Previous IPE

SOLVED PAPERS

MARCH -2025 (TS)

PREVIOUS PAPERS

IPE: MARCH-2025 (TS)

Time : 3 Hours **JR.PHYSICS** Max.Marks : 60

SECTION-A

I. Answer ALL the following VSAQs: **$10 \times 2 = 20$**

1. What is the contribution of S.Chandra Sekhar to Physics?
2. Why do we have different units for the same physical quantity?
3. Show that the trajectory of an object thrown at a certain angle with the horizontal is a parabola.
4. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.
5. Give the expression for the excess pressure in a an air bubble inside the liquid.
6. What are water proofing agents and water wetting agents? What do they do?
7. Does the body radiate heat at 0K? Does it radiate heat at 0^0 C?
8. What is latent heat of vapourisation?
9. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule?
10. When does a real gas behave like an ideal gas?

BABY BULLET-Q

SECTION-B

II. Answer any SIX of the following SAQs: **$6 \times 4 = 24$**

11. A ball is dropped from the roof of a tall building and simultaneously another ball is thrown horizontally with some velocity from the same roof. Which ball lands first? Explain your answer.
12. If $|\vec{a}+\vec{b}| = |\vec{a}-\vec{b}|$ prove that the angle between $\vec{a}$ and $\vec{b}$ is 90^0?
13. Distinguish between centre of mass and centre of gravity.
14. Define vector product. Explain the properties of a vector product with two examples.
15. What is orbital velocity? Obtain an expression for it.
16. Describe the behaviour of a wire under gradually increasing load.
17. Explain conduction, convection and radiation with examples.
18. Mention the methods used to decrease friction.

SECTION-C

III. Answer any TWO of the following LAQs: **$2 \times 8 = 16$**

19. Develop the notions of work and kinetic energy and show that it leads to work-energy theorem. A machine gun fires 360 bullets per minute and each bullet travels with a velocity of 600 ms^{-1}. If the mass of each bullet is 5gm, find the power of the machine gun?
20. Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum?
21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

IPE TS MARCH-2025
ANSWERS

SECTION-A

1. What is the contribution of S. Chandra Sekhar to physics ?

A: Chandra Sekhar limit, structure and evolution of stars, motion of Galaxy.

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2. Why do we have different units for the same physical quantity?

A: 1) Generally any physical quantity contains a 'wide range of magnitudes'.
So, we need to use different units for different ranges of the 'same physical quantity'.

2) **Ex:** Mass is measured in mg, g, kg,...; Length is measured in mm, cm, m, km,....

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3. Show that the trajectory of an object thrown at a certain angle with the horizontal is a parabola.

A: 1) Suppose the object P(x, y) is projected from the origin 'O' with an angle of projection θ. Let its initial velocity is u.

Horizontal component of u is $u_x = u\cos\theta$ and
Vertical component of u is $u_y = u\sin\theta$

2) Motion along horizontal:
Horizontal component of u is $u_x = u\cos\theta$ and $a_x = 0$.
Also Horizontal displacement of P(x, y) is s = x

$$\text{Now, } s = u_x t + \frac{1}{2}a_x t^2 \Rightarrow x = (u\cos\theta)t + \frac{1}{2}(0)t^2 = (u\cos\theta)t$$

$$\Rightarrow t = \frac{x}{u\cos\theta} \quad ....(i)$$

3) Motion along vertical direction:
Here, Vertical component of u is $u_y = u\sin\theta$ and $a_y = -g$
Also, Vertical displacement of P(x, y) is s = y

$$\text{Now, } s = u_y t + \frac{1}{2}a_y t^2 \Rightarrow y = (u\sin\theta)t - \frac{1}{2}gt^2 ....(ii)$$

4) From (i) & (ii) we get

$$y = \cancel{u}\sin\theta\left(\frac{x}{\cancel{u}\cos\theta}\right) - \frac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2 \Rightarrow y = (\tan\theta)x - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2$$

This equation is in the form $y = Ax - Bx^2$ .....(iii)

where, $A = \tan\theta;\ B = \frac{g}{2u^2\cos^2\theta}$

Here, (iii) represents the equation of a Parabola.
So, the Trajectory of a projectile is a Parabola.

4. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.

A: 1) This is due to the **'law of conservation of momentum'.**

2) When the bomb explodes into two pieces, the two pieces must have equal and opposite momenta. So, the pieces must travel in opposite directions.

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5. Give the expression for the excess pressure in an air bubble inside the liquid.

A: 1) An air bubble inside the liquid contain only one free surface.

2) The excess pressure is $P = \frac{2T}{r}$, where r = radius of the air bubble, T = surface tension

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6. What are water proofing agents and water wetting agents? What do they do?

A: **1) Water proofing agents** are the materials which **increase the angle of contact.** When they are added to water they do not penetrate through cloth.

Ex: Rain coat fabric.

2) Water Wetting agents are the materials which **decrease the angle of contact.** When they are added to water they easily penetrate through cloth.

Ex: Soaps, detergents and dying substances.

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7. Does the body radiate heat at 0K? Does it radiate heat at 0^0 C?

A: i) No, the body does not radiate heat at 0K.

ii) Yes, the body radiates heat at 0^0C.

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8. What is latent heat of vapourisation?

A: Latent heat of vapourisation of water: The amount of heat required to change 'unit mass of a liquid' into vapour, at constant temperature is called Latent heat of Vapourisation.

For water the latent heat of vapourisation 540 $calgm^{-1}$ (or) 2.26×10^6 J/kg.

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9. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule?

A: 1) Let $T_2 = 3\,T_1$

2) rms velocity $\Rightarrow C \propto \sqrt{T} \Rightarrow \frac{C_1}{C_2} = \sqrt{\frac{T_1}{T_2}}$ of the gas molecule = $C = \sqrt{\frac{3RT}{M}}$

$\therefore \frac{C_1}{C_2} = \sqrt{\frac{\cancel{T_1}}{3\cancel{T_1}}} \Rightarrow C_2 = \sqrt{3}C_1$

3) The r.m.s velocity of the gas molecule becomes $\sqrt{3}$ times of initial rms velocity.

4) Increase in r.m.s velocity of the gas molecule

$= C_2 - C_1 = \sqrt{3}C_1 - C_1 = 1.732C_1 - C_1 = 0.732C_1$

5) Percentage increase in rms velocity $= \frac{C_2 - C_1}{C_1} \times 100 = 73.2\%$

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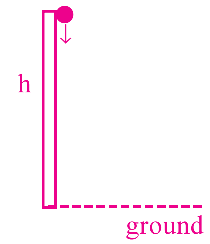
10. When does a real gas behave like an ideal gas?

A: At 'low pressures and high temperatures', a real gas behaves like an ideal gas.

SECTION-B

11. A ball is dropped from the roof of a tall building and simultaneously another ball is thrown horizontally with some velocity from the same roof. Which ball lands first? Explain your answer.

A: 1) For the dropped ball:



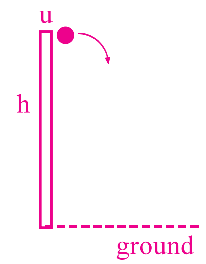
Let the height of the tower = h

Initial velocity u = 0, acceleration a = + g,

displacement s = h; Time of jouney = t_1

Now, $s = ut + \frac{1}{2}at^2 \Rightarrow h = 0 + \frac{1}{2}gt_1^2 \Rightarrow t_1^2 = \frac{2h}{g} \Rightarrow t_1 = \sqrt{\frac{2h}{g}}$ ....(1)

2) For the horizontally projected ball:



Here, Initial vertical velocity $u_y = 0$,

Initial vertical displacement s = h,

acceleration $a_y = +g$, Time of journey = t_2

Now, $s = ut + \frac{1}{2}at^2 \Rightarrow h = 0 + \frac{1}{2}gt_2^2 \Rightarrow t_2^2 = \frac{2h}{g} \Rightarrow t_2 = \sqrt{\frac{2h}{g}}$ .....(2)

3) From (1) & (2), $t_1 = t_2$.

