Class XI Session 2023-24
Subject - Physics
Sample Question Paper - 7

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. Dimensions of resistance in an electrical circuit, in terms of dimension of mass M, of length L, of time T and of current I, would be **[1]**

a) $[ML^2T^{-1}I^{-1}]$ b) $[ML^2T^{-2}]$

c) $[ML^2T^{-3}I^{-1}]$ d) $[ML^2T^{-3}I^{-2}]$

2. Wave has simple harmonic motion whose period is 4 seconds while another wave which also possesses simple harmonic motion has its period 3 sec. If both are combined, then the resultant wave will have a period equal to **[1]**

a) 4 sec b) 3 sec

c) 5 sec d) 12 sec

3. The radius of gyration of a rod of mass 100 gm and length 100 cm about an axis passing through its edge and perpendicular to its length is given by: **[1]**

a) $\frac{100}{\sqrt{3}}$ b) $\frac{50}{2\sqrt{3}}$

c) $\frac{50}{3\sqrt{2}}$ d) $\frac{100}{3\sqrt{3}}$

4. 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

5. What is not conserved in the case of celestial bodies revolving around sun? **[1]**

a) linear momentum
b) kinetic energy
c) angular momentum
d) mass

6. A transverse wave is represented by y = sin (ωt - kx) For what value of the wavelength is the wave velocity equal to the maximum particle velocity? **[1]**

a) $\frac{\pi A}{2}$
b) πA
c) 2 πA
d) A

7. A jet plane lands with a speed of 100 m/s and can accelerate at a maximum rate of -5.00 $\mathrm{m/s^2}$ as it comes to rest. From the instant the plane touches the runway, what is the minimum time in seconds before it can come to rest? **[1]**

a) 20.0
b) 10.0
c) 25.0
d) 30.0

8. 50 tunning forks are arranged in increasing order of their frequencies such that each gives 4 beats/sec with its previous tuning fork. If the frequency of the last fork is the octave of the first, then the frequency of the first tuning fork is **[1]**

a) 196 Hz
b) 200 Hz
c) 204 Hz
d) none of these

9. The raindrops are in spherical shape due to **[1]**

a) thrust on drop
b) viscosity
c) surface tension
d) residual pressure

10. In what manner, does the escape velocity of a particle depend upon its mass? **[1]**

a) m
b) m^2
c) m^{-1}
d) m^0

11. Two discs of same moment of inertia are rotating about their regular axis passing through centre and perpendicular to the plane of disc with angular velocities ω_1 and ω_2. They are brought into contact face to face coinciding the axis of rotation. The expression for loss of energy during this process is **[1]**

a) $\frac{1}{8}(\omega_1-\omega_2)^2$
b) $\frac{1}{4}I(\omega_1-\omega_2)^2$
c) $\frac{1}{2}I(\omega_1+\omega_2)^2$
d) $I(\omega_1-\omega_2)^2$

12. A piece of blue glass heated to a high temperature and a piece of red glass at room temperature, are taken inside a dimly lit room, then **[1]**

a) blue shines like brighter red compared to the red piece
b) red looks brighter red and blue looks ordinary blue
c) the blue piece will look blue and red will look as usual
d) both the pieces will look equally red

13. **Assertion (A):** A quick collision between two bodies is more violent than a slow collision, even when the initial and the final velocities are identical. **[1]**

Reason (R): The rate of change of momentum is greater in the first case.

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:** In an isolated system, the entropy increases. **[1]**

Reason: The processes in an isolated system are adiabatic.

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:** The time period of revolution of a satellite close to surface of earth is smaller than that revolving away from surface of earth. **[1]**

Reason: The square of time period of revolution of a satellite is directly proportional to cube of its orbital radius.

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):** The trajectory of projectile is quadratic in x and linear in y. **[1]**

Reason (R): y component of trajectory is independent of x-component.

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. A stone is dropped into a well and its splash is heard at the mouth of the well after an interval of 1.45 s. Find the depth of the well. Given that velocity of sound in air at room temperature is equal to 332 ms^{-1}. **[2]**

18. State the limitations of the method of dimensional analysis. **[2]**

19. In the expression $P = El^2m^{-5}G^{-2}$, E, l, m and G denote energy, angular momentum, mass and gravitational constant respectively. Show that P is a dimensionless quantity. **[2]**

20. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 ms^{-1}. If the mass of the ball is 0.15 kg, determine the impulse imparted to the ball. (Assume linear motion of the ball) **[2]**

21. The mass of moon is $\frac{M}{81}$(where M is mass of earth). Find the distance of the point where the gravitational field due to earth and moon cancel each other. Given distance of moon from earth is 60 R, where R is radius of earth. **[2]**

