Class XI Session 2024-25
Subject - Physics
Sample Question Paper - 10

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 dimensional formula of permeability of free space μ_0 is **[1]**

a) $[MLT^{-2}A^{-2}]$ b) $[M^0L^2T^{-1}A^2]$
c) $[M^0L^1T]$ d) $[M^0L^0T^0]$

2. An underwater sonar source operating at a frequency of 60 kHz directs its beam towards the surface. If the velocity of sound in air is 330 m/s, wavelength and frequency of the waves in air are **[1]**

a) 330 m, 60 kHz b) 5.5 mm, 60 kHz
c) 5.5 mm, 80 kHz d) 5.5 mm, 30 kHz

3. The motor of an engine is rotating about its axis with an angular velocity of 100 rev/m. It comes to rest in 15 s, after being switched off. Assuming constant angular deceleration, what are the number of revolutions made by it before coming to rest? **[1]**

a) 40 b) 15.6
c) 12.5 d) 32.6

4. A liquid is kept in a cylindrical jar, which is rotated about the cylindrical axis. The liquid rises at its ends. The radius of the jar is r and speed of rotation is ω. The difference in height at the centre and the sides of jar is **[1]**

a) $\frac{g}{r^2g^2}$ b) $\frac{r^2\omega^2}{g}$
c) $\frac{2g}{r^2\omega^2}$ d) $\frac{r^2\omega^2}{2g}$

5. A satellite is moving with a constant speed v in a circular orbit about the earth. An object of mass m is ejected from the satellite such that it just escapes from the gravitational pull of the earth. At the time of its ejection, the kinetic energy of the object is: **[1]**

a) $\frac{1}{3}mv^2$

b) mv^2

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

d) $\frac{2}{3}mv^2$

6. The equation of a wave travelling on a string is $y = 4\sin\left[\frac{\pi}{2}\left(8t - \frac{x}{8}\right)\right]$ where x, y are in cm and t in second. The velocity of the wave is **[1]**

a) 64 cms^{-1}, in -x direction

b) 32 cm s^{-1}, in +x direction

c) 32 cm s^{-1}, in -x direction

d) 64 cms^{-1}, in +x direction

7. A 100 m long train is moving with a uniform velocity of 45 km/h. The time taken by the train to cross a bridge of length 1 km is: **[1]**

a) 78 s

b) 68 s

c) 58 s

d) 88 s

8. The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (velocity of sound = 340 ms^{-1}) **[1]**

a) 4

b) 6

c) 7

d) 5

9. A steel ball is dropped in oil, then **[1]**

a) the speed of ball will keep on decreasing

b) the ball stops

c) the ball attains constant velocity after some time

d) the speed of ball will keep on increasing

10. As observed from earth, the sun appears to move in an approximate circular orbit. For the motion of another planet like mercury as observed from earth, this would **[1]**

a) not be true because the major gravitational force on mercury is due to sun

b) not be true because mercury is influenced by forces other than gravitational forces

c) be similarly true

d) not be true because the force between earth and mercury is not inverse square law

11. A Merry-go-round, made of a ring-like platform of radius R and mass M, is revolving with angular speed ω. A person of mass M is standing on it. At one instant, the person jumps off the round, radially away from the centre of the round (as seen from the round). The speed of the round afterwards is **[1]**

a) 2ω

b) 0

c) $\frac{\omega}{2}$

d) ω

12. Consider two rods of same length and different specific heats (c_1, c_2), thermal conductivities (K_1, K_2) and area of cross-sections (A_1, A_2) and both having temperatures (T_1, T_2) at their ends. If their rate of loss of heat due to conduction is equal, then: **[1]**

a) $\frac{K_2 A_1}{c_2} = \frac{K_1 A_2}{c_1}$

b) $K_1A_1 = K_2A_2$

c) $K_2A_1 = K_1A_2$

d) $\frac{K_1A_1}{c_1} = \frac{K_2A_2}{c_2}$

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

Reason (R): The rate of change of momentum determines that the force is small or large.

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 (A):** Efficiency of a Carnot engine increases on reducing the temperature of sink. **[1]**

Reason (R): The efficiency of a Carnot engine is defined as ratio of net mechanical work done per cycle by the gas to the amount of heat energy absorbed per cycle from the source.

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.

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):** Two vectors are equal when their magnitude and direction both are equal. **[1]**

Reason (R): For any two vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$, if angle between them is $\frac{\pi}{4}$ rad, then $\vec{\mathbf{A}} \times \vec{\mathbf{B}} = \vec{\mathbf{A}} \cdot \vec{\mathbf{B}}$.

