Previous IPE

SOLVED PAPERS

MARCH -2024 (TS)

PREVIOUS PAPERS

IPE: MARCH-2024(TS)

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

SECTION-A

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

1. What is physics ?
2. How can systematic errors be minimised or eliminated?
3. Two forces of magnitudes 3 units and 5 units act at 60^{o} with each other. What is the magnitude of their resultant?
4. A horse has to exert a greater force during the start of the motion than later. Explain.
5. What is the principle behind the carburetor of an automobile?
6. Why are drops and bubbles spherical?
7. Distinguish between heat and temperature.
8. Why utensils are coated black? Why the bottom of the utensils are made of copper?
9. When does a real gas behave like an ideal gas?
10. State Dalton's law of partial pressures.

SECTION-B

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

11. State Parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector.
12. Mention the methods used to decrease friction.
13. Distinguish between centre of mass and centre of gravity.
14. Define angular velocity(ω). Derive $v = r\omega$.
15. What is orbital velocity? Obtain an expression for it.
16. In what way is the anomalous behaviour of water advantageous to aquatic animals?
17. A man runs across the roof of a tall building and jumps horizontally on to the lower roof of an adjacent building . If his speed is $9ms^{-1}$ and the horizontal distance between the buildings is 10m and the height difference between the roofs is 9m, will he be able to land on the next building ? ($g=10ms^{-2}$)
18. Describe the behaviour of a wire under gradually increasing load.

SECTION-C

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

19. State second law of thermodynamics. How is heat engine different from a refrigerator.
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. (a) State and prove law of conservation of energy in case of freely falling body.

    (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?

IPE TS MARCH-2024
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. How can systematic errors be minimised or eliminated?

A: The Systematic errors can be minimized by

i) selecting 'better instruments' with 'higher resolution'

ii) avoiding personal bias in taking reading.

iii) improving the 'experimental techniques'.

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3. Two forces of magnitudes 3 units and 5 units act at 60° with each other. What is the magnitude of their resultant?

A: 1) Given that P = 3 and Q = 5 and $\theta = 60^\circ \Rightarrow \cos\theta = \cos 60^\circ = 1/2$

2) Magnitude of Resultant $R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta} = \sqrt{3^2 + 5^2 + \not{2} \times 3 \times 5 \times \frac{1}{\not{2}}}$

$= \sqrt{9 + 25 + 15} = \sqrt{49} = 7$ units

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4. A horse has to exert a greater force during the start of the motion than later. Explain.

A: 1) Before starting the motion, Horse has 'static friction' and later it will be converted into 'kinetic friction'. We know that Static friction is more than kinetic friction ($f_{ms} > f_k$).

2) Hence, Horse has to exert a greater force during the start of the motion than later.

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5. What is the principle behind the carburetor of an automobile?

A: **1)** 'Bernoulli's principle' works behind the carburetor of an automobile .

2) **Working:** The carburetor of automobile contains a nozzle through which air flows with a high speed. The pressure is then lowered at the narrow neck and the petrol is sucked up in the chamber. It provides the correct mixture of air to fuel necessary for combustion.

6. Why liquid drops and bubbles are 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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7. Distinguish between heat and temperature.

A:

HEAT	TEMPERATURE
1) Heat is the **total amount** of 'thermal Energy' in a system.	1) Temperature is the **measure of intensity** of thermal energy.
2) Heat **flows** from Hot part to Cold part within the system.	2) Temperature **cannot flow** from Hot part to Cold part.
3) **C.G.S unit: calorie (cal)** **S.I unit: Joule (J)**	3) **C.G.S unit**: °C **S.I unit:** Kelvin (K)
4) **Calorimeter** is used to measure Heat.	4) **Thermometer** is used to measure Temp.

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8. Why utensils are coated black? Why the bottom of the utensils are made of copper?

A: 1) Black bodies are good absorbers of heat. So black coated utensils absorb heat quickly.

2) Copper is a good conductor of heat. So copper bottom untensils absorb heat slowly. Hence it promotes the distribution of heat over the bottom of a vessel for uniform cooking.

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9. 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.

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10. State Dalton's law of partial pressures.

A: **1) Dalton's law of partial pressures: Total pressure(P) of a mixture** of ideal gases is equal to **sum of partial pressures.**

2) $P = p_1 + p_2 + p_3 + - - - -$ where p_1, p_2, p_3, ...are partial pressures.

