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September 2024
Pages 100 | ₹ 75

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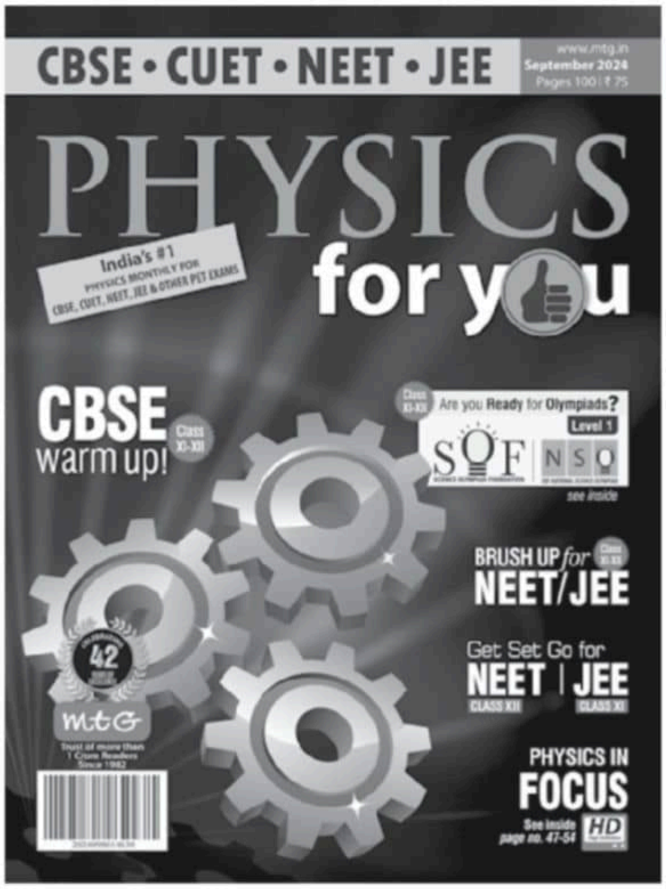
NEET CLASS XII | **JEE** CLASS XI

PHYSICS IN FOCUS
See inside page no. 47-54
HD High Definition



PHYSICS for you

VOLUME 32 No. 9 September 2024

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Printed and Published by Mahabir Singh on behalf of MTG Learning Media Pvt. Ltd. Printed at HT Media Ltd., B-2, Sector-63, Noida, UP-201307 and published at 406, Taj Apartment, Ring Road, Near Safdarjung Hospital, New Delhi - 110029.
Editor : Anil Ahlawat

GET SET GO *for* JEE

with exclusive and brain storming MCQs

Practicing these MCQs help to strengthen your concepts and give you extra edge in your JEE preparation

1. Under the same load, wire A having length 5.0 m and the cross section 2.5×10^{-5} m^2 stretches uniformly by same amount as another wire B of length 6.0 m and a cross-section of 3.0×10^{-5} m^2 stretches. The ratio of the Young's modulus of wire A to that of wire B will be

(a) 1 : 4 (b) 1 : 1 (c) 1 : 10 (d) 1 : 2

2. The temperature of equal masses of three different liquids x, y and z are 10°C, 20°C and 30°C respectively. The temperature of mixture when x is mixed with y is 16°C and that when y is mixed with z is 26°C. The temperature of mixture when x and z are mixed will be

(a) 25.62°C (b) 20.28°C
(c) 28.32°C (d) 23.84°C

3. A helicopter rises from rest on the ground vertically upwards with a constant acceleration g. A food packet is dropped from the helicopter when it is at a height h. The time taken by the packet to reach the ground is close to [g is the acceleration due to gravity]

(a) $t = \frac{2}{3}\sqrt{\left(\frac{h}{g}\right)}$ (b) $t = 1.8\sqrt{\left(\frac{h}{g}\right)}$

(c) $t = 3.4\sqrt{\left(\frac{h}{g}\right)}$ (d) $t = \sqrt{\left(\frac{2h}{3g}\right)}$

4. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A : An electric fan continues to rotate for some time after the current is switched off.

Reason R : Fan continues to rotate due to inertia of motion.

In the light of above statements, choose the most appropriate answer from the options given below.

(a) A is not correct but R is correct.
(b) Both A and R are correct and R is the correct explanation of A.
(c) A is correct but R is not correct.
(d) Both A and R are correct but R is NOT the correct explanation of A.

5. In a linear Simple Harmonic Motion (SHM)

(A) Restoring force is directly proportional to the displacement.
(B) The acceleration and displacement are opposite in direction.
(C) The velocity is maximum at mean position.
(D) The acceleration is minimum at extreme points.

Choose the correct answer from the options given below.

(a) (C) and (D) only (b) (A), (C) and (D) only
(c) (A), (B) and (C) only (d) (A), (B) and (D) only

6. In the following 'I' refers to current and other symbols have their usual meaning. Choose the option that corresponds to the dimensions of electrical conductivity.
(a) $[M^{-1}L^{-3}T^3I]$ (b) $[M^{-1}L^{-3}T^3I^2]$
(c) $[M^{-1}L^3T^3I]$ (d) $[ML^{-3}T^{-3}I^2]$

7. Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW is the work done and ΔU is change in internal energy of the system.

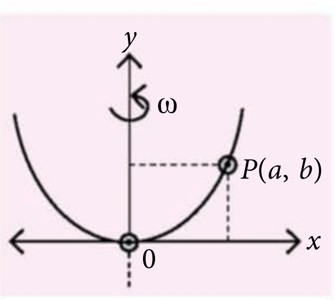
Process	Condition
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$
(IV) Isobaric	(D) $\Delta U = 0$

(a) (I)-(B), (II)-(D), (III)-(A), (IV)-(C)
(b) (I)-(A), (II)-(A), (III)-(B), (IV)-(C)
(c) (I)-(A), (II)-(B), (III)-(D), (IV)-(D)
(d) (I)-(B), (II)-(A), (III)-(D), (IV)-(C)

8. For a solid rod, the Young's modulus of elasticity is 3.2×10^{11} Nm^{-2} and density is 8×10^3 kg m^{-3}. The velocity of longitudinal wave in the rod will be
(a) 3.65×10^3 m s^{-1} (b) 18.96×10^3 m s^{-1}
(c) 145.75×10^3 m s^{-1} (d) 6.32×10^3 m s^{-1}

9. Given below are two statements.
Statement I : An elevator can go up or down with uniform speed when its weight is balanced with the tension of its cable.
Statement II : Force exerted by the floor of an elevator on the foot of a person standing on it is more than his/her weight when the elevator goes down with increasing speed.
In the light of the above statements, choose the correct answer from the options given below.
(a) Statement I is false but statement II is true.
(b) Statement I is true but statement II is false.
(c) Both statement I and statement II is false.
(d) Both statement I and statement II are true.

10. A bead of mass m stays at point $P(a, b)$ on a wire bent in the shape of a parabola $y = 4Cx^2$ and rotating with angular speed ω (see figure). The value of ω is (neglect friction)



(a) $2\sqrt{2gC}$ (b) $2\sqrt{gC}$ (c) $\sqrt{\frac{2gC}{ab}}$ (d) $\sqrt{\frac{2g}{C}}$

NUMERICAL VALUE TYPE

11. An object is projected in the air with initial velocity u at an angle θ. The projectile motion is such that the horizontal range R, is maximum. Another object is projected in the air with a horizontal range half of the range of first object. The initial velocity remains same in both the case. The value of the angle of projection, at which the second object is projected, will be ________ degree.

12. Two satellites S_1 and S_2 are revolving in circular orbits around a planet with radius $R_1 = 3200$ km and $R_2 = 800$ km respectively. The ratio of speed of satellite S_1 to the speed of satellite S_2 in their respective orbits would be $\frac{1}{x}$, where $x =$ _______.

13. A monoatomic gas performs a work of $\frac{Q}{4}$, where Q is the heat supplied to it. The molar heat capacity of the gas will be _______ R, during this transformation, where R is the gas constant.

14. A body of mass 1 kg collides head on elastically with a stationary body of mass 3 kg. After collision, the smaller body reverses its direction of motion and moves with a speed of 2 m/s. The initial speed of the smaller body before collision is ______ m s^{-1}.

15. A spherical drop of liquid splits into 1000 identical spherical drops. If u_i is the surface energy of the original drop and u_f is the total surface energy of the resulting drops, the (ignoring evaporation), $\frac{u_f}{u_i} = \left(\frac{10}{x}\right)$. Then value of x is ______

SOLUTIONS

1. **(b):** Length of wire A, $L_A = 5$ m
Length of wire B, $L_B = 6$ m
$A_A = 2.5 \times 10^{-5}$ m^2, $A_B = 3 \times 10^{-5}$ m^2
As applied force F and extension ΔL are same for both wires A and B,
$$\therefore \frac{F}{\Delta L} = \frac{Y_A A_A}{L_A} = \frac{Y_B A_B}{L_B}$$
$$\therefore \frac{Y_A}{Y_B} = \frac{L_A A_B}{L_B A_A} = \frac{5 \times 3 \times 10^{-5}}{6 \times 2.5 \times 10^{-5}} = 1$$
The ratio of the Young's modulus of wire A to that of wire B is 1 : 1

2. **(d):** For $x : m_1 = m$, $T_1 = 10°C$, specific heat $= s_1$
For $y : m_2 = m$, $T_2 = 20°C$, specific heat $= s_2$

For z : $m_3 = m$, $T_3 = 30°C$, specific heat = s_3

When x and y is mixed, the temperature is T.

By the principle of calorimetry,

$m_1s_1T_1 + m_2s_2T_2 = (m_1s_1 + m_2s_2)T$

$s_1 \times 10 + s_2 \times 20 = (s_1 + s_2) \times 16$

$\therefore \quad s_1 = \frac{2}{3}s_2$ ... (i)

When y and z is mixed, the final temperature is T'.

By the principle of calorimetry,

$m_2s_2T_2 + m_3s_3T_3 = (m_2s_2 + m_3s_3)T'$

$20s_2 + 30s_3 = (s_2 + s_3) \times 26; \quad s_3 = \frac{3}{2}s_2$ ... (ii)

When x and z is mixed, the final temperature is T''.

By the principle of calorimetry,

$m_1s_1T_1 + m_3s_3T_3 = (m_1s_1 + m_3s_3)T''$

$$\frac{2}{3}s_2 \times 10 + \frac{3}{2}s_2 \times 30 = \left(\frac{2}{3}s_2 + \frac{3}{2}s_2\right) \times T''$$

$\therefore \quad T'' = 23.84°C$

3. **(c) :** For upward motion of helicopter,

From equation of motion, $v^2 = u^2 + 2as$

$\Rightarrow u^2 = 0 + 2gh$ or $u = \sqrt{2gh}$ ...(i)

This is initial velocity of packet in upward direction.

Now food packet will start moving under gravity,

$v^2 = u^2 + 2as$ or $v^2 = 2gh + 2gh$ (Using eq. (i))

$v = \sqrt{4gh}$

This is the velocity of packet just before hitting the ground.

We know, $v = u + at$

$$\sqrt{4gh} = -\sqrt{2gh} + gt \quad \Rightarrow \quad t = \sqrt{\frac{4h}{g}} + \sqrt{\frac{2h}{g}} = 3.4\sqrt{\frac{h}{g}}$$

4. **(b):** Fan continues to rotate for some time after current is switched off due to inertia of motion.

Hence, both A and R are correct and R is the correct explanation of A.

5. **(c) :** In a simple harmonic motion

$F = kx$ i.e., $F \propto -x \quad \Rightarrow \quad ma \propto -x \Rightarrow a \propto -x$

At the extreme position, acceleration is maximum.

6. **(b):** Electrical conductivity = $[M^{-1}L^{-3}T^3I^2]$

7. **(a) :** Here, ΔQ = Heat supplied

ΔU = Change in internal energy; ΔW = Work done

For adiabatic process $\rightarrow \Delta Q = 0$

For isothermal process $\rightarrow \Delta T = 0, \Delta U = 0$

For isochoric process $\rightarrow \Delta W = 0$

For isobaric process $\rightarrow \Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$

(I) $\rightarrow$ (B), (II) $\rightarrow$ (D), (III) $\rightarrow$ (A), (IV) $\rightarrow$ (C)

8. **(d):** Given, Young's modulus of elasticity

$Y = 3.2 \times 10^{11}$ Nm^{-2} and density, $\rho = 8 \times 10^3$ kg/m^3

Velocity of longitudinal wave in the rod,

$$v = \sqrt{\frac{Y}{\rho}} = \sqrt{\frac{3.2 \times 10^{11}\ \text{Nm}^{-2}}{8 \times 10^3\ \text{kg m}^{-3}}} = 6.32 \times 10^3\ \text{m/s}$$

9. **(b):** When the elevator is going up with acceleration a, the apparent weight is given by $W' = m(g + a)$

Similarly, when going down, $W' = m(g - a)$

$\Rightarrow W' < W$

Also, weight of the elevator is balanced by the tension in the cable.

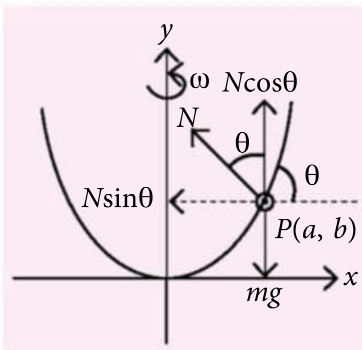
10. **(a) :** As mass is in equilibrium,

$\therefore \quad mg = N\cos\theta$

$N\sin\theta = m\omega^2 a$

$$\frac{mg}{\cos\theta} \times \sin\theta = m\omega^2 a$$

$$\omega = \sqrt{\frac{g\tan\theta}{a}}$$



Given that, $y = 4Cx^2$

$$\Rightarrow \frac{dy}{dx} = 8Cx$$

At point P, $\tan\theta = \frac{dy}{dx} = 8\,Ca$

$$\Rightarrow \omega = \sqrt{\frac{g(8Ca)}{a}} = 2\sqrt{2gC}$$

11. **(15):** We know range, $R = \frac{u^2 \sin 2\theta}{g}$

Initial speed of first object is u.

For range to be maximum $\theta = 45°$

$$R_{max} = \frac{u^2 \sin(2 \times 45°)}{g} \quad \text{or} \quad R_{max} = \frac{u^2 \sin 90°}{g}$$

$$\Rightarrow R_{max} = \frac{u^2}{g} \qquad \text{...(i)}$$

Now, another object is projected with some initial speed u, but horizontal range is half of the range of first object *i.e.*,

Motivational Quote

"Success can come to you by courageous devotion to the task lying in front of you."

– *C.V. Raman*

$$\frac{R_{max}}{2}=\frac{u^2 \sin 2\phi}{g} \quad ...(ii)$$

Dividing equation (i) and (ii),

$$\frac{R_{max}}{\frac{R_{max}}{2}}=\frac{u^2/g}{u^2\sin 2\phi/g}\ ;\ \sin 2\phi=\frac{1}{2}\ \Rightarrow\ \sin 2\phi=\sin 30°$$

$2\phi = 30°$; $\phi = 15°$

12. (2): Here : $R_1 = 3200$ km, $R_2 = 800$ km

$$v=\sqrt{\frac{GM}{R}};$$

So, $\frac{v_1}{v_2}=\sqrt{\frac{R_2}{R_1}}=\sqrt{\frac{800}{3200}}=\frac{1}{2}\ \Rightarrow\ x=2$

13. (2) : By first law of thermodynamics, $\Delta Q = \Delta U + \Delta W$

$$\Delta U=\Delta Q-\frac{\Delta Q}{4}=\frac{3}{4}\Delta Q$$

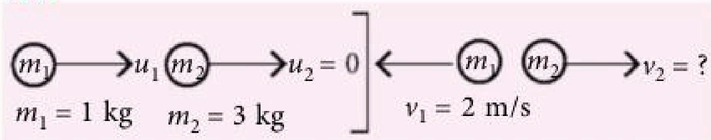
$$\Rightarrow nC_v dT=\frac{3}{4}\Delta Q \quad ...(i)$$

$$\Rightarrow nCdT=\Delta Q \quad ...(ii)$$

Dividing equation (i) by (ii), we get

$$\frac{C_v}{C}=\frac{3}{4}\ \text{ or }\ C=\frac{4}{3}C_v=\frac{4}{3}\times\frac{3}{2}R=2R$$

14. (4):



Given elastic collision, $e = 1$ (using conservation of momentum)

$$m_1u_1+m_2u_2=m_1v_1+m_2v_2 \Rightarrow 1u_1+0=-1\times 2+3v_2$$

$$u_1 = 3v_2 - 2 \quad ...(i)$$

$$e=1=\frac{v_2-(-2)}{u_1}\ \text{ or }\ u_1=v_2+2 \quad ...(ii)$$

From (i) and (ii), we get, $3v_2 - 2 = v_2 + 2$

$v_2 = 2$ m/s and from (ii), we get, $u_1 = 2 + 2 = 4$ m/s

15. (1): 1 big drop = 1000 small drops

$$\frac{4}{3}\pi R^3=1000\times\frac{4}{3}\pi r^3$$

$$R = 10\,r,\ r = R/10 \quad ...(i)$$

U_i = surface tension (T) × Area

$U_i = T \times 4\pi R^2$; $U_f = T \times 4\pi r^2 \times 1000$

$$\therefore\ \frac{U_f}{U_i}=\frac{T\times 4\pi r^2\times 1000}{T\times 4\pi R^2}=\frac{1000r^2}{R^2},\ \frac{U_f}{U_i}=\frac{10}{1}$$

(Using (i))

So, $x = 1$

UNSCRAMBLE ME

Unscramble the words given in column I and match them with their explanations in column II.

Column I		Column II
1. RIEOLAC	(a)	A radiation of high penetrating power that originates from outer space.
2. YARMICSOC	(b)	A unit of heat.
3. THRAE	(c)	A device that maintain a system at a constant temperature.
4. ESFU	(d)	The spontaneous emission of radiation from atomic nuclei.
5. PEUSTMI	(e)	A connection between an electrical circuit or device and the earth, which is at zero potential.
6. ESCENECINMUL	(f)	A safety device which prevents damage to electrical applications.
7. CTVIIAYTIODIAR	(g)	The force that sets a body in motion or that tends to resist changes in a body's motion.
8. MOTATSERTH	(h)	Rotating neutron stars.
9. UMCUAV	(i)	A region containing no air.
10. ASSLURP	(j)	The emission of light at low temperatures by any process other than incandescence.

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

Brush Up for NEET/JEE

Class XI

Brush up your concepts to get high rank in NEET/JEE (Main and Advanced) by reading this column. This specially designed column is updated year after year by a panel of highly qualified teaching experts well-tuned to the requirements of these Entrance Tests.

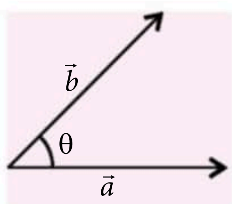
Series 4 Work, Energy and Power

Scalar Product of Two Vectors

- Consider two vectors $\vec{a}$ and $\vec{b}$. Angle between $\vec{a}$ and $\vec{b}$ is θ, where $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ and $\vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$.

  Their scalar product is given by

  $\vec{a}\cdot\vec{b} = |\vec{a}|\,|\vec{b}|\cos\theta$, where



  $|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$,

  $|\vec{b}| = \sqrt{b_x^2 + b_y^2 + b_z^2}$

  Angle θ can be determined as $\cos\theta = \dfrac{\vec{a}\cdot\vec{b}}{|\vec{a}||\vec{b}|}$

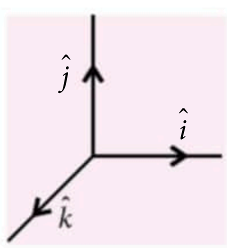
- For three unit vectors $\hat{i}, \hat{j}$ and $\hat{k}$ along three axes,

  $\hat{i}\cdot\hat{i} = 1\times 1\cos 0° = 1 \quad (\because |\hat{i}| = 1 = |\hat{j}| = |\hat{k}|)$

  $\therefore \quad \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = \hat{i}\cdot\hat{i} = 1$

  and $\hat{i}\cdot\hat{j} = 1\times 1\times\cos 90° = 0$

  $\therefore \quad \hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$



  In component form,

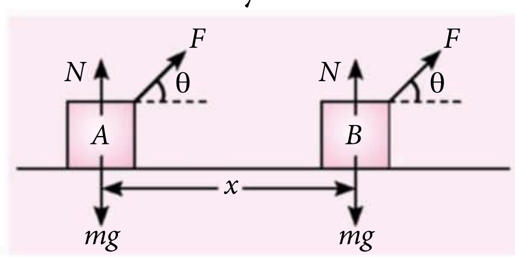
  $\vec{a}\cdot\vec{b} = (a_x\hat{i} + a_y\hat{j} + a_z\hat{k})\cdot(b_x\hat{i} + b_y\hat{j} + b_z\hat{k})$

  $\Rightarrow \quad \vec{a}\cdot\vec{b} = a_x b_x + a_y b_y + a_z b_z$

Work Done

- The work is said to be done when a force applied to the body displaces the body through a certain distance in the direction of applied force.

- **Work Done by a Constant Force :** Let a constant force $\vec{F}$ be applied on the body making an angle θ with the displacement direction. $d\vec{x}$ be the small displacement in the body.



  $\vec{F}$ is resolved in two components, $F\cos\theta$ along $d\vec{x}$ and $F\sin\theta$ perpendicular to $d\vec{x}$.

  ∴ Small work done in moving the body by displacement $d\vec{x}$ is $dW = \vec{F}\cdot d\vec{x}$

  Integrating, we get

  $dW = \vec{F}\cdot d\vec{x} \Rightarrow W = F\cos\theta\,(x_f - x_i)$

  $\therefore \quad W = \vec{F}\cdot\vec{x}$

  (a) If 0 ≤ θ < 90° then work done is positive (component of F is parallel to the displacement)

  (b) If θ = 90° then work done = 0. (No translational work done is there).

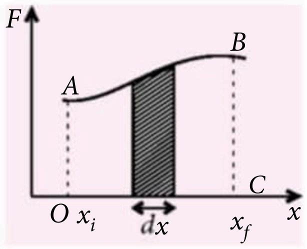
  (c) If 90° < θ ≤ 180° then work done = negative. (component of force is antiparallel to the displacement)

- **Work Done by a Variable Force :** Let a force $\vec{F}$ applied to a body whose magnitude and direction changes with position. For a very small displacement $d\vec{x}$, F can be assumed to be constant.

  ∴ Small work done dW in displacing the body by displacement dx is $dW = \vec{F}\cdot d\vec{x}$

Also, graphically we can say that the area under the $F - x$ curve on x-axis gives the total work done.

Integrating, we get

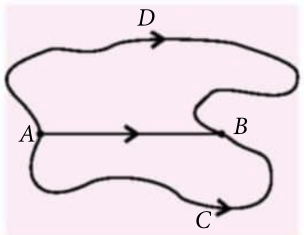


$$\int dW = \int_{x_i}^{x_f} \vec{F} \cdot \overrightarrow{dx}$$

$$\Rightarrow W = \int_{x_i}^{x_f} \vec{F} \cdot d\vec{x}$$

$\therefore$ W = Area $OABCO$

- **Work Done by a Conservative Force**
  - Work done by the conservative forces are independent of the path followed by the body.
  - Total work done over a closed path is zero.



Hence, $W_{ADB} = W_{AB} = W_{ACB}$ and $W_{AB} + W_{BA} = 0$

- **Work Done by a Non-conservative Force**
  - Work done by a non-conservative force depends over the path of the body between two points.
  - Total work done for a complete cycle can never be zero for non-conservative forces like frictional force, viscous force and air drag etc.

Work-Energy Theorem

- **For constant force (acceleration) under a rectilinear motion**

From equation $v_f^2 = v_i^2 + 2ax$,

Multiply both sides by $m/2$

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + 2a\frac{1}{2}mx$$

$$\text{KE}_f - \text{KE}_i = m\vec{a} \cdot \vec{x} \text{ or } \Delta K = \vec{F} \cdot \vec{x} = W$$

The change in KE of a particle is equal to the work done on it by the net force.

- **For a variable force :** As the time rate change of KE

is $\frac{dK}{dt} = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = m\frac{dv}{dt}v = F \times v$

$$\Rightarrow \frac{dK}{dt} = F\frac{dx}{dt}; dK = Fdx$$

Integrating, we get

$$\int_{K_i}^{K_f} dK = \int_{x_i}^{x_f} Fdx \Rightarrow K_f - K_i = \int_{x_i}^{x_f} Fdx$$

$$\Rightarrow \Delta K = \int_{x_i}^{x_f} Fdx \text{ or } W = \Delta K$$

Power

- The time rate change of work done or energy transferred is called power.

$$P = \frac{dW}{dt} = \vec{F} \cdot \frac{d\vec{x}}{dt} \Rightarrow P = \vec{F} \cdot \vec{v}$$

(where $\vec{v}$ = instantaneous velocity)

Average power, $P_{av} = \frac{W(\text{Net work done})}{t(\text{time taken})}$

- It is a scalar quantity like work and energy.
- Commercial unit of power is horse power denoted by hp.

1 hp = 746 Watt

Electrical energy is measured in kW h.

1 kW h = 1 × 1000 × 60 × 60 W s = 3600000 W s

1 kW h = 3.6×10^6 J

Potential Energy

- The energy possessed by a particle due to its position is called potential energy. Potential energy is defined only for conservative forces.
- Gravitational potential energy of an object at any height h is $U(h) = mgh$

Gravitational PE is negative of the work done by the gravitational force in raising the object to that height. The force F involved is given by

$$F = -\frac{dU(h)}{dh} = -mg \quad \text{...(i)}$$

From the above equation, $Fdx = -dU(h)$

($\because$ x be the height *i.e.*, $x = h$)

Integrating, we get

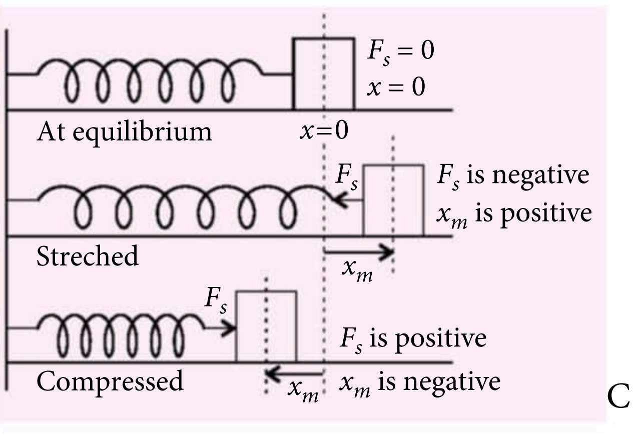
$$\int_{x_i}^{x_f} Fdx = -\int_{U_i}^{U_f} dU = -(U_f - U_i), \therefore -\Delta U = F\Delta x$$

Potential Energy of Spring

- While stretching and compressing the spring by displacement x_m, the total work done by the spring force is

$$W = \int_0^{x_m} F_s dx = -\int_0^{x_m} kx dx = -\frac{kx_m^2}{2}$$

- This work done is negative because F_s and x_m are in opposite direction as shown in the figure.



C

– When spring is compressed or elongated by x then potential energy is stored in it.

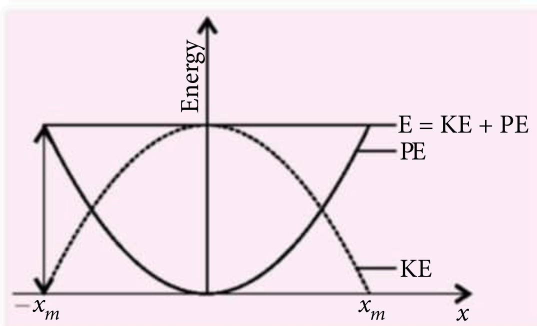
$$PE = U = \frac{1}{2}kx^2$$

– Since the spring force is conservative, the total work done by spring in a cyclic process is zero.

