Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 1

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

General Instructions:

1. There are 33 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 sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five 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. In SI system the fundamental units are **[1]**

a) meter, kilogram, second, ampere, Kelvin, mole and watt

b) meter, Newton, second, ampere, Kelvin, mole and candela

c) meter, kilogram, second, coulomb, Kelvin, mole, candela and horse power

d) meter, kilogram, second, ampere, Kelvin, mole and candela

2. Two tuning forks of frequency 250 Hz and 256Hz produce beats. If a maximum is produced just now, after how much time the minimum is produced at the same place: **[1]**

a) $\frac{1}{6}s$

b) $\frac{1}{12}s$

c) $\frac{1}{24}$s

d) 0.25 s

3. If $\vec{\mathbf{a}} = \mathrm{a_x}\hat{\mathbf{i}} + \mathrm{a_y}\hat{\mathbf{j}} + \mathrm{a_z}\hat{\mathbf{k}}$ and $\vec{\mathbf{b}} = \mathrm{b_x}\hat{\mathbf{i}} + \mathrm{b_y}\hat{\mathbf{j}} + \mathrm{b_z}\hat{\mathbf{k}}$ then the cross product $\vec{\mathbf{a}} \times \vec{\mathbf{b}}$ is given by: **[1]**

a) $\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$

b) $\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_y & a_z \\ b_x & b_y & b_x \end{vmatrix}$

c) $\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_y & a_z \\ b_x & b_x & b_z \end{vmatrix}$

d) $\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_x & a_z \\ b_x & b_x & b_z \end{vmatrix}$

4. Soldering of two metals possible because of the property of: **[1]**

a) osmosis

b) cohesion

c) surface tension | d) viscosity

5. A spherical planet has a mass M_p and diameter D_p. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to: **[1]**

a) $\frac{\mathrm{GM}_P}{D_P^2}$ | b) $\frac{4\mathrm{GM}_P m}{D_P^2}$

c) $\frac{4\mathrm{GM}_P}{D_P^2}$ | d) $\frac{\mathrm{GM}_P m}{D_P^2}$

6. In a resonance tube, the first resonance with a tuning fork occurs at 16 cm and the second at 49 cm. If the velocity of sound is 330 m/s, the frequency of the tuning fork is **[1]**

a) 330 | b) 300

c) 500 | d) 165

7. A body moving with uniform acceleration has a velocity of 12.0 cm/s in the positive x-direction when its x coordinate is 3.00 cm. If its x coordinate 2.00 seconds later is -5.00 cm, what is the magnitude of its acceleration in $\mathrm{cm/s^2}$? **[1]**

a) -14.0 | b) -12.0

c) -16.0 | d) -18.0

8. A wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is **[1]**

a) 40 m/s | b) 10 m/s

c) 5 m/s | d) 20 m/s

9. The velocity of efflux of a liquid through an orifice in the bottom of the tank does not depend upon **[1]**

a) acceleration due to Force | b) acceleration due to gravity

c) height of liquid | d) size of orifice

10. A satellite is revolving around the earth with a kinetic energy E. The minimum addition of kinetic energy needed to make it escape from its orbit is: **[1]**

a) $\sqrt{E}$ | b) $\frac{E}{2}$

c) E | d) 2E

11. A ring of radius r and mass m rotates about its central axis. The kinetic energy is: **[1]**

a) $\frac{mr\omega^2}{2}$ | b) $\frac{\mathrm{mr}^2\omega^2}{2}$

c) mr ω^2 | d) $\mathrm{mr}^2\ \omega^2$

12. Ratio of the amount of heat radiation, transmitted through the body to the amount of heat radiation incident on it, is known as **[1]**

a) absortance | b) inductance

c) transmittance | d) conductance

13. **Assertion (A):** Power developed in circular motion is always zero. **[1]**

Reason (R): Work done in case of circular motion is zero.

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.

14. **Assertion:** If two bodies are in thermal equilibrium in one frame, they will be in thermal equilibrium in all frames. **[1]**

Reason: The transfer of energy from a hot body to a cold body is a non mechanical process, i.e., the energy is transferred from one body to the other, without any mechanical work.

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.

15. **Assertion (A):** The force of attraction due to a hollow spherical shell of uniform density, on a point mass situated inside it is zero. **[1]**

Reason (R): Various region of the spherical shell attract the point mass inside it in various directions. These forces cancel each other completely.

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.

16. **Assertion (A):** Speed is constant in uniform circular motion. **[1]**

Reason (R): Acceleration is constant in uniform circular motion.

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

17. If two waves of the same frequency but of different amplitudes travelling in opposite directions through a medium superpose upon each other, will they form stationary wave? Is energy transferred? Are there any nodes? **[2]**

18. Find the value of 60 W on a system having 100 g, 20 cm and 1 min as the fundamental units. **[2]**

19. The displacement of a progressive wave is represented by y = A sin(ωt - kx), where x is distance and t is time. Write the dimensional formula of **[2]**

i. ω and

ii. k.

