# SAMPLE PAPER - 8

## Class 11 - Physics

**Time Allowed: 3 hours** **Maximum Marks: 70**

**General Instructions:**

1. There are 35 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

**Section A**

1. Physical quantity x depends upon y and z as x = Ay + Bz + C where A, B and C are physical constant. Which one of the following relations is incorrect? **[1]**

a) $[BC] = \frac{[x^2]}{[z]}$

b) None of these

c) $\left[\frac{A}{B}\right] = \left[\frac{z}{y}\right]$

d) $\left[\frac{B}{C}\right] = \left[\frac{1}{z}\right]$

2. Two bodies of mass m and 4m have equal kinetic energy. What is the ratio of their momentum? **[1]**

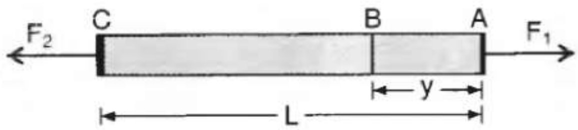
a) 2 : 1

b) 1 : 4

c) 1 : 2

d) 1 : 1

3. A rod of length L and mass M is acted on by two unequal forces $F_1$ and $F_2$ ($< F_1$) as shown in the following figure. **[1]**




The tension in the rod at a distance y from the end A is given by:

a) $(F_1 - F_2)\frac{y}{L}$

b) $F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$

c) $F_2\left(1-\frac{y}{L}\right)+F_1\left(\frac{y}{L}\right)$

d) None of these

4. For a constant hydraulic stress on an object, the fractional change in the object's volume ($\frac{\Delta V}{V}$) and its bulk modulus (B) are related as **[1]**

a) $\frac{\Delta V}{V} \propto \frac{1}{B}$

b) $\frac{\Delta V}{V} \propto B^2$

c) $\frac{\Delta V}{V} \propto B$

d) $\frac{\Delta V}{V} \propto \frac{1}{B^2}$

5. The time period T of the moon of planet Mars (mass $M_m$) is related to its orbital radius R (G = Gravitational constant) as: **[1]**

a) $T^2 = \frac{4\pi^2 R^3}{GM_m}$

b) $T^2 = 4\pi M_m G R^3$

c) $T^2 = \frac{2\pi R^3 G}{M_m}$

d) $T^2 = \frac{4\pi^2 G R^3}{M_m}$

6. A gas at one atmosphere and having volume 100 ml is mixed with another gas of equal moles at 0.5 atm and having volume 50 ml in flask of one litre, what is the final pressure? **[1]**

a) 1 atm

b) 0.125 atm

c) 0.75 atm

d) 0.5 atm

7. 1 kg of water is heated from $30^oC$ to $60^oC$, if its volume remains constant, then the change in internal energy is: (specific heat of water = 4148 $Jkg^{-1}K^{-1}$) **[1]**

a) $1.24 \times 10^5$ J

b) $1 \times 10^5$ J

c) $2.48 \times 10^5$ J

d) $2 \times 10^5$ J

8. A thin plane membrane separates hydrogen at 7° C from hydrogen at 47° C, both being at the same pressure. If a collimated sound beam travelling from the cooler gas makes an angle of incidence of 30° at the membrane, the angle of refraction is: **[1]**

a) $\sin^{-1}\sqrt{\frac{7}{4}}$

b) $\sin^{-1}\sqrt{\frac{4}{7}}$

c) $\sin^{-1}\sqrt{\frac{2}{7}}$

d) $\sin^{-1}\sqrt{\frac{7}{32}}$

9. Two non-mixing liquids of densities $\rho$ and $n\rho$ ($n > 1$) are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length $pL(p < 1)$ in the denser liquid. The density of d is equal to: **[1]**

a) $[1 + (n - 1)p]\rho$

b) $[1 + (n + 1)p]\rho$

c) $[2 + (n + 1)p]\rho$

d) $[2 + (n - 1)p]\rho$

10. The value of g at a particular point is 9.8 $m/s^2$. Suppose the Earth suddenly shrinks uniformly to half its present size without losing any mass. The value of g at the same point (assuming that the distance of the point from the centre of Earth does not shrink) will now be: **[1]**

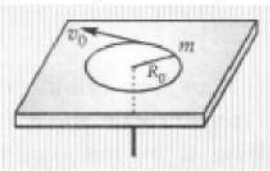
a) 9.8 $m/sec^2$

b) 19.6 $m/sec^2$

c) 3.1 $m/sec^2$

d) 4.9 $m/sec^2$

11. A mass m moves in a circle on a smooth horizontal plane with velocity $v_0$ at a radius $R_0$. The mass is attached to a string which passes through a smooth hole in the plane as shown. The tension in the string is increased gradually and finally m moves in a circle of radius $\frac{R_0}{2}$. The final value of the kinetic energy is **[1]**




a) $2mv_0^2$

b) $\frac{1}{2}mv_0^2$

c) $mw_0^2$

d) $\frac{1}{4}mv_0^2$

12. The average kinetic energy of gas molecules depends upon which of the following factor? **[1]**

a) Both Temperature of the gas and nature of the gas

b) Nature of the gas

c) Temperature of the gas

d) Volume of the gas

13. A uniform rope of length 12 m and mass 6 kg hangs vertically from a rigid support. A block of mass 2 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.06 metre is produced at the lower end of the rope. What is the wavelength of the pulse when it reaches the top of the rope? **[1]**

a) 0.09 metre

b) 0.12 metre

c) 0.06 metre

d) 0.03 metre

14. The theory of refrigerator is based on: **[1]**

a) Newton's particle theory

b) Joule-Thomson effect

c) Joules's effect

d) None of these

15. The escape velocity of a projectile on the earth's surface is 11.2 km $s^{-1}$. A body is projected out with thrice this speed. The speed of the body far away from the earth will be: **[1]**

a) 33.6 km $s^{-1}$

b) 31.7 km $s^{-1}$

c) None of these

d) 22.4 km $s^{-1}$

16. **Assertion (A):** The cross product of a vector with itself is a null vector. **[1]**
**Reason (R):** The cross-product of two vectors results in a vector quantity.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

17. **Assertion:** Stress is the internal force per unit area of a body. **[1]**
**Reason:** Rubber is more elastic than steel.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

18. **Assertion (A):** In the relation f = $\frac{1}{2l}\sqrt{\frac{T}{\mu}}$, where symbols have standard meaning, m represent linear mass density. **[1]**
**Reason (R):** The frequency has the dimensions of inverse of time.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

**Section B**

19. Suppose there existed a planet that went around the sun twice as fast as the earth. What would be its orbital size **[2]**

as compared to that of the earth?