SECTION-B

11. State Parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector.

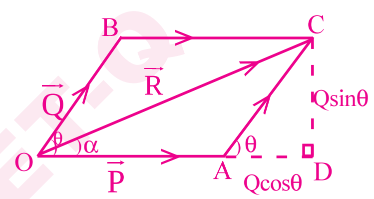
A: 1) **Parallelogram law:** "If two vectors act as two adjacent sides of a parallelogram drawn from a point then their resultant is the diagonal passing through the same point".

2) Let two vectors $\vec{P} = \overline{OA}$ and $\vec{Q} = \overline{OB}$ be acting at a point 'O' as shown in the figure.

Let 'θ' be the angle between $\vec{P}$ and $\vec{Q}$.

The horizontal component of $\vec{Q}$ is AD=Qcosθ ....(1)

The vertical component of $\vec{Q}$ is CD=Qsinθ ....(2)



3) **Magnitude of the Resultant vector $\vec{R}$:**

From ΔCOD,

$OC^2 = OD^2 + CD^2$

$\Rightarrow OC^2 = (OA+AD)^2 + CD^2$ (Since, OD = OA+AD)

$\Rightarrow OC^2 = [OA^2+AD^2+2(OA)(AD)]+CD^2$ [As per $(a+b)^2$ formula]

$\Rightarrow OC^2 = OA^2+AD^2+CD^2 + 2(OA)(AD)$

$\Rightarrow R^2 = P^2 + Q^2\cos^2\theta + Q^2\sin^2\theta + 2P(Q\cos\theta)$ [From (1) & (2)]

$\Rightarrow R^2 = P^2 + Q^2(\cos^2\theta + \sin^2\theta) + 2PQ\cos\theta$

$\Rightarrow R^2 = P^2 + Q^2(1) + 2PQ\cos\theta$

$\Rightarrow R^2 = P^2 + Q^2 + 2PQ\cos\theta$

$$\therefore \quad R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

4) **Direction of the resultant(α) :** Let the resultant $\vec{R}$ makes an angle 'α' with $\vec{P}$.

From ΔCOD, $\tan\alpha = \dfrac{CD}{OA+AD} = \dfrac{Q\sin\theta}{P+Q\cos\theta}$ [From (1) & (2)]

$$\therefore \alpha = \mathrm{Tan}^{-1}\left(\frac{Q\sin\theta}{P+Q\cos\theta}\right)$$

12. 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.

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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.

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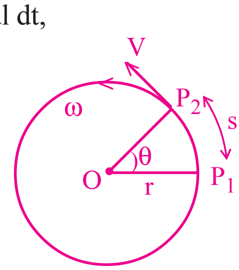
14. Define angular velocity(ω). Derive v = rω.

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

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



2) **Derivation of the relation v = rω**

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 = rθ

4) Differentiating s = rθ w.r.to 't', we get

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

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

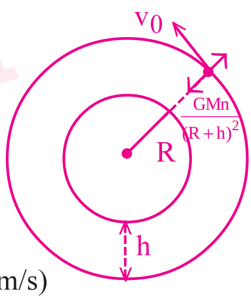
15. What is orbital velocity? Obtain an expression for it.

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 ≈ R. Also we know $GM = gR^2$

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

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

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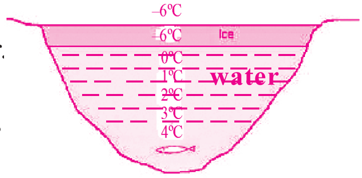
16. In what way is the <u>anomalous behaviour of water</u> advantageous to aquatic animals?

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.

17. A man runs across the roof of a tall building and jumps horizontally on to the lower roof of an adjacent building . If his speed is $9ms^{-1}$ and the horizontal distance between the buildings is 10m and the height difference between the roofs is 9m, will he be able to land on the next building ? ($g = 10ms^{-2}$)

A: If his horizontal range is greater than 10m, then he can land safely on the other building.

In vertical direction,

initial velocity (u) = 0

uniform acceleration (a) = +g = $+10ms^{-2}$

distance travelled (s) = height difference = 9m

time taken (t) = ?

From $S = ut + \frac{1}{2}at^2$

$\Rightarrow S = 0 + \frac{1}{2}gt^2 \Rightarrow 9 = \frac{1}{2} \times 10 \times t^2 \Rightarrow 5t^2 = 9$

$\Rightarrow t^2 = \frac{9}{5} \Rightarrow t = \frac{3}{\sqrt{5}} = \frac{3}{2.236} = 1.34\ s$

Now horizontal range = horizontal velocity × time of fall = 9 × 1.34= 12.08m ≃ 12.1 m

Since he can jump upto nearly 12.1m, so he can safely land on the roof of adjacent building.

