Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 6

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. The equation $\left(P+\frac{a}{V^2}\right)(V-b)$ = Constant. The units of a are **[1]**

   a) dyne cm^{-2} b) dyne $\times$ cm^5

   c) dyne $\times$ cm^4 d) dyne cm^{-3}

2. What is the minimum length of a tube, open at both ends, that resonates with a tuning fork of frequency 350 Hz? [velocity of sound in air = 350 m/s] **[1]**

   a) 100 cm b) 50 cm

   c) 25 cm d) 75 cm

3. The vector product of two vectors a and b is a vector c such that c is perpendicular to the plane containing a and b and the direction is given by: **[1]**

   a) left hand rule b) left-handed screw rule

   c) index finger rule d) right-handed screw rule

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

   a) thrust on drop b) viscosity

   c) surface tension d) residual pressure

5. The total energy of a satellite is E. What is its P.E.? **[1]**

   a) -E b) E

c) -2 E

d) 2 E

6. Two vibrating tuning forks produce waves given by y_1 = 4 sin 500πt and y_2 = 2 sin 506πt. A number are beats produced per minute is **[1]**

a) 360

b) 180

c) 60

d) 3

7. A truck on a straight road starts from rest, accelerating at 2.00 m/s^2 until it reaches a speed of 20.0 m/s. Then the truck travels for 20.0 s at a constant speed until the brakes are applied, stopping the truck in a uniform manner in an additional 5.00 s. What is the average velocity in m/s of the truck for the motion described? **[1]**

a) 15.7

b) 16.2

c) 154

d) 17.5

8. If wave y = A cos (ωt + kx) is moving along x-axis, the shape of pulse at t = 0 and t = 2 s: **[1]**

a) may not be different

b) may not be same

c) are same

d) are different

9. A sphere of mass M and radius R is falling in a viscous fluid. The terminal velocity attained by the falling object will be proportional to **[1]**

a) $\frac{1}{R}$

b) R

c) $\frac{1}{R^2}$

d) R^2

10. A body is projected from earth's surface to become its satellite. Its time period of revolution will not depend upon: **[1]**

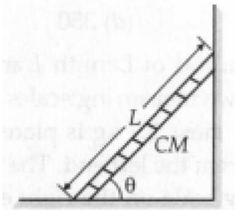
a) mass of earth

b) its own mass

c) gravitational constant

d) radius of earth

11. A ladder of length L leans against a wall at an angle of θ from the horizontal, as shown in the figure. **[1]**



What torque is applied about the ladder's centre of mass by the normal force F_N exerted by the ground on the ladder?

a) $F_N(\frac{L}{2})$ cos θ

b) $F_N(\frac{L}{2})$

c) F_N L sin θ

d) F_N L cos θ

12. The value of coefficient of volume expansion of glycerin is 5 $\times$ 10^{-4} K^{-1}. The fractional change in the density of glycerin for a rise of 40^o C in its temperature, is **[1]**

a) 0.020

b) 0.010

c) 0.025

d) 0.015

13. **Assertion (A):** Mass and energy are not conserved separately, but are conserved as a single entity called mass - **[1]**

energy.

Reason (R): Mass and energy conservation can be obtained by Einstein equation for energy.

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:** It is not possible for a system, unaided by an external agency to transfer heat from a body at lower temperature to another body at a higher temperature. **[1]**

Reason: According to Clausius statement "No process is possible whose sole result is the transfer of heat from a cooled object to a hotter object."

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):** There is no effect of rotation of the earth on acceleration due to gravity at poles. **[1]**

Reason (R): The rotation of the earth is about the polar axis.

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):** Horizontal range is same for the angle of projection θ and (90 - θ). **[1]**

Reason (R): Horizontal range is independent of angle of projection.

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. What are longitudinal waves? Give examples too. **[2]**

18. In CGS system, the value of Stefan's constant is $\sigma = 5.67 \times 10^{-5}$ erg s^{-1} cm^{-2} K^{-4}. Find its value in SI units. Given 1 J = 10^7 erg. **[2]**

19. A small spherical ball of radius r falls with velocity v through a liquid having coefficient of viscosity η. Find the viscous drag F on the ball assuming it depends on η, r and v. Take K = 6π. **[2]**

20. The mass of a bicycle rider along with the bicycle is 100 kg. He wants to cross over a circular turn of radius 100 m with a speed of 10 ms^{-1}. If the coefficient of friction between the tyres and the road is 0.6, will the rider be able to cross the turn? Take g = 10 ms^{-2}. **[2]**

21. 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}. **[2]**

OR

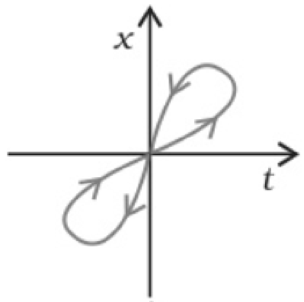
An astronaut inside a small space ship orbiting around the earth cannot detect gravity. If the space station orbiting around the earth has a large size, can he hope to detect gravity?

