Previous IPE

SOLVED PAPERS

MAY -2026(AP)

PREVIOUS PAPERS

IPE : MAY-2026 (AP)

Time : 3 Hours

JR. PHYSICS

Max.Marks : 85

SECTION-A

I. Answer ALL the following questions. **$9 \times 1 = 9$**

1. Which of the following equation is dimensionally correct?

   1) $\frac{1}{2}mv^2 = mgh$ 2) $V = ut + at$ 3) $s = ut + at^3$ 4) $t = s + uv$

2. The type of stress which acts tangentially to a body's surface is

   1) Hydraulic stress 2) Shearing stress

   3) Compressive stress 4) Tensile stress

3. The relation between the gas pressure P and average kinetic energy per unit volume E is

   1) $P = \frac{1}{2}E$ 2) $P = E$ 3) $P = \frac{3}{2}E$ **4)** $P = \frac{2}{3}E$

4. The resultant of multiplying the scalar with a vector is a ______

5. If R is the radius of the earth and g is the acceleration due to gravity on the earth's surface, then the mean density of the earth is ______

6. Mechanical waves, like sound waves require ______ for propagation.

7. Draw velocity - time graph for a particle moving with uniform velocity.

8. Write the mathematical equation of Newton's Second Law.

9. Write the equation of continuity.

SECTION-B

II. Answer ALL the following questions. **$14 \times 2 = 28$**

10. Distinguish between fundamental units and derived units.

11. A vehicle travels half the distance L with speed v_1 and half with speed v_2. What is the average speed ?

12. If $\vec{P} = 2\vec{i} + 4\vec{j} + 14\vec{k}$ and $\vec{Q} = 4\vec{i} + 4\vec{j} + 10\vec{k}$ find the magnitude of $\vec{P} + \vec{Q}$.

13. Write the expressions for maximum possible speed of a car moving on

    (a) level road (b) banked road.

14. State the sign of work done by a force in the following.

    a) Work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.

    b) work done by gravitational force in the above case.

15. By spinning eggs on a table top, how will you distinguish a hard boiled egg from a raw egg?
16. State the vector form of Newton's Law of Gravitation.
17. State the units and dimensions of stress.
18. Why are liquid drops and bubbles spherical ?
19. State Weins displacement law.
20. Define Thermal equilibrium. How does it lead to Zeroth law of Thermodynamics?
21. Define mean free path.
22. Give two examples of periodic motion which are not oscillatory.
23. What are harmonics ?

III. Answer ANY EIGHT of the following questions. **$8 \times 4 = 32$**

24. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 kmh^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 kmh^{-1}. What is the (a) magnitude of average velocity and (b) average speed of the man over the time interval 0 to 50 min.
25. Define unit vector, null vector and position vector
26. Explain the advantages and disadvantages of friction.
27. Define angular velocity(ω). Derive v = rω.
28. Find the scalar and vector product of two vector, $\bar{a} = (3\bar{i} - 4\bar{j} + 5\bar{k})$ and $\bar{b} = (-2\bar{i} + \bar{j} - 3\bar{k})$
29. What is orbital velocity? Obtain an expression for it.
30. Define strain and explain the types of strain.
31. What is atmospheric pressure and how is it determined using Barometer?
32. In what way is the anomalous behaviour of water advantageous to aquatic animals?
33. Explain triple point of water with the help of pressure-temperature graph.
34. Explain the concept of absolute zero of temperature on the basis of kinetic theory.
35. Explain the modes of vibration of an air column in an closed pipe.

SECTION-D

IV. Answer ANY TWO of the following questions. **$2 \times 8 = 16$**

36. (a) Define work and kinetic energy. State and prove work-energy theorem for constant force.
(b) State the relation between the kinetic energy and momentum of a body.
37. Describe the working of Carnot engine. Obtain an expression for the efficiency.
37. (a) Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.
(b) A particle executing SHM has amplitude of 4cm, and its acceleration at a distance of 1cm from the mean position is 3cms^{-2}. What is its velocity when it is at a distance of 2cm from its mean position?

