Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 8

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. Measurement of a physical quantity is essentially the **[1]**

a) process of comparing with a standard using an instrument

b) process of observing the physical quantity

c) process of taking readings on an instrument

d) process of subdividing the physical quantity

2. Equation of plane wave is $y = 4\sin\frac{\pi}{4}\left[2t + \frac{x}{8}\right]$ **[1]**

The phase difference at any given instant of two particles 16 cm apart is

a) 60°

b) 30°

c) 90°

d) 120°

3. What is the distance of the centre of mass of a half ring from its centre if its radius is 0.5 m? **[1]**

a) $\frac{1}{3\pi}m$

b) $\frac{1}{\pi}m$

c) $\frac{2}{3\pi}m$

d) $\frac{1}{2\pi}m$

4. A tank with a square base of area 2.0 m^2 is divided into two compartments by a vertical partition in the middle. There is a small hinged door of face area 20 cm^2 at the bottom of the partition. Water is filled in one compartment and acid, of relative density 1.7, in the other, both to a height of 4m. If g = 10 ms^{-2} the force necessary to keep the door closed is: **[1]**

a) 80.88 N

b) 20.92 N

c) 40.52 N

d) 54.88 N

5. A particle falls towards earth from infinity. Its velocity on reaching the earth would be: **[1]**

a) Infinity

b) Zero

c) $2\sqrt{gR}$

d) $\sqrt{2gR}$

6. A closed organ pipe (closed at one end) is excited so as to support the third overtone. It is then found that there are in the pipe: **[1]**

a) three nodes and four antinodes

b) four nodes and three antinodes

c) four nodes and four antinodes

d) three nodes and three antinodes

7. A jet lands on an aircraft carrier at 30 m/s. It stops in 2.0 s. What is the displacement of the plane when it stops? **[1]**

a) 45

b) 30

c) 35

d) 40

8. The wavelength difference of light waves of wave numbers 2×10^6 / m and 2.25×10^6 / m is **[1]**

a) 0.556×10^6 m

b) 0.556×10^{-6} m

c) 0.0556×10^6 m

d) 0.0556×10^{-6} m

9. A raindrop is released from a cloud 1000 m above ground. When the drop is about to hit the ground, its speed will be **[1]**

a) Cannot be predicted

b) Constant terminal speed

c) Decreasing due to retardation from air drag

d) Increasing due to acceleration due to gravity

10. Deimos, a moon of Mars, is about 12 km in diameter with mass 2.0×10^{15} kg. Suppose you are stranded alone on Deimos and want to play a one-person game of baseball. You would be the pitcher, and you would be the batter! With what speed would you have to throw a baseball so that it would go into a circular orbit just above the surface and return to you so you could hit it? **[1]**

a) 4.7 m/s

b) 5.1 m/s

c) 4.3 m/s

d) 4.9 m/s

11. The instantaneous angular position of a point on a rotating wheel is given by the equation $\theta(t) = 2t^3 - 6t^2$. The torque on the wheel becomes zero at **[1]**

a) t = 0.25 s

b) t = 0.5 s

c) t = 2 s

d) t = 1 s

12. A liquid boils when its vapour pressure is equal to **[1]**

a) atmospheric pressure

b) double of atmospheric pressure

c) 6.0 cm of Hg column

d) 1000 pa or more

13. **Assertion:** In elastic collision between two bodies, the relative speed of the bodies after collision is equal to the relative speed before the collision. **[1]**

Reason: In an elastic collision, the linear momentum is conserved.

a) Assertion and reason both are correct statements and reason is correct explanation

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

explanation for assertion.

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

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

14. **Asseertion:** Thermodynamics processes in nature are irreversible. **[1]**

Reason: Dissipative effects cannot be eliminated.

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:** Moon travellers tie heavy weight at their back before landing on moon. **[1]**

Reason: The value of g is small at moon.

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.

16. **Assertion (A):** If $\vec{A}$ is parallel to $\vec{B}$ then $\vec{A} \times \vec{B}$ is a null vector. **[1]**

Reason (R): The magnitude cross product of two vectors is given by, $|\vec{A} \times \vec{B}|$ = AB sin θ.

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

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

c) A is true but R is false.

d) A is false but R is true.

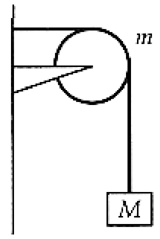
Section B

17. Two monoatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate containers kept at the same temperature. What is the ratio of the speed of sound in gas 1 to that in gas 2? **[2]**

18. State the rules for finding the number of significant figures in a measurement. **[2]**

19. 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 its length (l), mass of the bob (m) and acceleration due to gravity (g). Derive the expression for its time period using method of dimensions. **[2]**

20. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in figure. Find the force exerted on the pulley by the clamp. **[2]**



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

OR

A spherical planet has mass M_P and diameter D_P. A particle of mass m falling freely near the surface of this planet will experience acceleration due to gravity, equal to whom?