20. What do you mean by inertia of motion? Give an example to illustrate it. **[2]**

21. How much below the surface of the earth does the acceleration due to gravity become 70% of its value at the surface of the earth? Radius of the earth is 6400 km. **[2]**

OR

The mass of planet Jupiter is 1.9×10^{27} kg and that of the sun is 1.99×10^{30}kg. The mean distance of Jupiter from the Sun is 7.8×10^{11}m. Calculate gravitational force which sun exerts on Jupiter, and the speed of Jupiter.

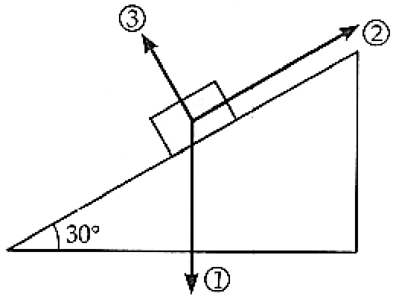
Section C

22. A mercury drop of radius 1.0 cm is sprayed into 10^6 droplets of equal size. Calculate the energy expended. The surface tension of mercury = 32×10^{-2} Nm^{-1}. **[3]**

23. Define thermal conduction. Briefly explain its molecular mechanism. **[3]**

24. A particle is moving along a straight line and its position is given by the relation $x = (t^3 - 6t^2 - 15t + 40)$m Find: **[3]**
   a. The time at which velocity is zero.
   b. Position and displacement of the particle at that point.
   c. Acceleration of the particle at that point.

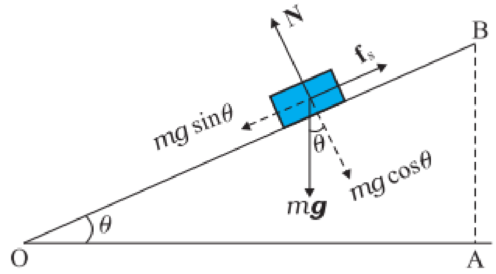
25. A block of wood of mass 3 kg is resting on the surface of a rough inclined surface, inclined at an angle θ as shown in the figure. **[3]**



   a. Name the forces (1, 2, 3).
   b. If the coefficient of static friction is 0.2, calculate the value of all three forces.
   (use $g = 10 m/s^2$)

26. One kilogram molecule of a gas at 400k expands isothermally until its volume is doubled. Find the amount of work done and heat produced. **[3]**

27. A mass of 4 kg rests on a horizontal plane. The plane is gradually inclined until at an angle $\theta = 15°$ with the horizontal, the mass just begins to slide. What is the coefficient of static friction between the block and the surface? **[3]**



28. The flow rate of water from a tap of diameter 1.25 cm is 0.48 $\frac{L}{min}$. The coefficient of viscosity of water is 10^{-3} Pa s. After some time the flow rate is increased to 3 L/min. Characterise the flow for both the flow rates. **[3]**

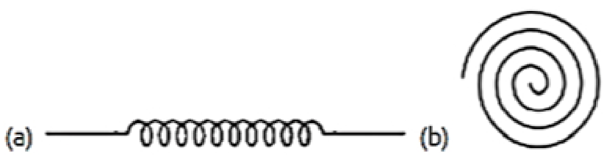
OR

What is terminal velocity and derive an expression for it?

Section D

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

There are many types of spring. Important among these are helical and spiral springs as shown in the figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of the elastic potential energy of the spring. Thus, the potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

(a) The potential energy of a spring increases in which of the following cases?

a) If work is done against conservative force
b) If work is done by non-conservative force
c) If work is done by conservative force
d) If work is done against non-conservative force

(b) The potential energy, i.e. U(x) can be assumed zero when

a) gravitational force is constant
b) x = 0
c) infinite distance from the gravitational source
d) All of these

(c) The ratio of spring constants of two springs is 2 : 3. What is the ratio of their potential energy, if they are stretched by the same force?

a) 3 : 2
b) 9 : 4
c) 2 : 3
d) 4 : 9

OR

The potential energy of a spring when stretched through a distance x is 10 J. What is the amount of work done on the same spring to stretch it through an additional distance x?

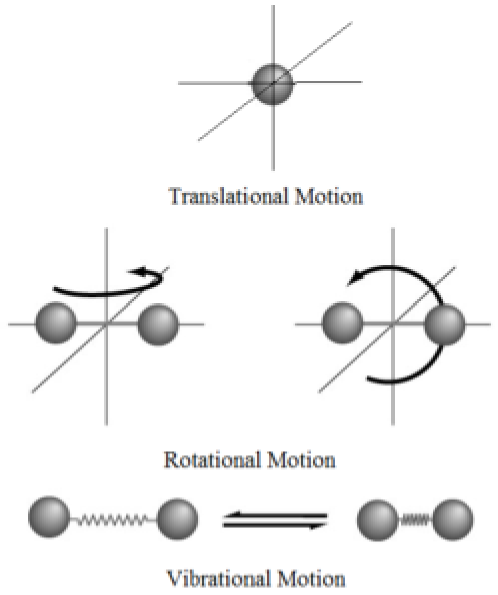
a) 40 J
b) 10 J
c) 30 J
d) 20 J

(d) The potential energy of a spring increases by 15 J when stretched by 3 cm. If it is stretched by 4 cm, the increase in potential energy is

a) 36 J
b) 30 J
c) 27 J
d) 33 J

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

The number of independent ways by which a dynamic system can move, without violating any constraint imposed on it, is called the number of **degrees of freedom**. According to the law of equipartition of energy, for any dynamic system in thermal equilibrium, the total energy for the system is equally divided among the degree of freedom.



