

SAMPLE QUESTION PAPER – D

1. The value of g on moon is small, therefore, the weight of moon travellers will also be small. 1
2. Since there is no water under the block to exert an upward force on it, therefore, there is no buoyant force. 1
3. At the boiling point, vapour pressure of a liquid is equal to the atmospheric pressure. So, when the atmospheric pressure on the surface of the liquid increases, the liquids boil at higher temperature to generate greater vapour pressure. 1
4. Since there is no acceleration in the body at the mean position, hence the resultant force on it will be zero, *i.e.*, the force applied by the spring will be exactly equal to the weight of the body. 1
5. Yes, it is applicable to electromagnetic waves. 1
6. The dimension of L.H.S.,

$$\begin{aligned} \text{F.S.} &= [\text{MLT}^{-2}] \cdot [\text{L}] \\ &= [\text{ML}^2\text{T}^{-2}] \end{aligned}$$

1/2

The dimensions of R.H.S.,

$$\begin{aligned} \frac{1}{2}mv^2 \text{ or } \frac{1}{2}mu^2 &= [\text{M}] [\text{LT}^{-1}]^2 \\ &= [\text{ML}^2\text{T}^{-2}] \end{aligned}$$

1/2

So, dimensions of L.H.S. = R.H.S

So, given equation is dimensionally correct. 1

7. $\text{IN} = 1 \text{ kg} \times 1 \text{ ms}^{-2}$
 $= (1000 \text{ g}) (100 \text{ cms}^{-2})$
 $= 10^5 \text{ cms}^{-2}$

i.e., 1 newton = 10^5 dyne. 2**Or**

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

1/2

$$\cos\theta - |\vec{a}|^2 + |\vec{b}|^2 - 2|\vec{a}||\vec{b}|\cos\theta$$

$$= 4|\vec{a}||\vec{b}|\cos^2\frac{\theta}{2}$$

1

= a negative quantity

Hence

$$|\vec{a} - \vec{b}| < |\vec{a}| + |\vec{b}|$$

1/2

8. Instantaneous power is defined as the limiting value of the average power when time tends to zero.

In general,

$$P = \frac{d\omega}{dt} = \frac{d\vec{F} \cdot d\vec{r}}{dt}$$

1

$$\vec{F} \frac{d\vec{r}}{dt} = \vec{F} \cdot \vec{V},$$

where V is instantaneous velocity. 1

9. Put the given graph for a stress of $150 \times 10^6 \text{ Nm}^{-2}$, the strain is 0.002.
 (a) From the formula Young's modulus of the material (Y) is given by

$$\begin{aligned} Y &= \frac{\text{Stress}}{\text{Strain}} = \frac{150 \times 10^6}{0.002} = \frac{150 \times 10^6}{2 \times 10^{-3}} \\ &= 75 \times 10^9 \text{ Nm}^{-2} \\ &= 7.5 \times 10^9 \text{ Nm}^{-2}. \end{aligned}$$

1

(b) Yield strength of a material is defined as the maximum stress it can sustain.

∴ From graph, the approximate yield strength of the given material

$$= 300 \times 10^6 \text{ Nm}^{-2} = 3 \times 10^8 \text{ Nm}^{-2}.$$

1

10. The P.E. of a particle executing S.H.M. is given by :

$$E_P = \frac{1}{2} m \omega^2 y^2.$$

1/2

E_P is maximum when $y = r =$ amplitude of vibration *i.e.*, the particle is passing from the extreme position and is minimum when $y = 0$, *i.e.*, the particle is passing from the mean position :

1/2

The K.E. of a particle executing S.H.M. is given by,

$$E_K = m \omega^2 (r^2 - y^2)$$

E_K is maximum when $y = 0$, *i.e.*, the particle is passing from the mean position and E_K is minimum when $y = r$, *i.e.*, the particle is passing from the extreme position.

1

11. Size or diameter of a planet can be measured with the help of parallax method. Distance D of the planet from earth is measured with the help of relation $D = h/\theta$, where h is the distance between two observatories on earth and θ is the angle between two directions along which planet was viewed from two observations.