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 transverse waves? Give examples too. **[2]**

18. The wavelength λ associated with a moving particle depends upon its mass m, its velocity v and Planck's constant h. Show dimensional relation between them. **[2]**

19. If the units of force, energy and velocity are 20 N, 200 J and 5 ms^{-1}, find the units of length, mass and time. **[2]**

20. Why do the passengers fall in backward direction when a bus suddenly starts moving from the rest position? **[2]**

21. Why is the weight of a body at the poles more than the weight at the equator? Explain. **[2]**

OR

Define gravitational potential energy. Give its SI unit.

Section C

22. Briefly explain the cause of special cylindrical shape of bullets. **[3]**

23. Briefly explain the formation of trade wind. **[3]**

24. A police jeep on a patrol duty on national highway was moving with a speed of 54km/hr. It finds a thief rushing up in a car at a rate of 126km/hr in the same direction. Police sub-inspector fired at the car of the thief with his service revolver with a muzzle speed of 100m/s. With what speed will the bullet hit the car of thief? **[3]**

25. a. State impulse-momentum theorem. **[3]**

b. A ball of mass 0.1kg is thrown against a wall. It strikes the wall normally with a velocity of 30m/s and rebounds with a velocity of 20m/s. Calculate the impulse of the force exerted by the ball on the wall.

26. Describe Carnot's cycle. **[3]**

27. A body of mass 15 kg is hung by a spring balance in a lift. What would be the reading of the balance when **[3]**

i. the lift is ascending with an acceleration of 2 ms^{-2}

ii. descending with the same acceleration

iii. descending with a constant velocity of 2 ms^{-1}?

Take g = 10 ms^{-2}.

28. Eight rain drops of radius 1 mm each falling down with terminal velocity of 5 cms^{-1} coalesce to form a bigger drop. Find the terminal velocity of the bigger drop. **[3]**

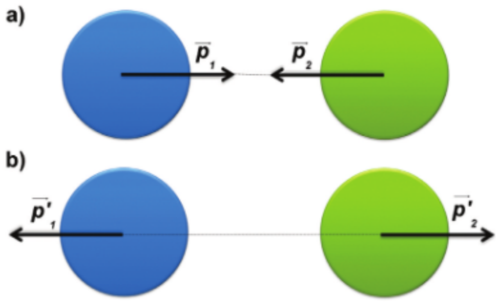
OR

A soap bubble of radius 4 cm and surface tension 30 dyne cm^{-1} is blown at the end of a tube of length 10 cm and internal radius 0.20 cm. If the viscosity of air is 1.89×10^{-4} poise, find the time taken by the bubble to be reduced to a radius of 2 cm.

Section D

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

The kinetic energy of an object is the energy associated with the object which is under motion. It is defined as "the energy required by a body to accelerate from rest to stated velocity." It is a vector quantity and the momentum of an object is the virtue of its mass. It is defined as the product of mass and velocity. It is a vector quantity. The relation between them is given by E = $\frac{P^2}{2m}$. In case of the elastic collision both of these quantities remain constant.



(a) Two masses of 1 gm and 4gm are moving with equal linear momentum. The ratio of their kinetic energy is:

a) 1:2 b) 4:1

c) 1:1 d) 4:2

(b) If the linear momentum is increased by 50%, then K.E will be increased by:

a) 50% b) 200%

c) 125% d) 100%

(c) A heavy object and a light object have the same momentum. Which has the greater speed?

a) both heavy and light object
b) heavy object
c) Moderate object
d) light object

OR

When a body moves with a constant speed along a circle then

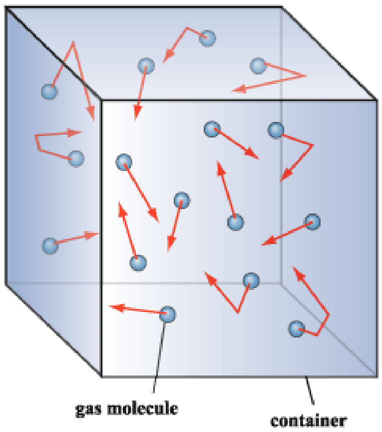
a) no acceleration is produced
b) no work is done on it
c) no displacement on it
d) no force acts on it

(d) Kinetic energy with any reference must be ________.

a) Change
b) negative
c) zero
d) positive

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

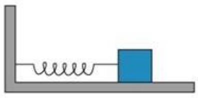
b) $M^1L^1T^{-1}$

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

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

Section E

31. A spring having with a spring constant 1200 N m^{-1} is mounted on a horizontal table as shown in Fig. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released. **[5]**



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

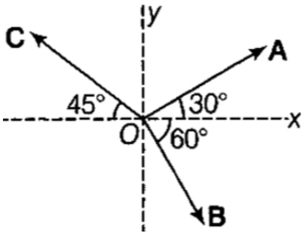
a. at the mean position,
b. at the maximum stretched position, and
c. at the maximum compressed position.