IPE AP MAY - 2026

SOLUTIONS

SECTION-A

1. Which of the following equation is dimensionally correct?

✓ **1) $\frac{1}{2}mv^2 = mgh$** 2) $V = ut + at$ 3) $s = ut + at^3$ 4) $t = s + uv$

2. The type of stress which acts tangentially to a body's surface is [2]

1) Hydraulic stress **2) Shearing stress**
3) Compressive stress 4) Tensile stress

3. The relation between the gas pressure P and average kinetic energy per unit volume E is

1) $P = \frac{1}{2}E$ 2) $P = E$ 3) $P = \frac{3}{2}E$ ✓ **4) $P = \frac{2}{3}E$**

4. The resultant of multiplying the scalar with a vector is a **vector**

5. If R is the radius of the earth and g is the acceleration due to gravity on the earth's surface, then the mean density of the earth is $\underline{\frac{3g}{4\pi RG}}$

6. Mechanical waves, like sound waves require **medium** for propagation.

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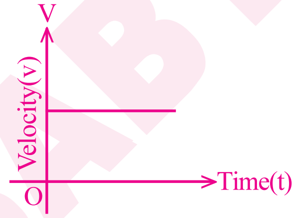
7. Draw velocity-time graph for a particle moving with uniform velocity.

A:



Uniform velocity

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8. Write the mathematical equation of Newton's Second Law.

A: F = ma is the mathematical equation of Newton's Second Law.

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9. Write the equation of continuity.

A: Equation of continuity is $A_1V_1 = A_2V_2$

SECTION-B

10. Distinguish between fundamental units and derived units.

A:

Fundamental Units	Derived Units
1) 'Units of fundamental quantities' are called fundamental units. **Ex:** m, kg, s, A, K,....	1) 'Units of derived quantities' are called derived units. **Ex:** m^2, ms^{-1}, N,....
2) There are only 7 fundamental quantities. So, 'only 7' fundamental units exist.	2) There are many derived quantities. So, 'so many derived units' exist.

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11. A vehicle travels half the distance L with speed v_1 and half with speed v_2. What is the average speed ?

A: Time taken to travel the first half distance, $t_1 = \dfrac{L}{v_1}$

Time taken to travel the second half distance, $t_2 = \dfrac{L}{v_2}$

Total time taken, $t = t_1 + t_2 = \dfrac{L}{v_1} + \dfrac{L}{v_2} = L\left[\dfrac{1}{v_1} + \dfrac{1}{v_2}\right] = L\left[\dfrac{v_1 + v_2}{v_1 v_2}\right]$

Now average speed $(v_{avg}) = \dfrac{\text{Total path length}}{\text{Total time taken}} = \dfrac{L + L}{t_1 + t_2} = \dfrac{2\cancel{L}}{\cancel{L}\left(\dfrac{v_1 + v_2}{v_1 v_2}\right)} = \dfrac{2v_1 v_2}{v_1 + v_2}$

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12. If $\vec{P} = 2\vec{i} + 4\vec{j} + 14\vec{k}$ and $\vec{Q} = 4\vec{i} + 4\vec{j} + 10\vec{k}$ find the magnitude of $\vec{P} + \vec{Q}$.

A: 1) Given that $\vec{P} + \vec{Q} = (2\vec{i} + 4\vec{j} + 14\vec{k}) + (4\vec{i} + 4\vec{j} + 10\vec{k}) = 6\vec{i} + 8\vec{j} + 24\vec{k}$

2) $\therefore |\vec{P} + \vec{Q}| = \sqrt{6^2 + 8^2 + 24^2} = \sqrt{676} = 26$ units.

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13. Write the expressions for maximum possible speed of a car moving on (a) level road (b) banked road.