Section C

22. Describe the cleansing action of detergents. **[3]**

23. An ice cube of mass 0.1 kg at 0^oC is placed in an isolated container which is at 227^oC. The specific heat S of the container varies with temperature T according to the empirical relation S = A + BT, where A = 100 cal/kg-K and B = 2×10^{-2} cal/kg-K^2. If the final temperature of the container is 27^oC, determine the mass of the container. (Latent heat of fusion of water = 8×10^4 call kg. Specific heat of water = 10^3 cal /kg-K). **[3]**

24. Look at the graphs (a) to (d) (figure) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of a particle. **[3]**

a.


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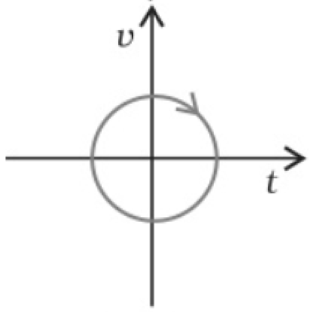

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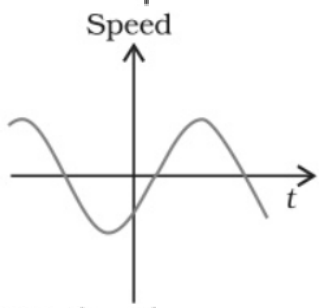

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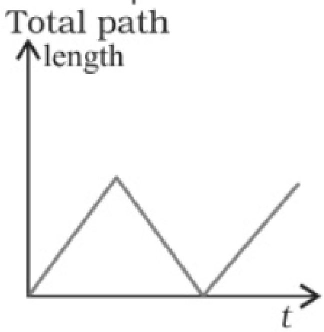


25. State and prove the principle of law of conservation of linear momentum. **[3]**

26. Show that $C_P - C_V = R$ where C_P = specific heat at constant pressure; C_V = specific heat at constant volume and R = Universal Gas constant for an ideal gas. **[3]**

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. A U-tube is made up of capillaries of bore 1 mm and 2 mm respectively. The tube is held vertically and partially filled with a liquid of surface tension 49 dyne cm^{-1} and zero contact angle. Calculate the density of the liquid, if **[3]**

the difference in the levels of the meniscus is 1.25 cm. Take g = 980 cms^{-2}.

OR

In giving a patient a blood transfusion, the bottle is set up so that the level of blood is 1.3 m above needle, which has an internal diameter of 0.36 mm and is 3 cm in length. If 4.5 cm^3 of blood passes through the needle in one minute, calculate the viscosity of blood. The density of blood is 1020 kgm^{-3}.

Section D

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

Certain collisions are referred to as elastic collisions. Elastic collisions are collisions in which both momentum and kinetic energy are conserved. The total system kinetic energy before the collision equals the total system kinetic energy after the collision. If total kinetic energy is not conserved, then the collision is referred to as an inelastic collision.

The coefficient of restitution, denoted by (e), is the measure of degree elasticity of collision. It is defined as the ratio of the final to inital relative speed between two objects after they collide. It normally ranges from 0 to 1 where 1 would be a perfectly elastic collision. A perfectly inelastic collision has a coefficient of 0. In real life most of the collisions are neither perfectly elastic nor perfectly inealstic and $0 < e < 1$.

(a) The following are the data of a collision between a truck and a car.

Mass of the car = 1000 kg

Mass of the truck = 3000 kg

Mass of the truck Before collision:

Speed of the car = 20 m/s

Momentum of the car = 20000 kg m/s

Speed of the truck = 20 m/s

Momentum of the truck = 60000 kg m/s

After collision:

Speed of the car = 40 m/s in the opposite direction

Momentum of the car = 40000 kg m/s in the opposite direction

Speed of the truck = 0

Momentum of the truck = 0

The collision is

a) Both elastic since kinetic energy and momentum is conserved

b) Elastic since momentum is conserved

c) Inelastic since kinetic energy is conserved

d) Elastic since kinetic energy is conserved

(b) The coefficient of restitution is the measure of

a) Malleability of a substance

b) Conductivity of a substance

c) degree of elasticity of collision

d) Elasticity of a substance

(c) Coefficient of restitution is defined as

a) $\frac{\text{Relative velocity before collision}}{\text{Relative velocity after collision}}$

b) Relative velocity after collision $\times$ relative velocity before collision

c) Relative velocity after collision +

d) $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

relative velocity before collision

OR

In real life most of the collisions are

a) Range of coefficient of restitution is 0 < e < 1

b) both neither perfectly nor perfectly inelastic and range of coefficient of restitution is 0 < e < 1.

c) neither perfectly elastic nor perfectly inelastic

d) perfectly inelastic

(d) For perfectly elastic and perfectly inelastic collision, the value of coefficient of restitution are respectively

a) +1, -1

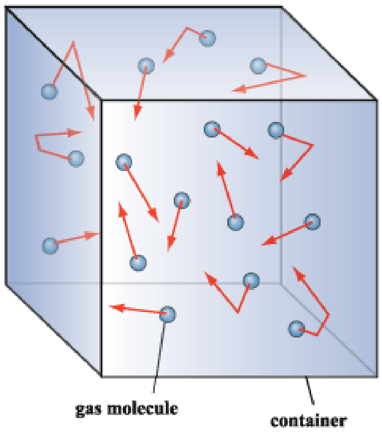
b) 0, 1

c) 0, -1

d) 1, 0

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

Gas molecules move in random motion inside the container. The **pressure exerted** by the gas is due to the continuous collision of the molecules against the walls of the container. Due to this continuous collision, the walls experience a continuous force which is equal to the total momentum imparted to the walls per second.