20. Two particles of masses $m_1$ and $m_2$ in projectile motion have velocities $\overrightarrow{v}_1$ and $\overrightarrow{v}_2$ respectively at time t = 0. They collide at time $t_0$. Their velocities become $\overrightarrow{v_1'}$ and $\overrightarrow{v_2'}$ at time $2t_0$ while still moving in air. The value of $\left|\left(m_1\overrightarrow{v'}_1+m_2\overrightarrow{v'}_2\right)-\left(m_1\overrightarrow{v}_1+m_2\overrightarrow{v}_2\right)\right|$. **[2]**

21. Derive an expression for work done against gravity. **[2]**

OR

A body hanging from a spring stretches it by 1 cm at the earth's surface. How much will the same body stretch at a place 1600 klm above the earth's surface? Radius of earth 6400 km.

22. Two wires A and B are of the same material. Their lengths are in the ratio 1:2 and the diameters in the ratio 2:1. If they are pulled by the same force, then what will be the ratio of their increase in lengths? **[2]**

23. Calculate the limiting ratio of the internal energy possessed by helium and hydrogen gases at 10,000 K. **[2]**

OR

Four molecules of gas have speeds 2, 4, 6, 8, km/s. respectively. Calculate

i. Average speed.
ii. Root Mean square speed.

24. A particle is moving in a straight line. Its displacement at any instant t is given by $x = 10t + 15t^3$, where x is in metres and t is in seconds. Then find **[2]**

i. the average acceleration in the interval t = 0 to t = 2 s
ii. instantaneous acceleration at t = 2 s.

25. What is kinetic friction? Is it self-adjusting? **[2]**

**Section C**

26. If for hydrogen $C_P - C_V = a$ and for oxygen $C_P - C_V = b$ where $C_P$ & $C_V$ refer to specific heat at constant pressure and volume then what is the relation between a and b? **[3]**

27. A small body tied to one end of the string is whirled in a vertical circle. Represent the forces on a diagram when the string makes an angle $\theta$ with initial position below the fixed point. Find an expression for the tension in the string. Also, find the tension and velocity at the lowest and highest points respectively. **[3]**

28. At a depth of 1000 m in an ocean **[3]**

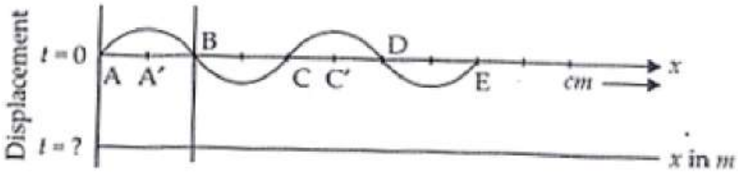
a. what is the absolute pressure?
b. What is the gauge pressure?
c. Find the force acting on the window of area 20 cm $\times$ 20 cm of a submarine at this depth, the interior of which is maintained at sea level atmospheric pressure.

(The density of sea water is $1.03 \times 10^3$ kg m$^{-3}$, g = 10 ms$^{-2}$.)

OR

An iron ball has an air space in it. It weighs 1 kg in air and 0.6 kg in water. Find the volume of air space. Density of iron = 7200 kgm$^{-3}$.

29. The pattern of standing waves formed on a stretched string at two instants of time is shown in Figure. The velocity of two waves super-imposing to form stationary waves is 360 ms$^{-1}$and their frequencies are 256 Hz. **[3]**




a. Calculate the time at which the second curve is plotted.

b. Mark nodes and antinodes on the curve.

c. Calculate the distance between A′ and C ′.

OR

What correction was applied by Laplace in Newton's formula for speed of sound waves? Does it lead to correct value of speed of sound in air?

30. Briefly explain, what do you mean by the terms thermal strain and thermal stress? Write expressions for them. **[3]**

**Section D**

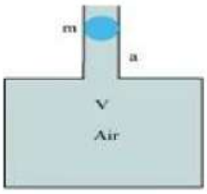
31. A person normally weighing 50 kg stands on a mass less platform which oscillates up and down harmonically at a frequency of 2.0 $s^{-1}$ and an amplitude 5.0 cm. A weighing machine on the platform gives the persons weight against time. **[5]**

i. Will there be any change in weight of the body, during the oscillation? Figure In extensible string.

ii. If answer to part (a) is yes, what will be the maximum and minimum reading in the machine and at which position?

OR

An air chamber of volume V has a neck area of cross section a into which a ball of mass m just fits and can move up and down without any friction (Figure). Show that when the ball is pressed down a little and released, it executes SHM. Obtain an expression for the time period of oscillations assuming pressure-volume variations of air to be isothermal.




32. At what angle should a body be projected with a velocity 24 $ms^{-1}$ just to pass over the obstacle 16 m high at a horizontal distance of 32 m? Take g = 10 $ms^{-2}$. **[5]**

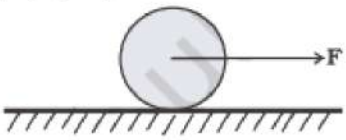
OR

i. Pick out only the vector quantities from the following: Temperature, pressure, impulse, time, power, charge.

ii. Show by drawing a neat diagram that the flight of a bird is an example of composition of vectors.

iii. A man is travelling at 10.8 km $h^{-1}$ in a topless car on a rainy day. He holds his umbrella at an angle 37° to the vertical to protect himself from the rain which is falling vertically downwards. What is the velocity of the rain? [ Given cos 37°= $\frac{4}{5}$ ]

33. A uniform disc of radius $R$, is resting on a table on its rim. The coefficient of friction between disc and table is $\mu$ (Figure). **[5]**



Now the disc is pulled with a force $\vec{F}$ as shown in the figure. What is the maximum value of F for which the disc rolls without slipping?