– Maximum speed of the spring or block v_m is given by $\frac{1}{2}kx_m^2 = \frac{1}{2}mv_m^2$

$$\therefore \quad v_m = \sqrt{\frac{k}{m}}x_m \,;\, x_m = \text{amplitude of block}$$

– In spring-block system the kinetic energy get converted to potential energy and vice-versa, however, the total mechanical energy remains constant. Hence, total sum of KE and PE is constant.

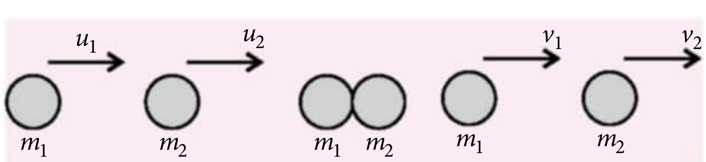


Collisions

When two or more than two bodies collide for a very short time and the conservation of linear momentum (some time energy and momentum) of the system is followed is called collision.

- **Elastic Collision :** The collision in which momentum and kinetic energy both are conserved before and after the collision is called elastic collision.
- **Inelastic Collision :** The collision in which kinetic energy is not conserved but linear momentum is conserved before and after the collision is called inelastic collision.

Elastic Collision in One Dimension



Using conservation of momentum,

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$\Rightarrow \; m_1(u_1 - v_1) = m_2(v_2 - u_2)$ ...(i)

Now, from conservation of KE,

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$\Rightarrow \; m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2)$ ...(ii)

Dividing (ii) by (i), we get

$v_1 + u_1 = v_2 + u_2 \Rightarrow u_1 - u_2 = v_2 - v_1$

$\therefore$ Relative velocity of approach

= Relative velocity of separation

– Coefficient of restitution (e)

$$e = \frac{\text{relative velocity of separation}}{\text{relative velocity of approach}} = \frac{v_2 - v_1}{u_1 - u_2}$$

For $e = 1$; perfectly elastic collision

For $e = 0$; perfectly inelastic collision

For inelastic collision, $0 < e < 1$

– **Velocities after collision**

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2}{m_1 + m_2}u_2$$

$$\text{and } v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1}{m_1 + m_2}u_1$$

Special Cases

- If $m_1 >> m_2$ *i.e.*, target is lighter.
  $v_1 = u_1$ and $v_2 = 2u_1 - u_2$
- If $m_1 << m_2$ *i.e.*, target is heavier.
  $v_1 = 2u_2 - u_1$ and $v_2 = u_2$
- If $m_1 = m_2$; $v_1 = u_2$ and $v_2 = u_1$
- If target is at rest *i.e.*, $u_2 = 0$ and $m_1 >> m_2$.
  $v_1 = u_1$ and $v_2 = 2u_1$

Inelastic Collision in One Dimension

As linear momentum is conserved,

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ ...(i)

Also, $e(u_1 - u_2) = (v_2 - v_1)$ ...(ii)

Solving (i) and (ii), we get

$$v_1 = \left(\frac{m_1 - em_2}{m_1 + m_2}\right)u_1 + \left(\frac{(1+e)m_2}{m_1 + m_2}\right)u_2$$

$$v_2 = \left(\frac{(1+e)m_1}{m_1 + m_2}\right)u_1 + \left(\frac{m_2 - em_1}{m_1 + m_2}\right)u_2$$

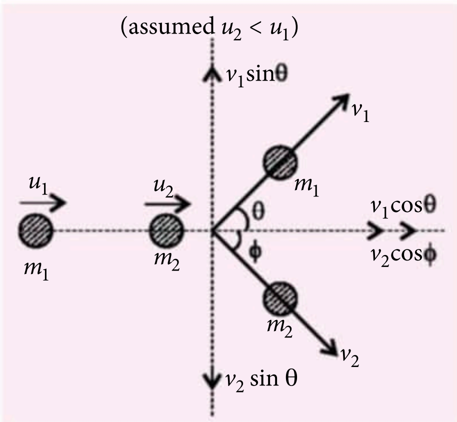
Substituting $e = 0$, we get the equation for final velocity of particle in perfectly inelastic collision.

- Loss in kinetic energy,

$$\Delta K = \frac{1}{2}\left[\frac{m_1m_2}{m_1 + m_2}\right](1 - e^2)(u_1 - u_2)^2$$

Elastic Collision in Two Dimensions

Consider two bodies of masses m_1 and m_2 are moving with velocities u_1 and u_2. After an oblique collision, m_1 deviates by angle θ and m_2 deviates angle ϕ from the main path as shown in the figure.



As momentum is conserved, then along x-axis,

$m_1u_1 + m_2u_2 = m_1v_1\cos\theta + m_2v_2\cos\phi$ ...(i)

and along y-axis, $0 = m_1v_1\sin\theta - m_2v_2\sin\phi$ ...(ii)

As KE is also conserved then

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad \text{...(iii)}$$

For $m_1 = m_2$, $u_2 = 0$ and $u_1 = u$

From eqn. (i) and eqn. (ii), we get

$u = v_1\cos\theta + v_2\cos\phi$ ...(iv)

$0 = v_1\sin\theta - v_2\sin\phi$ ...(v)

Squaring and adding eqn. (iv) and eqn. (v), we get

$u^2 = v_1^2 + v_2^2 + 2v_1v_2\cos(\theta + \phi)$ ...(vi)

Now, from eqn. (iii), we get

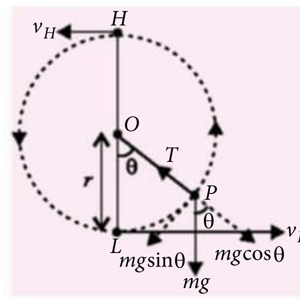
$u^2 = v_1^2 + v_2^2$ ...(vii)

By comparing eqn. (vi) and eqn. (vii), $\cos(\theta + \phi) = 0$

or $\theta + \phi = \pi/2$

Hence, velocities v_1 and v_2 are perpendicular to each other.

Motion in a Vertical Circle



- When a small body of mass m is attached to an inextensible light string of length r and whirling in a vertical circle about a fixed point O to which the other end of the string is attached as shown in figure, then
- Tension at any position of angular displacement, (θ) along a vertical circle is given by $T = \frac{mv^2}{r} + mg\cos\theta$
- Tension at the lowest point ($\theta = 0$) is given by $T_L = \frac{mv_L^2}{r} + mg$
- Tension at the highest point ($\theta = 180°$) is given by $T_H = \frac{mv_H^2}{r} - mg$
- Minimum speed at the highest point, $v_H = \sqrt{gr}$
- Minimum speed at the lowest point for looping the loop, $v_L = \sqrt{5gr}$.
- When the string is horizontal, $\theta = 90°$, minimum velocity, $v = \sqrt{3gr}$
- Height through which a body should fall for looping the vertical loop or radius r is, $h = 5r/2$.

WRAP it up!

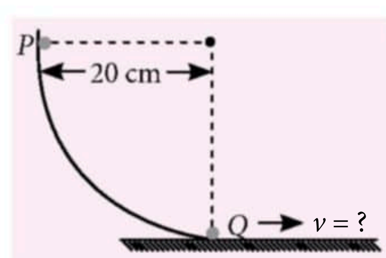
1. A block of mass 2 kg moving on a horizontal surface with speed of 4 m s^{-1} enters a rough surface ranging from $x = 0.5$ m to $x = 1.5$ m. The retarding force in this range of rough surface is related to distance by $F = -kx$ where $k = 12$ N m^{-1}. The speed of the block as it just crosses the rough surface will be

(a) zero (b) 1.5 m s^{-1}
(c) 2.0 m s^{-1} (d) 2.5 m s^{-1}

2. A uniform force of $(3\hat{i} + \hat{j})$ newton acts on a particle of mass 2 kg. Hence, the particle is displaced from position $(2\hat{i} + \hat{k})$ metre to position $(4\hat{i} + 3\hat{j} - \hat{k})$ metre. The work done by the force on the particle is

(a) 13 J (b) 15 J (c) 9 J (d) 6 J

3. As per the given figure, a small ball P slides down the quadrant of a circle and hits the other ball Q of equal mass which is initially at rest.



Neglecting the effect of friction and assume the collision to be elastic, the velocity of ball Q after collision will be ($g = 10$ m/s^2)

(a) 4 m/s (b) zero (c) 0.25 m/s (d) 2 m/s

4. A body of mass 3 kg is under a constant force which causes a displacement s in metres in it, given by the relation $s = \frac{1}{3}t^2$, where t is in seconds. Work done by the force in 2 seconds is

(a) $\frac{19}{5}$ J (b) $\frac{5}{19}$ J (c) $\frac{3}{8}$ J (d) $\frac{8}{3}$ J

5. A particle moves so that its position vector is given by $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\,\hat{y}$, where ω is a constant. Which of the following is true?

(a) Velocity is perpendicular to $\vec{r}$ and acceleration is directed towards the origin.
(b) Velocity is perpendicular to $\vec{r}$ and acceleration is directed away from the origin.
(c) Velocity and acceleration both are perpendicular to $\vec{r}$.
(d) Velocity and acceleration both are parallel to $\vec{r}$.

6. Given below are two statements:

Statement-I : A truck and a car moving with same kinetic energy are brought to rest by applying breaks which provides equal retarding forces. Both come to rest in equal distance.

Statement-II : A car moving towards east takes a turn and moves towards north, the speed remains unchanged. The acceleration of the car is zero.

In the light of given statements, choose the most appropriate answer from the options given below.

(a) Both Statement-I and Statement-II are correct.
(b) Statement-I is incorrect and Statement-II is correct.
(c) Both Statement-I and Statement-II are incorrect.
(d) Statement-I is correct but Statement-II is incorrect.

7. Potential energy as a function of r is given by $U = \frac{A}{r^{10}} - \frac{B}{r^5}$, where r is the interatomic distance, A and B are positive constants. The equilibrium distance between the two atoms will be

(a) $\left(\frac{A}{B}\right)^{1/5}$ (b) $\left(\frac{B}{A}\right)^{1/5}$

(c) $\left(\frac{2A}{B}\right)^{1/5}$ (d) $\left(\frac{B}{2A}\right)^{1/5}$

8. A particle of mass m moving in the x direction with speed $2v$ is hit by another particle of mass $2m$ moving in the y-direction with speed v. If the collision is perfectly inelastic, the percentage loss in the energy during the collision is close to

(a) 56% (b) 62% (c) 44% (d) 50%

9. A body of mass $4m$ is lying in x-y plane at rest. It suddenly explodes into three pieces. Two pieces, each of mass m move perpendicular to each other with equal speeds v. The total kinetic energy generated due to explosion is

(a) mv^2 (b) $\frac{3}{2}mv^2$ (c) $2mv^2$ (d) $4mv^2$

10. A particle with total energy E is moving in a potential energy region $U(x)$. Motion of the particle is restricted to the region when

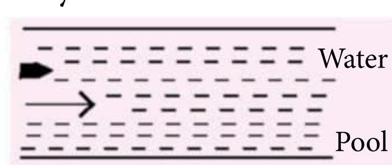
(a) $U(x) < E$ (b) $U(x) = 0$
(c) $U(x) \le E$ (d) $U(x) > E$

11. An electric lift with a maximum load of 2000 kg (lift + passengers) is moving up with a constant speed of 1.5 m s^{-1}. The frictional force opposing the motion is 3000 N. The minimum power delivered by the motor to the lift in watts is (g = 10 m s^{-2})

(a) 23000 (b) 20000 (c) 34500 (d) 23500

12. A bullet of mass 200 g having initial kinetic energy 90 J is shot inside a long swimming pool as shown in the figure. It's kinetic energy reduces to 40 J within 1 s, the minimum length of the pool, the bullet has to travel so that it completely comes to rest is

(a) 45 m
(b) 90 m
(c) 125 m
(d) 25 m



13. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : Body P having mass M moving with speed u has head-on collision elastically with another body Q having mass m initially at rest. If $m << M$, body Q will have a maximum speed equal to $2u$ after collision.

Reason (R) : During elastic collision, the momentum and kinetic energy are both conserved.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both A and R are true but R is not the correct explanation of A.
(b) A is correct but R is not correct.

(c) Both A and R are correct and R is the correct explanation of A.
(d) A is not correct but R is correct.

14. Body A of mass $4m$ moving with speed u collides with another body B of mass $2m$, at rest. The collision is head on and elastic in nature. After the collision the fraction of energy lost by the colliding body A is
(a) 5/9 (b) 1/9 (c) 8/9 (d) 4/9

15. A particle of mass m is initially at rest at the origin. It is subjected to a force and starts moving along the x-axis. Its kinetic energy K changes with time as $dK/dt = \gamma t$, where γ is a positive constant of appropriate dimensions. Which of the following statements is not true?
(a) The force applied on the particle is constant
(b) The speed of the particle is proportional to time
(c) The distance of the particle from the origin increases linearly with time
(d) The force is conservative.

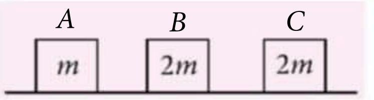
16. A block of mass M is attached to the lower end of a vertical spring. The spring is hung from a ceiling and has force constant value k. The mass is released from rest with the spring initially unstretched. The maximum extension produced in the length of the spring will be
(a) $2Mg/k$ (b) $4Mg/k$ (c) $Mg/2k$ (d) Mg/k

17. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1/E_2 is
(a) m_2/m_1 (b) m_1/m_2
(c) 1 (d) m_1v_2/m_2v_1

18. Water falls from a 40 m high dam at the rate of 9×10^4 kg per hour. Fifty percentage of gravitational potential energy can be converted into electrical energy. Using this hydroelectric energy number of 100 W lamps, that can be lit, is (Take $g = 10$ m s^{-2})
(a) 25 (b) 50
(c) 100 (d) 18

19. The potential energy of a system increases if work is done
(a) upon the system by a non-conservative force
(b) by the system against a conservative force
(c) by the system against a nonconservative force
(d) upon the system by a conservative force.

20. Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. The masses of A, B and C are m, $2m$ and $2m$ respectively. A moves towards B with a speed of 9 m/s and makes an elastic collision with it. Thereafter B makes a completely inelastic collision with C. All motions occur along same straight line. The final speed of C is



(a) 6 m/s (b) 9 m/s (c) 4 m/s (d) 3 m/s

SOLUTIONS

1. (c) : Mass of the block, $m = 2$ kg
Initial velocity, $v_i = 4$ m s^{-1} and $k = 12$ N m^{-1}

Initial kinetic energy, $K_i = \frac{1}{2}mv_1^2 = \frac{1}{2}\times 2\times(4)^2 = 16$ J

$$W = \int_{0.5}^{1.5} F dx = \int_{0.5}^{1.5} -kx\, dx$$

or $$W = -12\int_{0.5}^{1.5} x\, dx = -12\left[\frac{x^2}{2}\right]_{0.5}^{1.5}$$

$= -6[(1.5)^2 - (0.5)^2] = -6 \times 2 = -12$ J

Now, work done = change in kinetic energy
i.e., $W = K_f - K_i$
∴ Final kinetic energy, $K_f = K_i + W$

or $\frac{1}{2}mv_f^2 = (16-12)$ or $v_f = 2$ m s^{-1}

2. (c) : Here, $\vec{F} = (3\hat{i} + \hat{j})$ N

Initial position, $\vec{r}_1 = (2\hat{i} + \hat{k})$ m

Final position, $\vec{r}_2 = (4\hat{i} + 3\hat{j} - \hat{k})$ m

Displacement, $\vec{r} = \vec{r}_2 - \vec{r}_1$

$\vec{r} = (4\hat{i} + 3\hat{j} - \hat{k})\text{ m} - (2\hat{i} + \hat{k})\text{ m} = 2\hat{i} + 3\hat{j} - 2\hat{k}$ m

Work done, $W = \vec{F}\cdot\vec{r} = (3\hat{i} + \hat{j})\cdot(2\hat{i} + 3\hat{j} - 2\hat{k})$
$= 6 + 3 = 9$ J

3. (d): Total potential energy of first ball will be converted to total kinetic energy of second ball since collision is elastic.

Mathematically, $mgh = \frac{1}{2}mv^2$

$m(10)(0.2) = \frac{1}{2}mv^2 \Rightarrow v = 2$ m/s

4. (d): $s = \frac{t^2}{3}; \frac{ds}{dt} = \frac{2t}{3}; \frac{d^2s}{dt^2} = \frac{2}{3}$ m/s^2

Work done, $W = \int F ds = \int m\frac{d^2s}{dt^2}ds$

$$= \int m \frac{d^2s}{dt^2}\frac{ds}{dt}dt = \int_0^2 3 \times \frac{2}{3} \times \frac{2t}{3} dt = \frac{4}{3}\int_0^2 t dt$$

$$= \frac{4}{3}\left|\frac{t^2}{2}\right|_0^2 = \frac{4}{3} \times 2 = \frac{8}{3} \text{ J}$$

5. (a) : Given, $\vec{r} = \cos\omega t \hat{x} + \sin\omega t \hat{y}$

$\therefore \quad \vec{v} = \frac{d\vec{r}}{dt} = -\omega\sin\omega t \hat{x} + \omega\cos\omega t \hat{y}$

$\vec{a} = \frac{d\vec{v}}{dt} = -\omega^2\cos\omega t \hat{x} - \omega^2 \sin\omega t \hat{y} = -\omega^2\vec{r}$

Since, position vector $(\vec{r})$ is directed away from the origin, so, acceleration $(-\omega^2\vec{r})$ is directed towards the origin. Also,

$\vec{r}\cdot\vec{v} = (\cos\omega t\hat{x} + \sin\omega t\hat{y})\cdot(-\omega\sin\omega t\hat{x} + \omega\cos\omega t\hat{y})$

$= -\omega \sin\omega t \cos\omega t + \omega\sin\omega t\cos\omega t = 0$

$\Rightarrow \quad \vec{r} \perp \vec{v}$

6. (d)

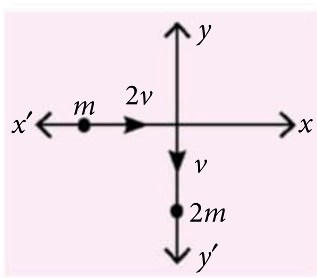
7. (c) : Given potential energy, $U = \frac{A}{r^{10}} - \frac{B}{r^5}$

For equilibrium $F = 0$, $F = -\frac{dU}{dr} = 0$

$\Rightarrow -10r^{-11}A + 5r^{-6}B = 0$

$\frac{2A}{r^5} = B$ or $r = \left(\frac{2A}{B}\right)^{1/5}$

8. (a) : Applying the principle of momentum conservation



$m(2v\hat{i}) + 2m(v\hat{j}) = (m+2m)\vec{v}'$

$\Rightarrow \quad \vec{v}' = \frac{2v}{3}(\hat{i}+\hat{j})$

$v' = |\vec{v}'| = \frac{2\sqrt{2}}{3}v$

Initial energy of the system,

$E_i = \frac{1}{2}m(2v)^2 + \frac{1}{2}(2m)v^2 = 2mv^2 + mv^2 = 3mv^2$

Final energy of the system, $E_f = \frac{1}{2}(3m)v'^2 = \frac{4}{3}mv^2$

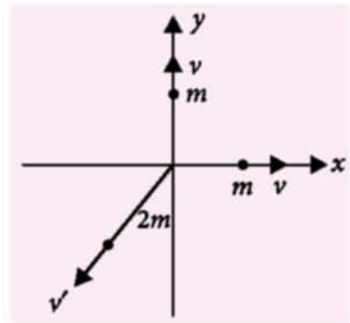
Percentage loss in the energy $= \frac{E_i - E_f}{E_i} \times 100 = 56\%$

9. (b) : Let $\vec{v}'$ be velocity of third piece of mass $2m$.

Initial momentum, $\vec{p}_i = 0$ (As the body is at rest)

Final momentum, $\vec{p}_f = mv\hat{i} + mv\hat{j} + 2m\vec{v}'$

According to law of conservation of momentum,



$\vec{p}_i = \vec{p}_f$

or, $0 = mv\hat{i} + mv\hat{j} + 2m\vec{v}'$

or, $\vec{v}' = -\frac{v}{2}\hat{i} - \frac{v}{2}\hat{j}$

The magnitude of v' is

$v' = \sqrt{\left(-\frac{v}{2}\right)^2 + \left(-\frac{v}{2}\right)^2} = \frac{v}{\sqrt{2}}$

Total kinetic energy generated due to explosion,

$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)v'^2$

$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)\left(\frac{v}{\sqrt{2}}\right)^2 = mv^2 + \frac{mv^2}{2} = \frac{3}{2}mv^2$

10. (c)

11. (c) : Given, mass of lift + passengers, $m = 2000$ kg

Speed, $v = 1.5$ m/s

Frictional force, $F = 3000$ N

Power delivered, P = Force × velocity ...(i)

Force acting, $F = mg + f$

$F = 2000 \times 10 + 3000$

$F = 23000$ N

Using value of 'F' in equation (i),

$P = 23000 \times 1.5 = 34500$ W

12. (a) : Given : Bullet of mass, $m = 200$ g $= 0.2$ kg

Time, $t = 1$ sec; Initial kinetic energy = 90 J

$\frac{1}{2}mu^2 = 90 \text{ J} \Rightarrow \frac{1}{2} \times 0.2 \times u^2 = 90 \text{ J} \Rightarrow u = 30$ m/s

From equation of motion, $v = u + at$

$20 = 30 - a \times 1 \Rightarrow a = -10$ m/s^2

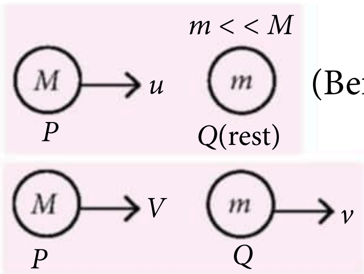
Negative sign shows deceleration.

For minimum length of the pool,

$\Rightarrow\ v^2 - u^2 = 2as \Rightarrow 0 - (30)^2 = 2 \times (-10) \times s$

$\Rightarrow\ s = 45$ m

13. (c) : (Before collision) (After collision)



Using conservation of linear momentum

$Mu = MV + mv$ ...(i)

By, definition of coefficient of restitution

$$e = \frac{V - v}{0 - u} = 1 \Rightarrow V = v - u$$

putting in equation (i) $\Rightarrow Mu = M(v - u) + mv$

$$v = \frac{2Mu}{M + m} \text{ if } M >> m;\ v = 2u$$

14. (c) : According to conservation of momentum,

$4mu_1 = 4mv_1 + 2mv_2 \Rightarrow 2(u_1 - v_1) = v_2$ ...(i)

From conservation of energy,

$$\frac{1}{2}(4m)u_1^2 = \frac{1}{2}(4m)v_1^2 + \frac{1}{2}(2m)v_2^2$$

$\Rightarrow\ 2(u_1^2 - v_1^2) = v_2^2$ ...(ii)

From (i) and (ii), $2(u_1^2 - v_1^2) = 4(u_1 - v_1)^2$

$3v_1 = u_1$ ...(iii)

Now, fraction of loss in kinetic energy for mass $4m$,

$$\frac{\Delta K}{K_i} = \frac{K_i - K_f}{K_i} = \frac{\frac{1}{2}(4m)u_1^2 - \frac{1}{2}(4m)v_1^2}{\frac{1}{2}(4m)u_1^2} \quad ...(iv)$$

Substituting (iii) in (iv), we get $\frac{\Delta K}{K_i} = \frac{8}{9}$

15. (c) : As $\frac{dK}{dt} = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = \frac{1}{2}m\left(2v\frac{dv}{dt}\right) = mv\frac{dv}{dt}$

As per question, $mv\frac{dv}{dt} = \gamma t$

$$\therefore \int_0^v v\,dv = \frac{\gamma}{m}\int_0^t t\,dt \Rightarrow \frac{v^2}{2} = \frac{\gamma}{m}\frac{t^2}{2};\ v = \sqrt{\frac{\gamma}{m}}\,t$$

or $v \propto t$ ...(i)

Hence, the speed of the particle is proportional to time.

From equation (i),

$$\frac{dv}{dt} = a = \text{constant} \quad \therefore \quad F = ma = \text{constant}$$

Also, $v = \frac{dx}{dt} \propto t$ so, $x \propto t^2$

Since work done by the force F is

$$W = \int_{x_i}^{x_f} F\,dx = F(x_f - x_i) \quad (\because F \text{ is constant})$$

As work done by this force depends only on initial and final position. So, the force is conservative in nature.

16. (a) : When the mass attached to a spring fixed at the other end is allowed to fall suddenly, it extends the spring by x. Potential energy lost by the mass is gained by the spring.

$$Mgx = \frac{1}{2}kx^2 \Rightarrow x = \frac{2Mg}{k}.$$

17. (a) : $m_1v_1 = m_2v_2$

(conservation of linear momentum)

$$\frac{E_1}{E_2} = \frac{(1/2)m_1v_1^2}{(1/2)m_2v_2^2} = \frac{m_1^2v_1^2}{m_2^2v_2^2}\cdot\frac{m_2}{m_1} = \frac{m_2}{m_1}$$

18. (b): Given, height of the dam, $h = 40$ m

Mass of falling water, $m = 9 \times 10^4$ kg per hour

Power of lamps, $P = 100$ W

Now, gravitational potential energy of water, PE = mgh

$$= \frac{9 \times 10^4 \times 10 \times 40}{3600} = 10^4\,\text{J}$$

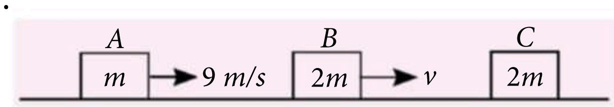
Given that, fifty percent of potential energy can be converted into electrical energy,

$\therefore$ Electrical energy, $E = \frac{1}{2} \times \text{PE} = 0.5 \times 10^4$ J

Number of bulbs, $n = \frac{0.5 \times 10^4}{100} = 50$

19. (b)

20. (d): Let the speed of B is v after collision and that of A is v'.



By using conservation of momentum for A and B,

$m \times 9 = mv' + 2mv;\ 9 = v' + 2v$ ...(i)

As collision is elastic,

$\Rightarrow e = \frac{v - v'}{9 - 0} = 1 \quad \therefore\ v - v' = 9$ ...(ii)

From (i) and (ii), $v = 6$ m/s and $v' = -3$ m/s

Now B strikes C inelastically.

Let the combined velocity of B and C is V.

Using conservation of momentum for B and C,

$2m \times 6 + 0 = (2m + 2m)V$

$12 = 4V \ \therefore\ V = 3$ m/s

◆◆

CBSE Warm-up!

CLASS-XI

Chapterwise practice questions for CBSE Exams as per the latest pattern and syllabus by CBSE for the academic session 2024-25.

