SAMPLE PAPER - 1

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. Consider a new system of measurement in which the unit of mass is 1 kg, the unit of length is 100 km and the unit of time is 10 s. In this new system, the unit of pressure is called lacsap. How many pascal are contained in one lacsap? **[1]**

   a) 10^7 b) 10^3

   c) 10^{-3} d) 10^{-7}

2. Which of the following is non-conservative force? **[1]**

   a) Viscous force b) Electrostatic force

   c) Interatomic force d) Gravitational force

3. A solid sphere rolling on a surface has total kinetic energy given by: **[1]**

   a) $\frac{7}{10}mv^2$ b) $\frac{1}{2}mv^2$

   c) $\frac{3}{10}mv^2$ d) $\frac{7}{5}mv^2$

4. A 5 m aluminium wire ($7 = 7 \times 10^{10} N/m^2$) of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in a copper wire ($7 = 12 \times 10^{10} N/m^2$), of the same length under the same weight, the diameter should be (in mm): **[1]**

   a) 1.75 b) 2.3

   c) 5.0 d) 2.0

5. Suppose g_e be the acceleration due to gravity at the equator and g_p be that at the poles. Assuming the earth to be **[1]**

a sphere of radius R_e rotating about its own axis with angular speed ω, then (g_p - g_e) is given by:

a) $\frac{\omega^2}{R_e^2}$

b) $R_e\omega^2$

c) $\omega^2 R_e^2$

d) $\frac{\omega^2}{R_e}$

6. An ideal gas is expanding such that pT^2 = constant. The coefficient of volume expansion of the gas is **[1]**

a) $\frac{3}{T}$

b) $\frac{2}{T}$

c) $\frac{4}{T}$

d) $\frac{1}{T}$

7. Which of the following statements is correct? **[1]**

a) None of these

b) Total heat of the universe is conserved

c) A thermometer should have a small thermal capacity

d) Atmospheric temperature in cities on the sea-coast changes very much

8. Two sources are at a finite distance apart. They emit sounds of wavelength λ, An observer situated between them on the line joining the sources approaches one source with speed v. Then, the number of beats heard/sec by the observer will be: **[1]**

a) $\frac{\lambda}{2v}$

b) $\frac{2v}{\lambda}$

c) $\frac{v}{\lambda}$

d) $\frac{\lambda}{v}$

9. If W is the amount of work done in forming a soap bubble of volume V, then the amount of work done in forming a bubble of volume 8V from the same solution will be **[1]**

a) 2W

b) 4W

c) 8W

d) $\frac{W}{8}$

10. If the radius of orbit of a satellite is changed by a factor of 4, then the time period is changed by a factor of: **[1]**

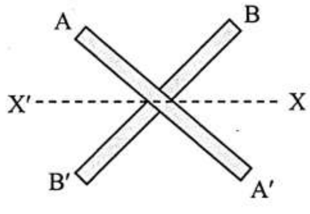
a) 6

b) 4

c) 8

d) None of these

11. AA' and BB' are two identical rods each of mass M and length L. They are joined to form a cross as shown in the figure. The moment of inertia of the cross about a bisector axis (XX') is **[1]**



a) $\frac{ML^2}{12}$

b) $\frac{ML^2}{3}$

c) $2ML^2$

d) $\frac{ML^2}{6}$

12. A given volume of air at 17° C exerts a pressure of 870 mm of mercury. The temperature at which the pressure becomes 1800 mm of Hg is: **[1]**

a) 400 K

b) 500 K

c) 600 K

d) 300 K

13. A steel rod 100 cm long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod is given to be 2.53 kHz. What is the speed of sound in steel? **[1]**

a) 7.06 km/s

b) 6.06 km/s

c) 5.06 km/s

d) 8.06 km/s

14. Consider two containers A and B containing identical gases at the same pressure, volume and temperature. The gas in container A is compressed to half of its original volume isothermally while the gas in container B is compressed to half of its original value adiabatically. The ratio of final pressure of the gas in B to that of gas in A is: [1]

a) $\left(\frac{1}{2}\right)^{\gamma-1}$

b) $\left(\frac{1}{1+\gamma}\right)^2$

c) $2^{\gamma-1}$

d) $\left(\frac{1}{1-\gamma}\right)^2$

15. A satellite of mass **m** is revolving in circular orbit of radius **r** round the earth. Its angular momentum w.r.t. the centre of its orbit is (M = mass of earth, G = universal gravitational constant) [1]

a) $(\mathrm{GMmr})^{\frac{1}{2}}$

b) $(GMm^2r^2)^{\frac{1}{2}}$

c) $(\mathrm{GM^2\ m^2r})^{\frac{1}{2}}$

d) $(\mathrm{GMm^2r})^{\frac{1}{2}}$

16. **Assertion (A):** In uniform circular motion, acceleration is time-dependent. [1]

Reason (R): In uniform circular motion, tangential force acting on the body is time-dependent.

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):** Spring balances show correct readings even after they had been used for a long time interval. [1]

Reason (R): On using for long time, spring balances loose its elastic strength.

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.

18. **Assertion (A):** Dimension of coefficient of viscosity is $[ML^{-1}T^{-1}]$ [1]

Reason (R): The coefficient of viscosity is the force acting per unit area per unit velocity gradient.

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. The value G in CGS system is 6.67×10^{-8} dyne $cm^2\ g^{-2}$. Calculate the value in SI units. [2]

20. Is friction a non-conservative force? [2]

21. If the radius of earth shrinks by 2.0%, mass remaining constant. How would the value of acceleration due to gravity change? [2]

OR

Write four characteristics of gravitational force.

22. What do you mean by compressibility? Why are solids least compressible and gases most compressible? [2]

23. i. Write ideal gas equation in terms of density, [2]

ii. If molar volume is the volume occupied by 1 mole of any (ideal) gas at STP, show that it is 22.4 L (take R $=8.313\ Jmol^{-1}K^{-1}$).

OR

When do the real gases obey more correctly the gas equation : PV = nRT?