OR

A metal bar 70 cm long and 4.00 kg in mass supported on two knife-edges placed 10 cm from each end. A 6.00 kg load is suspended at 30 cm from one end. Find the reactions at the knife-edges. (Assume the bar to be of uniform cross-section and homogeneous).

## Section E

34. **Read the text carefully and answer the questions:** **[4]**

The highway police chased down and arrested a man accused of vehicle theft. He was nabbed after a kilometers-long chase while trying to flee with a car stolen from the nearby area. The car had been parked with the key still in the ignition. The owner raised an alarm on seeing his car being driven away. The highway police, who happened to pass through the area then, gave the accused a chase. He then tried to escape after abandoning the car, and the police personnel pursued him. The police van was moving on a highway with a speed of 30 km/h fired a bullet at a thief's car speeding away in the same direction with a speed of 192 km/h. The muzzle speed of the bullet was 150 m/s.


(i) What is the speed of the police van in m/s?

(ii) What is the speed of bullet when fired from moving car?

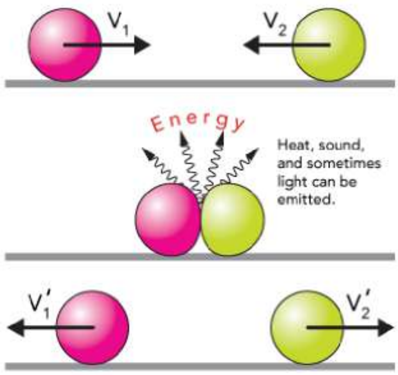
(iii) With what speed the bullet will hit the thief's vehicle?

**OR**

What was the difference between the speed of the police van and the car in m/s?

35. **Read the text carefully and answer the questions:** **[4]**

An **elastic collision** is a **collision** in which there is no net loss in kinetic energy in the system as a result of the **collision**. Both momentum and kinetic energy are conserved quantities in **elastic collisions**.




(i) Describe a motion in which the momentum changes but K.E does not?

(ii) Two balls after collision, stick to each other, What type of collision is it?

(iii) What happens to the momentum of two objects moving with the same speed but in opposite directions upon collision?

**OR**

In elastic collision, What is the ratio of relative speed of approach and separation.

## Solution

## SAMPLE PAPER - 8

## Class 11 - Physics

### Section A

1. **(b)** None of these

   **Explanation:** From principle of homogeneity, [A][y] = [B][z]

   $\Rightarrow \left[\frac{A}{B}\right] = \left[\frac{z}{y}\right]$

   Also, $\left[\frac{B}{C}\right] = \left[\frac{1}{z}\right]$

   Now, [x] = [B] [z] and [x] = [C]

   $\therefore$ [B][C] = $\frac{[x]}{[z]}$[C]

   $\therefore$ [BC] = $\frac{[x^2]}{[z]}$

2. **(c)** 1 : 2

   **Explanation:** For same k,

   $\frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}}$

   = $\sqrt{\frac{m}{4m}}$

   = $\frac{1}{2}$

   = 1 : 2

3. **(b)** $F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$

   **Explanation:** Net force on the rod = $F_1$ - $F_2$ ($\because F_1 > F_2$)

   As mass of the rod is M, hence acceleration of the rod is:

   $a = \frac{(F_1-F_2)}{M}$

   If we now consider the motion of part AB of the rod [whose mass is equal to ($\frac{M}{L}$)y], then

   $F_1 - T = \frac{M}{L}y \times a$

   where T is the tension in the rod at the point B.

   Now, $F_1 - T = \frac{M}{L}y \times \left(\frac{F_1-F_2}{M}\right)$

   or T = $F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$

4. **(a)** $\frac{\Delta V}{V} \propto \frac{1}{B}$

   **Explanation:** Bulk modulus $= \frac{\text{Hydraulic stress}}{\text{Volumetric strain}}$

   $B = \frac{\text{Hydraulic stress}}{\Delta V/V}$

   or $\frac{\Delta V}{V} = \text{Hydraulic stress} \times \frac{1}{B}$

   $\therefore$ For constant hydraulic stress

   $\frac{\Delta V}{V} \propto \frac{1}{B}$

5. **(a)** $T^2 = \frac{4\pi^2R^3}{GM_m}$

   **Explanation:** Time period of satellite is given by,

   $= \frac{\text{Circumference of an orbit}}{\text{Velocity in orbit}}$

   $= \frac{2\pi R}{v_0}$

   $= \frac{2\pi R}{\sqrt{\frac{GM_m}{R}}}$

   $= \frac{2\pi R^{3/2}}{\sqrt{GM_m}}$

6. **(b)** 0.125 atm

   **Explanation:** Total number of moles is conserved.

   $\therefore \frac{P_1V_1}{RT}+\frac{P_2V_2}{RT}=\frac{PV}{RT}$

$\frac{1\times100}{RT}+\frac{0.5\times50}{RT}=\frac{P\times1000}{RT}$

or P = 0.125 atm

7. **(a)** $1.24 \times 10^5$ J

**Explanation:** Since volume of water remains constant, then work done

$\Delta W = PdV = 0$

According to first pair of thermodynamics

dQ = dU + dW

dU = dQ

$= ms\Delta T$

$= 1 \times 4148 \times (60 - 30)$

$= 4148 \times 30$

$= 124440 \text{ J} = 1.24 \times 10^5$ J

8. **(c)** $\sin^{-1}\sqrt{\frac{2}{7}}$

**Explanation:** $v_7=\sqrt{\frac{3R(273+7)}{M}}$

$av_{47}=\sqrt{\frac{3R(273+47)}{M}}$

$\frac{v_7}{v_{47}}=\sqrt{\frac{280}{320}}=\sqrt{\frac{7}{8}}$

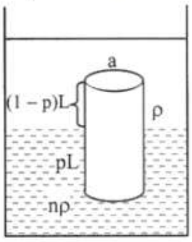
Now, $\frac{\sin i}{\sin r}=\frac{v_7}{v_{47}}=\sqrt{\frac{7}{8}}$

sin r - sin 30° $\times\sqrt{\frac{8}{7}}=\sqrt{\frac{2}{7}}$

or $r=\sin^{-1}\sqrt{\frac{2}{7}}$

9. **(a)** $[1 + (n - 1)p]\rho$

**Explanation:**




Let ‘a’ be the area of the cylinder.

