

SAMPLE QUESTION PAPER – B

1. It is called so because this law holds good irrespective of the nature of interacting bodies at all places and at all times. 1
2. It is the ratio of change in dimension of a body to the original dimension when some deforming force is applied to it, *e.g.*, longitudinal strain. 1
3. The upward force on a body, dipped in a liquid is called buoyant force. 1
4. Time period decreases as effective value of acceleration due to gravity increases (*i.e.*, $g' = g + a$) and ($T \propto 1/\sqrt{g'}$). 1

5. Intensity = (Amplitude)² $\propto \frac{1}{(\text{distance})^2}$

$\therefore$ Amplitude $\propto \frac{1}{\text{distance}}$

Hence, $\frac{A_1}{A_2} = \frac{r_2}{r_1} = \frac{25}{9}$ 1

6. % error in $\rho = \left(3 \frac{\Delta a}{a} + 2 \frac{\Delta b}{b} + \frac{1}{2} \frac{\Delta c}{c} + \frac{\Delta d}{d} \right) \times 100$ 1

$= 3 \times 1 + 2 \times 3 + \frac{1}{2} \times 4 + 1$ 1

$= 3 + 6 + 2 + 1 = 12\%$

7. Mass given by the equation $a = \frac{F}{M}$, *i.e.*, $M = \frac{F}{a}$ is called inertial mass. Clearly, higher the mass means lesser the acceleration. Thus mass of a body resists the acceleration, *i.e.*, rate of change in velocity coming up due to external force or in other words it is the measure of inertia of a body. 2

Or

$$|\vec{a} + \vec{b}|^2 - (|\vec{a}| + |\vec{b}|)^2 = |\vec{a}|^2 + |\vec{b}|^2 + 2|\vec{a}||\vec{b}|\cos\theta - (|\vec{a}|^2 + |\vec{b}|^2 + 2|\vec{a}||\vec{b}|) = -2|\vec{a}||\vec{b}|(1 - \cos\theta)$$

$$= -2|\vec{a}||\vec{b}|\sin^2\frac{\theta}{2}$$

= a negative quantity 1

Hence, $|\vec{a} + \vec{b}| < |\vec{a}| + |\vec{b}|$ 1/2

8. It should be greater in night. In the day time the body is pulled by earth and sun in two opposite directions. This will result into decrease in weight. 1
- During night time the earth and the sun pull the body in the same direction so the weight will increase in night. 1

9. Monoatomic gas :

$$C_v = \frac{F}{2}R - \frac{3}{2}R$$

$$C_p = \left(1 + \frac{F}{2}\right)R$$

$$= \left(1 + \frac{3}{2}\right)R = \frac{5}{2}R$$

$$\gamma = \left(1 + \frac{2}{f}\right) = \left(1 + \frac{2}{3}\right)$$

$$= \frac{5}{3} = 1.67$$

1

Diatomic gas : For diatomic gas $f = 5$

$$C_v = \frac{f}{2}R = \frac{5}{2}R$$

$$C_p = \left(1 + \frac{f}{2}\right)R$$

$$= \left(1 + \frac{5}{2}\right)R = \frac{7}{2}R$$

$$\gamma = \left(1 + \frac{2}{f}\right) = \left(1 + \frac{2}{5}\right) = \frac{7}{5} = 1.4$$

10. Motion of piston in a cylinder is another example of vibrating system.

Restoring force in this case is given by :

$$F = -mg = -kx$$

1

where m is mass of the piston and x is the displacement time period of vibration is given by

$$T = 2\pi \sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$$

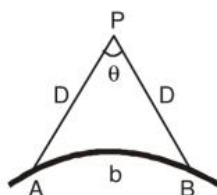
$$= 2\pi \sqrt{\frac{M}{k}}$$

1

11. Let there be a planet P far away from earth. The planet is observed from two different observation points A and B on earth called observatories. If distance AB = b and angle APB = θ radian, then θ

being very small $\frac{b}{D} \ll 1$. Angle θ is called parallax or parallactic angle.

$\frac{1}{2}$



$\frac{1}{2}$

Now radius :

$$AP = BP = D = \frac{b}{\theta}$$

So that

$$b = D\theta$$

1

12. (a) Since the motion of the train between two distant stations is smooth throughout so keeping in view the long distance covered between the two stations in reasonable duration of time, the size of the train is neglected and it is considered as a point object.

1

(b) The distance covered by the monkey is reasonable duration of time is more so it is considered as a point object.