24. The position of an object moving along the x-axis is given by $x = a + bt^2$, where a = 8.5 m, b = 2.5 m and t is measured in seconds. What is its velocity at t = 0 s and t = 2.0 s? What is the average velocity between t = 0 s and t = 4.0 s? **[2]**

25. A constant retarding force of 50 N is applied to a body of mass 30 kg moving initially with a speed of 18 ms^{-1}. How long does the body take to come to a halt? **[2]**

Section C

26. What is a cyclic process? What is change in internal energy of the system in a cyclic process? In changing the state of a gas adiabatically from an equilibrium states A to B, an amount of 40.5 J of work is done on the system. If the gas is taken from states A to B via a process in which net heat absorbed by the system is 12.6 cal. How much is the net work done by the system in the later case? (1 cal =4.19 J) **[3]**

27. A 100 kg gun fires a ball of 1 kg horizontally from a cliff of height 500 m. It falls on the ground at a distance of 400 m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10 ms^{-2}). **[3]**

28. Two mercury droplets of radii 0.1 cm. and 0.2 cm. collapse into one single drop. What amount of energy is released? The surface tension of mercury $T = 435.5 \times 10^{-3}\ N\ m^{-1}$. **[3]**

OR

What is venturi-meter? On which principle does it work? How is the principle of venturi-meter applied in automobiles?

29. The two individual wave functions are $y_1 = 5 \sin (4x - t)$ cm and $y_2 = 5 \sin (4x + t)$ cm where, x and y are in centimeters. Find out the maximum displacement of the motion at x = 2.0 cm. Also, find the positions of nodes and antinodes. **[3]**

OR

Earthquakes generate sound waves inside the earth. Unlike a gas, the earth can experience both transverse (S) and longitudinal (P) sound waves. Typically the speed of S wave is about 4.0 km s^{-1}, and that of P wave is 8.0 kms^{-1}. A seismograph records P and S waves from an earthquake. The first P wave arrives 4 min before the first S wave. Assuming the waves travel in straight line, at what distance does the earthquake occur?

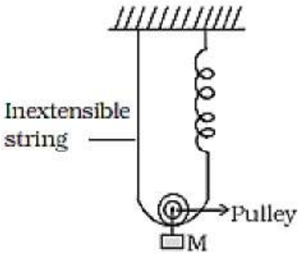
30. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0 kg. How much is the rise in temperature of the block in 2.5 minutes, assuming 50% of power is used up in heating the machine itself or lost to the surroundings. Specific heat of aluminium = 0.91 J g^{-1} K^{-1}. **[3]**

Section D

31. A tunnel is dug through the centre of the Earth. Show that a body of mass '*m*' when dropped from rest from one end of the tunnel will execute simple harmonic motion. **[5]**

OR

Find the time period of mass M when displaced from its equilibrium positon and then released for the system shown in figure.

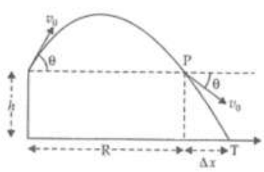


32. A marble rolls along a table at a constant speed of 1.00 m/s and then falls off the edge of the table to the floor 1.00 m below, **[5]**

i. How long does the marble take to reach the floor?
ii. At what horizontal distance from the edge of the table does the marble land?
iii. What is its velocity as it strikes the floor?

OR

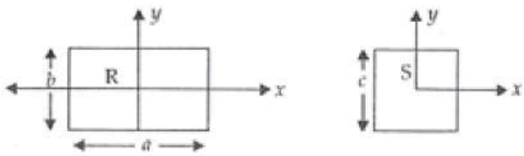
A gun can fire shells with maximum speed v_0 and the maximum horizontal range that can be achieved is R $=\frac{v_0^2}{g}$. If a target farther away by distance Δx (beyond R) has to be hit with the same gun as shown in the figure here, show that it could be achieved by raising the gun to a height at least h = $\Delta x\left[1+\frac{\Delta x}{R}\right]$



[Hint: This problem can be approached in two different ways:

i. Refer to the diagram: target T is at the horizontal distance $x=R+\Delta x$ and below the point of projection y = - h.
ii. From point P in the diagram: Projection at speed v_0 at an angle θ below horizontal with height h and horizontal rangeΔx.]

33. A uniform square plate S (side c) and a uniform rectangular plate R (sides b, a) have identical areas and masses (Figure). **[5]**



Show that

i. $\frac{I_{xR}}{I_{xs}}<1$
ii. $\frac{I_{yR}}{I_{ys}}>1$
iii. $\frac{I_{zR}}{I_{zs}}>1$

OR

a. Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be$\frac{2MR^2}{5}$, where M is the mass of the sphere and R is the radius of the sphere.
b. Given the moment of inertia of a disc of mass M and radius R about any of its diameters to be $\frac{MR^2}{4}$, find its moment of inertia about an axis normal to the disc and passing through a point on its edge.

Section E

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

Free fall is a kind of motion that everybody can observe in daily life. We drop something accidentally or purposely and see its motion. At the beginning its speed is zero and until the end it gains speed and before it reaches ground its maximum speed. It gains speed approximately 10 m/s in a second while falling because of the gravitation.

During the fall, the air resistance is neglected and the acceleration remains constant (equal to g). The object is said to be in free fall. If the height through which the object falls is small compared to the earth's radius, g can be taken to be constant and equal to 10 m/s^2 approximately.

f the object is dropped from the top of a tall building, and it takes t seconds to reach the ground hen the velocity when it reaches ground is gt. The height of the building is $\frac{1}{2}gt^2$.

(i) If an object dropped from the top of a tall building takes 2 seconds to reach ground, find the height of the building?

(ii) Which assumptions are considered when object falls freely from height?

(iii) Draw velocity time graph of an object during free fall.

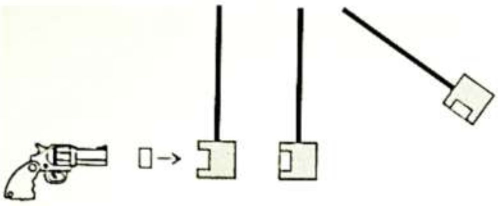
OR

Draw acceleration-time graph during free fall.

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

The ballistic pendulum was invented in 1742 by English mathematician Benjamin Robins.

A Ballistic Pendulum is a device for measuring a bullet's momentum and speed by employing perfectly inelastic collision.



A large wooden block suspended by two cords serves as the pendulum bob. When a bullet is fired into the bob, it gets embedded in the bob and its momentum is transferred to the bob.

The bullet's momentum and velocity can be determined from the amplitude of the pendulum swing. The velocity of the bullet, in turn, can be derived from its calculated momentum.

