Previous IPE

SOLVED PAPERS

MARCH -2020 (TS)

PREVIOUS PAPERS

IPE: MARCH-2020(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 discovery of Sir C.V.Raman?
2. The percentage error in the mass and speed are 2% and 3% respectively. What is the maximum error in kinetic energy calculated using these quantities?
3. If $\vec{A} = \vec{i} + \vec{j}$ What is the angle between vector $\vec{A}$ with x -axis?
4. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 ms^{-1}. If the mass of the ball is 0.15kg, determine the impulse imparted to the ball. (Assume linear motion of the ball)
5. Give the expression for the excess pressure in a liquid drop.
6. What is angle of contact?
7. State Weins displacement law?
8. Distinguish between heat and temperature.
9. State Dalton's law of partial pressures.
10. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule?

SECTION-B

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

11. 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.
12. State Parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector.
13. State laws of rolling friction.
14. Find the scalar and vector product of two vector, $\bar{a} = (3\bar{i} - 4\bar{j} + 5\bar{k})$ and $\bar{b} = (-2\bar{i} + \bar{j} - 3\bar{k})$
15. Define angular acceleration and torque. Establish the relation between angular acceleration and torque.
16. State Kepler's laws of planetary motion.
17. Describe the behavior of a wire under gradually increasing load.
18. Explain conduction, convection and radiation with examples.

SECTION-C

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

19. State and prove the law of conservation of energy in case of a freely falling body. A pump is required to lift 600kg of water per minute from a well 25m deep and to eject it with a speed of 50ms^{-1}. Calculate the power required toperform the above task?
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. State second law of thermodynamics. How is heat engine different from a refrigerator.

IPE TS MARCH-2020
ANSWERS

SECTION-A

1. What is the discovery of C.V. Raman ?

A: 1) The discovery of C.V.Raman is **Raman effect**.

2) It deals with **scattering of light** by air molecules.

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2. The percentage error in the mass and speed are 2% and 3% respectively. What is the maximum error in kinetic energy calculated using these quantities? [TS 20] [AP 18,20]

Sol: Percentage error in mass is 2% $\Rightarrow \frac{\Delta m}{m} \times 100 = 2$

Percentage error in velocity is 3% $\Rightarrow \frac{\Delta v}{v} \times 100 = 3$

Now , K.E is given by $K = \frac{1}{2}mv^2 \Rightarrow \frac{\Delta K}{k} \times 100 = \frac{\Delta m}{m} \times 100 + 2 \times \frac{\Delta v}{v} \times 100 = 2 + 2 \times 3 = 2 + 6 = 8$

$\therefore$ Maximum error in the K.E = 8%

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3. If $\vec{A} = \vec{i} + \vec{j}$ What is the angle between vector $\vec{A}$ with x -axis?

A: 1) Comparing the vector $\vec{i} + \vec{j}$ with $x\vec{i} + y\vec{j}$, we get x=1 and y=1

2) **Formula:** $\tan\theta = \frac{y}{x} = \frac{1}{1} = 1 = \tan 45^\circ \Rightarrow \theta = 45^\circ$

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4. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 ms^{-1}. If the mass of the ball is 0.15kg, determine the impulse imparted to the ball. (Assume linear motion of the ball) [AP 17][TS 19,20]

Sol: Change in momentum = (0.15 × 12)–(–0.15×12) = 3.6 Ns

Impulse = 3.6 Ns in the direction from the batsman to the bowler.

5. 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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6. 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°.

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

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7. 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) $\lambda_m = \frac{\text{Constant}}{T}$ (or) $\lambda_m T = \text{Constant}$

Wein's constant is 2.9×10^{-3} mK

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8. 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.

9. 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.

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10. 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 $= \frac{C_2 - C_1}{C_1} \times 100 = 73.2\%$

SECTION-B

11. 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.

A: 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,

$$t_2 = \frac{\text{distance}}{\text{speed}} = \frac{2.5\text{km}}{7.5\,\text{kmh}^{-1}} = \frac{1}{3}\text{hr} = \frac{1}{3} \times 60\,\text{min} = 20\,\text{min}$$

$$\text{(a) Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}} = \frac{0}{50} = 0$$

($\because$ In 50 minutes the man reaches his home)

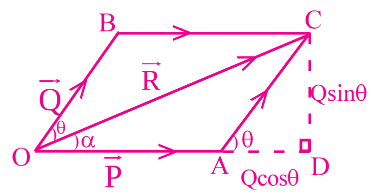
$$\text{(b) Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{2.5+2.5}{\frac{1}{2}+\frac{1}{3}} = \frac{5}{\frac{3+2}{6}} = \frac{30}{5} = 6\text{ km/hr}$$

12. 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)]

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

13. State the laws of rolling friction.

A: 1) Rolling friction (f_R) is directly proportional to the normal reaction (N)

Thus, $f_R \propto N$............(1)

2) Rolling friction (f_R) is inversely proportional to the radius(r) of the rolling wheel.