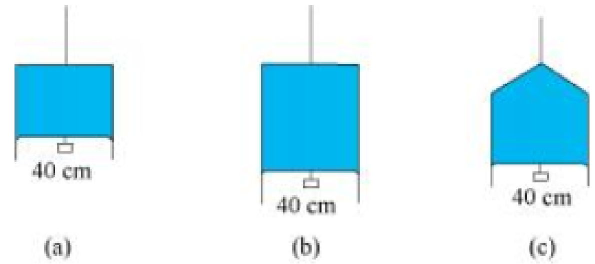
OR

If earth has a mass 9 times and radius twice that of a planet Mars, calculate the minimum velocity required by a rocket to pull out of the gravitational force of Mars. Take the escape velocity on the surface of earth to be 11.2 kms^{-1}.

Section C

22. In a given Figure (a) shows a thin liquid film supporting a small weight $= 4.5 \times 10^{-2}$ N. What is the weight **[3]**

supported by a film of the same liquid at the same temperature in Fig. (b) and (c)? Explain your answer physically.



23. Define the terms **[3]**

i. absorptive power,
ii. emissive power and
iii. emissivity.

Write their SI units, if any.

24. A parachutist bails out from an aeroplane and after dropping through a distance of 40 m, he opens the parachute and decelerates at 2 ms^{-2}. If he reaches the ground with a speed of 2 ms^{-1}, how long is he in the air? At what height did he bailout from the plane? **[3]**

25. A railway car of mass 20 tonnes moves with an initial speed of 54km/hr. On applying brakes, a constant negative acceleration of 0.3m/s^2 is produced. **[3]**

i. What is the breaking force acting on the car?
ii. In what time it will stop?
iii. What distance will be covered by the car before it finally stops?

26. An ideal refrigerator runs between -23°C and 27°C **[3]**

i. Find the heat rejected to atmosphere for every joule of work input.
ii. Also, find heat extracted from cold body.
iii. Find coefficient of performance of the refrigerator.

27. A small body tied to one end of the string is whirled in a vertical circle. Represent the forces on a diagram when the string makes an angle θ with initial position below the fixed point. Find an expression for the tension in the string. Also, find the tension and velocity at the lowest and highest points respectively. **[3]**

28. In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are 70 ms^{-1} and 63 ms^{-1} respectively. What is the lift on the wing if its area is 2.5 m^2? Take the density of air to be 1.3 kg m^{-3}. **[3]**

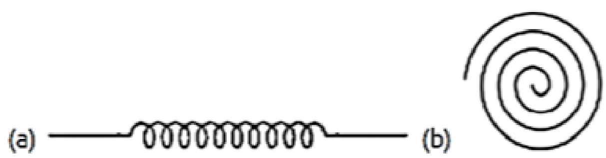
OR

Calculate the radius of new bubble formed when two bubbles of radius r_1 and r_2 coalesce?

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.

(i) 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

(ii) 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

(iii) 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

(iv) 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

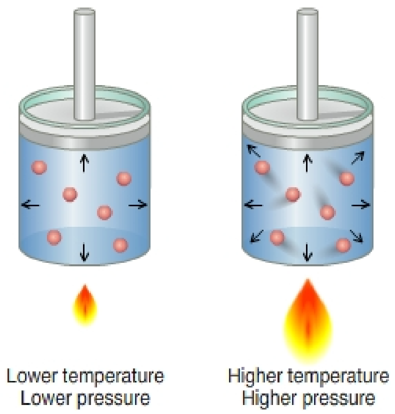
b) 30 J

c) 27 J

d) 33 J

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

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(i) If the temperature of the gas increases from 300 K to 600 K then the average kinetic energy becomes:

a) same

b) becomes double

c) becomes half   d) none of these

(ii) What is the average velocity of the molecules of an ideal gas?

a) Infinite   b) Same

c) None of these   d) Zero

(iii) Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will ________.

a) decrease   b) none of these

c) increase   d) remains same

(iv) Find the ratio of average kinetic energy per molecule of Oxygen and Hydrogen:

a) 1:1   b) 4:1

c) 1:2   d) 1:4

OR

The velocities of the three molecules are 3v, 4v, and 5v. calculate their root mean square velocity?

a) 4.0 v   b) 4.02 v

c) 4.08 v   d) 4.04 v

Section E

31. Show that simple harmonic motion may be regarded as the projection of uniform circular motion along the diameter of the circle. Hence derive an expression for the displacement of a particle in S.H.M. **[5]**

OR

Let us take the position of mass when the spring is unstretched as x = 0 and the direction from left to right as the positive direction of x-axis. Given x as a function of time t for the oscillating mass, if at the moment we start the stopwatch (t = 0), the mass is

i. at the mean position,
ii. at the maximum stretched position and
iii. at the maximum compressed position.