Section C

22. The reading of pressure meter attached to a closed pipe is 3.5×10^5 Nm^{-2}. On opening the valve of the pipe, the reading of the pressure meter is reduced to 3.0×10^5 Nm^{-2}. Calculate the speed of the water flowing in the pipe. **[3]**

23. Calculate the stress developed inside a tooth cavity filled with copper when hot tea at temperature of 57^oC is drunk. You can take body (tooth) temperature to be 37^o C and $\alpha = 1.7 \times 10^{-5}$/K. Bulk modulus for copper = 140 $\times$ $10^9 N/m^2$. **[3]**

24. At t = 0, a particle is at rest at origin. Its acceleration is 2 m/s^2 for the first 3 s and -2 m/s^2 for next 3s. Plot the acceleration versus time and velocity versus time graph. **[3]**

25. State three basic laws of motion. Show that the first law of motion gives the definition of force and the second law of motion gives the measure of force. **[3]**

26. In a refrigerator, heat from inside of a refrigerator at 270 K is transferred to a room at 300 K. **[3]**
    i. What is its coefficient of performance?
    ii. How much heat will be delivered to the room for each joule of electric energy consumed? Assume the refrigerator to be an ideal one.

27. A moving neutron with speed 10^6 m /s collides with a deuteron at rest and sticks to it. Find the speed of the combination if masses of the neutron and deuteron are 1.67×10^{-27} kg and 3.34×10^{-27} kg, respectively. **[3]**

28. In a glass capillary tube, water rises upto a height of 10.0 cm while mercury fall down by 5.0 cm in the same capillary. If the angles of contact for mercury glass is 60^o and water glass is 0^o, then find the ratio of surface tension of mercury and water. **[3]**

OR

A ball floats on the surface of water in a container exposed to the atmosphere. Will the ball remain immersed at its initial depth or will it sink or rise somewhat if the container is shifted to the moon?

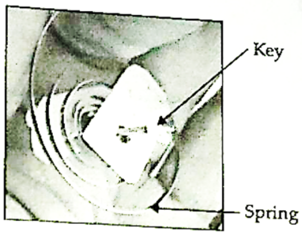
Section D

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

Clockwork refers to the inner workings of mechanical clock or watch (where it is known as "movement") and different types of toys which work using a series of gears driven by a spring. Clockwork device is completely mechanical and its essential parts are:

- A key (or crown) which you wind to add energy
- A spiral spring in which the energy is stored
- A set of gears through which the spring's energy is released. The gears control how quickly (or slowly) a clockwork machine can do things. Such as in mechanical clock/watch the mechanism is the set of hands that sweep around the dial to tell the time. In a clockwork car toy, the gears drive the wheels.

Winding the clockwork with the key means tightening a sturdy metal spring, called the mainspring. It is the process of storing potential energy. Clockwork springs are usually twists of thick steel, so tightening them (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.



While the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower. In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

(a) What is the meaning of **movement** of old age mechanical clocks?

a) The pendulum of the clock
b) The gears which move the hands of the clock
c) A spring and combination of gears which move the hands of the clock
d) The hands of the clock

(b) What type of energy is stored in the spring while winding it?

a) Potential
b) Heat
c) Both kinetic and potential
d) Kinetic

(c) When the spring of a clockwork uncoils

a) Kinetic energy is converted into potential energy
b) Potential energy is converted into kinetic
c) Potential energy is converted into heat, light and sound energy
d) Kinetic energy is converted into heat, light and sound energy

OR

More energy is stored in a spring if the

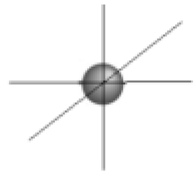
a) Spring is larger, harder and wound fur a longer time
b) Spring is smaller, harder and wound for a shorter time
c) Spring is larger, harder and wound for a shurter time
d) Spring is larger, softer and wound for a shorter time

(d) In clockwork devices, ________ transform the speed of a rotating ________ to drive wheels slower or faster.

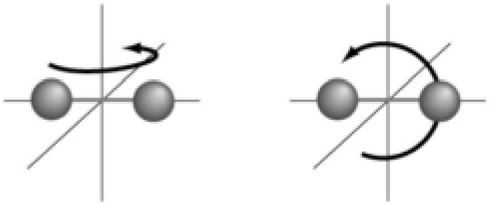
a) Shaft, spring
b) shaft, gear
c) Gear, Shaft
d) Spring, gear

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.



Translational Motion



Rotational Motion

Vibrational Motion

(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. Show that for a particle in linear S.H.M., the average kinetic energy over a period of oscillation is equal to the average potential energy over the same period. At what distance from the mean position is the kinetic energy in simple harmonic oscillator equal to potential energy? **[5]**

OR

Find the total energy of the particle executing S.H.M. and show graphically the variation of P.E. and K.E. with time in S.H.M. What is the frequency of these energies with respect to the frequency of the particle executing S.H.M?