After collision, if the pendulum reaches a height h, then from principle of conservation of mechanical energy

$\frac{1}{2}(m+M)v_p^2$ = (m + M)gh

where, m= mass of bullet, M = mass of the bob v_P = velocity of the bob-bullet combination

$\therefore v_p = \sqrt{2gh}$

Now, Momentum before collision = Momentum after collision

$mv_B = (m+M)v_p$

where, v_B = velocity of bullet

$v_B = \frac{m+M}{m}\sqrt{2gh}$

the ballistic pendulum used to be a common tool for the determination of the muzzle velocity of bullets as a measure of the performance of firearms and ammunition (Nowadays, the ballistics pendulum has been replaced by the ballistic chronograph, an electronic device).

(i) What type of collision occurs in ballistic pendulum and why?

(ii) Which two principles of Physics are applied to find the velocity of the bullet?

(iii) Ballistic pendulum has been replaced by which electronic device?

OR

A ballistic pendulum of 1 kg is fired with a bullet of mass 1 g. If the pendulum rises 2 cm, find the velocity of the bullet.

Solution

SAMPLE PAPER - 1

Class 11 - Physics

Section A

1. **(d)** 10^{-7}

   Explanation: $[P] = [M^1L^{-1}T^{-2}]$

   [1 lacsap] = [1 kg] $[100 \text{ km}]^{-1}$ $[10 \text{ s}]^{-2}$

   $= 1 \text{ kg} \times 10^{-5} \text{ m}^{-1} \times 10^{-2} \text{ s}^{-2}$

   $= 10^{-7} \text{ kg m}^{-1} \text{ s}^{-2} = 10^{-7}$ Pa

2. **(a)** Viscous force

   Explanation: Viscous force is a non-conservative force.

3. **(a)** $\frac{7}{10}mv^2$

   Explanation: The total kinetic energy of a solid sphere rolling on the surface is given by:

   $\text{KE} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

   $= \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right) \times \left(\frac{v}{R}\right)^2$

   $= \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2$

4. **(b)** 2.3

   Explanation: 2.3

5. **(b)** $R_e\omega^2$

   Explanation: Acceleration due to gravity at a place of latitude λ due to rotation of earth is $g' = g - R_e\omega^2 \cos^2 \lambda$

   At equator, $\lambda = 0$, cos 0 = 1

   $\therefore g' = g_e = g - R_e\omega^2$

   At poles, $\lambda = 90$, cos 90 = 0

   $\therefore g' = g_p = g$

   $\therefore g_p - g_e = g - (g - R_e\omega^2) = R_e\omega^2$

6. **(a)** $\frac{3}{T}$

   Explanation: pT^2 = constant

   $\therefore \left(\frac{nRT}{V}\right)T^2$ = constant or T^3V^{-1} = constant

   Differentiating the equation, we get

   $\frac{3T^2}{V} \cdot dT - \frac{T^3}{V^2}dV = 0$ or $3dT = \frac{T}{V} \cdot dV$ ...(i)

   From the equation

   $dV = V_\gamma dT$

   γ = coefficient of volume expansion of gas = $\frac{dV}{V \cdot dT}$

   From Eq. (i) $\gamma = \frac{dV}{V \cdot dT} = \frac{3}{T}$

7. **(c)** A thermometer should have a small thermal capacity

   Explanation: To measure the temperature of a body, the thermometer is kept in contact with the body and heat transfer from the body to thermometer takes place. If the thermometer has a large thermal capacity, then the temperature of the body may change significantly. To minimise the change in temperature of the body, the thermal capacity of the thermometer is kept very low. According to Einstein, mass and energy are interconvertible. If Δm mass is lost then the energy released will be equal to E = $(\Delta m)c^2$. But the total energy of the universe is constant. Therefore, it should be said that the total mass and energy of the universe is conserved. Heat energy alone is not conserved.

   When the temperature of the atmosphere tries to increase the evaporation of water from the sea surface takes place. Therefore, it permits a little change in the temperature. Hence, the temperature in cities on the coast changes very little.

8. **(c)** $\frac{v}{\lambda}$

   Explanation: Let the two sources A, B emit sound of frequency $v_o = \frac{v}{\lambda}$

When observer moves B $\rightarrow$ A,

It receives compressed waves from A, whose frequency is:

$v_A = v_o\left(\frac{u+v}{u}\right)$ [From Doppler'n Effect]

It receives elongated waves from B, given by

$v_B = v_o\left(\frac{u-v}{u}\right)$

Thus, frequency of beats observed by him:

$v_{beat} = |v_A - v_B| = v_o\left(\frac{u+v-u+v}{u}\right)$

$\Rightarrow v_{beat} = \frac{2v^2}{u\lambda}\left(as v_o = \frac{v}{\lambda}\right)$

9. **(b)** 4W

Explanation: $V = \frac{4}{3}\pi r^3$ or $V \propto r^3$ or $r \propto V^{1/3}$

Now,

$W = 8\pi r^2 T$

$\therefore W \propto r^2 \propto V^{2/3}$

$\therefore \frac{W'}{W} = \left(\frac{V'}{V}\right)^2 = \left(\frac{8V}{V}\right)^{2/3} = (8)^{2/3} = 4$

or W' = 4W

10. **(c)** 8

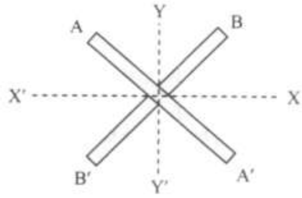
Explanation: $T \propto R^{3/2}$

$\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2}$

$\therefore T_2 = T_1(4)^{3/2} = 8T_1$

11. **(a)** $\frac{ML^2}{12}$

Explanation:



Moment of inertia of each rod about an axis passing through their centre of mass and perpendicular to length is,

$I_{ZZ'} = \frac{ML^2}{12}$

$\therefore$ M.I. of cross about ZZ' axes is $= 2\left(\frac{ML^2}{12}\right)$

$= \frac{ML^2}{6}$

Now, consider axes YY' $\perp$ XX'

$\therefore$ Izz' = Ixx' + Iyy' ...(perpendicular axes theorem)

$= 2I_{XX'}$

$\therefore I_{XX'} = \frac{I_{ZZ'}}{2} = \frac{ML^2}{12}$

12. **(c)** 600 K

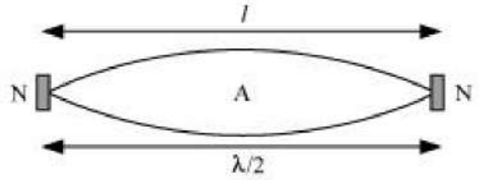
Explanation: 600 K

13. **(c)** 5.06 km/s

Explanation: Length of the steel rod, l = 100 cm = 1 m

Fundamental frequency of vibration, v = 2.53 kHz = 2.53×10^3 Hz

When the rod is plucked at its middle, an antinode (A) is formed at its centre, and nodes (N) are formed at its two ends, as shown in the given figure.