In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

32. **[5]**
a. What is the angle between $\overrightarrow{A}$ and $\overrightarrow{B}$ if $\overrightarrow{A}$ and $\overrightarrow{B}$ denote the adjacent sides of a parallelogram drawn form a point and the area of the parallelogram is $\frac{1}{2}AB$?
b. State and prove triangular law of vector addition.

OR

Given $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$, which of the following statements are correct:

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?

33. A metre scale AB is held vertically with its one end A on the floor and is then allowed to fall. Find the speed of the other end B when it strikes the floor, assuming that the end on the floor does not slip. **[5]**

OR

A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. Determine the force exerted by the liquid at the other end.

Solution

Section A

1.

(d) $[ML^2T^{-3}I^{-2}]$

Explanation: $[R] = \frac{V}{I} = \frac{W}{qI} = \frac{[ML^2\,T^{-2}]}{[IT][I]}$

$= [ML^2T^{-3}I^{-2}]$

2.

(d) 12 sec

Explanation: On the superposition of the two waves, beats are produced.

Beat frequency = $\frac{1}{T_2} - \frac{1}{T_1} = \frac{1}{3} - \frac{1}{4} = \frac{1}{12}$

3. **(a)** $\frac{100}{\sqrt{3}}$

Explanation: Moment of inertia of the rod about an axis passing through its centre of gravity and perpendicular to its length

$I = \frac{Ml^2}{3}$

Moment of inertia of rod in terms of the radius of gyration

$I = Mk^2$

M = 100 gm

l = 100 cm

$Mk^2 = \frac{Ml^2}{3}$

$k = \sqrt{\frac{l^2}{3}} = \sqrt{\frac{100\times100}{3}}$

$k = \frac{100}{\sqrt{3}}\text{cm}$

4.

(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.

5.

(b) kinetic energy

Explanation: K.E. changes due to the change in the speed of celestial body around the sun.

6.

(c) $2\pi A$

Explanation: Maximum particle velocity = Wave velocity

$\omega A = \frac{\omega}{k}$

or $k = \frac{2\pi}{\lambda} = \frac{1}{A}$

$\therefore \lambda = 2\pi A$

7. **(a)** 20.0

Explanation: Initial velocity, u = 100 m/s

As it stops so final velocity, v = 0

Acceleration a = - 5 m/s^2

We know, v - u = at

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

$\Rightarrow t = \frac{0-100}{-5} = \frac{-100}{-5}$

$\Rightarrow$ t = 20.0 s

8. **(a)** 196 Hz

Explanation: Let the frequency of the first fork = ν

Frequency of second fork = $\nu + 8$

Frequency of third fork = ν + 2 $\times$ 8

Frequency of 16th fork = ν +15 $\times$ 8

But the frequency of the last is the octave of the first.

$2\nu = \nu + 49 \times 4$

ν = 196 Hz

9.

(c) surface tension

Explanation: Rain drops are spherical due to surface tension.

10.

(d) m^0

Explanation: Escape velocity (v_e) = $\sqrt{2gR_e}$. Therefore it is independent of the mass of the particle or it will depend on m^0.

11.

(c) $\frac{1}{2}I(\omega_1+\omega_2)^2$

Explanation: By conservation of angular momentum,

$I\omega_1 + I\omega_2 = 2I\omega$

$\Rightarrow \quad \omega = \frac{\omega_1+\omega_2}{2}$

Loss of K.E. = $K_i - K_f$

$= \frac{1}{2}I\left(\omega_1^2+\omega_2^2\right) - \frac{1}{2} \times 2I\left(\frac{\omega_1+\omega_2}{2}\right)^2$

$= \frac{1}{2}I\left[\left(\omega_1^2+\omega_2^2\right) - \frac{\omega_1^2+\omega_1^2+2\omega_1\omega_2}{2}\right]$

$= \frac{1}{2}I\left[\frac{2\omega_1^2+2\omega_2^2-\omega_1^2-\omega_2^2-2\omega_1\omega_2}{2}\right]$

$= \frac{1}{4}I(\omega_1-\omega_2)^2$

12. **(a)** blue shines like brighter red compared to the red piece

Explanation: According to Stefan's law,

$E \propto T^4$

As the temperature of blue glass is more than that of red glass, so it will appear brighter than red glass.

13. **(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.

