CBSE Class 11 Physics
Sample Paper 01 (2019-20)

Maximum Marks: 70
Time Allowed: 3 hours

General Instructions:

1. All questions are compulsory. There are 37 questions in all.
2. This question paper has four sections: Section A, Section B, Section C and Section D.
3. Section A contains twenty questions of one mark each, Section B contains seven questions of two marks each, Section C contains seven questions of three marks each, and Section D contains three questions of five marks each.
4. There is no overall choice. However, internal choices have been provided in two questions of one mark each, two questions of two marks, one question of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.

Section A

1. The major contribution of C.V. Raman was
   a. Measurement of electronic charge
   b. Inelastic scattering of light by molecules
   c. model of hydrogen atom
   d. Nuclear model of atom
2. Passengers on a carnival ride move at constant speed in a horizontal circle of radius 5.0 m, making a complete circle in 4.0 s. What is their acceleration?
   a. 14 m s^{-2}
   b. 16 m s^{-2}

c. 12 m s^{-2}

d. 15 m s^{-2}

3. A monkey of mass 40 kg climbs on a rope which can stand a maximum tension of 600 N. What is the tension in the rope if the monkey climbs up with an acceleration of 6 m s^{-2}

a. 740 N

b. 760 N

c. 600 N

d. 640 N

4. An elevator is descending with uniform acceleration. A person in the elevator drops a marble at the moment the elevator starts to measure the acceleration of the elevator. The marble is 2 m above the floor when it is dropped. It takes 1.2 s to reach the floor of the elevator. What is the acceleration of the floor. Take g = 10 ms^{-2}.

a. 8.18 m s^{-2}

b. 6.58 m s^{-2}

c. 7.2 m s^{-2}

d. 6.08 m s^{-2}

5. A weight of 20kg falls from a height of 10 m. The work done by the gravitational force is (Take g = 10 m s^{-2})

a. 3000 J

b. 2500 J

c. 1500 J

d. 2000 J

6. A steel rod 2.0 m long has a cross-sectional area of 0.30 cm^2 . It is hung by one end from a support, and a 550-kg milling machine is hung from its other end. Determine the elongation. Take Young's modulus of steel as 20 $\times$ 10^{10} Pa

   a. 2.0 mm

   b. 1.8 mm

   c. 1.6 mm

   d. 2.2 mm

7. A 3.00-g lead bullet at 30.0°C is fired at a speed of 240 m/s into a large block of ice at 0 $^\circ$C, in which it becomes embedded. What quantity of ice melts? Latent heat of ice =3.33 x 10^{-5} J/Kg, specific heat of lead = $128 J/Kg^\circ C$

   a. 3.04 g

   b. 2.54 g

   c. 2.94 g

   d. 2.74 g

8. A thermodynamic process (state i $\longrightarrow$ state f) is reversible

   a. if the process can be turned back such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe.

   b. if the process can be turned back such that both the system and the surroundings return to different states, with lots of change in the universe.

   c. if the process can be turned back such that both the system and the surroundings return to their different states, with no other change anywhere else in the universe.

   d. if the process can be turned back such that both the system and the surroundings return to their original states, with lots of change in the universe.

9. Air in a thundercloud expands as it rises. If its initial temperature was 300 K, and if no energy is lost by thermal conduction on expansion, what is its temperature when the initial volume has doubled? $\gamma_{air} = 1.41$

   a. 257 K

   b. 237 K

   c. 247 K

   d. 227 K

10. When sound travels from air to water the quantity that remains unchanged is

    a. speed

    b. wavelength

    c. frequency

    d. intensity

11. Fill in the blanks:

    When a body moves with a ________, then $v_{an} = v_{inst}$.

    OR

    Fill in the blanks:

    The distance and the magnitude of displacement of an object have the same values, when the body is moving along a ________ path in a fixed direction.

12. Fill in the blanks:

    _______ group of physics deals with the subjects included in classical physics like mechanics, electrodynamics, optics and thermodynamics.

13. Fill in the blanks:

    A vector that extends from a reference point to the point at which particle is located is called ________.

14. Fill in the blanks:

    If the deforming forces produce a change in the shape of the body, then the strain is called ________ strain.

15. Fill in the blanks:

    ________ motion is the to and fro motion of the molecules about their mean positions.

16. Is walking on a road be an example of resolution of vectors?

17. Define triple point of water.

18. State the law of floatation?

19. Why are Calorimeters made up of metal only?

20. What is the physical quantity that gets transmitted with propagation of longitudinal waves through a medium?

    OR

    Why longitudinal waves are called pressure waves?

21. On a 60km straight road, a bus travels the first 30 km with a uniform speed of 30 kmh^{-1}. How fast must the bus travel the next 30 km so as to have average speed of 40 kmh^{-1} for the entire trip?

22. Two forces 5 and 10 kg weights are acting with an inclination of 120^o between them. What is the angle which the resultant makes with 10kg weight?

23. A wheel has a constant angular acceleration of 4.2 rad/s^2. During a certain 8.05 s interval, it turns through angle of 140 rad. Assuming that wheel started from rest, how long it had been in motion before the start of the 8.0 s?

24. A satellite orbits the earth at a height of 400 km above the surface. How much energy must be expanded to rocket the satellite out of the earth's gravitational influence?

Mass of the satellite = 200 kg, mass of the earth, M = 6.0×10^{24} kg, radius of the earth $= 6.4 \times 10^{6}$m, G = 6.67×10^{-11} Nm^2/kg^2.