1

Let d be the diameter of planet and α the angle subtended by the diameter d at a point E on earth, then α being very small, $b/D < 1$. Let AB be an arc (of length d) of a circle with centre E , then distance

$$AB = d = D\alpha$$

1

Or

$$\alpha = \frac{d}{D}$$

∴ Diameter'

$$d = \alpha D$$

1

12. (i) Velocity at $t = 0$, $u = 0$

Velocity at $t = 2$ sec, $v = 20$ m/s

So, from $v = u + at$

We get $a = 10$ m/s²

So distance covered between 0 to 2 sec.

$$\begin{aligned} s &= ut + \frac{1}{2} at^2 \\ &= 0 \times 2 + \frac{1}{2} \times 10(2)^2 \\ &= 20 \text{ m} \end{aligned}$$

1

From 2 sec to 5 sec, velocity is same 20 m/s.

So, distance travelled = $20 \times 3 = 60$ m

∴ Total distance covered between 0 to 5 sec

$$= 20 + 60 = 80 \text{ m}$$

1

(ii) At $t = 5$ sec, $u = 20$ m/s,

At $t = 10$ sec, $v = 0$ m/s

So, from $v = u + at \Rightarrow 0 = 20 + a \times 5$

$$\Rightarrow a = -4 \text{ m/s}^2$$

So, distance covered from $v^2 = u^2 + 2as$,

$$(0)^2 = (20)^2 - 2 \times 4 \times s$$

$$\Rightarrow s = \frac{400}{8} = 50 \text{ m}$$

So, total distance covered = $80 + 50$

$$= 130 \text{ m.}$$

1

13. The nature of a vector may or may not be changed when it is multiplied.

1

For example, when a vector is multiplied by a pure number like 1, 2, 3, ..., etc., then the nature of the vector does not change.

1

On the other hand, when a vector is multiplied by a scalar physical quantity, then the nature of the vector changes. For example, when acceleration (vector) is multiplied by mass (scalar) of a body,

then it gives force (a vector quantity) whose nature is different than acceleration.

14. Given, $F = 50 \text{ N}$, $m_1 = 5 \text{ kg}$, $m_2 = 10 \text{ kg}$, $m_3 = 15 \text{ kg}$.

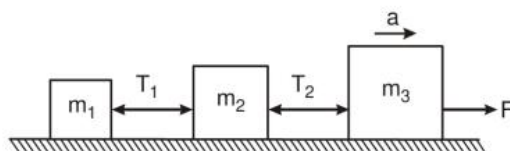


Fig. (a)

Since, the three blocks move with an acceleration 'a'.

So,

$$a = \frac{F}{m_1 + m_2 + m_3}$$

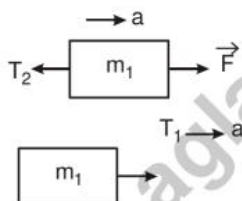
$$\Rightarrow a = \frac{50}{5 + 10 + 15} = \frac{50}{30}$$

$$= \frac{5}{3} \text{ ms}^{-2}.$$

1

To determine T_2 : Imagine the free body diagram (a).

Here $\vec{F}$ and $\vec{T}_2$ act towards right and left respectively.



Since, the motion is towards the right side, so according to Newton's Second law of motion :

$$F - T_2 = m_3 a$$

$$\Rightarrow 50 - T_2 = 15 \times \frac{5}{3} = 25$$

$$\Rightarrow T_2 = 50 - 25 = 25 \text{ N}.$$

1

To determine T_1 : Consider the free body diagram (b).

Here

$$m_1 a = T_1$$

Or

$$T_1 = m_1 a = 50 \times \frac{5}{3} = \frac{25}{3}$$

$$= 8.33 \text{ N}.$$

1

15. Following are some important points about the uniform motion :

- (i) The velocity in uniform motion does not depend upon the time interval $(t_2 - t_1)$. 1/2
- (ii) The velocity in uniform motion is independent of the choice of origin. 1/2
- (iii) No force acts on the object having uniform motion. 1
- (iv) Velocity is taken to be positive when the object moves towards right of the origin and it is taken -ve if object moves toward left of the origin. 1

16. The vehicle stops when its K.E. is spent in working against the force or friction between the tyres and the road. This force of friction varies directly with the weight of the vehicle. 1

As

$$\text{K.E.} = \text{work done}$$

$$= \text{Force of friction} \times \text{distance}$$

Or

$$E = f \times S$$

1/2

Or

$$S = E/f$$

1/2

For given K.E. S will be smaller where F is larger such as in the case of truck. 1

17. Using theorem of perpendicular axis,

$$I_z = I_x + I_y$$

As I_x and I_y are along the two diameters of disc so using symmetry,

$$I_x = I_y.$$

So,

$$I_z = 2I_x, \text{ But } I_z = \frac{MR^2}{2}$$

So,

$$I_x = \frac{I_z}{2} = \frac{MR^2}{4}.$$

3

Or

Momentum conservation and motion of the centre of the mass.