A: (a) Maximum possible speed of a car on level road is $v_{max} = \sqrt{\mu_s R g}$

(b) Maximum possible speed of a car on banked road is $v_{max} = \sqrt{Rg \tan\theta}$

θ = angle of banking, R = radius of the curve, g = acceleration due to gravity

μ_s = co-efficient of static friction between the tire and road

14. State the sign of work done by a force in the following.

a) Work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.

b) work done by gravitational force in the above case.

A: a) Work done by the man is **positive.** Because force applied by the man in the displacement of the bucket are in the same direction.

b) Work done by the gravity is **negative.** Because gravitational force is acting in the down ward direction and bucket is moving in the upward direction.

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15. By spinning eggs on a table top, how will you distinguish a hard boiled egg from a raw egg?

A: 1) A boiled egg is nearly a rigid body and has low moment of inertia.

2) Hence, for the same torque 'boiled egg spins faster'.

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16. State the vector form of Newton's law of gravitation.

A: The vector form of Newton's law of gravitation is

$$\vec{F} = G\frac{m_1 m_2}{r^2}(\hat{r}) \quad \text{(or)} \quad \vec{F} = G\frac{m_1 m_2}{r^3}\vec{r} \quad \left(\because \hat{r} = \frac{\vec{r}}{r}\right)$$

Where G is the universal gravitational constant, $\hat{r}$ is the unit vector from m_1 to m_2 and r is the distance between the two bodies.

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17. State the units and dimensions of stress.

A: **1) For Stress,** **C.G.S Unit:** dyne cm^{-2} ; **S.I Unit :** N m^{-2} (or) Pascal

2) Dimensional Formula : $[ML^{-1}T^{-2}]$

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18. Why are liquid drops and bubbles spherical ?

A: 1) Due to **surface tension** rain drops and water bubbles are spherical in nature.

2) For a given volume, **Sphere has minimum surface area**.So liquid drops attain spherical shape.

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19. State Wein's displacement law.

A: 1) **Wein's displacement law**: The wavelength(λ_m) for which energy is maximum is inversely proportional to absolute temperature of the body.

2) $\lambda_m \propto \frac{1}{T}$ (or) $\lambda_m = \frac{\text{Constant}}{T}$ (or) $\lambda_m T = \text{Constant}$

Wein's constant is 2.9×10^{-3} mK

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20. Define Thermal equilibrium. How does it lead to Zeroth law of Thermodynamics?

A: **1) Thermal equilibrium:**

Two systems are said to be in thermal equilibrium, if the temperatures of two systems are equal and there is no net flow of heat between them when they are brought into thermal contact.

2) Zeroth law of Thermodynamics:

If two systems are in thermal equilibrium with a third system separately then they must be in thermal equilibrium with each other.

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21. Define mean free path.

A: **Mean free path:** It is the **'average distance'** covered by a molecule between **'two successive collisions'.**

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22. Give two examples of periodic motion which are not oscillatory.

A: 1) **Ex 1:** The revolution of Planets around the Sun is Periodic, but it is not Oscillatory.

2) **Ex 2:** The revolution of Electrons around the Nucleus is Periodic, but it is not Oscillatory.

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23. What are harmonics ?

A: The integral multiples of fundamental frequencies are called harmonics.

SECTION-C

24. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 kmh^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 kmh^{-1}. What is the

a) magnitude of average velocity and

b) average speed of the man over the time interval 0 to 50 min.

Sol: Time taken to go from home to market, $t_1 = \frac{\text{distance}}{\text{speed}} = \frac{2.5\text{km}}{5\text{kmh}^{-1}} = 0.5\text{hr} = \frac{5}{10}\text{hr} = \frac{1}{2}\text{hr}$

Time taken to come to home from market, $t_2 = \frac{\text{distance}}{\text{speed}} = \frac{2.5\text{km}}{7.5\text{ kmh}^{-1}} = \frac{1}{3}\text{hr}$

a) Average velocity $= \frac{\text{Total displacement}}{\text{Total time taken}} = \frac{0}{50} = 0$ ($\because$ In 50 minutes the man reaches his home)

b) Average speed $= \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{2.5+2.5}{\frac{1}{2}+\frac{1}{3}} = \frac{5}{\frac{3+2}{6}} = \frac{30}{5} = 6\text{ km/hr}$

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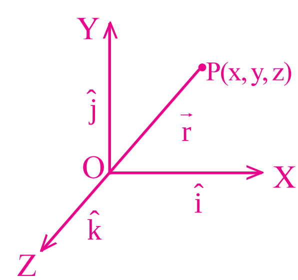
25. Define unit vector, null vector and position vector

A: **1) Unit Vector:** A vector of magnitude one unit is called a unit vector.

