SAMPLE PAPER - 2

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. Dimensional formula $[ML^{-1}T^{-1}]$ is related to **[1]**

a) Torque
b) Energy
c) Coefficient of viscosity
d) Work

2. The distance covered by a body to come to rest when it is moving with a speed of 4 m s^{-1} is s, when a retarding force F is applied. If the KE is doubled, the distance covered by it to come to rest for the same retarding force F is: **[1]**

a) 8 s
b) 6 s
c) 4 s
d) 2 s

3. The moment of inertia of a solid sphere of density ρ and radius R about its diameter is: **[1]**

a) $\frac{105}{176}R^5\rho$
b) $\frac{176}{105}R^2\rho$
c) $\frac{105}{176}R^2\rho$
d) $\frac{176}{105}R^5\rho$

4. Isobaric modulus of elasticity is equal to: **[1]**

a) infinite
b) isochoric modulus of elasticity
c) zero
d) isothermal modulus of elasticity

5. If the earth is supposed to be a sphere of radius R, g_{30° is the value of acceleration due to gravity at the latitude of 30° and g at the equator, the value of g - g_{30° is: **[1]**

a) $\frac{3}{4}\omega^2 R$
b) $\omega^2 R$

c) $\frac{1}{4}\omega^2 R$

d) $\frac{1}{2}\omega^2 R$

6. Which one of the following is not an assumption of kinetic theory of gases? **[1]**

a) The collision between the molecules is elastic.

b) All molecules have the same speed.

c) The volume occupied by the molecules of the gas is negligible.

d) The force of attraction between the molecules is negligible.

7. For an adiabatic process, **[1]**

a) $\Delta U = 0$

b) $\Delta S = 0$

c) $\Delta Q = 0$

d) W = 0

8. The intensity of a harmonic wave: **[1]**

i. depends on its frequency and not amplitude
ii. depends on its amplitude and not frequency
iii. depends on both its frequency and amplitude
iv. depends neither on frequency nor on its amplitude

a) iv and i

b) only iii

c) i and ii

d) ii and iii

9. Surface tension is phenomenon due to ________ force. **[1]**

i. conservative
ii. non-conservative
iii. short-range
iv. contact

a) (ii), (iii) and (iv)

b) (i), (iii) and (iv)

c) (ii) and (iv)

d) (i) and (iii)

10. What is the distance (in metre) from the Earth, the magnitude of the gravitational force of the Earth and the moon is zero? **[1]**

a) 15.8992×10^8

b) None of these

c) 9.36572×10^8

d) 93.6572×10^8

11. Mass is distributed uniformly over a thin square plate. If two end points of a diagonal are (-2, 0) and (2, 2), what are the co-ordinates of the centre of mass of plate? **[1]**

a) (2, 2)

b) (1, 10)

c) (2, 1)

d) (0, 1)

12. Two balloons are filled, one with pure He gas and the other by air, respectively. If the pressure and temperature of these balloons are the same, then the number of molecules per unit volume is: **[1]**

a) more in air filled balloon

b) in the ratio of 1 : 4

c) same in both balloons

d) more in the He filled balloon

13. A travelling wave is partly reflected and partly transmitted from a rigid boundary. Let a_i, a_r and a_t be the **[1]**

amplitudes of the incident wave, reflected wave and transmitted wave and I_i, I_r and I_t be the corresponding intensities. Then, choose the correct alternative:

a) $\frac{I_r}{I_t} = \left(\frac{a_r}{a_t}\right)^2$

b) $\frac{I_i}{I_r} = \left(\frac{a_i}{a_r}\right)^2$

c) All of these

d) $\frac{I_i}{I_t} = \left(\frac{a_i}{a_t}\right)^2$

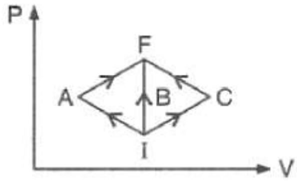
14. In the P - V diagram, I is the initial state and F is the final state. The gas goes from I to F by **[1]**

i. IAF

ii. IBF

iii. ICF

The heat absorbed by the gas is:



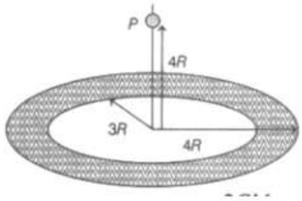
a) greater in (i) than in (ii)

b) the same in (i) and (ii)

c) the same in (i) and (iii)

d) the same in all three processes

15. A thin uniform annular disc {see figure) of mass M has outer radius 4R and inner radius 3R. The work required to take a unit mass from point P on its axis to infinity is **[1]**



a) $\frac{GM}{4R}$

b) $\frac{2GM}{5R}(\sqrt{2}-1)$

c) $\frac{2GM}{7R}(4\sqrt{2}-5)$

d) $-\frac{2GM}{7R}(4\sqrt{2}-5)$

16. **Assertion (A):** The scalar product of two vectors will be zero if angle between them is 180^o. **[1]**

Reason (R): The scalar product of two vectors $\vec{A}$ and $\vec{B}$ is given by $\vec{A} \cdot \vec{B}$ = AB cos θ.

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:** A hollow shaft is found to be stronger than a solid shaft made of same material. **[1]**

Reason: The torque required to produce a given twist in hollow cylinder is greater than that required to twist a solid cylinder of same size and material.

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):** Dimensional analysis is used to check the correctness of an equation. **[1]**

Reason (R): It is done by using the principle of homogeneity.

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. Find the value of 60 J per min on a system that has 100 g, 100 cm and 1 min as the base units. **[2]**

20. A light string passing over a smooth pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $\frac{g}{8}$, find the ratio of the two masses. **[2]**

21. Two bodies of masses M and m (M > m) are allowed to fall freely from the same height. If air resistance for each body is same, which one will reach the ground first. **[2]**

OR

An artificial satellite revolves around the earth at a height of 1000 km. The radius of the earth is 6.38×10^3 km. Mass of the earth is 6×10^{24} kg and G = $6.67 \times 10^{-11} Nm^2kg^{-2}$. Find its orbital velocity and period of revolution.