The distance between two successive nodes is $\frac{\lambda}{2}$.

$\therefore l = \frac{\lambda}{2}$

$\lambda = 2l = 2 \times 1 = 2m$

The speed of sound in steel is given by the relation:

$v = \nu\lambda$

$= 2.53 \times 10^3 \times 2$

$= 5.06 \times 10^3$ m/s

= 5.06 km/s

14. **(c)** $2^{\gamma-1}$

Explanation: The gas in container A is compressed isothermally

$\therefore P_1V_1 = P_2V_2$

or $P_2 = \frac{P_1V_1}{V_2} = P_1\frac{V_1}{\frac{V_1}{2}} = 2P_1 \left[\because V_2 = \frac{V_1}{2}\right]$

Again the gas in container B is compressed adiabatically.

$\therefore \quad P_1V_1^{\gamma} = P_2'(V_2')^{\gamma}$

or $P_2 = P_1\frac{V_1^{\gamma}}{(V_2')^{\gamma}} = P_1\left[\frac{V_1}{\frac{V_1}{2}}\right]^{\gamma}$

$= 2^{\gamma}P_1$

Hence, $\frac{P_2'}{P_2} = \frac{2^{\gamma}P_1}{2P_1} = 2^{\gamma-1}$

15. **(d)** $(GMm^2r)^{\frac{1}{2}}$

Explanation: The angular momentum L of a satellite is given by

L = mvr (where, r = radius of orbit = R + h)

$= m\left[\sqrt{\left(\frac{GM}{r}\right)}\right] r = (m^2GMr)^{\frac{1}{2}}$

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

Explanation: A is true but R is false.

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

Explanation: When a spring balance has been used for a long time, the spring in the balance gets fatigued and there is loss of strength of the spring. In such a case, the extension in the spring is more for a given load and hence the balance gives wrong readings.

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

Explanation: Coefficient of of viscosity is force acting per unit area per unit velocity gradient i.e.

$[\eta] = \frac{[F]}{[A][(\frac{du}{dr})]} = \frac{[MLT^{-2}]}{[L^2][LT^{-1}L^{-1}]} = [ML^{-1}T^{-1}]$

Section B

19. As $F = G\frac{m_1m_2}{r^2}$

$\therefore G = \frac{Fr^2}{m_1m_2}$

$[G] = \frac{MLT^{-2}\cdot L^2}{MM} = M^{-1}L^3T^{-2}$

$\therefore$ a = -1, b = 3, c = -2

$\therefore n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$

$= 6.67 \times 10^{-8}\left[\frac{1}{1000}\right]^{-1}\left[\frac{1}{100}\right]^3\left[\frac{1}{1}\right]^{-2}$

Hence in SI units,

$G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}

20. Yes. When the direction of motion of a body reverses, the direction of friction is also reversed. Work has to be done against friction both during the forward and return journey i.e., work done against friction along a closed path is not zero. So friction is a non-conservative force.

21. Acceleration due to gravity on the surface of the earth is given by

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

Taking logarithm of both sides, we get

log g = log G + log M - 2 log R

As G and M are constant, so differentiation of the above equation gives

$\frac{dg}{g} = 0 + 0 - 2\frac{dR}{R}$

As radius of the earth decreases by 2%, so

$\frac{dR}{R} = -\frac{2}{100}$

$\frac{dg}{g} \times 100 = -2\frac{dR}{R} \times 100$

$= -2 \times \left(-\frac{2}{100}\right) \times 100 = 4\%$

OR

i. It is a central force.
ii. It is a conservation force.
iii. It obeys inverse square law.
iv. It is a universal force and is always attractive in nature.
v. It is an action reaction pair.
vi. The gravitational force between two particles is independent of presence or absence of other particles.
vii. The work done in moving a particle once around a closed path under the action of gravitational force is zero.

22. Compressibility of the material of a body is defined as the fractional change in volume per unit increase in pressure. It is the reciprocal of its bulk modulus.

Mathematically,

$Compressibility, K = \frac{1}{B} = -(\frac{\Delta V}{V}) \times \frac{1}{p}$

The solids are least compressible whereas gases are most compressible. It is on account of the fact that in solids neighbouring atoms are tightly coupled but molecules in gases are very poorly coupled to their neighbours.

23. i. The perfect gas equation can be written as, pV= nRT

where, p is pressure and n number of moles,

$R = N_A k_B$ is universal constant and T is absolute temperature in Kelvin. We know that,

$n = \frac{M}{M_0} = \frac{N}{N_A}$

where, M = mass of the gases

In terms of density, perfect gas equation is

$p = \frac{\rho RT}{M_0}$, ρ = M/V = density of the gas.

ii. p = 1 atm = 0.76 m of Hg

$= 0.76 \times \left(13.6 \times 10^3\right) \times 9.8\ Pa$

T = 273 K, R =8.31 J $mol^{-1}K^{-1}$, n = 1 mole

We know from ideal gas equation, pV = nRT

or, $V = \frac{\mu RT}{p} = \frac{1 \times 8.31 \times 273}{0.76 \times (13.6 \times 10^3) \times 9.8}$

= 22.4 × 10^{-3} m^3 = 22.4 L, this is the aquired volume by one mole of an ideal gas at NTP.

OR

An ideal gas is one whose molecules have zero volume and no mutual force between them. At low pressure, the volume of a gas is large and so the volume occupied by the molecules is negligible in comparison to the volume of the gas. At high temperature, the molecules have large velocities and so the intermolecular force has no influence on their motion. Hence at low pressure and high temperature, the behaviour of real gases approach the ideal gas behaviour.