Series-4 System of Particles and Rotational Motion

General Instructions : Read the following instructions very carefully and follow them :

(1) This question paper contains 33 questions. **All questions are compulsory**.
(2) Question paper is divided into **FIVE** section – **Section A, B, C, D** and **E**.
(3) **Section A –** Question number **1** to **16** are Multiple Choice (MCQ) type questions. Each question carries 1 mark.
(4) **Section B –** Question number **17** to **21** are Very Short Answer type questions. Each question carries 2 mark.
(5) **Section C –** Question number **22** to **28** are Short Answer type questions. Each question carries 3 mark.
(6) **Section D –** Question number **29** and **30** are Case-Based questions. Each question carries 4 mark.
(7) **Section E –** Question number **31** to **33** are Long Answer type questions. Each question carries 5 mark.
(8) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section–A.
(9) Kindly note that there is a separate question paper for Visually Impaired candidates.
(10) Use of calculators is **NOT** allowed.
You may use the following values of physical constants wherever necessary :
(i) $c = 3 \times 10^8$ m/s (ii) $h = 6.63 \times 10^{-34}$ Js (iii) $e = 1.6 \times 10^{-19}$ C
(iv) $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} (v) $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2} (vi) $\frac{1}{4\pi\varepsilon_0} = 9\times10^9$ N m^2 C^{-2}
(vii) Mass of electron $(m_e) = 9.1 \times 10^{-31}$ kg (viii) Mass of neutron $= 1.675 \times 10^{-27}$ kg (ix) Mass of proton $= 1.673 \times 10^{-27}$ kg
(x) Avogadro's number $= 6.023 \times 10^{23}$ per gram mole (xi) Boltzmann constant $= 1.38 \times 10^{-23}$ JK^{-1}

Time Allowed : 3 hours **Maximum Marks :** 70

SECTION-A

1. The angular speed of a fly wheel moving with uniform angular acceleration changes from 1200 rpm to 3120 rpm in 16 seconds. The angular acceleration in rad/s^2 is
(a) 2π (b) 4π (c) 12π (d) 104π

2. If $\vec{F}$ is the force acting on a particle having position vector $\vec{r}$ and $\vec{\tau}$ be the torque of this force about the origin, then
(a) $\vec{r}\cdot\vec{\tau} > 0$ and $\vec{F}\cdot\vec{\tau} < 0$
(b) $\vec{r}\cdot\vec{\tau} = 0$ and $\vec{F}\cdot\vec{\tau} = 0$
(c) $\vec{r}\cdot\vec{\tau} = 0$ and $\vec{F}\cdot\vec{\tau} \neq 0$
(d) $\vec{r}\cdot\vec{\tau} \neq 0$ and $\vec{F}\cdot\vec{\tau} = 0$

3. A body A of mass M while falling vertically downwards under gravity breaks into two parts; a body B of mass $\frac{1}{3}M$ and body C of mass $\frac{2}{3}M$. The center of mass of bodies B and C taken together shifts compared to that of body A towards
(a) body C (b) body B
(c) depends on height of breaking
(d) does not shift

4. A solid sphere of mass m and radius R is rotating about its diameter. A solid cylinder of the same mass and same radius is also rotating about its geometrical axis with an angular speed twice that of the sphere. The ratio of their kinetic energies of rotation $(E_{sphere}/E_{cylinder})$ will be
(a) 2 : 3 (b) 1 : 5 (c) 1 : 4 (d) 3 : 1

5. If force $\vec{F}=3\hat{i}+4\hat{j}-2\hat{k}$ acts on a particle having position vector $2\hat{i}+\hat{j}+2\hat{k}$ then, the torque about the origin will be
(a) $3\hat{i}+4\hat{j}-2\hat{k}$
(b) $-10\hat{i}+10\hat{j}+5\hat{k}$
(c) $10\hat{i}+5\hat{j}-10\hat{k}$
(d) $10\hat{i}+\hat{j}-5\hat{k}$

6. A ring of mass m and radius r rotates about an axis passing through its centre and perpendicular to its plane with angular velocity ω. Its kinetic energy is
(a) $\frac{1}{2}mr^2\omega^2$
(b) $mr\omega^2$
(c) $mr^2\omega^2$
(d) $\frac{1}{2}mr\omega^2$

7. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$, respectively. The centre of mass of this system has a position vector
(a) $-2\hat{i}-\hat{j}+\hat{k}$
(b) $2\hat{i}-\hat{j}-2\hat{k}$
(c) $-\hat{i}+\hat{j}+\hat{k}$
(d) $-2\hat{i}+2\hat{k}$

8. In a physical balance working on the principle of moments, when 5 mg weight is placed on the left pan, the beam becomes horizontal. Both the empty pans of the balance are of equal mass. Which of the following statements is correct?
(a) Left arm is shorter than the right arm.
(b) Left arm is longer than the right arm.
(c) Every object that is weighed using this balance appears lighter than its actual weight.
(d) Both the arms are of same length.

9. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?
(a) 0.25 rad s^{-2}
(b) 25 rad s^{-2}
(c) 5 m s^{-2}
(d) 25 m s^{-2}

10. Angular momentum of a single particle moving with constant speed along circular path
(a) remains same in magnitude but changes in the direction
(b) remains same in magnitude and direction
(c) is zero
(d) changes in magnitude but remains same in the direction.

11. A solid cylinder of mass 2 kg and radius 4 cm is rotating about its axis at the rate of 3 rpm. The torque required to stop it after 2π revolutions is
(a) 2×10^6 N m
(b) 2×10^{-6} N m
(c) 2×10^{-3} N m
(d) 12×10^{-4} N m

12. What is the value of linear velocity, if $\vec{r}=3\hat{i}-4\hat{j}+\hat{k}$ and $\vec{\omega}=5\hat{i}-6\hat{j}+6\hat{k}$?
(a) $4\hat{i}-13\hat{j}+6\hat{k}$
(b) $18\hat{i}+13\hat{j}-2\hat{k}$
(c) $6\hat{i}+2\hat{j}-3\hat{k}$
(d) $6\hat{i}-2\hat{j}+8\hat{k}$

For Questions number 13 to 16, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(b) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).
(c) If Assertion (A) is true and Reason (R) is false.
(d) If both Assertion (A) and Reason (R) are false.

13. **Assertion :** The centre of mass of system of n particles is the weighted average of the position vector of the n particles making up the system.
Reason : The position of the centre of mass of a system is independent of co-ordinate system.

14. **Assertion :** It is harder to open and shut the door if we apply force near the hinge.
Reason : Torque is maximum at hinge of the door.

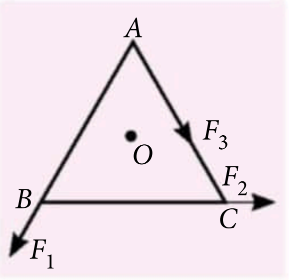
15. **Assertion :** A particle moving on a straight line with a uniform velocity, its angular momentum is always zero.
Reason : The momentum is zero when particle moves with a uniform velocity.

16. **Assertion :** The total kinetic energy of a rolling solid sphere is the sum of translational and rotational kinetic energies.
Reason : For all solid bodies total kinetic energy is always twice translational kinetic energy.

SECTION-B

17. A system consisting of two objects has a total momentum of 16 kg m s^{-1} and its centre of mass has the velocity of 2 m s^{-1}. One of the object has the mass 5 kg and velocity 1.6 m s^{-1}. What is the mass and velocity of the other object?

18. O is the centre of an equilateral triangle ABC. F_1, F_2 and F_3 are three forces acting along the sides AB, BC and AC as shown in figure. What should be the magnitude of F_3, so that the total torque about O is zero?



OR

Find the scalar and vector products of two vectors. $\vec{a} = (3\hat{i} - 4\hat{j} + 5\hat{k})$ and $\vec{b} = (-2\hat{i} + \hat{j} - 3\hat{k})$.

19. The moment of inertia of two rotating bodies A and B are I_A and I_B ($I_A > I_B$) and their angular momentum are equal. Which one has a greater kinetic energy?

20. A cord is wound over the rim of a flywheel of mass 20 kg and radius 25 cm. A mass 2.5 kg attached to the cord is allowed to fall under gravity. Calculate the angular acceleration of the flywheel.

21. A wheel of radius 0.5 m rolls without a slipping on a horizontal surface. Starting from rest, the wheel moves with constant acceleration 6 rad s^{-2}. Find the distance travelled by the centre of the wheel from $t = 0$ to $t = 3$ sec.

SECTION-C

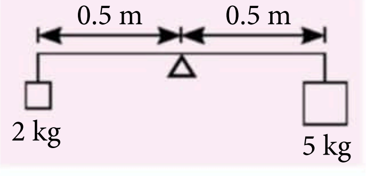
22. A ring, a disc and a sphere all of the same radius and same mass rolls down an inclined plane from the same height h. Which of the three reaches the bottom at the earliest?

23. **(a)** The density of a non-uniform rod of length 1 m is given by $\rho(x) = a(1 + bx^2)$ where a and b are constants and $0 \le x \le 1$. Find the centre of mass of the rod.

(b) A body having a moment of inertia about its axis of rotation equal to 3 kg m^2 is rotating with angular velocity of 3 rad s^{-1}. Kinetic energy of this rotating body is same as that of a body of mass 27 kg moving with velocity v. Find the value of v.

24. **(a)** Define radius of gyration. On what factors does it depends.

(b) A light rod of length 1 m is pivoted at its centre and two masses 5 kg and 2 kg are hung from the ends as shown in figure. Find the initial angular acceleration of the rod assuming that it was horizontal in the beginning.



25. Derive the expression for relation between angular momentum and torque.

OR

(i) For a given mass and size, moment of inertia of a solid disc is smaller than that of a ring. Why?

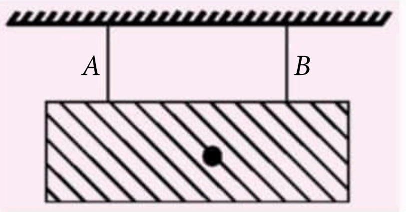
(ii) A disc of mass 200 kg and radius 0.5 m is rotating at the rate of 8 revolutions per second. Find the constant torque required to stop the disc in 11 rotations.

26. A child stands at the centre of a turn table with his two arms outstretched. The turn table is set rotating with an angular speed of 40 rpm.

(i) How much is the angular speed of the child, if he folds his hands back reducing the moment of inertia to $(2/5)^{th}$ of its initial value?

(ii) Show that the child's new kinetic energy of rotation is more than the initial one. Also show by how many times its has increased?

27. The figure shows a horizontal block of mass M suspended by two wires A and B. The centre of mass of the block is closer to B than A.



(i) Is the magnitude of the torque due to wire A is greater, less or equal to that due to B?

(ii) Which wire A or B exerts more force on the block?

28. A flywheel mass 500 kg and 1 m diameter makes 500 revolutions per minute. Assuming the mass to be concentrated along the rim, calculate :
(i) the angular velocity (ii) the moment of inertia and (iii) energy of the flywheel.

SECTION-D

Case Study Based Questions

Question no. 29 to 30 are case based questions. Read the following paragraph and answer the questions that follow.

29. In static equilibrium, if the sum of moments acting on the object is zero, then the object will not be in motion (neither translational nor rotational). If the resultant of moments of the forces is zero, it means that sum of clockwise moments should be equal to sum of anti-clockwise moments.

Moment of force = force × perpendicular distance

(i) The length of see-saw is 2 m. A child of mass 40 kg is sitting on the left end, then find the location of 50 kg child from fulcrum, so that it is in equilibrium.

(a) 0.4 m (b) 0.8 m
(c) 0.2 m (d) 0.6 m

(ii) What is the reaction on fulcrum?

(a) 882 N (b) 290 N (c) 90 N (d) 110 N

(iii) If a radial vector $\vec{r}$ is in x-direction and force vector $\vec{F}$ in y-direction, then torque vector $\vec{\tau}$ will have the direction if $\vec{\tau}=\vec{r}\times\vec{F}$

(a) + z-direction (b) – z-direction
(c) + x-direction (d) + y-direction

(iv) Consider the following two statements A and B and identify the correct choice.

A. The torques produced by two forces of the couple are opposite to each other.
B. The direction of torque is always perpendicular to the plane of rotation of the body.

(a) A is true and B is false
(b) B is true and A is false
(c) Both are true
(d) Both are false.

OR

A couple produces
(a) linear and rotational motion
(b) no motion
(c) purely linear motion
(d) purely rotational motion.

30. There is a system of two particles of masses m_1, m_2 and their position vectors $\vec{r}_1$ and $\vec{r}_2$ respectively. The centre of mass of system is given by

$$\vec{R}_{CM}=\frac{m_1\vec{r}_1+m_2\vec{r}_2}{m_1+m_2}$$

The velocity of centre of mass is given by

$$\vec{v}_{CM}=\frac{m_1\vec{v}_1+m_2\vec{v}_2}{m_1+m_2}$$

And the total linear momentum of a system of particles is given by $\vec{p}=m_1\vec{v}_1+m_2\vec{v}_2$

In an isolated system, the vector sum of external forces acting on a system of particle is zero.

$$\frac{d\vec{p}}{dt}=0 \Rightarrow \vec{p}=\text{constant} \Rightarrow m\vec{v}_{CM}=\text{constant}$$

$\vec{v}_{CM}=\text{constant}$

Mass m_1 = 40 g and m_2 = 200 gm moving with velocity $\vec{v}_1=6.2\hat{i}$ cm/s and $\vec{v}_2=3.4\hat{j}$ cm/s at $\vec{r}_1=6\hat{i}$ cm and $\vec{r}_2=4\hat{j}$ cm.

(i) Find the position of centre of mass.

(a) $\left(\frac{3\hat{i}+6\hat{j}}{5}\right)$cm (b) $\left(\hat{i}+\frac{10\hat{j}}{3}\right)$cm
(c) $\left(3\hat{i}+\frac{\hat{j}}{3}\right)$cm (d) $\left(\frac{2\hat{i}+6\hat{j}}{3}\right)$cm

(ii) Find the velocity of centre of mass?

(a) $\left(\frac{31}{30}\hat{i}+\frac{17}{6}\hat{j}\right)$cm/s (b) $\left(\frac{21}{2}\hat{i}+\frac{17}{6}\hat{j}\right)$cm/s
(c) $\left(\frac{-31}{30}\hat{i}+\frac{17}{6}\hat{j}\right)$cm/s (d) $\left(\frac{-31}{30}\hat{i}+\frac{21}{2}\hat{j}\right)$cm/s

(iii) Consider on an isolated system consist of two particles of mass m_1 and m_2 having velocities, v_1 and v_2. If external force acting on the system is zero, then which of the following statement is true?

(a) $R_{CM}=\frac{m_1\vec{r}_1+m_2\vec{r}_2}{m_1+m_2}$ is fixed
(b) $P = m_1\vec{v}_1+m_2\vec{v}_2$ is constant
(c) mV_{CM} = constant
(d) both (b) and (c)

OR

A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass
(a) of the box remains constant
(b) of the box plus the ball system remains constant
(c) of the ball remain constant
(d) of the ball relative to box remain constant.

(iv) Two objects P and Q initially at rest move towards each other under a mutual force of attraction. At the instant when the velocity of P is v and that of Q is $2v$, the velocity of centre of mass of the system is

(a) v (b) $2v$
(c) $3v$ (d) zero

SECTION-E

31. Derive an expression for kinetic energy of a body rolling without slipping.

OR

Show that moment of a couple does not depend on the point about which you take the moments.

32. **(a)** Derive an expression for the position vector of centre of mass of a system of particles in terms of cartesian coordinate components.

OR

(b) (i) Differentiate between translational motion and rotational motion with example.

(ii) A projectile projected at a certain angle with the horizontal, hits the ground at *P*. However, if this particle explodes at the highest point into two pieces of equal mass. One piece falls to the ground vertically downwards at *Q*, while the other travels horizontally and hit the ground at *R*. What is the distance of *R* from *P*.

(iii) How will you prove that the centre of mass of two particles divides the line joining the particles in the inverse ratio of their masses?

33. **(a)** (i) Explain how angular momentum can be expressed as the vector product of two vectors?

(ii) Find the torque of a force $(7\hat{i}+3\hat{j}-5\hat{k})$ about the origin, if the force acts on a particle whose position vector is $\hat{i}-\hat{j}+\hat{k}$.

(iii) A dumb bell consists of two small balls of mass 1/2 kg each connected to the two ends of a 50 cm long light rod. The dumb bell is rotating about a fixed axis through the centre of the rod and perpendicular to it at an angular speed 10 rad s^{-1}. An impulsive force of average magnitude 5 N acts on one of the masses in the direction of its velocity for 0.1 s. Find the angular velocity of the system.

OR

(b) (i) Starting from rest, a fan takes five seconds to attain the maximum speed of 400 rpm (revolutions per minute). Assuming constant acceleration, find the time taken by the fan in attaining half the maximum speed.

(ii) A ring and a disc rolls on a horizontal surface without slipping with same linear velocity. If both have same mass and total kinetic energy of the ring is 4 J, then calculate the total kinetic energy of the disc.

SOLUTIONS

1. **(b) :** Initial angular speed,

$$\omega_0 = \frac{2\pi\times 1200}{60}\text{ rad s}^{-1} = 40\pi\text{ rad s}^{-1}$$

Final angular speed,

$$\omega = \frac{2\pi\times 3120}{60}\text{ rad s}^{-1} = 104\pi\text{ rad s}^{-1}$$

$\therefore$ Angular acceleration, $\alpha = \frac{\omega-\omega_0}{t} = \frac{104\pi-40\pi}{16} = 4\pi\text{ rad s}^{-2}$

2. **(b) :** Torque is always perpendicular to $\vec{F}$ as well as $\vec{r}$.

$\vec{r}\cdot\vec{\tau}=0$ as well as $\vec{F}\cdot\vec{\tau}=0$.

3. **(d) :** The centre of mass of bodies *B* and *C* taken together does not shift as no external force is applied horizontally.

4. **(b) :** $\dfrac{E_{\text{Sphere}}}{E_{\text{Cylinder}}} = \dfrac{\frac{1}{2}I_s\omega_s^2}{\frac{1}{2}I_c\omega_c^2} = \dfrac{I_s\omega_s^2}{I_c\omega_c^2}$

Here, $I_s = \frac{2}{5}mR^2,\ I_c = \frac{1}{2}mR^2,\ \omega_c = 2\omega_s$

$$\frac{E_{\text{Sphere}}}{E_{\text{Cylinder}}} = \frac{\frac{2}{5}mR^2\times\omega_s^2}{\frac{1}{2}mR^2\times(2\omega_s)^2} = \frac{4}{5}\times\frac{1}{4} = \frac{1}{5}$$

5. **(b) :** Given : $\vec{F} = 3\hat{i}+4\hat{j}-2\hat{k},\ \vec{r} = 2\hat{i}+\hat{j}+2\hat{k}$

Torque, $\vec{\tau} = \vec{r}\times\vec{F}$; $\vec{\tau} = \begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 2 & 1 & 2\\ 3 & 4 & -2\end{vmatrix}$

$\vec{\tau} = \hat{i}(-2-8)-\hat{j}(-4-6)+\hat{k}(8-3)$; $\vec{\tau} = -10\hat{i}+10\hat{j}+5\hat{k}$

6. **(a) :** Kinetic energy $= \frac{1}{2}I\omega^2$, and for ring, $I = mr^2$.

Hence, $KE = \frac{1}{2}mr^2\omega^2$

7. **(a) :** $\vec{r}_1 = \hat{i}+2\hat{j}+\hat{k}$ for $M_1 = 1$ kg

$\vec{r}_2 = -3\hat{i}-2\hat{j}+\hat{k}$ for $M_2 = 3$ kg

$$r_{CM} = \frac{\sum m_i r_i}{\sum m_i}$$

$$\Rightarrow \quad r_{CM} = \frac{(1\hat{i}+2\hat{j}+1\hat{k})\times 1+(-3\hat{i}-2\hat{j}+\hat{k})\times 3}{4}$$

$$\Rightarrow \quad r_{CM} = \frac{-8\hat{i}-4\hat{j}+4\hat{k}}{4} = -2\hat{i}-\hat{j}+\hat{k}$$

8. (a)

9. (b) : Here, $m = 3$ kg, $r = 40$ cm $= 40 \times 10^{-2}$ m, $F = 30$ N

Moment of inertia of hollow cylinder about its axis

$= mr^2 = 3 \text{ kg} \times (0.4)^2 \text{ m}^2 = 0.48 \text{ kg m}^2$

The torque is given by, $\tau = I\alpha$

where, I = moment of inertia, α = angular acceleration

In the given case, $\tau = rF$, as the force is acting perpendicularly to the radial vector.

$$\therefore \quad \alpha = \frac{\tau}{I} = \frac{Fr}{mr^2} = \frac{F}{mr} = \frac{30}{3\times 40\times 10^{-2}} = \frac{30\times 100}{3\times 40}$$

$\alpha = 25$ rad s^{-2}

10. (b) : Angular momentum, $\vec{L} = m(\vec{r}\times\vec{v})$

where, $\vec{r}$ is distance, $\vec{v}$ is velocity.

$|\vec{L}| = mvr$

The direction of $\vec{L}$ is perpendicular to the plane of $\vec{r}$ and $\vec{v}$ which is constant.

When both $(\vec{v})$ and $(\vec{r})$ are constant, the magnitude and direction of angular momentum will also be constant.

11. (b) : Given : Mass $M = 2$ kg, Radius $R = 4$ cm

Initial angular speed,

$$\omega_0 = 3\,\text{rpm} = 3\times\frac{2\pi}{60}\,\text{rad/s} = \frac{\pi}{10}\,\text{rad/s}$$

We know that, $\omega^2 = \omega_0^2 + 2\alpha\theta$

$$\Rightarrow \quad 0 = \left(\frac{\pi}{10}\right)^2 + 2\times\alpha\times 2\pi\times 2\pi \Rightarrow \alpha = \frac{-1}{800}\,\text{rad/s}^2$$

Moment of inertia of a solid cylinder,

$$I = \frac{MR^2}{2} = \frac{2\times\left(\frac{4}{100}\right)^2}{2} = \frac{16}{10^4}$$

$$\text{Torque, } \tau = I\alpha = \left(\frac{16}{10^4}\right)\times\left(-\frac{1}{800}\right) = -2\times 10^{-6}\,\text{N m}$$

12. (b) : $$\vec{v} = \vec{\omega}\times\vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -6 & 6 \\ 3 & -4 & 1 \end{vmatrix} = 18\hat{i}+13\hat{j}-2\hat{k}$$

13. (b) : By definition, the position vector of centre of mass of the system of n particles,

$$\vec{r}_{CM} = \sum_{i=1}^{i=n}\frac{m_i\vec{r}_i}{M} \quad \text{or} \quad \vec{r}_{CM} = \frac{m_1\vec{r}_1+m_2\vec{r}_2.....+m_n\vec{r}_n}{m_1+m_2+.......+m_n}$$

i.e., $(m_1 + m_2 + ... + m_n)\vec{r}_{CM} = (m_1\vec{r}_1 + m_2\vec{r}_2 + ... + m_n\vec{r}_n)$.

Hence, position of centre of mass of n particles of the system is such that the product of total mass and position vector of centre of mass is equal to sum of the products of individual masses of the particles and their respective position vectors.

14. (c) : Torque = Force × perpendicular distance of line of force from the axis of rotation. Hence, for a given applied force, torque or true tendency of rotation will be high for large value of d. If distance d is smaller, then greater force is required to cause the same torque, hence it is harder to open or shut down the door by applying a force near the hinge.

15. (d) : As a particle is moving with uniform velocity, therefore its linear momentum $(m\vec{v})$ is constant.

But about a point off the line of motion, the moment of momentum *i.e.*, angular momentum can be non-zero.

Reason is false because the momentum is a constant and not zero.

16. (c) : Kinetic energy of a rolling sphere = $K_T + K_R$.

$$= \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}\times\frac{2}{5}mR^2\omega^2 = \frac{7}{10}mv^2.$$

Since, I is different for different solid bodies. Therefore, different solid bodies have different kinetic energy.

17. Total momentum = total mass × velocity of the centre of mass

16 kg m s^{-1} = $(m + 5) \times 2$ m s^{-1}; $16 = 2m + 10$

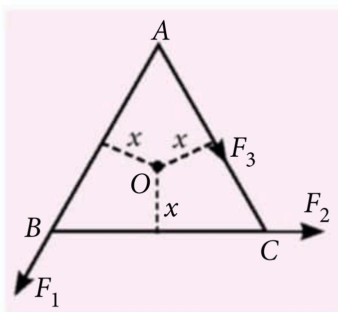
$\Rightarrow \quad m = 3$ kg

$$\text{Now, } v_{CM} = \frac{(m_1v_1+m_2v_2)}{(m_1+m_2)}$$

$$\Rightarrow \quad 2 = \frac{(5\times 1.6+3\times v_2)}{(5+3)} \Rightarrow 2 = \frac{8+3v_2}{8}$$

$\Rightarrow \quad v_2 = 2.67$ m s^{-1}

18. Let x be the distance of each side of the ΔABC from the centre O. Then total torque about O will be,



$$F_1x + F_2x - F_3x = 0 \text{ or } F_1 + F_2 = F_3$$

OR

$$\vec{a}\cdot\vec{b} = (3\hat{i} - 4\hat{j} + 5\hat{k}).(-2\hat{i} + \hat{j} - 3\hat{k})$$
$$= -6 - 4 - 15 = -25$$

$$\vec{a}\times\vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -4 & 5 \\ -2 & 1 & -3 \end{vmatrix} = 7\hat{i} - \hat{j} - 5\hat{k}$$

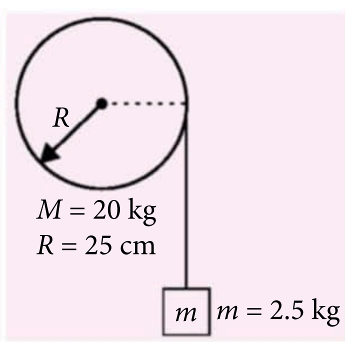
Note : $\vec{b}\times\vec{a} = -7\hat{i} + \hat{j} + 5\hat{k}$

19. $K = \frac{1}{2}I\omega^2$ and $L = I\omega$ $\therefore$ $K = \frac{(I\omega)^2}{2I} = \frac{L^2}{2I}$

As angular momentum of two bodies is same,

$\therefore \frac{K_A}{K_B} = \frac{I_B}{I_A}$. As $I_A > I_B$, $\therefore$ $K_B > K_A$

20. Moment of inertia of flywheel about its axis,



$$I = \frac{MR^2}{2}$$

$$= \frac{(20 \text{ kg})(25\times10^{-2} \text{ m})^2}{2}$$

$= 25 \times 25 \times 10^{-3}$ kg m^2

Torque acting on the flywheel,

$\tau = FR = mgR = (2.5 \text{ kg})\ (10 \text{ m/s}^2)\ (25 \times 10^{-2} \text{ m})$
$= 25 \times 25 \times 10^{-2}$ N m

Angular acceleration of the flywheel,

$$\alpha = \frac{\tau}{I} = \frac{25\times25\times10^{-2}}{25\times25\times10^{-3}} = 10 \text{ rad/s}^2$$

21. In case of slipping, $a = r\alpha$

$\therefore$ $a = (0.5) \times 6 = 3$ m s^{-2}

Distance travelled, $S = \frac{1}{2}at^2 = \frac{1}{2}\times3\times(3)^2 = 13.5$ m

22. Acceleration of an object rolls down an inclined plane is given by

$$a = \frac{g\sin\theta}{1+\frac{I}{mr^2}}$$

For a ring, $I = mr^2$

$$\therefore\ a_{ring} = \frac{g\sin\theta}{1+1} = 0.5\, g\sin\theta$$

For a disc, $I = \frac{1}{2}mr^2$

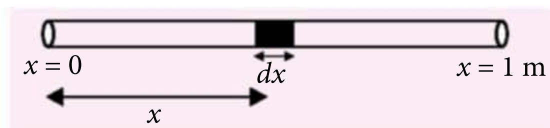
$$\therefore\ a_{disc} = \frac{g\sin\theta}{1+\frac{1}{2}} = \frac{2}{3}g\sin\theta = 0.67\, g\sin\theta$$

For a sphere, $I = \frac{2}{5}mr^2$

$$\therefore\ a_{sphere} = \frac{g\sin\theta}{1+\frac{2}{5}} = \frac{5}{7}g\sin\theta = 0.71\, g\sin\theta$$

As a_{sphere} is maximum, it will reach the bottom at the earliest.