(a) If the mass of each molecule is halved and speed is doubled, find the ratio of initial and final pressure:

a) 1:16

b) 1:4

c) 1:8

d) 1:2

(b) The pressure exerted by the gases is:

a) inversely proportional to the density

b) inversely proportional to the square of the density

c) directly proportional to the density

d) directly proportional to the square of the density

(c) If the force of attraction between the molecules suddenly disappears, then what will be the change in pressure:

a) pressure increase

b) pressure decrease

c) pressure remains constant

d) pressure falls

(d) If the pressure of a given gas is halved at a certain temperature. what will be its volume:

a) becomes triple

b) becomes double

c) remains constant

d) becomes half

OR

Dimension formula for R?

a) $M^1L^2T^2K^{-1}$

b) $M^1L^1T^{-1}$

c) $M^{-1}L^0T^1$

d) $M^1L^2T^{-2}K^{-1}$

Section E

31. Using the correspondence of S.H.M. and uniform circular motion, find displacement, velocity, amplitude, time period and frequency of a particle executing S.H.M? **[5]**

OR

Plot the corresponding reference circle for each of the following simple harmonic motions. Indicate the initial (t = 0) position of the particle, the radius of the circle, and the angular speed of the rotating particle. For simplicity, the sense of rotation may be fixed to be anticlockwise in every case: (x is in cm and t is in s).

a. $x = -2 \sin (3t + \frac{\pi}{3})$
b. $x = \cos (\frac{\pi}{6} - t)$
c. $x = 3 \sin (2\pi t + \frac{\pi}{4})$
d. $x = 2 \cos \pi t$

32. **[5]**
i. What is projectile motion?
ii. The maximum range of projectile is $\frac{2}{\sqrt{3}}$ times actual range. What is the angle of projection for the actual range?
iii. Two balls are thrown with the same initial velocity at angles α and (90 °- α) with the horizontal. What will be the ratio of the maximum heights attained by them? When will this ratio be equal to 1?

OR

i. Show that for two complementary angles of projection of a projectile thrown with the same velocity, the horizontal ranges are equal.
ii. For what angle of projection of a projectile, is the range maximum?
iii. For what angle of projection of a projectile, are the horizontal range and maximum height attained by the projectile equal?

33. 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. **[5]**

OR

Calculate the moment of inertia of uniform circular disc of mass 500 g, radius 10 cm about

i. diameter of the disc
ii. the axis tangent to the disc and parallel to its diameter and
iii. the axis through the centre of the disc and perpendicular to its plane.

Solution

Section A

1.

(c) dyne $\times$ cm^4

Explanation: Unit of a = Unit of P $\times$ Unit of V^2

= dyne cm^{-2} $\times$ $(cm^3)^2$

= dyne cm^4

2.

(b) 50 cm

Explanation: The fundamental frequency of open pipe $= \frac{v}{2L}$

350 = $\frac{350}{2L}$

$L = \frac{1}{2}$ m = 50 cm

3.

(d) right-handed screw rule

Explanation: If vectors A and B lie in the plane of this page, the vector C will be perpendicular to this plane.

The sense (upward or downward) of the direction of the vector product is given by the direction of the advance of the tip of a right-handed screw when rotated from A to B through angle θ between them, the screw being placed with its axis perpendicular to the plane containing the two vectors.

4.

(c) surface tension

Explanation: Rain drops are spherical due to surface tension.

5.

(d) 2 E

Explanation: Potential energy of satellite U = $-\frac{GMm}{r}$ and total energy of satellite E = $-\frac{GMm}{2r}$

Therefore, U = 2E

6.

(b) 180

Explanation: y_1 = 4 sin 500 πt and y_2 = 2 sin 506 πt

$\omega_1 = 2\pi v_1 = 500\pi$

$\therefore \nu_1$ = 250 Hz

$\omega_2 = 2\pi v_2 = 506\pi$

$\therefore \nu_2$ = 253 Hz

7. **(a)** 15.7

Explanation: As start from rest,

So Initial velocity u = 0 m/s

Final velocity v = 20 m/s

Acceleration a = 2 m/s^2

Let Time during this period = t_1

Also let distance covered = s_1

We know,

v - u = at

So, 20 − 0 = $2t_1$

$t_1 = \frac{20}{2}$ =10 s

Also,

$v^2 - u^2 = 2as_1$

$\Rightarrow 400 - 0 = 2 \times 2 \times s_1$

$s_1 = \frac{400}{4}$ =100 m

Now travel with constant speed of 20 m/s for time t_2 = 20 s

Distance covered

$s_2 = 20 \times 20 = 400$ m

Time taken to stop

t_3 = 5s

Before stopping it covers distance $= s_3$

$s_3 = \frac{1}{2}(20 - 0)5$ = 50 m

Total distance covered = 100 + 400 + 50 = 550 m

Total time of motion t = 10 + 20 + 5 = 35 s

Average velocity $v_{avg} = \frac{total\ distance}{total\ time}$

$= \frac{550}{35}$ = 15.7 m/s

8.