24. We know that, $v = \frac{dx}{dt}$

$v = \frac{d}{dt}(a + bt^2)$ = 2bt = 5t m/s .....(i)

At t = 0, from equation (i) we have v = 0,

At t = 2 from equation (i) we have v = 10 m/s

Average velocity = $\frac{x(4) - x(2)}{4 - 2} = \frac{a + 16b - a - 4b}{2}$ $= 6 \times b = 6 \times 2.5$ = 15 m/s

25. Here F = - 50 N, m = 30 kg, u = 18 ms^{-1} and v = 0.

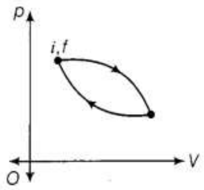
Acceleration, a = $\frac{F}{m} = \frac{-50}{30} = \frac{-5}{3} ms^{-2}$

Now from the equation v = u + at, we have,

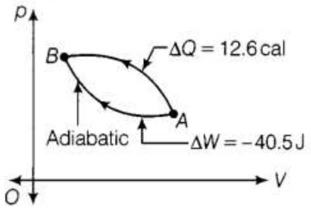
t = $\frac{v-u}{a} = \frac{0-18}{\left(\frac{-5}{3}\right)} = 10.8$ sec

Section C

26. After completion of the cycle, A cyclic process restores the system back to its initial state after completion of the cycle.



As internal energy is a state function, so its value at initial point is same as that at final point (initial state is same as that of final state).



For adiabatic process $A \rightarrow B$,

$\Delta \mathrm{Q}=0$, Using first law of thermodynamics

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

$\Delta U=-\Delta W=-(-40.5)=40.5 J$

For another process, $A \rightarrow B$

$\Delta Q=+12.6 \mathrm{cal}$

$=12.6 \times 4.19 \mathrm{J}=52.8 \mathrm{J}$

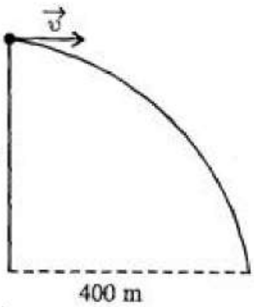
Using the first law of thermodynamics,

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

$\Rightarrow \Delta W=\Delta Q-\Delta U$

$\Rightarrow \Delta W=52.8-40.5=12.3 \mathrm{J}$

27. 500 m



Let the horizontal speed of the ball is $u m s^{-1}$ its vertical component will be zero.

Consider the motion off ball vertically downward

Here, mass of ball, m_b=1kg, Mass of gun, M_G = 100 kg

u_b = initial velocity of ball,

v_b = final velocity of ball,

v_g = final velocity of gun

u = 0, s = h = 500 m, g = 10 s m^{-2}

$s=u t+\frac{1}{2} a t^2$

$500=a \times t+\frac{1}{2} \times 10 t^2 \Rightarrow t^2=\frac{500}{5}=100$

$t=\sqrt{100}=10 \sec$

Horizontal distance covered by the ball is $x=u \times 10$

$400=v \times 10 \Rightarrow v=40 m / \sec$

By the law of conservation of momentum

$m_b u_j+M_G u_g=m_b v_b+M_G v_G$

$\Rightarrow m_b \times 0+M_G \times 0=1 \times 40+100 v_G$

100 v_G = - 40

Recoil velocity of Gun$=\frac{-40}{100} m s^{-1}=\frac{-2}{5} m s^{-1}$ = - 0.4 ms^{-1} i.e opposite to the speed of ball.

28. Energy due to surface Tension $E=\sigma \Delta A$

By law of conservation of mass, volume of drop $V_1+V_2=V$

$r_1 = 0.1cm = 0.1 \times 10^{-2}m = 10^{-3}m$

$r_2 = 0.2\text{cm} = 2 \times 10^{-3}\text{m}$

$\Delta A = 4\pi r_1^2 + 4\pi r_2^2 - 4\pi R^2 = 4\pi\left[r_1^2 + r_2^2 - R^2\right]$

R is the radius of new drop formed by the combination of two smaller drops.

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r_1^3 + \frac{4}{3}\pi r_2^3$

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi\left[r_1^3 + r_2^3\right] \Rightarrow R^3 = r_1^3 + r_2^3$

$R^3 = \left[\left(1 \times 10^{-3}\right)^3 + \left(2 \times 10^{-3}\right)^3\right] = \left[10^{-9} + 8 \times 10^{-9}\right] = 9 \times 10^{-9}$

$\text{R} = 2.1 \times 10^{-3}\text{m}$

$E = \Delta A\sigma = 4 \times 3.14\left[\left(10^{-3}\right)^2 + \left(2.0 \times 10^{-3}\right)^2\right.$

$\left.-\left(2.1 \times 10^{-3}\right)^2\right] \times 435.5 \times 10^{-3}$

$E = 4 \times 3.14 \times 435.5 \times 10^{-3} \times \left(10^{-3}\right)^2\left[1 + 4 - (2.1)^2\right]$

$= 4 \times 3.14 \times 435.5 \times 10^{-9}[5 - 41];$

$E = 1742.0 \times 3.14 \times 10^{-9}[0.59] = 5469.88 \times 0.59 \times 10^{-9}$

$E = 3227.23 \times 10^{-9} = 32.2723 \times 10^{-7}J$

$E = 32.27 \times 10^{-7}J$

Energy is released due to formation of bigger drop from smaller drops because final area will be smaller than former case.

OR

Venturi-meter is a device used to measure the flow speed of a liquid. It is basically based on Bernoulli's principle and works on the principle that when a liquid flows in the tube from wide neck to a narrow constriction, the speed of flow increases and the pressure falls.

Bernoulli's principle states that with the increase in the velocity of the fluid its pressure decreases (or) there is a decrease in the fluid pressure energy. This decrease in the fluid pressure in the areas where the flow velocity is increased is called the Bernoulli effect.

It is utilised in the carburettor of automobiles. The carburettor has a venturi channel (fine nozzle) through which air flows with a large speed. The pressure is then lowered at the narrow neck as a result, the valve of petrol chambers opens and the petrol is sucked up in the chamber to provide the correct mixture of air and petrol necessary for combustion.

29. Given, $y_1 = 5 \sin(4x - t)$ cm

$y_2 = 5 \sin(4x + t)$ cm

We know that the resulting wave equation,

y = (2A sin kx) cos ωt

Now, comparing the given equation in the question with the above resulting wave equation we get,

$y_1 = 5 \sin(4x - t)$ cm with $y_1 = A \sin(kx - \omega t)$.