1

(c) Since, the turning of the ball is not smooth but sharp so the distance covered by it in reasonable duration of time is not large so this ball cannot be treated as a point object.

$\frac{1}{2}$

(d) Since the beaker is tumbling and then slips off. So, the distance covered by it in reasonable duration of time is not large. so it is not treated as a point object. 1/2

13. When the stone is dropped, it falls freely under the acceleration due to gravity g . With respect to the earth the acceleration of the stone is g . 1

Inside the carriage the stone possesses two accelerations :

(i) Horizontal acceleration ' a ' due to the motion of carriage. 1

(ii) Vertical downward acceleration ' g ' due to gravity.

The acceleration of the stone w.r.t. the carriage

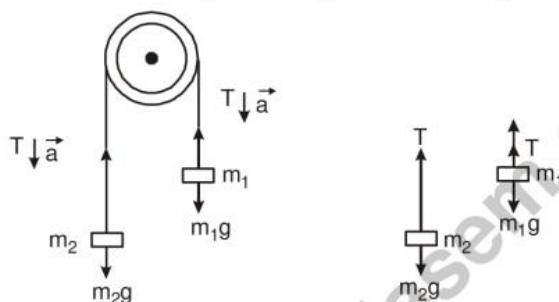
$$= \sqrt{a^2 + g^2}$$

14. Suppose m_1 and m_2 be the masses suspended at the ends of a light inextensible string passing over the pulley.

$\therefore m_1 = 8 \text{ kg}, m_2 = 12 \text{ kg}$

Suppose T = Tension in the string = ?

a = common acceleration with which m_1 moves upward and m_2 moves downward = ?



The equations of motion of m_1 and m_2 are given by

$$T - m_1g = m_1a \quad \dots(i)$$

and

$$m_2g - T = m_2a \quad \dots(ii) \quad 1/2$$

Adding equations (i) and (ii), we get

$$(m_2 - m_1)g = (m_1 + m_2)a$$

$$a = \frac{(m_2 - m_1)g}{m_1 + m_2} \quad 1/2$$

$\therefore$ From equations (i) and (iii), we get

$$T = m_1g + m_1 \frac{(m_2 - m_1)g}{m_1 + m_2} \quad 1/2$$

$\Rightarrow$

$$T = \frac{m_2g}{m_1 + m_2}(m_1 + m_2 + m_2 - m_1)$$

$\Rightarrow$

$$T = \frac{2m_1m_2}{m_1 + m_2}g \quad \dots(iv) \quad 1/2$$

Putting $m_1 = 8 \text{ kg}$ and $m_2 = 12 \text{ kg}$ and $g = 10 \text{ ms}^{-2}$ in equations (iii) and (iv), we get

$$a = \left(\frac{12 - 8}{8 + 12} \right) \times 10$$

$\Rightarrow$

$$= \frac{4}{20} \times 10 = 2 \text{ ms}^{-2} \quad 1/2$$

15. (a)

$$v = \frac{dx_A}{dt} = 2$$

and

$$a = \frac{d^2x_A}{dt^2} = 0$$

As per this equation the particle has no acceleration at all. 1

$$\begin{aligned}
 (b) \quad v &= \frac{dx_B}{dt} \\
 &= 3 \times 2t + 2 + 0 \\
 &= 6t + 2 \\
 a &= \frac{d^2x_B}{dt^2} = 6
 \end{aligned}$$

Here acceleration is uniform.

1

$$\begin{aligned}
 (c) \quad v &= \frac{dx_C}{dt} \\
 &= 5 \times 3t^2 + 4 \\
 &= 15t^2 + 4 \\
 a &= \frac{dv}{dt} = \frac{d^2x_C}{dt^2} \\
 &= 15 \times 2t + 30t
 \end{aligned}$$

Here, acceleration depend upon time so it is not uniform.

1

16.

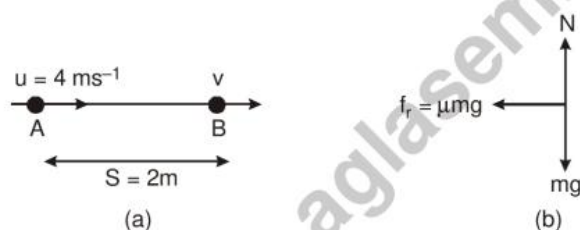


Figure (a) here shows the initial position A and the final position B of the object. Let the speed of particle at B be v . The particle does work against force of friction which is a non-conservative force.