Weight of container

= Thrust due to liquid 1 + Thrust due to liquid 2

$\therefore$ aLdg = a(1 - p)L$\rho$g + apL(n$\rho$)g

$\therefore$ d = (1 - p)$\rho$ + np$\rho$ = $\rho$ + (n - 1)p$\rho$

$\therefore$ d = $\rho$[1 + (n - 1)p]$\rho$

10. **(a)** 9.8 m/sec$^2$

**Explanation:** As we know that,

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

Since M and r are constant, so

g = 9.8 m/s$^2$

11. **(a)** $2mv_0^2$

**Explanation:** Angular momentum is conserved because torque due to tension is zero.

$L_i=L_f\Rightarrow mv_0R_0=mv\frac{R_0}{2}$

$\Rightarrow v=2v_0$

Final K.E $=\frac{1}{2}m(2v_0)^2=2mv_0^2$

12. **(c)** Temperature of the gas

**Explanation:** The average kinetic energy of gas molecules depends on the temperature of the gas as E = $\frac{3}{2}K_BT$.

13. **(b)** 0.12 metre

**Explanation:** v = $\sqrt{\frac{T}{m}}$, but v = n$\lambda$

$\therefore \lambda = \frac{1}{n}\sqrt{\frac{T}{m}}$

As the transverse wave travels upwards along the rope, there is neither any change in frequency nor in mass per unit length m.

$\therefore \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{T_1}{T_2}}$

At the lower end: $T_1 = 2 \times 9.8$ N, $\lambda_1 = 0.06$ m

At the top end: $T_2 = 8 \times 9.8$ N

$\therefore \frac{0.06}{\lambda_2} = \sqrt{\frac{2\times 9.8}{8\times 9.8}} = \frac{1}{2}$

or $\lambda_2 = 0.12$ m

14. **(d)** None of these

**Explanation:** None of these

15. **(b)** 31.7 km $s^{-1}$

**Explanation:** 31.7 km $s^{-1}$

16. **(b)** Both A and R are true but R is not the correct explanation of A.

**Explanation:** According to statement of reason, $\vec{A} \times \vec{B}$ = AB sin $\theta$.

As $\vec{B} = \vec{A}$, angle between $\vec{A} \times \vec{A}$, $\theta$ = 0. Therefore,

$\vec{A} \times \vec{A}$ = A sin $0^o = \vec{0}$ i.e. the cross product of a vector with itself is zero.

17. **(c)** Assertion is correct statement but reason is wrong statement.

**Explanation:** Assertion is correct statement but reason is wrong statement.

18. **(b)** Both A and R are true but R is not the correct explanation of A.

**Explanation:** From, f = $\frac{1}{2l}\sqrt{\frac{T}{\mu}}$, $f^2 = \frac{T}{4l^2\mu}$

or, $\mu = \frac{T}{4l^2f^2} = \frac{[\mathrm{MLT}^{-2}]}{\mathrm{L}^2\,\mathrm{T}^{-2}} = \frac{\mathrm{M}}{\mathrm{L}}$

= $\frac{\text{Mass}}{\text{length}}$ = linear mass density.

**Section B**

19. Let the period of revolution of the earth = $T_e$

As the planet goes round the sun twice as fast as the earth, so its period of revolution is

$T_p = \frac{1}{2}T_e$

Orbital size of the earth, $a_c$ = 1 AU

Orbital size of the planet, $a_p$ = ?

From Kepler's law of periods,

$\frac{T_p^2}{T_e^2} = \frac{a_p^3}{a_e^3}$

$\therefore a_p = = \left[\frac{T_p}{T_e}\right]^{2/3} \times a_e = \left[\frac{T_e/2}{T_e}\right]^{1/3} \times$ 1 AU

= $(0.5)^{2/3}$ AU = 0.63 AU

20. As there is no external force in the horizontal direction, the momentum is changed in the vertical direction only by the gravitational force in time 0 to 2 $t_0$.

Change in momentum = external force $\times$ time interval

$\therefore \left|\left(m_1\overrightarrow{v'}_1 + m_2\overrightarrow{v'}_2\right) - \left(m_1\overrightarrow{v_1} + m_2\overrightarrow{v_2}\right)\right|$

= $(m_1 + m_2)$g $\times$ $(2f_0 - 0)$ = $2(m_1 + m_2)gt_0$.

21. Potential energy of the body on the surface of the earth = $\frac{-GMm}{R}$

Potential energy at a $height\ h$ from the surface of the earth = - $\frac{GMm}{(R+h)}$

$Work\ done = \left(-\frac{GMm}{R+h}\right) - \left(-\frac{GMm}{R}\right)$

= $\frac{GMm}{R}$ - $\frac{GMm}{R+h}$

$= GMm\left(\frac{1}{R} - \frac{1}{R+h}\right)$

$= \frac{GMmh}{R(R+h)} = \frac{MgR^2h}{R(R+h)} \left[\because g = \frac{GM}{R^2}\right]$

$= \frac{(Mgh)R}{(R+h)} = \frac{Mgh}{1+\frac{h}{R}}$

OR

In equilibrium mg = kg, $g = \frac{GM}{R^2}$

At height h mg' = kx', $g' = \frac{GM}{(R+h)^2}$

$\frac{g'}{g} = \frac{x'}{x} = \frac{R^2}{(R+h)^2}$

$\frac{x'}{x} = \frac{(6400)^2}{(6400+1600)^2} = \frac{6}{25}$

$\therefore x = \frac{16}{25} \times 1cm = 0.64cm$

22. As we know, $\Delta L = \frac{FL}{AY}$, $\frac{L_A}{L_B} = \frac{1}{2}$ and $\frac{r_A}{r_B} = \frac{1}{2}$

[$\because$ the wires $A\ and\ B$ are pulled by the same force and they are made up of same material, hence,