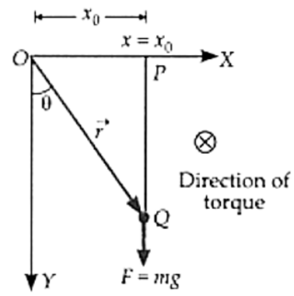
32. A marble rolls along a table at a constant speed of 1.00 m/s and then falls off the edge of the table to the floor 1.00 m below, **[5]**

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

On an open ground, a motorist follows a track that turns to his left by an angle of 60^{o} after every 500 m. Starting from a given turn, specify the displacement of the motorist at the third, sixth and eighth turn. Compare the magnitude of the displacement with the total path length covered by the motorist in each case.

33. A particle of mass m is released from point P at x = x_0 on the X-axis from origin O and falls vertically along the Y-axis, as shown in Fig. **[5]**



i. Find the torque t acting on the particle at a time t when it is at point Q with respect to O.
ii. Find the angular momentum L of the particle about O at this time t.
iii. Show that $\tau = \frac{dL}{dt}$ in this example.

OR

State the law of conservation of angular momentum and illustrate it with the example of planetary motion.

Solution

Section A

1. **(a)** process of comparing with a standard using an instrument
Explanation: The Measurement of a given quantity is essentially an act or result of comparison between a quantity whose magnitude (amount) is unknown, with a similar quantity whose magnitude (amount) is known, the latter quantity being called a Standard.

2. **(c)** 90°

Explanation: $y = 4\sin\left[\frac{2\pi}{4}t + \frac{\pi}{32}x\right]$
$y = A\sin\left[\frac{2\pi}{T}t + \frac{2\pi}{\lambda}x\right]$
$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = \frac{\pi}{32} \times 16 = \frac{\pi}{2}$

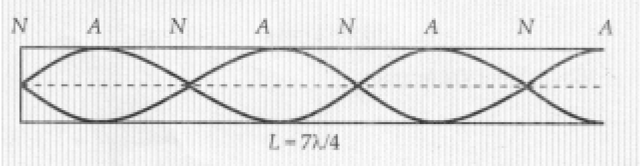
3. **(b)** $\frac{1}{\pi}m$
Explanation: Distance of the centre of mass of a half ring from its centre,
y = $\frac{2R}{\pi} = \frac{2\times0.5}{\pi}\text{m} = \frac{1}{\pi}\text{m}$

4. **(d)** 54.88 N
Explanation: Water compartment
P = $h\rho g$
= 4 × 1.0 × 10^3 × 9.8
= 39.2 × 10^3Pa
Acid Compartment,
P' = $h\rho' g$
= 4 × 1.7 × 10^3 × 9.8
= 66.64 × 10^3Pa
Now,
P′ − P = 66.64 × 10^3 − 39.2 × 10^3
P′ − P = 27.44 × 10^3 Pa
A = 20 cm^2 = 20 × $10^{-4}m^2$
Force using pressure,
Pressure = $\frac{Force}{Area}$
Force = pressure × area F = 27.44 × 10^3 × 20 × 10^{-4}
F = 54.88 N

5. **(d)** $\sqrt{2gR}$
Explanation: $\frac{1}{2}mv^2 = U_i - U_f = 0 - \left(-\frac{GMm}{R}\right)$
$\frac{1}{2}mv^2 = \frac{gR^2m}{R}$ [GM = gR^2]
v = $\sqrt{2gR}$

6. **(c)** four nodes and four antinodes
Explanation:

In third overtone, the length of the closed organ pipe is $\frac{7\lambda}{4}$. Air in the pipe will have four nodes and four antinodes as shown in the figure.



7.

(b) 30

Explanation: Initial velocity u, = 30 m/s

As it stop so final velocity, v = 0 m/s

Time t = 2 s

Distance covered = s

we know that ,v= u +at

0= 30 + a(2)

a= - 15m/s^2

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

$\Rightarrow s = 30 \times 2 + \frac{1}{2}(-15) \times 2^2$

$\Rightarrow$ s = 30 m

8.

(d) 0.0556 $\times$ 10^{-6} m

Explanation: $\Delta\lambda = \lambda_1 - \lambda_2 = \frac{1}{2\times10^6} - \frac{1}{2.25\times10^6}$

= $\frac{0.25\times10^{-6}}{2\times2.25}$ m = 0.0556 $\times$ 10^{-6} m

9.

(b) Constant terminal speed

Explanation: The rain drops acquire terminal velocity after falling long distance due to balance of buoyant force and weight of the drop due to gravity.