(a) If gas has n degree of freedom, the ratio of specific heat is:

a) -2n
b) 2n
c) 1 + 2/n
d) 1 - 2/n

(b) The kinetic energy, due to translational motion, of most of the molecules of an ideal gas at absolute temperature T, is:

a) kT^3
b) kT^2
c) kT
d) k/T

(c) The mean free path is the:

a) length of the container that contains the gas
b) mean of the square of the average distance between two successive collisions
c) the average distance covered by a molecule between two successive collisions
d) height of the container that contains the gas

(d) The law of equipartition of energy is applicable to the system whose constituents are:

a) in non random motion
b) in random motion
c) in orderly motion
d) in rest

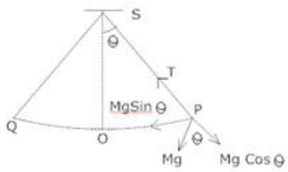
OR

Thermochemical calorie is equal to

a) 41.48 joule
b) 4.148 joule
c) 4148 joule
d) 414.8 joule

Section E

31. What is Simple pendulum? Find an expression for the time period and frequency of a simple pendulum? **[5]**



OR

A particle executes simple harmonic motion of amplitude A.

i. At what distance from the mean position is its kinetic energy equal to its potential energy?
ii. At what points is its speed half the maximum speed?

32. Given $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$, which of the following statements are correct: **[5]**

i. $\vec{a}, \vec{b}, \vec{c}$, and $\vec{d}$ must each be a null vector.
ii. The magnitude of $(\vec{a} + \vec{c})$ equals the magnitude of $(\vec{b} + \vec{d})$.
iii. The magnitude of '$\vec{a}$' can never be greater than the sum of the magnitudes of $\vec{b}, \vec{c}$, and $\vec{d}$.
iv. $\vec{b} + \vec{c}$ must lie in the plane of $\vec{a}$ and $\vec{d}$ if $\vec{a}$ and $\vec{d}$ are not collinear, and in the line of $\vec{a}$ and $\vec{d}$, if they are collinear?

OR

A fighter plane is flying horizontally at an altitude of 1.5 km with a speed of 720 km/h. At what angle of sight (w.r.t horizontal) when the target is seen, should the pilot drop the bomb in order to attack the target?

Main concept used: u = 720 km/h = $720 \times \frac{5}{18}$ m/s = 200m/s

33. Determine the position of the centre of mass of a hemisphere of radius R. **[5]**

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.

Solution

Section A

1.

(d) meter, kilogram, second, ampere, Kelvin, mole and candela

Explanation: The SI base units and their physical quantities are the metre for measurement of length, the kilogram for mass, the second for time, the ampere for electric current, the kelvin for temperature, the candela for luminous intensity, and the mole for amount of substance.

2.

(d) 0.25 s

Explanation: The time interval between two consecutive maxima and minima is

$\triangle t = \frac{1}{n_1 - n_2}$

For consecutive maxima and minima, the time interval will be $\frac{1}{4}$ s or 0.25s

Thus time interval between maxima and minima at the same place will be $\frac{1}{4}$ s or 0.25s

3. **(a)** $\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$

Explanation: $\vec{\mathbf{a}} \times \vec{\mathbf{b}}$ = $(a_y b_z - a_z b_y)\hat{\mathbf{i}}$ - $(a_x b_z - a_z b_x)\hat{\mathbf{j}}$ + $(a_x b_y - a_y b_x)\hat{\mathbf{k}}$

As the cross product is the determinant of a 3x3 matrix.

$\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \mathrm{a_x} & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$

4.

(b) cohesion

Explanation: Cohesion is the attractive force among the same kind of materials. Thus soldering of two metals is possible due to cohesion.

5.

(c) $\frac{4\mathrm{GM}_P}{D_P^2}$

Explanation: Gravitational attraction on the particle,

F = $G\frac{M_p m}{\left(\frac{D_p}{2}\right)^2}$

Acceleration due to gravity,

$g = \frac{F}{m} = \frac{4GM_P}{D_P^2}$

6.

(c) 500

Explanation: v = 2 ν(l_2 - l_1)

330 = 2ν(0.49 - 0.16)

$\nu = \frac{330}{2 \times 0.33}$ = 500 Hz

7.

(c) -16.0

Explanation: Distance covered s = Final position - initial position = -5 - 3 = -8 cm

Initial velocity u = 12.0 cm/s

Time taken t = 2.0 s

We know

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

$\Rightarrow$ - 8 = 2 $\times$ 12.0 + $\frac{1}{2}a \times 4$

$\Rightarrow$ -8 = 24 + 2a

$\Rightarrow$ a $=\frac{-8-24}{2}$ = −16.0 cm/s^2 hence this is required result

8.