$$K_i - K_f = W \quad 1$$

where W is the work done against the force of friction. Figure (b) shows all the forces acting on the object,

$$\begin{aligned}
 W &= f_r + S = mgS \\
 &= (0.15 \times 0.1 \times 10 \times 2) \text{ J} \\
 &= 0.3 \text{ J}
 \end{aligned} \quad 1$$

$$\text{Hence} \quad \frac{1}{2} \times 0.1 \times [4^2 - v^2] = 0.3$$

$$\begin{aligned}
 \text{Or} \quad 16 - v^2 &= 6 \\
 v &= \sqrt{10} \text{ ms}^{-1} = 3.16 \text{ ms}^{-1}
 \end{aligned} \quad 1$$

17. Velocity of centre of mass of a system,

$$\vec{v}_{\text{cm}} = \frac{d\vec{r}}{dt}$$

$$\begin{aligned}
 \text{Total external force } \vec{F} &= M \frac{d^2\vec{r}}{dt^2} \\
 &= M \frac{d\vec{v}_{\text{CM}}}{dt} \quad \dots(1) \quad 1
 \end{aligned}$$

Internal forces cancel out in pairs, so velocity of centre of mass is not affected by internal force.
Putting $\vec{F} = 0$ in equation (i),

$$= \frac{d\vec{v}_{CM}}{dt} = 0, (\because m \neq 0) \quad 1$$

i.e., $\vec{v}_{cm} = \text{constant}$

If resultant external force is zero, the velocity of centre of mass remains same. 1

Or

Expression for torque in cartesian co-ordinates from rotation of a particle in a plane : Physical meaning of torque :

Fig.

Consider a particle of mass m rotating in a plane XY about the origin O. Let P be the position of the particle at any instant, where $\vec{OP} = \vec{r}$ and $\angle XOP = \theta$. Let the rotation occur under the action of a force $\vec{F}$ applied at P, along $\vec{PA}$.

In a small time dt , let the particle at P reach Q, where

and $\vec{OQ} = (\vec{r} + d\vec{r})$
 $\angle POQ = d\theta$

In vector triangle OPQ,

$$\begin{aligned} \vec{OP} + \vec{PQ} &= \vec{OQ} \\ \vec{PQ} &= \vec{OQ} - \vec{OP} \\ &= (\vec{r} + d\vec{r}) - \vec{r} \\ \vec{PQ} &= d\vec{r} \end{aligned}$$

1/2

Small amount of work done in rotating the particle from P to Q is

$$dW = \vec{F} \cdot d\vec{r} \quad \dots(i)$$

If F_x, F_y are rectangular components of force F and dx, dy are rectangular component of displacement of $d\vec{r}$, then

$$\begin{aligned} \vec{F} &= (\hat{i} F_x + \hat{j} F_y) \\ d\vec{r} &= (\hat{i} dx + \hat{j} dy) \end{aligned}$$

From equation (i), we get

$$\begin{aligned} dW &= (\hat{i} F_x + \hat{j} F_y) (\hat{i} dx + \hat{j} dy) \\ dW &= F_x dx + F_y dy \end{aligned}$$

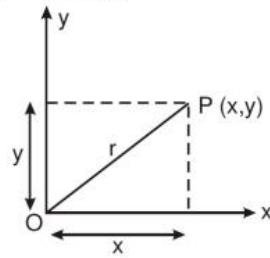
Let the co-ordinates of the point P be (x, y) as is clear from fig.

$$x = r \cos \theta$$

....(ii) $\frac{1}{2}$

$$y = r \sin \theta$$

....(iii)



Differentiating equation (iii) w.r.t. θ

$$\frac{dx}{d\theta} = \frac{d}{d\theta}(r \cos \theta)$$

$$= r \frac{d}{d\theta}(\cos \theta)$$

$$= r(-\sin \theta) = -r \sin \theta$$

$$= -y$$

....(iv) $\frac{1}{2}$

$$dx = -y d\theta$$

....(v)

Again, differentiating equation (iv) w.r.t. θ

$$\frac{dy}{d\theta} = \frac{d}{d\theta}(r \sin \theta)$$

$$= r \cos \theta$$

$$= x$$

....(vi)

$\therefore$

$$dy = x d\theta$$

....(vii) $\frac{1}{2}$

Substituting equation (ii)

$$dW = F_x(-y d\theta) + F_y(x d\theta)$$

$$= xF_y d\theta - yF_x d\theta$$

$$dW = (xF_y - yF_x) d\theta$$

....(viii)

$$dW = \tau(d\theta)$$

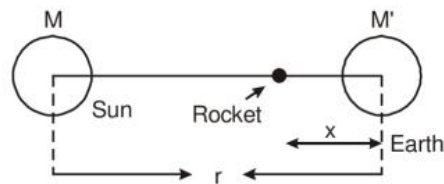
....(ix)

$$\tau = (xF_y - yF_x)$$

....(x) $\frac{1}{2}$

τ is called torque.