2) Null Vector: A vector of zero magnitude and arbitrary direction is called a zero vector or Null vector.

3) Position Vector($\overline{OP}$): The position vector of a point P(x,y,z) is the vector from the origin 'O' of the coordinate system to the position of the point P.



4) The position vector of P(x,y,z) is $\overrightarrow{OP} = \vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

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26. Explain the <u>advantages</u> and <u>disadvantages</u> of <u>friction.</u>

A: **A) Advantages of Friction:**

1) Friction helps us to 'walk on the road'.
2) Friction helps us to 'pick and hold a book' in our hands.
3) Friction helps to 'drive Nails and Screws' into the walls.
4) Friction helps to 'stop a moving vehicle' when we apply breaks.

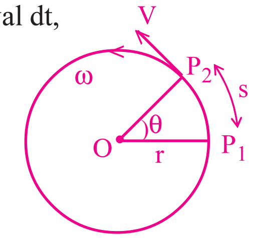
B) Disadvantages of Friction:

1) Friction decreases the 'speed of moving vehicles'.
2) Friction causes 'Wear and Tear' of machines.
3) Friction between tree branches causes 'forest fire'.
4) Friction produces 'unwanted heat' in engines which lead to loss of energy.

27. Define angular velocity(ω). Derive $v = r\omega$.

A: 1) **Angular velocity(ω):** The rate of change of angular displacement is called angular velocity. If a particle undergoes an angular displacement $d\theta$ in the time interval dt,

then its angular velocity, $\omega = \dfrac{d\theta}{dt}$



2) **Derivation of the relation $v = r\omega$**

Let us consider a particle moving along a circular path

Let r = radius of the circular path

s = distance travelled by the particle when it moves from p_1 to p_2 in time t.

v = linear velocity (or tangential velocity) of the particle

ω = angular velocity of the particle.

3) The arc $\overset{\frown}{P_1P_2}$ of length s subtends an angle θ at the centre, then $s = r\theta$

4) Differentiating $s = r\theta$ w.r.to 't', we get

$$\frac{ds}{dt} = \frac{d}{dt}(r\theta) = r\frac{d\theta}{dt} \quad (\because r \text{ is constant})$$

$$\therefore v = r\omega. \qquad \left(\because \frac{ds}{dt} = v \text{ and } \frac{d\theta}{dt} = \omega\right)$$

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28. Find the scalar and vector product of two vector, $\bar{a} = (3\bar{i} - 4\bar{j} + 5\bar{k})$ and $\bar{b} = (-2\bar{i} + \bar{j} - 3\bar{k})$

Sol: $\bar{a}.\bar{b} = (3\bar{i} - 4\bar{j} + 5\bar{k}).(-2\bar{i} + \bar{j} - 3\bar{k}) = 3(-2) + (-4)(1) + 5(-3) = -6 - 4 - 15 = -25$

$$\bar{a} \times \bar{b} = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ 3 & -4 & 5 \\ -2 & 1 & -3 \end{vmatrix} = \bar{i}(12-5) - \bar{j}(-9+10) + \bar{k}(3-8) = 7\bar{i} - \bar{j} - 5\bar{k}$$

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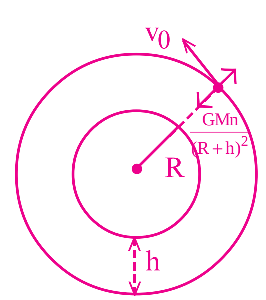
29. What is orbital velocity? Obtain an expression for it.