25. A steel cable with a radius of 1.5 cm supports a chairlift at a ski area. If the maximum stress is not to exceed 10^8 N m^{-2}, what is the maximum load the cable can support?

26. A steel wire of 2.0 mm^2 cross-section is held straight (but under no tension) by attaching it firmly to two points a distance 1.50 m apart at 30°C. If the temperature now decreases to 5°C and if the two points remain fixed, what will be the tension in the wire?

    Given that Young's modulus of steel = 2×10^{11} Nm^2 and coefficient of thermal expansion of steel a =1.1×10^{-5}/ °C.

OR

A filament type electric lamp contains a small quantity of some inert gas too. Explain why.

27. Calculate the rms speed of a oxygen molecule at 27 ^{o}C. Atomic mass of oxygen is 16.

OR

At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the r.m.s speed of a helium gas atom at- 20^0C? Given Atomic Mass of Ar = 39.9 and of He = 4.0.

28. Consider a simple pendulum, having a bob attached to a string, that oscillates under the action of the force of gravity. Suppose that the period of oscillation of the simple pendulum depends on

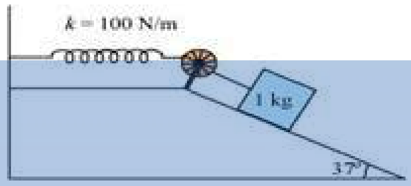
    i. mass m of the bob,
    ii. length l of the pendulum and
    iii. acceleration due to gravity g at the place.

    Derive the expression for its time period using method of dimensions.

29. A boy standing on a stationary lift (open from above) throws a ball upwards with the

maximum initial speed he can, equal to 49 m/s. How much time does the ball take to return to his hands? If the lift starts moving up with a uniform speed of 5 m/s and the boy again throws the ball up with the maximum speed he can, how long does the ball take to return to his hands?

30. A 1 kg block situated on a rough incline is connected to a spring of spring constant 100 Nm^{-1} as shown in figure. The block is released from rest with the spring in the unstretched position. The block moves 10 cm down the incline before coming to rest. Find the coefficient of friction between the block and the incline. Assume that the spring has a negligible mass and the pulley is frictionless.



31. Imagine a tunnel dug along a diameter of the earth. Show that a particle dropped from one end of the tunnel executes simple harmonic motion. What is the time period of this motion?

32. In deriving Bernoulli's equation, we equated the work done on the fluid in the tube due to its change in the potential and kinetic energy.

    a. What is the largest average velocity of blood flow in an artery of diameter 2×10^{-3} m if the flow must remain laminar?(Given, $\eta_{blood} = 2.084 \times 10^{-3} PaS$ and $\rho_{blood} = 1.06 \times 10^{3} Kg/m^{3}$)
    b. Do the dissipative forces become more important as the fluid velocity increases? Discuss qualitatively.

OR

In problem if 15.0 cm of water and spirit each are further poured into the respective arms of the tube, what is the difference in the levels of mercury in the two arms? (Specific gravity of mercury = 13.6)

33. What amount of heat must be supplied to 2.0×10^{-2} kg of nitrogen (at room temperature) to raise its temperature by 45 °C at constant pressure? (Molecular mass of N_2 = 28; R = 8.3 J mol^{-1} K^{-1}.)

34. Explain the terms wavelength, frequency and amplitude for a harmonic wave.

35. When a body slides down from rest along a smooth inclined plane making an angle of 45^o with the horizontal, it takes time T to reach the bottom. When the same body slides down from rest along a rough inclined plane making the same angle and through the same distance, it is seen to take time pT, where p is some number greater than 1. Calculate the co-efficient of friction between the body and the rough plane.

OR

i. Define impulse. State its S.I. unit. State and prove impulse-momentum theorem.
ii. Consider a ball falling from a height of 2 m and rebounding to a height of 0.5 m. If the mass of the ball is 60 g, find the impulse and the average force between the ball and the ground. The time for which the ball and the ground remained in contact was 0.2 s.

36. a. Prove the theorem of perpendicular axes.
(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 man stands on a rotating platform, with his arms stretched horizontally holding a 5 kg weight in each hand. The angular speed of the platform is 30 revolutions per minute. The man then brings his arms close to his body with the distance of each weight from the axis changing from 90cm to 20cm. The moment of inertia of the man together with the platform may be taken to be constant and equal to 7.6 kg m^2.

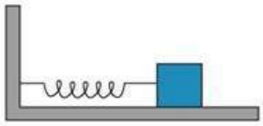
a. What is his new angular speed? (Neglect friction.)
b. Is kinetic energy conserved in the process? If not, from where does the change come about?

37. A cylindrical piece of cork of base area A, density ρ and height L floats in a liquid of density ρ_L. The cork is depressed slightly and then released. Show that the cork

oscillates up and down simple harmonically and find its time period of oscillations.

OR

A spring having with a spring constant 1200 N m^{-1} is mounted on a horizontal table as shown in Fig. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released.



Determine

i. the frequency of oscillations,
ii. maximum acceleration of the mass, and
iii. the maximum speed of the mass.