When a system of n particles is under the action of a total force f , then according to Newton's second law,

$$\vec{f} = \sum_{i=1}^{i=n} \frac{d}{dt} (m_i \vec{v}_i) \quad \dots(1)$$

$$\vec{f} = \frac{d}{dt} (m_1 \vec{v}_1 + m_2 \vec{v}_2 + \dots + m_n \vec{v}_n) \quad \dots(2) \quad \frac{1}{2}$$

If no external force acts on the system, then total force $\vec{f} = 0$. From (1) we obtain,

$$\begin{aligned} \frac{d}{dt} (m_1 \vec{v}_1 + m_2 \vec{v}_2 + \dots + m_n \vec{v}_n) &= 0 \\ (m_1 \vec{v}_1 + m_2 \vec{v}_2 + \dots + m_n \vec{v}_n) &= k \end{aligned} \quad \dots(2) \quad \frac{1}{2}$$

If M is the total mass of the system concentrated at the centre of mass, whose position vector is r , then

$$M \frac{d^2 \vec{r}}{dt^2} = \vec{f}$$

Or

$$M \frac{d}{dt} \left(\frac{d\vec{r}}{dt} \right) = \vec{f}$$

But

$$\frac{d\vec{r}}{dt} = \vec{v}$$

$\frac{1}{2}$

Or

$$M \frac{d}{dt} \left(\frac{d\vec{r}}{dt} \right) = \vec{f}$$

But

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

= velocity of centre of mass of the system

$\therefore$

$$M \frac{d}{dt} (\vec{v}_{CM}) = \vec{f}$$

$\dots(3) \quad \frac{1}{2}$

If no external force acting then $\vec{f} = 0$

From eqn. (3), we get

$$M \frac{d}{dt} (\vec{v}_{CM}) = 0$$

$$M \neq 0$$

∴

$$\frac{d}{dt}(\vec{v}_{CM}) = 0$$

$$\vec{v}_{CM} = \text{constant.} \quad \frac{1}{2}$$

18. The minimum energy required to free a satellite from the gravitational attraction is called binding energy. Binding energy is the negative value of total energy. Let a satellite of mass m be revolving around the earth of mass M and radius R . 1

Total energy of satellite = P.E. + K.E.

$$\begin{aligned} &= \frac{GMm}{R} + \frac{1}{2}mv^2 \\ &= \frac{GMm}{R} + \frac{m}{2} \cdot \frac{GM}{R} \\ &= \frac{GMm}{2R} \end{aligned} \quad \text{1}$$

∴

Binding energy of satellite = - [total energy of satellite]

$$= \frac{GMm}{2R} \quad \text{1}$$

19. (i) $v_{\max} = A\omega$. If amplitude A is doubled, then value of maximum velocity becomes double. 1

(ii) Total energy, $E = \frac{1}{2}m\omega^2 A^2$.

If a is doubled, then E becomes four times. 1

(ii) $T = 2\pi\sqrt{\frac{m}{k}}$, since m and k do not change with the change in amplitude of oscillation, hence period of oscillator remains unchanged with change in amplitude of oscillations. 1

20. Here,

$$\begin{aligned} y &= 2 \cos 2\pi (10t - 0.0080x + 0.35) \\ &= 2 \cos [2\pi (10t - 0.0080x) + 2\pi (0.35)] \\ &= 2 \cos \left[2\pi \times 0.0080 \left(\frac{10}{0.0080}t - x \right) + 2\pi \times 0.35 \right] \end{aligned} \quad \frac{1}{2}$$

Standard equation for a travelling wave is 1/2

$$y = r \cos \left[\frac{2\pi}{\lambda}(vt - x) + \phi \right]$$

Here

$$\phi = \frac{2\pi}{\lambda}x = 2\pi \times 0.008x \quad \frac{1}{2}$$

$$\left[\therefore \frac{2\pi}{\lambda} = 0.008 \right]$$

(a) When $x = 4 \text{ m} = 400 \text{ cm}$,

$$\begin{aligned} \phi &= 2\pi \times 0.008 \times 400 \\ &= 6.4\pi \text{ rad.} \end{aligned} \quad \frac{1}{2}$$

(b) When $x = 0.5 \text{ m} = 50 \text{ cm}$,

$$\begin{aligned} \phi &= 2\pi \times 0.008 \times 50 \\ &= 0.8\pi \text{ rad.} \end{aligned} \quad \frac{1}{2}$$