23. (a)



Mass of a small element of length dx of the rod at a distance x from the one end of the rod is

$dm = \rho dx = a(1 + bx^2)dx$

The centre of mass of the rod is,

$$X_{CM} = \frac{\int_0^1 x\, dm}{\int_0^1 dm} = \frac{\int_0^1 xa(1+bx^2)\,dx}{\int_0^1 a(1+bx^2)\,dx}$$

$$= \frac{\int_0^1 (x+bx^3)dx}{\int_0^1 (1+bx^2)dx} = \frac{\left[\frac{x^2}{2}+\frac{bx^4}{4}\right]_0^1}{\left[x+\frac{bx^3}{3}\right]_0^1} = \frac{\left[\frac{1}{2}+\frac{b}{4}\right]}{\left[1+\frac{b}{3}\right]} = \frac{3(2+b)}{4(3+b)}$$

(b) Here, Moment of inertia of the body about its axis of rotation, $I = 3$ kg m^2

Angular velocity of rotation, $\omega = 3$ rad s^{-1}

Kinetic energy of rotation of the body is $K_R = \frac{1}{2}I\omega^2$

Kinetic energy of body of mass m (= 27 kg) moving with velocity v is $K_T = \frac{1}{2}mv^2$

As per question, $K_R = K_T$ $\therefore$ $\frac{1}{2}I\omega^2 = \frac{1}{2}mv^2$

$\Rightarrow \frac{1}{2}\times3\times3^2 = \frac{1}{2}\times27\times v^2$ or $v^2 = 1$ or $v = 1$ m s^{-1}

24. (a) The radius of gyration of a body about a given axis is equal to the root mean square distance of the constituent particles of the body from the given axis. It is denoted by k and is given by,

$$k=\sqrt{\frac{r_1^2+r_2^2+\ldots+r_n^2}{n}}$$

The value of radius of gyration shall depends upon shape and size of the body, position and configuration of the axis of rotation, and also on the distribution of mass of the body w.r.t. the axis of rotation.

(b) About the pivot,

I_{system} = (2 kg)(0.5 m)^2 + (5 kg) (0.5 m)^2 = 1.75 kg m^2

τ_{pivot} = (5 × 9.8 N) (0.5 m) – (2 × 9.8 N) (0.5 m)

= 14.7 N m (clockwise).

$$\Rightarrow \alpha=\frac{\tau}{I}=\frac{14.7\,\text{N m}}{1.75\,\text{kg}\cdot\text{m}^2}=8.4 \text{ rad s}^{-2} \text{ (clockwise)}$$

25. The vector relation between angular momentum $\vec{L}$ and linear momentum $\vec{p}$ is $\vec{L}=\vec{r}\times\vec{p}$

Differentiating both sides with respect to time, we get

$$\frac{d\vec{L}}{dt}=\frac{d}{dt}(\vec{r}\times\vec{p})$$

Applying the product rule for differentiation to the right hand side,

$$\frac{d}{dt}(\vec{r}\times\vec{p})=\frac{d\vec{r}}{dt}\times\vec{p}+\vec{r}\times\frac{d\vec{p}}{dt} \quad \text{...(i)}$$

Now, $\frac{d\vec{r}}{dt}=\vec{v}$ = velocity of the particle

and $\vec{p}=m\vec{v}$ = linear momentum of the particle

$\therefore \frac{d\vec{r}}{dt}\times\vec{p}=\vec{v}\times m\vec{v}=0,$ as the cross product of two parallel vectors is zero. Also, $\frac{d\vec{p}}{dt}=\vec{F}$

Hence, from eqn. (i), we get

$$\frac{d}{dt}(\vec{r}\times\vec{p})=\vec{r}\times\vec{F}=\vec{\tau} \Rightarrow \frac{d}{dt}(\vec{L})=\vec{\tau}.$$

OR

(i) This is because entire mass of a ring is at its periphery, *i.e.*, at maximum distance from the centre, whereas the mass of a disc is distributed from the centre to the rim.

(ii) Here, m = 200 kg, r = 0.5 m

n_1 = 8 rps; n_2 = 0 ; τ = ?

θ = 11 × 2π radian

As $\omega_2^2-\omega_1^2=2\alpha\theta$

$\therefore$ 0 – (2π × 8)^2 = 2α(11 × 2π)

$$\alpha=-\frac{16\pi\times16\pi}{44\pi}=-16\times\frac{22}{7}\times\frac{16}{44}=\frac{-128}{7}\text{ rad s}^{-2}$$

As $\tau=I\alpha=\left(\frac{1}{2}mr^2\right)\alpha$; $\tau=\frac{1}{2}\times200\times(0.5)^2\times\left(\frac{-128}{7}\right)$

τ = –457.01 N m

26. Given that ω_0 = 40 rpm

(i) If child folds his hands by reducing the moment of inertia to (2/5)th of its initial values, *i.e.*, $I_2=\frac{2}{5}I_1$

then, according to principle of conservation of angular momentum, $I_1\omega_1=I_2\omega_2$

or $I_1\times40=\frac{2}{5}I_1\times\omega_2$ [∵ $\omega_1=\omega_0$ = 40 rpm]

or $\omega_2=\frac{40\times5}{2}=100$ rpm

(ii) Initial kinetic energy of rotation

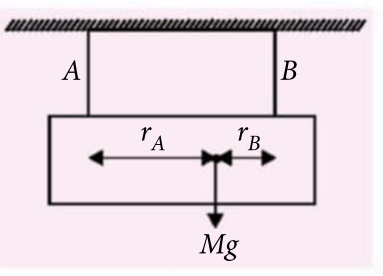
$$K_1=\frac{1}{2}I_1\omega_1^2=\frac{1}{2}I_1(40)^2=800\ I_1$$

New kinetic energy of rotation

$$K_2=\frac{1}{2}I_2\omega_2^2=\frac{1}{2}\times\frac{2}{5}I_1\times(100)^2=2000\ I_1$$

$$\therefore \frac{K_2}{K_1}=\frac{2000\ I_1}{800\ I_1}=2.5$$

27. (i) Given, the centre of mass is closer to B than A.



$\therefore$ $r_A>r_B$

Torque, $\vec{\tau}=\vec{r}\times\vec{F}$

Torque about A,

$|\vec{\tau}_A|=r_AMg$

Torque about B, $|\vec{\tau}_B|=r_BMg$

As, $r_A>r_B$ ∴ $|\vec{\tau}_A|>|\vec{\tau}_B|$

(ii) Force at A × distance from CM

= Force at B × distance from CM

As B is closer to CM, the force at B is greater.

MONTHLY TEST DRIVE CLASS XII ANSWER KEY

1.	(c)	2.	(c)	3.	(c)	4.	(c)	5.	(b)
6.	(c)	7.	(d)	8.	(a)	9.	(d)	10.	(b)
11.	(a)	12.	(c)	13.	(a)	14.	(c)	15.	(d)
16.	(c)	17.	(a)	18.	(c)	19.	(a, d)	20.	(b, d)
21.	(b, c)	22.	(a, d)	23.	(b)	24.	(18)	25.	(17)
26.	(45)	27.	(b)	28.	(a)	29.	(a)	30.	(b)

28. (i) Here, mass of flywheel, $M = 500$ kg

Frequency of the flywheel, $\upsilon = \frac{500}{60} = 8.3$ rps

Thus, $\omega = 2\pi\upsilon = (2 \times 3.14 \times 8.3)$ rad s^{-1} = 52 rad s^{-1}

(ii) Since the mass of the flywheel is supposed to be concentrated at the rim (edge), distance of the rim from the axis of rotation (passing through the centre)

= radius of gyration (k) = $\frac{1}{2}$ (diameter of wheel) = 0.5 m

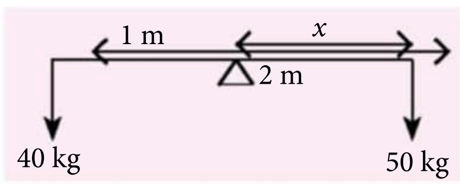
Moment of inertia of the flywheel about the axis of rotation, *i.e.*,

$$I = Mk^2 = [500 \times (0.5)^2] \text{ kg m}^2 = 125 \text{ kg m}^2$$

(iii) Kinetic energy of rotation of the flywheel,

$$= \frac{1}{2} I\omega^2 = \left[\frac{1}{2} \times 125 \times (52)^2\right] = 1.7 \times 10^5 \text{ J}$$

29. (i) (b) :



Take moments about fulcrum.

Let x is the location of child of mass 50 kg from fulcrum.

$$1 \times 40 \times g = x \times 50 \times g$$

$$x = \frac{4}{5} \text{ m} = 0.8 \text{ m}$$

(ii) (a) : Reaction = 40 + 50; R = 90 kg wt = 882 N

(iii) (a) : The direction of $\vec{\tau} = \vec{r} \times \vec{F}$ is along + z-direction according to right-handed screw rule.

(iv) (b) : The direction of torque is always perpendicular to the plane of rotation of the body as a cross product is in the perpendicular plane to $\vec{r}$ and $\vec{F}$ vectors and the torque produced by the two forces of the couple are in the same direction to each other.

OR

(d) : A couple produces only rotational motion.

30. (i) (b) : $m_1 = 40$ g, $m_2 = 200$ g;

$\vec{r}_1 = 6\hat{i}$ cm, $\vec{r}_2 = 4\hat{j}$ cm

$$\vec{r}_{CM} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2} = \frac{40 \times 6\hat{i} + 200 \times 4\hat{j}}{40 + 200} = \left(\hat{i} + \frac{10}{3}\hat{j}\right) \text{cm}$$

(ii) (a) : $\vec{v}_1 = 6.2\,\hat{i}$ cm/s, $\vec{v}_2 = 3.4\,\hat{j}$ cm/s,

$$\vec{v}_{CM} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2} = \frac{40 \times 6.2\,\hat{i} + 200 \times 3.4\,\hat{j}}{40 + 200}$$

$$\vec{v}_{CM} = \left(\frac{31}{30}\hat{i} + \frac{17}{6}\hat{j}\right) \text{cm/s}$$

(iii) (d) : both (b) and (c)

OR

(b) : If we take the box and ball as one system, then their collisions create internal forces only. $\vec{F}_{ex} = M\vec{a}_{cm}$

As, $\vec{F}_{ex} = 0$ here, $\vec{a}_{cm} = 0$

$\Rightarrow$ $\vec{v}_{cm}$ of box and ball system is constant.

(iv) (d) : Since the objects move due to the mutual interaction between them so, the centre of mass of the system remains the same and its velocity is zero.

31. *Refer solution no. 18, page no. 255, Class-11, MTG 100 percent Physics 2024-25.*

OR

Refer solution no. 18, page no. 239, Class-11, MTG 100 percent Physics 2024-25.

32. (a) *Refer solution no. 18, page no. 227, Class-11, MTG 100 percent Physics 2024-25.*

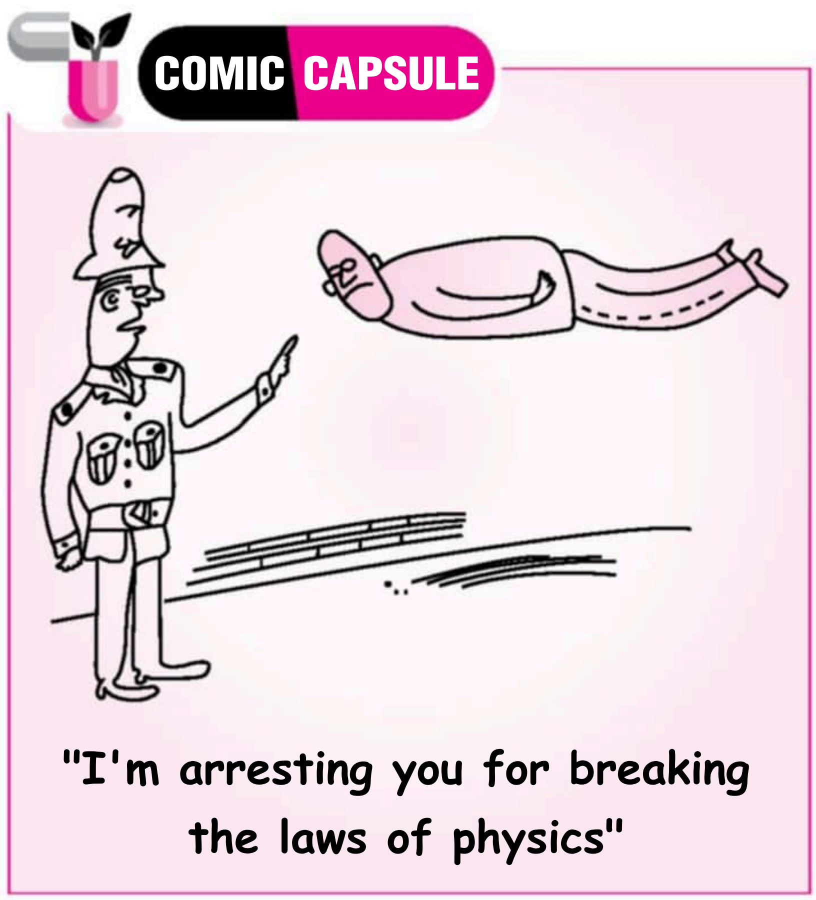
OR

(b) *Refer solution no. 16, page no. 226-227, Class-11, MTG 100 percent Physics 2024-25.*

33. (a) *Refer solution no. 17, page no. 239, Class-11, MTG 100 percent Physics 2024-25.*

OR

(b) *Refer solution no. 4, page no. 252, Class-11, MTG 100 percent Physics 2024-25.*



Quiz CLUB

Unlock Your Knowledge!

1. What is the size of electron as compared to proton and neutron?
2. One light year is equal to _______.
3. Who discovered X-ray?
4. According to the quantum theory of light the energy of light is carried in discrete units are called ?
5. Who gave black hole theory?
6. When all forces and torques are balanced in a mechanical body, body is said to be in _______.
7. A ball pen functions on the principal of _______.
8. The value of coefficient of restitution in perfectly elastic collision.
9. Echo is heard due to _______.
10. According to Rutherford's atomic model, the electrons inside an atom are _______.
11. Rainbow is formed due to a combination of _______.
12. Heavy water is used in nuclear reactor to _______.
13. Who is known as "Father of Quantum theory"?
14. "God particles" is _______.
15. Sound wave do not show the phenomenon of _______.
16. 1 amu is equivalent to _______.
17. Raman effect is explained by _______.
18. LED works on the principle of _______.
19. Which instrument is used for detecting the presence of electric current in a circuit ?
20. Light entres the eye through a thin membrane called _______.

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

Are you ready for Olympiads?

LEVEL 1 Exam on
18th Oct., 12th Nov. & 3rd Dec., 2024

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CLASS XI

SYLLABUS*

Following the protocol of NEP (2020), NCF (2023), NCERT and CBSE guidelines, National and various State Boards for the convenience of schools and students, any change/reduction in the syllabi will be reflected in actual question papers.

Section – 1 : *Physics* : Units and Measurements, Mechanics, Properties of Matter, Heat and Thermodynamics, Oscillations, Waves.
Chemistry : Some Basic Concepts of Chemistry, Structure of Atom, Classification of Elements and Periodicity in Properties, Chemical Bonding and Molecular Structure, Thermodynamics, Equilibrium, Redox Reactions, Organic Chemistry - Some Basic Principles and Techniques, Hydrocarbons.

Section – 2 : Higher Order Thinking Questions - Syllabus as per Section – 1.

Section – 3 : Sets, Relations and Functions, Logarithms, Complex Numbers & Quadratic Equations, Linear Inequalities, Sequences and Series, Trigonometry, Straight Lines, Conic Sections, Permutations and Combinations, Binomial Theorem, Statistics, Limits and Derivatives, Probability, Introduction to 3-D Geometry.

OR

Section – 3 : Diversity in the Living World, Structural Organisation in Plants and Animals, Cell : Structure and Functions, Plant Physiology, Human Physiology.

Total Questions : 50 Time : 1 hr.

PATTERN & MARKING SCHEME

Section	(1) Physics & Chemistry	(2) Achievers Section	(3) Mathematics or Biology
No. of Questions	25	5	20
Marks per Ques.	1	3	1

Practice Questions

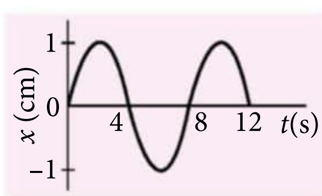
1. A particle of mass M originally at rest is subjected to a force whose direction is constant but magnitude varies with time according to the relation

$$F = F_0\left[1-\left(\frac{t-T}{T}\right)^2\right]$$

where F_0 and T are constants. The force acts only for the time interval $2T$. The velocity v of the particle after time $2T$ is

A. $4F_0T/3M$ B. $F_0T/3M$
C. $F_0T/2M$ D. $2F_0T/M$

2. The x-t graph of a particle undergoing simple harmonic motion is shown.



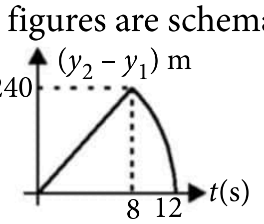
The acceleration of the particle at $t = 4/3$ s is

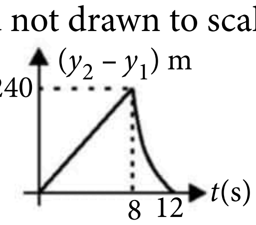
A. $\frac{\sqrt{3}}{32}\pi^2\ \text{cm/s}^2$ B. $\frac{-\pi^2}{32}\ \text{cm/s}^2$
C. $\frac{\pi^2}{32}\ \text{cm/s}^2$ D. $-\frac{\sqrt{3}}{32}\pi^2\ \text{cm/s}^2$

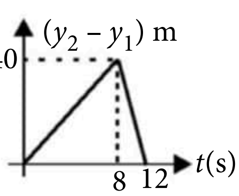
3. A cubical solid aluminium block $\left(\text{bulk modulus} = -V\frac{dP}{dV} = 70\ \text{GPa}\right)$ has an edge length of 1 m on the surface of the earth. It is kept on the floor of a 5 km deep ocean. Taking the average density of water and the acceleration due to gravity to be 10^3 kg m^{-3} and 10 m s^{-2}, respectively, the change in the edge length of the block in mm is

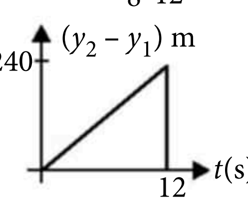
A. 2.4 mm B. 0.24 mm
C. 6.2 mm D. 2.0 mm

4. Two stones are thrown up simultaneously from the edge of a cliff 240 m high with initial speed of 10 m/s and 40 m/s respectively. Which of the following graph best represents the time variation of relative position of the second stone with respect to the first?
(Assume stones do not rebound after hitting the ground and neglect air resistance, take $g = 10\ \text{m/s}^2$)
(The figures are schematic and not drawn to scale)

A.


B.


C.


D.


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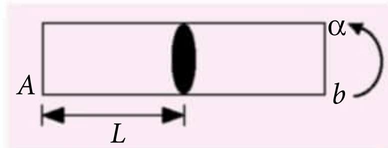
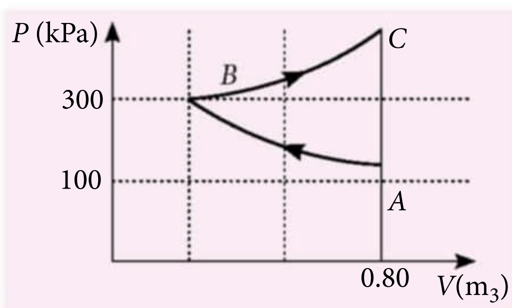
5. A long horizontal rod has a bead which can slide along its length and initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ, and gravity is neglected, then the time after which the bead starts slipping is



A. $\sqrt{\mu/\alpha}$
B. $\mu/\sqrt{\alpha}$
C. $1/\sqrt{\mu\alpha}$
D. infinitesimal

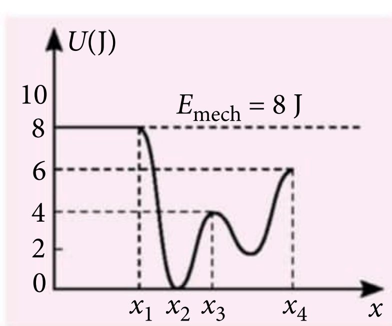
6. In the given P-V diagram, a monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ is first compressed adiabatically from state A to state B. Then it expands isothermally from state B to state C. [Given: $\left(\frac{1}{3}\right)^{0.6} \simeq 0.5$, $\ln 2 \simeq 0.7$].



Which of the following statement is incorrect?

A. The magnitude of the total work done in the process $A \rightarrow B \rightarrow C$ is 144 kJ.
B. The magnitude of the work done in the process $B \rightarrow C$ is 84 kJ.
C. The magnitude of the work done in the process $A \rightarrow B$ is 60 kJ.
D. The magnitude of the work done in the process $C \rightarrow A$ is zero.

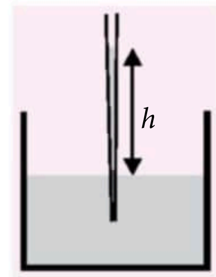
7. Given below is the plot of a potential energy function $U(x)$ for a system, in which a particle is in one dimensional motion, while a conservative force $F(x)$ acts on it.



Suppose that $E_{mech} = 8$ J, the incorrect statement for this system is
[where K.E. = kinetic energy]

A. at $x = x_2$, K.E. is greatest and the particle is moving at the fastest speed.
B. at $x < x_1$, K.E. is smallest and the particle is moving at the slowest speed.
C. at $x = x_3$, K.E. = 4 J
D. at $x > x_4$, K.E. is constant throughout the region.

8. A glass capillary tube is of the shape of a truncated cone with an apex angle α so that its two ends have cross sections of different radii. When dipped in water vertically, water rises in it to a height h, where the radius of its cross section is b. If the surface tension of water is S, its density is ρ, and its contact angle with glass is θ, the value of h will be (g is the acceleration due to gravity)



A. $\frac{2S}{b\rho g}\cos(\theta - \alpha)$
B. $\frac{2S}{b\rho g}\cos(\theta + \alpha)$
C. $\frac{2S}{b\rho g}\cos(\theta - \alpha/2)$
D. $\frac{2S}{b\rho g}\cos(\theta + \alpha/2)$

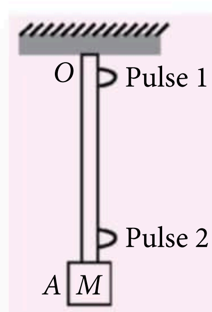
9. A small ball of mass m is thrown upward with velocity u from the ground. The ball experiences a resistive force mkv^2 where v is its speed. The maximum height attained, by the ball is

A. $\frac{1}{k}\ln\left(1 + \frac{ku^2}{2g}\right)$
B. $\frac{1}{k}\tan^{-1}\frac{ku^2}{2g}$
C. $\frac{1}{2k}\tan^{-1}\frac{ku^2}{g}$
D. $\frac{1}{2k}\ln\left(1 + \frac{ku^2}{g}\right)$

10. If e is the electronic charge, c is the speed of light in free space and h is Planck's constant, the quantity $\frac{1}{4\pi\varepsilon_0}\frac{|e|^2}{hc}$ has dimensions of

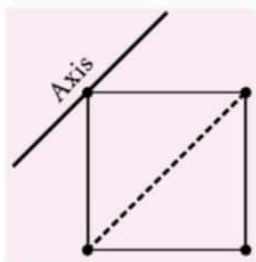
A. $[M\,L\,T^{-1}]$
B. $[L\,C^{-1}]$
C. $[M\,L\,T^0]$
D. $[M^0\,L^0\,T^0]$

11. A block M hangs vertically at the bottom end of a uniform rope of constant mass per unit length. The top end of the rope is attached to a fixed rigid support at O. A transverse wave pulse (Pulse 1) of wavelength λ^0 is produced at point O on the rope. The pulse takes time T_{OA} to reach point A. If the wave pulse of wavelength λ^0 is produced at point A (Pulse 2) without disturbing the position of M it takes time T_{AO} to reach point O. Which of the following options is correct?



A. The time $T_{AO} \neq T_{OA}$
B. The wavelength of Pulse 1 becomes longer when it reaches point A.
C. The velocity of any pulse along the rope is independent of its frequency and wavelength.
D. The velocities of the two pulses (Pulse 1 and Pulse 2) are the same at the midpoint of rope.

12. Four point masses, each of mass m, are fixed at the corners of a square of side l. The square is rotating with angular frequency ω, about an axis passing through one of the corners of the square and parallel to its diagonal, as shown in the figure. The angular momentum of the square about this axis is

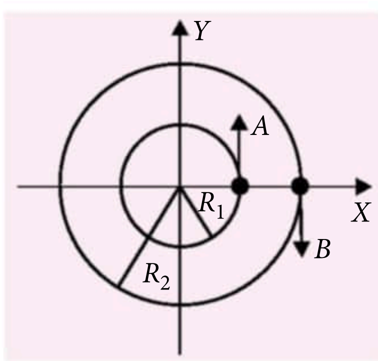


A. $ml^2\omega$ B. $4ml^2\omega$ C. $3ml^2\omega$ D. $2ml^2\omega$

13. A particle starts from the origin at $t = 0$ with an initial velocity of $3.0\hat{i}$ m/s and moves in the x-y plane with a constant acceleration $(6.0\hat{i} + 4.0\hat{j})$ m/s^2. The x-coordinate of the particle at the instant when its y-coordinate is 32 m is D metres. The value of D is

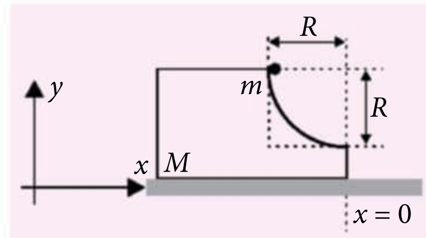
A. 50 B. 40 C. 32 D. 60

14. Two particles A, B are moving on two concentric circles of radii R_1 and R_2 with equal angular speed ω. At $t = 0$, their positions and direction of motion are shown in the figure. The relative velocity $\vec{v}_A - \vec{v}_B$ at $t = \dfrac{\pi}{2\omega}$ is given by



A. $-\omega(R_1 + R_2)\hat{i}$ B. $\omega(R_1 - R_2)\hat{i}$
C. $\omega(R_2 - R_1)\hat{i}$ D. $-\omega(R_1 + R_2)\hat{i}$

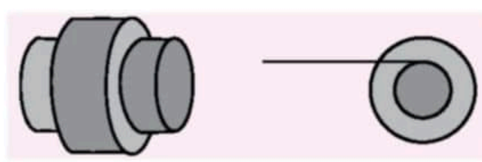
15. A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surface of a fixed table. Initially the right edge of the block is at $x = 0$, in a coordinate system fixed to the table. A point mass m is released from rest at the topmost point of the path as shown and it slides down. When the mass loses contact with the block, its position is x and the velocity is v. At that instant, which of the following options is correct?

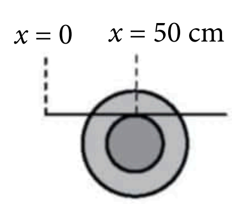


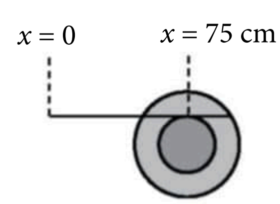
A. The velocity of the point mass m is : $v = \sqrt{\dfrac{2gR}{1 + \dfrac{m}{M}}}$.
B. The x component of displacement of the center of mass of the block M is : $\dfrac{2mR}{M + m}$.
C. The position of the point mass is : $x = -\sqrt{2}\dfrac{mR}{M + m}$.
D. The velocity of the block M is : $V = -\dfrac{m}{M}\sqrt{2gR}$.

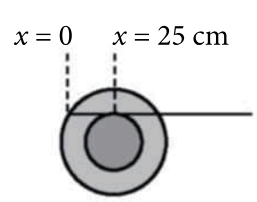
ACHIEVERS SECTION

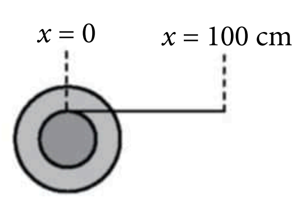
16. A small roller of diameter 20 cm has an axle of diameter 10 cm (see figure below on the left). It is on a horizontal floor and a meter scale is positioned horizontally on its axle with one edge of the scale on top of the axle (see figure on the right). The scale is now pushed slowly on the axle so that it moves without slipping on the axle, and the roller starts rolling without slipping. After the roller has moved 50 cm, the position of the scale will look like (Figures are schematic and not drawn to scale.)



A.


B.


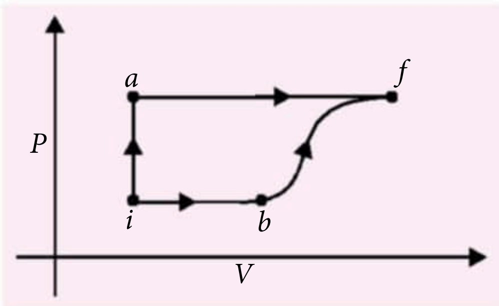
C.