18. Suppose the force of gravitation vanish when the rocket is at distance x from the earth.



Let. M , M' and m be the masses of the sun, the earth and the rocket respectively.

The force of attraction between the rocket and the sun = $\frac{GMm}{(r-x)^2}$ and is directed towards the sun

$$= g \left(1 - \frac{1}{2} \right) = g \times \left(\frac{1}{2} \right)$$

$$= \frac{g}{2}$$

....(v) 1

$$\begin{aligned} \therefore W_d &= mg_d = m \frac{g}{2} \\ &= \frac{1}{2} mg = \frac{1}{2} W \\ &= \frac{1}{2} \times 250 = 125 \text{ N.} \end{aligned}$$

$\therefore$ Weight of the body half way down to the centre of earth = 125 N.

- 19. Displacement :** Consider a reference particle moving on a circle of reference of radius a with uniform angular velocity ω . Let the particle start from the point X and trace angular θ radian in time t as it reaches the point P.

Therefore, $\omega = \frac{\theta}{t}$ or $\theta = \omega t$. 1/2

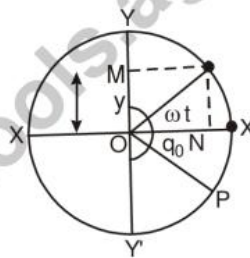
Let the projection of the particle P on diameter YOY' be at M. Then OM = y is the displacement in S.H.M. at time t .

In ΔOPM , $\sin \theta = \frac{OM}{OP} = \frac{y}{a}$
or $y = a \sin \theta = a \sin \omega t$ (i) 1/2

Important notes : (1) If projection of P is taken on diameter XOX', then point N will be executing S.H.M. Here, ON = x = displacement in S.H.M. at time t

In ΔONP , $\cos \theta = \frac{ON}{OP}$
or $x = a \cos \theta = a \cos \omega t$ (ii) 1/2

(2) If A is the starting position of the particle of reference such that $\angle AOX = \phi_0$ and $\angle AOP = \omega t$.

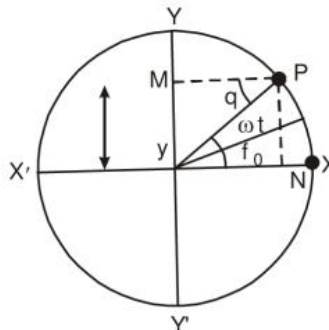


$$\theta = \angle XOP = \omega t - \phi_0$$

Here $(-)\phi_0$ is called the initial phase or epoch of S.H.M.

If B is the starting position of the particle of reference such that

$$\begin{aligned} \angle BOX &= \phi_0 \\ \angle BOP &= \omega t. \end{aligned}$$



$$\theta = \angle XOP = \omega t + \phi_0$$

From equation (i),

$$y = a \sin (\omega t + \phi_0)$$

From equation (ii),

$$x = a \cos (\omega t + \phi_0)$$

1/2

1/2

1/2

Here (+) ϕ_0 is called initial phase or epoch of S.H.M.

20. (a) The formula for velocity of sound in air is given by

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \dots(1)$$

where

γ = constant for a given gas, i.e., air

ρ = density of the gas

From gas equation,

$$PV = RT \quad \dots(1)$$

Or

$$P = \frac{RT}{V} \quad \dots(2)$$

$\therefore$ From equations (1) and (2), we get

$$v = \sqrt{\frac{\gamma RT}{\rho V}} = \sqrt{\frac{\gamma RT}{M}} \quad \dots(3)$$

where $\rho V = M$ = molecular weight of air or gas.

For a given gas, m = constant

R is also constant.

When T = constant, then from equation (3), we conclude that v independent of the pressure of air (gas) if temperature remains constant. 1

(b) Effect of temperature : We know that

$$PV = RT$$

Or

$$P = \frac{RT}{V}$$

Also

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{\rho V}} = \sqrt{\frac{\gamma RT}{M}}$$

where $M = \rho V$ = molecular weight of the gas. Since γ , R and M are constants, so

$$v \propto \sqrt{T}$$

It means velocity of sound in a gas is directly proportional to the square root of its temperature, hence we conclude that the velocity of sound in air increases with increase in temperature. 1

(c) Effect of humidity : The presence of water vapours in air changes the density of air, thus the velocity of sound changes with humidity of air.