(c) When $x = \frac{\lambda}{2}$,

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi \text{ rad.} \quad \frac{1}{2}$$

(d) When $x = \frac{3}{4}\lambda$,

$$\phi = \frac{2\pi}{\lambda} \times \frac{3\lambda}{4} = \frac{3}{2}\pi \text{ rad.} \quad \frac{1}{2}$$

21. (a) The height of the blood column in the human body is more at the feet than at the brain. That is why, the blood exerts more pressure at the feet than at the brain ($\because$ pressure = $h\rho g$) 1
 (b) We know that the density of air is maximum near the surface of earth and decreases rapidly with height and at a height of about 6 km. it decreases to nearby half its value at the sea level. Beyond 6 km height the density of air decreases very slowly with height. Due to this reason the atmospheric pressure at the height of about 6 km decreases to nearly half of its value at sea level. 1
 (c) Since, due to applied force on liquid the pressure is transmitted equally in all directions inside the liquid. That is why there is no fixed direction for pressure due to liquid. Hence hydrostatic pressure is a scalar quantity. 1
22. (a) The gas would rush from A to B. The change in pressure or volume will take place under adiabatic conditions. The final pressure in the two cylinders would be 0.5 atm. 1/2
 (b) The change in internal energy of the gas will be zero. 1/2
 (c) The change in temperature will be zero. 1
 (d) Since the process is rapid, the intermediate states are not equilibrium states and hence do not satisfy the gas equation. So, the intermediate states of the system do not lie on the P – V – T surface. 1
23. (a) Radha takes care of things and has concern for others. Practical in finding the solutions to problems. 2
 (b) When the wheel is rolling, the angular momentum is conserved. However, due to frictional force, it continues to decrease. Thus, the wheel can stay upright on its rim only for a certain interval of time. In the stationary position, the wheel falls due to unstable equilibrium. 2
24. (a) Using the relation for kinetic energy,

$$\text{K.E.} = \frac{1}{2}mv^2,$$

we get rate of change of K.E. with respect to time as

$$\begin{aligned} \frac{d}{dt}(\text{K.E.}) &= \frac{d}{dt} \left[\frac{1}{2}mv^2 \right] \\ &= \frac{1}{2}m \cdot 2 \frac{dv}{dt} v = \frac{mdv}{dt} \end{aligned}$$

But $\frac{mdv}{dt} = ma = F.$ 1

where a is acceleration and F is force.

$$\therefore \frac{d}{dt} \text{K.E.} = Fv = F \frac{dx}{dt}$$

Or $d(\text{K.E.}) = F dx$ 1

Integrating between the initial and final energies, i.e., K.E._f and also position, i.e., x_i and x_f respectively, we get

$$\int_{\text{K.E.}_f}^{\text{K.E.}_i} d(\text{K.E.}) = \int_{x_i}^{x_f} F dx$$

$\therefore \text{K.E.}_f - \text{K.E.}_i = W.$ 1

(b) Potential energy will increase. This is because in bringing two protons closer, work has to be done against the force of repulsion. This is stored up in the form of potential energy. 1
However, the potential energy will decrease when a proton and an electron are brought nearer. 1
Work will be done by the force of attraction between them. 1

Or

(a) Let mass of the block = m

After breaking, $m_1 = \frac{2}{5}m$ and $m_2 = \frac{3}{5}m$

Initial momentum, $P_f = m_1 \vec{v}_1 + m_2 \vec{v}_2$ 1/2

According to law of conservation of momentum

$$P_f = P_i$$

$$\Rightarrow m_1 \vec{v}_1 + m_2 \vec{v}_2 = 0 \quad 1$$

$\vec{v}_1$ = velocity of smaller part

$\vec{v}_2$ = velocity of bigger part

$$\Rightarrow \frac{2}{5}m(8\hat{i} + 6\hat{j}) + \frac{3}{5}m(\vec{v}_2) = 0 \quad 1/2$$

$$\Rightarrow \frac{3}{5}m\vec{v}_2 = -\frac{1}{5}m(16\hat{i} + 12\hat{j})$$

$$\vec{v}_2 = -\left(\frac{16}{3}\hat{i} + 4\hat{j}\right) \quad 1$$

(b) As energy associated with discharge of a single neutron is 10^{-10} J, therefore total energy in a nerve impulse, where 10^5 neutrons are fired is $10^{-10} \times 10^5 \text{ J} = 10^{-5} \text{ J}$. 2

25. (a) When we blow over a piece of paper, velocity of air above the paper becomes more than that below it. Since, K.E. of air above the paper increases, so in accordance with Bernoulli's theorem

$(P + \frac{1}{2}\rho v^2 = \text{constant})$, its pressure energy and hence its pressure decreases. Because of greater value of pressure below the piece of paper – atmospheric pressure, it remains horizontal and does not fall.