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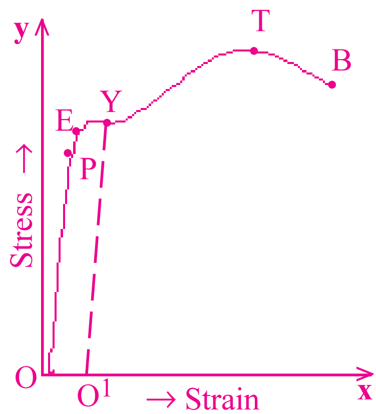
18. Describe the <u>behaviour of a wire</u> under gradually increasing load.

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

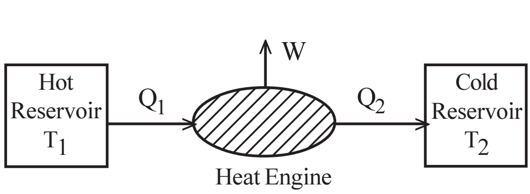
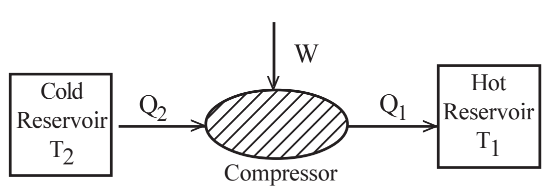
A: **A) Second law of thermodynamics**: It consists of two statements.

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.

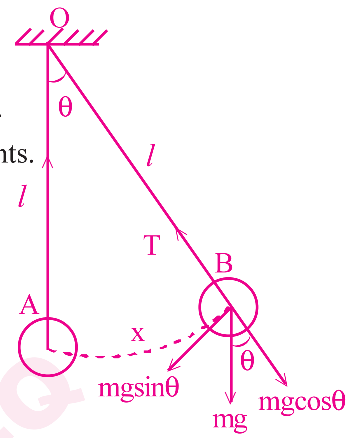
II) Clausius Statement: It is impossible to transfer heat from a colder object to a hotter object. (or) It is impossible to construct an ideal refrigerator.

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.
	

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 $\theta = \frac{x}{l}$ $[\because x = r\theta$ as arc length = radius × angle$]$

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

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

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, $\cancel{-}\omega^2\cancel{x} = \cancel{-}\left(\frac{g}{l}\right)\cancel{x} \Rightarrow \omega^2 = \frac{g}{l} \Rightarrow \omega = \sqrt{\frac{g}{l}}$.

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

(c) Seconds pendulum:

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

P. What is the length of a simple pendulum, which ticks seconds?

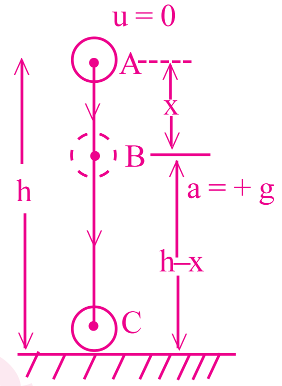
Sol: The time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow T^2 = 4\pi^2\frac{L}{g} \Rightarrow L = \frac{gT^2}{4\pi^2}$

The time period of a simple pendulum, which ticks seconds is T = 2s.
Also $g = 9.8\ ms^{-2}$.

$$\therefore L = \frac{9.8(ms^{-2}) \times 4(s^2)}{4\pi^2} \approx 1\,m$$

21. 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'.

∴ Potential Energy P.E = mgh...............(i)

At A, velocity $v_A = u = 0$

∴ 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)

∴P.E = mg(h–x) = mgh – mgx...............(i)

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

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

∴ K.E $= \frac{1}{2} mv_B^2 = \frac{1}{\cancel{2}} m(\cancel{2}gx) = mgx$...............(ii)

From (i) & (ii) T.E = P.E + K.E $= (mgh - \cancel{mgx}) + \cancel{mgx} = mgh$ ....(B)

5) At Point C:

Let the body hits the ground at C.

So height of the body h = 0

∴P.E = mgh= mg (0) = 0 ....(i)

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

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

∴K.E $= \frac{1}{2} mv_C^2 = \frac{1}{\cancel{2}} m(\cancel{2}gh) = mgh$ ....(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.

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