(d) 20 m/s

Explanation: Distance between two nodes, i.e.,

($\frac{\lambda}{2}$) = 10 or λ = 20 cm

Now, v = nλ = 100 $\times$ 20 cm/sec = 20 m/sec

9.

(d) size of orifice

Explanation: Velocity of efflux, v = $\sqrt{2gh}$

Clearly, it does not depend on the size of the orifice.

10.

(c) E

Explanation: v_0 = $\sqrt{\frac{GM}{r}}$ and v_e = $\sqrt{\frac{2GM}{r}}$

Initial K.E., E = $\frac{1}{2}mv_0^2 = \frac{1}{2}\frac{\text{CMm}}{r}$

Total K.E. neede for escaping,

$E = \frac{1}{2}mv_e^2 = \frac{1}{2}m \times \frac{2GM}{r} = \frac{GMm}{r}$ = 2E

Additional K.E. needed for escaping

= E' - E = 2E - E = E

11.

(b) $\frac{\text{mr}^2\omega^2}{2}$

Explanation: The kinetic energy of the body in rotational motion is $KE = \frac{1}{2}I\omega^2 = \frac{1}{2}mr^2\omega^2$ as a moment of inertia of ring about its central axis is I = mr^2.

12.

(c) transmittance

Explanation: The ratio of the amount of heat transmitted through an object to the amount of heat incident on it is called transmittance.

13.

(d) A is false but R is true.

Explanation: In case of the uniform circular motion, the tangential force is zero, only force is the centripetal force. Since the velocity of the body along the direction of the centripetal force is zero, so the power developed by the centripetal force is zero or in term of work done which is zero in circular motion (because displacement is zero) thus the power which is work done per unit time is also zero.

In the case of the non-uniform circular motion, the body has velocity in the direction of the tangential force. That is why, we say that this force develops power. In uniform motion α = 0, τ = 0. No work is done.

14.

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

Explanation: Assertion and reason both are correct statements but reason is not correct explanation for assertion.

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

Explanation: Both A and R are true and R is the correct explanation of A.

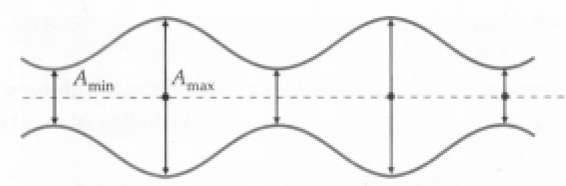
16.

(c) A is true but R is false.

Explanation: A is true but R is false.

Section B

17. Yes, the given waves superpose to form stationary waves of the form shown in Fig. No energy is transferred. There are no nodes but there are positions of minimum amplitude.



18. Given, n_1 = 60 W, power, P is $[M^1L^2T^{-3}]$

In first system, M_1 = 1 kg = 1000 g, L_1 = 1 m = 100 cm, and T_1 = 1 s

In second system, M_2 = 100 g, L_2 = 20 cm and T_2 = 1 min = 60 s

In a given physical quantity, the product of its magnitude and unit is always constant.

$n_1u_1 = n_2u_2$

$n_2 = n_1\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-3}$

$= 60\left[\frac{1000\text{g}}{100\text{g}}\right]\left[\frac{100\text{cm}}{20\text{cm}}\right]^2\left[\frac{1\text{s}}{60\text{s}}\right]^{-3}$

$= 60 \times \frac{1000}{100} \times \frac{100}{20} \times \frac{100}{20} \times 60 \times 60 \times 60$

$= 3.24 \times 10^9$ units

19. Dimensional formula in L.H.S. and R.H.S. by principal of homogeneity are equal.

$\therefore$ Dimension of y = dimensions of A sin (ωt - kx)

[L] = [L] $\times$ dimensions of (ωt - kx)

as (ωt - kx) are angle of sin (Trigonmetrical ratio)

So (ωt - kx) = No dimension or dimensions of ωt = dimensions of kx

$\frac{2\pi}{T}$ = Kx $\Rightarrow$ $[M^0L^0T^0]$ = k[L]

Hence, Dimension of k = $\frac{[M^0L^0T^9]}{|L|}$ = $[M^0L^{-1}T^0]$, Dimension of ω = No dimension

20. Inertia of motion is the tendency of a body to maintain its state of uniform motion. As an illustration, we observe that a person jumping out of a running train or bus falls with his head in forward direction due to the inertia of motion. Similarly, passengers experience a forward push when the driver of a bus running at high speed suddenly applies brakes.

21. Here, it is given that the acceleration due to gravity becomes 70% of the value on surface of the Earth at a depth d.

So, 70% value of g means $\frac{70}{100}$g = 0.7 g

Hence, it is clear that g at depth d becomes g(d) = 0.7 g

Now, we know the formula for g at depth as

g(d) = g(1 - $\frac{d}{R_E}$)

Here, R_E is the radius of the Earth and g is the acceleration due to gravity on the surface of the Earth.