While we blow under the paper, the pressure on the lower side decreases. The atmospheric pressure above the paper will therefore bend the paper downward. So the paper will not remain horizontal. 1

(b) This can be cleared from the equation of continuity, i.e., $a_1 v_1 = a_2 v_2$. We try to close a water tap with our fingers, the area of cross-section of the outlet of water jet is reduced considerable as the openings between our fingers provide constriction (i.e., regions of smaller area). Hence, velocity of water increase greatly and fast jets of water come through the openings between our fingers. 1

(c) From Bernoulli's theorem, we know that

$$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant} \quad \dots(i)$$

Here the size of the needle controls the velocity of flow and the thumb pressure controls pressure. Now P occurs with power 1 and velocity (v) occurring with power 2 in equation (i) therefore, the velocity has more influence. That is why the needle of syringe has a better control over the flow rate. 1

(d) If a fluid is flowing out of a small hole in a vessel, it acquires a large velocity and hence possesses large momentum. Since no external force is acting on the system, a backward velocity must be attained by the vessel (according to the law of conservation of momentum). As a result of it, an impulse (backward thrust) is experienced by the vessel. 1

(c) This is because of Magnus effect : Let a ball moving to the right be given a spin at the top of the ball. The velocity of air at the top is higher than the velocity of air below the ball. So according to Bernoulli's theorem, the pressure above the ball is less than the pressure below the ball. Thus there is a net upward force on the spinning ball, so the ball follows a curved path. This effect is known as magnus effect. 1

Or

Given, Atmospheric pressure,

$$P_0 = 76 \text{ cm of Hg.}$$

(a) In figure (a) pressure head,

$$h_1 = 20 \text{ cm of Hg.}$$

∴ Absolute pressure (P) of the gas is greater than the P_0 , i.e.,

$$\begin{aligned} P &= P_0 + h_1 \rho g \\ &= 76 \text{ cm of Hg} + 20 \text{ of Hg} \\ &= 96 \text{ cm of Hg.} \end{aligned}$$

1

Gauge pressure is the difference between the absolute pressure and the atmospheric pressure. $\frac{1}{2}$

It means,

$$\begin{aligned} \text{Gauge pressure} &= P - P_0 \\ &= 96 \text{ cm of Hg} - 76 \text{ cm of Hg} \\ &= 20 \text{ cm of Hg} \end{aligned}$$

In figure (b), pressure head.

$$h^2 = -18 \text{ cm of Hg.}$$

∴ The absolute pressure of the gas is lesser than the atmospheric pressure is given by

$$\begin{aligned} P &= P_0 + h_2 \rho g \\ &= 76 \text{ cm of Hg} + (-18 \text{ cm}) \text{ of Hg} \\ &= 58 \text{ cm of Hg} \end{aligned}$$

$$\begin{aligned} \text{Gauge pressure} &= \text{absolute pressure} - \text{atmospheric pressure} \\ &= 58 \text{ cm of Hg} - 76 \text{ cm of Hg} \\ &= -18 \text{ cm of Hg} \end{aligned}$$

It means, Gauge pressure is simply equal to h cm of Hg. $\frac{1}{2}$

(b) Given 13.6 cm of water added in the right limb is equivalent to $\frac{13.6}{13.6} = 1$ cm of Hg column.

i.e., $h = 1$ cm of Hg column, which can be calculated as follows,

$$h_w = 13.6 \text{ cm of water}$$

Suppose h_m = height of Hg column equivalent to 13.6 cm of water, thus equilibrium,

$$h_m \rho_m g = h_w \rho_w g \quad \frac{1}{2}$$

Or

$$h_m = h_w \frac{\rho_w}{\rho_m} = \frac{h_w}{\left(\frac{\rho_m}{\rho_w}\right)}$$

$$= \frac{13.6}{13.6} = 1 \text{ cm of Hg.} \quad \frac{1}{2}$$

The mercury will rise in the left limb such that the difference in the height of Hg column in the two limbs

$$\begin{aligned} &= 20 \text{ cm} - 1 \text{ cm} \\ &= 19 \text{ cm of Hg column.} \end{aligned} \quad 1$$

26. (a) It states that if the pressure remains constant, then the volume of a given mass of a gas increases or decreases by of its volume at 0°C for each 1°C rise of fall of temperature.