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

OR

The motion of a particle executing simple harmonic motion is described by the displacement function, $x(t) = A\cos(\omega t + \phi)$ If the initial (t = 0) position of the particle is 1 cm and its initial velocity is ω cm /s, then what are its amplitude and initial phase angle? The angular frequency of the particle is π s^{-1}. If instead of the cosine function, we choose the sine function to describe the SHM, $x = B\sin(\omega t + \phi)$, then what are the amplitude and initial phase of the particle with the above initial conditions?

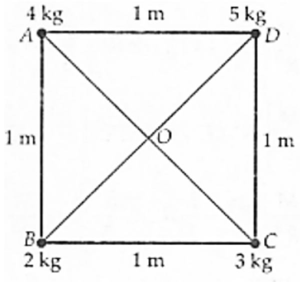
32. The figure shows three vectors $\overrightarrow{OA}$, $\overrightarrow{OB}$ and $\overrightarrow{OC}$ which are equal in magnitude (say, F). Determine the direction of $\overrightarrow{OA} + \overrightarrow{OB} - \overrightarrow{OC}$. **[5]**



OR

At what angle should a body be projected with a velocity 24 ms^{-1} just to pass over the obstacle 16 m high at a horizontal distance of 32 m? Take g = 10 ms^{-2}.

33. Four particles of masses 4 kg, 7 kg, 3 kg and 5 kg are respectively located at the four corners A, B, C and D of a square of side 1 m, as shown in Fig. Calculate the moment of inertia of the system about **[5]**



i. an axis passing through the point of intersection of the diagonals and perpendicular to the plane of the square,
ii. the side AB, and
iii. the diagonal BD.

OR

Define moment of inertia of a body. Give its units and dimensions. What is the physical significance of moment of inertia?

Solution

Section A

1. **(a)** [$MLT^{-2}A^{-2}$]
Explanation: $[\mu_0] = \frac{4\pi rF}{I_1 I_2 l}$
$= \frac{L \cdot MLT^{-2}}{A^2 \cdot L}$
= [$MLT^{-2}A^{-2}$]

2.
(b) 5.5 mm, 60 kHz
Explanation: Frequency in air will also be 60 kHz.
$\lambda_a = \frac{v_A}{\nu} = \frac{330}{60 \times 10^3}$ = 5.5 × 10^{-3} m = 5.5 mm

3.
(c) 12.5
Explanation: Given
Time = t = 15s $= \frac{15}{60} = \frac{1}{4}$ min
Angular displacement:
$\theta = \left[\frac{\omega + \omega_0}{2}\right] t = \left[\frac{0+100}{2} \times \frac{1}{4}\right] = \frac{50}{4}$ = 12.5 revolutions

4.
(d) $\frac{r^2\omega^2}{2g}$
Explanation: $mgh = \frac{1}{2}I\omega^2 = \frac{1}{2} \times mr^2\omega^2$
$\therefore h = \frac{r^2\omega^2}{2g}$

5.
(b) mv^2
Explanation: Escape speed = $\sqrt{2}$ × orbital speed
$v_e = \sqrt{2}v$
At the time of its ejection, kinetic energy of the object will be
K = $\frac{1}{2}mv_e^2 = \frac{1}{2}m(\sqrt{2}v)^2$ = mv^2

6.
(d) 64 cms^{-1}, in +x direction
Explanation: $y = 4\sin\left(4\pi t - \frac{\pi}{16}x\right)$
$\Rightarrow \omega = 4\pi, k = \frac{\pi}{6}$
$v = \frac{\omega}{k}$ 64 cms^{-1} along +x direction

7.
(d) 88 s
Explanation: Total distance = Length of train + Length of bridge
= (100 + 1000)m = 1100 m
Speed = 45 km/h = 45 $\times \frac{5}{18}$ m/s = $\frac{25}{2}$ m/s
Time taken = $\frac{\text{Total distance}}{\text{Speed}}$
= $\frac{1100}{\frac{25}{2}}$ s = 88 s

8.
(b) 6
Explanation: Fundamental frequency is $\nu = \frac{v}{4l} = \frac{340\text{ ms}^{-1}}{4 \times 0.85\text{ m}} = 100$ Hz
Only odd harmonics are present in the pipe closed at one end. So the possible harmonics less than 12500 Hz are

100 Hz, 300 Hz, 500 Hz, 700 Hz, 900 Hz, 1100 Hz

These are six in number.

9.

(c) the ball attains constant velocity after some time

Explanation: The ball attains constant velocity after falling through some distance in oil when the weight of the ball gets balanced by upthrust and the upward viscous force.