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

Explanation: The time period of satellite, $T \propto r^{3/2}$

or T $\propto$ $(R_e + h)^{3/2}$

For a satellite revolving close to surface of the earth, h = 0.

$\therefore T \propto (R_e)^{3/2}$

It is evident that the period of revolution of a satellite depends upon its height above the earth's surface. Greater is the height of a satellite above the earth's surface greater is its period of revolution.

16.

(c) A is true but R is false.

Explanation: The equation of the trajectory of a projectile is y = x $\tan\theta - \frac{1}{2}\frac{g}{u^2\cos^2\theta}x^2$. Thus y component depends on x component.

Section B

17. Let h be the depth of the well. Then time t_1 taken by the stone to fall into well under gravity is given by

$h = 0 + \frac{1}{2}gt_1^2$ or $t_1 = \sqrt{\frac{2h}{g}}$

Time taken for the splash to travel height h is given by $t_2 = \frac{h}{v}$

where v = velocity of sound

But $t_1 + t_2 = 1.45$ s

$\therefore \quad \sqrt{\frac{2h}{g}} + \frac{h}{v} = 1.45$

or $\sqrt{\frac{2h}{9.8}} + \frac{h}{332} = 1.45$

On solving, h = 9.9 m.

18. Method of dimensional analysis suffers from the following limitations :
    i. It does not enable us to determine the value of the constant of proportionality which may be a pure number or a dimensionless ratio.
    ii. Since many physical quantities have the same dimensions (e.g., momentum and impulse, work and torque, etc.), the method of dimensions is not a full-proof method to check the correctness of physical relation.
    iii. The use of the method of dimensions requires a sound background of the subject, otherwise, the method may lead to incorrect results.
    iv. It does not test whether a physical quantity is a scalar or a vector.
    v. It cannot derive relation or formula if a physical quantity depends upon more than three factors having dimensions.
    vi. It cannot derive a formula containing trigonometric function, exponential function, and logarithmic function.
    vii. It cannot derive a relation having more than one part in an equation.
19. The formulae or expressions that indicate how and which fundamental quantities are there in a physical quantity are called as the Dimensional Formula of the Physical Quantity.

Dimension of E = $[ML^2T^{-2}]$

Dimension of l = $[ML^2T^{-1}]$

Dimension of G = $[M^{-1}L^3T^{-2}]$

Hence, P = $El^2m^{-5}G^{-2}$ will have dimensions:

$[P] = \frac{[E][l^2]}{[m^5][G^2]} = \frac{[ML^2T^{-2}][ML^2T^{-1}]^2}{[M]^5[M^{-1}L^3T^{-2}]^2} = [M^0L^0T^0]$

Thus, P is a dimensionless quantity.

20. Impulse = change in linear momentum

initial momentum of ball = mu

= 0.15 × 12 = 1.8kg.m/secfinal momentum of ball = −mu

=−0.15 × 12 = −1.8kgm/sec

now,

change in momentum of ball = final − initial

= −1.8 − 1.8 = −3.6kgm/sec

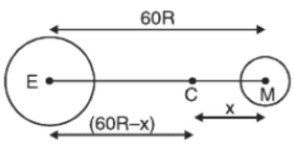
so,

change in momentum of bat = −change in momentum of ball

change in momentum of bat = 3.6kgm/s

now,

impulse imparted to ball = change in momentum of bat = 3.6kgm/s = 3.6Ns

21. 

Gravitational field at C due to earth

= Gravitational field at C due to moon

$\frac{GM}{(60R-x)^2} = \frac{Gm/81}{x^2}$

$81x^2 = (60R - x)^2$

9x = 60R - x

X = 6 R

OR

Here, $M_e = 9M_m$, and $R_e = 2R_m$

v_e (escape speed on surface of Earth) = 11.2 km/s

Let V_m be the speed required to pull out of the gravitational force of mars.

We know that

$v_e = \sqrt{\frac{2GM_e}{R_e}}$ and $v_m = \sqrt{\frac{2GM_m}{R_m}}$

Dividing, we get $\frac{v_m}{v_e} = \sqrt{\frac{2GM_m}{R_m} \times \frac{R_e}{2GM_e}}$

$= \sqrt{\frac{M_m}{M_e} \times \frac{R_e}{R_m}} = \sqrt{\frac{1}{9} \times 2} = \frac{\sqrt{2}}{3}$

$\Rightarrow v_m = \frac{\sqrt{2}}{3}$ (11.2 km/s) = 5.3 km/s

Section C

22. In case "a"-

The length of the liquid film supported by the weight is given by, l = 40cm = 0.4cm

The weight supported by the film is given by, $W = 4.5 \times 10^{-2} N$

A liquid film has two free surfaces thus

Surface tension is given by $S = \frac{W}{2l} = \frac{4.5 \times 10^{-2}}{2 \times 0.4} = 5.625 \times 10^{-2} \mathrm{Nm}^{-1}$

In all the three figures, the liquid is the same. Temperature is also the same for each case.