Let

ρ_m = density of moist air

ρ_d = density of dry air

v_m = velocity of sound in moist air

v_d = velocity of sound in dry air

From relation $v = \sqrt{\frac{\gamma P}{\rho}}$, we get

$$v_m = \sqrt{\frac{\gamma P}{\rho_m}} \quad \dots(i)$$

and

$$v_d = \sqrt{\frac{\gamma P}{\rho_d}} \quad \dots(ii)$$

Dividing equation (i) by equation (ii), we get

$$\frac{v_m}{v_d} = \sqrt{\frac{\rho_d}{\rho_m}}$$

Also we know that density of water vapours is less than the density of dry air. It means dry air is heavier than water vapours as the molecular mass of water is less than that of N_2 (28) and O_2 (32), so $\rho_m < \rho_d$

Or $\frac{\rho_d}{\rho_m} > 1$ (iv)

∴ from equations (iii) and (iv), we get

$$\frac{v_m}{v_d} > 1$$

∴ $v_m > v_d$

It means velocity of sound in air increases with humidity, i.e., velocity of moist air is greater than the velocity of sound in dry air. That is why sound travels faster on rainy day than a dry day. 1

21. Given : Radius, $r = 1.0 \text{ cm} = 10^{-2} \text{ cm}$

Length of tube, $l = 1.5 \text{ m}$

Density of glycerine, $\rho = 1.3 \times 10^3 \text{ kg m}^{-3}$

Mass of glycerine flowing per sec,

$$M = 4 \times 10^{-3} \text{ kg s}^{-1}$$

Viscosity of glycerine, $\eta = 0.83 \text{ Pas.}$

$$= 0.83 \text{ Nm}^{-2} \text{ s.}$$

Suppose P = pressure difference between to ends of the tube = ?

Reynold number, $N_R = ?$

Suppose V = Volume of glycerine flowing per second

$$= \frac{M}{\rho}$$

$$= \frac{4 \times 10^{-3} \text{ kgs}^{-1}}{1.3 \times 10^3 \text{ kgm}^{-3}}$$

$$= \frac{4}{1.3}$$

$$= 10^{-6} \text{ m}^3 \text{ s}^{-1}$$

1/2

Now from Poiseulle's formula, we have

$$V = \frac{hpr^4}{8\eta l}$$

or

$$P = 8\eta lV/\pi r^4$$

⇒

$$P = \frac{8 \times 0.83 \times 1.5 \times \left(\frac{4}{1.3} \times 10^{-6}\right)}{3.142 \times (10^{-2})^4}$$

$$= 9.7537 \times 10^2 \text{ Pa}$$

$$= 9.8 \times 10^2 \text{ Pa.}$$

1

To check the assumption of laminar flow in the tube, let us find out the value of Reynold's number given by

$$N_R = \frac{\rho D v_c}{\eta} \quad \text{....(i)}$$

Where

v_c = critical velocity

$$= \frac{\text{volume flowing out per sec}}{\text{area of cross-section}}$$

$$= \frac{M/\rho}{\pi r^2}$$

....(ii) 1/2

For Laminar flow, N_R lies between 0 to 2000.

Now from equations (i) and (ii), we get

$$NR = \frac{\rho D}{\eta} \left(\frac{M}{\rho} \right) \times \frac{1}{\pi r^2}$$

$$= \frac{2rM}{\pi r^2 \eta}, (\because D = 2r)$$

$$= \frac{2M}{\pi r \eta}$$

$$= \frac{2 \times 4 \times 10^{-3}}{3.142 \times 10^{-2} \times 0.83}$$

$$= 3.07 \times 10^{-1} = 0.307 = 0.31.$$

1

22. Molar specific heat of a substance is defined as the amount of heat required to raise the temperature of one gram mole of the substance through a unit degree. By definition one mole of any substance is a quantity of the substance whose mass in gram is numerically equal to the molecular mass M . Thus

$$c = Mc$$

....(i) 1

$n \rightarrow$ no. of moles

$m \rightarrow$ mass of substance in grams.