Solution

Section A

1. (b) Inelastic scattering of light by molecules
   Explanation: The Indian physicist C.V. Raman helped the growth of science in his country. He received the Nobel Prize for Physics in 1930 for the discovery that when light passes through a transparent material, some of the light changes in wavelength. This phenomenon is now called Raman scattering.
2. (c) 12 m s^{-2}
   Explanation:

   The speed is constant, so this is uniform circular motion. We are given the radius R=5.0 m and the period T=4.0 s, so we can calculate the acceleration directly using equation

   $a_{rad} = \frac{4(\pi)^2 R}{T^2}$

   $= \frac{4\times22\times22\times5.0}{7\times7\times4.0\times4.0} = 12 m/s^2$
3. (d) 640 N
   Explanation:
   $T - mg = ma$
   $T = mg + ma$
   $T = m(g + a) = 40(10 + 6) = 640\,N$
4. (c) 7.2 m s^{-2}
   Explanation:

   Let the acceleration of the elevator be 'a' downwards. As the elevator is going downwards the marble has to travel a distance more than 2 m in order to strike the floor.

   Initial velocity, u = 0 for both the marble and the elevator.

Distance travelled by elevator in 1.2 s = $\frac{1}{2}a \times (1.2)^2$

Distance travelled by marble in 1.2 s = $\frac{1}{2}g \times (1.2)^2 = \frac{1}{2} \times 10 \times (1.2)^2$

This distance should be equal to height of marbel + distance covered by elevator.

So, $\frac{1}{2} \times 10 \times (1.2)^2 = 2 + \frac{1}{2} \times a \times (1.2)^2$

On solving, we get, a = 7.2 ms^{-2} downwards

5. (d) 2000 J
   Explanation: $W = F_{SCOS}\theta = mgh\cos 0^\circ$
   $W = 20 \times 10 \times 10 \times 1 = 2000J$
6. (b) 1.8 mm
   Explanation: young's modulus $y = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{strain} = \frac{\text{stress}}{y}$
   stress $= \frac{\text{restoring force}}{\text{area}}$ in given case restoring will be tension, which will be equal to the weight 'mg' of machine.
   using standard value of young modulus for steel $y = 2 \times 10^{11} N/m^2$ strain
   $= \frac{mg}{A \times y} \Rightarrow \frac{550 \times 9.8 \times 10^4}{0.30 \times 2 \times 10^{11}} = 8.9 \times 10^{-4} \approx 9.0 \times 10^{-4}$
   for given case strain will be longitudinal $i.e.\ \frac{\Delta L}{L}$
   $\Rightarrow \frac{\Delta L}{L} = 9 \times 10^{-4}$ (given L= 2.0m)
   $\Rightarrow \Delta L = 2.0 \times 9.0 \times 10^{-4} \Delta L = 1.8\text{mm}$
7. (c) 2.94 g
   Explanation: $\frac{1}{2}m_{Pb}v^2 + m_{Pb}s_{Pb}(30 - 0) = m_{ice}L_{ice}$
   $\left(\frac{1}{2} \times 3 \times 10^{-3} \times 240 \times 240\right) + \left(3 \times 10^{-3} \times 128 \times 30\right) = m_{ice} \times 3.33 \times 10^5$
   $m_{ice} = 2.94gm$
8. (a) if the process can be turned back such that both the system and the surroundings return to their original states, with no other change anywhere else in the universe.
   Explanation: Irreversible process is one which can be reversed in such a way that all changes taking place in the direct process are exactly replaced in the inverse order and opposite sense and no changes are left behind.
9. (d) 227 K
   Explanation: $\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma - 1}$

$\frac{300}{T_2} = (2)^{1.4-1}$

$T_2 = 227K$

10. (c) frequency

    Explanation: When wave travel from one medium to another only the velocity and wavelength changes in such a way that its frequency remains constant.

11. uniform velocity

OR

straight line

12. Macroscopic
13. position vector
14. Shear
15. Vibrational
16. Yes, when a man walks on the road, he presses the road obliquely, i.e. along an angle with respect to the ground. The horizontal component of the reaction helps the man to walk on the road whereas the vertical component balances man's weight.
17. Triple point of water represents the values of pressure and temperature at which water co-exists in equilibrium in all the three states of matter.
18. Law of floatation states that a body will float in a liquid, if weight of the liquid displaced by the immersed part of the body is at least equal to or greater than the weight of the body.
19. Calorimeters are made up of metal only because they are good conductor of heat and hence the heat exchange is quick which is the basic requirement for the working of calorimeter.
20. Propagation of longitudinal waves through a medium leads to transmission of the physical quantity 'energy' along with the wave, through the medium.

OR

Because propagation of longitudinal waves through a medium, involves changes in pressure and volume of air when compressions and rarefactions are formed.

21. $V_{avg} = \frac{S_1 + S_2}{t_1 + t_2}$

$= \frac{S + S}{S\left(\frac{1}{V_1} + \frac{1}{V_2}\right)}$

$= \frac{2V_1V_2}{V_1 + V_2}$

22. F_1 = 5 kg wt

F_2 = 10 kg wt

$\theta = 120^\circ$

$\Rightarrow F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

and $\tan\beta = \frac{F_2\sin\theta}{F_1+F_2\cos\theta}$

$\tan\beta = \frac{5\sin 120^\circ}{10+5\cos 120^\circ}$

$\tan\beta = \frac{5\times\sqrt{3}/2}{10-5\times1/2}$

$\tan\beta = \frac{1}{\sqrt{3}}$

$\Rightarrow \beta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30^\circ$

23. suppose, ω_0 = initial angular speed at $t = 0$

Angle turned at the end of 8.0 s is 140°.

using $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\Rightarrow \omega_0 = \frac{\theta - \frac{1}{2}\alpha t^2}{t}$

$\omega_0 = \frac{140 - \frac{1}{2}(4.2)(8.0)^2}{8.0}$

ω_0 = 0.7 rad/s

Using $\omega = \omega_0 + \alpha t$ and taking $\omega = 0$.