So, both the bodies reach to the ground simultaneously

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12. If $|\vec{a}+\vec{b}| = |\vec{a}-\vec{b}|$ then what is the angle between $\vec{a}$ and $\vec{b}$ is 90^0?

A: 1) Given that $|\vec{a}+\vec{b}| = |\vec{a}-\vec{b}| \Rightarrow \sqrt{a^2+b^2+2ab\cos\theta} = \sqrt{a^2+b^2-2ab\cos\theta}$

2) Squaring on both sides, $a^2 + b^2 + 2ab\cos\theta = a^2 + b^2 - 2ab\cos\theta$

$\Rightarrow 4ab\cos\theta = 0$

$\Rightarrow \cos\theta = 0 \quad \therefore \theta = 90^o$. Hence the angle between $\bar{a}$ and $\bar{b}$ is 90^o

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13. Distinguish between centre of mass and centre of gravity.

A:

Centre of mass	Centre of gravity
1) This is the point at which entire mass of the body is supposed to be concentrated.	1) This is the point at which the weight of the body acts.
2) Centre of mass is independent of acceleration due to gravity.	2) Centre of gravity depends upon acceleration due to gravity.
3) It lies inside or outside the body.	3) It always lie inside the body.
4) This concept is useful while dealing with motion of body	4) This concept is useful while dealing with stability of body.

BABY BULLET-Q

14. Define vector product. Explain the properties of vector product with 2 examples.

A: **1) Vector Product:** The vector product of two vectors $\overline{a},\overline{b}$ with angle θ between them, is

$$\overline{a}\times\overline{b}=|\overline{a}||\overline{b}|\sin\theta\,\hat{n}$$

Here, $\hat{n}$ is the unit vector normal to the plane of $\overline{a},\overline{b}$.

2) Properties of Vector Product :

(i) Commutative law is not satisfied : $\overline{a}\times\overline{b}\neq\overline{b}\times\overline{a}$

(ii) Distributive law is satisifed : $\overline{a}\times(\overline{b}+\overline{c})=(\overline{a}\times\overline{b})+(\overline{a}\times\overline{c})$

(iii) Vector product of two parallel vectors is null vector.

Ex: $\overline{i}\times\overline{i}=\overline{j}\times\overline{j}=\overline{k}\times\overline{k}=\overline{o}$

(iv) Vector product of two perpendicular unit vectors is unit normal vector.

Ex: $\overline{i}\times\overline{j}=\overline{k},\quad \overline{j}\times\overline{k}=\overline{i},\quad \overline{k}\times\overline{i}=\overline{j}$

3) Examples: Torque $\overline{\tau}=\overline{r}\times\overline{F}$; Velocity $\overline{v}=\overline{\omega}\times\overline{r}$

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

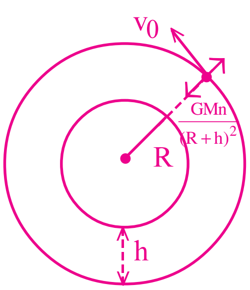
A: **1) Orbital Velocity (V_0) :** The **horizontal velocity** required for a body to revolve around a planet in a circular orbit is called "orbital velocity".

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.

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



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

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

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

BABY BULLET-Q

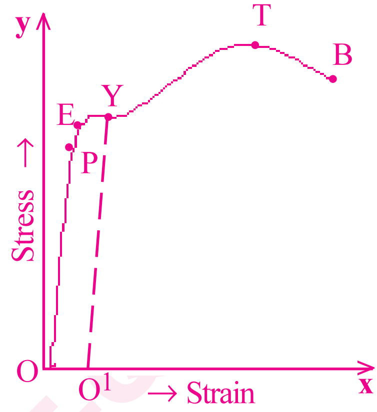
16. Describe the behaviour of a wire under gradually increasing load.