D.


17. A water drop of radius 1 cm is broken into 729 equal droplets. If surface tension of water is 75 dyne/cm, then the gain in surface energy upto first decimal place will be
[Given $\pi = 3.14$]

A. 8.5×10^{-4} J B. 8.2×10^{-4} J
C. 7.5×10^{-4} J D. 5.3×10^{-4} J

18. A thermodynamic system is taken from an initial state i with internal energy U_i = 100 J to the final state f along two different paths iaf and ibf, as schematically shown in the figure.

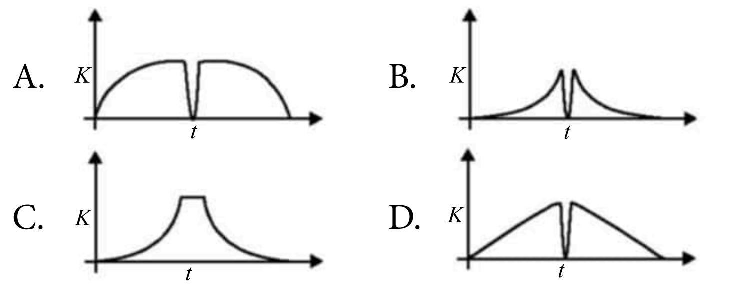


The work done by the system along the paths af, ib and bf are W_{af} = 200 J, W_{ib} = 50 J and W_{bf} = 100 J respectively. The heat supplied to the system along the path iaf, ib and bf are Q_{iaf}, Q_{ib} and Q_{bf} respectively. If the internal energy of the system in the state b is U_b = 200 J and Q_{iaf} = 500 J, the ratio Q_{bf}/Q_{ib} is

A. 2 B. 3 C. 5 D. 6

19. A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy K with time t most appropriately?

The figures are only illustrative and not to the scale.



20. A source, approaching with speed u towards the open end of a stationary pipe of length L, is emitting a sound of frequency f_s. The farther end of the pipe is closed. The speed of sound in air is v and f_0 is the fundamental frequency of the pipe. For which of the following combination of u and f_s, will the sound reaching the pipe lead to a resonance?

A. $u = 0.8v$ and $f_s = 3f_0$

B. $u = 0.8v$ and $f_s = 2f_0$

C. $u = 0.8v$ and $f_s = 0.5f_0$

D. $u = 0.5v$ and $f_s = 1.5f_0$

Darken your choice with HB Pencil

1.	Ⓐ Ⓑ Ⓒ Ⓓ	5.	Ⓐ Ⓑ Ⓒ Ⓓ	9.	Ⓐ Ⓑ Ⓒ Ⓓ	13.	Ⓐ Ⓑ Ⓒ Ⓓ	17.	Ⓐ Ⓑ Ⓒ Ⓓ
2.	Ⓐ Ⓑ Ⓒ Ⓓ	6.	Ⓐ Ⓑ Ⓒ Ⓓ	10.	Ⓐ Ⓑ Ⓒ Ⓓ	14.	Ⓐ Ⓑ Ⓒ Ⓓ	18.	Ⓐ Ⓑ Ⓒ Ⓓ
3.	Ⓐ Ⓑ Ⓒ Ⓓ	7.	Ⓐ Ⓑ Ⓒ Ⓓ	11.	Ⓐ Ⓑ Ⓒ Ⓓ	15.	Ⓐ Ⓑ Ⓒ Ⓓ	19.	Ⓐ Ⓑ Ⓒ Ⓓ
4.	Ⓐ Ⓑ Ⓒ Ⓓ	8.	Ⓐ Ⓑ Ⓒ Ⓓ	12.	Ⓐ Ⓑ Ⓒ Ⓓ	16.	Ⓐ Ⓑ Ⓒ Ⓓ	20.	Ⓐ Ⓑ Ⓒ Ⓓ

SOLUTIONS

1. (A) : $F = F_0\left[1-\left(\frac{t-T}{T}\right)^2\right]$

Mass of the particle = M

Initial velocity, u = 0,

acceleration a is given by

$$a = \frac{F}{M} = \frac{F_0}{M}\left[1-\left(\frac{t-T}{T}\right)^2\right]$$

$$\frac{dv}{dt} = \frac{F_0}{M}\left[1-\left(\frac{t-T}{T}\right)^2\right]$$

$$\int_0^v dv = \int_0^{2T}\frac{F_0}{M}\left[1-\frac{(t-T)^2}{T^2}\right]dt$$

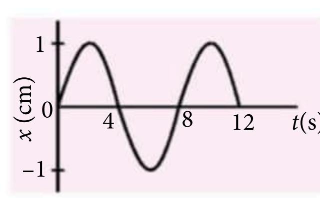
$$\Rightarrow \quad v = \frac{F_0}{T^2 M}\int_0^{2T}(T^2 - t^2 - T^2 + 2tT)dt$$

or $v = \frac{F_0}{MT^2}\left[4T^3 - \frac{8T^3}{3}\right] = \frac{F_0}{MT^2}\left[\frac{4T^3}{3}\right]$

$\therefore \; v = \frac{4F_0 T}{3M}$

2. (D) : The displacement is zero at 0 s. Therefore this is a sinusoidal curve.

A = 1; Equation is $x = A \sin\omega t$



$\omega = \frac{2\pi}{T} \Rightarrow x = 1\sin\left(\frac{2\pi}{T}t\right)$

$a = -\omega^2 A \sin\omega t$

$\therefore$ acceleration, $\frac{d^2x}{dt^2} = -1\left(\frac{2\pi}{T}\right)^2 \sin\frac{2\pi}{T}t$

At $t = \frac{4}{3}$ s, $T = 8$ s

$$a = -\left(\frac{2\pi}{8}\right)^2 \sin\frac{\pi}{3} \Rightarrow a = -\frac{4\pi^2}{64} \times \frac{\sqrt{3}}{2}$$

$$\Rightarrow a = -\frac{\sqrt{3}\,\pi^2}{32} \text{ cm/s}^2$$

3. (B) : Given : bulk modulus,

$$B = -\frac{VdP}{dV} = 70 \times 10^9 \text{ Pa}$$

$$\therefore \frac{dV}{V} = \frac{-dP}{B} \quad \text{...(i)}$$

For a cube, $V = l^3 \Rightarrow dV = 3l^2 dl$

Then $\frac{dV}{V} = \frac{3l^2 dl}{l^3} = \frac{3}{l} dl$ ...(ii)

Also since the cube is placed in 5 km deep ocean, the pressure difference for that point,

$dP = \Delta P = \rho g h$ ...(iii)

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

$$\Rightarrow dl = \frac{\rho g h l}{3B} = \frac{10^3 \times 10 \times 5000 \times 1}{3 \times 70 \times 10^9} = \frac{5 \times 10^7}{3 \times 7 \times 10^{10}}$$

$= 0.238 \times 10^{-3} \simeq 0.24$ mm

4. (A) : Using, $h = ut + \frac{1}{2}at^2$

For stone 1, $y_1 = 10t - \frac{1}{2}gt^2$

For stone 2, $y_2 = 40t - \frac{1}{2}gt^2$

Relative position of the second stone with respect to the first, $\Delta y = y_2 - y_1 = 40t - \frac{1}{2}gt^2 - 10t + \frac{1}{2}gt^2$

$\Rightarrow \Delta y = 30t$

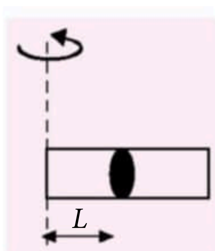
After 8 seconds, stone 1 reaches ground,

i.e., $y_1 = -240$ m

$\therefore \Delta y = y_2 - y_1 = 40t - \frac{1}{2}gt^2 + 240$

Therefore, it will be a parabolic curve till other stone reaches ground.

5. (A) : The frictional force provides the necessary centripetal force for circular motion.



Linear acceleration, $a = L\alpha$

$mL\omega^2 = \mu(ma)$ or $mL\omega^2 = \mu mL\alpha$

or $\omega^2 = \mu\alpha$ or $(\alpha t)^2 = \mu\alpha$

or $\alpha t = \sqrt{\mu\alpha}$ or $t = \sqrt{\frac{\mu}{\alpha}}$

6. (A) : $\gamma = \frac{5}{3}$

$A \to B \to$ adiabatic compression

$B \to C$ isothermal expansion

For process $A \to B$ (adiabatic compression)

$P_A V_A^{\gamma} = P_B V_B^{\gamma}$

$10^5 \times (0.8)^{5/3} = 3 \times 10^5 (V_B)^{5/3}$

$$V_B = 0.8 \times \left(\frac{1}{3}\right)^{0.6} = 0.4 \text{ m}^3$$

Work done in $A \to B$ (adiabatic compression)

$$W_{AB} = \frac{P_A V_A - P_B V_B}{\gamma - 1} = \frac{10^5 \times 0.8 - 3 \times 10^5 \times 0.4}{\frac{5}{3} - 1}$$

$W_{AB} = -60$ kJ $\Rightarrow |W_{AB}| = 60$ kJ

Work done in $B \to C$ (isothermal process)

$$W_{BC} = nRT \ln\frac{V_C}{V_B} = P_B V_B \ln\frac{V_C}{V_B}$$

$$W_{BC} = 3 \times 10^5 \times 0.4 \ln\frac{0.8}{0.4} = 84 \text{ kJ}$$

$W_{CA} = P\Delta V = 0$

So, total work done

$W_{ABC} = W_{AB} + W_{BC} + W_{CA} = -60 + 84 + 0$

$W_{ABC} = 24$ kJ

7. (B) : Mechanical energy, $E_{mech} = 8$ J

At $x = x_2$, $U = 0$, $E_{mech} = K = 8$ J

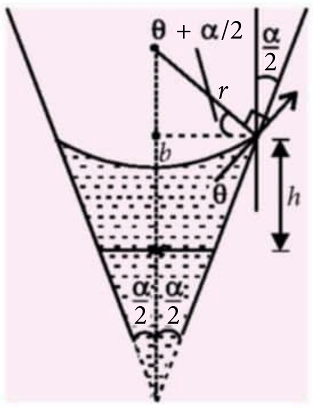
At $x < x_1$, $U =$ constant $= 8$ J

So, $K = E_{mech} - U = 8 - 8 = 0$ J

At $x = x_3$, $U = 4$ J, $U + K = 8$ J $\therefore$ $K = 4$ J
At $x > x_4$, U = constant = 6 J
$\therefore$ $K = E_{mech} - U = 2$ J
which is constant throughout the region.

8. (D) : Let r = radius of curvature of meniscus

$$b = r\cos\left(\theta + \frac{\alpha}{2}\right)$$



Excess pressure on concave side of meniscus $= \frac{2S}{r}$

$$\Rightarrow (P_0 + h\rho g) - P_0 = \frac{2S}{r}$$

$$\Rightarrow h\rho g = \frac{2S\cos\left(\theta + \frac{\alpha}{2}\right)}{b}$$

or $h = \frac{2S}{b\rho g}\cos\left(\theta + \frac{\alpha}{2}\right)$

9. (D) : Given : mass = m,
initial velocity = u,
resistive force = mkv^2
Let the maximum height be h.

$$F_{net} = ma - mg - mkv^2 = mv\frac{dv}{ds}, \quad \frac{vdv}{ds} = -g - kv^2$$

$$\int_u^0 \frac{vdv}{g + kv^2} = -\int_0^h ds \qquad (\because g + kv^2 = t,\ 2kv\,dv = dt)$$

$$[S]_0^h = -\int\frac{dt}{2k.t} = -\frac{1}{2k}\ln t = -\frac{1}{2k}[\ln(g + kv^2)]_u^0$$

$$h - 0 = -\frac{1}{2k}\ln(g + ku^2)_u^0$$

$$h = -\frac{1}{2k}\left[\ln(g) - \ln(g + ku^2)\right]$$

$$h = \frac{1}{2k}\ln\left(\frac{g + ku^2}{g}\right) = \frac{1}{2k}\ln\left(1 + \frac{ku^2}{g}\right)$$

10. (D) : As, $F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r^2}$

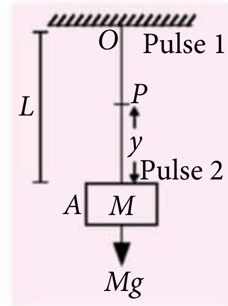
and photon energy, $E = \frac{hc}{\lambda}$

So, $\frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{hc} = \frac{Fr^2}{E\lambda} = \frac{[MLT^{-2}][L^2]}{[ML^2T^{-2}][L]} = [M^0L^0T^0]$

11. (C) : The velocity of the transverse wave is given by

$$v = \sqrt{\frac{T}{\mu}} \qquad \text{...(i)}$$

where, T is the tension in the rope and is given by
$T = Mg + \mu yg$
where, y = distance of point P on the rope from its bottom
L = total length of the rope



Putting the value of T in eqn. (i),

we get $v = \sqrt{\frac{Mg + \mu yg}{\mu}}$ ...(ii)

The velocity at the midpoint is different for both the pulses as they are moving in opposite directions.
So, option D is incorrect.
Since, both the pulse travel in the same medium and velocity is medium dependent, the velocity of any pulse along the rope depends on tension in the rope and linear mass density. So, it is independent of its frequency and wavelength.
So, option C is correct.
Also, $v = \upsilon\lambda$ or $\lambda \propto v$
($\because$ frequency of a wave depends on the source)
For pulse 1, the velocity decreases at point A as tension decreases. So, the wavelength of pulse 1 becomes shorter when it reaches point A.
So, option B is incorrect.
From eqn. (ii), the velocity is given as

$$v = \sqrt{\frac{Mg + \mu yg}{\mu}} \text{ or } \frac{dy}{dt} = \sqrt{\frac{Mg + \mu yg}{\mu}}$$

$$\Rightarrow dt = \frac{dy}{\sqrt{\frac{Mg + \mu yg}{\mu}}}$$

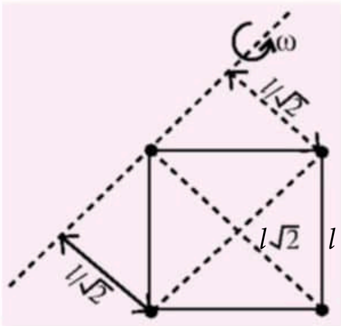
Integrating both sides, $\int_0^T dt = \int_0^L \frac{dy}{\sqrt{\frac{Mg}{\mu} + yg}}$

$$\therefore T = \frac{2}{g}\left(\sqrt{\frac{Mg}{\mu} + Lg} - \sqrt{\frac{Mg}{\mu}}\right)$$

where, T is time taken by pulse to travel distance L.
Since, T depends upon g, M, L and μ which are constant
$\therefore$ Time taken by pulse 1 to reach point A and time taken by pulse 2 to reach point O is same.
$\therefore$ $T_{AO} = T_{OA}$; So, option (A) is incorrect.

12. (C) : Angular momentum of the square about the given axis, $L = I_1\omega + I_2\omega + I_3\omega$

$$= m\left(\frac{l}{\sqrt{2}}\right)^2\omega + m(l\sqrt{2})^2\omega + m\left(\frac{l}{\sqrt{2}}\right)^2\omega = 3ml^2\omega$$



13. (D) : For y-coordinate, $s = ut + \frac{1}{2}at^2$

or $32 = 0 + \frac{1}{2} \times 4 \times t^2$ or $t = 4$ s

For x-coordinate, $s = ut + \frac{1}{2}at^2$

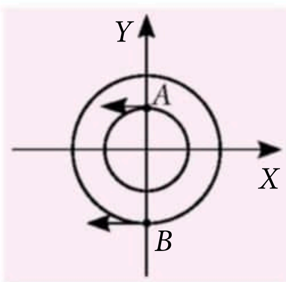
or $D = 3(4) + \frac{1}{2}(6)(4)^2 = 60$ m

14. (C) : The angle transversed in time $\frac{\pi}{2\omega}$ is

$\theta = \omega t = \frac{\omega\pi}{2\omega} = \frac{\pi}{2}$

i.e., at $t = \frac{\pi}{2\omega}$,

the position of two particles is shown in the figure.



$\therefore$ The relative velocity, $\vec{v}_A - \vec{v}_B$ is

$$= -R_1\omega\hat{i} - (-R_2\omega\hat{i}) = \omega(R_2 - R_1)\hat{i}$$

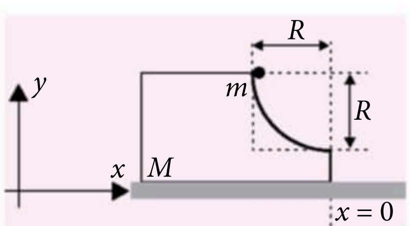
15. (A) : V be the velocity of the block of mass M and v be the velocity of the point mass m.

From the conservation of momentum,

$mv = -MV$

$$V = \frac{-mv}{M} \quad \text{...(i)}$$

From the conservation of energy,



$$\frac{1}{2}mv^2 - mgR = \frac{1}{2}MV^2$$

$$\frac{1}{2}mv^2 + \frac{1}{2}MV^2 = mgR$$

$$\frac{1}{2}mv^2 + \frac{1}{2}\frac{Mm^2v^2}{M^2} = mgR \quad \text{[Using eqn. (i)]}$$

$$v^2 + \frac{mv^2}{M} = 2gR\,;\; v^2\left[1 + \frac{m}{M}\right] = 2gR \text{ or } v = \sqrt{\frac{2gR}{1 + \frac{m}{M}}}$$

This is required velocity of the point mass.

So, option (A) is correct.

Velocity of the block is $V = \frac{-m}{M}\sqrt{\frac{2gR}{1 + \frac{m}{M}}}$

So, option D is incorrect.

Since, there is no external force applied on the system, so, centre of mass remains stationary.

Let us assume that block of mass M moves by x distance towards left

$Mx = m(R - x)$

$x(M + m) = mR$

$x = \frac{mR}{M + m}$ (towards left)

$\therefore$ $x = -\frac{mR}{M + m}$; negative sign because x is towards left.

So, option B is incorrect.

16. (B)

17. (C) : Given, radius of water drop, R = 1 cm

Surface tension, T = 75 dyne/cm = 0.075 N/m

Volume of 1 drop = Volume of 729 droplets

$\frac{4}{3}\pi R^3 = 729 \times \frac{4}{3}\pi r^3$ $\quad\therefore\quad$ $R^3 = 729\, r^3$

Contributed by : Nisha Singla, Ghaziabad (UP)

SOLUTIONS TO AUGUST 2024 WORD GRID

W	A	V	E	L	E	N	G	T	H	N	R	M	I	E	B	I
R	O	M	R	E	F	F	L	P	V	O	Q	U	T	A	A	T
D	S	E	L	F	R	A	D	I	A	T	I	O	N	R	R	E
R	U	T	R	A	D	I	I	O	R	W	A	P	R	D	O	Q
R	P	E	F	C	D	I	A	M	A	G	N	E	T	I	C	U
A	E	R	L	N	T	I	M	R	O	T	O	R	P	U	O	A
P	R	M	U	L	T	I	P	L	E	X	E	R	E	M	L	R
G	S	M	O	A	R	A	L	S	H	Y	I	R	R	N	L	J
O	O	O	R	U	O	R	I	M	L	E	S	T	I	P	E	L
M	N	U	E	T	T	O	F	R	P	K	L	O	H	E	C	O
U	I	K	S	J	U	P	I	T	E	R	A	C	E	I	T	N
G	C	A	C	T	N	I	E	A	T	T	E	E	L	O	O	P
H	T	G	E	A	S	T	R	N	N	U	Q	U	I	S	R	O
I	R	O	N	N	G	S	U	H	C	M	M	T	O	O	N	W
E	S	U	C	L	I	M	A	T	I	O	N	K	N	O	P	H
B	C	L	E	W	L	I	S	S	Y	F	R	A	N	C	I	S

Across

1. Jupiter
2. Diamagnetic
3. Wavelength
4. Iron
5. Multiplexer

Down

1. Supersonic
2. Fluorescence
3. Perihelion
4. Amplifier
5. Collector

where, r is the radius of small droplets

$\Rightarrow \ (10^{-2})^3 = 729\ r^3$

$\Rightarrow \ (10^{-2})^3 = (9)^3\ r^3 \quad \Rightarrow \quad r = \frac{1}{9}\times 10^{-2}$ m

Work done or gain in surface energy is given by,

$W = T\Delta A$

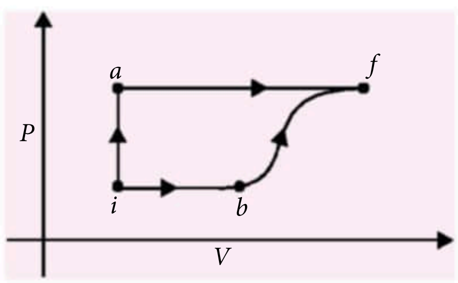
where, ΔA is the change in surface area

$\therefore \quad W = T[n \times 4\pi r^2 - 4\pi R^2]$

$$= 0.075\left[729\times\left(\frac{1}{9}\times 10^{-2}\right)^2 - (10^{-2})^2\right]\times 4\pi$$

$= 0.075\ [9 \times 10^{-4} - 10^{-4}] \times 4\pi = 7.536 \times 10^{-4}$ J

18. (A) :



Along the path ia, V = constant

$\therefore \quad W_{ia} = 0$

Along the path iaf,

$W_{iaf} = W_{ia} + W_{af} = 0$ J + 200 J = 200 J

$Q_{iaf} = 500$ J

$U_{iaf} = Q_{iaf} - W_{iaf} = 500$ J – 200 J = 300 J

$\therefore \quad U_f - U_i = 300$ J

$U_f = 300$ J + U_i = 300 J + 100 J = 400 J

Along the path ib,

$U_{ib} = U_b - U_i = 200$ J – 100 J = 100 J

$W_{ib} = 50$ J

$\therefore \quad Q^{ib} = U_{ib} + W_{ib} = 100$ J + 50 J = 150 J

Along the path bf,

$U_{bf} = U_f - U_b = 400$ J – 200 J = 200 J

$W_{bf} = 100$ J

$\therefore \quad Q_{bf} = U_{bf} + W_{bf} = 200$ J + 100 J = 300 J

The required ratio is $\frac{Q_{bf}}{Q_{ib}} = \frac{300\text{ J}}{150\text{ J}} = 2$

19. (B) : As tennis ball is dropped, so its initial velocity, $u = 0$

Suppose its velocity at any time $t = v$

Acceleration due to gravity = g

$\therefore \quad v = u + gt$

$\Rightarrow \quad v = gt$ ...(i)

We know, kinetic energy,

$K = \frac{1}{2}mv^2 = \frac{1}{2}m(g^2t^2)$ [Using eqn. (i)]

$\Rightarrow \quad K = \frac{1}{2}mg^2t^2$

$\Rightarrow \quad K \propto t^2$ (As m and g are constant)

This shows that relation between kinetic energy of tennis ball K and time t is parabolic.

During the collision, velocity of the ball falls sharply to zero as it is compressed and regains maximum velocity in the same short time interval.

This relation is best illustrated by the option B.

20. (D) : Speed of source = u

Open end pipe length = L

Speed of sound in air = v

Fundamental frequency = f_0

According to the formula of Doppler's effect,

$$f = f_0 = \left(\frac{v}{v-u}\right)$$

(A) $u = 0.8\ v$, $f_s = f_0$; So, $f = f_0\left(\frac{v}{v-0.8v}\right) = 5\ f_0$

(B) $u = 0.8\ v$, $f_s = f_0$; $f = 2f_0\left(\frac{v}{v-0.8v}\right) = 10\ f_0$

(C) $f = u = 0.8\ v$, $f_s = 0.5\ f_0$

$$f = 0.5\ f_0\left(\frac{v}{v-0.8v}\right) = 2.5\ f_0$$

(D) $u = 0.8\ u$, $f_s = 1.5\ f_0$

$$f = 1.5\ f_0\left(\frac{v}{v-0.8v}\right) = 3\ f_0$$

As the pipe is closed at one end so all odd harmonics are present. So, option D is correct.

For other sections/subjects please refer to Chemistry Today and Biology Today

TRIO

ANSWERS AUGUST 2024

The three letter sequence is **L U M**.

VO**LUM**E

IL**LUM**INATE

LUMINOUS

PENDU**LUM**

Winners : Amit Nagar, Chennai

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CLASS XII

SYLLABUS*

Following the protocol of NEP (2020), NCF (2023), NCERT and CBSE guidelines, National and various State Boards for the convenience of schools and students, any change/reduction in the syllabi will be reflected in actual question papers.

Section – 1 : *Physics* : Electricity and Magnetism, Electromagnetic Induction, Alternating current, Electromagnetic waves, Optics, Modern Physics, Semiconductor Electronics.

Chemistry : Solutions, Electrochemistry, Chemical Kinetics, The *d*- and *f*-Block Elements, Coordination Compounds, Haloalkanes and Haloarenes, Alcohols, Phenols and Ethers, Aldehydes, Ketones and Carboxylic Acids, Amines, Biomolecules.

Section – 2 : Higher Order Thinking Questions - Syllabus as per Section-1.

Section – 3 : Relations and Functions, Inverse Trigonometric Functions, Matrices and Determinants, Continuity and Differentiability, Application of Derivatives, Integrals, Application of Integrals, Differential Equations, Vector Algebra, Three Dimensional Geometry, Probability, Linear Programming.

OR

Section – 3 : Reproduction, Genetics and Evolution, Biology in Human Welfare, Biotechnology, Ecology.

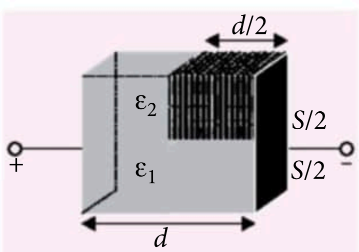
Total Questions : 50 | Time : 1 hr.

PATTERN & MARKING SCHEME

Section	(1) Physics & Chemistry	(2) Achievers Section	(3) Mathematics or Biology
No. of Questions	25	5	20
Marks per Ques.	1	3	1

Practice Questions

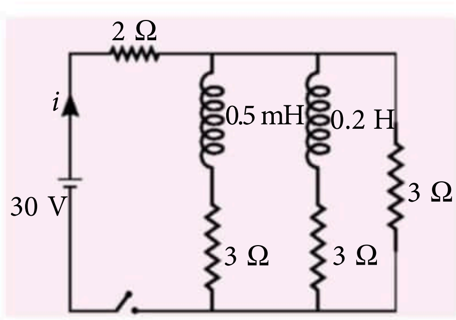
1. A parallel plate capacitor having plates of area S and plate separation *d*, has capacitance C_1 in air. When two dielectrics of different relative permittivities ($\varepsilon_1 = 2$ and $\varepsilon_2 = 4$) are introduced between the two plates as shown in figure, the capacitance becomes C_2. The ratio $\frac{C_2}{C_1}$ is



A. 6/5 B. 5/3

C. 7/5 D. 7/3

2. For the given circuit the current *i* through the battery when the key is closed and the steady state has been reached is



A. 10 A B. 6 A

C. 25 A D. 0 A

3. A linearly polarized electromagnetic wave in vacuum is $E = 3.1\cos[(1.8)z - (5.4\times10^6)t]\,\hat{i}$ N/C is incident normally on a perfectly reflecting wall at $z = a$. Choose the correct option.

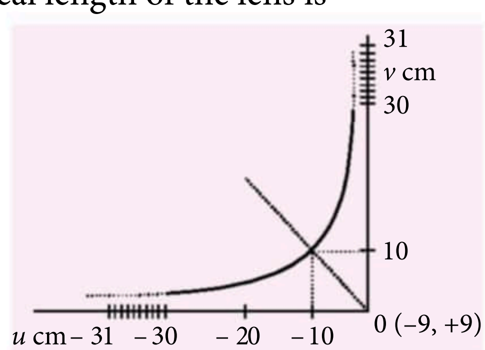
A. The reflected wave will be $3.1\cos[(1.8)z + (5.4\times10^6)t]\,\hat{i}$ N/C.