$\Rightarrow t = \frac{\omega - \omega_0}{\alpha} = \frac{0 - \omega_0}{4.2}$

$= -\frac{0.7}{4.2} = -0.16s$

So, wheel starts from rest $0.16s$ before.

24. Mass of the earth, $M = 6.67 \times 10^{24} kg$

Mass of the satellite, $M = 200kg$

Radius of the earth, $R = 6.4 \times 10^6 m$

Height of the satellite above the earth's surface, $h = 400 km = 0.4 \times 10^6 m$

Radius of the orbit of the satellite, $r = R + h$

$= 6.4 \times 10^6 + 0.4 \times 10^6$

$= 6.8 \times 10^6 m$

Total energy of the satellite,

$E = -\frac{GMm}{2r} = -\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 200}{2 \times 6.8 \times 10^6}$

$= -5.9 \times \ 10^9 J$

Negative total energy denoted that the satellite is round to the earth. Therefore, to pull the satellite out of the earth's gravitational influence, the energy required

$= 5.9 \times 10^9 J.$

25. Radius of the steel cable, r = 1.5 cm = 0.015 m

Maximum allowable stress $= 10^8 Nm^{-2}$

Maximum stress $= \frac{\text{Maximum force}}{\text{area of cross section}}$

Maximum force = maximum stress $\times$ area of cross section

$F_{\max} = 10^8 \times \left(\pi \times (0.015)^2\right)$

$F_{\max} = 7.065 \times 10^4 N$

Hence, the cable can support the maximum load of $7.065 \times 10^4 N$

26. According to the question, cross-section area, $A = 2.0\ mm^2 = 2 \times 10^{-6} m^2$

Change in temperature, $\Delta T = 30 - 5 = 25°\text{C}$

Young's modulus of steel wire, $Y = 2 \ \times \ 10^{11} \ Nm^{-2}$

and coefficient of linear expansion steel, $a = 1.1 \times 10^{-5} / ^oC$

Tension developed in the rod,

$F = YA\alpha\Delta T$

$= 2 \times 10^{11} \times 2 \times 10^{-6} \times 1.1 \times 10^{-5} \times 25$

$F = 110 N$

OR

A filament type electric lamp contains small quantity of some inert gases e.g., helium or argon, etc. The purpose of adding the inert gas is to uniformly spread the heat energy emitted by the bulb. As the filament of the electric lamp is heated up on passing electric current, inert gas particles coming in contact with filament acquire heat energy and drift away. In turn, colder gas particles move towards the filament. Thus, convection currents are set up and inert gas is uniformly heated and so is the glass bulb.

27. Here T = 27 ^{0}C = 300 K and atomic mass of oxygen = 16. Since oxygen is a diatomic gas, hence its molar mass $M_0 = 2 \times 16 = 32$ g = 32×10^{-3} kg

$\therefore$ rms speed of oxygen molecule v = $\sqrt{\frac{3RT}{M_0}}$

$= \sqrt{\frac{3\times8.31\times300}{32\times10^{-3}}}$

$= 483.4$ ms^{-1} $\cong 5 \times 10^5$ ms^{-1}

OR

Suppose, Vr.m.s. and V^{1}r.m.s. are the root mean square speeds of Argon and helium atoms at temperature T and T^1 respectively.

R = Universal Gas constant

T = Temperature

M = Atomic Mass of Gas

Now, Vr.m.s. $= \sqrt{\frac{3RT}{M}}$

$V^1 \text{rm. s.} = \sqrt{\frac{3RT^1}{M^1}}$

Now, M = Mass of Argon = 39.9

M^1 = Mass of Helium = 4.0

T^1 = Temperature of helium = -20^{0}C

T^1 = 273 + (-20) = 253 K.

T = Temperature of Argon = ?

Since Vr.m.s. = V^{-1}r.m.s

$$\sqrt{\frac{3RT}{M}} = \sqrt{\frac{3RT^1}{M^1}}$$

Squaring both side,

$\frac{3RT}{M} = \frac{3RT^1}{M^1}$

$\frac{T}{M} = \frac{T^1}{M^1} \Rightarrow T = \frac{T^1 M}{M^1}$

Putting the values of T^1, M^1 & M

$T = \frac{253 \times 39.9}{4.0} = 2523.7\text{K}$

28. Let us assume that T $\propto m^a l^b g^c$

or, T = $km^a l^b g^c$ ....(i)

where, k is a dimensionless constant.

The dimensions of various quantities are

[T] = T, [m] = M,

[l] = L, and [g] = LT^{-2}

Substitute these values in Eq.(i), we obtain

T = $[M]^a[L]^b[LT^{-2}]^c$

or, $M^0L^0T^1 = M^aL^{b+c}T^{-2c}$

Now equate the powers of M, L and T on both sides, we obtain

a = 0, b + c = 0, -2c = 1

On solving, a = 0, $b = \frac{1}{2}, \quad c = -\frac{1}{2}$

$\therefore T = km^0 l^{1/2} g^{-1/2} = k\sqrt{\frac{l}{g}}$

From experiments, k = 2π

Therefore, T = $2\pi\sqrt{\frac{l}{g}}$, which is the required expression.