10. **(a)** not be true because the major gravitational force on mercury is due to sun

Explanation: As observed from the earth, the sun appears to move in an approximately circular orbit. The gravitational force of attraction between the earth and the sun always follows inverse square law. All planets move around the sun due to the huge gravitational force of the sun acting on them. The gravitational force on the mercury due to earth is much smaller as compared to that acting on it due to sun and hence it revolves around the sun and not around the earth.

11.

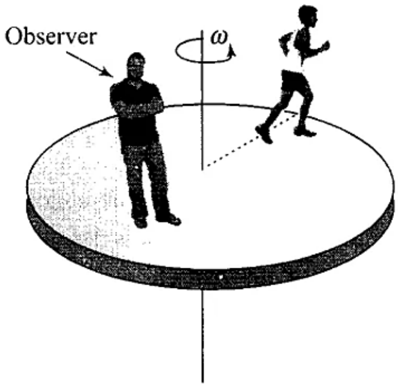
(d) ω

Explanation:

As no torque is exerted by the person jumping, radially away from the centre of the round (as seen from the round), let the total moment of inertia of the system is 21 (round + Person (because the total mass

is 2 M) and the round is revolving with angular speed wsince the angular momentum of the person when it jumps off the round is 1 ω the actual momentum of round seen from ground is 2|ω-| ω = |ω

So we conclude that the angular speed remains same, i.e ω



12.

(b) $K_1A_1 = K_2A_2$

Explanation: Given: $\frac{Q_1}{t} = \frac{Q_2}{t}$

or $\frac{K_1A_1(T_1-T_2)}{l} = \frac{K_2A_2(T_1-T_2)}{l}$

or $K_1A_1 = K_2A_2$

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

Explanation: In a quick collision, time t is small. As F $\times$ t = constant. Therefore, force involved is large, i.e., collision is more violent in comparison to slow collision.

14.

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

Explanation: Efficiency of Carnot cycle $\eta = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$, for carnot engine when T_2 decrease η increase.

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: A is true but R is false.

Section B

17. Transverse waves are the waves in which the medium particles vibrate to and fro about their mean positions at right angles to the direction of wave propagation. Transverse waves travel in the form of crests and troughs. One crest and the adjoining trough constitute one wave.

A simple example is given by the waves that can be created on a horizontal length of string by anchoring one end and moving the other end up and down. Another example is the waves that are created on the membrane of a drum. The waves propagate in directions that are parallel to the membrane plane, but the membrane itself gets displaced up and down, perpendicular to that plane. Light is another example of a transverse wave, where the oscillations are the electric and magnetic fields, which point at right angles to the ideal light rays that describe the direction of propagation.

18. Suppose wavelength λ associated with a moving particle depends upon (i) its mass (m), (ii) its velocity (v) and (iii) Planck's constant (h), then

$\lambda = km^a v^b h^c$ ..(1)

where, k is a dimensionless constant.

Representing the above equation in terms of its dimensions, we get

$[M^0L^1T^0] = [M]^a[LT^{-1}]^b[ML^2T^{-1}]^c$

$\Rightarrow [M^0L^1T^0] = M^{a+c}L^{b+2c}T^{-b-c}$ ..(2)

Comparing power of M, L and T on both sides of equation (2), we get

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

we get a = -1, b = -1, c = + 1

putting the value of a,b, and c in equation (1), we get

$\lambda = km^{-1}v^{-1}h^1$

$\lambda = \frac{kh}{mv}$

Hence, the relation becomes $\lambda = \frac{kh}{mv}$ and it gives the de broglie wavelength of a moving particle.

19. $MLT^{-2} = 20N$ ....(i)

$ML^2T^{-2} = 200$ J ....(ii)

$LT^{-1} = 5\ ms^{-1}$ .....(iii)

Dividing (ii) by (i),

L = $\frac{200}{20}$ = 10 m

Putting the value of L in (iii),

$10\ T^{-1} = 5$ or T = 2 s

From (i),

$M \times 10 \times (2)^{-2} = 20$ or M = 8 kg

20. When the bus suddenly starts moving, the lower part of the passenger's body begins to move along with the bus while the upper part tend to remain at rest due to inertia of rest. That is why a passenger standing or sitting loosely in a bus falls backward when the bus suddenly starts moving.

21. As g = $\frac{GM}{R^2}$ and the value of R at the poles is less than that at the equator, so g at poles is greater that g at the equator.

Now, as $g_p > g_e$, hence $mg_p > mg_e$

i.e., the weight of a body at the poles is more than the weight at the equator.

OR

The amount of work required to transport a body of unit mass from infinity to some point is known as gravitational potential. The mathematical expression will be G = Wm.