B. The wavelength is 5.4 m.

C. The transmitted wave will be $3.1\cos[(1.8)z - (5.4\times10^6)t]\,\hat{i}$ N/C.

D. The frequency of electromagnetic wave is 54×10^4 Hz.

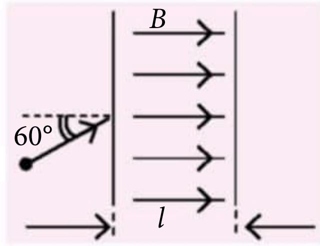
4. The graph shows relationship between object distance and image distance for an equiconvex lens. Then, focal length of the lens is



A. 0.50 ± 0.05 cm B. 0.50 ± 0.10 cm

C. 5.00 ± 0.05 cm D. 5.00 ± 0.10 cm.

5. The figure shows a region of length 'l' with a uniform magnetic field of 0.3 T in it and a proton entering the region with velocity 4×10^5 m s^{-1} making an angle 60° with the field. If the proton completes 10 revolution by the time it cross the region shown, 'l' is close to (mass of proton = 1.67×10^{-27} kg, charge of the proton = 1.6×10^{-19}C)



A. 0.88 m B. 0.22 m C. 0.11 m D. 0.44 m

6. As an electron makes a transition from an excited state to the ground state of a hydrogen-like atom/ion

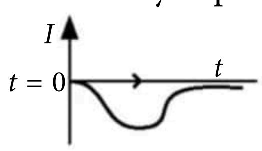
A. its kinetic energy decreases, potential energy increases but total energy remains same

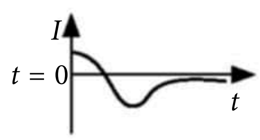
B. its kinetic energy and total energy decrease but potential energy increases

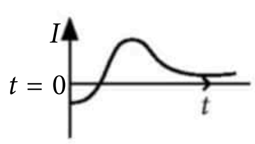
C. its kinetic energy increases but potential energy and total energy decrease

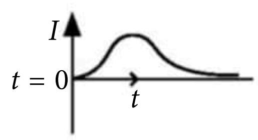
D. its kinetic energy, potential energy and total energy decrease.

7. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}$ ($k > 0$), as a function of time ($t \geq 0$). Counter clockwise current is taken to be positive. A circular conducting coil of radius $2R$ is placed in the equatorial plane of the solenoid and concentric with the solenoid. The current induced in the outer coil is correctly depicted, as a function of time, by

A. 

B. 

C. 

D. 

8. A charged shell of radius R carries a total charge Q. Given ϕ as the flux of electric field through a closed cylindrical surface of height h, radius r and with its center same as that of the shell. Here, center of cylinder is a point on the axis of the cylinder which is equidistant from its top and bottom surfaces. Which of the following option is incorrect? [ε_0 is the permittivity of free space]

A. If $h > 2R$ and $r = \frac{4R}{5}$ then $\phi = \frac{Q}{5\varepsilon_0}$

B. If $h > 2R$ and $r = \frac{3R}{5}$ then $\phi = \frac{Q}{5\varepsilon_0}$

C. If $h < \frac{8R}{5}$ and $r = \frac{3R}{5}$ then $\phi = 0$

D. If $h > 2R$ and $r > R$ then $\phi = \frac{Q}{\varepsilon_0}$

9. A microammeter has a resistance of 100 Ω and a full scale range of 50 μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination

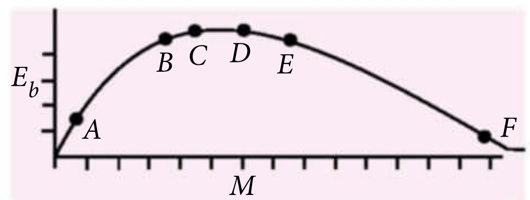
A. 50 V range with 10 kΩ resistance in series

B. 10 V range with 200 kΩ resistance in series

C. 1 mA range with 1 Ω resistance in parallel

D. 10 mA range with 1 Ω resistance in parallel.

10.



The above is a plot of binding energy per nucleon E_b, against the nuclear mass M; A, B, C, D, E, F correspond to different nuclei. Consider four reactions

(i) $A + B \rightarrow C + \varepsilon$ (ii) $C \rightarrow A + B + \varepsilon$

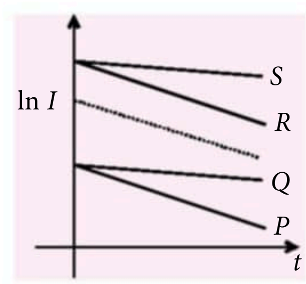
(iii) $D + E \rightarrow F + \varepsilon$ (iv) $F \rightarrow D + E + \varepsilon$

where ε is the energy released. In which reactions is ε positive?

A. (i) and (iv) B. (i) and (iii)

C. (ii) and (iv) D. (ii) and (iii)

11. A capacitor is charged using an external battery with a resistance x in series. The dashed line shows the variation of ln I with respect to time. If the resistance is changed to $2x$, the new graph will be



A. P B. Q C. R D. S

12. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is

A. $\sin^{-1}(\lambda/d)$ B. $\sin^{-1}(\lambda/2d)$

C. $\sin^{-1}(\lambda/3d)$ D. $\sin^{-1}(\lambda/4d)$.

13. The dipole moment of a circular loop carrying a current I is m and the magnetic field at the centre of the loop is B_1. When the dipole moment is doubled by keeping the current constant, the magnetic field at the centre of the loop is B_2. The ratio B_1/B_2 is

A. 2 B. $\sqrt{3}$ C. $\sqrt{2}$ D. $\frac{1}{\sqrt{2}}$

14. Imagine that a reactor converts all given mass into energy and that it operates at a power level of 10^9 watt. The mass of the fuel consumed per hour in the reactor will be (velocity of light, c is 3×10^8 m/s)

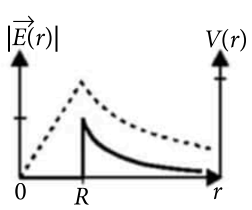
A. 4×10^{-2} gm
B. 6.6×10^{-5} gm
C. 0.8 gm
D. 0.96 gm

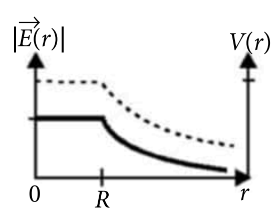
15. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter $2d$. The way these wires are connected is given in the options. How much time in minutes will it take to raise the temperature of the same amount of water by 40 K?

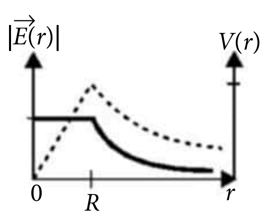
A. 2 if wires are in series
B. 2 if wires are in parallel
C. 1 if wires are in series
D. 0.5 if wires are in parallel.

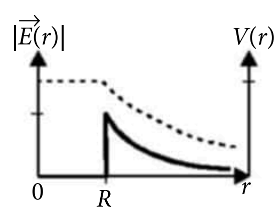
ACHIEVERS SECTION

16. Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field and the electric potential $V(r)$ with the distance r from the centre, is best represented by which graph?

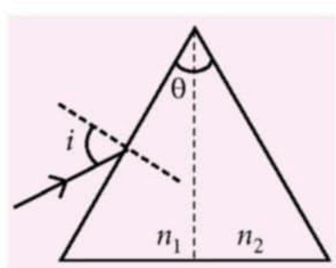
A. 

B. 

C. 

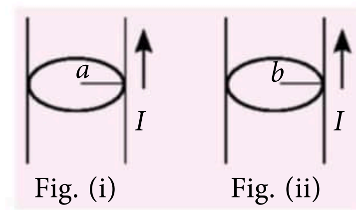
D. 

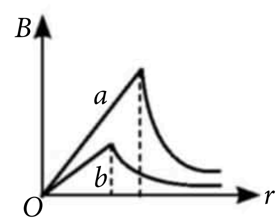
17. For a prism of prism angle $\theta = 60°$, the refractive indices of the left half and the right half are, respectively, n_1 and n_2 ($n_2 \geq n_1$) as shown in the figure The angle of incidence i is chosen such that the incident light rays will have minimum deviation if $n_1 = n_2 = n = 1.5$. For the case of unequal refractive indices, $n_1 = n$ and $n_2 = n + \Delta n$ (where $\Delta n << n$), the angle of emergence $e = i + \Delta e$. Which of the following statement is correct?

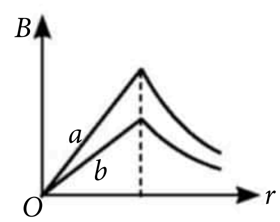


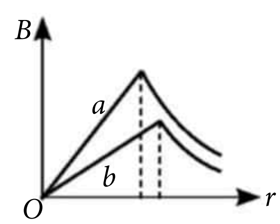
A. The value of Δe (in radians) is greater than that of Δn.
B. Δe is inversly proportional to Δn.
C. Δe lies between 2.0 and 3.0 milliradians, if $\Delta n = 2.8 \times 10^{-3}$.
D. Δe lies between 1.0 and 1.6 milliradians, if $\Delta n = 2.8 \times 10^{-3}$.

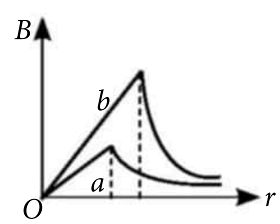
18. Figure (i) and (ii) show two long straight wires of circular cross-section (a and b with $a < b$), carrying current I which is uniformly distributed across the cross-section. The magnitude of magnetic field B varies with radius r and can be represented as



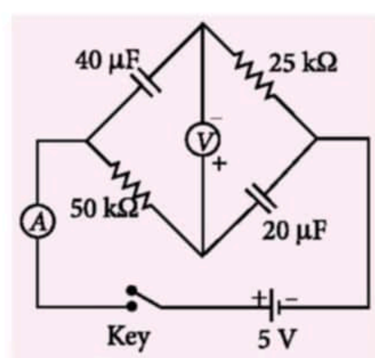
A. 

B. 

C. 

D. 

19. In the circuit shown below, the key is pressed at time $t = 0$. Which of the following statement is true?



A. The voltmeter displays –5 V as soon as the key is pressed, and displays +5 V after a long time
B. The voltmeter will display 0 V at time $t = \ln 2$ seconds
C. The current in the ammeter becomes $1/e$ of the initial value after 1 second
D. All of these.

20. Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be

A. $> v\left(\frac{4}{3}\right)^{1/2}$
B. $< v\left(\frac{4}{3}\right)^{1/2}$
C. $= v\left(\frac{4}{3}\right)^{1/2}$
D. $= v\left(\frac{3}{4}\right)^{1/2}$

Darken your choice with HB Pencil

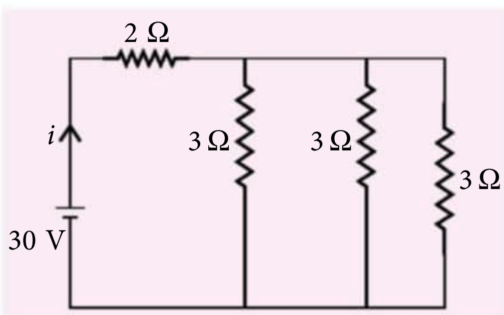
1.	Ⓐ Ⓑ Ⓒ Ⓓ	5.	Ⓐ Ⓑ Ⓒ Ⓓ	9.	Ⓐ Ⓑ Ⓒ Ⓓ	13.	Ⓐ Ⓑ Ⓒ Ⓓ	17.	Ⓐ Ⓑ Ⓒ Ⓓ
2.	Ⓐ Ⓑ Ⓒ Ⓓ	6.	Ⓐ Ⓑ Ⓒ Ⓓ	10.	Ⓐ Ⓑ Ⓒ Ⓓ	14.	Ⓐ Ⓑ Ⓒ Ⓓ	18.	Ⓐ Ⓑ Ⓒ Ⓓ
3.	Ⓐ Ⓑ Ⓒ Ⓓ	7.	Ⓐ Ⓑ Ⓒ Ⓓ	11.	Ⓐ Ⓑ Ⓒ Ⓓ	15.	Ⓐ Ⓑ Ⓒ Ⓓ	19.	Ⓐ Ⓑ Ⓒ Ⓓ
4.	Ⓐ Ⓑ Ⓒ Ⓓ	8.	Ⓐ Ⓑ Ⓒ Ⓓ	12.	Ⓐ Ⓑ Ⓒ Ⓓ	16.	Ⓐ Ⓑ Ⓒ Ⓓ	20.	Ⓐ Ⓑ Ⓒ Ⓓ

SOLUTIONS

1. **(D)**

2. **(A) :** In the steady state, inductor behaves as a conducting wire.

Circuit diagram becomes,

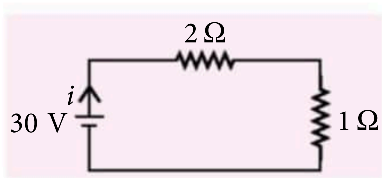


Equivalent resistance of circuit is,

$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$$

$\therefore$ $R_p = 1\ \Omega$

Now circuit becomes



Now, $R_s = 2\,\Omega + 1\,\Omega = 3\,\Omega$

$\therefore$ $R_{eq} = 3\ \Omega$

From Ohm's law, $i = \frac{V}{R} = \frac{30}{3} = 10$ A

3. **(A) :** $\vec{E} = 3.1\cos[(1.8)z - (5.4\times10^6)t]\,\hat{i}$ N/C

As the wave is reflected by the wall at $z = a$, so the deviation of reflected wave is opposite to the direction of incident wave.

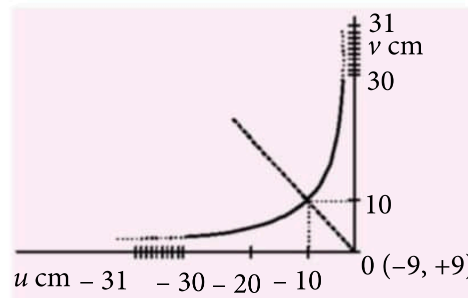
$\therefore$ $E = 3.1\cos[(1.8)z + (5.4\times10^6)t]\,\hat{i}$ N/C

4. **(C) :** Using lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \text{ or } \frac{1}{f} = \frac{1}{10} - \frac{1}{-10}$$

or $\frac{1}{f} = \frac{2}{10} = \frac{1}{5}$ or $f = +5$ cm ... (i)

$\Delta u = 0.1$, from graph, $\Delta v = 0.1$, from graph



$\because$ $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

For maximum error in f, errors are added.

$$\Rightarrow \frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}$$

$$\text{or } \frac{\Delta f}{(5)^2} = \frac{0.1}{(10)^2} + \frac{0.1}{(10)^2}$$

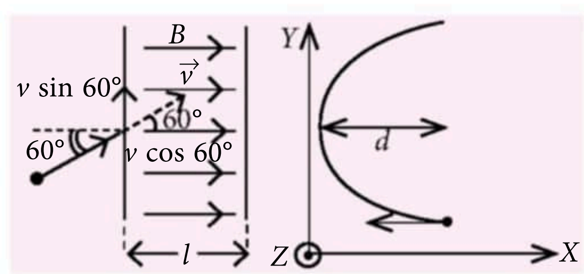
$$\text{or } \Delta f = \frac{25\times2\times0.1}{100} \text{ or } \Delta f = 0.05$$

$\therefore$ Focal length of lens $= f \pm \Delta f = 5.00 \pm 0.05$ cm.

Option (C) is correct.

As the graph between v and u indicates, it is the curve of a convex lens where $u = -10$ cm, $v = 10$ cm, $f = 5$ cm. Object is placed at $2f$ and real, inverted and equal size image is formed at $2f$, on the other side of the lens.

5. **(D) :** Given : $v = 4\times10^5$ m/s, $\theta = 60°$,
$m = 1.67\times10^{-27}$ kg, $q = 1.6\times10^{-19}$ C, $B = 0.3$ T



Time of one revolution, $T = \frac{2\pi m}{qB}$

$$l = (v\cos 60°)\times(10\,T) = \frac{10\pi mv}{qB}$$

$$\Rightarrow l = \frac{10\times3.14\times(1.67\times10^{-27})\times(4\times10^5)}{(1.6\times10^{-19})(0.3)}$$

Here, $l = 0.4369$ m ≈ 0.44 m

6. (C) : For an electron in n^{th} excited state of hydrogen atom,

kinetic energy $= \dfrac{e^2}{8\pi\varepsilon_0 n^2 a_0}$

potential energy $= \dfrac{-e^2}{4\pi\varepsilon_0 n^2 a_0}$

and total energy $= \dfrac{-e^2}{8\pi\varepsilon_0 n^2 a_0}$, where a_0 is Bohr radius.

As electron makes a transition from an excited state to the ground state, n decreases. Therefore, kinetic energy increases but potential energy and total energy decrease.

7. (C) : Since, $\phi = \vec{B}.d\vec{s}$,

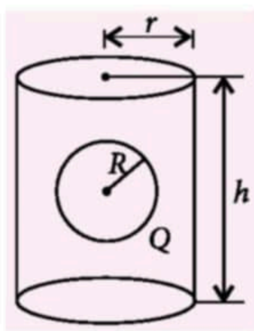
$\phi = \mu_0 nIds = \mu_0 nkte^{-\alpha t}4\pi R^2$

$$\varepsilon = \frac{-d\phi}{dt} = -\mu_0 nk4\pi R^2 e^{-\alpha t}[1-\alpha t] = -Ce^{-\alpha t}[1-\alpha t]$$

Induced current, $i = \dfrac{\varepsilon}{\text{Resistance}} = -\dfrac{Ce^{-\alpha t}[1-\alpha t]}{\text{Resistance}}$

At $t = 0$, $i = -C$

8. (A) : For $h > 2R$ and $r > R$



Net charge inside the cylinder is Q.

$\therefore$ Flux through the closed cylindrical surface,

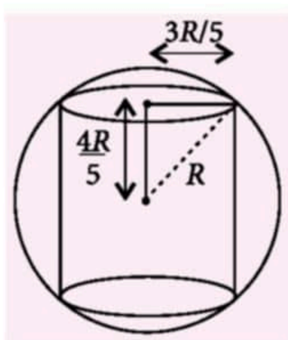
$$\phi = \frac{q_{encl}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

For, $h = \dfrac{8R}{5}$ and $r = \dfrac{3R}{5}$

Here in this case, net charge inside the cylinder is 0.

$\therefore$ Flux through the closed cylindrical surface,

$$\phi = \frac{q_{encl}}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0$$



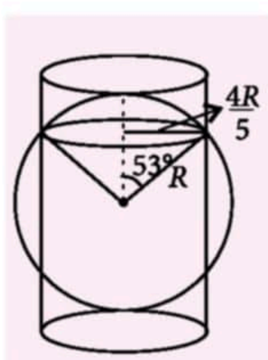
So, for $h < \dfrac{8R}{5}$ and $r = \dfrac{3R}{5}$; $\phi = 0$

Now, for $h > 2R$ and $r = \dfrac{4R}{5}$

Net charge inside the cylinder is

$$q_{encl} = 4\pi(1-\cos 53°)\times\frac{Q}{4\pi}$$

$$= 4\pi\left(1-\frac{3}{5}\right)\times\frac{Q}{4\pi} = \frac{2}{5}\times Q = \frac{2Q}{5}$$



$\therefore$ Required flux, $\phi = \dfrac{q_{encl}}{\varepsilon_0} = \dfrac{2Q}{5\varepsilon_0}$

For $h > 2R$ and $r = \dfrac{3R}{5}$,

net charge inside the cylinder is

$$q_{encl} = 2\times 2\pi(1-\cos 37°)\times\frac{Q}{4\pi} = 4\pi\left(1-\frac{4}{5}\right)\times\frac{Q}{4\pi} = \frac{Q}{5}$$

$\therefore$ Required flux, $\phi = \dfrac{q_{encl}}{\varepsilon_0} = \dfrac{Q}{5\varepsilon_0}$

9. (B)

10. (A) : When two nucleons combine to form a third one, and energy is released, one has fusion reaction. If a single nucleus splits into two, one has fission. The possibility of fusion is more for light elements and fission takes place for heavy elements.

Out of the choices given for fusion, only A and B are light elements and D and E are heavy elements. Therefore, $A + B \rightarrow C + \varepsilon$ is correct. The possibility of fission is only for F and not C. Therefore, $F \rightarrow D + E + \varepsilon$ is the correct choice.

11. (B) : Charging current, $I = \dfrac{E}{x}e^{-\frac{t}{xC}}$

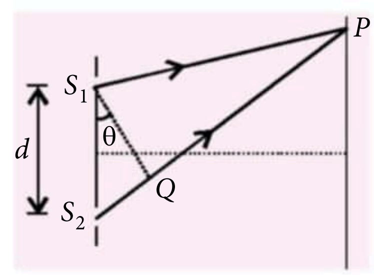
or $\ln I = \ln\left(\dfrac{E}{x}\right) - \dfrac{t}{xC}$

Slope of $\ln I$ versus t curve $= -\dfrac{1}{xC}$

When x is changed to $2x$, the slope of the curve increases and current decreases. Obviously, the new graph is Q.

12. (C) : In Young's double slit experiment, intensity at any point P is given by $I = I_{max}\cos^2(\phi/2)$.

where ϕ denotes the phase difference at P.



$\because \quad I = I_{max}\cos^2\left(\dfrac{\phi}{2}\right)$

$\therefore \quad \dfrac{I_{max}}{4} = I_{max}\cos^2\left(\dfrac{\phi}{2}\right)$

or $\cos\left(\dfrac{\phi}{2}\right) = \dfrac{1}{2} = \cos\left(\dfrac{\pi}{3}\right)$

or $\dfrac{\phi}{2} = \dfrac{\pi}{3}$ or $\phi = \dfrac{2\pi}{3}$ or $\dfrac{2\pi}{\lambda}\Delta x = \dfrac{2\pi}{3}$ or $\Delta x = \lambda/3$

Path difference, $\Delta x = S_2Q = d\sin\theta$

or $d\sin\theta = \lambda/3$

or $\theta = \sin^{-1}\left(\dfrac{\lambda}{3d}\right)$

13. (C) : Initially, dipole moment of circular loop is

$m = I.A = I.\pi R^2$ and magnetic field, $B_1 = \dfrac{\mu_0 I}{2R}$

Finally, dipole moment becomes double, keeping current constant, so radius of the loop becomes $\sqrt{2}R$.

$$B_2 = \frac{\mu_0 I}{2(\sqrt{2}R)} = \frac{B_1}{\sqrt{2}}; \quad \therefore \frac{B_1}{B_2} = \sqrt{2}$$

14. (A) : Here, $P = 10^9$ W, $c = 3 \times 10^8$ m s^{-1}, $\frac{\Delta m}{\Delta t} = ?$

We know, $P = \frac{E}{\Delta t} = \frac{\Delta mc^2}{\Delta t}$

$$\therefore \quad \frac{\Delta m}{\Delta t} = \frac{P}{c^2} = \frac{10^9}{(3\times10^8)^2} = \frac{10^{-7}}{9}\,\text{kg s}^{-1}$$

$$= \frac{10^{-7}}{9} \times 1000 \times 3600\,\text{g h}^{-1} = 4\times10^{-2}\,\text{g h}^{-1}$$

15. (D) : In a given heater,

$$R = \frac{\rho L}{\pi(d/2)^2} = \frac{4\rho L}{\pi d^2}; \quad H = \frac{V^2}{R}t$$

In a new heater,

$$R_1 = \frac{\rho L}{\pi(2d/2)^2} = \frac{\rho L}{\pi d^2} \text{ and } R_2 = \frac{\rho L}{\pi(2d/2)^2} = \frac{\rho L}{\pi d^2}$$

$$\therefore \quad R_1 = R_2 = \frac{R}{4}$$

If wires are connected in series, their equivalent resistance is

$$R_s = R_1 + R_2 = \frac{R}{4} + \frac{R}{4} = \frac{R}{2}$$

$$\text{Then, } H_s = \frac{V^2}{R_s}t_s = \frac{V^2}{(R/2)}t_s = \frac{2V^2}{R}t_s$$

As, $H = H_s$

$$\therefore \quad \frac{V^2}{R}t = \frac{2V^2}{R}t_s \text{ or } t_s = \frac{t}{2} = \frac{4}{2} = 2\text{ min}$$

If the wires are connected in parallel, their equivalent resistance is

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{(R/4)} + \frac{1}{(R/4)} = \frac{4}{R} + \frac{4}{R} = \frac{8}{R}$$

$$R_p = \frac{R}{8}$$

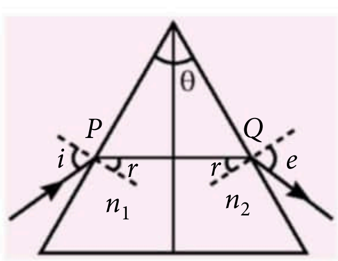
$$\text{Then, } H_p = \frac{V^2}{R_p}t_p = \frac{V^2}{(R/8)}t_p = \frac{8V^2}{R}t_p$$

As $H = H_p$

$$\therefore \quad \frac{V^2}{R}t = \frac{8V^2}{R}t_p \text{ or } t_p = \frac{t}{8} = \frac{4}{8} = 0.5\text{ min}$$

16. (D)

17. (C) : $\theta = 60°$



Using Snell's law at P

$1 \times \sin i = n_1 \sin \theta/2$

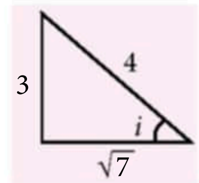
$\sin i = n_1 \sin 30°$

$$\sin i = \frac{n_1}{2} = \frac{3}{4} \qquad \text{...(i)}$$

$n_1 = n_2 = n = 1.5$

Using Snell's law at Q, $n_2 \sin 30° = 1 \times \sin e$

Differentiate both sides, $\Delta n = \sin 30° = \Delta e$ (cone)



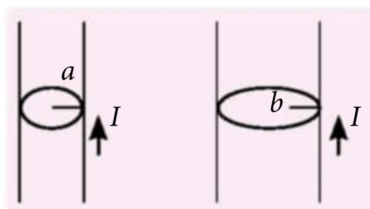
$$\Delta e = \frac{\Delta n}{2\cos e} \qquad (i = e)$$

$$\Delta e = \frac{\Delta n \times 4}{2\times\sqrt{7}} = \frac{2}{\sqrt{7}}\Delta n$$

So, $\Delta e < \Delta n$, if $\Delta n = 2.8 \times 10^{-3}$

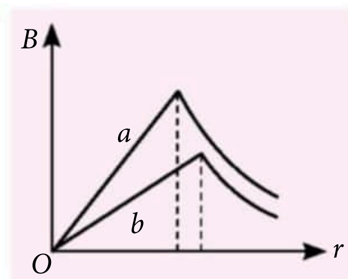
$$\Delta e = \frac{2.8\times10^{-3}\times 2}{\sqrt{7}} = 2.11\text{ m rad}$$

18. (C) : The magnetic field outside the wire is given by



$$B = \frac{\mu_0 I}{2\pi r}$$

So, $B_a = \frac{\mu_0 I}{2\pi a}$, $B_b = \frac{\mu_0 I}{2\pi b}$



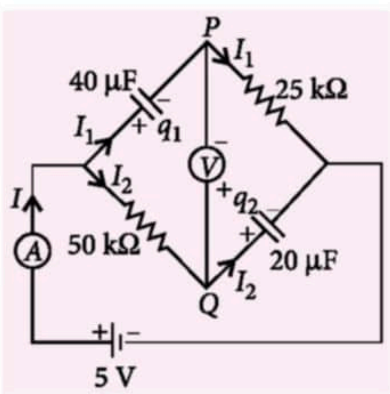
As $a < b$, so, $B_a > B_b$

$B \propto r$ (inside)

B = constant (maximum) on the surface;

$$B \propto \frac{1}{r} \text{ (outside)}$$

19. (D) :



When the key is just pressed, there is no charge on capacitors

$\therefore \quad 5 = 25000 I_1$

$$\Rightarrow I_1 = \frac{5}{25000} = 0.2 \text{ mA}$$

and $5 = 50000 I_2 \Rightarrow I_2 = \dfrac{5}{50000} = 0.1 \text{ mA}$

Reading of voltmeter,

$= V_Q - V_P = -25000 I_1 = -25000 \times 0.2 \times 10^{-3}$ V $= -5$ V

After a very long time, steady state is reached, *i.e.*,

$I_1 = I_2 = 0$

$$\therefore \quad 5 = \frac{q_1}{40 \times 10^{-6}} \text{ or } q_1 = 200\,\mu\text{C}$$

$$\text{and } 5 = \frac{q_2}{20 \times 10^{-6}} \text{ or } q_2 = 100\,\mu\text{C}$$

Now, reading of voltmeter $= V_Q - V_P$

$$= \frac{q_2}{20\,\mu\text{F}} = \frac{100\,\mu\text{C}}{20\,\mu\text{F}} = 5 \text{ V}$$

For capacitor of 40 μF,

$\tau_1 = RC = 25 \times 10^3 \times 40 \times 10^{-6} = 1$ s

and for capacitor of 20 μF,

$\tau_2 = RC = 50 \times 10^3 \times 20 \times 10^{-6} = 1$ s

$\therefore$ At any instant t,

$q_1 = 200[1 - e^{-t}]$ μC,

$q_2 = 100[1 - e^{-t}]$ μC

$I_1 = 0.2\, e^{-t}$ mA, $I_2 = 0.1\, e^{-t}$ mA

$$V_Q - V_P = \frac{100(1 - e^{-t})\,\mu\text{C}}{20\,\mu\text{F}} - 25 \text{ k}\Omega \times 0.2 e^{-t} \text{ mA}$$

$= 5(1 - e^{-t}) - 5e^{-t} = 5 - 10e^{-t}$

At $t = \ln 2$ s; $V_Q - V_P = 5 - 10e^{-\ln 2} = 5 - \dfrac{10}{2} = 0$ V

Initially, $I_0 = 0.1$ mA $+ 0.2$ mA $= 0.3$ mA

At $t = 1$ s, $I = I_1 + I_2 = (0.2\, e^{-1} + 0.1\, e^{-1})$

$$= \frac{0.3}{e} \text{ mA} = \frac{I_0}{e}$$

20. (A) : According to Einstein's photo-electric effect, maximum kinetic energy of a photoelectron,

$$\text{KE} = \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$$

According to question, for incident radiation of wavelength λ, maximum speed of photoelectron is v.

$$\therefore \quad \frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi \qquad \text{...(i)}$$

Assume speed of fastest photoelectron is v' when incident photon has wavelength

$$\therefore \quad \frac{1}{2}mv'^2 = \frac{4hc}{3\lambda} - \phi$$

$$\text{or } \frac{1}{2}mv'^2 = \frac{4}{3}\left(\frac{1}{2}mv^2 + \phi\right) - \phi$$

$$\text{or } \frac{1}{2}mv'^2 = \frac{2}{3}mv^2 + \frac{\phi}{3} \text{ or}$$

$$v' = \sqrt{\frac{4}{3}v^2 + \frac{2\phi}{3m}} \quad \therefore \quad v' > \sqrt{\frac{4}{3}}\,v$$

For other sections/subjects please refer to Chemistry Today and Biology Today

TRIO

The same THREE LETTERS will complete these five words.