A = 5 cm, k = 4 cm^{-1} and ω = 1 rad/s

Hence, y = (2A sin kx) cos ωt becomes

y =(10 sin 4x) cos t

The maximum displacement of the motion at position

x = 2.0 cm equals to

y_{max} =10 sin 4x, x = 2.0 and t = 0

= 10 sin (4 × 2) = 10 sin (8 rad)

$\Rightarrow y_{max}$ = 9.89 cm

The wavelength by using the relation between wavelength and wave number, we get

$k = \frac{2\pi}{\lambda} = 4$

$\Rightarrow \lambda = \frac{2\pi}{4} = \frac{\pi}{2}\text{cm}$

The nodes and antinodes can be given as

Nodes at $x = \frac{n\lambda}{2} = n \times \left(\frac{\pi}{4}\right)$ cm,

where n = 0,1,2, ... any integer

Antinodes at $x = (2n + 1)\frac{\lambda}{4} = (2n + 1) \times \left(\frac{\pi}{8}\right)$ cm,

where n = 0,1,2,...any integer

OR

Let v_S and v_P be the velocities of S(Secondary wave) and P(Primary Wave) waves respectively.

Let L be the distance between the epicenter and the seismograph.

We have:

$L = v_S t_S$ ....(i)

$L = v_P t_P$ ....(ii)

Where,

t_S and t_P are the respective times taken by the S and P waves to reach the seismograph from the epicentre

It is given that:

$v_P = 8$ km/s

$v_S = 4$ km/s

From equations (i) and (ii), we have:

$V_S t_S = v_P t_P$

$4 \times t_S = 8 \times t_P$

$t_S = 2t_P$ ....(iii)

It is also given that:

$t_S - t_P = 4$ min = 240 s

from the equation (iii) ,we get $2t_P - t_P = 240$

$t_P = 240$ sec

so time taken by P wave to reach from epicenter to seismograph is 240 sec and we know that $t_S = 2t_P$

$t_s = 2 \times 240$ = 480 sec

From equation (ii), we get:

$L = 8 \times 240$

= 1920 km

Hence, distance of earthquake from epicenter is 1920 km.

30. Power of the drilling machine, P = 10 kW = 10×10^3 W $=10^4$ W

Mass of the aluminum block, m= 8.0 kg = 8000 g

Time, t = 2.5 min = 2.5×60 = 150 s

Specific heat of aluminium, c= 0.91 J $g^{-1}K^{-1}$

Let rise in the temperature of the block after drilling = δT

Total energy of the drilling machine = $P \times T$

$= 10 \times 10^3 \times 150 = 1.5 \times 10^6 J$

As only 50% of the energy is useful as per the question

so useful energy , $\Delta Q = \frac{50}{100} \times 1.5 \times 10^6 = 7.5 \times 10^5 J$

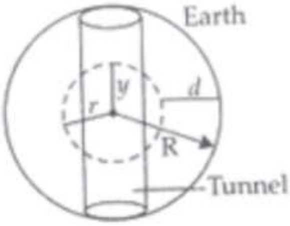
But $\Delta Q = mc\Delta T$

$\therefore \Delta T = \frac{\Delta Q}{mc}$

$= \frac{7.5 \times 10^5}{8 \times 10^3 \times 0.91}$ = 103°C

Therefore, temperature of block increases by 103^0 C in drilling for 2.5 minutes.

Section D

31. 

If the acceleration due to gravity of earth inside the earth is at a depth of d is g', then we know that,

$g' = g\left(1 - \frac{d}{R}\right) = g\left[\frac{R-d}{R}\right]$ .....(i)(g = acceleration due to gravity on the surface of the earth, R = Radius of earth)

Now if 'y' be distance of the point where acceleration due to gravity is g' from the centre of the earth, then R - d = y , and from equation (i) we get,

$\therefore g' = g\frac{y}{R}$

Force on the body of mass m placed at depth d from the surface of the earth is

$F = -mg' = -mg\frac{y}{R}$

$F \propto (-y)$, i.e. the force is proportional to displacement but opposite to the direction of displacement.

So motion of body in tunnel is SHM.

Now to get the time period of this simple harmonic motion we can write,

ma = - mg'

$\Rightarrow a = \frac{-g}{R}y$

$\therefore -\omega^2 y = \frac{-g}{R}y \; (\because a = -\omega^2 y)$

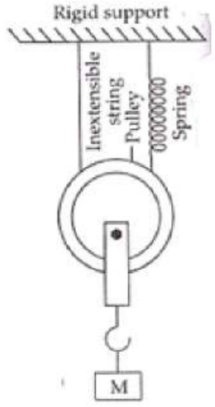
$\therefore \frac{2\pi}{T} = \sqrt{\frac{g}{R}}$ or $T = 2\pi\sqrt{\frac{R}{g}}$,

This is the time period of the simple harmonic motion executed by the body.

OR

When mass M is pulled and released then , mass M oscillates up and down along with pulley

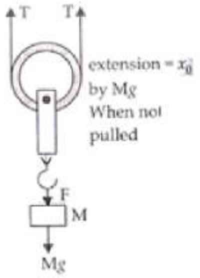
Let the spring extends by x_0 when loaded by the mass M. The extension and compression of spring from initial position is larger and smaller respectively due to gravity by same amount of forces always. So effect of gravitational force can be neglected here.



Now let the mass 'M' is pulled by force 'F' downward by displacement x. Then extension in spring will be $2x$ as string can not be extended.

So, total extension in spring is given by $= (x_0 + 2x)$

$T' = k(x_0 + 2x)$ (when pulled downward by x)



$T = kx_0$ (when no pulling)

$F = 2T$

$F = 2kx_0$

And,

$F' = 2T'$

$\rightarrow F' = 2k(x_0 + 2x)$

Restoring force is given by ;

$\rightarrow F_{rest} = -(F' - F)$

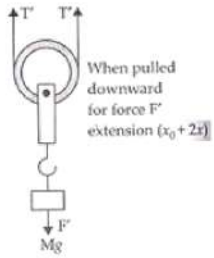
$\rightarrow f_{rest} = -[2k(x_0 + 2x) - 2kx_0)]$

$\rightarrow F_{rest} = -2k.2x$

$\rightarrow Ma = -4kx$

$a \propto -x$

$\rightarrow$ Hence, the motion is said to be simple harmonic motion(SHM).