10. **(a)** 4.7 m/s

Explanation: $v = \sqrt{\frac{GM}{r}}$

Here, G = 6.67 $\times$ 10^{-11}N m^2 kg^{-2}

M = 2 $\times$ 10^{15} kg

$r = \frac{12000}{2}$ = 6000

$\Rightarrow v = \sqrt{\frac{6.67\times10^{-11}\times2\times10^{15}}{6000}}$

$\Rightarrow$ v = 4.7 m/sec

11.

(d) t = 1 s

Explanation: θ(t) = 2 t^3 - 6t^2

$\omega = \frac{d\theta}{dt}$ = 6t^2 - 12t

$\alpha = \frac{d\omega}{dt}$ = 12t - 12 = 0

$\Rightarrow$ t = 1s

12. **(a)** atmospheric pressure

Explanation: When vapour pressure is equal to atmospheric pressure, then boiling occurs.

13.

(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.

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

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

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

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

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

Explanation: As, $\vec{A} \| \vec{B}, \therefore \theta = 0 \Rightarrow \vec{A} \times \vec{B}$ = AB sin 0 = $\vec{0}$

ie. $\vec{A} \times \vec{B}$ is a null vector. Where null vector is a vector whose magnitude is zero but has a direction.

Section B

17. The speed of sound in a gas of molecular mass M is

$v=\sqrt{\frac{\gamma RT}{M}}$ i.e., $v \propto \frac{1}{\sqrt{M}}$

$\therefore \quad \frac{v_1}{v_2}=\sqrt{\frac{m_2}{m_1}}$

18. Following rules are to be followed for finding the number of significant figures in a measurement:

i. All the non-zero digits are significant.

ii. All the zeros between two non-zero digits are significant, no matter where the decimal point is, if at all.

iii. If the number is less than 1, the zeros on the right side of decimal point but to the left of the first non-zero digit are not significant. For example, in 0.00456, the underlined zeros are not significant.

iv. The trailing zero(s) in a number without a decimal point are not significant. For example, 14500 have three significant figures as trailing zeros being not significant.

v. The trailing zero(s) in a number with a decimal point are significant. For example, 1.6500 have five significant figures.

vi. If a measurement is expressed in terms of powers of ten, then these powers are not significant.

19. 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

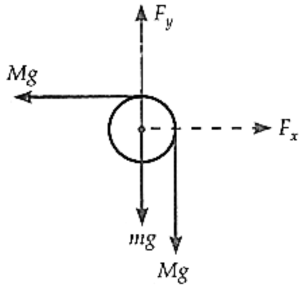
On solving, a = 0, $b=\frac{1}{2}, \quad c=-\frac{1}{2}$

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

From experiments, k = 2π

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

20. The free body diagram for the pulley is shown in Figure.



For the equilibrium of the pulley,

F_x = Horizontal component of the force by the clamp on the pulley = Mg

F_y = Vertical component of the force by the clamp on the pulley = (M + m) g

The net force exerted on the pulley by the clamp,

$F=\sqrt{F_x^2+F_y^2}=g\sqrt{(M+m)^2+M^2}$.

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

Let F be the air resistance on each body.

Net downward force on mass M = Mg - F

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

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

As M > m, so a > a'

OR

Force experience by the body is given by

$F = \frac{GM_e m}{R^2} = \frac{GM_p m}{(D_p/2)^2} = \frac{4GM_p m}{D_p^2}$

$\frac{F}{m} = \frac{4GM_p}{D_p^2}$

Section C

22. Before opening the valve:

$p_1 = 3.5 \times 10^5$ Nm^{-2}, $v_1 = 0$

After opening the valve:

$p_2 = 3.0 \times 10^5$ Nm^{-2}, v_2 = ?

In horizontal flow, P.E. remains unchanged. So Bernoulli's theorem can be written as

$p_2 + \frac{1}{2}\rho v_2^2 = p_1 + \frac{1}{2}\rho v_1^2$

$3.0 \times 10^5 + \frac{1}{2} \times 10^3 \times v_2^2 = 3.5 \times 10^5 + \frac{1}{2} \times 10^3 \times (0)^2$

$\frac{1}{2} \times 10^3 \times v_2^2 = (3.5 - 3.0) \times 10^5 = 0.5 \times 10^5$

or $v_2^2 = 2 \times 0.5 \times 10^2 = 100$

or $v_2 = 10$ ms^{-1}

23. First of all, the stress on the object(tooth) developed over here is dependent on bulk modulus of the material and the temperature difference. That's the stress is called a thermal stress over here.

Now, change in temperature $\Delta T = 57 - 37 = 20^\circ C$ = 20 K (since temperature difference is same here in both the scales)

Coefficient of linear expansion α of (tooth) body = 1.7×10^{-5} K^{-1}

Cubical expansion $\gamma = 3\alpha = 3 \times 1.7 \times 10^{-5} = 5.1 \times 10^{-5} K^{-1}$, [As, $\alpha = \frac{\gamma}{3}$]

Let the volume of the cavity be V and its volume increased by ΔV due to increase in temperature ΔT.