29. **Case I** : When the lift was stationary,

t = time to each maximum height

u = 49 m/s , v = 0 at maximum height.

Since upward motion, therefore a = - 9.8 ms^{-2}

v = u + at

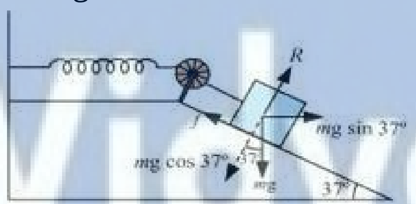
$t = \frac{v-u}{a}$

$= \frac{-49}{-9.8} = 5s$

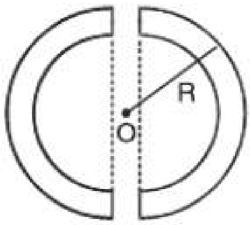
Hence, the total time of flight = 2t = 2$\times$5 = 10 s.

Case II : The lift was moving up with a uniform velocity of 5 m/s. In this case, the relative velocity of the ball with respect to the boy remains the same i.e., 49 m/s. Therefore, in this case also, the ball will return back to the boy's hand after 10 s.

30. The principle of work and kinetic energy (also known as the work-energy theorem) states that the work done by the sum of all forces acting on a particle equals the change in the kinetic energy of the particle. This definition can be extended to rigid bodies by defining the work of the torque and rotational kinetic energy.
The work W done by the net force on a particle equals the change in the particle's kinetic energy KE:
$$\mathbf{W} = \Delta \mathrm{KE} = \frac{1}{2}\mathrm{mv}_\mathrm{f}^2 - \frac{1}{2}\mathrm{mv}_\mathrm{i}^2$$
where v_i and v_f are the speeds of the particle before and after the application of force, and m is the particle's mass.
Given:
Mass of the block, m = 1 kg
Spring constant, k = 100 N m^{-1}
Displacement in the block, x = 10 cm = 0.1 m
The given situation can be shown as in the following figure.



At equilibrium:
Normal reaction, R= mg cos 37°
Frictional force, f = μ R = mg sin 37°
Where μ is the coefficient of friction
Net force acting on the block = mg sin 37^o - f
$$= mg \sin 37^\circ - \mu mg \cos 37^\circ$$
$$= mg(\sin 37^\circ - \mu \cos 37^\circ)$$
At equilibrium, the work done by the block is equal to the potential energy of the spring, i.e.,
$$mg(\sin 37^\circ - \mu \cos 37^\circ)x = \frac{1}{2}kx^2$$
$$1 \times 9.8(\sin 37^\circ - \mu \cos 37^\circ) = \frac{1}{2} \times 100 \times 0.1$$
$$0.602 - \mu \times 0.799 = 0.510$$
$$\therefore \mu = \frac{0.092}{0.799} = 0.115$$

31. 

Let AB be the imaginary tunnel dug across a diameter of the Earth and O its centre as shown in. Let P be the Free Videos section at any instant of the body dropped from one end of the tunnel, where OP-x The Earth can be considered to be made of two parts. Its outer shell-I does not exert any force on the particle. The gravitational force on the particle is only due to the sphere-ll of radius x. If p is the density of the Earth, The acceleration due to gravity at a depth *d* below the earth surface is given by:

$g_d = g\left(1 - \frac{d}{R}\right) = g\left(\frac{R-d}{R}\right)$

$= \frac{g}{R}x$ where x is distance from centre of earth

$g_d \propto x$

As acceleration is proportional to displacement Hence the motion is S.H.M

T = Time period $= 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}$

$= 2\pi\sqrt{\frac{x}{g_d}}$

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

32. a. Diameter of the artery, $d = 2 \times 10^{-3} m$

Viscosity of blood, $\eta = 2.084 \times 10^{-3}\text{Pas}$

Density of blood, $\rho = 1.06 \times 10^{3}\text{kg/m}^{3}$

Reynolds' number for laminar flow, N_R = 2000

The largest average velocity of blood is given as:

$(V_{\text{avg}})_{max} = \frac{N_{\text{R}} \times \eta}{\rho \times d}$

$= \frac{2000 \times 2.084 \times 10^{-3}}{1.06 \times 10^{3} \times 2 \times 10^{-3}}$

= 1.966 m/s

Therefore, the largest average velocity of blood is 1.966 m/s.

b. Yes, As the fluid velocity increases, the dissipative forces become more important. From Newton's law of viscous drag, we know that $F = -\eta A\frac{dv}{dx}$.This is because of the rise of turbulence. From this equation it can be explained that, as v increases, velocity gradient $\frac{dv}{dx}$ also increases, causing more viscous drag i.e. the dissipative force also increases because of turbulence.

OR

Height of the water column, h_1 = 10 + 15 = 25 cm

Height of the spirit column, h_2 = 12.5 + 15 = 27.5 cm

Density of water, ρ_1 = 1 g cm^{-3}

Density of spirit, ρ_2 = 0.8 g cm^{-3}

Density of mercury = 13.6 g cm^{-3}

Let h be the difference between the levels of mercury in the two arms.

Pressure exerted by height h, of the mercury column:

= hρg

= h$\times$13.6g ... (i)

Difference between the pressures exerted by water and spirit:

$= h_1\rho_1 g - h_1\rho_1 g$

$= g(25 \times 1 - 27.5 \times 0.8)$

= 3g ... (ii)

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

13.6 hg = 3g

h = 0.220588 $\approx$ 0.221 cm

Hence, the difference between the levels of mercury in the two arms is 0.221 cm.