22. Graphite consists of planes of carbon atoms. Between atoms in the planes there are only weak forces. What kind of elastic properties do you expect from graphite? **[2]**

23. Estimate the volume of a water molecule. Given density of water is 1000 kg m^{-3} and Avogadro's number = 6×10^{23} $mole^{-1}$. **[2]**

OR

If three gas molecules have velocities of 0.5, 1 and 2 kms^{-1} respectively, calculate the ratio of their root mean square speed and the average speed.

24. The acceleration experienced by a boat after the engine is cut-off, is given by $\frac{dv}{dt} = -kv^3$, where k is a constant. If v_0 is the magnitude of the velocity at cut off, find the magnitude of the velocity at time t after the cut-off. **[2]**

25. Why does a cyclist lean to one side, while going along curve? In what direction does he lean? **[2]**

Section C

26. The ends of the two rods of different materials with their thermal conductivities, radii of cross-section and lengths, in the ratio 1:2 are maintained at the same temperature difference. If the rate of flow of heat through the larger rod is 4 cal/s, what is the rate of flow through the shorter rod? **[3]**

27. How is centripetal force provided in case of the following? **[3]**

   i. Motion of planet around the sun,
   ii. Motion of moon around the earth.
   iii. Motion of an electron around the nucleus in an atom.

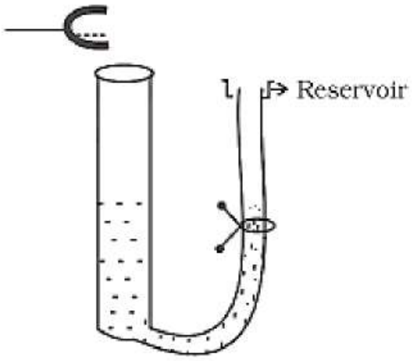
28. With what terminal velocity will an air bubble of density 1 kgm^{-3} and 0.8 mm in diameter rise in a liquid of viscosity 0.15 Nsm^{-2} and specific gravity 0.9? What is the terminal velocity of same bubble in water of $\eta = 1 \times 10^{-3}$ Nsm^{-2}? **[3]**

OR

A vertical off-shore structure is built to withstand a maximum stress of 10^9 Pa. Is the structure suitable for putting up on top of an oil well in the ocean? Take the depth of the ocean to be roughly 3 km, and ignore ocean currents.

29. A tuning fork vibrating with a frequency of 512Hz is kept close to the open end of a tube filled with water (Figure). The water level in the tube is gradually lowered. When the water level is 17cm below the open end, **[3]**

maximum intensity of sound is heard. If the room temperature is 20° C, calculate



a. speed of sound in air at room temperature

b. speed of sound in air at 0° C

c. if the water in the tube is replaced with mercury, will there be any difference in your observations?

OR

Given below are some functions of x and t to represent the displacement of an elastic wave.

i. y = 5 cos (4x) sin (20t)

ii. $y = 4 \sin (5x - \frac{t}{2}) + 3 \cos (5x - \frac{t}{2})$

iii. $y = 10 \cos [(252 - 250) \pi t] \cos [(252 + 250)\pi t]$

iv. $y = 100 \cos (100\pi t + 0.5x)$

State which of these represent

a. a travelling wave along -x direction

b. a stationary wave

c. beats

d. a travelling wave along +x direction.

Given reasons for your answers

30. A steel tape 1m long is correctly calibrated for a temperature of 27.0 °C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0 °C. What is the actual length of the steel rod on that day? What is the length of the same steel rod on a day when the temperature is 27.0 °C? Coefficient of linear expansion of steel = 1.20×10^{-5} K^{-1}. **[3]**

Section D

31. One end of a V-tube containing mercury is connected to a suction pump and the other end to atmosphere. The two arms of the tube are inclined to horizontal at an angle of 45° each. A small pressure difference is created between two columns when the suction pump is removed. Will the column of mercury in V-tube execute simple harmonic motion? Neglect capillary and viscous forces. Find the time period of oscillation. **[5]**

OR

Using the correspondence of S.H.M. and uniform circular motion, find displacement, velocity, amplitude, time period and frequency of a particle executing S.H.M?

32. A hill is 500 m high. Supplies are to be sent across the hill using a canon that can hurl packets at a speed of 125m/s over the hill. The canon is located at a distance of 800 m from the foot of the hill and can be moved on the ground at a speed of 2 m/s; so that its distance from the hill can be adjusted. What is the shortest time in which a packet can reach on the ground across the hill? Take g = 10 m/s^2. **[5]**

OR

a. What is the angle between $\vec{A}$ and $\vec{B}$ if $\vec{A}$ and $\vec{B}$ denote the adjacent sides of a parallelogram drawn form a point and the area of the parallelogram is $\frac{1}{2}AB$?

b. State and prove triangular law of vector addition.

33. a. Prove the theorem of perpendicular axes. **[5]**

(Hint: Square of the distance of a point (x, y) in the x–y plane from an axis through the origin perpendicular to the plane is $x^2 + y^2$).

b. Prove the theorem of parallel axes.

(Hint: If the centre of mass is chosen to be the origin $\sum m_i r_i = 0$).

OR

a. A cat is able to land on its feet after a fall. Why?

b. If angular momentum moment of inertia is decreased, will its rotational K.E. be also conserved? Explain.

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]**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

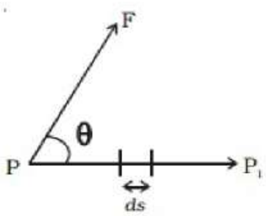


Fig. Work done by a force

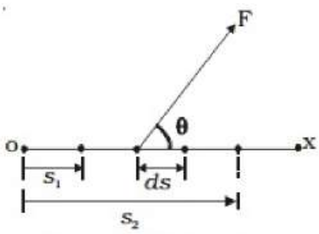


Fig. Work done by a constant force

(i) A box is pushed through 4.0 m across a floor offering 100 N resistance. How much work is done by the applied force?

(ii) What do you mean by non conservative forces, give an example.

(iii) What is the work done to revolve the body with constant speed in a circle?