So, we get

0.7g = g(1 - $\frac{d}{R_E}$)

0.7 = 1 - $\frac{d}{R_E}$

$\frac{d}{R_E}$ = 1 - 0.7 = 0.3

$\therefore$ d = 0.3 R_E = 0.3 $\times$ 6400 = 1920 km

Hence, we can see that at a depth of 1920 km from the surface of the Earth, the value of g becomes 70% as that on surface.

OR

The mass of planet Jupiter is(m_2) = 1.9 $\times$ 10^{27} kg

The mass of sun is 1.99 $\times$ 10^{30}kg.

The mean distance of Jupiter from the Sun is(r) = 7.8 $\times$ 10^{11}m

$F = \frac{GMm_2}{r^2}$

$= \frac{6.67\times10^{-11}\times1.99\times10^{30}\times1.9\times10^{27}}{\left(7.8\times10^{11}\right)^2}$

$F = 4.1 \times 10^{23}N$

$\therefore F = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{GMm}{r^2} \times \frac{r}{m}}$

$v = 1.3 \times 10^4\text{ms}^{-1}$

Section C

22. The volume of 10^6 droplets = Volume of a larger drop

$10^6 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

r = 10^{-2} R = $10^{-2} \times 1.0 = 10^{-2}$ cm = 10^{-4} m

The surface area of a larger drop

= $4\pi R^2 = 4\pi \times (10^{-2})^2 = 4\pi \times 10^{-4} m^2$

The surface area of 10^6 droplets

= $4\pi r^2 \times 10^6 = 4\pi \times (10^{-4})^2 \times 10^6$

= $4\pi \times 10^{-2}$ m^2

∴ Increase in surface area

= $4\pi \times 10^{-4} (100 - 1) = 4\pi \times 99 \times 10^{-4}$ m^2

∴ Work done in spraying a spherical drop of mercury

= Surface tension × increase in surface area

= $32 \times 10^{-2} \times 4\pi \times 99 \times 10^{-4} = 3.98 \times 10^{-2}$ J

23. Conduction of Heat is a process where heat is transferred from the hotter part of the body to the colder part without involving any actual movement of the body molecules.

In conduction, the heat transfer takes place at the molecular level without actual movement of molecules, from the hottest to the coldest surface.

In the process of heat transfer, the molecules pump into their neighbors and transfer the energy to them which continue as long as heat is still being added

The transfer between bodies continue unit the temperature different decays and a state knows as thermal equilibrium occurs.

Greater the value thermal conductivity K of body better is its heat conducting capability.

For insulator this value of K is zero.

24. x = $t^3 - 6t^2 - 15t + 40$

$\therefore v = \frac{dx}{dt} = \left(3t^2 - 12t - 15\right) m/s$ (As velocity = 1st order derivative of displacement, x with respect to time, t) and

$a = \frac{dv}{dt} = (6t - 12)\, m/s^2$ (As acceleration = 1st order derivative of velocity, v with respect to time, t)

a. By the problem, v = $3t^2 - 12t - 15 = 0$

⇒ $3t^2 - 15t + 3t - 15 = 0$

⇒ 3t(t - 5) + 3(t - 5) = 0

⇒ (3t + 3)(t - 5) = 0

So we get, either t = -1 or t = 5

But we know that time cannot be negative.

∴ t = 5 seconds.

b. Now, position at t = 5 s,

$x_5 = (5)^3 - 6(5)^2 - 15(5) + 40 = -60$ m (final position)

and (ii) Now to get displacement, at t = 0 s, position x_0 = 40m (initial position)

∴Displacement from t = 0s to t = 5s,

s = $x_5 - x_0$

⇒ s = -60 - 40

⇒ s = -100m

c. Acceleration at t = 5s, using the equation $a = 6t^2 - 12\, m/s^2$

∴a = 6(5) - 12

⇒ a = (30 - 12)

⇒ a = 18 m/s^2

This is the acceleration of the particle at that instant when velocity becomes zero.

25. a. Force 1 = The weight mg acting vertically downwards

Force 2 = The static frictional force opposing the impending motion

Force 3 = The normal force of the plane of the block

b. Here m is mass of body and g is value of acceleration due to gravity.

Thus, Force 1 = m g = 3 × 10 = 30 Newton

If θ = 30° and μ = 0.2 then angle θ is greater than the angle of repose. Hence the force of friction f has its maximum value f_m = μmg cos θ.

Therefore, Force 2 = $\mu mg \cos\theta = 0.2 \times 3 \times 10 \times \cos 30^\circ$ = 5.2 Newton

Force 3 = mg cos θ = 26 Newton

26. Initial volume of gas ,V_1= V

Final volume of gas, V_2 = 2 V

Initial temperature of gas T = Final temperature of gas = 400 K (∴ process is isothermal)

Universal gas constant, R = 8. 3 kJ /mole / K = 8.3x10^{-3} J/mole/ K

Work done during isothermal process=w=2.3026 RT $\text{Log}_{10}\left(\frac{V_2}{V_1}\right)$

$W = 2.3026 \times 8.3 \times 10^{-3} \times 400 \times \log_{10}\left(\frac{2V}{V}\right)$

$W = 2.3026 \times 8.3 \times 10^{-3} \times 400 \times log_{\ 10}\ (2)$

W = 2.3016J

If H is the heat produced then,

$H = \frac{W}{J} = \frac{2.3016}{4.2} = 0.548 cal$

27. The forces acting on a block of mass m at rest on an inclined plane are

i. the weight mg acting vertically downwards
ii. the normal force N of the plane on the block, and
iii. the static frictional force fs opposing the impending motion.