The SI unit of gravitational potential is JKg^{-1}

Section C

22. A special cylindrical shape is given to the bullets to ensure that when a bullet is fired form revolver/rifle/gun, it does not bend from trajectory due to Magnus effect. When we trigger of a rifle, the bullet requires a translational motion as well as spinning motion and the bullet, if spherical in shape, may deviate from its path. But in case of bullet of special cylindrical shape the axis of spinning motion is parallel to that of translational motion. Consequently, the pressure on the sides of cylindrical bullet remains uniform throughout and hence the bullet will not bend from its trajectory.

23. Trade winds are steady surface winds on the earth due to the natural convection phenomenon. The equatorial and polar regions of the earth receive unequal solar heat. The equatorial region receives more heat than the polar region. So air at the earth's surface near the equator is hotter than the air in the upper atmosphere of the poles, due to which a convection current would be set up, with the hot air at the equatorial surface rising and moving out towards the poles and in turn, colder air at poles descending and streaming in towards the equator. Because of earth's rotation about its own axis, the air close to the equator region has an eastward speed of 1600 km h^{-1}, while it is zero close to the polar region. As a result, the hot air from the equator descends not at the poles but at 30^o N latitude and returns to the equator. So in this way trade winds are formed.

24. Velocity of the police jeep, V_{PJ} = 54km/hr = $\frac{(54\times5)}{18}$ = 15m/s

Velocity of the thief car, V_{TC} = 126km/hr = $\frac{(126\times5)}{18}$ = 35m/s

Muzzle speed of the bullet V_B = 100m/s.

Now velocity of the thief car, V_{TC} with respect to the police jeep (V_{PJ}), $V_{CP} = V_{TC} - V_{PJ}$ = 35 - 15 = 20m/s.

$V_{BC} = V_B - V_{CP}$ = 100 - 20 = 80 m/s

Where, V_{BC} = Velocity of bullet, V_B w.r.t the relative velocity of the thief car, V_{CP}

Thus bullet will hit the car with a velocity of 80m/s.

25. a. The impulse-momentum theorem states that the change in momentum of an object equals the impulse applied to it Impulse= $m(v-u) = \overline{P}_2 - \overline{P}_1$

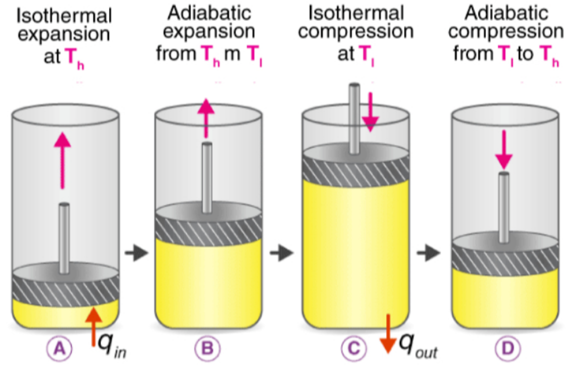
b. m = 0.1kg ,u = 30m/s ,$v = -20m/s$

Impulse = $\overline{P}_2 - \overline{P}_1 = m(v-u)$

Impulse = $m(v-u)$

Impulse = m (-20 – 30) = -5 Ns

26. Carnot cycle is defined as an ideal reversible closed thermodynamic cycle. Four successive operations are involved: isothermal expansion, adiabatic expansion, isothermal compression, and adiabatic compression.



In (a), the process is reversible isothermal gas expansion. In this process, the amount of heat absorbed by the ideal gas is q_{in} from the heat source at a temperature of T_h The gas expands and does work on the surroundings.

In (b), the process is reversible adiabatic gas expansion. Here, the system is thermally insulated, and the gas continues to expand and work is done on the surroundings. Now the temperature is lower, T_l

In (c), the process is a reversible isothermal gas compression process. Here, the heat loss q_{out} occurs when the surroundings do the work at temperature T_l.

In (d), the process is reversible adiabatic gas compression. Again the system is thermally insulated. The temperature again rises back to T_h as the surrounding continue to do their work on the gas.

27. i. m = mass of the body hanged from spring balance = 15 kg

W = actual weight of the body hanged in downward direction = mg = 15 x 9.8 = 147 N

a = acceleration of the lift in upward direction = 2 m/s²

F = reading of the spring balance

force equation for the motion of the body hanged in the lift is given as

F - W = ma

F - 147 = 15 (2)

F = 177 N

ii. a = acceleration of the lift in downward direction = 2 m/s²

force equation for the motion of the body hanged in the lift is given as

W - F = ma

147 - F = 15 x 2

F = 117 N

iii. Since the lift is going at constant velocity

a = acceleration of the lift = 0 m/s²

W - F = 0

F = W

28. Radius of each small drop, r = 1 mm = 0.1 cm

Terminal velocity of each small drop, v = 5 cms^{-1}

Volume of bigger drop = Volume of 8 small drops

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$

or R = 2r = 2 $\times$ 0.1 cm = 0.2 cm

Terminal velocity of each small drop is given by

v = $= \frac{2}{9}\frac{r^2}{\eta}(\rho - \rho')$ g ...(i)