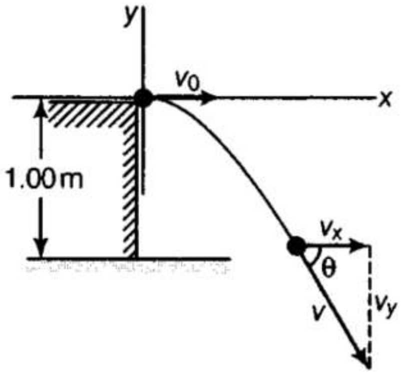


$\rightarrow a=-\omega^2 x$
$\therefore \omega^2=\frac{-a}{x}=\frac{+4k}{M}$
$\omega=2\sqrt{\frac{k}{M}}$
$\Rightarrow \frac{2\pi}{T}=2\sqrt{\frac{k}{M}}$
$T=\pi\sqrt{\frac{M}{k}}.$

$\rightarrow$Therefore, Time period is given by the relation $\rightarrow T=\pi\sqrt{\frac{\mathrm{M}}{\mathrm{k}}}$

32. As the marble was rolling on the table, therefore it has horizontal velocity and it will act as a projectile as soon as it leaves the edge of the table and fall freely under the effect of gravity.

Since, the marble is initially moving horizontally, v_{y0} = 0 and v_{x0} = 1.00 m/s. We must consider the origin to be at the edge of the table, so that $x_0 = y_0 = 0$



i. t = ? and y = -1.00 m

$\therefore$ y = $\frac{-1}{2}gt^2$

$\Rightarrow t=\sqrt{\frac{-2y}{g}}=\sqrt{\frac{(-2)(-1.00)}{9.8}}$ = 0.452 s

ii. x = ?, when t = 0.452 s

$\therefore$ x = $v_{x0}t$ = 1.00 × 0.452 s = 0.452 m

iii. v = ?, θ = ? at t = 0.452 s

The x-component of velocity is constant throughout the motion,

$v_x = v_{x0}$ = 1.00 m/s

The y-component of velocity is given by

$v_y = v_{y0} - gt$ = 0 - 9.8 × 0.452 = - 4.43 m/s

$\therefore v=\sqrt{v_x^2+v_y^2}=\sqrt{(1.00)^2+(-4.43)^2}$ = 4.54 m/s, the magnitude of the resultant velocity of the motion.

$\theta=\tan^{-1}\left|\frac{v_y}{v_x}\right|=\frac{4.43}{1.00}=77.3^\circ$

As the marble hits the floor, its velocity is 4.54 m/s directed 77.3° downward with respect to the horizontal.

OR

Maximum range of projectile, $R=\frac{V_0{}^2}{g}$ ....(i)

We know, maximum range is achieved at $\theta=45^\circ$

Let the gun is raised to a height h from the horizontal level of target T, so that the projectile can hit the target T.

Total range of projectile must be $R_{\text{total}}=R+\Delta x$

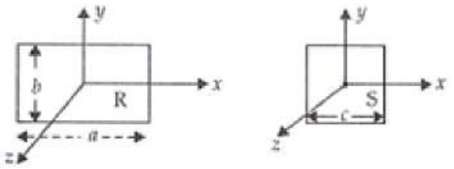
Horizontal component of velocity at $A=v_0\cos(\theta)$

As A and P are on the same level, the magnitude of velocity will be the same at A and P.

But the direction of velocity will be below horizontal,

So horizontal velocity at P, $v_x = -v_0\cos(\theta)$
and vertical velocity at P, $v_y = v_0\sin(\theta)$
Now $h = ut + \frac{1}{2}at^2$
$h = -v_0\sin\theta(t) + \frac{1}{2}gt^2$ ....(ii)
Consider horizontal motion from A to T , distance $(R+\Delta x) = v_0\cos\theta.t$
$t = \frac{R+\Delta x}{v_0\cos\theta}$
Substitute t in (ii) we get
$h = -v_0\sin\theta\left[\frac{R+\Delta x}{\nu_0\cos\theta}\right] + \frac{1}{2}g\frac{(R+\Delta x)^2}{v_0^2\cos^2\theta}$
$h = -\tan\theta\,(R+\Delta x) + \frac{1}{2}\left(\frac{g}{v_0^2}\right)\frac{(R+\Delta x)^2}{1/2}\quad (\because \theta = 45^\circ \Rightarrow \tan(45) = 1)$
$h = -(R+\Delta x) + \frac{1}{R}(R^2 + \Delta x^2 + 2R\Delta x)\left[\because \frac{g}{v_0^2} = \frac{1}{R}\right]$
h $= -R - \Delta x + R + \frac{\Delta x^2}{R} + 2\Delta x = \Delta x + \frac{\Delta x^2}{R}$
$h = \Delta x\left[1 + \frac{\Delta x}{R}\right]$
Hence Proved.

33. Moment of inertia, in physics, quantitative measure of the rotational inertia of a body- i.e., the opposition that the body exhibits to having its speed of rotation about an axis altered by the application of a torque (turning force). The axis may be internal or external and may or may not be fixed. The moment of inertia (*I*), however, is always specified with respect to that axis and is defined as the sum of the products obtained by multiplying the mass of each particle of matter in a given body by the square of its distance from the axis. The unit of moment of inertia is a composite unit of measure. In the International System (SI), m is expressed in kilograms and *r* in metres, with I (moment of inertia) having the dimension kilogram-metre square.
$m_R = m_S = m$
Area of square = Area of rectangle
$c^2 = ab$ ...(i)



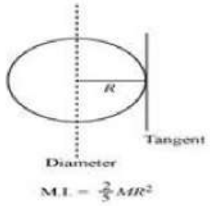
a. $\because I = mr^2$
$\frac{I_{xR}}{I_{xz}} = \frac{m\cdot\left(\frac{b}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{b^2}{4}\frac{4}{c^2} = \frac{b^2}{c^2}$
$\because c > b$ [from (i)]
Or $c^2 > b^2$
$1 > \frac{b^2}{c^2} : \frac{I_{xR}}{I_{xs}} < 1$
Hence proved.

b. $\frac{I_{yR}}{I_{ys}} = \frac{m\left(\frac{a}{2}\right)^2}{m\left(\frac{c}{2}\right)^2} = \frac{a^2}{4}\cdot\frac{4}{c^2} = \frac{a^2}{c^2}$
$\because a > c \Rightarrow \frac{a^2}{c^2} > 1$
$\frac{I_{yR}}{I_{ys}} > 1$

c. $I_{zR} - L_{zs} = m\left(\frac{d_R}{2}\right)^2 - m\left(\frac{ds}{2}\right)^2$
$I_{zR} - I_{zS} = \frac{m}{4}\left[d_R^2 - d_S^2\right] = \frac{m}{4}\left[a^2 + b^2 - 2c^2\right]$
$\therefore I_{zR} - I_{zS} = \frac{m}{4}(a^2 + b^2 - 2ab) = \frac{m}{4}(a-b)^2\quad (c_2 = ab)$
$\therefore I_{zR} - I_{zS} > 0 \because \frac{m}{4}(a-b)^2 > 0$
$\Rightarrow \frac{I_{zR}}{I_{zS}} > 1$ Hence proved.

