Previous IPE

SOLVED PAPERS

MARCH-2023 (AP)

PREVIOUS PAPERS

IPE: MARCH-2023(AP)

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

SECTION-A

I. Answer ALL the following VSAQs: **10 × 2 = 20**

1. What is physics ?
2. Express unified atomic mass unit in Kg.
3. The vertical component of a vector is equal to its horizontal component. What is the angle made by the vector with X-axis ?
4. Can the coefficient of friction be greater than one?
5. What is angle of contact?
6. Give the expression for the excess pressure in a liquid drop.
7. What is latent heat of fusion?
8. State Weins displacement law?
9. State Boyle's law and Charles law.
10. Define mean free path.

SECTION-B

II. Answer any SIX of the following SAQs: **6 × 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. Show that maximum height and range of projectile are $\frac{u^2\sin^2\theta}{2g}$, $\frac{u^2\sin 2\theta}{g}$ respectively when the terms have their regular meaning.
13. Explain the advantages and disadvantages of friction
14. Distinguish between centre of mass and centre of gravity.
15. Write the equations of motion for a particle rotating about a fixed axis.
16. State Kepler's laws of planetary motion.
17. Pendulum clocks generally go fast in winter and slow in summer. Why?
18. Describe the behaviour of a wire under gradually increasing load.

SECTION-C

III. Answer any TWO of the following LAQs: **2 × 8 = 16**

19. State and prove law of conservation of energy in case of freely falling body. 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. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic. What is seconds pendulum?
21. State second law of thermodynamics. How is heat engine different from a refrigerator.

IPE AP MARCH-2023
ANSWERS

SECTION-A

1. What is physics ?

A. Physics is a branch of science which deals with the **study of the basic laws of nature** and their applications in different phenomena.

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2. Express unified atomic mass unit in Kg. **[TS 19]**

A. 1 unified atomic unit (u) = 1.67 x 10^{-27} kg

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3. The vertical component of a vector is equal to its horizontal component. What is the angle made by the vector with X-axis ?

A. 1) Let ‘θ’ be angle made by the vector $\vec{R}$ with X-axis.

2) Vertical component of $\vec{R}$ = R sinθ and Horizontal component of $\vec{R}$ = R cosθ

3) $\therefore \not{R}\cos\theta = \not{R}\sin\theta \Rightarrow \frac{\sin\theta}{\cos\theta} = 1 \Rightarrow \tan\theta = 1 \Rightarrow \theta = 45^o$

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4. Can the coefficient of friction be greater than one?

A. 1) Yes. In general, coefficient of friction is less than one.

2) If the surfaces are polished heavily then adhesive forces between the molecules increase and then coefficient of friction will be greater than one.

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5. What is angle of contact?

A. 1) **Angle of contact:** When a solid body is dipped in a liquid,the angle between solid surface and the tangent drawn to the liquid surface, at the point of contact, inside the liquid, is called Angle of contact.

2) For Pure water and glass, angle of contact is 0^o.

For Mercury and glass, angle of contact is 140^0.

6. Give the expression for the excess pressure in a liquid drop.

A. 1) Liquid drop in air contains only one interface.

2) Hence excess pressure in a liquid drop = $P_{inside} - P_{outside} \Rightarrow P_{excess} = \frac{2T}{r} = P_{inside} - P_{outside}$

Where r = radius of the liquid drop

T = surface tension of the liquid-air interface.

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7. What is latent heat of fusion? **[AP 23]**

A. **Latent heat of fusion of ice:** The latent heat of fusion of ice is the amount of heat required to convert 'unit mass of water' at 0^0C into ice at 0^0C.

For water the latent heat of fusion is 80 $calgm^{-1}$ (or) 3.33×10^5 Jkg^{-1}

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8. State Weins displacement law.

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

i.e $\lambda_m \propto \frac{1}{T}$ (or) $\lambda_m = \frac{Constant}{T}$ (or) $\lambda_m T = Constant$

Wein's constant is 2.9×10^{-3} mK

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9. State Boyle's law and Charles law.

A. **1) Boyle's law:** Pressure (P)is 'inversely proportional' to its volume(V),at constant temperature(T). for a given mass of gas. Thus $P \propto \frac{1}{V}$, (T is constant) (or) PV = Constant,

2) Charles law: Volume(V) is 'directly proportional' to its absolute temperature(T) , at constant pressure(P) for a given mass of gas.