A: 1) **Orbital Velocity(V_0) :** The **horizontal velocity** required for a body to revolve around a planet in a circular orbit is called "orbital velocity".

2) **Derivation:** Consider a body of mass m revolving around planet of mass M and radius R.Let 'h' be the distance of centre of mass of the body from the surface of the planet. Let V_0 be the horizontal speed of the body when it revolves around the planet .

3) Centrifugal force on the body = Gravitational force of attraction of the planet on the body.

$$\therefore \frac{mV_0^2}{\cancel{(R+h)}} = \frac{GMm}{\cancel{(R+h)^2}} \Rightarrow V_0^2 = \frac{GM}{(R+h)} \Rightarrow V_0 = \sqrt{\frac{GM}{(R+h)}}$$



4) As h<<R we take R+h $\approx$ R. Also we know $GM = gR^2$

5) $\therefore V_0 = \sqrt{\dfrac{GM}{R+h}} \cong \sqrt{\dfrac{g\cancel{R^2}}{\cancel{R}}} = \sqrt{gR}$

$\therefore V_0 = \sqrt{gR}.$ (Its value for the earth is V_0=7.92 km/s)

30. Define strain and explain the types of strain.

A: **Strain:** The ratio of change in the dimension of a body to the original dimension is called strain.

$$\text{Strain} = \frac{\text{Change in dimension}}{\text{Original dimension}}$$

Different types of strain :

1) **Longitudinal strain:** The ratio of the change in length of a body to the original length of the body is called longitudinal strain.

$$\text{Longitudinal strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{e}{l}$$

2) **Volume strain:** The ratio of the change in volume of a body to the original volume of the body is called volume strain.

$$\text{Volume strain} = \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\Delta V}{V}$$

3) **Shearing strain:** Shearing strain is the ratio of the displacement of a layer to its distance from the fixed layer.

$$\text{Shearing strain } \theta = \frac{x}{l}$$

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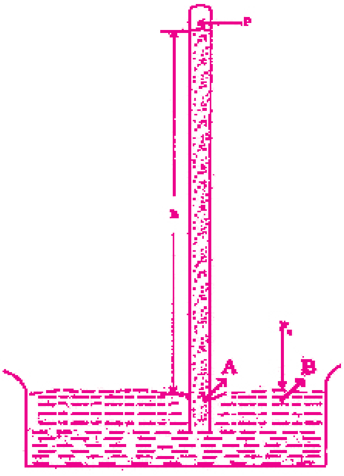
31. What is atmospheric pressure and how is it determined using Barometer?

A: The pressure of atmosphere at any point is equal to the weight of air column of unit cross-sectional area.

It extends from that point to the top of the atmosphere.



Barometer: Mercury barometer consists of a long glass tube closed at one end and filled with mercury. It is inverted into a trough of mercury as shown in figure. The space above the mercury column in the tube contains only mercury vapour whose pressure(P) may be neglected.

Points A and B are at same level.

Hence pressure at A = pressure at B

$P_a = h \rho g$

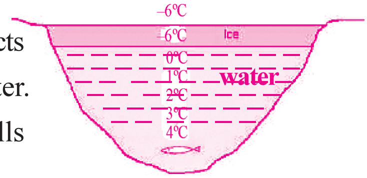
Where ρ = density of mercury

h = height of the mercury column in the tube

p_a = atmospheric pressure

32. In what way is the anomalous behaviour of water advantageous to aquatic animals?

A: 1) **Anomalous behaviour:** Water attains **maximum density** at 4°C.



2) So, when temperature increases from 0°C to 4°C water contracts instead of expansion. This is anomalous behaviour of water.

3) During winter, when the temperature of the atmosphere falls below 0°C , the surface of lakes gradually freezes to ice.

4) But ice is bad conductor of heat. Under the frozen upper layers, the water remains in its liquid form and does not freeze. Thus aquatic animals are survived in this water.