Then from the defination of coefficient of volume expansion,

$\Delta V = \gamma V \cdot \Delta T$

$\Rightarrow \frac{\Delta V}{V} = \gamma \Delta T$

Thermal stress produced = Bulk modulus $\times$ Volume strain

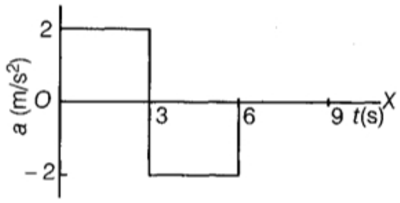
$= B \times \frac{\Delta V}{V} = B \times \gamma \times \Delta T$

Hence, thermal stress = $140 \times 10^9 \times 5.1 \times 10^{-5} \times 20 = 14280 \times 10^4$ N/m^2 , as bulk modulus = 140×10^9 N/m^2(given)

= 1.428×10^8 Nm^{-2}

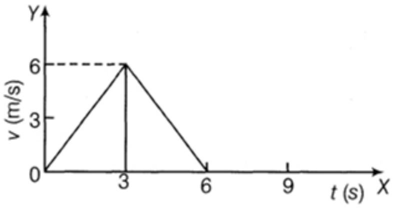
This stress is about 10^3 times of atmospheric pressure i.e., 1.013×10^5 Nm^{-2}.

24. The acceleration -time graph is



The area enclosed between a-t curve gives change in velocity for the corresponding interval.

At t = 0, v = 0, hence final velocity at t = 3 s will increase to 6 m/s. In next 3 s, the velocity will decrease to zero. Thus, the velocity-time graph is



25. **Newton's First Law of Motion** also known as **Law of Inertia** states that every object persists to stay in uniform motion in a straight line or in the state of rest unless an external force acts upon it. In a simpler form, the first law of motion may also be stated

as "If the net external force on a body is zero, its acceleration is zero. Acceleration can be non-zero only if there is a net external force on the body".

Newton's Second Law of Motion states that force is equal to the change in momentum per change in time. For a constant mass, force equals mass times acceleration, i.e.

F = ma

Thus, $\vec{F} \propto \frac{\Delta \vec{p}}{\Delta t}$ or $\vec{F} = k\frac{\Delta \vec{p}}{\Delta t}$, where k is a constant of proportionality, Δp is the change in momentum and p = mv.

Newton's Third Law of Motion: It states that "For every action, there is an equal and opposite reaction".

According to the first law of motion, in the absence of an external force, a body will maintain its position of rest or state of uniform motion along a straight line. Thus, to change the position of rest or uniform motion of a body, we shall have to apply an external force. If the external force is large enough, it may change the state of rest or of uniform motion. However, if the magnitude of the force is small then it may not be able to change that state. Hence, "force is that external cause (push or pull) which changes or tries to change the state of rest or of uniform motion along a straight line of a given body".

Also, we know that,

F = ma

where F is the vector sum of all forces acting on the body, m is the mass of body and equation can be regarded as a statement of Newton's 2nd law of motion.

This relation can be used to have the measure of a force.

26. Given: Temp of source T_1 = 300 K and Temp of sink T_2 = 270 K

   i. Coefficient of performance, $\alpha = \frac{T_2}{T_1 - T_2} = \frac{270}{300 - 270}$ = 9

   ii. Electric energy consumed by refrigerator = Work done by external agency on refrigerator

   Here, W = 1 J

   As $\alpha = \frac{Q_2}{W}$, hence Q_2 = $W \times \alpha = 1\text{J} \times 9 = 9\text{J}$

   Thus, the heat delievered to the room, Q_1 = Q_2 + W = 9 J + 1 J = 10 J.

27. Given:

Mass of neutron, m_n = 1.67×10^{-27}kg

Initial Speed of neutron, u_n =10^6 m/s

Mass of deuteron, m_d = 3.34 $\times 10^{-27}$ kg

Initial speed of deuteron, u_d = 0 [$\because$the deuteron is at rest]

From principle of conservation of linear momentum for the given collision,

$m_1u_1 + m_2u_2 = (m_1 + m_2)$ v (common velocity v as the particles stick together and move with a common velocity)

$1.67 \times 10^{-27} \times 10^6 + 3.34 \times 10^{-27} \times 0 = (3.34 + 1.67) \times 10^{-27} \times v$

$v = \frac{1.67 \times 10^{-27} \times 10^{+6}}{5.01 \times 10^{-27}} = 33.33 \times 10^4$m/s = 3.33 $\times 10^5$ m/s

