cylinder is placed on an insulator an the piston is allowed to move downward when we do sot then the temp of the working substance will increase, pressure also increase but volume will decrease not heat is given or taken out from the system so this compression is known as adiabatic compression. Adiabatic compression on P-V diagram can be represented as follows.

STEP 4-1: ADIABATIC COMPRESSION



If we combine all above four processes we will obtain following cycle, which is known as Carnot cycle.The PV diagram of Carnot cycle is given below.



10.9.3 Derive the formula for efficiency of Carnot engine and use it In solving numerical. (COGNITIVE LEVEL:A)

EFFICIENCY OF CARNOT ENGINE :-

The efficiency of Carnot engine is defined, as follows ;

$$E = \frac{output}{input} \times 100 \text{ ------(i)}$$

In the case of Carnot engine,

Input= Heat=Q_1

Output=Mechanical Work=W=$Q_1 - Q_2$

Putting values in eq(i)

=> $$E = \frac{Q_1 - Q_2}{Q_1} \times 100$$

$$E = \left(\frac{Q_1}{Q_1} - \frac{Q_2}{Q_1}\right) \times 100$$

$$\boxed{E = \left(1 - \frac{Q_2}{Q_1}\right) \times 100}$$

As we know that the temperature is directly proportional to the heat, therefore, efficiency can also be given as

$$\boxed{E = \left(1 - \frac{T_2}{T_1}\right) \times 100}$$

Where T_1 is the temp of source T_2 is temp of sink. From above formula it is clear the at the efficiency of carnot engine depends upon temp of source and temp of sink to keep efficiency of carnot upto 100% we have kept ration T_2/T_1 equals to zero.

But we know that this ratio will be equal to zero when it is equal to infinity or T_2 is equal to zero, we know that practically there is no source whose temp is infinite and there is no sink whose temp is O.K hence we conclude that the ratio $T_2/T_1 = 0$ hence efficiency of even constant engine is not equal to 100%.

PROBLEM 1: Carnot engine operates with efficiency of 40 %. How much must the temperature of the hot reservoir increase, so that the efficiency increases to 50 %? The temperature of the cold reservoir remains at 7 °C.

SOLUTION:

First we convert the temperature of sink into Kelvin: T_2=7 + 273 =280 K

Now first we will calculate the temperature of hot reservoir when efficiency is 40 %

For e = 40 %

$$e = \left(1 - \frac{373}{673}\right) \times 100$$

$$e = (1 - 0.55) \times 100$$

$$e = (0.45) \times 100$$

$$\boxed{e = 45\%}$$ (Answer)

<u>PROBLEM 3:</u> A Carnot engine has an efficiency of 20% and it performs 200J of work in each cycle. Find the amount of heat absorbed and expelled by the system.

<u>SOLUTION:</u>

As we know that

$$E = \left(1 - \frac{Q_2}{Q_1}\right) \times 100$$

$$E = \left(\frac{Q_1 - Q_2}{Q_1}\right) \times 100$$

$$E = \left(\frac{W}{Q_1}\right) \times 100 \qquad \because W = Q_1 - Q_2$$

$$Q_1 = \left(\frac{W}{E}\right) \times 100$$

$$Q_1 = \left(\frac{200}{20}\right) \times 100$$

$$\boxed{Q_1 = 1000\,J}$$

$$\because W = Q_1 - Q_2$$

$$200 = 1000 - Q_2$$

$$\boxed{Q_2 = 800\,J}$$ (Answer)

<u>10.10 REFRIGERATOR</u>

10.10.1 Describe refrigerator as it is a reverse of heat engine. (COGNITIVE LEVEL:K)

<u>REFRIGERATOR AS A REVERSE OF HEAT ENGINE:</u>

The heat engine produces work by absorbing heat from source and liberating some heat to sink. The refrigerator transfers the heat from sink to the source with the help of external work.

The engine is the device that produces the work by absorbing heat from the high temperature reservoir or source and releasing the remaining heat to the low temperature reservoir or sink. The Carnot cycle comprises of two reversible isothermal processes and two reversible adiabatic processes. Since all the processes in Carnot cycle are considered to be reversible, whole cycle is

also considered to be reversible. If all the processes of the Carnot cycle are reversed, what we get is a machine which is called as reversed heat engine.

Refrigerator engine works exactly opposite to the heat engine. The heat engine produces work by absorbing heat from the source and liberating some heat to the sink. The refrigerator absorbs the work and transfers heat from the sink to the source. That means that the reversed heat engine absorbs work and transfers heat from low temperature reservoir to high temperature reservoir.

The natural tendency of the heat is to flow from the high temperature reservoir to the low temperature reservoir. The concept of refrigerator clearly shows that to transfer heat from the low temperature reservoir to the high temperature reservoir external work must be performed on the system. The refrigerator comprises of all the processes that the Carnot heat engine has, but they operate in a reverse manner.

The refrigerator concept bolsters the findings made by Clausius about second law of thermodynamics. His statement for second law of thermodynamics says, "It is impossible to construct a device which, operating in a cycle, will produce no affect other than the transfer of heat from a colder to a hotter body." This means that when the device transfers heat from low temperature to high temperature reservoir, it cannot do so without producing any other effect. This any other effect is absorbing the work. The heat will not flow spontaneously form low temperature to high temperature reservoir; some external work has to be done on it.