Let V_0 be the volume of the given mass of gas at 0°C . According to Charles's law its volume at 1°C , 1

$$\begin{aligned} V_1 &= V_0 \frac{V_0}{273.15} \\ &= V_0 \left[1 + \frac{1}{273.15} \right] \end{aligned} \quad 1$$

Volume of the gas at 2°C ,

$$V_2 = V_0 \left[1 + \frac{2}{273 \cdot 15} \right]$$

∴ Volume of the gas at $t^\circ\text{C}$,

$$\begin{aligned} V_1 &= V_0 \left[1 + \frac{t}{273 \cdot 15} \right] \\ &= V_0 \left[\frac{273 \cdot 15 + t}{273 \cdot 15} \right] \end{aligned} \quad 1$$

If T_0 and T are temperatures on kelvin scale corresponding to 0°C and $t^\circ\text{C}$, then

$$T_0 = 273 \cdot 15 + 0 = 273 \cdot 15$$

$$T = 273 \cdot 15 + t$$

$$V_t = V_0 \frac{T}{T_0}$$

$$\frac{V_t}{T} = \frac{V_0}{T_0}$$

$$\frac{V}{T} = \text{constant}$$

i.e.,

$$V \propto T. \quad 1$$

(b) This equation given the relation between pressure P , volume V and absolute temperature T of a gas,

$$PV = nRT. \quad \frac{1}{2}$$

Derivation. According to Boyle's law,

$$V \propto \frac{1}{P} \quad \dots(1) \quad \frac{1}{2}$$

According to Charles's law,

$$V \propto T \quad \dots(2) \quad \frac{1}{2}$$

Comparing (1) and (2), we have

$$\frac{PV}{T} = \text{constant}$$

As

$$PV = RT.$$

For n moles of gas $PV = nRT$

This is perfect or ideal gas equation.

$\frac{1}{2}$

Or

(a) **Numerical value of R** : Consider one mole of a gas at STP, then

$$R = \frac{P_0 V_0}{T_0} \quad \frac{1}{2}$$

Standard pressure,

$$\begin{aligned} P_0 &= 0.76 \text{ m of Hg column} \\ &= 0.76 \times 13.6 \times 10^3 \times 9.8 \text{ N/m}^2 \end{aligned}$$

$$\text{Standard temperature} = T_0 = 273 \cdot 15 \text{ K}$$

$$\text{Volume of one mole of gas at} = 22.4 \times 10^{-3} \text{ m}^3$$

$$R = \frac{0.76 \times 13.6 \times 10^3 \times 9.8 \times 22.4 \times 10^{-3}}{273 \cdot 15}$$

$$= 8.01 \text{ J mole}^{-1} \text{ K}^{-1}.$$

1

$$R = \frac{8.31}{4.2} \text{ cal mole}^{-1} \text{ }^{\circ}\text{C}^{-1}$$

$$= 1.98 \text{ cal mole}^{-1} \text{ }^{\circ}\text{C}^{-1}.$$

 $\frac{1}{2}$

Numerical value of K_B . We know that

$$K_B = \frac{R}{N_A}$$

$$K_B' = \frac{8.31 \text{ J mole}^{-1} \text{ K}^{-1}}{6.02 \times 10^{23} \text{ mole}^{-1}}$$

$$= 1.38 \times 10^{-23} \text{ J/K}.$$

 $\frac{1}{2}$

(b) Suppose a polyatomic gas molecule has n degrees of freedom.

 $\frac{1}{2}$

Total energy associated with the gram molecule of gas, *i.e.*,

$$E = n \times \frac{1}{2} RT \times N = \frac{n}{2} RT$$

As

$$C_v = \frac{dE}{dT}$$

 $\therefore$

$$C_v = \frac{d}{dT}(E)$$

 $\frac{1}{2}$

$$= \frac{d}{dT} \left(\frac{n}{2} RT \right) = \frac{n}{2} R$$

As

$$C_p = C_v + R$$

$$C_p = \frac{n}{2} R + R$$

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

 $\frac{1}{2}$

As

$$\gamma = \frac{C_p}{C_v}$$

$$\gamma = \frac{\left(\frac{n}{2} + 1 \right) R}{\frac{n}{2} R} = \frac{2}{n} \left(\frac{n}{2} + 1 \right)$$

$$\gamma = 1 + \frac{2}{n}.$$

1