(c) are same

Explanation: At t = 0 and t = 2 s, the shapes of y - x graphs are same.

9.

(d) R^2

Explanation: v = $\frac{2}{9}\frac{R^2}{\eta}(\rho - \sigma)g$

$\therefore v \propto R^2$

10.

(b) its own mass

Explanation: T = $2\pi\sqrt{\frac{(R+h)^3}{GM}}$, Clearly, T does not depend on the mass m of the satellite.

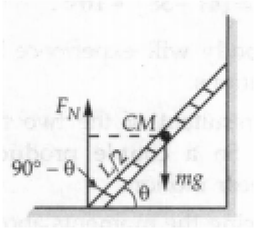
11. **(a)** $F_N(\frac{L}{2})\cos\theta$

Explanation:

$\tau = F_N \times$ perpendicular distance from CM

$= F_N \times \frac{L}{2}\sin(90^\circ - \theta)$

$= F_N\left(\frac{L}{2}\right)\cos\theta$



12. **(a)** 0.020

Explanation: Fractional change in density is

$\frac{\rho_0 - \rho_t}{\rho_0} = \gamma\Delta T$ = $5 \times 10^{-4} \times 40 = 0.020$

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

Explanation: $\Rightarrow$ From Einstein equation $E = mc^2$

it can be observed that if mass is conserved then only energy is conserved and vice versa. Thus, both cannot be treated separately.

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

Explanation: Second law of thermodynamics can be explained with the help of example of refrigerator, as we know that refrigerator, the working substance extracts heat from colder body and rejects a large amount of heat to a hotter body with the help of an external agency, i. e, the electric supply of the refrigerator. No refrigerator can ever work without external supply of electric energy to it.

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

Explanation: At poles, the radius of the horizontal circle is zero.

$\therefore$ Centripetal force F = mrω^2 = 0.

Hence g at poles is not affected by the rotation of the earth.

16.

(c) A is true but R is false.

Explanation: Horizontal range, $R_1 = \frac{u^2 \sin 20}{g}$ for angle θ

$R_2 = \frac{u^2 \sin 2(90^\circ - \theta)}{g} = \frac{u^2 \sin 2\theta}{g}$ for angle $(90^o - \theta)$

$\therefore R_1 = R_2$

Hence horizontal range is same for angle of projection θ and $(90^o - \theta)$ and the horizontal range depends on the angle of projection.

Section B

17. Longitudinal waves are the waves in which medium particles vibrate to and fro about their mean positions along a straight line parallel to the direction of wave propagation. In a longitudinal wave, each particle of matter vibrates about its normal rest position and along the axis of propagation, and all particles participating in the wave motion behave in the same manner, except that there is a progressive change in phase of vibration—*i.e.*,each particle completes its cycle of reaction at a later time. The combined motions result in the advance of alternating regions of compression and rarefaction in the direction of propagation.

Waves setup in springs, waves set up in air columns (organ pipes), sound waves, transfer of motion from the engine to last bogey (or wagon) in a train etc., are common examples of longitudinal waves.

18. In CGS system, $\sigma = 5.67 \times 10^{-5}$ erg s^{-1} cm^{-2} K^{-4}. The SI unit of work is joule. We have,

1 erg = 10^{-7} J and 1 cm = 10^{-2} m

$\therefore$ The value of Stefan's constant in SI units is

$\sigma = 5.67 \times 10^{-5} [10^{-7}J] s^{-1} [10^{-2} m]^{-2} 2K^{-4}$

$= 5.67 \times 10^{-5} \times 10^{-7} \times 10^4 Js^{-1} m^{-2} K^{-4}$

$= 5.67 \times 10^{-8} Js^{-1} m^{-2} K^{-4}$

19. Let F = $K\eta^a r^b v^c$, then

$M^1L^1T^{-2} = [ML^{-1}T^{-1}]^a[L]^b[LT^{-1}]^c$

$= M^a L^{-a + b + c} T^{-a - c}$

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

On solving, a = b = c = 1

Hence F = $K\eta rv = 6\pi\eta rv$ (Stoke's law)

20. The centripetal force acting on the bicycle is given by,

$F_c = \frac{mv^2}{r}$

$= \frac{100 \times 10 \times 10}{100}$

= 100 N

21. 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

OR

Yes,

If the spaceship is large enough then the astronaut will definitely detect the Earth’s gravity as Gravitational Force on the spaceship is directly proportional to the mass of spaceship so as a mass of bigger spaceship will be large and hence it will experience a noticeable amount of force which can be detected, we know gravitational force on a body is given as

$F = \frac{Gm_1m_2}{r^2}$

Where, F is the gravitational force

G is the universal gravitational Constant

m_1 is mass of first body which in this case is earth

m_2 is the mass of second body which is the spaceship

and r is the distance between earth and spaceship

so as the mass of spaceship m_2 increases the gravitational force experienced by it increases and hence can be detected i.e. Gravity can be detected.