33. Mass of nitrogen, m = 2.0×10^{-2} kg = $2.0 \times 10^{-2} \times 1000$ = 20 g
Increase in temperature of gas =ΔT = 45°C
Molecular mass of nitrogen = M = 28 gram

gas constant, R = 8.3 J mol^{-1} K^{-1}

if m is mass of gas in grams

Number of moles = $n = \frac{m}{M}$

n $= \frac{2.0 \times 10^{-2} \times 10^{3}}{28} = 0.714$

Molar specific heat at constant pressure for nitrogen, $C_P = \frac{7}{2} R$

$= \frac{7}{2} \times 8.3$

= 29.05 J $mol^{-1} K^{-1}$

by heat formula :

$\Delta Q = nC_p \Delta T$

$= 0.714 \times 29.05 \times 45$

= 933.38 J

So 933.38 J is the amount of heat required to increase the temperature by 45^0C..

34. i. **The wavelength** of a harmonic wave is the distance covered by the wave motion during the time in which a medium particle completes one vibration to and fro about its mean position. Alternately, it is the distance (parallel to the direction of wave propagation) between the consecutive repetitions of the shape of a wave. It is the minimum distance between two consecutive points in the same phase.
    ii. **Frequency** of a harmonic wave is the number of vibrations per unit time by a medium element as the wave passes through it. The frequency of a wave is defined as reciprocal of its time period and is related to angular frequency ω by the relation,
    Frequency ν = $\frac{1}{T}$ = $\frac{\omega}{2\pi}$
    SI unit of frequency is s^{-1} or Hz.
    iii. The **amplitude** of a harmonic wave is the magnitude of maximum displacement of a medium particle (or element) from its equilibrium position as the wave passes through it. The amplitude of a wave is a positive quantity and its SI unit is 1 metre.

35. As the body slides down from rest along a smooth plane inclined at angle 45^0 in Time T,

Initial velocity(u) = 0, distance along the inclined plane = s, time taken(t) = T

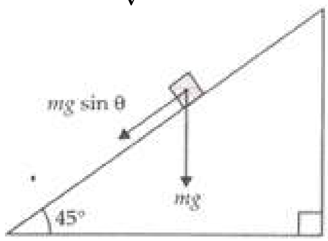
$a = g \sin 45^\circ = \frac{g}{\sqrt{2}}$, the component of acceleration along the inclined plane.

Now from Newton's equation of motion,

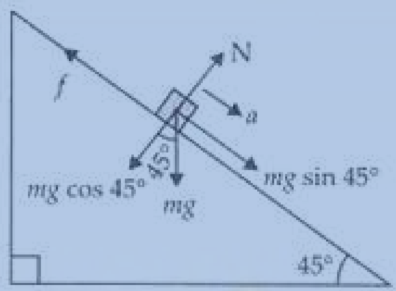
$s = ut + \frac{1}{2}at^2$

$\Rightarrow s = 0 + \frac{1}{2}\frac{g}{\sqrt{2}}T^2$

$\therefore s = \frac{gT^2}{2\sqrt{2}}$



Now for motion of the body along rough inclined plane, mg sin 45° exceeding static frictional motion μ mg cos 45° will cause the downward motion of the body along the inclined plane with acceleration a.



Initial velocity, u = 0, distance along the inclined plane, $s = \frac{gT^2}{2\sqrt{2}}$ ....(i)

$\Rightarrow$ ma = mg sin 45^0 – f_s

$= mg\frac{1}{\sqrt{2}} - \mu N$,(as static frictional force, $f_s = \mu N$)

= $\frac{mg}{\sqrt{2}} - \mu mg \cos 45^\circ = mg\left[\frac{1}{\sqrt{2}} - \frac{\mu}{\sqrt{2}}\right]$ (as, normal force, N = mg cos 45°)

$\therefore ma = \frac{mg}{\sqrt{2}}[1-\mu] \Rightarrow a = \frac{g}{\sqrt{2}}(1-\mu)$

In this case time t = pT, distance $s = \frac{gT^2}{2\sqrt{2}}$ and acceleration $a = \frac{g}{\sqrt{2}}(1-\mu)$, again applying Newton's equation of motion,

$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}\cdot\frac{g}{\sqrt{2}}(1-\mu)(pT)^2$

$\therefore s = \frac{g}{2\sqrt{2}}(1-\mu)p^2T^2$ ...(ii)

Distances in both cases are equal (given). Hence, equating equation (i) with equation (ii) we get,

$\frac{gT^2}{2\sqrt{2}} = \frac{g}{2\sqrt{2}}(1-\mu)p^2T^2$

$\Rightarrow 1 = (1-\mu)p^2 \Rightarrow 1 = p^2 - \mu p^2$

$\Rightarrow \mu p^2 = p^2 - 1$

$\therefore \mu = \left[1 - \frac{1}{p^2}\right]$

OR

i. When a force acts on a body or on a system or on a particle for some time, then the product of the force and the time interval is called impulse.

Impulse $\overline{I} = \overline{F} \times t$

S.I. Unit - NS

Impulse is a vector quantity directed along the average force $\overline{F}av$.

Impulse of a force is equal to the change in momentum of the body.