Can you find the three-letter sequence?

N E U _ _ _ N O

E L E C _ _ _ C I T Y

_ _ _ A N G U L A R

C E N _ _ _ P E T A L F O R C E

P H O T O E L E C _ _ _ C

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names will be published in next issue.

Physics in FOCUS

Class 12

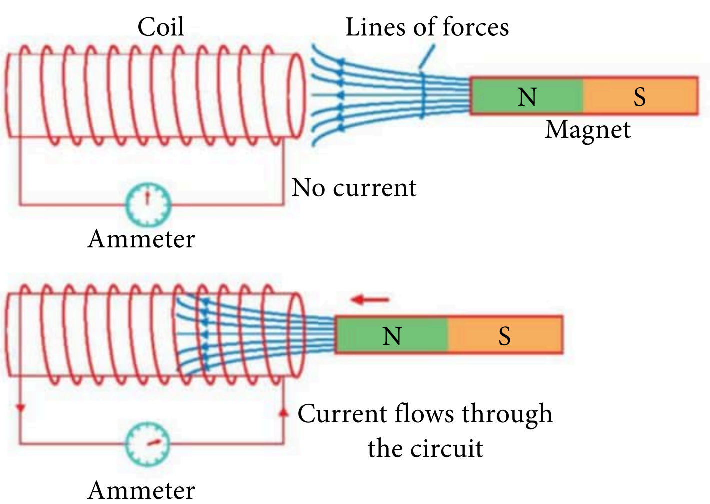
TOPIC

Electromagnetic Induction

Detailed theory with High Definition images of the given topic are covered under this heading.

Electromagnetic Induction

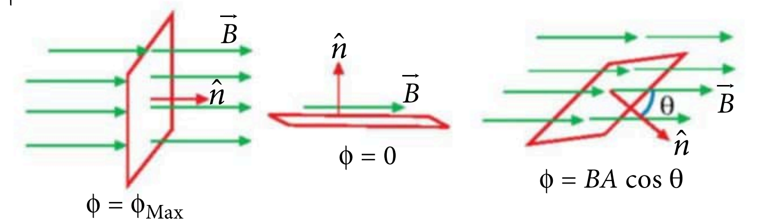
Electromagnetic Induction is the phenomenon of production of emf in a coil when magnetic flux linked with the coil is changed. The emf so produced is called induced emf and the current so produced is called induced current.



Magnetic Flux

The magnetic flux through a surface of area $\vec{A}$ placed in a uniform magnetic field $\vec{B}$ is defined as,

$\phi = \vec{B} \cdot \vec{A} = BA\cos\theta$



where, θ is the angle between direction of the magnetic field and normal to the surface.

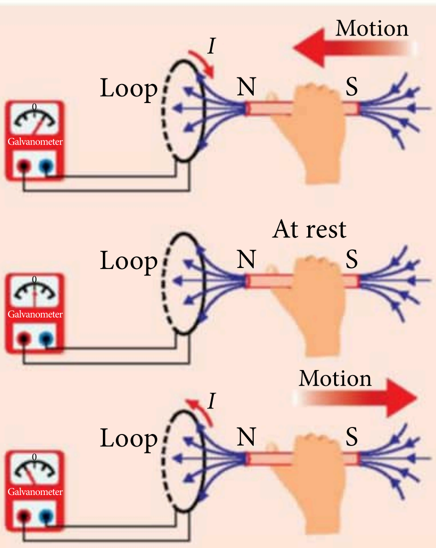
- The SI unit of magnetic flux is weber (Wb).
- Magnetic flux can be changed by
  - Changing the intensity of the magnetic field.
  - Changing the orientation of coil with respect to magnetic field.
  - Changing the area of the closed current.

Faraday's Laws of Electromagnetic Induction

- **First Law :** Whenever there is change in magnetic flux with respect to time for a coil or circuit, an emf is induced in it till change in flux takes place.
- **Second Law :** The induced emf is directly proportional to the rate of change of flux through the coil.

  Mathematically, $\varepsilon = -\dfrac{d\phi}{dt}$

  If the coil has N turns then net induced emf is given by, $\varepsilon = -N\dfrac{d\phi}{dt}$

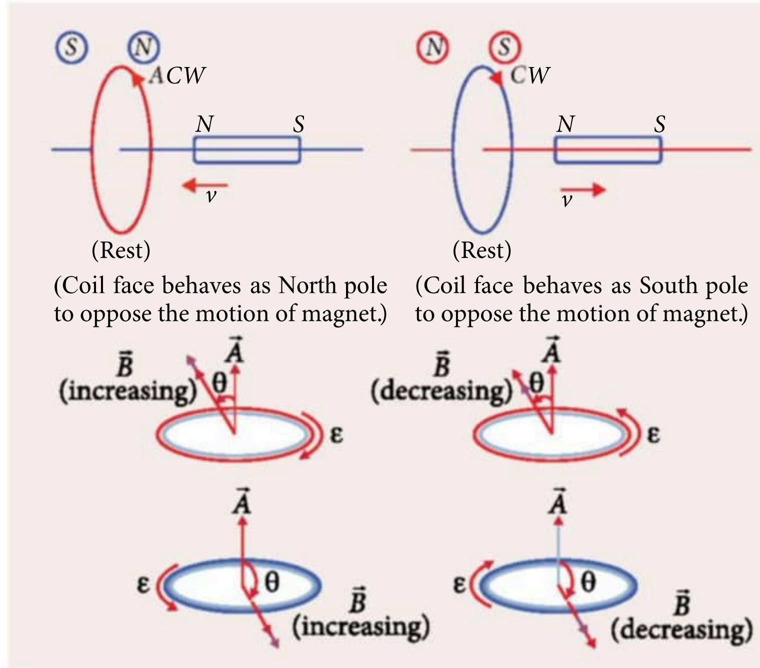


Lenz's Law

- Lenz's law states that the polarity of the induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.

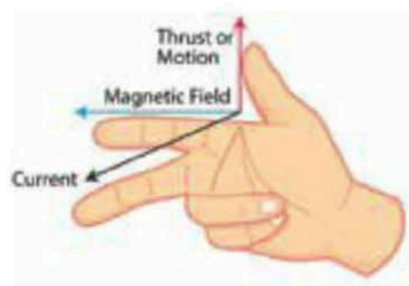
  $\varepsilon = (-)\frac{d\phi}{dt}$, where negative sign indicates the Lenz's law.

- **Direction of induced emf** (ε)
  - Induced emf does not depend on nature of the coil, *i.e.*, resistance of the coil.
  - Magnitude of induced emf is directly proportional to the relative speed of coil-magnet system.



Fleming's Right Hand Rule

Fleming's right hand rule gives the direction of induced emf or current. According to this rule, if we stretch the forefinger, central finger and thumb of our right hand perpendicular to each other such that thumb points along the direction of motion of the conductor and forefinger points towards the direction of magnetic field, then, the central finger would give the direction of induced current or emf.



Motional Electromotive Force

- **Rotating rod :**
  - When a conducting rod moves in an external magnetic field in such a way it cuts the field, so, all the free electrons in the rod transfer from one end to another end (C to D) and emf is induced in the rod. This emf is known as motional emf.
  - The emf induced within $d\vec{l}$

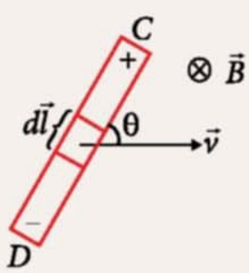
    $d\varepsilon = (\vec{v} \times \vec{B}) \cdot d\vec{l}$

    Net emf across the rod,

    $\varepsilon = \int (\vec{v} \times \vec{B}) \cdot d\vec{l} = vBl \sin\theta$

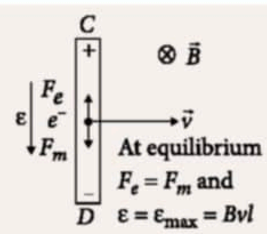
    Induced electric field in the rod,

    $\vec{E}_{in} = -(\vec{v} \times \vec{B}) = (\vec{B} \times \vec{v})$



  - If any two out of $\vec{v}, \vec{B}$ and $d\vec{l}$ become parallel or antiparallel, ε will become zero.
  - If $\theta = 90°$, *i.e.*, $\vec{v}, \vec{B}$ and $\vec{l}$ are perpendicular to each other.

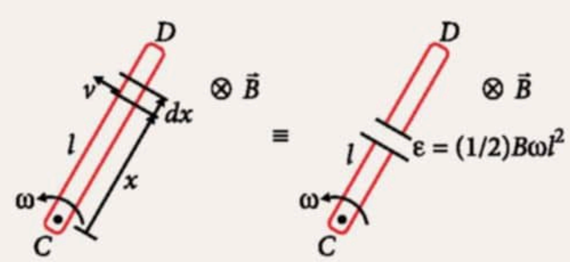
    Induced emf, $\varepsilon = Blv$



- **Rotating straight conductor :** emf induced in small element dx

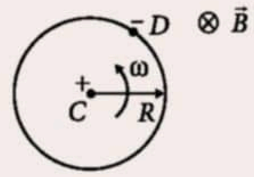
  $d\varepsilon = (\vec{v} \times \vec{B}) \cdot d\vec{x} = -vBdx$

  Net emf $\varepsilon = -\int_0^l vBdx = -B\omega \int_0^l xdx = -\frac{1}{2}B\omega l^2$



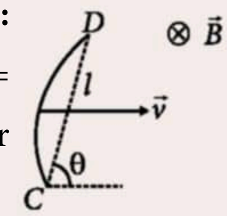
Negative sign indicates that end C will be at higher potential.

- **A rotating conducting disc:** Induced emf between centre C and circumference D is



$$\varepsilon = \frac{1}{2} B\omega R^2$$

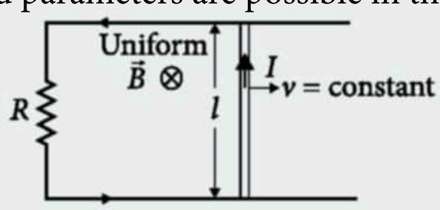
- **A conductor of arbitrary shape:** Induced emf in this conductor = Induced emf in straight conductor connected between C and D, *i.e.*,



$\varepsilon = Blv \sin\theta$

Effect of Motional emf Developed in a Circuit

For a circuit shown in figure, if the metal rod moves with uniform velocity v by an external agent then all the induced parameters are possible in the circuit.



- Induced emf in the circuit, $\varepsilon = Bvl$
- Current flows through the circuit, $I = \dfrac{\varepsilon}{R} = \dfrac{Bvl}{R}$
- Retarding opposing force exerted on metal rod by action of induced current

  $\vec{F}_m = I(\vec{l} \times \vec{B})$; $F_m = BIl$ where $\theta = 90°$

  $$F_m = \frac{B^2 l^2 v}{R}$$

- External mechanical force required for uniform velocity of metal rod

(i) For constant velocity, resultant force on metal rod must zero and for that $F_{ext} = F_m$

(ii) $F_{ext} = F_m = \dfrac{B^2 l^2 v}{R}$

(iii) If $(B, l, R) \to$ constant $\Rightarrow F_{ext} \propto v$

- For uniform motion of metal rod, mechanical power delivered by external source is given as

  $P_{mech} = P_{ext} = \vec{F}_{ext} \cdot \vec{v} = F_{ext} v$

  $P_{ext} = P_{mech} = \dfrac{B^2 l^2 v^2}{R}$

  If $(B, l, R) \to$ constant $\Rightarrow P_{mech} \propto v^2$

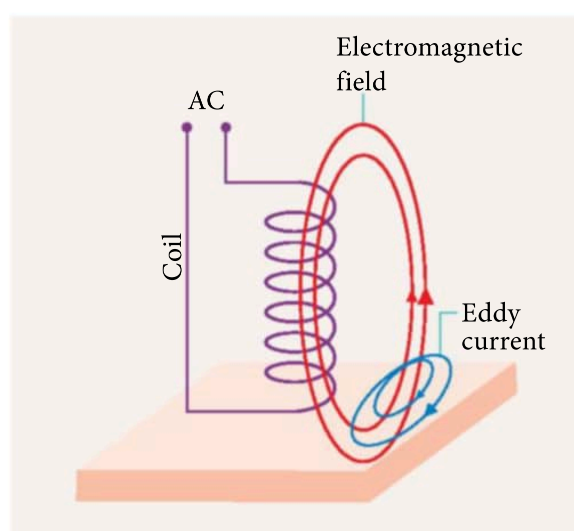
- Thermal power developed across resistor

  $$P_{thermal} = I^2 R = \left(\frac{Bvl}{R}\right)^2 R = \frac{B^2 l^2 v^2}{R}$$

  It is clear that $P_{thermal} = P_{mech}$ which is consistent with the principle of conservation of energy.

Eddy Currents

- Changing magnetic field can set up current loops in nearby metal (conductor) bodies. They dissipate electrical energy as heat. Such currents are called eddy currents.

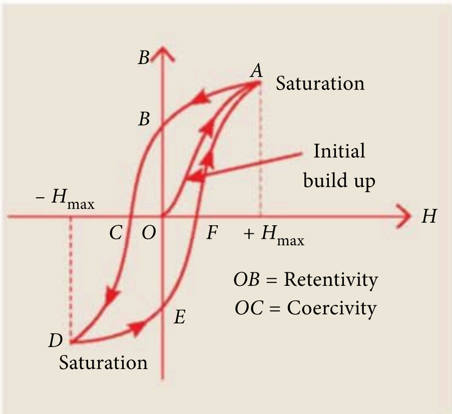


- **Application of eddy currents**
  - Inductance furnace is based on the heating effect of eddy currents.
  - Speedometer is a device used to measure the instantaneous speed of a vehicle is also on complete of eddy currents.
  - Concept of eddy currents is used in energy meter to record the consumption of electricity.

BRAIN MAP

MAGNETISM AND MATTER

Hysteresis



When a ferromagnetic sample is placed in a magnetising field, the sample gets magnetised by induction. As the magnetising field intensity H varies, the magnetic induction B does not vary linearly with H, *i.e.*, the permeability $\mu(=B/H)$ is not constant but varies with H. In fact, it also depends on the past history of the sample.

Ferromagnetic

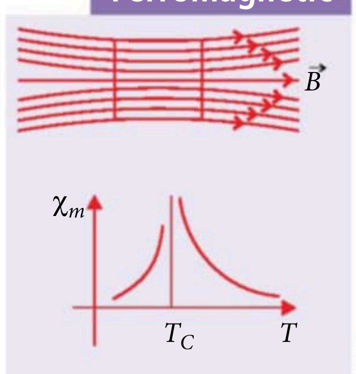
Strong magnetisation in same direction.

Here, $B_m >>> B_0$

$\chi_m \to$ Very large, positive and temperature dependent *i.e.*,

$$\chi_m \propto \frac{1}{T - T_C}$$

(Curie-Weiss law) (for $T > T_C$)



Diamagnetic

Poor magnetisation in opposite direction.

Here, $B_m < B_0$

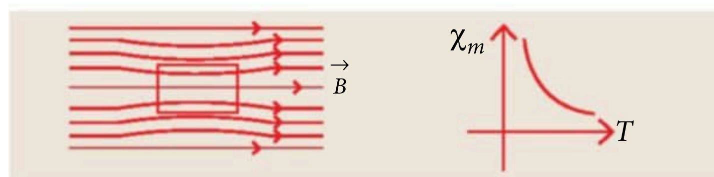
$\chi_m \to$ Small, negative and temperature independent *i.e.*, $\chi_m \propto T_0$

Paramagnetic

Poor magnetisation in same direction.

Here, $B_m > B_0$

$\chi_m \to$ Small, positive and varies inversely with temperature *i.e.*, $\chi_m \propto 1/T$ (Curie's law)



Classification of Magnetic Materials

MAGNETISM AND MATTER

Magnetisaton and Magnetic Intensity

- Relation between B, χ_m and H,

$$\vec{B} = \vec{B}_0 + \mu_0\vec{M} \Rightarrow \vec{B} = \mu_0(\vec{H} + \vec{M}) \quad (\because\ \vec{B}_0 = \mu_0\vec{H})$$

$$\Rightarrow \vec{B} = \mu_0(1+\chi_m)\vec{H} = \mu\vec{H} \quad (\because\ \vec{M} = \chi_m\vec{H})$$

- $\mu = \mu_0\mu_r = \mu_0(1 + \chi_m) \Rightarrow \mu_r = 1 + \chi_m$

Bar Magnet as an Equivalent Solenoid

For solenoid of length $2l$ and radius a consisting n turns per unit length, the magnetic field is given by

$$B = \frac{\mu_0 2m}{4\pi r^3}$$

(where m = magnetic moment of solenoid

$= n(2l)I(\pi a^2)$)

Gauss's Law for Magnetism

Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero.

$$\phi = \sum_{\substack{\text{all area} \\ \text{elements } \Delta S}} \vec{B}\cdot\Delta\vec{S} = 0$$

This law establishes that isolated magnetic poles do not exist.

Magnetic Field at a Point due to Magnetic Dipole (bar magnet)

- The magnetic field due to a bar magnet at any point on the axial line (end on position) is

$$B_{axial} = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}$$

where, r = distance between the centre of the magnet and the given point on the axial line, $2l$ = magnetic length of the magnet and M = magnetic moment of the magnet.

For short magnet, $l^2 << r^2$; $B_{axial} = \dfrac{\mu_0 2M}{4\pi r^3}$

The direction of B_{axial} is along SN.

- The magnetic field due to a bar magnet at any point on the equatorial line (board-side on position) of the bar magnet is, $B_{equatorial} = \dfrac{\mu_0 M}{4\pi(r^2 + l^2)^{3/2}}$

For short magnet, $B_{equatorial} = \dfrac{\mu_0 M}{4\pi r^3}$

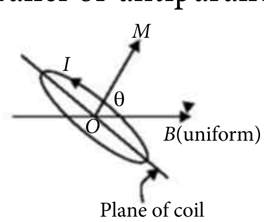
The direction of $B_{equatorial}$ is parallel to NS.

Properties of Dia-, Para- and Ferromagnetic Substances

	Property	Diamagnetic substances	Paramagnetic substances	Ferromagnetic substances
1.	Effect of magnets	They are feebly repelled by magnets.	They are feebly attracted by magnets.	They are strongly attracted by magnets.
2.	In external magnetic field	Acquire feeble magnetisation in the opposite direction of the magnetising field.	Acquire feeble magnetisation in the direction of the magnetising field.	Acquire strong magnetisation in the direction of the magnetising field.
3.	Magnetic moment of single atom	Atoms do not have any permanent magnetic moment	Atoms have permanent magnetic moment which are randomly oriented (*i.e.*, in absence of external magnetic field the magnetic moment of whole material is zero).	Atoms have permanent magnetic moment which are organised in domains.
4.	In a non-uniform magnetic field	Tend to move slowly from stronger to weaker parts of the field.	Tend to move slowly from weaker to stronger parts of the field.	Tend to move quickly from weaker to stronger parts of the field.
5.	In a uniform magnetic field	A freely suspended diamagnetic rod aligns itself perpendicular to the field.	A freely suspended paramagnetic rod aligns itself parallel to the field.	A freely suspended ferromagnetic rod aligns itself parallel to the field.
5.	Susceptibility value (χ_m)	Susceptibility is small and negative. $-1 \leq \chi_m < 0$	Susceptibility is small and positive. $0 \leq \chi_m < \varepsilon$, where ε is a small number	Susceptibility is very large and positive. $\chi_m > 1000$
6.	μ_r	$1 > \mu_r > 0$, $(\mu < \mu_0)$	$(1 + \varepsilon) > \mu_r > 1$, $(\mu > \mu_0)$	$\mu_r >>> 1$, $(\mu >>> \mu_0)$
7.	Examples	Bismuth, copper, lead, water, sodium chloride	Aluminium, sodium, calcium, oxygen, copper chloride	Iron, cobalt, nickel, gadolinium

Torque on a Magnetic Dipole placed in a Uniform Magnetic Field

- When a magnetic dipole of dipole moment $\vec{M}$ is placed in a uniform magnetic field $\vec{B}$, it will experience a torque and is given by $\vec{\tau} = \vec{M} \times \vec{B}$; $\tau = MB\sin\theta$, where θ is the angle between $\vec{M}$ and $\vec{B}$
- Torque acting on a dipole is maximum($\tau_{max} = MB$) when dipole is perpendicular to the field, *i.e.*, $\theta = 90°$.
- Torque acting on dipole is minimum ($\tau_{max} = 0$) when dipole is parallel or antiparallel to the field, *i.e.*, $\theta = 0°$ or $180°$.
- Torque on coil or loop,
  $\vec{\tau} = \vec{M} \times \vec{B}$, here, $\vec{M} = NI\vec{A}$,
  $\vec{\tau} = NI(\vec{A} \times \vec{B})$, $\tau = BINA \sin\theta$



- When a dipole is placed in a uniform magnetic field, it will experience only torque and the net force on the dipole is zero, while when it is placed in a non uniform magnetic field, it will experience both torque and net force.

Potential Energy of a Magnetic Dipole

- Potential energy of a magnetic dipole in a uniform magnetic field is $U = -\vec{M} \cdot \vec{B} = -MB\cos\theta$
- The potential energy of the dipole will be minimum $(= -MB)$ when $\theta = 0°$, *i.e.*, the dipole is parallel to the field, and maximum $(= MB)$ when $\theta = 180°$, *i.e.*, the dipole is antiparallel to the field.

Inductance

- Inductance is the tendency of an electrical conductor to oppose a change in electric current flowing through it.
- Inductance depends only on the geometry of the coil and intrinsic material properties. It is the ratio of flux linkage to the current.

$$L = \frac{N\phi}{I} = \frac{NBA}{I} = \frac{\phi_{total}}{I}$$

Self Inductance

Whenever the current passing through a coil or circuit changes, the magnetic flux linked with it will also change. As a result, an emf is induced in the coil or the circuit which opposes the change that causes it. This phenomenon is known as **self induction** and the emf induced is known as **self induced emf** or **back emf**.

The self-induced emf is given by,

$$\varepsilon = -L\frac{dI}{dt}$$

where, L is the self-inductance of the coil. It is a measure of the inertia of the coil against the change of current through it.

The self inductance of a long solenoid, the core of which consists of a magnetic material of permeability μ_r is

$$L = \frac{\mu_0 \mu_r N^2 A}{l} = \mu_r \mu_o n^2 Al = \mu_r m_0 n^2 V$$

here, V = volume of solenoid = Al

Energy Stored in an Inductor

When a time varying current flows through an inductor, an emf is induced in it.

Power supplied to inductor, $P = (\varepsilon_{in}) I = \left(L\frac{dI}{dt}\right)I$

Magnetic energy stored in the inductor,

$$U_B = \frac{1}{2}LI^2$$

Magnetic energy per unit volume,

$$u_B = \frac{U_B}{V} = \frac{B^2}{2\mu_0}$$

Mutual Inductance

Whenever the current passing through a coil or circuit changes, the magnetic flux linked with a neighboring coil or circuit will also change. Hence, an emf will be induced in the neighboring coil or circuit. This phenomenon is known as **mutual inductance**. The coil or circuit in which the current changes is known as **primary** while the other in which emf is set up is known as **secondary**.

- Mutual Inductance of two coils is numerically equal to magnetic flux linked with one coil, when current flows through the neighboring coil

  $$M_{12} = \frac{N_1\phi_1}{I_2} \text{ and } M_{21} = \frac{N_2\phi_2}{I_1}$$

  For same length and different number of turns per unit length of two solenoids, mutual inductance is given by

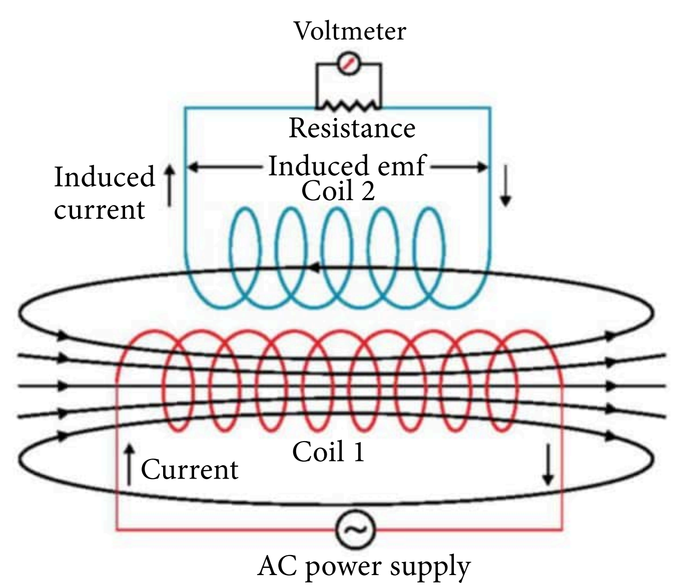
  $$M_{12} = M_{21} = \mu_r \mu_0 n_1 n_2 \pi r_1^2 l$$

  r_1 = radius of inner coil

- For two coupled coils, $M = k\sqrt{L_1L_2}$, where k denotes the coefficient of coupling between the coils.