28. For water, h_1 = 10.0 cm = 0.1 m

ρ_1 = 10^3 kg/m^3, θ = 0°

For mercury, h_2 = 5.0 cm = 0.05 m

ρ_2 = 13.6 $\times$ 10^3 kg/m^3, θ = 60°

Suppose S_1 and S_2 are the surface tensions for water and mercury, respectively, then

$S_1 = \frac{h_1 R \rho_1 g}{2\cos\theta_1}$ and $S_2 = \frac{h_2 R \rho_2 g}{2\cos\theta_2}$

The ratio of surface tension of mercury and water,

$\frac{S_2}{S_1} = \frac{h_2 R \rho_2 g}{2\cos\theta_2} \times \frac{2\cos\theta_1}{h_1 R \rho_1 g}$

$\frac{S_2}{S_1} = \frac{h_2 \rho_2 \cos\theta_1}{h_1 \rho_1 \cos\theta_2}$

= $\frac{0.05 \times 13.6 \times 10^3 \times \cos 0^\circ}{0.1 \times 1000 \times \cos 60^\circ}$ = 13.6 : 1

OR

The gravity on moon is about one-sixth of that on the earth. But gravity has equal effect both on weight of the body and the upthrust. So equilibrium of the floating body is not affected. On the earth, weight of the floating body is balanced by upthrust due to both water and air.

$\therefore$ W = mg = $V_w \rho_w$ g + V_a ρ_a g

or m = $V_w \rho_w$ + V_a ρ_a ...(i)

But the moon has no atmosphere. So

W = mg = $V_w' \rho_w$ g

or m = $V_w' \rho_w$

From (i) and (ii), we note that

$V_w' = V_w + \frac{V_a \rho_a}{\rho_w}$

Clearly, $V'_w > V_w$

That is, the volume of ball immersed in water on the moon is greater than that on earth. Hence ball will sink slightly more in water when taken to the moon.

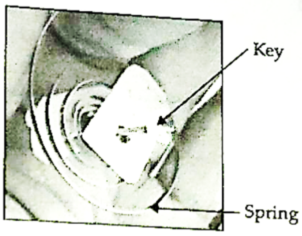
Section D

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

Clockwork refers to the inner workings of mechanical clock or watch (where it is known as "movement") and different types of toys which work using a series of gears driven by a spring. Clockwork device is completely mechanical and its essential parts are:

- A key (or crown) which you wind to add energy
- A spiral spring in which the energy is stored
- A set of gears through which the spring's energy is released. The gears control how quickly (or slowly) a clockwork machine can do things. Such as in mechanical clock/watch the mechanism is the set of hands that sweep around the dial to tell the time. In a clockwork car toy, the gears drive the wheels.

Winding the clockwork with the key means tightening a sturdy metal spring, called the mainspring. It is the process of storing potential energy. Clockwork springs are usually twists of thick steel, so tightening them (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.



While the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower. In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

(i) **(c)** A spring and combination of gears which move the hands of the clock

Explanation: Movement refers to the inner workings of mechanical clock using a series of gears driven by a spring.

(ii) **(a)** Potential

Explanation: Winding the spring means tightening a sturdy metal spring. It is the process of storing potential energy (forcing the spring to occupy a much smaller space) is actually quite hard work. With each turn of the key, fingers do work and potential energy is stored in the spring.

(iii) **(b)** Potential energy is converted into kinetic

Explanation: When the spring uncoils, the potential energy is converted into kinetic energy through gears, cams, cranks and shafts which allow wheels to move faster or slower.

OR

(a) Spring is larger, harder and wound fur a longer time

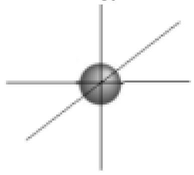
Explanation: With each turn of the key, fingers do work and potential energy is stored in the spring. The amount of energy stored depends on the size and tension of the spring. Harder a spring is to turn and longer it is wound, the more energy it stores.

(iv) **(c)** Gear, Shaft

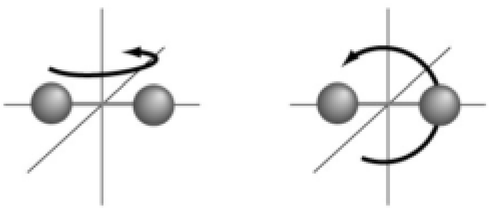
Explanation: In an ancient clock, gears transform the speed of a rotating shaft so that it drives the second hand at one speed, the minute hand at $\frac{1}{60}$ of that speed, and the hour hand at $\frac{1}{3600}$ of that speed. Clockwork toy cars often use gears to make themselves race along at surprising speed.