$$i.e., \quad n = \frac{m}{M}$$

$$or \quad m = nM$$

1

From equation (i),

$$c = \frac{\Delta\theta}{m(\Delta t)} = \frac{\Delta\theta}{mM(\Delta t)}$$

$$Mc = \frac{1}{n} \left(\frac{\Delta\theta}{\Delta t} \right)$$

Using equation (i)

$$C = \frac{1}{n} \left(\frac{\Delta\theta}{\Delta t} \right)$$

1

23. (a) Rahim loves animals and feeds them, don't frighten animals with cveapong. 1
 (b) (i) The tension developed in the string when the monkey climbs up with an acceleration of 6 m/s^2 is given by $T = m(g + a) = 40(10 + 6) = 640 \text{ N}$. 1
 (ii) The tension developed when the monkey climbs down with an acceleration of 4 m/s^2 is given by $T = m(g - a) = 40(10 - 4) = 40 \times 6 = 240 \text{ N}$. $\frac{1}{2}$
 (iii) When the monkey climbs with uniform speed of 5 m/s acceleration is zero and the tension in the string is $T = mg = 40 \times 10 = 400 \text{ N}$. $\frac{1}{2}$
 (iv) As the monkey falls down the rope nearly under gravity, the tension in the string is given by $T = m(g - a) = m(g - g) = 0$
 Since the string can withstand a maximum tension of 600 N , hence the rope will break only in the first case (i) $\frac{1}{2}$

24. (a) Let a constant force $\vec{F}$ be applied to a body moving with initial velocity $\vec{u}$, so that its velocity becomes $\vec{v}$ along the direction of force when s is its displacement. Using Newton's second law of motion we get magnitude of force $F = ma$ and from equation of motion, we get $v^2 - u^2 = 2as$, where a is the acceleration of the body. 1

Multiplying both sides by m , we get

$$mv^2 - mu^2 = 2mas$$

$$i.e., \quad \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

$$i.e., \quad \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs = W$$

$$i.e., \quad K.E._{(f)} - K.E._{(i)} = W$$

1

where $K.E._{(f)}$ is final kinetic energy and $K.E._{(i)}$ is initial kinetic energy.

Thus work done on a body by a net force is equal to the change in kinetic energy of the body. 1

(b) Suppose, ΔW be the amount of work done in a small time interval Δt , when P_{av} be the average power, then

$$P_{av} = \frac{\Delta W}{\Delta t} \quad \dots(i) \quad \frac{1}{2}$$

When P be the instantaneous power, then by def.

$$\begin{aligned} P &= \lim_{\Delta t \rightarrow 0} P_{av} \\ &= \lim_{\Delta t \rightarrow 0} \frac{\Delta W}{\Delta t} \end{aligned} \quad \frac{1}{2}$$

$$\Rightarrow P = \frac{dW}{dt} = \frac{d}{dt}(W) \quad \dots(ii)$$

$$\text{Now } W = \vec{F} \cdot \vec{s} \quad \dots(iii) \quad \frac{1}{2}$$

where F = constant force producing a displacement

$\therefore$ From equations (ii) and (iii), we get

$$\begin{aligned} P &= \frac{d}{dt}(\vec{F} \cdot \vec{S}) \\ &= \vec{F} \cdot \frac{d\vec{S}}{dt} = \vec{F} \cdot \vec{v} \end{aligned} \quad \frac{1}{2}$$

Or

(a) In physics work is not said to be done, if (a) The applied force (F) is zero. A body moving with uniform velocity on a smooth surface has some displacement but no external force so in the case work done is zero. 1

(b) The displacement (s) is zero. A labourer standing with a load on his head does no work. 1/2

(c) The angle between force and displacement (θ) is $\pi/2$ rad or 90° . Then $\cos \theta = \cos 90^\circ = 0$. Thus work done is also zero.

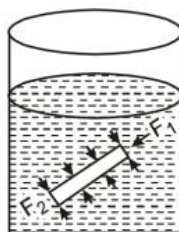
In circular motion, instantaneous work done is always zero because of this reasons. 1

(d) The change in kinetic energy (ΔKE) is zero 1/2

(b) If roads were to go straight up, the slope θ would have been large, the frictional force ($\mu mg \cos \theta$) would be small. The wheels of the vehicle would slip. Also for going up a large slope, a greater power shall be required. 2

25. It states that if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same. 1/2

Proof: Consider two points C and D inside the liquid in a container which is in equilibrium of rest. Imagine a right circular cylinder with axis CD of uniform cross-section area A such that points C and D lie on flat faces of the cylinder in figure. 1