Hence, the surface tension in figure (b) and figure (c) is the same as in figure (a) i.e. $S = 5.625 \times 10^{-2} Nm^{-1}$

Since the length of the film in all the cases is 40 cm, hence the total weight supported in each case is given by $4.5 \times 10^{-2} N$.

23. **Absorptive power:** The absorptive power of a body for a given wavelength λ is defined as the ratio of amount of heat energy absorbed in a certain time to the total heat energy incident on it in the same time within a unit wavelength range around the wavelength λ. It is denoted by a_λ. A perfect black body absorbs all the heat radiations incident upon it. So its absorptive power is unity.

If the radiant energy dQ in wavelength range λ and λ + d λ is incident on a body of absorptive power a_λ, then amount of radiant energy absorbed by the body =a_λ dQ

The absorptive power is a dimensionless quantity.

Emissive power: The amount of heat energy radiated by a body per second depends upon

i. the area of its surface,
ii. the temperature of its surface and
iii. the nature of its surface. The strength of emission is measured by a quantity called emissive power. The emissive power of a body at a given temperature and for a given wavelength λ is defined as the amount of radiant energy emitted per unit time per unit surface area of the body

If heat radiation of wavelength range λ to λ + d λ is incident on the surface of a body of emissive power e_2, then the amount of radiant energy emitted per second per unit area = $e_\lambda d\lambda$

The SI unit of emissive power is Js^{-1} m^{-2} or Wm^{-2}.

Emissivity: The emissivity of a body is defined as the ratio of the heat energy radiated per unit time per unit area by the given body to the amount of heat energy radiated per unit time per unit area by a perfect black body of the same temperature i.e., it is the ratio of the emissive power (e) of a body to the emissive power (E) of a black body at the same temperature. It is denoted by ε.

Thus $\varepsilon = \frac{e}{\varepsilon}$

It is dimensionless quantity. Its value lies between 0 and 1. The emissivity of a perfect black body is 1. The emissivities of polished copper, polished aluminium and lamp black are 0.018, 0.05 and 0.95 respectively.

24. When the parachutist falls freely :

u = 0, v = 9.8 ms^{-2}, s = 40m, t = ?, u = ?

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

$\therefore 40 = 0 + \frac{1}{2} \times 9.8 \times t^2$

or t = $\sqrt{\frac{80}{9.8}} = \frac{20}{7}$ s = 2.86 s

Also, v = u + gt = 0 + 9.8 $\times \frac{20}{7}$ = 28 ms^{-1}

When the parachutist decelerates uniformly:

u = 28 ms^{-1}, a = -2 ms^{-2}, 5 = 2 ms^{-1}

Time taken, t = $\frac{v-u}{a} = \frac{2-28}{-2}$ = 13 s

Distance, s = ut + $\frac{1}{2}at^2$ = $28 \times 13 - \frac{1}{2} \times 2 \times (13)^2$

= 364 - 169 = 195 m

Total time of parachutist in air

= 2.86 + 13 = 15.86 s

Height at which parachutist bails out

= 40 + 195 = 235 m

25. Mass of the railway car,m = 20 tonnes = 20 $\times$ 1000 kg=20 $\times$ 10^4 kg , Initial speed ,u = 54 km/hr = 54 $\times$ $\frac{5}{18}$=15 m/s

Negative acceleration,a = -0.3 m/s^2

a. Breaking force acting on the car ,F = -ma

$F=-(2\times10^4kg)\times(-0.3ms^{-2})$

$F=6000N$

b. When the railway car stops, its final velocity is zero.

i.e. $v=0$

Using the relation: $v-u=at$

$\Rightarrow\ 0=15+(-0.3)t$

$\Rightarrow t=50s$

c. Using the relation : $v^2-u^2=2as$

$\Rightarrow\ 0-(15)^2=2(-0.3)s$

$\Rightarrow\ s=375m$

26. Let heat rejected $Q_1=x$ and $W=1J$

Now, $Q_2=Q_1-W=x-1$

Given, $T_1=273+27=300K,\ T_2=273-23=250K$

i. For an ideal process, $\frac{Q_2}{Q_1}=\frac{T_2}{T_1}\Rightarrow\frac{x-1}{x}=\frac{250}{300}$