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. Let x = A sinωt

Then, $v = \frac{dx}{dt} = A\omega \cos(\omega t)$

K. E. = $\frac{1}{2}mv^2$

Average kinetic energy is

$$\frac{1}{T}\int_0^T \frac{1}{2}mv^2 dt = \frac{1}{4}mA^2\omega^2$$

Average potential energy is

$$\frac{1}{T}\int_0^T \frac{1}{2}kx^2 dt = \frac{1}{4}mA^2\omega^2$$

Let x be the distance where KE is equal to PE. Kinetic energy of particles executing SHM is

KE = $\frac{1}{2}m\omega^2(a^2 - x^2)$

Potential energy of particles is given by PE = $\frac{1}{2}m\omega^2x^2$ Let x be the distance where KE = PE

$\frac{1}{2}m\omega^2(a^2 - x^2) = \frac{1}{2}m\omega^2x^2$

$(a^2 - x^2) = x^2$

$x = \frac{a}{\sqrt{2}}$

Kinetic energy equal to its potential energy at $x = \frac{a}{\sqrt{2}}$

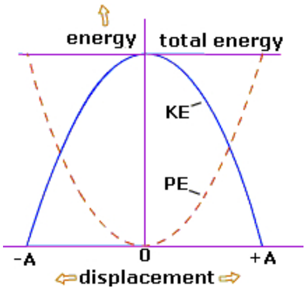
OR

The total energy of the system of a block and a spring is equal to the sum of the potential energy stored in the spring plus the kinetic energy of the block and is proportional to the square of the amplitude.

$\frac{1}{2}m\omega^2(A^2 - x^2) + \frac{1}{2}m\omega^2x^2$

$E = \frac{1}{2}m\omega^2A^2$

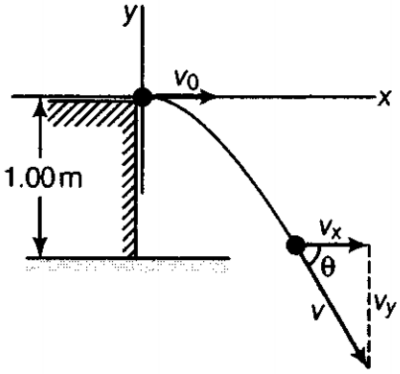
Hence, the total energy of the particle in SHM is constant and it is independent of the instantaneous displacement. Relationship between potential energy, kinetic energy, and time in Simple Harmonic Motion at t = 0, when $x = \pm A$.



The frequency of kinetic energy is twice the frequency of SHM.

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

$\therefore x = v_{x0}t = 1.00 \times 0.452$ 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

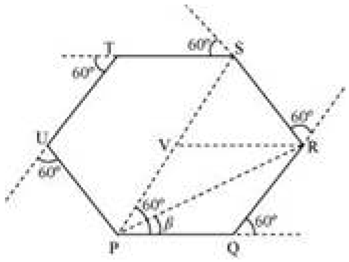
$v_y = v_{y0} - gt = 0 - 9.8 \times 0.452 = -4.43$ m/s

$\therefore v = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.00)^2 + (-4.43)^2}$ = 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



The path followed by the motorist is a regular hexagon with side 500 m, as shown in the given figure.
Let the motorist start from point P. The motorist takes the third turn at S.
Magnitude of displacement = PS = PV + VS = 500 + 500 = 1000 m $(\because PV = QR, VS = SR)$
Total path length, d_1 = PQ + QR + RS = 500 + 500 + 500 = 1500 m

The motorist take the sixth turn at point P, which is the starting point
$\therefore$ Magnitude of displacement = 0
Total path length, d_2 = PQ + QR + RS + ST + TU + UP

d_2 = 500 + 500 + 500 + 500 + 500 = 3000 m

The motorist takes the eight turn at point R
$\therefore$ Magnitude of displacement = PR

$PR = \sqrt{PQ^2 + QR^2 + 2(PQ)\cdot(QR)\cos 60^\circ}$

$PR = \sqrt{500^2 + 500^2 + (2 \times 500 \times 500 \times \cos 60^\circ)}$

$PR = \sqrt{250000 + 250000 + \left(500000 \times \frac{1}{2}\right)}$

$PR = 866.03\ m$

$\beta = \tan^{-1}\left(\frac{500 \sin 60^\circ}{500+500 \cos 60^\circ}\right) = 30^\circ$

Therefore, the magnitude of displacement is 866.03 m at an angle of 30^o with PR.
Total path length = Circumference of the hexagon + PQ + QR
Total path length= 6 $\times$ 500 + 500 + 500 = 4000 m
The magnitude of displacement and the total path length corresponding to the required turns is shown in the given table

Turn	**Magnitude of displacement (m)**	**Total path length (m)**
Third	1000	1500
Sixth	0	3000
Eighth	866.03; 30^o	4000

33. i. The force of gravity, F= mg produces the torque τ. Let $\vec{r}$ be the position vector of Q. Then the magnitude of the torque is given by

$\tau = rF \sin\theta$

$= r \times mg \times \frac{x_0}{r} = mgx_0 \ \left[\because \sin\theta = \frac{x_0}{r}\right]$