Section C

22. Cleansing action of detergents: Oil stains and grease on dirty clothes cannot be removed by simply washing the clothes with water because water does not wet them. By adding detergent or soap to water, the greasy dirt can be easily removed. The cleansing action of detergents can be explained as follows:
    i. Soap or detergent molecules have the shape of a hairpin.
    ii. When detergent is dissolved in water, the heads of its hairpin shape molecules get attracted to water surface.
    iii. When clothes with greasy stains are dipped in water containing detergent, the pointed ends of detergent molecules get attached to the molecules of grease. So a water-grease interface is formed. Thus surface tension is greatly reduced. The greasy dirt is held suspended.
    iv. When the clothes are rinsed in water, the greasy dirt is washed away by running water.

    So when detergent is added to water, the surface tension of water is reduced, its area of contact with grease is increased and hence its cleansing ability is increased.
23. Let M be the mass of container.

    Heat released by container is absorbed by ice untl thermal equilibrium is achieved.

    For container, $T_1 = 227^{o}$ C = (227 + 273) K = 500 K

    Final temperature, $T_2 - 27^{o}$ C = (27 + 273) K = 300 K

    So, $T_1 - T_2$ = 200 K

    $\int_{T_2}^{T_1} Ms \cdot dT = mL + ms_{\text{water}}\ (T_2 - 273)$

    $M \cdot \int_{T_2}^{T_1} (A + BT)dT = (0.1 \times 8 \times 10^4) + 0.1 \times 10^3 \times (300 - 273)$

    $M \cdot \left[[AT]_{T_2}^{T_1} + B\left[\frac{T^2}{2}\right]_{T_2}^{T_1}\right] = 8000 + 2700$

    $M \cdot \left\{A(T_1 - T_2) + \frac{B}{2}(T_1^2 - T_2^2)\right\} = 10700$

    $M\left\{100 \times (200) + \frac{2\times10^{-2}}{2}(-9 \times 10^4 + 25 \times 10^4)\right\} = 10700$

    $M \times 21600 = 10700$

    $M = \frac{10700}{21600} = 0.495$ Kg
24. a. The given x-t graph, shown in (a), does not represent one-dimensional motion of the particle. This is because a particle cannot have two positions at the same instant of time.
    b. The given v-t graph, shown in (b), does not represent one-dimensional motion of the particle. This is because a particle can never have two values of velocity at the same instant of time.
    c. The given v-t graph, shown in (c), does not represent one-dimensional motion of the particle. This is because speed being a scalar quantity cannot be negative.
    d. The given v-t graph, shown in (d), does not represent one-dimensional motion of the particle. This is because the total path length travelled by the particle cannot decrease with time.
25. The principle of conservation of linear momentum states that,"If no external forces act on the system of two colliding objects, then the vector sum of the linear momentum of each body remains constant and is not affected by their mutual interaction." i.e. if $\overline{F}ext = 0$ then $\overline{P} =$ constant . To prove this principle, we consider a collision between two spheres **A** and **B** having masses of $\mathbf{m_1}$ and $\mathbf{m_2}$ respectively.Let $\mathbf{u_1}$ and $\mathbf{u_2}$ be the velocities of the spheres before collision such that $\mathbf{u_1} > \mathbf{u_2}$ and moving on the same straight line . After collision, let their velocities be $\mathbf{v_1}$ and $\mathbf{v_2}$ on the same line. If they collide with each other for a short time

interval **t**, each sphere exerts a force on the other sphere and so, the force experienced by **A** is given as

$F_2 = \frac{change\ in\ momentum}{time} = \frac{m_1 v_1 - m_1 u_1}{t}$

Similarly, force experienced by **B** is $F_1 = \frac{change\ in\ momentum}{time} = \frac{m_2 v_2 - m_2 u_2}{t}$

According to Newton's third law of motion, the force experienced by **A** and **B** are equal and opposite, $\vec{F_2} = -\vec{F_1}$

$\Rightarrow m_2 v_2 - m_2 u_2 = -(m_1 v_1 - m_1 u_1)$

$\Rightarrow m_2 v_2 + m_1 v_1 = m_1 u_1 + m_2 u_2$

$\Rightarrow P_f = P_i$

That is, total momentum before collision is equal to total momentum after collision if no external forces act on them which proves the principle of conservation of linear momentum.