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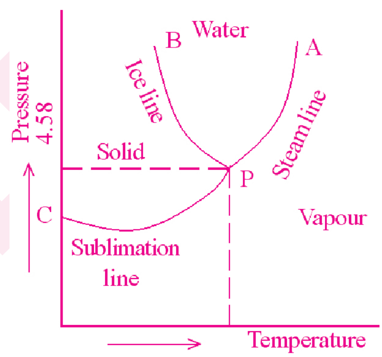
33. Explain triple point of water with the help of pressure-temperature graph.

A: 1) **Triple point:** The point P at which the 'three phases of matter co-exist' in equilibrium is called Triple point. For water, Triple point P = (273.16K, 4.58 mm of Hg)



2) A graph is drawn between temperature and pressure of a substance. It describes distinct phases of physical states at equilibrium and is called **Phase diagram**.

3) **Ice Line(PB):** The temperature at which the ice and water are in equilibrium is called the Melting point. It is along the curve PB and is called ice line.

4) **Steam Line (PA):** The temperature at which steam and water are in equilibrium is called Steam point. It is along the curve PA and is called steam line.

5) **Sublimation line (PC):** The temperature at which ice and steam are in equilibrium is called Sublimation point. It is along the curve PC and is called sublimation line.

6) The 3 curves PB, PA and PC meet at a single point 'P', called the Triple point of water.

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34. Explain the concept of absolute zero of temperature on the basis of kinetic theory.

A: The average kinetic energy of a molecule.

$$\frac{1}{2}m\bar{V}^2 = \frac{3}{2}K_BT \Rightarrow \bar{V}^2 \propto T \Rightarrow V_{rms} \propto \sqrt{T}$$

When T=0 K then $V_{rms} = 0$. This leads us to the following definition of absolute zero of temperature. Absolute zero of temperature may be defined as that temperature at which the velocities of the gas molecules becomes zero.

In other words all molecular motion ceases at absolute zero of temperature. This definition is true only in the case of an ideal gas. The value of absolute zero for an ideal gas is –273.15°C. Before the absolute zero of temperature is reached all the gases change their state to liquids and then to solids.

35. Explain the modes of vibration of an air column in an closed pipe.

A: Frequencies of various modes of Vibration:

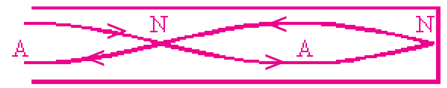
First Harmonic: Here one node and one antinode is formed.

Thus, the length of the air column $l = \frac{\lambda_1}{4} \Rightarrow \lambda_1 = 4l$

$\therefore$ Frequency of Vibration $\nu_1 = \frac{V}{\lambda_1} = \frac{V}{4l}$.

This frequency is called first harmonic (or) Fundamental frequency.

Third Harmonic: Here two nodes and two antinodes are formed.

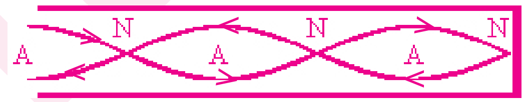


Thus, the length of air column $l = \frac{\lambda_3}{4} + \frac{\lambda_3}{4} + \frac{\lambda_3}{4} = \frac{3\lambda_3}{4} \Rightarrow \lambda_3 = \frac{4l}{3}$

$\therefore$ Frequency of Vibration $\nu_3 = \frac{V}{\lambda_3} = \frac{3V}{4l} = 3\left(\frac{V}{4l}\right) = 3\nu_1$

This frequency is called third harmonic (or) first overtone.

Fifth Harmonic:



Here three nodes and three antinodes are formed.

Thus, the length of air column $l = \frac{5\lambda_5}{4} \Rightarrow \lambda_5 = \frac{4l}{5}$

$\therefore$ Frequency of Vibration $\nu_5 = \frac{V}{\lambda_5} = \frac{5V}{4l} = 5\left(\frac{V}{4l}\right) = 5\nu_1$

This frequency is called fifth harmonic (or) second overtone.