A: Consider a wire suspended from a rigid support and loaded at the other end.

Suppose the load is increased gradually until it breaks.

A graph is plotted between strain on the X-axis and the stress on the Y-axis.

The nature of graph is shown here.



Behaviour of a wire under increasing load:

1) **Proportionality limit(OP):** The part OP is a straight line which shows that stress is proportional to strain.The wire obeys Hooke's law upto the point P . So P is called the proportionality limit of the wire.

2) **Elastic limit (PE):** Beyond P upto E, the graph is slightly curved. When the load is removed, the wire will regain its natural length. Upto E, the wire can be deformed elastically.

3) **Yielding point(Y):** Beyond elastic limit, when the load is removed at the point Y, the wire does not regain its natural length completely. It will have a permanent increase in length. In the region EY the wire shows plastic behaviour.

4) **Tensile Point(T):** Beyond the point Y, the strain increases rapidly without any increase in the load. Even if the load is not removed, the strain increases continuously till the wire reaches the point T. The stress corresponding to T is called the tensile strength of the given material.

5) **Breaking Point(B):** Beyond the point T, the wire shows necks at few points along the length of the wire. Consequently, the wire breaks at B. This point B is called 'breaking point'.

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17. Explain conduction, convection and radiation with examples.

A: 1) **Conduction:** Transfer of heat from one place to another place **without the actual movement** of the particles is called conduction.

Ex: Heat transfer from the hot end of the rod to the other end.

2) **Convection:** Transfer of heat from one place to another place **with the actual movement** of particles is called convection.

Ex: Sea breeze, Land breeze, Trade wind.

3) **Radiation:** Transfer of heat from one place to another place **without the help of the material** of the medium is called Radiation. Radiation is the quickest mode of heat transmission.

Ex: Transfer of heat energy from the Sun to Earth.

18. Mention the methods used to decrease friction.

A: Methods used to decrease Friction:

1) **Polishing:** It reduces the frictional force of the polished surfaces.
2) **Lubricants:** They reduce the friction by forming thin layers between the surfaces in contact.
3) **Ball bearings:** They reduce friction in the wheels of motor vehicles while revolving.
4) **Stream lining:** It reduces friction due to air when Aeroplanes and Cars are streamlined in their front surfaces.

BABY BULLET-Q

SECTION-C

19. Develop the notions of work and kinetic energy and show that it leads to work-energy theorem.

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.

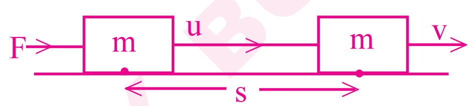
Formula: Kinetic Energy, $K.E = \frac{1}{2}mv^2$

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 ⇒ $s = \left(\frac{v + u}{2}\right)t$ ....(ii)

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

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

8) $W = m\left(\frac{v - u}{t}\right)\left(\frac{v+u}{2}\right)t$

$= \frac{1}{2}m(v^2 - u^2) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

W = Final K.E – Initial K.E.

Hence, the Work Energy theorem is proved.

BABY BULLET-Q

b. A machine gun fires 360 bullets per minute and each bullet travels with a velocity of 600 ms^{-1}. If the mass of each bullet is 5gm, find the power of the machine gun?

Sol: 1) Given Mass of each bullet (m) = 5gm = 5×10^{-3} kg

Velocity of each bullet (v) = 600 ms^{-1}

Number of bullets (n) = 360; Time (t) = 1 minute = 60 s; Power (p) =?