Thus, $f_R \propto \frac{1}{r}$ ....(2)

$\therefore$ From (1) & (2), $f_R \propto \frac{N}{r} \Rightarrow f_R = \frac{\mu_R N}{r}$ where μ_R = coefficient of rolling friction.

3) Rolling friction increases with increase in the area of contact.

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14. Find the scalar and vector product of two vector, $\bar{a} = (3\bar{i} - 4\bar{j} + 5\bar{k})$ and $\bar{b} = (-2\bar{i} + \bar{j} - 3\bar{k})$ [TS 20]

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

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

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15. Define Angular acceleration and Torque. Establish the relation between angular acceleration and torque.

A: 1) Angular acceleration(α): Rate of change of angular velocity(ω) is called angular acceleration.

Formula: Angular acceleration, $\alpha = \frac{d\omega}{dt}$ ....(i)

2) Torque(τ): The turning effect about an axis of rotation is called torque.

Torque is the rate of change of angular momentum(L).

Formula: Torque, $\tau = \frac{dL}{dt}$ ....(ii)

3) Relation between angular acceleration(α) and torque(τ):

If I is moment of inertia of a rotating body with angular velocity 'ω' then its

Angular momentum is L= Iω

4) On differentiating the above equation w.r.t time 't' we get, $\frac{dL}{dt} = I\frac{d\omega}{dt}$

$\therefore$ from (i) & (ii) we get $\tau = I\alpha$

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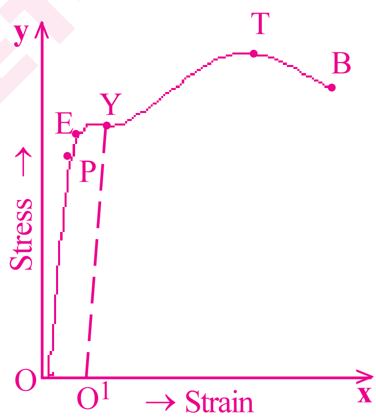
17. Describe the behaviour of a wire under gradually increasing load.

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'.

18. 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.

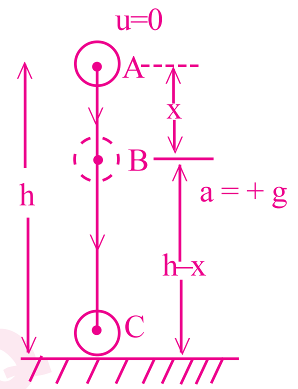
3) Radiation: Transfer of heat from one place to another place **without the help of the material** of the medium is called Radiation. Radiation is the quickest mode of heat transmission.

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

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

$\therefore$ 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 $= \frac{1}{2}mv_C^2 = \frac{1}{\cancel{2}}m(\cancel{2}gh) = mgh$ ....(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 pump is required to lift 600kg of water per minute from a well 25m deep and to eject it with a speed of $50ms^{-1}$. Calculate the power required to perform the above task?

A: 1) Given Mass of water lifted (m) = 600kg, depth of well (h) = 25m

2) Work done to lift water (W_1) = mgh = $600 \times 9.8 \times 25 = 147000$ J

3) Speed of water (v) = $50ms^{-1}$; Mass of water (m) = 600kg

4) Work done to give K.E to water, $w_2 = \frac{1}{2}mv^2 = \frac{1}{2} \times 600 \times (50)^2 = 300(2500) = 750000$ J

5) Total work done, $w = w_1 + w_2 = 147000 + 750000 = 897000J$

Time taken (t) = 1 minute = 60 s.

6) $\therefore$ Power required $= \frac{\text{work done}}{\text{time}} = \frac{897000}{60} = 14950 \text{ w} = 14.95 \text{ kW}$

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:

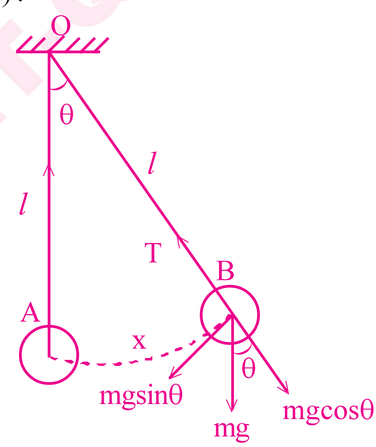
1) Consider a simple pendulum of length 'l', mass 'm' suspended from a rigid support as shown in the figure.

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 sinθ

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, sinθ=θ]

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

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

(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.