Thus $V \propto T$, (or) $\frac{V}{T}$ = Constant

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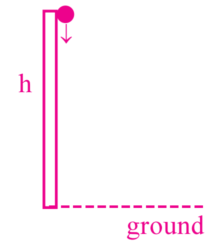
10. Define mean free path.

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

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:



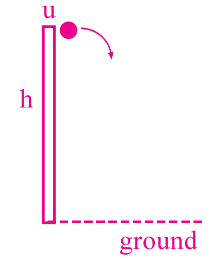
Let the height of the tower = h

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

12. Show that maximum height and range of projectile are $\frac{u^2\sin^2\theta}{2g}, \frac{u^2\sin 2\theta}{g}$ respectively when the terms have their regular meaning.

A. 1) Maximum height: It is the 'maximum vertical distance' travelled by the projectile where its 'vertical velocity' component becomes zero.

Let a body be projected with a velocity 'u' at an angle 'θ' with the horizontal.

2) In the vertical direction, Initial vertical velocity component $u = u\sin\theta$

At maximum height, final vertical velocity component $v = 0$

Acceleration in the vertical direction $a = -g$.

Now, $v^2 - u^2 = 2as \Rightarrow 0 - (u\sin\theta)^2 = -2gh_{max} \Rightarrow u^2\sin^2\theta = 2gh_{max}$

Hence, $h_{max} = \frac{u^2\sin^2\theta}{2g}$ ....(1)

3) Horizontal Range (R):

It is the horizontal distance travelled by a projectile during its 'time of flight'.

Range = Horizontal velocity x time of flight

$$R = u\cos\theta \times T = u\cos\theta \times \frac{2u\sin\theta}{g} \qquad \left[\because T = \frac{2u\sin\theta}{g}\right]$$

$$R = u\cos\theta \times \frac{2u\sin\theta}{g} = \frac{u^2(2\sin\theta\cos\theta)}{g} = \frac{u^2\sin 2\theta}{g}$$

$$\therefore R = \frac{u^2\sin 2\theta}{g}$$

4) At θ is 45°, the horizontal range of a projectile becomes maximum.

13. Explain the advantages and disadvantages of friction.

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.

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14. 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.

15. Write the equations of motion for a particle rotating about a fixed axis. [AP 19,23]

Ans: When a body is rotating with constant angular acceleration (α), the rotational kinematical equations are

1) $\omega = \omega_o + \alpha t$

2) $\theta = \omega_o t + \frac{1}{2}\alpha t^2$

3) $\omega^2 - \omega_o^2 = 2\alpha\theta$.

4) $\theta_n = \omega_o + \alpha\left(n - \frac{1}{2}\right)$

5) $\theta = \left(\frac{\omega + \omega_o}{2}\right)t$

where ω is angular velocity after time 't',

ω_o is initial angular velocity,

α is angular acceleration

t is time taken

θ is angular displacement

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16. State Kepler's laws of planetary motion.

A: **1) Law of orbits:** All planets move in elliptical orbits with the sun situated at one of the foci.

2) Law of areas: The line that joins any planet to the sun sweeps equal areas in equal intervals of time.

3) Law of periods: The square of the time period of revolution of a planet is proportional to the cube of the semi-major axis of the ellipse traced out by the planet.

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17. Pendulum clocks generally go fast in winter and slow in summer. Why?

Sol: The time period of pendulum clock is given by $T = 2\pi\sqrt{\frac{l}{g}}$.

At a given place, $T \propto \sqrt{l}$

The pendulum of a clock expands in summer, so its time period increases.
Hence, it makes less number of oscillations than required per day. Hence it will lose time or clock goes slow.
The pendulum of a clock contracts in winter, its length decreases so its time period decreases. Hence, it makes more number of oscillations than required per day. Hence it will gain time or clock goes fast.

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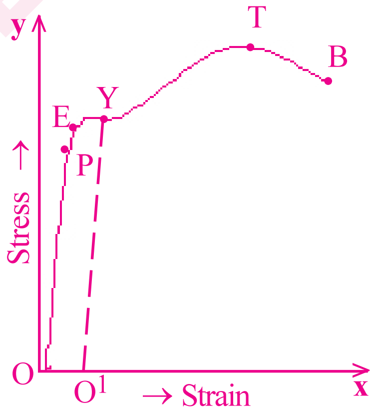
18. Describe the behaviour of a wire under gradually increasing load.

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'.