In equilibrium, the resultant of these forces must be zero. Resolving the weight mg along the two directions shown, we have mg sin θ = f_s, mg cos θ = N

As θ increases, the self-adjusting frictional force fs increases until at $\theta = \theta_{\text{max}'}$ f_s achieves its maximum value,

$(f_s)_{\text{max}} = \mu_s N$

Therefore,

$\tan\theta_{\text{max}} = \mu_s$ or $\theta_{\text{max}} = \tan^{-1}\mu_s$

When θ becomes just a little more than θ_{max}, there is a small net force on the block and it begins to slide.

Note that θ_{max} depends only on μ_s and is independent of the mass of the block.

For $\theta_{\text{max}} = 15^\circ$

$\mu_s = \tan 15^\circ$

= 0.27

28. Let the speed of the flow be v.

Given, diameter of tap = d = 1.25 cm

Volume of water flowing out per second.

Q = v × $\frac{\pi d^2}{4} \Rightarrow$ v = $\frac{4Q}{d^2\pi}$

Estimate Reynold's number, R_e = $\frac{4\rho Q}{\pi d\eta}$

Q = 0.48 $\frac{L}{min}$ = 8 × 10^{-3} $\frac{L}{s}$ = 8 × 10^{-6} $\frac{m^3}{s}$

$R_e = \frac{4\times10^3\times8\times10^{-6}}{3.14\times1.25\times10^{-2}\times10^{-3}}$

R_e = 815 [i.e. below 1000, the flow is steady] After some time, when

Q = 3 $\frac{L}{min}$ = 5 × 10^5 $\frac{m^3}{s}$

R_e = $\frac{4\times10^3\times5\times10^{-5}}{314\times1.25\times10^{-2}\times10^{-3}}$ = 5095

∴ The flow will be turbulent.

OR

Terminal velocity is the maximum constant velocity acquired by the body which is falling freely in a viscous medium, due to the balanced net downward force acting on the body with the upward resistive viscous force offered by the medium on the body.

When a small spherical body falls freely through a viscous medium then 3 forces act on it:-

i. Weight of body acting vertically downwards.
ii. Up thrust due to buoyancy = weight of fluid displaced by the body, acting upwards.
iii. Viscous drag (F_V) or resistive viscous force acting in the direction opposite to the motion of body.

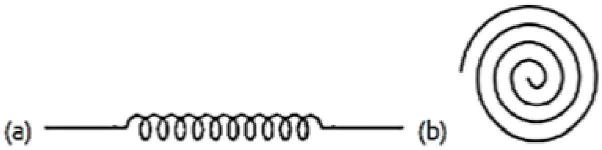
Let ρ = Density of the material of the spherical body

r = Radius of the spherical body
σ = Density of the viscous medium.
$\therefore$ True weight of the body = W = volume of the body $\times$ density of the body $\times$ g
$\therefore W=\frac{4}{3}\pi r^3\rho g$
Up ward thrust by the fluid, F_T = weight of medium displaced by the spherical body = volume of the body × density of the viscous medium × g
$=\frac{4}{3}\pi r^3\sigma g$
Say, v_T = Terminal velocity of body
According to Stoke's law, viscous drag or viscous force,
$F_V=6\pi\eta v_T$ (η being coefficient of viscosity of the medium)
When the body attains terminal velocity v_T, then
$F_T + F_V = W$
$\Rightarrow \frac{4}{3}\pi r^3\sigma g+6\pi\eta r v_T=\frac{4}{3}\pi r^3\rho g$
$\therefore v_T=\frac{2r^2(\rho-\sigma)g}{9\eta}$

i. v_T directly depends on radius of body and difference of the pressure of material and medium.
ii. v_T inversely depends of co-efficient of viscosity of the medium.

Section D

29. **Read the text carefully and answer the questions:**
There are many types of spring. Important among these are helical and spiral springs as shown in the figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of the elastic potential energy of the spring. Thus, the potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

(i) **(a)** If work is done against conservative force
Explanation: If work is done against conservative force

(ii) **(d)** All of these
Explanation: All of these

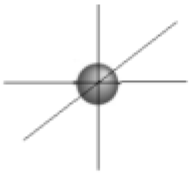
(iii) **(a)** 3 : 2
Explanation: 3 : 2

OR

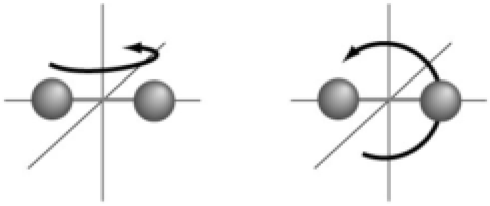
(c) 30 J
Explanation: 30 J

(iv) **(c)** 27 J
Explanation: 27 J

30. **Read the text carefully and answer the questions:**
The number of independent ways by which a dynamic system can move, without violating any constraint imposed on it, is called the number of **degrees of freedom**. According to the law of equipartition of energy, for any dynamic system in thermal equilibrium, the total energy for the system is equally divided among the degree of freedom.