Now, $\nu_1 : \nu_2 : \nu_3 : ... = \nu_1 : 3\nu_1 : 5\nu_1 .... = 1:3:5:..$

Conclusion: Thus, the harmonics in a closed pipe are in the ratio of odd numbers.

SECTION-D

36. a) Define work and kinetic energy. State and prove work-energy theorem for constant force.

b) State the relation between the kinetic energy and momentum of a body.

A: a) 1) Work: It is the dot product of 'force vector and displacement vector' .

Formula: Work $W = \vec{F}.\vec{s}$

2) Kinetic Energy: It is the energy possessed by a body by virtue of its motion.

Formula: Kinetic Energy, $K.E = \frac{1}{2}mv^2$

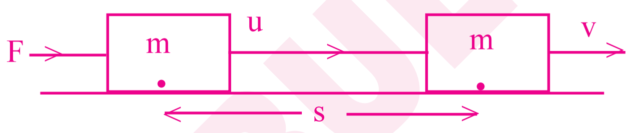
3) Work-energy theorem:

The work done by a net force acting on a body is equal to change in its Kinetic Energy.

Thus, $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

4) Proof : Suppose a body of mass 'm' is moving with an initial velocity u.

Let a constant force F acts on it in the same direction.Let its final velocity is v after time 't'.



5) We know, Acceleration $a = \frac{v-u}{t}$ .....(i) and average velocity $= \frac{v+u}{2}$

6) Displacement s = Average velocity × time $\Rightarrow s = \left(\frac{v+u}{2}\right)t$ ....(ii)

7) Now, Work done W = Force × displacement $\Rightarrow W = Fs = (ma)s$ ....(iii)

Substituting (i) and (ii) in (iii), we get

8) $W = m\left(\frac{v-u}{\cancel{t}}\right)\left(\frac{v+u}{2}\right)\cancel{t} = \frac{1}{2}m(v^2 - u^2) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

W = Final K.E – Initial K.E. Hence, the Work Energy theorem is proved.

b) State the relation between the kinetic energy and momentum of a body.

$K.E = \frac{1}{2}mv^2 = \frac{1}{2}mv^2 \times \frac{m}{m} = \frac{1}{2}\frac{m^2v^2}{m} = \frac{P^2}{2m}$, where p = mv is momentum of the body.

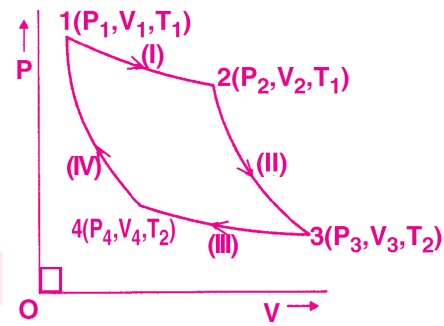
37. Describe the working of Carnot engine. Obtain an expression for the efficiency.

A: **Carnot engine:** A reversible heat engine operating between two temperatures is called a Carnot engine.

Working of Carnot engine: The carnot engine undergoes a cycle of processes called carnot cycle. It consists of two isothermal processes connected by two adiabatic processes. Ideal gas acts as the working substance in the carnot engine.

1) The 4 steps of Carnot cycle:

a) Step I: Isothermal Expansion (IE) of the gas from $1(P_1,V_1,T_1)$ to $2(P_2,V_2,T_1)$.



Work done by the gas on the environment

= Heat(Q_1) absorbed by the gas, from the reservoir, at constant temperature (T_1).

$$W_1 = Q_1 = nRT_1\log_e\left(\frac{V_2}{V_1}\right) \quad \text{...........(i)}$$

b) Step II : Adiabatic Expansion(AE) of the gas from $2(P_2,V_2,T_1)$ to $3(P_3,V_3,T_2)$.