OR

Force of 4N is applied on a body of mass 20 kg in the direction of motion. What will be the work done in displacing the body through 3 m ?

Solution

SAMPLE PAPER - 2

Class 11 - Physics

Section A

1. **(c)** Coefficient of viscosity
Explanation: Coefficient of viscosity

2. **(d)** 2 s
Explanation: 2 s

3. **(d)** $\frac{176}{105} R^5 \rho$
Explanation: For solid sphere,
$I = \frac{2}{5} MR^2 = \frac{2}{5} \left(\frac{4}{3} \pi R^3 \rho\right) R^2$
$= \frac{8}{15} \times \frac{22}{7} R^5 \rho = \frac{176}{105} R^5 \rho$

4. **(c)** zero
Explanation: B = $-\frac{\Delta p}{\Delta V/V}$
For isobaric process $\Delta p = 0$ so, B = 0

5. **(a)** $\frac{3}{4} \omega^2 R$
Explanation: Acceleration due to gravity at latitude λ is given by:
g' = g - Rω^2 $\cos^2 \lambda$
at 30°, $g_{30°}$ = g - R$\omega^2 \cos^2$ 30° = g - $\frac{3}{4} R\omega^2$
or g - $g_{30°}$ = $\frac{3}{4} \omega^2 R$

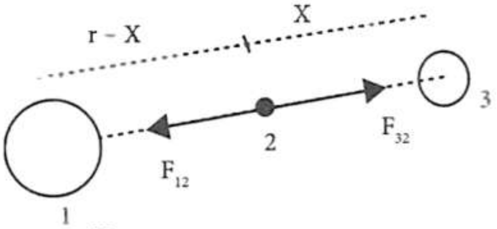
6. **(b)** All molecules have the same speed.
Explanation: Molecules of an ideal gas move randomly at different speeds.

7. **(c)** ΔQ = 0
Explanation: In an adiabatic process, no heat is exchanged between the system and surroundings. Hence total heat of the system remains constant.

8. **(b)** only iii
Explanation: depends on both its frequency and amplitude

9. **(b)** (i), (iii) and (iv)
Explanation: (i), (iii) and (iv)

10. **(c)** 9.36572 $\times$ 10^8
Explanation:
Given that,
Point 1: Earth's mass M = 5.97 $\times$ 10^{24} kg
Point 3: Moon's mass M_m = 7.35 $\times$ 10^{22} kg
The distance between Earth's centre and moon's centre (r) = 3.84 $\times$ 10^8 m
Universal constant (G) = 6.67 $\times$ 10^{-11} N m^2/kg^2



F_{12} = G$\frac{Mm_2}{(r-x)^2}$
F_{32} = G$\frac{m_2 M_m}{x^2}$
Net gravitational force is zero,

$\sum F = 0$

$F_{32} - F_{12} = 0$

$F_{32} = F_{12}$

$F\frac{Mm_2}{x^2} = G\frac{m_2M_m}{(r-x)^2}$

$\frac{M}{x^2} = \frac{M_m}{(r-x)^2}$

$\frac{M}{x^2} = \frac{M_m}{r^2-2rx+x^2}$

$\frac{5.97\times10^{24}}{x^2} = \frac{7.35\times10^{22}}{(3.84\times10^8)^2-2(3.84\times10^8)x+}$

$\frac{5.97\times10^2}{(5.97\times10^2)(14.7\times10^{16}-7.68\times10^8x+x^2)}$

= $(7.35x^2)$

$(87.76 \times 10^{18}) - (45.85 \times 10^{10})$

$(5.97 \times 10^2 - 7.35)x^2 = 0$

$(87.76 \times 10^{18}) - (45.85 \times 10^{10})x + 589.65\ x^2$

= 0

Use quadratic formula,

q = 589.65

$b = -45.85 \times 10^{10}$

$c = 87.76 \times 10^{18}$

$x_{1,2} = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$

$x_{1,2} = \frac{45.85\times10^{10}}{2(589.65)} \pm \frac{\sqrt{(-45.85\times10^{10})^2+4(589.65)(87.76\times10^{18})}}{2(589.65)}$

$x_{1,2} = \frac{45.85\times10^{10}\pm\sqrt{2102.22\times10^{20}+2069.90\times10^{24}}}{1179.3}$

$x_{1,2} = \frac{45.85\times10^{10}\pm64.60\times10^{10}}{1179.3}$

First root,

$x_1 = \frac{(45.85+64.60)\times10^{10}}{1179.3}$

$= 0.0936572 \times 10^{10}$

$= 9.36572 \times 10^8$

11. **(d)** (0, 1)

Explanation: We know that for a square plate, the centre of mass lies at the point of intersection of diagonals. Moreover we also know that the two diagonals of a square bisect each other.

∴ Co-ordinates of the centre of mass

$= \left(\frac{x_1+x_2}{2}, \frac{y_1+y_2}{2}\right) = \left(\frac{-2+2}{2}, \frac{0+2}{2}\right) = (0, 1)$

12. **(c)** same in both balloons

Explanation: Assuming the balloons have the same volume, as PV = nRT, if P, V and T are the same, n, the number of moles present will be the same, whether it is He or air. Hence, the number of molecules per unit volume will be the same in both the balloons.

13. **(b)** $\frac{I_i}{I_r} = \left(\frac{a_i}{a_r}\right)^2$

Explanation: $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2$ only when other properties like the density of medium, speed of wave, etc. remains the same ($I = \frac{1}{2}\rho v\omega^2 a^2$). In incident and reflected waves, medium is the same. Therefore, other properties are the same. Hence, $\frac{I_i}{I_r} = \left(\frac{a_i}{a_r}\right)^2$

14. **(a)** greater in (i) than in (ii)

Explanation: Heat absorbed in a thermodynamic process is given by:

$\Delta Q = \Delta U + \Delta W$

Here, ΔU is same for all the three processes as it depends only on initial and final states.