According to Newton's second law

$\overline{F} = \frac{d\overline{p}}{dt}$

or $d\overline{p} = \overline{F}dt$

Say, due to application of a force $\overline{F}$, the momentum of a body changes from $\overline{P}_1$ to $\overline{P}_2$ in the time interval 0 to t. i.e. At t = 0 $\overline{P} = \overline{P}_1$ and at

$t = t$, $\overline{P} = \overline{P_2}$

$\int_{\overline{P_1}}^{\overline{P_2}} d\overline{p} = \int_0^t \overline{F}dt$

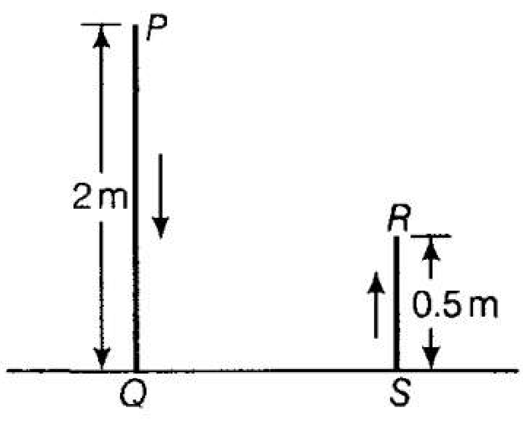
$\overline{P}_2 - \overline{P}_1 = \overline{F}t$

$\overline{P}_2 - \overline{P}_1 = \overline{I}$

$[\because \overline{F}t = \overline{I}(\text{ Impulse })]$

ii. The initial velocity of the ball at P is zero as it is dropped. Let the final velocity of the ball at Q be v.

Given PQ = s = 2 m, then



$v^2 = u^2 + 2as$

$$v^2 = 0 + 2 \times 9.8 \times 2 = 4 \times 9.8$$

$v = \sqrt{39.2}\mathrm{m/s} = 6.26\mathrm{m/s}$ before it touched the ground.

Now, Let u' be the velocity of rebound of the ball (after it lost some kinetic energy due to collision with the ground). Given, RS = s' = 0.5 m, the final velocity at R is zero, we have

$v'^2 = u'^2 + 2as$

$$0 = u'^2 + 2 \times (-9.8) \times 0.5$$

$v'^2 = u'^2 + 2as$

$$0 = u'^2 + 2 \times (-9.8) \times 0.5$$

$u' = -\sqrt{9.8}\mathrm{m/s} = -3.13\mathrm{m/s}$ (negative sign indicates that displacement is against the direction of acceleration due to gravity i.e. upward)

We know that, Impulse = Change in momentum

= mv - (- mu') = m(v + u')

$$= \frac{60}{1000}(6.26 + 3.13)$$

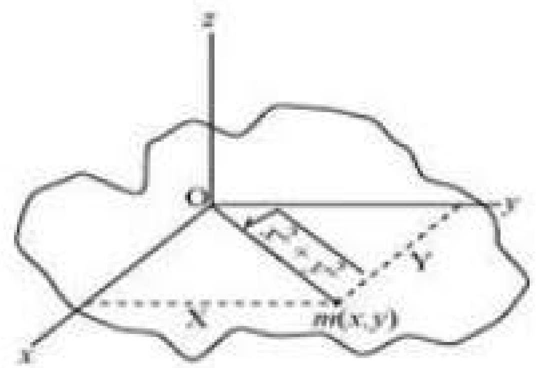
$$= 0.06 \times 9.39 = 0.563\mathrm{Ns}$$

From Newton's second law of motion,

$\because$ Average force = $\frac{\text{Impulse}}{\text{Time}} = \frac{0.563}{0.2} = 2.817\mathrm{N}$

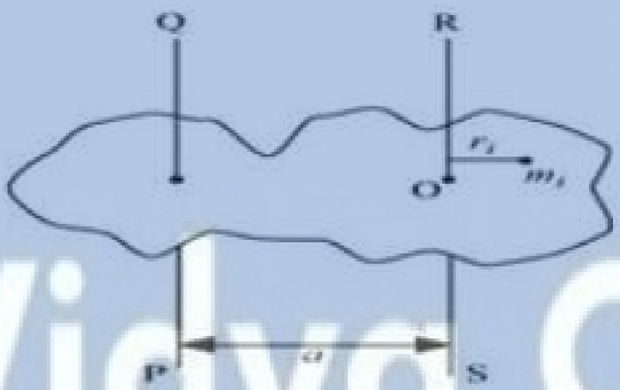
36. a. This theorem is applicable only to the planar bodies. Bodies which are flat with very less or negligible thickness. This theorem states that the moment of inertia of a planar body about an axis perpendicular to its plane is equal to the sum of its moments of inertia about two perpendicular axes 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, $I_x + I_y = mx^2 + my^2$
$= m\left(x^2+y^2\right)$
$= m\left(\sqrt{x^2+y^2}\right)^2$
$I_x + I_y = I_z$
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 :

$$I_{QP} = \sum_{i=1}^{n} m_i (a + r_i)^2$$
$$= \sum_{i=1}^{n} m_i \left(a^2 + r_i^2 + 2ar_i\right)$$
$$= \sum_{i=1}^{n} m_i {r_i}^2 + \sum_{i=1}^{n} m_i a^2 + \sum_{i=1}^{n} m_i 2ar_i$$

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

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

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

$\because$ a $\neq$ 0

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

Also,

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

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

Hence, the theorem is proved.