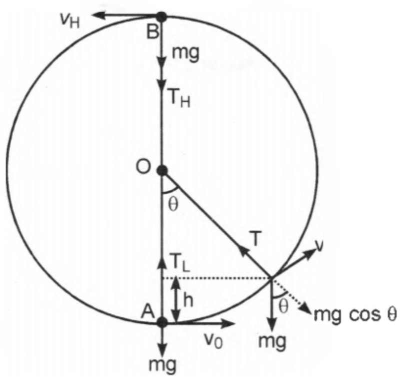
$Q_1=x=6J$

ii. $Q_2=5J$

iii. Coefficient of performance

$\beta=\frac{T_2}{T_1-T_2}=\frac{250}{300-250}=5$

27. Consider a small body of mass m attached to one end of a string (of length l) and whirled in a vertical circle of radius 'r'. Let body starts motion from its initial position A, just below the fixed point O, with a speed v$_o$.



The forces acting on the body, when the string makes an angle θ with the initial position are shown in the figure. Here, mg is the weight of body and T the tension in the string. If v be the instantaneous velocity at this point, then a centripetal force $F=\frac{mv^2}{l}$ is required radially inward. From figure, it is clear that in equilibrium the centripetal force is provided by resultant of two forces i.e.,

$T-mg\cos\theta=\frac{mv^2}{l}$

or $T=mg\cos\theta+\frac{mv^2}{l}$ ...(1)

If the body has covered a vertical distance h, then from law of conservation of mechanical energy, we have

$\frac{1}{2}mv_0^2=\frac{1}{2}mv^2+mgh$

$\Rightarrow v^2=v_0^2-2gh$ ...(ii)

which is the required expression for the velocity of a particle at any point.

At the lowest point θ = 0° and h = 0, hence we have

v$_L$ = v = v$_o$ ....[from (i) putting h = 0]

Thus,

$T_L=mg\cos0^\circ+\frac{m}{l}v_L^2=mg+\frac{mv_0^2}{l}$

and at the highest point θ = 180° and h = 2l. Hence,

$v_H^2=v^2=v_0^2-4gl$ [from (i) putting h = 2l]

or $v_H = \sqrt{v_0^2 - 4gl}$

and $T_H = mg\cos 180^\circ + \frac{mv_H^2}{l} = mg(-1) + \frac{m}{l}\left(v_0^2 - 4gl\right) = \frac{mv_0^2}{l} - 5mg$

which is the required expression for the Tension.

28. Speed of wind on the lower surface of the wing, $V_2 = 63\ \frac{m}{s}$

Area of the wing, $A = 2.5\ m^2$

Density of air, $\rho = 1.3\ kg\ m^{-3}$

According to Bernoulli's theorem, we have the relation:

$P_1 + \frac{1}{2}\rho V_1{}^2 = P_2 + \frac{1}{2}\rho V_2{}^2$

$P_1 - P_2 = \frac{1}{2}\rho\left(V_1{}^2 - V_2{}^2\right)$

Where,

P_1 = Pressure on the upper surface of the wing

P_2 = Pressure on the lower surface of the wing

The pressure difference between the upper and lower surfaces of the wing provides lift to the aeroplane.

Lift on the wing = $(P_2 - P_1)A$

$= \frac{1}{2}\rho\left(V_1^2 - V_2^2\right)$ A

$= \frac{1}{2}$ 1.3 $((70)^2 - (63)^2) \times 2.5$

= 1512.87

$= 1.51 \times 10^3$ N

Therefore, the lift on the wing of the aeroplane is 1.51×10^3N.

OR

Consider two soap bubbles of radii r_1 and r_2 and volumes as V_1 and V_2. Thus $V_1 = \frac{4\pi\ r_1^3}{3}\ \ and\ \ V_2 = \frac{4\pi\ r_2^3}{3}$. Let S be the surface tension of the soap solution. If P_1 and P_2 are excess pressure inside the two soap bubbles then $P_1 = \frac{4S}{r_1}; P_2 = \frac{4S}{r_2}$. Let r be the radius of the new soap bubble formed when the two soap bubble coalesces under isothermal conditions. If V and P are volume and excess of pressure inside the new soap bubble then $V = \frac{4}{3}\pi r^3\ \ P = \frac{4S}{r}$. As the new bubble is formed under isothermal condition, so Boyle’s law holds good and hence

$P_1V_1 + P_2V_2 = PV$

$\left(\frac{4S}{r_1} \times \frac{4}{3}\pi r_1^3\right) + \left(\frac{4S}{r_2} \times \frac{4}{3}\pi r_2^3\right) = \frac{4S}{r} \times \frac{4}{3}\pi r^3$