But ΔW_I = + ve, $\Delta W_{II} = 0$

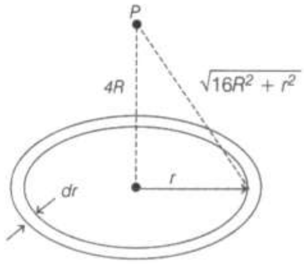
and ΔW_{III} = - ve

or $\Delta Q_{\text{I}} > \Delta Q_{\text{II}}$

15. **(c)** $\frac{2GM}{7R}(4\sqrt{2}-5)$

Explanation:

W = ΔU = U_f - U_i = U_∞ - U_p = $-U_p$ = $-mV_p$ = $-V_p$ (as m = 1)



Potential at point P will be obtained by integration as given below.

Let dM be the mass of small ring as shown

$dM = \frac{M}{\pi(4R)^2-\pi(3R)^2}(2\pi r)dr = \frac{2Mrdr}{7R^2}$

$dV_p = -\frac{GdM}{\sqrt{16R^2+r^2}}$

$= -\frac{2GM}{7R^2}\int_{3R}^{4R}\frac{r}{\sqrt{16R^2+r^2}}dr$

$= -\frac{2GM}{7R}(4\sqrt{2}-5)$

$\therefore$ W = + $\frac{2GM}{7R}(4\sqrt{2}-5)$

16. **(d)** A is false but R is true.

Explanation: If angle between two vectors is 180°, then their scalar product $\vec{A}\cdot\vec{B}$ = AB cos 180° = -AB. It will be zero, if angle between vector is 90°.

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

Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

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

Explanation: The principle of homogeneity states that the dimensions of each of the terms of a dimensional equation on both sides should be the same.

Dimensions of R.H.S and L.H.S. of the given equation are verified whether they are the same or not.

If they are the same then only the equation is correct. So, assertion and reason both are true and the reason explains the assertion.

Section B

19. We are given that, P = $\frac{60\text{ joule}}{1\text{min}} = \frac{60\text{ joule}}{60\ s}$ = 1 watt

which is the SI unit of power.

Also the dimensional formula of power = $[ML^2T^{-3}]$

SI	New System
$n_1 = 1$	n_2 = ?
M_1 = 1 kg = 1000 g	M_2 = 10 g
L_1 = 1 m = 100 cm	L_2 = 100 cm
T_1 = 1 s	T_2 = 1 min = 60 s

Using the formula $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$, we have

$n_2 = 1\left[\frac{1000}{100}\right]^{-1}\left[\frac{100}{100}\right]^{-2}\left[\frac{1}{60}\right]^{-3}$

$= 2.16 \times 10^6$

Therefore, 60 J min^{-1} = 2.16×10^6

That is the value of 60 J per minute in new units of power.

20. As $a=\frac{m_1-m_2}{m_1+m_2}g \therefore \frac{g}{8}=\frac{m_1-m_2}{m_1+m_2}g$

or $\frac{m_1-m_2}{m_1+m_2}=\frac{1}{8}$

or $\frac{(m_1+m_2)+(m_1-m_2)}{(m_1+m_2)-(m_1-m_2)}=\frac{8+1}{8-1}$

or $\frac{m_1}{m_2}=\frac{9}{7}$ = 9 : 7.

21. The heavier body of mass M will reach the ground first.

Let F be the air resistance on each body.

Net downward force on mass M = Mg - F

$\therefore$ Acceleration, a = $\frac{Mg-F}{M}$

Similarly, acceleration of mass m, $a'=\frac{mg-F}{m}$

As M > m, so a > a'

OR

Here: h = 1000 km 10^6m, R = 6.38 $\times$ 10^3 km = 6.38 $\times$ 10^6 m

$\therefore$ R + h = 7.38 $\times$ 10^6 m, M = 6 $\times$ 10^{24} kg

Orbital velocity,

$v_0=\sqrt{\frac{GM}{R+h}}=\sqrt{\frac{6.67\times10^{-11}\times6\times10^{24}}{7.38\times10^6}}$

= 7364 ms^{-1}

Period of revolution,

T = $\frac{2\pi(R+h)}{v_0}=\frac{2\pi\times7.38\times10^6}{7364}$ = 6297 s

22. Due to weak attractive forces between carbon atoms of different planes, it is easier to produce a large shearing strain by moving one plane of atoms over the other with the application of small tangential stress. Now,

Modulus of rigidity, $\eta=\frac{\text{Tangential stress}}{\text{Shear strain}}$

Hence graphite should possess a small modulus of rigidity.

23. Molecular mass of water = 18

$\therefore$ Number of molecules in 18 g or 0.018 kg of water

= 6 $\times$ 10^{23}

Mass of 1 molecule of water

$=\frac{0.018}{6\times10^{23}}$ = 3 $\times$ 10^{-26} kg

In the liquid phase, the molecules of water are closely packed. The density of water molecules may be taken equal to the density of bulk water = 1000 kg m^{-3}.

$\therefore$ The volume of a water molecule

$=\frac{\text{Mass}}{\text{Density}}=\frac{3\times10^{-26}}{1000}$ = 3 $\times$ 10^{-29} m^3.

OR

Root mean square speed,

$v_{rms}=\sqrt{\frac{(0.5)^2+1^2+2^2}{3}}=\sqrt{\frac{5.25}{3}}=\sqrt{1.75}$

= 1.3229 kms^{-1}

Average speed,

$\bar{v}=\frac{0.5+1+2}{3}=\frac{3.5}{3}$ = 1.1666 kms^{-1}

Ratio, $\frac{v_{rms}}{\bar{v}}=\frac{1.3229}{1.1666}$ = 1.13.

24. Given: $\frac{dv}{dt}$ = $-kv^3$, or v^{-3} dv = - kdt

Integrating within the conditions of motion,

$\int_0^v v^{-3}dv=-k\int_0^t dt$

or $\left[\frac{v^{-2}}{-2}\right]_{v_0}^{v}=-k[t]_0^t$

or $-\frac{1}{2}\left[\frac{1}{v^2}-\frac{1}{v_0^2}\right]$ = -k[t - 0]

or $\frac{1}{v^2}-\frac{1}{v_0^2}$ = 2 kt or $\frac{1}{v^2}=\frac{1}{v_0^2}+2kt=\frac{1+2ktv_0^2}{v_0^2}$

or v = $\frac{v_0}{\sqrt{1+2ktv_0^2}}$

25. A cyclist leans while going along curve because a component of normal reaction of the ground provides him the centripetal force he requires for turning. He has to lean inwards from his vertical position i.e. towards the centre of the circular path.