OR

a. The moment of inertia (M.I.) of a sphere about its diameter is given by $= \frac{2}{5}MR^2$



Given,

Moment of inertia of the sphere about its diameter is given by = $(\frac{2}{5})mR^2$

Use, parallel axis theorem ,

Moment of inertia of the sphere about tangent is given by = $I + mR^2$

$= (\frac{2}{5})mR^2 + mR^2$

$= (7/5)mR^2$

b. Moment of inertia of disc of mass m and radius R about any of its diameter is = $mR^2/4$

Moment of inertia about diameter is given by = $I_x = I_y = (\frac{1}{4})mR^2$

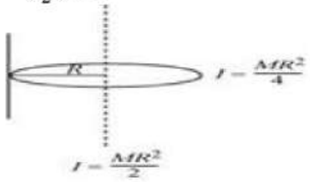
Using , perpendicular axis theorem,

$I_z = I_x + I_y$

Where I_z is moment of inertia about perpendicular axis of plane of disc. Hence,

$I_z = (\frac{1}{4})mR^2 + (\frac{1}{4})mR^2$

$= (\frac{1}{2})mR^2$



Moment of inertia of disc about passing through a point of its edge is given by;

Use , parallel axis theorem, we get

$I = I_z + mR^2$

$= (\frac{1}{2})\ mR^2 + mR^2$

$= (\frac{3}{2})mR^2$

Section E

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

Free fall is a kind of motion that everybody can observe in daily life. We drop something accidentally or purposely and see its motion. At the beginning its speed is zero and until the end it gains speed and before it reaches ground its maximum speed. It gains speed approximately 10 m/s in a second while falling because of the gravitation.

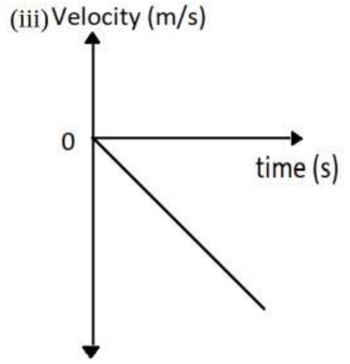
During the fall, the air resistance is neglected and the acceleration remains constant (equal to g). The object is said to be in free fall. If the height through which the object falls is small compared to the earth's radius, g can be taken to be constant and equal to 10 m/s^2 approximately.

f the object is dropped from the top of a tall building, and it takes t seconds to reach the ground hen the velocity when it reaches ground is gt. The height of the building is $\frac{1}{2}gt^2$.

(i) Height of building is given as

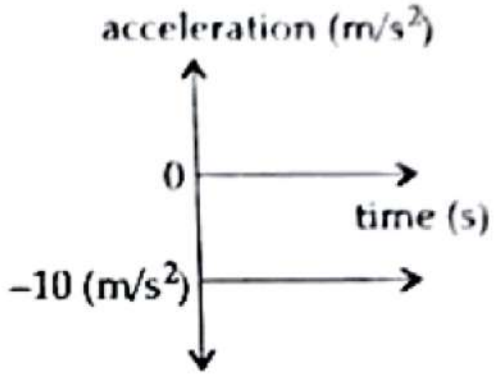
$H = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times 2^2 = 20$ m

(ii) It is assumed that there is no air resistance and height through which the object falls is small compared to the earth's radius.



OR

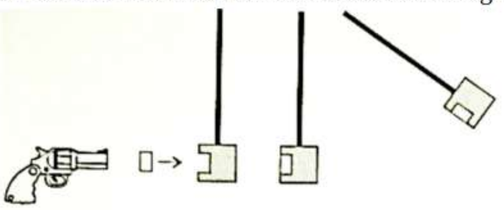
The acceleration is constant during the free fall, acceleration time graph is given as



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

The ballistic pendulum was invented in 1742 by English mathematician Benjamin Robins.

A Ballistic Pendulum is a device for measuring a bullet's momentum and speed by employing perfectly inelastic collision.



A large wooden block suspended by two cords serves as the pendulum bob. When a bullet is fired into the bob, it gets embedded in the bob and its momentum is transferred to the bob.

The bullet's momentum and velocity can be determined from the amplitude of the pendulum swing. The velocity of the bullet, in turn, can be derived from its calculated momentum.

After collision, if the pendulum reaches a height h, then from principle of conservation of mechanical energy

$\frac{1}{2}(m+M)v_p^2 = (m + M)gh$

where, m= mass of bullet, M = mass of the bob v_P = velocity of the bob-bullet combination

$\therefore v_p = \sqrt{2gh}$

Now, Momentum before collision = Momentum after collision

$mv_B = (m+M)v_p$

where, v_B = velocity of bullet

$v_B = \frac{m+M}{m}\sqrt{2gh}$

the ballistic pendulum used to be a common tool for the determination of the muzzle velocity of bullets as a measure of the performance of firearms and ammunition (Nowadays, the ballistics pendulum has been replaced by the ballistic chronograph, an electronic device).

(i) Perfectly inelastic takes place in ballistic pendulum. A large wooden block suspended by two cords serves as the pendulum bob.
When a bullet is fired into the bob, it gets embedded in the bob and its momentum is transferred to the bob. Hence the collision is perfectly inelastic.

(ii) Conservation of mechanical energy and conservation of momentum.
Principle of conservation of mechanical energy, an expression for the bob-bullet combination after collision is derived.
Then the principle of conservation of momentum is applied to find the velocity of the bullet before collision.

(iii) The ballistic pendulum. has now been replaced by the ballistic chronograph, an electronic device.

OR

$v_B = \frac{m+\mathrm{M}}{m}\sqrt{2gh}$

Putting, m = 1g = 0.001 kg

M = 1 kg

g = 10 m/s^2

h = 2 cm = 0.02 m

$v_\mathrm{B} = \frac{0.001+1}{0.001}\sqrt{2 \times 10 \times 0.02}$ = 633 m/s