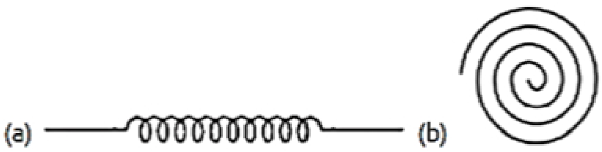
$\left(16 \times S \times \pi \times r_1^2\right) + \left(16 \times S \times \pi \times r_2^2\right) = 16S^2_{\pi r}$

$r = \sqrt{r_1^2 + r_2^2}$

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

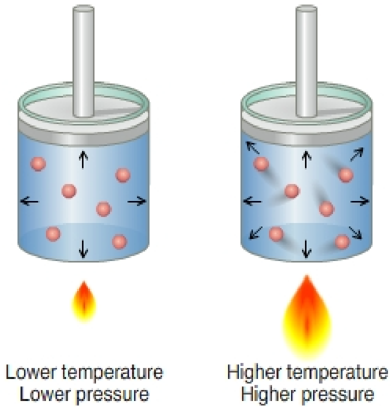
Explanation: 30 J

(iv) **(c)** 27 J

Explanation: 27 J

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

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



(i) **(b)** becomes double

Explanation: becomes double

(ii) **(d)** Zero

Explanation: Zero

(iii) **(d)** remains same

Explanation: remains same

(iv) **(a)** 1:1

Explanation: 1:1

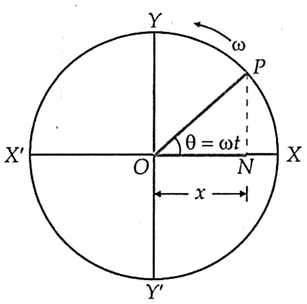
OR

(c) 4.08 v

Explanation: 4.08 v

Section E

31. Relation between S.H.M. and uniform circular motion. As shown in figure, consider a particle P moving along a circle of radius A with uniform angular velocity ω. Let N be the foot of the perpendicular drawn from the point P to the diameter XX'. Then N is called the projection of P on the diameter XX'. As P moves along the circle from X to Y, Y to X', X' to Y' and Y' to X; N moves from X to O, O to X', X' to O and O to X. Thus, as P revolves along the circumference of the circle, N moves to and fro about the point O along the diameter XX'. The motion of N about O is said to be simple harmonic. Hence **simple harmonic motion** may be defined as the projection of uniform circular motion upon a diameter of a circle. The particle P is called the reference particle or generating particle and the circle along which the particle P revolves is called the circle of reference.



Displacement in simple harmonic motion. As shown in Figure, consider a particle moving in the anticlockwise direction with uniform angular velocity ω along a circle of radius A and centre O. Suppose at time t = 0, the reference particle is at point A such that $\angle XOA = \phi_0$. At any time t, suppose the particle reaches the point P such that $\angle AOP = \omega t$. Draw PN $\perp$ XX'.

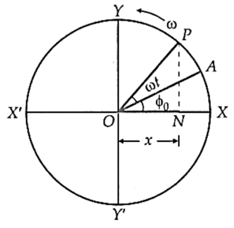


Fig. Displacement in S.H.M., epoch (+ ϕ_0)

Clearly, displacement of projection N from centre O at any instant t is x = O N.

In right-angled ΔONP,

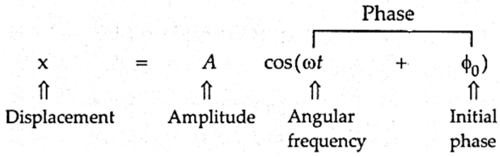
$\angle PON = \omega t + \phi_0$

$\therefore \frac{ON}{OP} = \cos(\omega t + \phi_0)$

or $\frac{x}{A} = \cos(\omega t + \phi_0)$

or $x = A\cos(\omega t + \phi_0)$

This equation gives the displacement of a particle in S.H.M. at any instant t. The quantity $\omega t + \phi_0$ is called the phase of the particle and ϕ_0 is called the initial phase or phase constant or epoch of the particle. The quantity A is called the amplitude of the motion. It is a positive constant whose value depends on how the motion is initially started. Thus



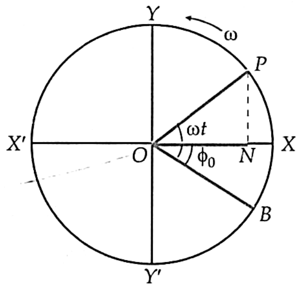


Fig. Epoch (− ϕ_0)

As shown in Figure, if the reference particle starts motion from the point P such that $\angle BOX = \phi_0$ and $\angle BOP = \omega t$, then

$\angle PON = \omega t - \phi_0$

$\therefore$ x = $A\cos(\omega t - \phi_0)$

Here $-\phi_0$ is the initial phase of the S.H.M.