Section C

26. K_1 = thermal conductivity of first rod

K_2 = thermal conductivity of second rod

r_1 = radius of cross-section of first rod

r_2 = radius of cross-section of second rod

l_1 = length of first rod

l_2 = length of second rod

θ_1 = heat flow through first rod

θ_2 = heat flow through second rod

Now, $\frac{K_1}{K_2}=\frac{1}{2}$ (given)

Also, $\frac{r_1}{r_2}=\frac{1}{2}$ and $\frac{l_1}{l_2}=\frac{1}{2}(\text{ Given })$

and $\frac{\theta_2}{t}$ = rate of flow of heat through the second rod

$\frac{\theta_2}{t}=4\ cal/sec$ (given)

$\theta_1-\theta_2$ = Same.

Now, we know, $\frac{\theta}{t}=\frac{KA(\theta_1-\theta_2)}{x}$ (from the defination of thermal conductivity of a material)

$\frac{\theta}{t}=\frac{K\pi r^2(\theta_1-\theta_2)}{r}$ ...(i) (cross-sectional area, A = πr^2)

So, Let

$\theta_1=T_1$ and

$\theta_2=T_2$

$\therefore\frac{\theta_1}{t_1}=\frac{K_1\pi r_1^2(T_1-T_2)}{l_1}$ ....(i)

And $\frac{\theta_2}{t_2}=\frac{K_2\pi r_2^2(T_1-T_2)}{l_2}$ ...(ii)

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

$\frac{\theta_1}{t_1}\times\frac{t_2}{\theta_2}=\frac{K_1(\pi r_1^2)(\theta_1-\theta_2)}{K_2(\pi r_2^2)(\theta_1-\theta_2)}\times\frac{l_2}{l_1}$

Since

$\frac{\theta_2}{t_2}=4,\frac{t_2}{\theta_2}=\frac{1}{4};\ and\ \frac{r_1}{r_2}=\frac{1}{2},\therefore\left(\frac{r_1}{r_2}\right)^2=\frac{1}{4}$

Again $\frac{l_1}{l_2}=\frac{1}{2};\frac{l_2}{l_1}=\frac{2}{1}$

Now putting all the above values we get, $\frac{\theta_1}{t_1}\times\frac{1}{4}=\frac{1}{2}\times\left(\frac{1}{2}\right)^2\times\left(\frac{1}{2}\right)$

$\Rightarrow\frac{\theta_1}{t_1}\times\frac{1}{4}=\frac{1}{2}\times\frac{1}{4}\times 2$

$\therefore\frac{\theta_1}{t_1}=1\ cal/sec$

27. i. The earth revolves round the sun.The earth is also acted upon by the centripetal force which is provided by the gravitational force of attraction between the sun and the earth.
    ii. The motion of moon around the earth is also in circular path.The necessary centripetal force is provided by the gravitational attraction of the earth on the moon.
    iii. In an atom,electrons revolve around the nucleus in various circular orbits.The necessary centripetal force for circular motion, is exerted by the electrostatic force of attraction between the positively-charged nucleus and the negatively charged electrons.

28. given that,

Here r = $\frac{0.8}{2}$ = 0.4 mm = 0.4 $\times$ 10^{-3} m, η = 0.15 Ns/m^2, g = 9.8 m/s^2

Specific gravity of the liquid = 0.9

Density of liquid (given medium),

ρ' = 0.9 $\times$ 10^3 kg m^{-3} = 900 kg m^{-3}

Density of air bubble (spherical object),

ρ = 1 kg m^{-3}

Terminal velocity of air bubble,

$v = \frac{2r^2 g(\rho-\rho')}{9\eta} = \frac{2\times(0.4\times10^{-3})^2\times9.8\times(1-900)}{9\times0.15}$

= -0.0021 ms^{-1}

The negative sign shows that the air bubble will rise up.

Terminal velocity of air bubble in water :

Here ρ' = 1000 kg m^{-3}, η = 10^{-3} Nsm^{-2}

$\therefore v = \frac{2\times(0.4\times10^{-3})^2\times9.8\times(1-1000)}{9\times10^{-3}}$

= -0.348 ms^{-1}

OR

The maximum allowable stress for the structure is, P = 10^9 Pa

Depth of the ocean is given by, d = 3 km= 3 $\times$ 10^3 m

Density of water is given by, ρ = 10^3 $\frac{kg}{m^3}$

Acceleration due to gravity is, g = 9.8 $\frac{m}{s^2}$

The pressure exerted at depth , d = ρdg

= 3 $\times$ 10^3 $\times$ 10^3 $\times$ 9.8

= 2.94 $\times$ 10^7 Pa

The maximum allowable stress for the structure (10^9 Pa) is greater than the pressure of the sea water (2.94 $\times$ 10^7 Pa). The pressure exerted by the ocean is less than the pressure that the structure can withstand. Hence, the structure is suitable for putting up on top of an oil well in the ocean.

29. If a pipe partially filled with water whose upper surface of the water acts as a reflecting surface of a closed organ pipe. If the length of the air column is varied until its natural frequency equals the frequency of the fork, then the column resonates and emits a loud note.

The frequency of tuning fork, f = 512 Hz

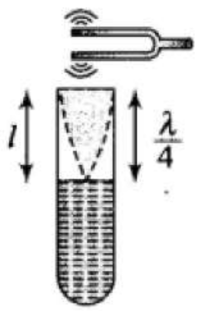
For observation of first maxima of intensity,

a. For the first maxima of intensity, the length of the air column

$l = \frac{\lambda}{4} \Rightarrow \lambda = 4l = 4 \times 17 \times 10^{-2}$m

Hence the speed of sound $v = f\lambda = 512 \times (4 \times 17 \times 10^{-2})$

= 348.16 m/s



b. We know that $v \propto \sqrt{T}$

Where temperature (T) is in kelvin.