$F_A = F_B = F, = Y_A = Y_B = Y$ ]

$\frac{\Delta L_A}{\Delta L_B} = \frac{L_A}{\pi r_A^2} \times \frac{\pi r_B^2}{L_B}$

$\frac{\Delta L_A}{\Delta L_B} = \frac{L_A}{L_B} \times \left(\frac{r_B}{r_A}\right)^2$

$\frac{\Delta L_A}{\Delta L_B} = \frac{1}{2} \times \left(\frac{1}{2}\right)^2 = \frac{1}{2}$

$\frac{\Delta L_A}{\Delta L_B} = \frac{1}{8}$

23. For helium gas : As helium is monoatomic gas, the number of degrees of freedom of helium molecule = 3

$\therefore$ The internal energy of helium molecule at 10,000 K

$U_{\text{He}} = 3 \times \frac{1}{2}k_BT$

$= 3 \times \frac{1}{2} \times k_B \times 10000 = 1.5 \times 10^4$ kB

For hydrogen gas : At 10,000 K, no. of degrees of freedom of a $H_2$ molecule = 7

$\therefore$ The internal energy of hydrogen molecule at 10,000 K,

$U_{\text{H}} = 7 \times \frac{1}{2}k_BT$

$= 7 \times \frac{1}{2}k_B \times 10000 = 3.5 \times 10^4\ k_B$

Hence $\frac{U_{\text{He}}}{U_{\text{H}}} = \frac{1.5\times10^4 k_B}{3.5\times10^4 k_B} = 3 : 7.$

OR

Here, $C_1$ = km/s= velocity of first gas

$C_2$ = 4km/s =velocity of second gas

$C_3$ = 6km/s=velocity of third gas

$C_4$ = 8km/s=velocity of fourth gas

i. Average speed $= \frac{C_1+C_2+C_3+C_4}{4}$

   Average Speed $= \frac{2+4+6+8}{4}$

   Average Speed $= \frac{20}{4} = 5\ km/s$

ii. Root Mean Square Speed $= \sqrt{\frac{C_1^2+C_2^2+C_3^2+C_4^2}{4}}$

   R. m. s of gas $\sqrt{\frac{2^2+4^2+6^2+8^2}{4}}$

   R. m. s. of gas $= \sqrt{\frac{120}{4}}$

   R. m. s of gas = 5.48km/s

24. It is given that a particle is moving in a straight line and its displacement at any instant t is given by, $x = 10t + 15t^3$

i. Now, the Velocity of particle, $\mathbf{v} = \frac{dx}{dt}$

   $\mathbf{v} = \frac{d}{dt}\left(10t + 15t^3\right) = 10 + 45t^2$

   At t = 0, $v_0 = 10 + 45(0) = 10$ m/s

At t = 2, $v_2 = 10 + 45(2)^2 = 10 + 180 = 190$ m/s

$\Delta \mathbf{v} = \mathbf{v}_2 - \mathbf{v}_0$ = 190 - 10 = 180 m/s

$\Delta$t = 2 - 0 = 2 s

$\therefore \mathbf{a}_{av} = \frac{\Delta \mathbf{v}}{\Delta t} = \frac{180}{2}$ = 90 m/s$^2$

ii. Also, a = $\frac{dv}{dt}$ = $\frac{d}{dt}\left(10 + 45t^2\right)$ = 90t

At t = 2 s, a = 90(2) = 180 m/s$^2$

Thus, the instantaneous acceleration of a particle at 2 s is 180 m/s$^2$.

25. Kinetic friction is the force of friction which comes into play between the surfaces of contact of two bodies when one body is in steady motion over the surface of another body. Kinetic friction is not self-adjusting. Rather it has a constant value for a given normal reaction.

**Section C**

26. Let

$C_P$ = Specific heat at constant pressure

$C_V$ = Specific heat at constant Volume

M = Molar mass

For an ideal gas , $C_p - C_v = R$

for other gases, $C_P - C_V = \frac{R}{M}$

For $H_2$, $C_P - C_V = a$

For $O_2 = C_P - C_V = b$

So, for $H_2 \Rightarrow C_P - C_V = a = \frac{R}{2}$

$M_{H2} = 2 \left| C_P - C_V = a = \frac{R}{2} \right.$ ...(i)

For $O_2 \Rightarrow \mathrm{C_P} - \mathrm{C_V} = \mathrm{b} = \frac{R}{32}$ ...(ii)

from equation (i)

$2a = R$

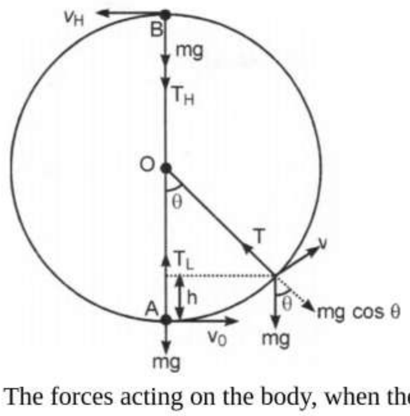
from equation (ii)

$32b = R$

$\therefore$ 2a = 32 b

a = 16 b

27. Consider a small body of mass m attached to one end of a string (of length l) and whirled in a vertical circle of radius 'r'. Let body starts motion from its initial position A, just below the fixed point O, with a speed $v_o$.




The forces acting on the body, when the string makes an angle $\theta$ with the initial position are shown in the figure. Here, mg is the weight of body and T the tension in the string. If v be the instantaneous velocity at this point, then a centripetal force $F = \frac{mv^2}{l}$ is required radially inward. From figure, it is clear that in equilibrium the centripetal force is provided by resultant of two forces i.e.,

$T - mg\cos\theta = \frac{mv^2}{l}$

or $T = mg\cos\theta + \frac{mv^2}{l}$ ...(1)

If the body has covered a vertical distance h, then from law of conservation of mechanical energy, we have

$\frac{1}{2}mv_0^2 = \frac{1}{2}mv^2 + mgh$

$\Rightarrow v^2 = v_0^2 - 2gh$ ...(ii)

which is the required expression for the velocity of a particle at any point.