Work done by the gas in this adiabatic process is $W_2 = \frac{nR}{(\gamma-1)}(T_1 - T_2)$ .... (ii)

c) Step III : Isothermal Compression(IC) of the gas from $3(P_3,V_3,T_2)$ to $4(P_4,V_4,T_2)$.

Work done on the gas by the environment

= Heat(Q_2) released by the gas to the reservoir, at constant temperature(T_2).

$$W_3 = Q_2 = nRT_2\log_e\left(\frac{V_3}{V_4}\right) \quad \text{........... (iii)}$$

d) Step IV: Adiabatic Compression (AC) of the gas from $4(P_4, V_4, T_2)$ to $1(P_1, V_1, T_1)$.

Work done on the gas in this adiabatic process is $W_4 = \frac{nR}{(\gamma-1)}(T_1 - T_2)$ .... (iv)

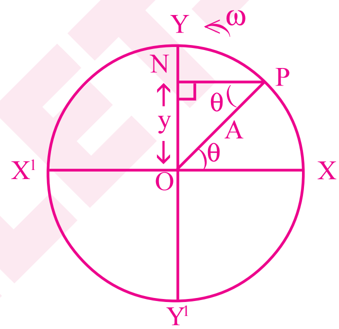
38. a) Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.

A: 1) **Simple Harmonic Motion (SHM):** The 'to and fro motion' of a particle along a straight line, about a fixed point is said to be **Simple Harmonic motion**, when the acceleration is always proportional to its displacement, but in opposite direction.

2) **Proof:** Suppose a particle P is moving along the circumference of a circle of radius A.

Let N be the projection of P on the diameter Y-axis.

If P completes one revolution then its projection point N makes one oscillation on the diameter.



3) If θ is the angular displacement of P at time t and ω is uniform angular velocity then $\theta = \omega t$

4) From ΔOPN, $\sin\theta = \dfrac{ON}{OP} = \dfrac{y}{A} \Rightarrow y = A\sin\theta$

$\therefore$ Displacement $y = A\sin(\omega t)$........... (i)

5) Velocity is the 'rate of change of displacement'.

$$\therefore \text{Velocity } v = \frac{d}{dt}(y) = \frac{d}{dt}A\sin(\omega t) = A\frac{d}{dt}\sin(\omega t)$$

$$= A\omega\cos(\omega t) \quad \left[\because \frac{d}{dx}\sin(kx) = k\cos(kx)\right]$$

6) Acceleration is the 'rate of change of velocity'.

$$\therefore \text{Acceleration } a = \frac{d}{dt}(v) = \frac{d}{dt}A\omega\cos(\omega t) = A\omega\frac{d}{dt}[\cos(\omega t)]$$

$$= -A\omega(\omega)[\sin(\omega t)] = -\omega^2[A\sin(\omega t)] = -\omega^2 y, \text{ [from (i)]} \left[\because \frac{d}{dx}\cos(kx) = -k\sin(kx)\right]$$

7) $\boxed{\therefore a \propto -y}$ $(\because \omega \text{ is a constant})$

8) Hence, the motion of projection N on any diameter is S.H.M.

b) A particle executing SHM has amplitude of 4cm, and its acceleration at a distance of 1cm from the mean position is 3cms^{-2}. What is its velocity when it is at a distance of 2cm from its mean position?

Sol: Given amplitude (A) = 4cm

In S.H.M., when the distance is x, then acceleration, a=ω^2x (only magnitude)

Given a=3cms^{-2} and x = 1cm

$$\therefore 3 = \omega^2 \times 1 \Rightarrow \omega^2 = 3 \Rightarrow \omega = \sqrt{3} \text{ rad / sec}$$

velocity of the particle at a distance 'y' is $v = \omega\sqrt{A^2 - y^2}$

Given y=2cm

$$\therefore v = \omega\sqrt{A^2 - y^2} = \sqrt{3}\sqrt{(4)^2 - (2)^2} = \sqrt{3}\sqrt{16-4} = \sqrt{3} \times \sqrt{12} = \sqrt{36} = 6\text{cms}^{-1}$$