$\frac{v_{20}}{v_0} = \sqrt{\frac{273+20}{273+0}} = \sqrt{\frac{293}{273}}$

$\frac{v_{20}}{v_0} = \sqrt{1.073} = 1.03$

$v_0 = \frac{v_{20}}{1.03} = \frac{348.16}{1.03} = 338\text{m/s}$

c. The resonance will still be observed for 17 cm length of air column above mercury. However, due to more complete reflection of sound waves at the mercury surface, the intensity of reflected sound increases.

OR

The four given equations are:

i. y = 5cos4x sin20t

ii. y = 4 sin (5x - $\frac{t}{2}$) + 3 cos (5x - $\frac{t}{2}$)

iii. y = 10cos(252 − 250)πtcos(252 + 250)πt

iv. y = 100 cos (100 πt + 0.5 x)

From the basic concepts, we know

a. Eqn. (iv) represents a wave travelling along -x direction.

b. Eqn. (i) represents a stationary wave as terms containing x and t are independent.

c. Eqn. (iii) represents beats involving sum and difference of two frequencies 252 and 250.

d. Eqn. (ii) represents a wave travelling along +x direction.

30. Here,

Length of steel tape at 27°C (L_0) = 1m or 100 cm

temperature Change(ΔT) = 45° - 27° = 18°C

Coefficient of linear expansion of steel (a) = 1.2 × 10^{-5} /°C

Length of steel tape at 45°C ,

Use expansion formula,

$L = L_o(1 + a\,\Delta\,T)$

= 100(1 + 1.2 × 10^{-5} × 18)

= 100 (1.000216)

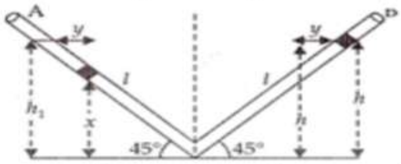
= 100.0216 cm

So, length of 1 cm at 45°C = 100.0216/100 = 1.000216 cm

So, length of 63cm at 45°C = 1.000216 × 63 = 63.0136 cm.

Section D

31. L et the liquid column in both arms of the V-tube were at h_0 heights initially. Now due to pressure difference the liquid columns in A arm is pressed by x and in arm B is liftted by x (so difference in vertical height between two levels $= 2x$) Consider an element of liquid of height dx inside the tube.



Then its dm = volume × density = A .dxρ(where, A =area of cross-section of tube, ρ = density of the liquid inside the tube)

Potential energy of the right arm with dm elementary mass column = (dm) gh

Potential energy of dm elementary mass in left arm column $= A\rho gxdx$ (putting the value of dm = $A.dx.\rho$ and h = x)

$\therefore$Total potential energy in left column $= \int_0^{h_1} A\rho gxdx = A\rho g\left[\frac{x^2}{2}\right]_0^{h_1}$

$= A\rho g\frac{h_1^2}{2}$

From above given figure $\sin 45^\circ = \frac{h_1}{l}$ $\therefore h_1 = h_2 = l\sin 45^\circ = \frac{l}{\sqrt{2}}$

$\therefore h_1^2 = h_2^2 = \frac{l^2}{2}$

$\therefore$ Potential energy in the left column = $A\rho g\frac{l^2}{4}$

Similarly potential energy in right column= $A\rho g\frac{l^2}{4}$

$\therefore$ Total potential energy $= A\rho g\frac{l^2}{4} + A\rho g\frac{l^2}{4} = \frac{A\rho gl^2}{2}$

Due to pressure difference, left element moves towards right side by 'y' units and the same element rises in the right arm by 'y' units.

Then the liquid column length in the left arm becomes by decreasing = (l - y)

And the liquid column length in the right arm becomes by increasing = (l + y)

Now decreased potential energy of liquid column in the left arm $= A\rho g(l-y)^2\sin^2 45^\circ$

Similarly increased potential energy of liquid column in the right arm $= A\rho g(l+y)^2\sin^2 45^\circ$

$\therefore$ Total potential energy due to two liquid columns in the left and right arm respectively $= A\rho g\left(\frac{1}{\sqrt{2}}\right)^2\left[(l-y)^2 + (l+y)^2\right]$

Final potential energy due to difference in liquid columns in the two arms,

$= \frac{A\rho g}{2}\left[l^2 + y^2 - 2ly + l^2 + y^2 + 2ly\right]$

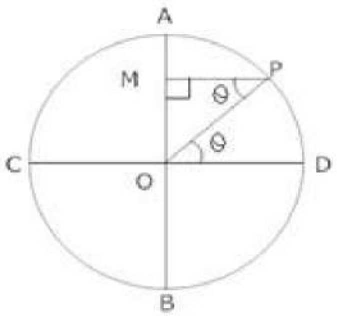
$\therefore$ Final potential energy $= \frac{A\rho g}{2}\left(2l^2 + 2y^2\right)$

Now change in potential energy = Final potential energy due to liquid columns in the two arms– Initial potential energy due to liquid columns in the two arms