26. Let us first heat the gas at constant volume till the temperature increases by ΔT if $\triangle Q$ is the amount of heat required to raise the temperature of 1 mole of gas to increase the temperature by $\triangle T$

So, $\Delta Q = C_V \Delta T$ ...(i)

Here C_V is the specific heat at constant volume. Since volume remains the same, hence no work is heating the gas then according to law of conservation of energy, the entire heat supplied goes into raising the internal energy and hence the temperature of the gas.

Now, $C_V \Delta T = \Delta U$ .....(ii)

$\therefore \Delta U$ = increase in the internal energy of the gas

Let us heat the gas at constant pressure till the temperature of the gas increases by ΔT. In this case external work is done to expand the gas hence by using first law of thermodynamics.

$\Delta Q^1 = \Delta U + \Delta W$

$\mathrm{C_p \Delta T = C_V \Delta T + \Delta W}$ (by equation (ii))

Here C_P is the specific heat at constant pressure.

But $\Delta W = P\Delta V$, so

$C_P \Delta T = C_V \Delta T + P\Delta V$ ...(iii)

Now, form ideal gas equation : PV = RT ....(iv)

or $P(V + \Delta V) = R(T + \Delta T)$ ...(v)

Subtracting equation (iv) from equation (v)

$P\Delta V = R\Delta T$

Put $P\Delta V = R\Delta T$ in equation (iii)

$C_P \Delta T = C_V \Delta T + P\Delta V$

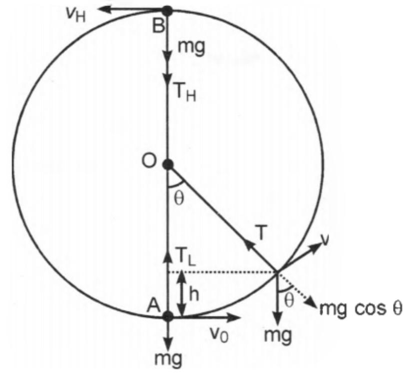
$C_P \Delta T = C_V \Delta T + R\Delta T$ .....(vi)

Divide eq (vi) by $\triangle T$

$C_P = C_V + R$

or $C_P - C_V = R$

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,

$T_L = mg\cos 0^\circ + \frac{m}{l}v_L^2 = mg + \frac{mv_0^2}{l}$

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. Here $h_1 = \frac{2\sigma\cos\theta}{r_1\rho g}$ and $h_2 = \frac{2\sigma\cos\theta}{r_2\rho g}$

$\therefore h_1 - h_2 = \frac{2\sigma\cos\theta}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

$\rho = \frac{2\sigma\cos\theta}{(h_1-h_2)g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

Now $r_1 = \frac{1}{2}$ mm = 0.05 cm,

$r_2 = \frac{2}{2}$ mm = 0.1 cm,

σ = 49 dyne cm^{-1},

$h_1 - h_2$ = 1.125cm, $\theta = 0^o$, g = 980 cm s^{-2}

$\therefore \rho = \frac{2\times 49\times\cos 0^\circ}{1.25\times 980}\left[\frac{1}{0.05} - \frac{1}{0.1}\right]$

$= \frac{2\times 49\times 1}{1.25\times 980} \times 10$ = 0.8g cm^{-3}

OR

Length of the needle, l = 3 cm

Radius of the needle, r = $\frac{0.36}{2}$ mm = 0.018 cm

Volume of blood flowing out per second,

Q = $\frac{\text{Total Volume}}{\text{Time}} = \frac{4.5}{60}$ = 0.075 cm^3 s^{-1}

Density of blood,

ρ = 1020 kg m^{-3} = 1020 $\times$ 10^{-3} g cm^{-3} = 1.02 g cm^{-3} (Given)

The bottle is set up so that the level of blood is 1.3 m above needle, pressure difference,

p = 1.3 m column of blood

= 1.3 $\times$ 100 $\times$ 1.02 $\times$ 980 dyne cm^{-2}

$\eta = \frac{\pi pr^4}{8Ql} = \frac{3.142\times 1.3\times 100\times 1.02\times 980\times (0.018)^4}{8\times 0.075\times 3}$

= 0.238 poise

Section D

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

Certain collisions are referred to as elastic collisions. Elastic collisions are collisions in which both momentum and kinetic energy are conserved. The total system kinetic energy before the collision equals the total system kinetic energy after the collision. If total kinetic energy is not conserved, then the collision is referred to as an inelastic collision.

The coefficient of restitution, denoted by (e), is the measure of degree elasticity of collision. It is defined as the ratio of the final to inital relative speed between two objects after they collide. It normally ranges from 0 to 1 where 1 would be a perfectly elastic collision. A perfectly inelastic collision has a coefficient of 0. In real life most of the collisions are neither perfectly elastic nor perfectly inealstic and 0 < e < 1.

(i) **(b)** Elastic since momentum is conserved

Explanation: From the given data kinetic energy is 800000 Joules, before and after collision and momentum is 40000 kg m/s before and after the collision. So the collision is elastic.