The liquid inside the cylinder is in equilibrium under the action of forces exerted by the liquid outside the cylinder. These forces are acting every where $\perp$ to the surface of the cylinder. Thus force on the flat faces of the cylinder at C and D will $\perp$ to the forces on the curved surface of the

cylinder. Since the liquid is in equilibrium therefore, the sum of forces acting on the curved surface of the cylinder must be zero. If P_1 and P_2 are the pressure at points C and D and F_1 and F_2 are the forces acting on the flat faces of the cylinder due to liquid, then 1/2

$$F_1 = P_1 A$$

and

$$F_2 = P_2 A$$

Since the liquid is in equilibrium, therefore

$$F_1 = F_2$$

or

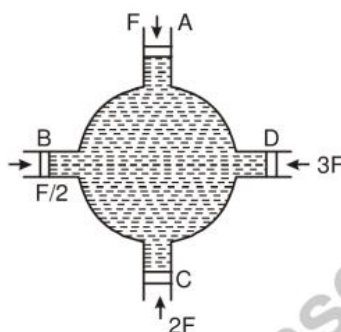
$$P_1 A = P_2 A$$

or

$$P_1 = P_2$$

It means the pressure at C and D are the same. 1/2

Experimental Proof : Consider a spherical vessel having four cylindrical tubes A, B, C and D each fitted with air tight frictionless piston are of cross-section a , $a/2$, $2a$ and $3a$ respectively.



Fill the vessel with an incompressible liquid so that no air gap is left inside the vessel and piston fitted in the various cylindrical tubes. Push the piston A with force F . The pressure developed on the liquid $= F/a = P$ (say) 1/2

It is seen that all other pistons will be pushed outwards. To keep the pistons at their respective original positions, the force $F/2$, $2F$ and $3F$ respectively required to be applied on pistons of tubes B, C and D respectively to hold them. Now pressure developed on liquid in tubes B, C and D are $F/2$, $2F/2a$, $3F/3a$ i.e., such equal to F/a . This indicates that the pressure applied is transmitted equally to all parts of liquid. This proves Pascal law. 1

Or

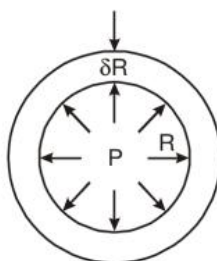
(i) Inside a liquid drop : Consider a liquid drop of radius R . The molecules lying on the surface of liquid drop, due to surface tension will experience a resultant force acting inward $\perp$ to the surface.

Let

S = Surface tension of liquid drop

P = excess pressure inside the drop

Due to excess of pressure, let there be increase in the radius of the drop by a small quantity δR , in figure.



Then work done by the excess pressure,

$$W = \text{force} \times \text{displacement}$$

$$= (\text{excess pressure} \times \text{area} \times \text{increase in radius})$$

$$= P \times 4\pi R^2 \times \delta R$$

....(i) 1/2

Increase in surface area of the drop

$$\begin{aligned}
 &= \text{final surface area} - \text{initial surface area} \\
 &= 4\pi (R + \delta R)^2 - 4\pi R^2 \\
 &= 4\pi [R^2 + 2R(\delta R) + (\delta R)^2 - R^2] \\
 &= 8\pi R \cdot \delta R \quad \quad \quad \frac{1}{2}
 \end{aligned}$$

[Neglecting, $(\delta R)^2$ being very very small]

$$\begin{aligned}
 \therefore \quad \text{Increase in surface energy} &= \text{increase in surface area} \times \text{surface tension} \\
 &= 8\pi R (\delta R) \times S \quad \quad \quad \dots(ii) \quad \frac{1}{2}
 \end{aligned}$$

As the increase surface energy is at the cost of work done by the excess pressure, therefore from (i) and (ii),

$$P \times 4\pi R^2 \times \delta R = 8\pi R \delta R \times S \quad \quad \quad \frac{1}{2}$$

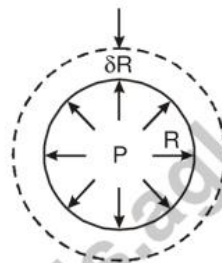
$$P = \frac{2S}{R}$$

(ii) Inside a liquid bubble : Consider a soap bubble of radius R the molecules lying on the surface of liquid bubble with experience a resultant force acting on water $\perp$ to the surface due to the surface tension.

Let

S = surface tension of the soap solution

P = excess of pressure inside the bubble.



Due to it, let there be increase in the radius of the bubble by a small amount δR in fig., then work done,

$$\begin{aligned}
 W &= \text{force} \times \text{distance} \\
 &= (\text{excess pressure} \times \text{area}) \times \text{increase in radius} \\
 &= P \times 4\pi R^2 \times \delta R \quad \quad \quad \dots(ii) \quad \frac{1}{2}
 \end{aligned}$$

The soap bubble has two free surface one outside the bubble and one inside the bubble when soap solution and air are in contact.