At the lowest point $\theta$ = 0° and h = 0, hence we have

$v_L = v = v_o$ ....[from (i) putting h = 0]

Thus,

$T_L = mg\cos 0^\circ + \frac{m}{l}v_L^2 = mg + \frac{mv_0^2}{l}$

and at the highest point $\theta$ = 180° and h = $2l$. Hence,

$v_H^2 = v^2 = v_0^2 - 4gl$ [from (i) putting h = $2l$]

or $v_H = \sqrt{v_0^2 - 4gl}$

and $T_H = mg\cos 180^\circ + \frac{mv_H^2}{l} = mg(-1) + \frac{m}{l}\left(v_0^2 - 4gl\right) = \frac{mv_0^2}{l} - 5mg$

which is the required expression for the Tension.

28. Here h = 1000m and $\rho = 1.03 \times 10^3 \text{kgm}^3$

a. Eq. $P_2 - P_1 = \rho gh$, absolute pressure

$P = P_a + \rho gh$

$= 1.01 \times 10^5 \text{Pa}$

$+1.03 \times 10^3 \text{kgm}^{-3} \times 10\text{ms}^{-2} \times 1000\text{m}$

$= 104.01 \times 10^5 \text{Pa}$

$\approx 104\text{atm}$

b. Gauge pressure is $P - P_a = \rho gh = P_g$

$P_g = 1.03 \times 10^3 \text{kgm}^{-3} \times 10\text{ms}^2 \times 1000\text{m}$

$= 103 \times 10^5 \text{Pa}$

$\approx 103$ atm

c. The pressure outside the submarine is P = $P_a + \rho gh$ and the pressure inside it is $P_a$. Hence, the net pressure acting on the window is gauge pressure, $P_g = \rho gh$. Since the area of the window is A = 0.04 $m^2$, the force acting on it is

$F = P_8 A = 103 \times 10^5 \text{Pa} \times 0.04\text{m}^2 = 4.12 \times 10^5 \text{N}$

OR

Loss of weight of the ball in water = 1 - 0.6 = 0.4 kg f (1 kg f=9.8 N)

Loss of weight of the ball = Weight of the water displaced = 0.4 kg f

= V × 1000 kg f

Volume of the iron ball with air space,

V = $\frac{0.4}{1000}$ = 0.4 × $10^{-3}$ $m^3$

Volume of iron alone

= $\frac{\text{Mass}}{\text{Density}} = \frac{1}{7200}$ = 0.138 × $10^{-3}$ $m^3$

∴ Volume of air space = (Volume of iron ball with air space - Volume of iron alone)

= 0.4 × $10^{-3}$ - 0.138 × $10^{-3}$ $m^3$

= 0.262 × $10^{-3}$ $m^3$

29. Given, frequency of the wave v = 256 Hz

Time period $T = \frac{1}{v} = \frac{1}{256}s = 3.9 \times 10^{-3} = s$

i. Time is taken to pass through mean position is

$t = \frac{T}{4} = \frac{1}{40} = \frac{3.9 \times 10^{-3}}{4}s = 9.8 \times 10^{-4}s$

ii. Nodes are A, B, C, D, E (i.e., zero displacements)

Antinodes are A', C' (i.e., maximum displacement)

iii. It is clear from the diagram A' and C' are consecutive hence separation = wavelength ($\lambda$)

$= \frac{v}{v} = \frac{360}{256} = 1.41\text{m}$

OR

Laplace applied a correction in Newton's formula, $\left[v = \sqrt{\frac{B_{isohermal}}{\rho}}\right]$ for speed of sound in gaseous media. Laplace argued that the compressions and rarefactions are taking place under the adiabatic condition on account of the following two reasons :

i. Gases are non-conducting in nature.

ii. Compressions and rarefactions are taking place so rapidly that there is practically no chance to exchange heat with the surrounding medium.

Thus, according to Laplace, v = $\sqrt{\frac{B_{ndiabatic}}{\rho}}$

We know that under adiabatic conditions $PV^{\gamma}$ = constant

$\therefore P \cdot \gamma V^{\gamma-1} dV + dP \cdot V^{\gamma} = 0$

$\Rightarrow V^{\gamma-1}[V \cdot dP + \gamma P dV] = 0$

$\Rightarrow \gamma P = -\frac{dP}{(dV/V)} = B_{\text{adiabatic}}$, where $\gamma$ is the ratio of two principal specific heats of a given gas. Hence, as per the Laplace modified formula, we have

$v = \sqrt{\frac{\gamma P}{\rho}}$

For air at STP conditions P = 1.013 $\times$ $10^5$ Pa, $\rho$ = 1.293 kg $m^{-3}$ and for air $\gamma$ = 1.41

$\therefore$ Speed of sound in air at STP, v = $\sqrt{\frac{1.41 \times 1.013 \times 10^5}{1.293}}$ = 332 $ms^{-1}$

The value so obtained resembles completely with experimentally determined value of the speed of sound in air. Hence, it is the correct relation.

30. When a metal rod, whose ends are rigidly fixed so as to prevent the rod from expansion or contraction, undergoes a change in temperature, thermal strains and thermal stresses are developed in the rod.

The **thermal strain** or deformation for an unrestricted thermal expansion can be defined as the ratio of change in length to the original length.

**Thermal Stress** occurs when restricted expansion is converted to stress.

If a rod of length l is heated by a temperature $\Delta$T, then increase in length of the rod is, $\Delta l = l \cdot \alpha \cdot \Delta T$

But due to being fixed at ends, the rod does not expand and a compressive thermal strain is developed in it which is given by,

Thermal (compressive) strain = $\frac{\Delta l}{l} = \alpha . \Delta T$ , here $\alpha$ = linear expansion coefficient of the material of rod.

Due to this strain, thermal stress is developed in the rod.

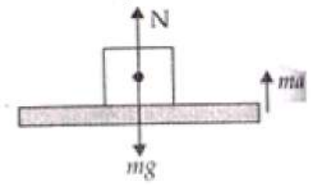
Thermal stress = Y $\times$ thermal strain = Y. $\alpha$ . $\Delta$T

Thus, the force (tension) exerted by the rod on the supports will be,

$F = Y\alpha \cdot \Delta T \cdot A$

**Section D**

31. a. Weight in weight machine will be due to the normal reaction (N) by platform. Consider the top position of platform, two forces acting on it are due to weight of person and oscillator. They both act downward.