(ii) **(c)** degree of elasticity of collision

Explanation: degree of elasticity of collision

(iii) **(d)** $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

Explanation: $\frac{\text{Relative velocity after collision}}{\text{Relative velocity before collision}}$

OR

(b) both neither perfectly nor perfectly inelastic and range of coefficient of restitution is $0 < e < 1$.

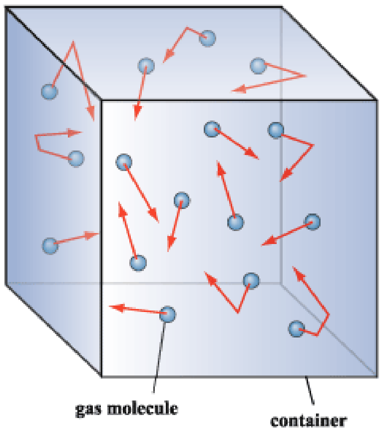
Explanation: both neither perfectly nor perfectly inelastic and range of coefficient of restitution is $0 < e < 1$.

(iv) **(d)** 1, 0

Explanation: 1, 0

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

Gas molecules move in random motion inside the container. The **pressure exerted** by the gas is due to the continuous collision of the molecules against the walls of the container. Due to this continuous collision, the walls experience a continuous force which is equal to the total momentum imparted to the walls per second.



(i) **(d)** 1:2

Explanation: 1:2

(ii) **(c)** directly proportional to the density

Explanation: directly proportional to the density

(iii) **(a)** pressure increase

Explanation: pressure increase

(iv) **(b)** becomes double

Explanation: becomes double

OR

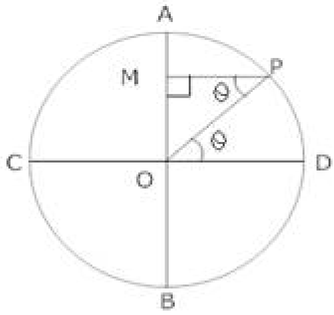
(d) $M^1L^2T^{-2}K^{-1}$

Explanation: $M^1L^2T^{-2}K^{-1}$

Section E

31. If initially at t = 0 particle was at D

Then at time t Particle is at point P



i. Then draw a perpendicular From P on AB,

If the displacement OM = Y

Ratios of circle of reference = Amplitude = a

then In ΔOMP, $\angle$POD = $\angle$OPM = θ ($\because$ Alternate Angles)

$sin\theta = \frac{OM}{OP}$

$\Rightarrow \sin\theta = \frac{y}{a}$, 'a' being radius of the above circle.

$\Rightarrow y = a\sin\theta$

Again $\theta = \omega t$

So, $y = a\sin\omega t$

ii. Velocity, $v = \frac{dy}{dt}$

$\Rightarrow v = \frac{d}{dt}(\mathrm{a}\sin\omega \mathrm{t})$

$\Rightarrow v = a\omega\cos\omega t$

again $\cos\theta = \sqrt{1-\sin^2\theta}$

So, $v = a\omega\times\ \sqrt{1-\sin^2\omega t}$

From equation of displacement : $\sin\omega t = \frac{y}{a}$

So, $v = a\omega\times\sqrt{1-\frac{y^2}{a^2}}$

$\Rightarrow v = aw\sqrt{\frac{a^2-y^2}{a^2}}$

$v = \omega\sqrt{a^2-y^2}$

iii. Acceleration : $f = \frac{dv}{dt}$

$\Rightarrow f = a\omega\times\omega(-\sin\omega t)$

$\Rightarrow f = -\omega^2 a\sin\omega t \Rightarrow f = -\omega^2 y$

iv. Time Period, $T = \frac{2\pi}{\omega}$

v. $freuency = \frac{1}{\mathrm{T}} = \frac{\omega}{2\pi}$

OR

a. x = $2\cos\left(3t+\frac{\pi}{3}+\frac{\pi}{2}\right)$

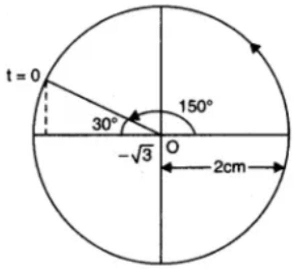
Radius of the reference circle, r = amplitude of SHM = 2 cm,

At t = 0, x = $-2\sin\frac{\pi}{3}$ = $\frac{-2\sqrt{3}}{2}$ = -$\sqrt{3}$ cm

Also ωt = 3t $\therefore$ ω = 3 rad/s

$\cos\phi_0 = -\frac{\sqrt{3}}{2}$, $\phi_0 = 150^{\circ}$

The reference circle is, thus, as plotted below.



b. x = $\cos\left(t-\frac{\pi}{6}\right)$

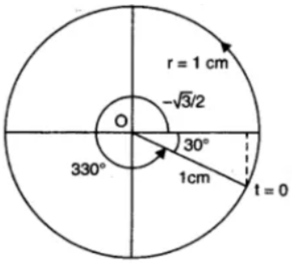
Radius oif circle, r = amplitude of SHM = 1 cm.