$\therefore$ The effective increase in surface area of the bubble

$$\begin{aligned}
 &= 2 [\text{final S.A} - \text{initial S.A.}] \\
 &= 2 [4\pi (R + \delta R)^2 - 4\pi R^2] \\
 &= 2 \times 4\pi [R^2 + 2R(\delta R) + (\delta R)^2 - R^2] \\
 &= 8\pi \times 2R (\delta R), \quad \quad \quad [\text{Neglecting } (\delta R)^2, \text{ being very small}] \\
 &= 16\pi R \cdot \delta R \quad \quad \quad \frac{1}{2}
 \end{aligned}$$

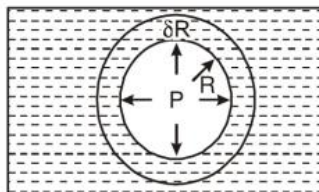
$\therefore$ Increase in surface energy is as the cost of work done by the excess pressure therefore from (iii) and (iv), we get

$$P \times 4\pi R^2 \times (\delta R) = 16\pi R (\delta R) \times S$$

$$\text{Or} \quad P = \frac{4S}{R} \quad \quad \quad \frac{1}{2}$$

(iii) Inside a bubble in liquid : Consider an air bubble of radius R . Just inside a liquid of surface tension S . The air bubble will have only one free surface as shown in figure. It can be shown that the pressure inside the air bubble is given by

$$P = \frac{2S}{R} \quad \quad \quad \frac{1}{2}$$



26. (a) (i) Size of a molecule of a gas is very small as compared to intermolecular distance.
 (ii) Behaviour of the molecules of the gas is perfectly elastic.
 (iii) Molecules do not exert any force on each other except in collision.
 (iv) Velocities of the molecules are in all directions.
 (v) Molecules are in random motion.
 (vi) The duration of collision is instantaneous.
 (vii) The molecules move in a straight line between two successive collisions.
 (viii) Collisions of the molecules with one another and the walls of the container are perfectly elastic. 1/2
- (b) Using the given relation,

$$P = \frac{1}{3} \rho v^2, \text{ we get}$$

$$P = \frac{1}{3} \frac{M}{V} v^2$$

$$PV = \frac{1}{3} M v^2 \quad \text{1/2}$$

Here M is fixed and $v^2 \propto T$

If temperature T is fixed then $PV = \text{constant}$.

Or $P \propto \frac{1}{V}$ 1/2

If temperature of a given mass of a gas is kept constant its pressure is inversely proportional to its volume.

Charle's law : $P = \frac{1}{3} P v^2$ 1/2

$$= \frac{1}{3} \frac{M}{V} v^2, \text{ we get}$$

$$V = \frac{1}{3} \frac{M}{P} v^2$$

$$v^2 \propto T \text{ and } M \text{ is fixed}$$

$$V \propto T.$$

If pressure of a given mass of gas is kept constant its volume is directly proportional to the temperature of the gas. 1/2

Or

(a) Pressure exerted by on. mole of gas,

$$P = \frac{1}{3} P v^2 = \frac{1}{3} \frac{M}{V} v^2$$

Or $PV = \frac{1}{3} M v^2$

But $PV = RT$ 1

$$\therefore \frac{1}{3} M v^2 = RT$$

$$\text{Or } \frac{1}{3} M v^2 = \frac{3}{2} RT$$

$$\text{Or } \frac{1}{2} (N m) v^2 = \frac{3}{2} RT, \quad (M = N m)$$

$$\text{Or } \frac{1}{2} M v^2 = \frac{3}{2} \frac{R}{N} T = \frac{3}{2} RT \quad 1$$

$$\therefore \text{Total random K.E. for one mole} = \frac{3}{2} RT$$

$$\text{and average K.E. per molecule} = \frac{3}{2} kT. \quad 1$$

(b) Root mean square velocity is defined as the square root of the average of the squares of the individual velocities of the gas molecules *i.e.*, $\frac{1}{2}$

$$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + \dots + v_n^2}{n}}$$

$$= \sqrt{\overline{v^2}}$$

where $v_1, v_2, v_3, \dots, v_n$ are individual velocities

$$v_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3RT}{m}}$$

$$i.e., \quad v_{rms} \propto \sqrt{T}. \quad 1$$