(mg = weight of the person with the oscillator is acting downwards, ma = force due to oscillation is acting upwards, N = normal reaction force acting upwards)

Now for the downward motion of the system with an acceleration a,

ma = mg - N .....(i)

When platform lifts form its lowest position to upward

ma = N - mg ......(ii)

$a = \omega^2 A$ is value of acceleration of oscillator

$\therefore$ From equation (i) we get,

$N = mg - m\omega^2 A$

Where A is amplitude, $\omega$ angular frequency and m mass of oscillator.

$\omega = 2\pi\nu$

$\therefore \omega = 2\pi \times 2 = 4\pi\ rad/\text{sec}$

Again using $A = 5\ cm = 5 \times 10^{-2} m$ we get

$N = 50 \times 9.8 - 50 \times 4\pi \times 4\pi \times 5 \times 10^{-2}$

$= 50\left[9.8 - 16\pi^2 \times 5 \times 10^{-2}\right]$ N

$= 50\left[9.8 - 80 \times 3.14 \times 3.14 \times 10^{-2}\right]$ N

$\Rightarrow N = 50[9.8 - 7.89] = 50 \times 1.91 = 95.50\text{N}$

So minimum weight is 95.50 N(for downward motion of the platform)

From equation (ii), N – mg = ma

For upward motion from the lowest to the highest point of oscillator,

$N = mg + ma$

$= m\left[9.81 + \omega^2 A\right] \quad \because a = \omega^2 A$

$= 50\left[9.81 + 16\pi^2 \times 5 \times 10^{-2}\right]$

$= 50[9.81 + 7.89] = 50 \times 17.70$ N = 885 N

Hence, there is a change in weight of the body during oscillation.

b. The maximum weight is 885 N, when platform moves from lowest to upward direction.

And the minimum weight is 95.5 N, when platform moves from the highest point to downward direction.

OR

Given

⇒ Volume of the air chamber = V

⇒ Area of cross-section of the neck = a

⇒ Mass of the ball = m

The pressure inside the chamber is equal to the atmospheric pressure.

Let the ball be depressed by x units. As a result of this depression, there would be a decrease in the volume and an increase in the pressure inside the chamber.

Decrease in the volume of the air chamber, $\Delta V = ax$

⇒ Volumetric strain $= \frac{\text{Change in volume}}{\text{Original valume}}$

$\Rightarrow \frac{\Delta V}{V} = \frac{ax}{V}$

⇒ Bulk Modulus of air, $B = \frac{\text{Stress}}{\text{Strain}} = \frac{-p}{\frac{ax}{V}}$

In this case, stress is the increase in pressure. The negative sign indicates that pressure increases with a decrease in volume.

$\Rightarrow p = \frac{-Bax}{V}$

⇒ The restoring force acting on the ball, F = p × a

$= \frac{-Ba^2x}{V}$

In simple harmonic motion, the equation for restoring force is:

⇒ F = -kx … (ii)

Where k is the spring constant

Comparing equations (i) and (ii), we get:

$= \frac{Ba^2}{V}$

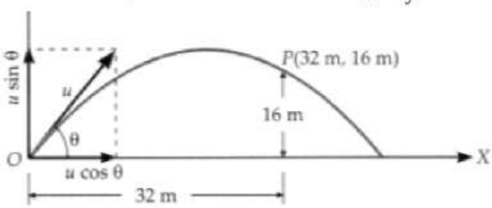
⇒ Time period, $T = 2\pi\sqrt{\frac{m}{k}}$

$= 2\pi\sqrt{\frac{Vm}{Ba^2}}$

32. As shown in figure, if point of projection is taken as the origin of the coordinate system, the projected body must pass through a point having coordinates (32 m, 16 m). If u be the initial velocity of the projectile and $\theta$ the angle of projection, then

Horizontal component of initial velocity, $u_x = u \cos\theta$

Vertical component of initial velocity, $u_y = u \sin\theta$




If the body passes through point P after time t, then horizontal distance covered,

x = (u cos $\theta$)t

or 32 = (24 cos $\theta$)t ..... (i)

Similarly, vertical distance covered,

$y = (u\sin\theta)t - \frac{1}{2}gt^2$

or $16 = (24\sin\theta)t - \frac{1}{2} \times 10 \times t^2$

From equation (i), $t = \frac{32}{24\cos\theta}$

Putting this value of t in equation (ii), we get

$16 = (24\sin\theta)\frac{32}{24\cos\theta} - \frac{1}{2} \times 10 \times \left(\frac{32}{24\cos\theta}\right)^2$

or 16 = 32 $\tan\theta - 5 \times \frac{16}{9\cos^2\theta}$

or $1 = 2\tan\theta - \frac{5}{9}\sec^2\theta$

or $9 = 18\tan\theta - 5(1 + \tan^2\theta)$

or $5\tan^2\theta - 18\tan\theta + 14 = 0$

$\therefore \tan\theta = \frac{18 \pm \sqrt{(18)^2 - 4\times5\times14}}{10}$

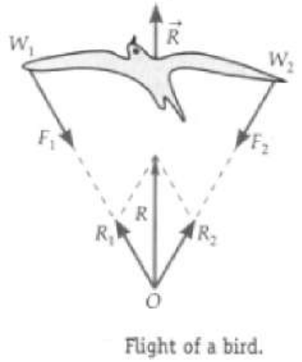
= 2.462 or 1.37

Hence $\theta = 67^o54'$ or $48^o40'$

OR

i. Impulse

ii. Flight of a bird. When a bird flies, it pushes the air with forces $F_1$ and $F_2$ in the downward direction with its wings $W_1$ and $W_2$. The lines of action of these two forces meet at point O. In accordance with Newton's third law of motion, the air exerts equal and opposite reactions $R_1$ and $R_2$. According to the parallelogram law, the resultant R of the reactions $R_1$ and $R_2$ acts on the bird in the upward direction and helps the bird to fly upward.