2) Power of machine gun $P = \frac{\text{work done by gun}}{\text{time}} = \frac{\text{K.E gained by all bullets}}{\text{time}} = \frac{n \times \frac{1}{2} mv^2}{t}$

3) $\therefore\ P = \frac{360 \times \frac{1}{2} \times 5 \times 10^{-3} \times 600 \times 600}{60} = 900 \times 6 = 5400 \text{ watt} = 5.4 \text{ kW}$

BABY BULLET-Q

20. Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum?

A: (a) To show that motion of simple pendulum is simple harmonic:

1) Consider a simple pendulum of length 'l', mass 'm' suspended from a rigid support as shown in the figure. Let the bob makes an angle 'θ' with the vertical at an instant.

2) The weight 'mg' is resolved into two perpendicular components. One component 'mgcosθ' balances the 'tension(T)'. The other component 'mgsinθ' provides 'restoring force(F)'.

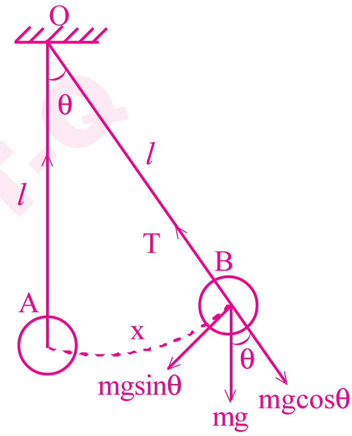
3) Restoring force is given by $F = -mg\sin\theta$

But we know $F = ma$

$\therefore \cancel{m}a = -\cancel{m}g\sin\theta$

$\Rightarrow a = -g\sin\theta$

$\Rightarrow a = -g\,\theta$ ....(i) [when θ is very small, $\sin\theta = \theta$]



4) Also $\theta = \dfrac{x}{l}$ [$\because x = r\theta$ as arc length = radius × angle]

From (i), $a = -g\left(\dfrac{x}{l}\right) \Rightarrow a = -\left(\dfrac{g}{l}\right)x$ ....(ii)

5) From (ii), $a \propto -x$, ($\because \left(\dfrac{g}{l}\right)$ is constant)

Hence, proved that the motion of the simple pendulum is S.H.M.

(b) Derivation for time period T:

6) If ω is angular velocity of the bob then its acceleration is $a = -\omega^2 x$.............(iii)

Equating (iii) & (ii) we get, $\cancel{-}\omega^2\cancel{x} = \cancel{-}\left(\dfrac{g}{l}\right)\cancel{x} \Rightarrow \omega^2 = \dfrac{g}{l} \Rightarrow \omega = \sqrt{\dfrac{g}{l}}$.

7) Time period $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{\sqrt{\dfrac{g}{l}}} = 2\pi\sqrt{\dfrac{l}{g}}$ $\boxed{\therefore T = 2\pi\sqrt{\dfrac{l}{g}}}$

(c) Seconds pendulum:

8) A pendulum with time period **2 seconds** is called seconds pendulum.

21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

A: 1) **Reversible process:** A process that can be 'retraced back' in the opposite direction is called a reversible process.

Ex: Fusion of ice and vaporisation of water.

2) **Irreversible process:** A process that can not be retraced back in the opposite direction is called an irreversible process.

Ex: Work done against friction.

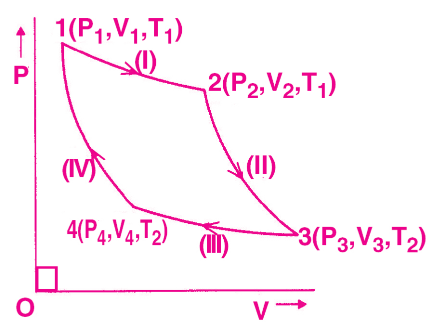
3) **Carnot engine:** A reversible heat engine operating between two temperatures is called Carnot engine.

Working of Carnot engine: The carnot engine undergoes a cycle of four 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.

4) 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).



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

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).

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

BABY BULLET-Q