Terminal velocity of bigger drop is given by

V = $\frac{2}{9}\frac{R^2}{\eta}(\rho - \rho')g$ ...(ii)

Dividing equation (ii) by (i), we get

$\frac{V}{v} = \frac{R^2}{r^2}$

or V = $v \times \frac{R^2}{r^2} = 5 \times \frac{(0.2)^2}{(0.1)^2}$

= 5 $\times$ 4 = 20 cms^{-1}

OR

Let R be the radius of the bubble at any instant. Its volume is

V = $\frac{4}{3}\pi R^3$

$\therefore$ Rate of flow of air

= $\frac{dV}{dt} = \frac{4}{3}\pi\times$ $3R^2$ $\frac{dR}{dt}$ = $4\pi R^2$ $\frac{dR}{dt}$

But $\frac{dV}{dt} = \frac{\pi p r^4}{8\eta l}$ and for a soap bubble, p = $\frac{4\sigma}{R}$

$\therefore \frac{dV}{dt} = \frac{\pi r^4}{8\eta l}\cdot\frac{4\sigma}{R}$ = $4\pi R^2$ $\frac{dR}{dt}$ or dt = $\frac{8\ln}{\sigma r^4}$ R^3 dR

Time taken by the bubble when its radius changes from R_1 to R_2 is

$$t = \int dt = \frac{8\ln}{\sigma r^4}\int_{R_2}^{R_1} R^3 dR = \frac{8\ln}{\sigma r^4}\left(\frac{R_1^4 - R_2^4}{4}\right)$$

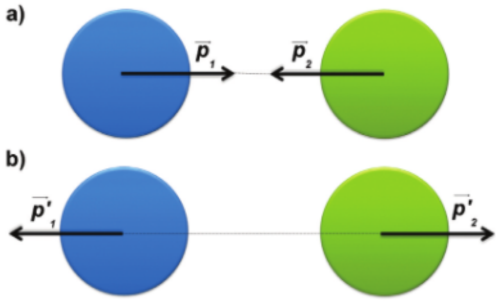
But R_1 = 4 cm, R_2 = 2 cm, σ = 30 dyne cm^{-1}, l = 10 cm, r = 0.2 cm, η = 1.85 $\times$ 10^{-4} poise

$\therefore t = \frac{8\times10\times1.85\times10^{-4}}{30\times(0.2)^4}\times\left(\frac{4^4-2^2}{4}\right)$ = 296 s

Section D

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

The kinetic energy of an object is the energy associated with the object which is under motion. It is defined as “the energy required by a body to accelerate from rest to stated velocity.” It is a vector quantity and the momentum of an object is the virtue of its mass. It is defined as the product of mass and velocity. It is a vector quantity. The relation between them is given by E = $\frac{P^2}{2m}$. In case of the elastic collision both of these quantities remain constant.



(i) **(b)** 4:1

Explanation: 4:1

(ii) **(c)** 125%

Explanation: 125%

(iii) **(d)** light object

Explanation: light object

OR

(b) no work is done on it

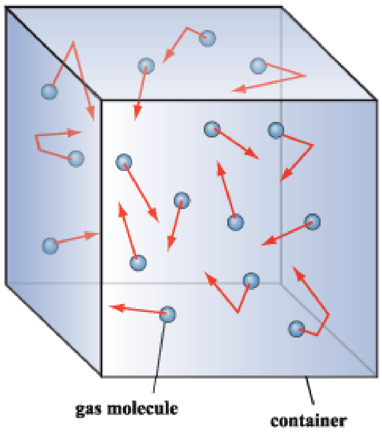
Explanation: no work is done on it

(iv) **(d)** positive

Explanation: positive

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. The functions have the same frequency and amplitude, but different initial phases.

Given:

Distance travelled by the mass sideways is given by, A = 2.0 cm

Force constant of the spring is given by, k = 1200 N m^{-1}

Mass, m is given by = 3 kg

Angular frequency of oscillation is given by:

$$\omega = \sqrt{\frac{spring\ cons\tan t}{mass}}$$

$$\Rightarrow \omega = \sqrt{\frac{k}{m}}$$

$$= \sqrt{\frac{1200}{3}} = \sqrt{400} = 20\text{rads}^{-1}$$

a. When the mass is at the mean position, the initial phase is 0.