Flight of a bird.

iii. $v_R$ = 10.8 km h$^{-1}$ = 3 ms$^{-1}$

Given: $\cos 37^\circ = \frac{4}{5} \therefore \tan 37^\circ = \frac{3}{4}$

But $\tan 37^o = \frac{v_R}{v_M}$ or $\frac{3}{4} = \frac{v_R}{3ms^{-1}}$

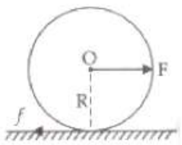
or $v_R = \frac{9}{4}$ = 2.25 ms$^{-1}$

33. Let a = is the linear acceleration of the disc

$\alpha =$ is the angular acceleration of the disc.

For linear motion, using newton second law of motion we get equation :-

$F - f = Ma$ ...(i)




M = mass of the disc. and f = is the force of friction.

force of friction is responsible for torque. But torque due to F is zero as F is along ‘O’.

$\therefore$ Torque to disc $\tau = I_d\alpha$

Moment of inertia of the disc, $I_d = \frac{1}{2}MR^2$

$f \times R = \frac{1}{2}MR^2 \times \frac{a}{R}$

$\because a = R\alpha$

$fR = \frac{1}{2}MRa \Rightarrow Ma = 2f \rightarrow f = \frac{Ma}{2}$ ...(ii)

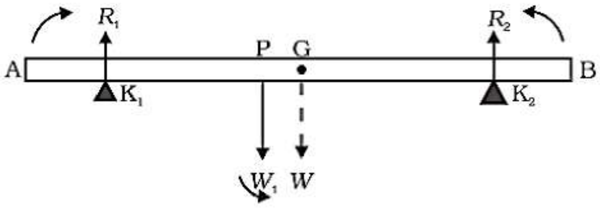
$F - f = 2f \rightarrow F = 3f \rightarrow f = \frac{F}{3}$

$\because N = Mg$

$f = \mu Mg = \frac{F}{3}$ Hence ,

$F = 3\mu Mg$ is the maximum force applied on disc to roll on surface without slipping.

OR




The figure shows the rod AB, the positions of the knife edges $K_1$ and $K_2$, the centre of gravity of the rod at G, and the suspended load at P.

Note the weight of the rod W acts at its centre of gravity G. The rod is uniform in cross-section and homogeneous; hence G is at the centre of the rod; AB = 70 cm. AG = 35 cm, AP = 30 cm, PG = 5 cm, $AK_1 = BK_2$ = 10 cm and $K_1G = K_2G$ = 25 cm. Also,

W = weight of the rod = 4.00 kg and $W_1$= suspended load = 6.00 kg;

$R_1$ and $R_2$ are the normal reactions of the support at the knife edges.

For translational equilibrium of the rod,

$R_1 + R_2 - W_1 - W = 0$ ..... (i)

Note $W_1$ and W act vertically down and $R_1$ and $R_2$ act vertically up.

For considering rotational equilibrium, we take moments of the forces. A convenient point to take moments about is G. The moments of $R_2$ and $W_1$ are anticlockwise (+ve), whereas the moment of $R_1$ is clockwise (-ve).

For rotational equilibrium,

$-R_1(K_1G) + W_1(PG) + R_2(K_2G) = 0$ .... (ii)

It is given that W = 4.00g N and $W_1$ = 6.00g

N, where g = acceleration due to gravity. We take g = 9.8 $m/s^2$.

With numerical values inserted, from (i)

$R_1 + R_2 - 4.00g – 6.00g = 0$

or $R_1 + R_2 = 10.00g$ N ....(iii)

= 98.00 N

From (ii), $-0.25 R_1 + 0.05 W_1 + 0.25 R_2 = 0$

or $R_1 - R_2 = 1.2g$ N = 11.76 N ....(iv)

From (iii) and (iv), $R_1$ = 54.88 N,

$R_2$ = 43.12 N

Thus the reactions of the support are about 55 N at $K_1$ and 43 N at $K_2$.

**Section E**

34. **Read the text carefully and answer the questions:**

The highway police chased down and arrested a man accused of vehicle theft. He was nabbed after a kilometers-long chase while trying to flee with a car stolen from the nearby area. The car had been parked with the key still in the ignition. The owner raised an alarm on seeing his car being driven away. The highway police, who happened to pass through the area then, gave the accused a chase. He then tried to escape after abandoning the car, and the police personnel pursued him. The police van was moving on a highway with a speed of 30 km/h fired a bullet at a thief's car speeding away in the same direction with a speed of 192 km/h. The muzzle speed of the bullet was 150 m/s.


(i) speed = 30 $kmh^{-1}$

$30 \times \frac{5}{18} = \frac{50}{6}$ = 8.3 m/sec

(ii) The resultant speed of bullet = speed of car + speed of bullet

= 150 + 8.33 = 158.33 m/s.

(iii) The speed with which the bullet will hit the thief's car is

= 158.33 - 53.33 = 105 m/s

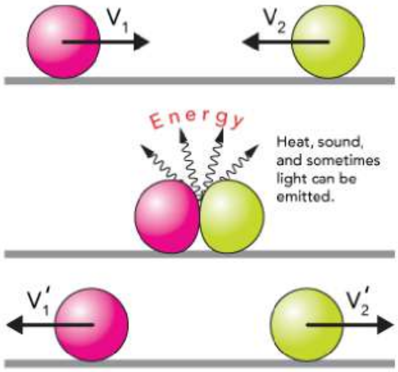
OR

Difference in speed of police van and thief's car =

192 - 30 = 162 km/h = 17.22 m/s

35. **Read the text carefully and answer the questions:**

An **elastic collision** is a **collision** in which there is no net loss in kinetic energy in the system as a result of the **collision**. Both momentum and kinetic energy are conserved quantities in **elastic collisions**.




(i) For a body revolving with constant speed, the momentum changes but kinetic energy remains constant.

(ii) If the bodies stick to each other after collision, then it is an inelastic collision.

(iii) Total momentum becomes zero after the collision.

OR

The relative speed of approach and separation remains same after the collision, so ratio will be 1 : 1.