OR

Assuming the standard equation

x(t) = Asin (ωt + ϕ)

i. When t = 0, x = 0 [mean position]

   $\Rightarrow$ 0 = Asin ($\omega \times 0 + \phi$)

   Asin ϕ = 0 [as A $\neq$ 0]

   or sinϕ = 0 $\therefore$ ϕ = 0

   $\therefore$ Required function is

   x(t) = Asin(ωt + 0) or x(t) = Asin ωt

   where, $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1200}{3.0}}$ = 20 rad/s

   $\therefore$ x(t) = Asin 20t or x(t) = 2sin 20t

ii. When t = 0, x = + A (maximum stretched position)

   x(t) = Asin(ωt + ϕ) at t = 0 and x = +A

   +A = A sin(ω x 0 + ϕ) or 1 = sin $\phi \Rightarrow \phi = \frac{\pi}{2}$

   $\therefore$ x(t) = Asin$\left(\omega t + \frac{\pi}{2}\right)$

   = A cos ωt = A cos 20t = 2 cos 20t

iii. When the spring is at maximum compressed position.

   At t =0, x(t) = -A

$\Rightarrow$ -A = Asin($\omega \times 0 + \phi$) or -1 = sinϕ or $\phi = \frac{3\pi}{2}$

So, the equations only differ in initial phase and in no other factors.

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

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

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

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

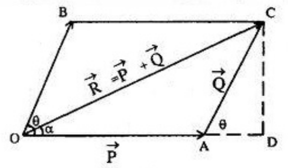
$\theta = \sin^{-1}\left(\frac{1}{2}\right)$

$\theta = 30^\circ$

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

Proof: in $\triangle$ADC

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



$(OC)^2 = (OA + AD)^2 + (DC)^2$

$(OC)^2 = (OA)^2 + (AD)^2 + 2(OA)(AD) + (DC)^2$

$(OC)^2 = \left(P^2\right) + (Q\cos\theta)2 + 2(P)(Q\cos\theta) + (Q\sin\theta)^2$

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

$(R)^2 = P^2 + Q + 2PQ\cos\theta\left(\because \sin^2\theta + \cos^2 Q\right)$

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

OR

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

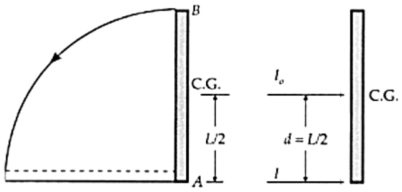
For $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$

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

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.

33. Let M be the mass and Lbe the length of the metre scale. When the upper end of the rod strikes the floor, its centre of gravity falls through height $\frac{L}{2}$.



M.I. of the scale about the lower end A, I = M.I. of the scale about the parallel axis through CG + Md_2

$= I_0 + Md^2 = \frac{ML^2}{12} + \frac{ML^2}{4} = \frac{ML^2}{3} \quad \left[\because d = \frac{L}{2}\right]$

Also, $\omega = \frac{v}{r} = \frac{v}{L}$

Gain in rotational K.E.

$= \frac{1}{2}I\omega^2 = \frac{1}{2} \cdot \frac{ML^2}{3} \cdot \frac{v^2}{L^2} = \frac{Mv^2}{6}$

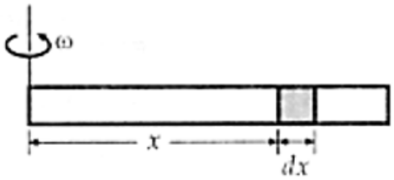
Now, Gain in rotational K.E. = Loss in P.E.

$\frac{Mv^2}{6} = Mg \cdot \frac{L}{2} \quad \text{or} \quad v^2 = 3gl$

or $v = \sqrt{3gL} = \sqrt{3 \times 9.8 \times 1} = 5.4 \text{ ms}^{-1}$

OR

Consider a small element of the liquid of length dx at a distance x from one end.



Mass of the small element = $\frac{M}{L}dx$

Centripetal force associated with the element

$dF = \left(\frac{M}{L}dx\right)x\omega^2 \;\; [\because F = mr\omega^2]$

Force exerted by the liquid = Total centripetal force at the other end

F = $\int dF = \int_0^L \frac{M}{L}\omega^2 x dx = \frac{M}{L}\omega^2\left[\frac{x^2}{2}\right]_0^L$

$= \frac{M}{L}\omega^2\frac{L^2}{2} = \frac{1}{2}M\omega^2 L$