10.10.2 Derive expression for its efficiency. (COGNITIVE LEVEL:A)

EFFICIENCY OF REFRIGERATOR:

In case of refrigerator the efficiency is described by co efficient of performance (COP), which can be derived as follows.

The efficiency of refrigerator is defined, as follows ;

$$COP = \frac{output}{input} \text{ ------(i)}$$

In the case of Refrigerator(reverse of heat engine),

Input= Work=W= $Q_1 - Q_2$

Output=Heat taken out= Q_2

Putting values in eq(i)

=> $$COP = \frac{Q_2}{W}$$

$$\boxed{COP = \left(\frac{Q_2}{Q_1 - Q_2}\right)}$$

10.11 ENTROPY

10.11.1 Explain the term entropy. (COGNITIVE LEVEL:U)

ENTROPY

DEFINITION:

Entropy is the measure of molecular disorder an in any process the entropy increases or remains constants that is the disorders increases or remains constants.

EXPLANATION:

Consider a large number of molecules of a gas confirmed in an insulated cylinder fixed with a removable partition as shown in figure (I) All the molecules are localized in volume V. if the partition is removed the molecules now occupy the whole volume 2v, as shown in fig (2) and are less localized than they were before the partition was removed. The degree of localization is a measure of disorder. As the system increase in volume the disorder increases and we say that the entropy increase.

Consider another example, equal number of black and white bolls occupy one half of box while the white balls occupy the other half of the box. We could say that the balls are placed in order. As we shake the box this order. As we shake the box this order of the black and white balls is disturbed. As the box is shaken more, the order is disturbed more. Thus disorder increases and the original arrangement cannot be resolved no matter how we shake the box. This situation can be described by saying that the entropy of the system has increased the natural phenomenon are taking place in such a way that the entropy of the universe is increasing.

If ΔQ be the heat transferred to a system at temp "T" then change in entropy ΔS

$$\Delta S = \frac{\Delta Q}{T}$$

10.11.2 Describe positive and negative entropy. (COGNITIVE LEVEL:U)

POSITIVE AND NEGATIVE ENTROPY:

Change in entropy is positive when the heat is added to the system and change of entropy is negative when heat is removed from the system.

Suppose, an amount of heat Q flows a reservoir at temperature T_1 through a conducting rod to reservoir at temperature T_2, when $T_1 > T_2$. The change in entropy of the reservoir, at temperature T_1, which loses heat, decreases by Q/T_1 and of the reservoir at temperature T_2, which gains heat increases by Q/T_2.

Hence, the total changes in entropy=$\frac{Q}{T_2} - \frac{Q}{T_1}$ is positive (+). It follows that in all the processes, where heat flows from one system to another, there is always a total increases in entropy. This is another statement of 2nd law of thermodynamic. According to this law, If a system undergoes a natural process, this will go in the same direction that causes the entropy of the system plus the environment to increase.

10.11.3 Explain that increase in entropy is an evidence of increase in temperature of a system. (COGNITIVE LEVEL:U)

ENTROPY IS AN EVIDENCE OF INCREASE IN TEMPERATURE OF A SYSTEM:

Several factors affect the amount of entropy in a system. If you increase temperature, you increase entropy in the following ways.

(1) More energy put into a system excites the molecules and the amount of random activity.

(2) As a gas expands in a system, entropy increases. This one is also easy to visualize. If an atom has more space to bounce around, it will bounce more. Gases and plasmas have large amounts of entropy when compared to liquids and solids.

(3) When a solid becomes a liquid, its entropy increases.

(4) When a liquid becomes a gas, its entropy increases. We just talked about this idea. If you give atoms more room to move around, they will move. You can also think about it in terms of energy put into a system. If you add energy to a solid, it can become a liquid. Liquids have more energy and entropy than solids.

10.11.4 Outline environmental crisis as an entropy crisis. (COGNITIVE LEVEL:K)

ENVIRONMENTAL CRISIS AS AN ENTROPY CRISIS:

The second law of thermodynamics provides us the basic key for understanding our environmental crisis as well as for understanding how we should deal with this crisis. From a human standpoint, the environmental crisis results from our attempts to the nature for our comforts. From a physical standpoint, however, the environmental crisis is an entropy or disorder crisis resulting from our useless efforts to ignore the second law of thermodynamics.

According to the second law, any increase in the order of a system will always produce an even greater increase in entropy or disorder in the environment. An individual impact may not have a major problem but an impact of large number of all individuals disorder producing activities may be affect the overall life support system. The energy process which we use is not very efficient. As a result much energy is lost as heat to the environment. Although we can improve the efficiency but 2nd law eventually produces an upper limit on improvement.

Thermal pollution is an inevitable consequence of 2nd law of thermodynamic and heat is the finally death of any form of energy. The increase in thermal pollution of environment means increase in the entropy and that causes greater concern, even in small temperature's change in the plant and in animals. This can cause serious problem of the overall ecological balance. In addition to the thermal pollution, the most of the energy transformation process such as heat engines used to transportation and for power generation cause air pollution. In effect of this, all forms of energy production have some unfavorable result and in some cases all the problems may not be anticipated in advance.