Displacement is given by,

$\Rightarrow$ x = A sin ωt = 2sin 20t

b. At the maximum stretched position, the mass is toward the extreme right. Hence, the initial phase is $\frac{\pi}{2}$.

hence, Displacement is given by,

$\Rightarrow x = A\sin\left(\omega t + \frac{\pi}{2}\right)$

$= 2\sin\left(20t + \frac{\pi}{2}\right)$ = 2cos 20t

c. At the maximum compressed position, the mass is toward the extreme left. Hence, the initial phase is $\frac{3\pi}{2}$.

Displacement is given by,

$\Rightarrow x = A\sin\left(\omega t + \frac{3\pi}{2}\right)$

$= 2\sin\left(20t + \frac{3\pi}{2}\right)$ = –2cos 20t

d. The functions have the same frequency $\left(\frac{20}{2\pi}Hz\right)$ and amplitude (2 cm), but initial phases are different $\left(0, \frac{\pi}{2}, \frac{3\pi}{2}\right)$.

OR

Given, displacement equation x(t) = Acos($\omega t + \phi$) ...(i)

At t = 0; x(0) = 1 cm, velocity of the particle v = ωcm/s

Angular frequency $\omega = \pi$ s^{-1}

$\Rightarrow 1 = A\cos(\omega t + \phi)$

For t = 0, 1 = A cosϕ..........(i)

Now, $v(t) = \frac{dx(t)}{dt} = \frac{d}{dt}A\cos(\omega t + \phi)$

$= -A\omega\sin(\omega t + \phi)$

Again at t = 0, $v = \omega$ cm/s

$\Rightarrow \omega = -A\omega\sin\phi$

$\Rightarrow -1 = A\sin\phi$ ....(ii)

Squaring and adding eqs.(i) and (ii),

$A^2\cos^2\phi + A^2\sin^2\phi = (1)^2 + (-1)^2$

$A^2 = 2 \Rightarrow A = \pm\sqrt{2}$cm

Hence, the amplitude of the SHM = $\sqrt{2}$ cm

Dividing Eq. (ii) by (i), we get

$\frac{A\sin\phi}{A\cos\phi} = \frac{-1}{1}$ or $\tan\phi = -1$

$\Rightarrow \phi = -\frac{\pi}{4}$ or $\frac{7\pi}{4}$

Now, if instead of cosine, we choose the sine function in the displacement equation, then

x(t) = B sin($\omega t + \alpha$)

At t = 0, x = 1 cm, $\Rightarrow 1 = B\sin(0 + \alpha)$

or $B\sin\alpha = 1$ ....(iii)

Velocity v(t) = $\frac{dx(t)}{dt} = \frac{d}{dt}[B\sin(\omega t + \alpha)]$

$= +B\omega\cos(\omega t + \alpha)$

Again at t = 0, v(t) = ω cm/s

B cosα = + 1..............(iv)

Squaring and adding Eqs.(iii) and (iv),

$B^2\sin^2\alpha + B^2\cos^2\alpha = (1)^2 + (+1)^2$

$\Rightarrow B^2\sin^2\alpha + B^2\cos^2\alpha = 2$

$B^2\left(\sin^2\alpha + \cos^2\alpha\right) = 2$

$B^2 1 = 2 \Rightarrow B = \pm\sqrt{2}$cm

Hence, amplitude of the simple harmonic motion in both types of trigonometric wave equation expression = $\sqrt{2}$ cm

Dividing Eq. (iii) by (iv), we get

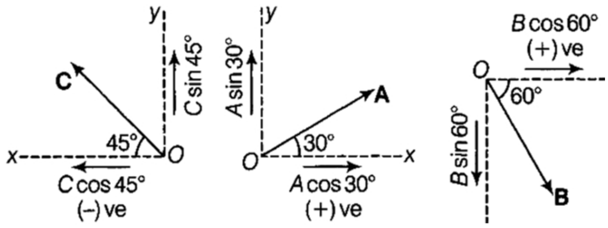
$\frac{B\sin\alpha}{B\cos\alpha} = \frac{1}{1}$ or $\tan\alpha = 1$

$\therefore \alpha = \frac{\pi}{4}$, only the phase angle differs for sine and cosine wave equation.

32. Given, $|\overrightarrow{O}A| = |\overrightarrow{O}B| = |\overrightarrow{O}C| = \overrightarrow{F}$

Angles are 30^{o}, 45^{o} and 60^{o}.