SECTION-C

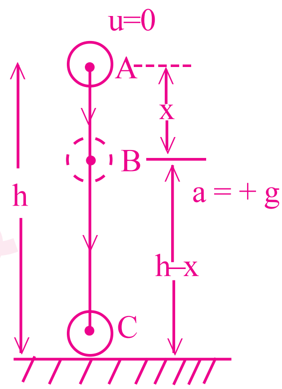
19. State and prove law of conservation of energy in case of freely falling body.

A: 1) Law of conservation of energy: Energy can neither be created nor be destroyed.

Total energy remains constant in a given system.

2) Proof: Consider a freely falling body of mass 'm' released from a point 'A'.

The acceleration of the body is a= +g



3) At Point A :

Let the height of the body from the ground is 'h'.

$\therefore$ Potential Energy P.E = mgh...............(i)

At A, velocity $v_A = u = 0$

$\therefore$ Kinetic Energy K.E= $\frac{1}{2} mv_A^2 = \frac{1}{2} m(0)^2 = 0$...............(ii)

From (i)& (ii) Total Energy T.E= P.E + K.E = mgh + 0 = mgh .....(A)

4) At Point B :

Let the body travels a displacement x and reaches the point B.

So height of the body from the ground is (h–x)

$\therefore$P.E = mg(h–x) = mgh – mgx...............(i)

At B, displacement s=x, u=0, v= v_B, a= +g

We know $v^2 - u^2 = 2as \Rightarrow v_B^2 - 0^2 = 2gx \Rightarrow v_B^2 = 2gx$

$\therefore$ K.E $= \frac{1}{2} mv_B^2 = \frac{1}{\not{2}} m(\not{2}gx) = mgx$...............(ii)

From (i) & (ii) T.E = P.E + K.E = (mgh − $\not{mgx}$) + $\not{mgx}$ = mgh ....(B)

5) At Point C:

Let the body hits the ground at C.

So height of the body h = 0

$\therefore$P.E = mgh= mg (0) = 0 ....(i)

At C, displacement s=h, u=0, v=v_C, a= +g

We know $v^2 - u^2 = 2as \Rightarrow v_C^2 - 0^2 = 2gh \Rightarrow v_C^2 = 2gh$

$\therefore$K.E $= \frac{1}{2} mv_C^2 = \frac{1}{\not{2}} m(\not{2}gh) = mgh$ ....(ii)

From (i)& (ii) T.E = P.E + K.E = 0 + mgh = mgh ....(C)

6) From (A) ,(B), (C) it is clear that the total energy 'T.E' is always constant.

Hence, the law of conservation of energy is proved.

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

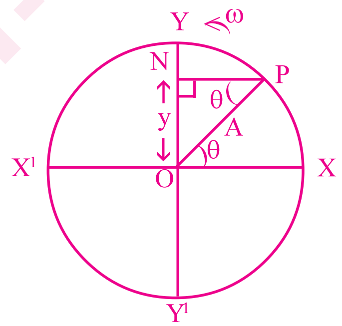
20. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.

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, $\sin\theta = \frac{ON}{OP} = \frac{y}{A} \Rightarrow y = A\sin\theta$

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

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

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

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

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

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

(c) Seconds pendulum:

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

21. State second law of thermodynamics. How is heat engine different from a refrigerator.

A: **A) Second law of thermodynamics:** It consists of two statements.

I) Kelvin - Plank Statement: It is impossible to construct a heat engine which absorbs heat from a hot reservoir that converts completely the heat into work .

(or) It is impossible to construct an ideal heat engine with 100% thermal efficiency.

II) Clausius Statement: It is impossible to transfer heat from a colder object to a hotter object.

(or) It is impossible to construct an ideal refrigerator.

B) Differences between Heat engine and Refrigerator:

HEAT ENGINE	REFRIGERATOR
1) 'Heat engine' converts heat into work.	1) 'Refrigerator' works 'reverse to heat engine'.
2) The 'working substance' absorbs heat (Q_1) from the 'hot reservoir' at high temperature (T_1)	2) The 'working substance' absorbs heat (Q_2) from the 'cold reservoir' at low temperature (T_2)
3) The 'working substance' rejects heat (Q_2) to 'cold reservoir' at lower temperature (T_2)	3) The 'working substance' rejects heat (Q_1) to the 'hot reservoir' at high temperature (T_1)
4) Here, work (W) is done by the system.	4) Here, work is done on the system
5) The efficiency (η) of a heat engine is $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$	5) The coefficient of performance of a refrigerator is $\alpha = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$
6) η is less than 1.	6) α is greater than 1.