$= \frac{A\rho g}{2}\left(2l^2+2y^2\right)-\frac{A\rho g l^2}{2}$
$= \frac{A\rho g}{2}\left[2l^2+2y^2-l^2\right]$
$\therefore$ Change in potential energy = $\frac{A\rho g}{2}\left(l^2+2y^2\right)$
If change in velocity (v) of total liquid column be v then change in kinetic energy,
$\Delta KE=\frac{1}{2}mv^2$
Again m = volume $\times$ density = (A.2l) ρ
$\therefore \Delta KE=\frac{1}{2}(A2l\rho)v^2=A\rho l v^2$
$\therefore$ Change in Total energy = change in potential energy + change in kinetic energy $=\frac{A\rho g}{2}\left(l^2+2y^2\right)+A\rho l v^2$
Again, from the law of conservation of energy, total change in energy $\Delta PE+\Delta KE=0$
$\therefore \frac{A\rho g}{2}\left[l^2+2y^2\right]+A\rho l v^2=0$
$\therefore \frac{A\rho}{2}\left[g\left(l^2+2y^2\right)+2lv^2\right]=0$
$\because \frac{A\rho}{2}\neq 0$
$\therefore g\left(l^2+2y^2\right)+2lv^2=0$
Differentiating on both sides of the above equation with respect to time,t we get $g\left[0+2\times 2y\frac{dy}{dt}\right]+2l.2v\cdot\frac{dv}{dt}=0$
$\therefore 4gy\frac{dy}{dt}+4vl\frac{d^2y}{dt^2}=0\ \left[\because a=\frac{dv}{dt}=\frac{d^2y}{dt^2}\right]$
$\Rightarrow 4gy\cdot v+4vl\frac{d^2y}{dt^2}=0\Rightarrow 4v\left[gy+l\cdot\frac{d^2y}{dt^2}\right]=0$
$\Rightarrow \frac{d^2y}{dt^2}+\frac{g}{l}y=0 \quad \because 4v\neq 0$ ....(i)
It is the equation of a simple harmonic motion and can be compared with the standard equation of a simple harmonic motion i.e.
$\frac{d^2y}{dt^2}+\omega^2y=0$ .....(ii) [ω is the angular acceleration or angular frequency of the particle executing simple harmonic motion]
Comparing the above two equations (i) and (ii) we get, $\therefore \omega^2=\frac{g}{l}$
$\therefore \frac{2\pi}{T}=\sqrt{\frac{g}{l}}\Rightarrow T=2\pi\sqrt{\frac{l}{g}}$ [$\because \omega=\frac{2\pi}{T}$, T being time period of the simple harmonic motion]

OR

If initially at t = 0 particle was at D
Then at time t Particle is at point P



i. Then draw a perpendicular From P on AB,
   If the displacement OM = Y
   Ratios of circle of reference = Amplitude = a
   then In ΔOMP, $\angle$POD = $\angle$OPM = θ ($\because$ Alternate Angles)
   $sin\theta=\frac{OM}{OP}$
   $\Rightarrow \sin\theta=\frac{y}{a}$, 'a' being radius of the above circle.
   $\Rightarrow y=a\sin\theta$
   Again $\theta=\omega t$
   So, $y=a\sin\omega t$
ii. Velocity, $v=\frac{dy}{dt}$
   $\Rightarrow v=\frac{d}{dt}(\mathrm{a}\sin\omega\mathrm{t})$
   $\Rightarrow v=a\omega\cos\omega t$
   again $\cos\theta=\sqrt{1-\sin^2\theta}$
   So, $v=a\omega\times\ \sqrt{1-\sin^2\omega t}$
   From equation of displacement : $\sin\omega t=\frac{y}{a}$

So, $v = a\omega \times \sqrt{1 - \frac{y^2}{a^2}}$

$\Rightarrow v = aw\sqrt{\frac{a^2 - y^2}{a^2}}$

$v = \omega\sqrt{a^2 - y^2}$

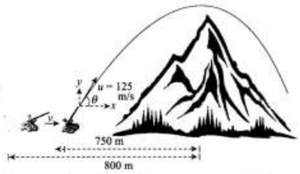
iii. Acceleration : $f = \frac{dv}{dt}$

$\Rightarrow f = a\omega \times \omega(-\sin\omega t)$

$\Rightarrow f = -\omega^2 a \sin\omega t \Rightarrow f = -\omega^2 y$

iv. $\text{Time Period}, T = \frac{2\pi}{\omega}$

v. $freuency = \frac{1}{\text{T}} = \frac{\omega}{2\pi}$

32. 

Speed of packets, u = 125 m/s

Height of hill, h = 500 m

For a packet to cross the hill the vertical components of the speed of packet (125 ms^{-1}) must be minimized so that it can attain a height of 500 m and the distance between hill and cannon must be half the range of packet.

$v^2 = u^2 + 2gh$

$0 = u_y^2 - 2gh$

$u_y = \sqrt{2gh} = \sqrt{2 \times 10 \times 500} = \sqrt{10000}$

$u_y = 100m/s$

$u^2 = u_x^2 + u_y^2$

$(125)^2 = u_x^2 + 100^2 \Rightarrow u_x^2 = 125^2 - 100^2$

$u_x^2 = (125 - 100)(125 + 100) = 25 \times 225$

$u_x = 5 \times 15 \Rightarrow [u_x = 75m/s]$

Vertical motion of packet

$v_y = u_y + gt$

0 = 100 - 10 t

Total time to reach the top of hill, t = 10 s

$\therefore$ Total time of flight = 2 $\times$ 10 = 20 s

So the canon must be at $= u_x \times 10 = 75 \times 10m = 750m$

Hence, the distance between hill and canon = 750 m

So the distance to which canon must move toward the hill = 800 - 750 = 50 m

Time taken to move canon in 50 m = $\frac{distance}{speed} = \frac{50}{2} = 25sec$

Hence, the total time taken by packet from 800 m away from hill to reach other side,

$T_{\text{total}} = 25s + 10s + 10s$ = 45 Seconds.

OR

a. Area of a parallelogram $= |\vec{A} \times \vec{B}|$ = $AB\sin\theta$ ($\because$ Applying cross product)

Given, area of parallelogram $= \frac{1}{2}AB$

So, $\frac{1}{2}AB = AB\sin\theta$

$\frac{1}{2} = \sin\theta$

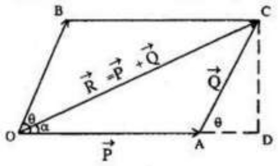
$\theta = \sin^{-1}\left(\frac{1}{2}\right)$

$\theta = 30^\circ$

b. Triangular law of vector addition states that if two vectors can be represented both in magnitude and direction by the sides of a triangle taken in order then their resultant is given by the third side of the triangle taken in opposite order.