Resolve all the vector components individually



$R_x = \mathbf{R}_{x_1} + \mathbf{R}_{x_2} + \mathbf{R}_{x_3}$

Sum of vectors in x-direction (i.e. R_x) and sum of vactors in y-direction (i.e. R_y)

R_x = A cos 30° + B cos 60° - C cos 45°

$= \frac{F\sqrt{3}}{2} + \frac{F}{2} - \frac{F}{\sqrt{2}}$ [∵ A = B = C = F]

$= \frac{F}{2\sqrt{2}}(\sqrt{6} + \sqrt{2} - 2)$

R_y = A sin 30° + C cos 45° - B sin 60°

$= \frac{F}{2} + \frac{F}{\sqrt{2}} - \frac{F\sqrt{3}}{2} = \frac{F}{2\sqrt{2}}(\sqrt{2} + 2 - \sqrt{6})$

Determination of magnitude,

$R = \sqrt{R_x^2 + R_y^2}$

$= \sqrt{\left[\frac{F}{2\sqrt{2}}(\sqrt{6} + \sqrt{2} - 2)\right]^2 + \left[\frac{F}{2\sqrt{2}}(\sqrt{2} + 2 - \sqrt{6})\right]^2}$

$= \sqrt{F^2(0.435) + F^2(0.116)}$

$= \sqrt{F^2(0.550)} + F\sqrt{0.550}$

⇒ R = 0.74 F

Determination of direction

$\tan\theta = \frac{R_y}{R_x} = \frac{\frac{F}{2\sqrt{2}}(\sqrt{2}+2-\sqrt{6})}{\frac{F}{2\sqrt{2}}(\sqrt{6}+\sqrt{2}-2)}$

$= \frac{0.97}{1.85} \approx 0.524$

$\theta \approx 27.65$

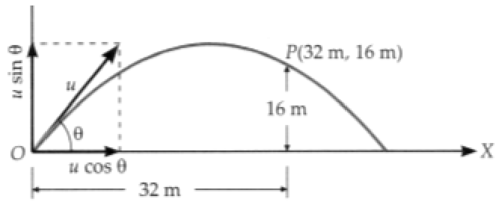
This is the angle which R makes with x-axis.

OR

As shown in figure, if point of projection is taken as the origin of the coordinate system, the projected body must pass through a point having coordinates (32 m, 16 m). If u be the initial velocity of the projectile and θ the angle of projection, then

Horizontal component of initial velocity, $u_x = u\cos\theta$

Vertical component of initial velocity, $u_y = u\sin\theta$



If the body passes through point P after time t, then horizontal distance covered,

$x = (u\cos\theta)t$

or $32 = (24\cos\theta)t$ ..... (i)

Similarly, vertical distance covered,

$y = (u\sin\theta)t - \frac{1}{2}gt^2$

or $16 = (24\sin\theta)t - \frac{1}{2} \times 10 \times t^2$

From equation (i), $t = \frac{32}{24\cos\theta}$

Putting this value of t in equation (ii), we get

$16 = (24\sin\theta)\frac{32}{24\cos\theta} - \frac{1}{2} \times 10 \times \left(\frac{32}{24\cos\theta}\right)^2$

or $16 = 32\tan\theta - 5 \times \frac{16}{9\cos^2\theta}$

or $1 = 2\tan\theta - \frac{5}{9}\sec^2\theta$

or $9 = 18\tan\theta - 5(1 + \tan^2\theta)$

or $5\tan^2\theta - 18\tan\theta + 14 = 0$

$\therefore \tan\theta = \frac{18 \pm \sqrt{(18)^2 - 4 \times 5 \times 14}}{10}$

= 2.462 or 1.37

Hence θ = $67^{o}54'$ or $48^{o}40'$

33. Here AB = BC = CD = DA = 1 m

$OA = OB = OC = OD = \frac{1}{2}\sqrt{1^2 + 1^2} = \frac{1}{\sqrt{2}}$ m

i. M.I. of the system about an axis through O and perpendicular to the plane of the square,

$I = 4(OA)^2 + 2(OB^2) + 3(OC)^2 + 5(OD)^2$

$= (4 + 2 + 3 + 5) \times \left(\frac{1}{\sqrt{2}}\right)^2 = 14 \times \frac{1}{2} = 7$ kg m^2

ii. M.I. of the system about the side AB,

$I = 3(BC)^2 + 5(AD)^2 = 3 \times 1 + 5 \times 1 = 8$ kg m^2

iii. M.I. of the system about the diagonal BD,

$I = 4(OA)^2 + 3(OC)^2$

$= 4 \times \frac{1}{2} + 3 \times \frac{1}{2} = 3.5$ kg m^2

OR

The moment of inertia is defined as the quantity expressed by the body resisting angular acceleration, which is the sum of the product of the mass of every particle with its square of the distance from the axis of rotation.

The units of M. l are kgm^2 and its dimensional formula is $[M^1L^2T^0]$.

The moment of inertia has the same physical significance as a mass in translational motion. The mass of a body is used to calculate inertia in translational motion.