The direction of the torque is directed into the plane of paper and perpendicular to it, as shown by $\otimes$.

ii. The magnitude of the angular momentum is $L = rp\sin\theta = rmv\sin\theta$

But the velocity v at point Q is given by v = u + at = 0 + gt = gt

$\therefore \quad L = rmgt.\frac{x_0}{r} = mgx_0 t$

The direction of angular momentum is the same as that of torque.

iii. Now L = mgx_0t

Differentiating both sides with respect to f, we get

$\frac{dL}{dt} = \frac{d}{dt}(mgx_0 t) = mgx_0 = \tau$

Hence the relation $\tau = \frac{dL}{dt}$ holds in this example.

OR

Law of conservation of angular momentum. Suppose the external torque acting on a rigid body due to external forces is zero. Then

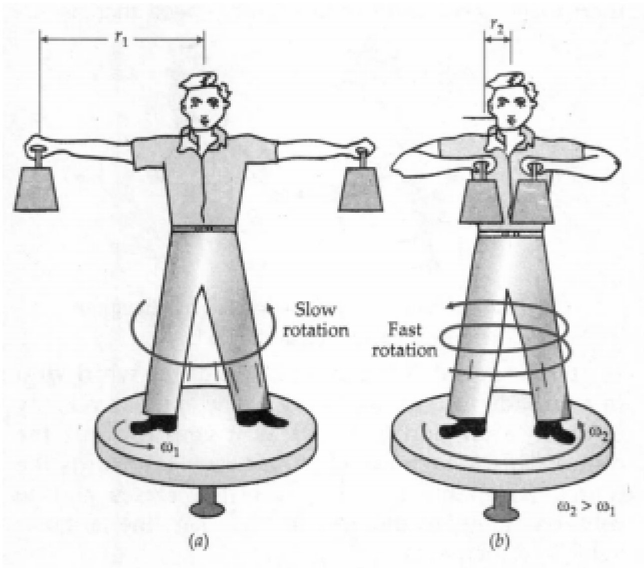
$\tau = \frac{dL}{dt} = 0$

Hence, L = constant

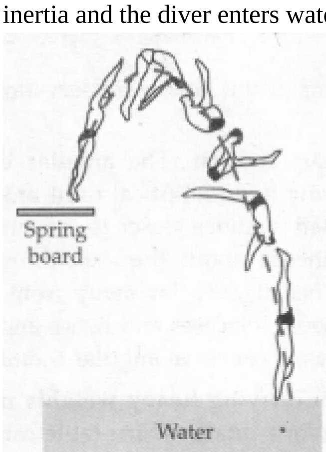
So when the total external torque acting on a rigid body is zero, the total angular momentum of the body is conserved. This is the

law of conservation of angular momentum.
Clearly, when $\tau = 0, L = I\omega$ = constant
or $I_1\omega_1 = I_2\omega_2$
This means that when no external torque is acting, the angular velocity co of the body can be increased or decreased by decreasing or increasing the moment of inertia of the body
Illustrations of the law of conservation of angular momentum:

i. **Planetary motion:** The angular velocity of a planet revolving in an elliptical orbit around the sun increases, when it comes closer to the sun because its moment of inertia about the axis through the sun decreases. When it goes far away from the sun, its moment of inertia increases and hence angular velocity decreases so as to conserve angular momentum.
ii. A man carrying heavy weights in his hands and standing on a rotating turn-table can change the angular speed of the turn-table. As shown in Fig., if a person stands on a turn-table with some heavyweights in his hands stretched out and the table is rotated slowly, his angular speed at once increases, as he draws his hands to his chest. The moment of inertia of man and weights taken together decreases, as he draws his arms inward. As moment of inertia decreases, the angular speed increases so as to conserve total angular momentum.



iii. A diver jumping from a spring board exhibits somersaults in air before touching the water surface. After leaving the spring board, a diver curls his body by pulling his arms and legs towards the centre of his body. This decreases his moment of inertia and he spins fast in midair. Just before hitting the water surface, he stretches out his arms. This decreases his moment of inertia and the diver enters water at a gentle speed.



iv. An ice-skater or a ballet dancer can increase her angular velocity by folding her arms and bringing the stretched leg close to the other leg. When she stretches her hands and a leg outward [Fig.], her moment of inertia increases and hence angular speed decreases to conserve angular momentum. When she folds her arms and brings the stretched leg close to the other leg [Fig.], her moment of inertia decreases and hence angular speed increases.
v. The speed of the inner layers of the whirlwind in a tarnado is alarmingly high. The angular velocity of air in a tarnado increases as it goes towards the centre. This is because as the air moves towards the centre, its moment of inertia (I) decreases and to conserve angular momentum (L = Iω), the angular velocity co increases.