At t = 0, x = $\cos\frac{\pi}{6} = \frac{\sqrt{3}}{2}$ cm

Also ωt = 1t $\Rightarrow$ ω = 1 rad/s

$\cos\phi_0 = \frac{\sqrt{3}}{2}, \quad \phi_0 = -\frac{\pi}{6}$

The reference circle is, thus as plotted below.



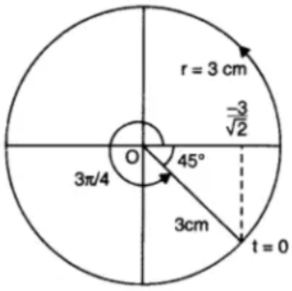
c. x = $3\cos\left(2\pi t+\frac{\pi}{4}+\frac{\pi}{2}\right)$

Here, radius of reference circle, r = 3 cm and at t = 0, x = 3 sin $\frac{\pi}{4}$ = $\frac{\sqrt{3}}{2}$ cm

ωt = 2πt $\Rightarrow$ ω = 2π rad/s

$\cos\phi_0 = \frac{\frac{\sqrt{3}}{2}}{3} = -\frac{1}{\sqrt{2}}$

Therefore, the reference circle is being shown below.



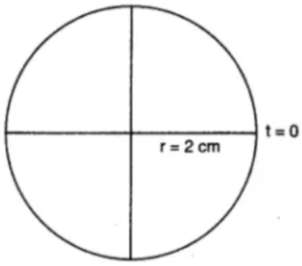
d. x = 2 cos πt

Radius of reference circle, r = 2 cm and at t = 0, x = 2 cm

$\therefore \omega t = \pi t$ or $\omega = \pi$ rad/s

$\cos\phi_0 = 1, \phi_0 = 0$

The reference circle is plotted below.



32. i. When a particle is thrown obliquely near the earth's surface, it moves along a curved path under constant acceleration that is directed towards the centre of the earth (we assume that the particle remains close to the surface of the earth). The path of such a particle is called a projectile and the motion is called projectile motion.

ii. $R_{\max} = \frac{2}{\sqrt{3}} R$ or $\frac{u^2}{g} = \frac{2}{\sqrt{3}} \times \frac{u^2 \sin 2\theta}{g}$

or $\sin 2\theta = \frac{\sqrt{3}}{2} = \sin 60^\circ \;\therefore \theta = 30^\circ$

iii. $h_1 = \frac{v^2 \sin^2 \alpha}{2g}$

$h_2 = \frac{y^2 \sin 2(90^\circ - (x)}{2g} = \frac{y^2 \cos^2 \alpha}{2g}$

Therefore, $\frac{h_1}{h_2} = \frac{v^2 \sin^2 \alpha}{2g} \times \frac{2g}{v^2 \cos^2 \alpha}$

$= \frac{\mathrm{lan}^2 \alpha}{1}$

Ratio:h_1:h_2 = tan^2 α:1

OR

i. Range of projectile = $\frac{u^2 \sin 2\theta}{g}$

for angle θ, Range R_1 = $\frac{u^2 \sin 2\theta}{g}$

for angle (90 - θ), Range R_2 = $\frac{u^2 \sin 2(90-\theta)}{g} = \frac{u^2 \sin(180-2\theta)}{g}$ R_2 = $\frac{u^2 \sin 2\theta}{g}$

therefore R_1 = R_2 i.e., two complementary angle of projection of projectile thrown with the same velocity, the horizontal range is equal.

ii. Let θ be the angles of projection for projectile thrown with speed v

Range of projectile = $\frac{u^2 \sin 2\theta}{g}$

for range to be maximum, sin 2θ = 1

or 2θ = 90^o

θ = 45^o

iii. Range of projectile = $\frac{u^2 \sin 2\theta}{g}$

height of projectile h = $\frac{u^2 \sin^2 \theta}{2g}$

as Range = height of projectile

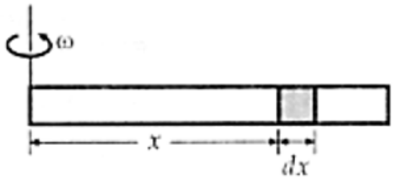
there fore, $\frac{u^2 \sin 2\theta}{g} = \frac{u^2 \sin^2 \theta}{2g}$

$2 \sin \theta \cos \theta = \frac{\sin^2 \theta}{2}$

$\tan \theta = 4$

$\theta = \tan^{-1} 4$

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

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

OR

i. M.I. of the disc about any diameter,

$I_d = \frac{1}{4} MR^2 = \frac{1}{4} \times 500 \times (10)^2$ = 12500 g cm^2

ii. By theorem of parallel axes, M.I. of the disc about a tangent parallel to the diameter of the disc,

$I = I_d + MR^2 = I = I_d + MR^2 = \frac{5}{4} MR^2 = \frac{5}{4} \times 500 \times (10)^2$

= 62500 g cm^2

iii. M.I. of the disc about an axis through its centre and perpendicular to its plane,

$I = \frac{1}{2} MR^2 = \frac{1}{2} \times 500 \times (10)^2$

= 25000 g cm^2