Translational Motion



Rotational Motion

Vibrational Motion

(i) **(c)** 1 + 2/n

Explanation: 1 + 2/n

(ii) **(c)** kT

Explanation: kT

(iii) **(c)** the average distance covered by a molecule between two successive collisions

Explanation: the average distance covered by a molecule between two successive collisions

(iv) **(b)** in random motion

Explanation: in random motion

OR

(b) 4.148 joule

Explanation: 4.148 joule

Section E

31. A simple pendulum is the most common example of the body executing S.H.M, it consists of heavy point mass body suspended by a weightless inextensible and perfectly flexible string from rigid support, which is free to oscillate. When a pendulum is displaced sideways from its resting, equilibrium position, it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. When released, the restoring force acting on the pendulum's mass causes it to oscillate about the equilibrium position, swinging back and forth. The time for one complete cycle, a left swing and a right swing, is called the period.

Let m = mass of bob

l = length of a pendulum

Let O is the equilibrium position, OP = X

Let θ = small angle through which the bob is displaced.

The forces acting on the bob are:-

i. The weight = Mg acting vertically downwards.
ii. The tension = T in string acting along Ps.

Resolving Mg into 2 components as Mg Cos θ and Mg Sin θ,

Now, T = Mg Cos θ

Restoring force F = - Mg Sin θ

- ve sign shows force is directed towards mean position.

Let θ = Small, so Sin $\theta \approx \theta$ = $\frac{\text{Arc(op)}}{1} = \frac{\text{x}}{1}$

Hence F = - mg θ

$\Rightarrow$F = - mg $\frac{x}{l} \rightarrow 3)$

Now, In S.H.M, F = k x $\rightarrow$ 4)

where,k = Spring constant

Equating equation 3) & 4) for F

$\Rightarrow$- k x = - m g $\frac{x}{l}$

$\Rightarrow$Spring factor = $k=\frac{mg}{l}$

Inertia factor = Mass of bob = m

Now, Time period = T

$=2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$

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

OR

The potential energy and kinetic energy of a particle at a displacement y are given

E_p = $\frac{1}{2}ky^2$

and E_k = $\frac{1}{2}k\left(A^2-y^2\right)$ ...(i)

where A is the amplitude and k is the force constant.

i. As E_k = E_p

$\therefore \frac{1}{2}k\left(A^2-y^2\right)=\frac{1}{2}ky^2$ or $2y^2 = A^2$

or y = $\pm\frac{A}{\sqrt{2}}=\pm$ 0.71 A

= 0.71 times the amplitude on either side of the mean position.

ii. Here, v = $\frac{1}{2}v_{\max}$

In general, kinetic energy

= $\frac{1}{2}mv^2=\frac{1}{2}m\left(\frac{1}{2}v_{\max}\right)^2$ = $\frac{1}{4}\cdot\frac{1}{2}mv_{\max}^2$

= $\frac{1}{4}\times$ Maximum kinetic energy

or E_k = $\frac{1}{4}\times(E_k)_{\max}$ ...(ii)

From equation (i),

E_k = $\frac{1}{2}k\left(A^2-y^2\right)$

$\therefore (E_k)_{max}$ = $\frac{1}{2}kA^2$ [Put y = 0]

Putting these values in equation (ii), we get

$\frac{1}{2}k\left(A^2-y^2\right)$ = $\frac{1}{4}\times\frac{1}{2}kA^2$

or $4y^2 = 3A^2$

or y = $\pm\frac{\sqrt{3}}{2}A=\pm$ 0.86 A

= 0.86 times the amplitude on either side of the mean position.

32. i. Incorrect

In order to make $\vec{a}+\vec{b}+\vec{c}+\vec{d}$ = 0, it is not necessary to have all the four given vectors to be null vectors. There are many other combinations that can give the sum zero.

ii. Correct

$\vec{a}+\vec{b}+\vec{c}+\vec{d}=0$

$\vec{a}+\vec{c}=-(\vec{b}+\vec{d})$

Taking modulus on both the sides, we get:

$|\vec{a}+\vec{c}|=|-(\vec{b}+\vec{d})|=|\vec{b}+\vec{d}|$

Hence, the magnitude of $(\vec{a}+\vec{c})$ is the same as the magnitude of $(\vec{b}+\vec{d})$.

iii. Correct

$\vec{a}+\vec{b}+\vec{c}+\vec{d}=0$

$\vec{a}=(\vec{b}+\vec{c}+\vec{d})$

Taking modulus both sides, we get:

$|\vec{a}|=|\vec{b}+\vec{c}+\vec{d}|$

$|\vec{a}|\leq|\vec{a}|+|\vec{b}|+|\vec{c}|$ ....(i)

Equation (i) shows that the magnitude of a is equal to or less than the sum of the magnitudes of $\vec{b}$, $\vec{c}$, and $\vec{d}$.