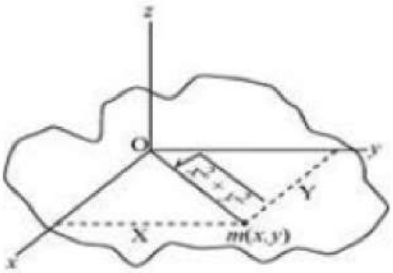
Proof: in $\triangle$ADC

$(OC)^2 = (OD)^2 + (DC)^2$



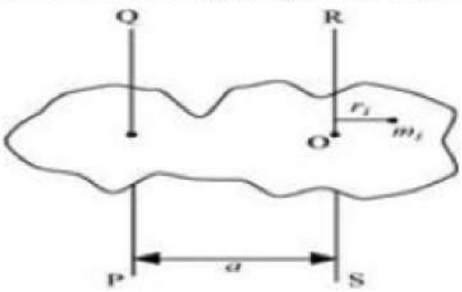
$(OC)^2 = (OA + AD)^2 + (DC)^2$
$(OC)^2 = (OA)^2 + (AD)^2 + 2(OA)(AD) + (DC)^2$
$(OC)^2 = (P^2) + (Q\cos\theta)2 + 2(P)(Q\cos\theta) + (Q\sin\theta)^2$
$(OC)^2 = P^2 + Q^2(\sin^2\theta + \cos^2\theta) + 2PQ\cos\theta \quad \left(\because \frac{CD}{AC} = \sin(\theta),\ \frac{AD}{AC} = \cos(\theta)\right)$
$(R)^2 = P^2 + Q + 2PQ\cos\theta\,(\because \sin^2\theta + \cos^2 Q)$
$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

33. a. This theorem is applicable only to the planar bodies. Bodies which are flat with very less or negligible thickness. This theorem states that the moment of inertia of a planar body about an axis perpendicular to its plane is equal to the sum of its moments of inertia about two perpendicular axes concurrent with the perpendicular axis and lying in the plane of the body.
A physical body with centre O and a point mass *m*, in the x – y plane at (x, y) is shown in the following figure:



Moment of inertia about *x*-axis, $I_x = mx^2$
Moment of inertia about *y*-axis, $I_y = my^2$
Moment of inertia about *z*-axis, $I_z = m\left(\sqrt{x^2 + y^2}\right)^2$
Now, $I_x + I_y = mx^2 + my^2$
$= m(x^2 + y^2)$
$= m\left(\sqrt{x^2 + y^2}\right)^2$
$I_x + I_y = I_z$
Hence, the theorem is proved.

b. Parallel axis theorem is applicable to bodies of any shape. The theorem of parallel axis states that the moment of inertia of a body about an axis parallel to an axis passing through the centre of mass is equal to the sum of the moment of inertia of body about an axis passing through centre of mass and product of mass and square of the distance between the two axes.



Suppose a rigid body is made up of *n* particles, having masses $m_1, m_2, m_3 = \ldots, m_n$ at perpendicular distances $r_1, r_2, r_3, \ldots, r_n$ respectively from the centre of mass O of the rigid body.
The moment of inertia about axis RS passing through the point O:
$I_{RS} = \sum_{i=1}^{n} m_i r_i^2$
The perpendicular distance of mass m_i, from the axis $QP = a + ri$
Hence, the moment of inertia about axis QP :
$I_{QP} = \sum_{i=1}^{n} m_i (a + r_i)^2$
$= \sum_{i=1}^{n} m_i \left(a^2 + r_i^2 + 2ar_i\right)$

$= \sum_{i=1}^{n} m_i {r_i}^2 + \sum_{i=1}^{n} m_i a^2 + \sum_{i=1}^{n} m_i 2ar_i$

$= I_{RS} + \sum_{i=1}^{n} m_i a^2 + 2\sum_{i=1}^{n} m_i ar_i$

At the centre of mass, the moment of inertia of all the particles about the axis passing through the centre of mass is zero,

$\Rightarrow 2\sum_{i=1}^{n} m_i ar_i = 0$

$\because$ a $\neq 0$

$\Rightarrow \sum_{i=1}^{n} m_i r_i = 0$

Also,

$\sum_{i=1}^{n} m_i = M = \text{Total mass of the rigid body}$

$\therefore I_{QP} = I_{RS} + Ma^2$

Hence, the theorem is proved.

OR

a. When cat lands on the ground, it stretches its tail as a result its moment of inertia increases
   As $I\omega$ = constant (In the absence of external torque,angular momentum of the system remains constant)
   $\therefore$ Angular speed will be small due to increase in moment of inertia and the cat is able to land on its feet without any harm as it provides enough time for cat to land on the ground.
b. Let moment of inertia of a system decrease from I to I'
   Then angular speed increase from ω to ω'
   $\Rightarrow I\omega = I'\omega'$ ($\because I\omega$ = constant because in the absence of external torque angular momentum of the system remains conserved)
   $\omega' = \frac{I\omega}{I'}$
   Kinetic Energy of rotation of the system
   $KE = \frac{1}{2}I'\omega'^2$
   $KE = \frac{1}{2}I'\left(\frac{I\omega}{I'}\right)^2$
   $\text{K.E} = \frac{1}{2}\frac{\text{I}^2\omega^2}{\text{I}'}$
   As I' < I
   $\therefore$ Kinetic Energy of the system has increased which means it will not remain constant.

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:**

In everyday life, the term work is used to refer to any form of activity that requires the exertion of mental or muscular efforts. In physics, work is said to be done by a force or against the direction of the force, when the point of application of the force moves towards or against the direction of the force. If no displacement takes place, no work is said to be done.

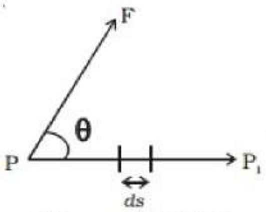


Fig. Work done by a force

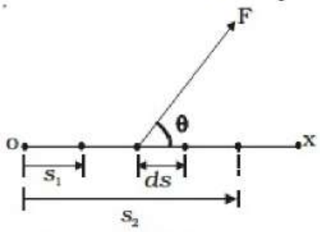


Fig. Work done by a constant force

(i) Force required in the direction of motion = -resistance force = 100 N

Work done = Force and distance = 100×4 = 400 Joule

(ii) Those forces in which the work done depends on the nature of path followed are non conservative forces, example frictional forces.

(iii)Work done will be zero, because in this case the centripetal force acting on the body will be at right angle to the direction of motion, so work done will be zero.

OR

W = FS

F = 4 N

S = 3 m

W = 12 Nm = 12 J