OR

THE **LAW OF CONSERVATION OF ANGULAR MOMENTUM** STATES THAT: "When the net external torque acting on a system about a given axis is. zero , the total **angular momentum** of the system about that axis remains constant." Mathematically, If then Iw= constant.

In this problem,as all the forces are conservative in nature and external torque on the system is zero so angular momentum of the system will remain conserved although energy of the system may not remain constant if external forces are acting on the system.

a. Moment of inertia of the man-platform system I= 7.6 kg m^2

Moment of inertia when the man stretches his hands to a distance of 90 cm:

$2 \times mr^2$

$= 2 \times 5 \times (0.9)^2$

= 8.1 kg m^2

Initial moment of inertia of the system,$I_i = 7.6 + 8.1 = 15.7 \text{kgm}^2$

Angular speed, $\omega_1 = 300 \text{ rev } / \text{min}$

Angular momentum, $L_i = I_i \omega_i = 15.7 \times 30$ ......(i)

Moment of inertia when the man folds his hands to a distance of 20 cm:

$2 \times m^2$

$= 2 \times 5(0.2)^2 = 0.4\text{kgm}^2$

Final moment of inertia, $I_f = 7.6 + 0.4 = 8kgm^2$

Final angular speed = ω_f

Final angular momentum, $L_f = I_f \omega_f = 0.79\omega_f$ ... (*ii*)

From the conservation of angular momentum, we have:

$I_i \omega_i = I_f \omega_f$

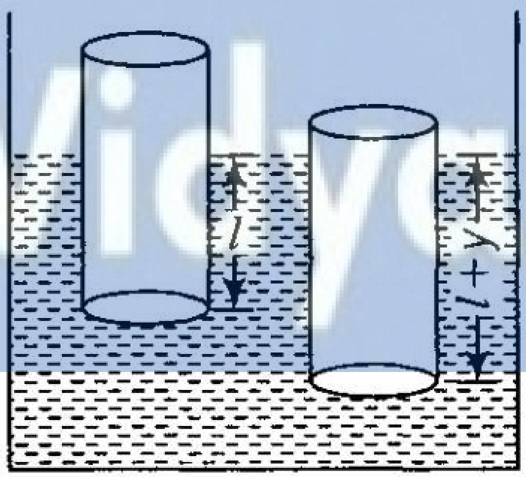
$\therefore \omega_f = \frac{15.7 \times 30}{8} = 58.88 rev/\text{min}$

b. Kinetic energy is not conserved in the given process. In fact, with the decrease in the moment of inertia, kinetic energy increases. The additional kinetic energy comes from the work done by the man to fold his hands toward himself.(muscular work done by the man will be converted into kinetic energy)

37. Consider a cylinder of mass m, length L, density of material ρ and uniform area of cross-section A.

Therefore, mass of the cylinder(m) = A Lρ

Let the cylinder is floating in the liquid of density ρ_1



In equilibrium, let l be the length of cylinder dipping in liquid.

In equilibrium, weight of cylinder = Weight of liquid displaced

$\Rightarrow$ mg = A l ρ_1 g

$\Rightarrow$ m = A lρ_1 ...(ii)

Now say the cylinder is pushed down by y into the liquid, then

Total upward thrust, F_2 = A (l + y) ρ_1 g (since effective depth = l+y)

Restoring force, F = - (F_2 - mg)

$\Rightarrow$F = -[A(l + y)ρ_1g - Alρ_1 g] = -A$\rho_1$gy........(iii)

We know that In SHM, F $\propto$ - y

$\Rightarrow$ F = - k y ...(iv)

Comparing equation (iii) with equation (iv) we get,

Spring factor, k = Aρ_1 g

Inertia factor = mass of the cylinder(m) = ALρ

Now, we know the formula of time period, T = $2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$

Hence, T = $2\pi\sqrt{\frac{AL\rho}{A\rho_1 g}} = 2\pi\sqrt{\frac{L\rho}{\rho_1 g}}$..............(v)

Using, m = Alρ_1 = ALρ

So, $l\rho_1 = L\rho$

Using the above value we get time period,

T = $2\pi\sqrt{\frac{l\rho_1}{g\rho_1}} = 2\pi\sqrt{\frac{l}{g}}$

OR

In mechanics and physics, Simple Harmonic Motion is a special type of periodic motion or oscillation motion where the restoring force is directly proportional to the displacement and acts in the direction opposite to that of displacement.

Spring constant, k = 1200 N m^{-1}

Mass, m = 3 kg

Displacement, A = 2.0 cm = 0.02 cm

i. Frequency of oscillation v, is given by the relation:

   $v = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

   Where T is the time period

   $\therefore v = \frac{1}{2\times 3.14}\sqrt{\frac{1200}{3}} = 3.18\text{m/s}$

   Hence, the frequency of oscillations is 3.18 cycles per second.

ii. Maximum acceleration (a) is given by the relation:

   $a = \omega^2 A$

   Where,

   ω = Angular frequency = $\sqrt{\frac{k}{m}}$

   A = Maximum displacement

$\therefore a = \frac{k}{m} A = \frac{1200 \times 0.02}{3} = 8ms^{-2}$

Hence, the maximum acceleration of the mass is 8.0 m/s^2.

iii. Maximum velocity, $v_{\max} = A\omega$

$= A\sqrt{\frac{k}{m}} = 0.02 \times \sqrt{\frac{1200}{3}} = 0.4 \mathrm{m/s}$

Hence, the maximum velocity of the object is 0.4 m/s at its mean position i.e at x = 0.