Hence, the magnitude of a vector can never be greater than the sum of the magnitudes of b, c, and d.

iv. Correct

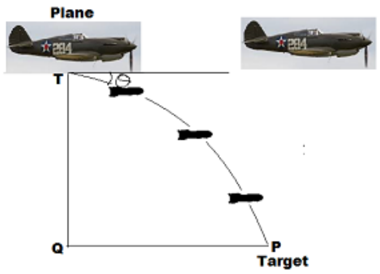
For $\vec{a}+\vec{b}+\vec{c}+\vec{d}=0$

$\vec{a}+(\vec{b}+\vec{c})+\vec{d}=0$

The resultant sum of the three vectors $\vec{a}$, $(\vec{b}+\vec{c})$, and d can be zero only if $(\vec{b}+\vec{c})$ lie in a plane containing a and d, assuming that these three vectors are represented by the three sides of a triangle.

If a and d are collinear, then it implies that the vector $(\vec{b} + \vec{c})$ is in the line of a and d. This implication holds only then the vector sum of all the vectors will be zero.

OR



Let the pilot drops the bomb in **t** second before the point **Q**, vertically up the target **T**.

The horizontal velocity of the bomb will be equal to the velocity of the fighter plane, but the vertical component of it is zero.

So, in time **t** bomb must cover the vertical distance **TQ** as free fall with the initial velocity zero.

Given that : $u = 0, \ \ H = 1.5 \ km = 1500m \ , \ \ g = +10 m/s^2$

By Using the equation, $H = ut + \frac{1}{2}gt^2$, we get

$1500 = 0 + \frac{1}{2}10t^2$

$t = \sqrt{\frac{1500}{5}} = \sqrt{300} = 10\sqrt{3}s$

$\therefore$ Distance covered by plane or bomb in this time **t**, is given by PQ = ut

$PQ = 200 \times 10\sqrt{3} = 2000\sqrt{3} \ m$

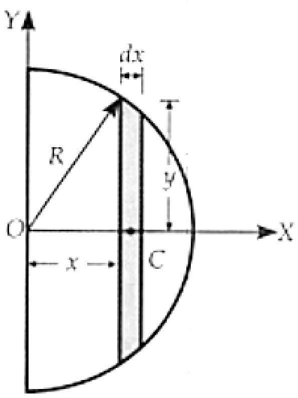
$\tan\theta = \frac{TQ}{PQ} = \frac{1500}{2000\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{15\sqrt{3}}{20\times 3} = \frac{\sqrt{3}}{4}$

$\tan\theta = \frac{1.732}{4} = 0.433 = \tan^{-1}23^\circ \ 42'$

$\Rightarrow \theta = 23^\circ 42'$

Thus the bomb should be thrown at an angle $23^\circ 42'$

33. Let ρ be the density of the material of the hemisphere. Take its centre O as the origin. The hemisphere can be assumed to be made of up a large number of co-axial discs. Consider one such elementary disc of radius y and thickness dx at a distance x from the origin.



Mass of the elementary disc = Volume $\times$ density

$dm = \pi y^2 dx \times \rho = \pi\left(R^2 - x^2\right) dx \cdot \rho$

The coordinates of the centre of mass of the hemisphere can be determined as follows:

$x_{CM} = \frac{1}{M}\int x dm = \frac{1}{M}\int_0^R x\pi\left(R^2 - x^2\right)\rho dx$

$= \frac{\pi\rho}{M}\int_0^R \left(R^2 x - x^3\right) dx = \frac{\pi\rho}{M}\left[R^2\frac{x^2}{2} - \frac{x^4}{4}\right]_0^R$

$= \frac{\pi\rho}{M}\left[\frac{R^4}{2} - \frac{R^4}{4}\right] = \frac{\pi\rho}{M}\left[\frac{R^4}{4}\right]$

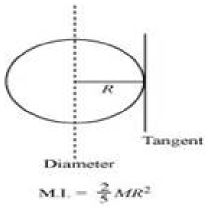
$= \frac{\pi\rho}{\frac{2}{3}\pi R^3\rho}\left(\frac{R^4}{4}\right) = \frac{3}{8}R \quad \left[\because M = \frac{2}{3}\pi R^3 \times \rho\right]$

Similarly, $y_{CM} = \int y dm = 0$ and $z_{CM} = \int z dm = 0$

Hence the coordinates of the centre of mass of the hemisphere are $\left(\frac{3}{8}R, 0, 0\right)$

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 = $I_x = I_y = (\frac{1}{4})mR^2$

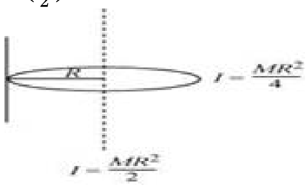
Using , perpendicular axis theorem,

$I_z = I_x + I_y$

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

$I = I_z + mR^2$

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

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