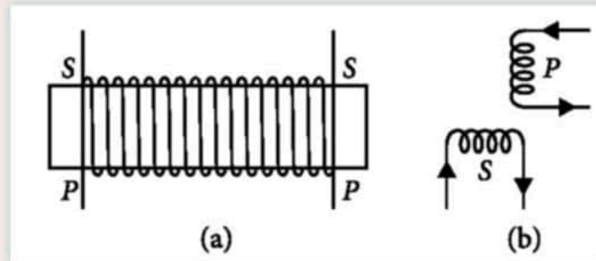
  If k = 1, the coils are said to be tightly coupled such that magnetic flux produced in primary is fully linked with the secondary.

  $M = \sqrt{L_1L_2}$ = maximum value of M.



Factors on which Mutual Inductance Depends

The mutual inductance of two solenoids depends on their geometry and the magnetic permeability of the core material as further explained.



(i) Number of turns : Larger the number of turns in the two solenoids, larger will be their mutual inductance.
$M \propto N_1N_2$

(ii) Common cross-sectional area : Larger the common cross-sectional area of two solenoids, larger will be their mutual inductance.

(iii) Relative separation : Larger the distance between two solenoids, smaller will be the magnetic flux linked with the secondary coil due to current in the primary coil. Hence smaller will be the value of M.

(iv) Relative orientation of the two coils : M is maximum when the entire flux of the primary is linked with the secondary, *i.e.*, when the primary coil completely envelopes the secondary coil as shown in figure (a). M is minimum when the two coils are perpendicular to each other, as shown in figure (b).

Combination of Inductances

- **Series combination**

$$\varepsilon = \varepsilon_1 + \varepsilon_2 - L_s\frac{dI}{dt} = -L_1\frac{dI}{dt} - L_2\frac{dI}{dt}$$

$\Rightarrow \quad L_s = L_1 + L_2 \qquad$ (take $M = 0$)

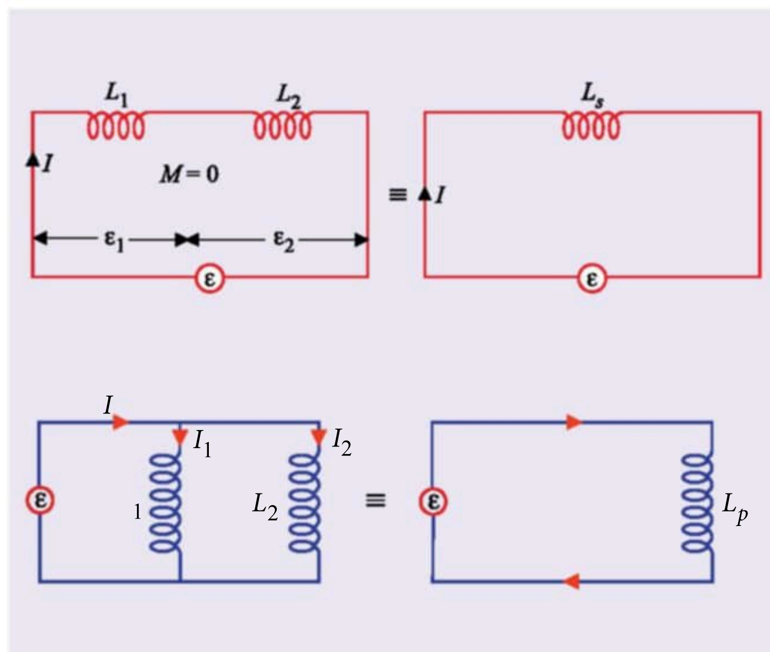
If $M \neq 0$, then, $L_S = L_1 = L_2 \pm 2M$.

The plus sign occurs if windings in the two coils are in the same sense, while minus sign occurs if windings are in opposite sense.

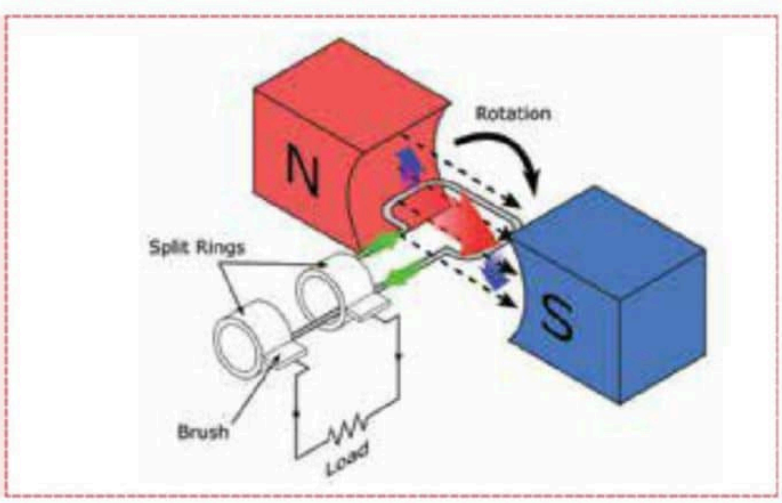
- **Parallel combination**

$$I = I_1 + I_2;\ \frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt} \text{ or } \frac{-\varepsilon}{L_p} = \frac{-\varepsilon}{L_1} + \frac{-\varepsilon}{L_2}$$

$$\Rightarrow L_p = \frac{L_1L_2}{L_1 + L_2}$$



AC Generator



- It is a device which produces a current that alternates or changes its direction regularly after a fixed interval of time and which converts mechanical energy into alternating form of electrical energy.

  The essential parts of the a.c. dynamo are armature, field magnets (N and S), slip ring and brushes.

- **Principle :** It is based on the phenomenon of electromagnetic induction. Whenever, amount of magnetic flux linked with a coil changes, an emf is induced in the coil. It lasts as long as the change in magnetic flux continues. The direction of current induced is given by Flemings right hand rule.

- If the coil of N turns and area A is rotated at υ revolutions per second in a uniform magnetic field B, then the motional emf produced is
  $\varepsilon = NBA\,(2\pi\upsilon)\sin(2\pi\,\upsilon t) = NBA\omega\sin\omega t$
  where we have assumed that at time $t = 0$ s, the plane of coil is perpendicular to the field.

Growth of Current in *LR* Circuit

- At $t = 0$, $I = 0$, now the switch is closed and the circuit is completed.
  Using Kirchhoff's loop law,

$$\varepsilon - L\frac{dI}{dt} - IR = 0 \Rightarrow \int_0^I \frac{dI}{\varepsilon - IR} = \int_0^t \frac{dt}{L}$$

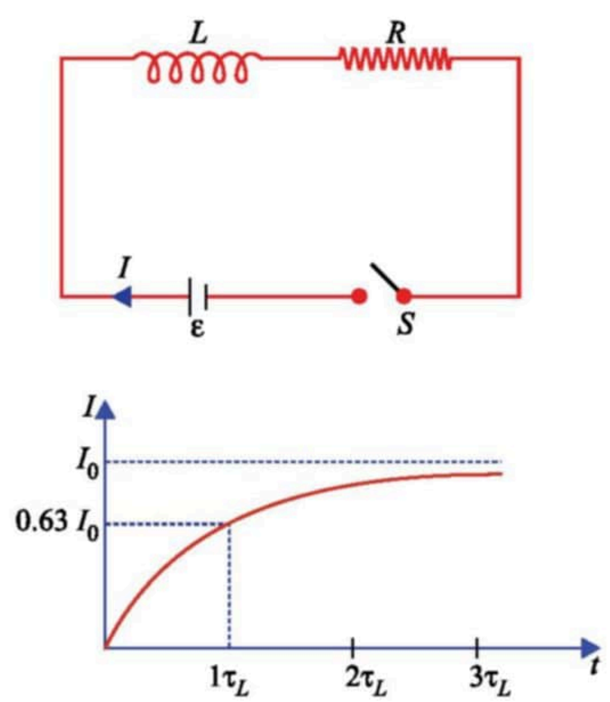
$$-\frac{1}{R}[\ln(\varepsilon - IR)]_0^I = \frac{t}{L} \Rightarrow \ln\left(\frac{\varepsilon - IR}{\varepsilon}\right) = -\frac{tR}{L}$$

or $\dfrac{\varepsilon - IR}{\varepsilon} = e^{(-tR/L)}$

or $I = \dfrac{\varepsilon}{R}(1 - e^{-tR/L}) = I_0(1 - e^{-t/\tau_L})$

$\tau_L = \dfrac{L}{R} =$ Time constant of LR circuit

- $I_0 = \dfrac{\varepsilon}{R} =$ Maximum current in the circuit
- At $t = \tau_L$, $I = I_0\left(1 - \dfrac{1}{e}\right) = 0.63 I_0$



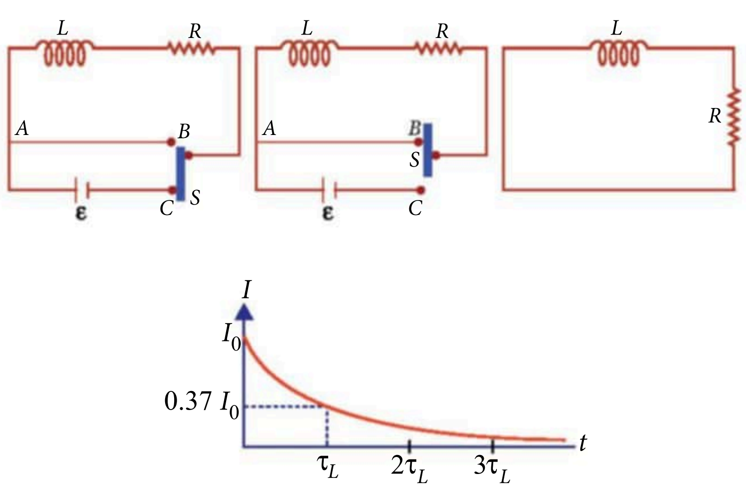
Decay of Current in *LR* Circuit

- At time $t = 0$, the switch S is moved to connect the point B and initial current $= I_0$.
- Now, current starts decreasing in the circuit and this induces an emf $\left(-L\dfrac{dI}{dt}\right)$ in the inductor.

$$\therefore\quad -L\frac{dI}{dt} = RI \quad \text{or,} \int_{I_0}^{I} \frac{dI}{I} = \int_0^t -\frac{R}{L}dt$$

or, $\ln\left(\dfrac{I}{I_0}\right) = -\dfrac{R}{L}t$ or, $I = I_0 e^{-tR/L} = I_0 e^{-t/\tau_L}$

- At $t = \tau_L$, $I = \dfrac{I_0}{e} = 0.37 I_0$



Class XI

Monthly test drive

This specially designed column enables students to self analyse their extent of understanding of specific chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Units and Measurement ▸ Kinematics

Time : 60 Min. **Total Marks :** 120

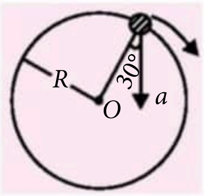
NEET

Only One Option Correct Type

1. A ball is thrown vertically downward with a velocity of 20 m/s from the top of a tower. It hits the ground after some time with a velocity of 80 m/s. The height of the tower is (g = 10 m/s^2)
(a) 360 m (b) 340 m
(c) 320 m (d) 300 m

2. The area of a rectangular field (in m^2) of length 55.3 m and breadth 25 m after rounding off the value for correct significant digit is
(a) 138×10^1 (b) 1382
(c) 1382.5 (d) 14×10^2

3. In the given figure, a = 15 m s^{-2} represents the total acceleration of a particle moving in the clockwise direction in a circle of radius R = 2.5 m at a given instant of time. The speed of the particle is



(a) 4.5 m s^{-1} (b) 5.0 m s^{-1}
(c) 5.7 m s^{-1} (d) 6.2 m s^{-1}

4. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be
(a) $\frac{t_1 t_2}{t_2 - t_1}$ (b) $\frac{t_1 t_2}{t_2 + t_1}$ (c) $t_1 - t_2$ (d) $\frac{t_1 + t_2}{2}$

5. Which two of the following five physical parameters have the same dimensions?
(i) energy density (ii) refractive index
(iii) dielectric constant (iv) Young's modulus
(v) magnetic field
(a) (i) and (iv) (b) (i) and (v)
(c) (ii) and (iv) (d) (iii) and (v)

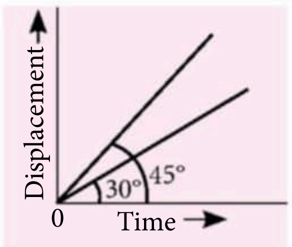
6. Motion of a particle is given by equation $s = (3t^3 + 7t^2 + 14t + 8)$ m. The value of acceleration of the particle at t = 1 sec is
(a) 10 m/s^2 (b) 32 m/s^2
(c) 23 m/s^2 (d) 16 m/s^2.

7. A metal wire has mass (0.4 ± 0.002) g, radius (0.3 ± 0.001) mm and length (5 ± 0.02) cm. The maximum possible percentage error in the measurement of density will nearly be
(a) 1.6% (b) 1.4%
(c) 1.2% (d) 1.3%

8. If a body A of mass M is thrown with velocity v at an angle of 30° to the horizontal and another body B of the same mass is thrown with the same speed at an angle of 60° to the horizontal, the ratio of horizontal range of A to B will be
(a) 1 : 3 (b) 1 : 1 (c) $1:\sqrt{3}$ (d) $\sqrt{3}:1$

9. A car starts from rest and accelerates at 5 m/s^2. At t = 4s, a ball is dropped out of a window by a person sitting in the car. What is the velocity and acceleration of the ball at t = 6 s? (Take g = 10 m/s^2)
(a) $20\sqrt{2}$ m/s, 10 m/s^2 (b) 20 m/s, 5 m/s^2
(c) 20 m/s, 0 (d) $20\sqrt{2}$ m/s, 0

10. The displacement-time graphs of two moving particles make angles of 30° and 45° with the x-axis as shown in the figure. The ratio of their respective velocity is



(a) $\sqrt{3}:1$ (b) 1 : 1 (c) 1 : 2 (d) $1:\sqrt{3}$

11. A bullet is fired from a gun at the speed of 280 m s^{-1} in the direction 30° above the horizontal. The maximum height attained by the bullet is
(g = 9.8 m s^{-2}, sin 30° = 0.5)
(a) 1000 m (b) 3000 m
(c) 2800 m (d) 2000 m

12. A physical quantity of the dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is the universal constant of gravitation and e is charge]

(a) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (b) $\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{1/2}$

(c) $\frac{1}{c}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]$ (d) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

Assertion & Reason Type

Directions : In questions 13 to 15, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** A body, whatever its motion is always at rest in a frame of reference which is fixed to the body itself.
Reason : The relative velocity of a body with respect to itself is zero.

14. **Assertion :** Two particle of different mass, projected with same velocity, the maximum height attained by both the particle will be same.
Reason : The maximum height of projectile is independent of particle mass.

15. **Assertion :** The resultant of two vectors $\vec{P}$ and $\vec{Q}$ is found out using parallelogram law.
Reason : The magnitude of resultant of two vectors cannot be less than the magnitude of either vector.

JEE (MAIN & ADVANCED)

Only One Option Correct Type

16. A student measuring the diameter of a pencil of circular cross-section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.54 mm, 5.65 mm. The average of these four readings is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as
(a) (5.5375 ± 0.0739) mm
(b) (5.5375 ± 0.0740) mm
(c) (5.538 ± 0.074) mm
(d) (5.54 ± 0.07) mm

17. Two projectiles are thrown with same initial velocity making an angle of 45° and 30° with the horizontal respectively. The ratio of their respective ranges will be
(a) $1:\sqrt{2}$ (b) $\sqrt{2}:1$ (c) $2:\sqrt{3}$ (d) $\sqrt{3}:2$

18. When a ball is dropped into a lake from a height 4.9 m above the water level, it hits the water with a velocity v and then sinks to the bottom with the constant velocity v. If reaches the bottom of the lake 4.0 s after it is dropped. The approximate depth of the lake is
(a) 19.6 m (b) 29.4 m
(c) 39.2 m (d) 73.5 m

More than One Option Correct Type

19. Starting at time t = 0 from the origin with speed 1 ms^{-1}, a particle follows a two-dimensional trajectory in the x-y plane so that its coordinates are related by the equation $y=\frac{x^2}{2}$. The x and y components of its acceleration are denoted by a_x and a_y, respectively. Then
(a) a_x =1 m s^{-2} implies that when the particle is at the origin, a_y = 1 ms^{-2}
(b) a_x = 0 implies a_y = 1 ms^{-2} at all times
(c) at $t=0$, the particle's velocity points in the x-direction
(d) a_x = 0 implies that at t =1 s, the angle between the particle's velocity and the x-axis is 45°.

20. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a

periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The value of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52s, 0.56s, 0.57s, 0.54s and 0.59s. The least count of the watch used for the measurement of time period is 0.01s. Which of the following statement(s) is(are) true?

(a) The error in the measurement of r is 10%
(b) The error in the measurement of T is 3.57%
(c) The error in the measurement of T is 2%
(d) The error in the determined value of g is 11%.

21. A physical quantity $\vec{S}$ is defined as $\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$, where, $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity(ies)?

(a) $\frac{\text{Energy}}{\text{Charge} \times \text{Current}}$ (b) $\frac{\text{Force}}{\text{Length} \times \text{Time}}$
(c) $\frac{\text{Energy}}{\text{Volume}}$ (d) $\frac{\text{Power}}{\text{Area}}$

22. The coordinates of a particle moving in a plane are given by $x(t) = a\cos(pt)$ and $y(t) = b\sin(pt)$, where, a, b ($< a$) and p are positive constants of appropriate dimensions. Then

(a) the path of the particle is an ellipse
(b) the velocity and acceleration of the particle are normal to each other at $t = \pi/(2p)$
(c) the acceleration of the particle is always directed towards a focus
(d) the distance travelled by the particle in time interval $t = 0$ to $t = \pi/(2p)$ is a.

23. A particle is moving eastwards with a velocity of 5 m/s. In 10s the velocity changes to 5 m/s northwards. The average acceleration in this time is

(a) zero
(b) $\frac{1}{\sqrt{2}}$ m/s^2 towards north-west
(c) $\frac{1}{\sqrt{2}}$ m/s^2 towards north-east
(d) $\frac{1}{2}$ m/s^2 towards north-west

Integer / Numerical Value Type

24. From the top of a tower, a ball is thrown vertically upward which reaches the ground in 6s. A second ball thrown vertically downward from the same position with the same speed reaches the ground in 1.5 s. A third ball released, from the rest from the same location, will reach the ground in ______ s.

25. To find the distance d over which a signal can be seen clearly in foggy conditions, a railways engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) S of the light from the signal and its frequency f. The engineer finds that d is proportional to $S^{1/n}$. The value of n is ______ .

26. A projectile is fired from horizontal ground with speed v and projection angle θ. When the acceleration due to gravity is g, the range of the projectile is d. If at the highest point in its trajectory, the projectile enters a different region where the effective acceleration due to gravity is $g' = \frac{g}{0.81}$, then the new range is $d' = nd$. The value of n is ________.

Comprehension Type

In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, [E] and [B] stand for dimensions of electric and magnetic fields respectively, while $[\varepsilon_0]$ and $[\mu_0]$ stand for dimensions of the permittivity and permeability of free space respectively. [L] and [T] are dimensions of length and time respectively. All the quantities are given in SI units.

27. The relation between [E] and [B] is

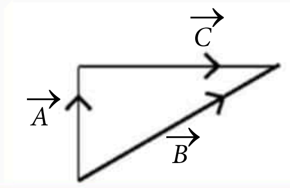
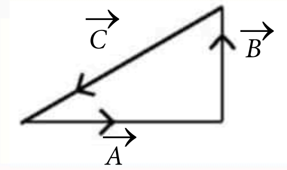
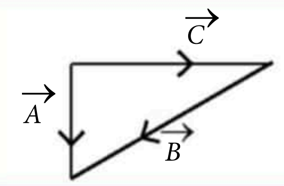
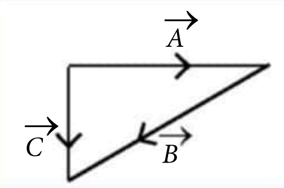
(a) $[E] = [B][L][T]$ (b) $[E] = [B][L]^{-1}[T]$
(c) $[E] = [B][L][T]^{-1}$ (d) $[E] = [B][L]^{-1}[T]^{-1}$

28. The relation between $[\varepsilon_0]$ and $[\mu_0]$ is

(a) $[\mu_0] = [\varepsilon_0][L]^2[T]^{-2}$ (b) $[\mu_0] = [\varepsilon_0][L]^{-2}[T]^2$
(c) $[\mu_0] = [\varepsilon_0]^{-1}[L]^2[T]^{-2}$ (d) $[\mu_0] = [\varepsilon_0]^{-1}[L]^{-2}[T]^2$

Matrix Match Type

29. Match List-I with List-II.

	List-I		List-II
(A)	$\vec{C} - \vec{A} - \vec{B} = 0$	(p)	
(B)	$\vec{A} - \vec{C} - \vec{B} = 0$	(q)	
(C)	$\vec{B} - \vec{A} - \vec{C} = 0$	(r)	
(D)	$\vec{A} + \vec{B} = -\vec{C}$	(s)	

Choose the correct answer from the options given below.

(a) (A) → (p), (B) → (s), (C) → (q), (D) → (r)
(b) (A) → (s), (B) → (r), (C) → (p), (D) → (q)
(c) (A) → (r), (B) → (q), (C) → (s), (D) → (p)
(d) (A) → (s), (B) → (p), (C) → (r), (D) → (q)

30. Match List-I with List-II.

	List-I		List-II
(A)	h (Planck's constant)	(p)	$[MLT^{-1}]$
(B)	E (kinetic energy)	(q)	$[ML^2T^{-1}]$
(C)	V (electric potential)	(r)	$[ML^2T^{-2}]$
(D)	P (linear momentum)	(s)	$[ML^2I^{-1}T^{-3}]$

Choose the correct answer from the options given below.

(a) (A) → (q), (B) → (r), (C) → (s), (D) → (p)
(b) (A) → (r), (B) → (q), (C) → (s), (D) → (p)
(c) (A) → (r), (B) → (s), (C) → (q), (D) → (p)
(d) (A) → (p), (B) → (q), (C) → (s), (D) → (r)

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SELF CHECK

No. of questions attempted ......
No. of questions correct ......
Marks scored in percentage ......

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

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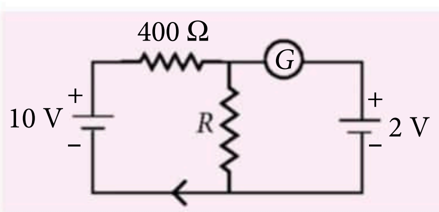
1. Which of the following combinations should be selected for better tuning of an L-C-R circuit used for communication?
(a) $R = 20\ \Omega$, $L = 1.5$ H, $C = 35\ \mu$F
(b) $R = 25\ \Omega$, $L = 2.5$ H, $C = 45\ \mu$F
(c) $R = 15\ \Omega$, $L = 3.5$ H, $C = 30\ \mu$F
(d) $R = 25\ \Omega$, $L = 1.5$ H, $C = 45\ \mu$F

2. If the galvanometer G does not show any deflection in the circuit shown, the value of R is given by



(a) 100 Ω (b) 400 Ω
(c) 200 Ω (d) 50 Ω

3. Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9 mW. The number of photons arriving per second on the average at a target irradiated by this beam is
(a) 3×10^{16} (b) 9×10^{15}
(c) 3×10^{19} (d) 9×10^{17}

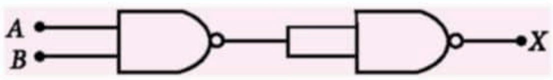
4. How does the Binding Energy per nucleon vary with the increase in the number of nucleons?
(a) Decrease continuously with mass number.
(b) First decreases and then increases with increase in mass number.
(c) First increases and then decreases with increase in mass number.
(d) Increases continuously with mass number.

5. A spherical conductor of radius 10 cm has a charge of 3.2×10^{-7} C distributed uniformly. What is the magnitude of electric field at a point 15 cm from the centre of the sphere? $\left(\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{N m}^2/\text{C}^2\right)$
(a) 1.28×10^4 N/C (b) 1.28×10^5 N/C
(c) 1.28×10^6 N/C (d) 1.28×10^7 N/C

6. A screw gauge gives the following readings when used to measure the diameter of a wire
Main scale reading : 0 mm
Circular scale reading : 52 divisions
Given that 1 mm on main scale corresponds to 100 divisions on the circular scale. The diameter of the wire from the above data is
(a) 0.052 cm (b) 0.52 cm
(c) 0.026 cm (d) 0.26 cm

7. A 250-turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85 μA and subjected to a magnetic field of strength 0.85 T. Work done for rotating the coil by 180° against the torque is
(a) 4.55 μJ (b) 2.3 μJ (c) 1.15 μJ (d) 9.1 μJ

8. The output (X) of the logic circuit shown in figure will be



(a) $X = A.B$ (b) $X = \overline{A + B}$

(c) $X = \overline{\overline{A}}.\overline{\overline{B}}$ (d) $X = \overline{A.B}$

9. In a Young' double slit experiment if there is no initial phase difference between the light from the two slits, a point on the screen corresponding to the fifth minimum has path difference.

(a) $5\frac{\lambda}{2}$ (b) $10\frac{\lambda}{2}$ (c) $9\frac{\lambda}{2}$ (d) $11\frac{\lambda}{2}$

10. Match List-I with List-II

List-I		List-II	
(A)	Ultraviolet rays	(i)	Study crystal structure
(B)	Microwaves	(ii)	Greenhouse effect
(C)	Infrared waves	(iii)	Sterilizing surgical instrument
(D)	X-rays	(iv)	Radar system

Choose the correct answer from the options given below.

(a) (A)-(iii), (B)-(iv), (C)-(ii), (D)-(i)
(b) (A)-(iii), (B)-(i), (C)-(ii), (D)-(iv)
(c) (A)-(iv), (B)-(iii), (C)-(ii), (D)-(i)
(d) (A)-(iii), (B)-(iv), (C)-(i), (D)-(ii)

11. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect?

(a) The change in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$.
(b) The charge on the capacitor is not conserved.
(c) The potential difference between the plates decreases K times.
(d) The energy stored in the capacitor decreases K times.

12. Consider 3rd orbit of He^+ (Helium), using non-relativistic approach, the speed of electron in this orbit will be [given $K = 9 \times 10^9$ constant, $Z = 2$ and h (Planck's constant) $= 6.6 \times 10^{-34}$ J s]

(a) 0.73×10^6 m/s (b) 3.0×10^8 m/s
(c) 2.92×10^6 m/s (d) 1.46×10^6 m/s

13. A biconvex lens has a radius of curvature of magnitude 20 cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30 cm from the lens?

(a) Virtual, upright, height = 1 cm
(b) Virtual, upright, height = 0.5 cm
(c) Real, inverted, height = 4 cm
(d) Real, inverted, height = 1 cm

14. Given below are two statements :

Statement I : Biot-Savart's law gives us the expression for the magnetic field strength of an infinitesimal current element (Idl) of a current carrying conductor only.

Statement II : Biot-Savart's law is analogous to Coulomb's inverse square law of charge q, with the former being related to the field produced by a scalar source, Idl while the latter being produced by a vector source, q.

In light of above statements choose the most appropriate answer from the options given below.

(a) Both Statement I and Statement II are correct.
(b) Both Statement I and Statement II are incorrect.
(c) Statement I is correct and Statement II is incorrect.
(d) Statement I is incorrect and Statement II is correct.

15. A cycle wheel of radius 0.5 m is rotated with constant angular velocity of 10 rad/s in a region of magnetic field of 0.1 T which is perpendicular to the plane of the wheel. The EMF generated between its centre and the rim is

(a) 0.25 V (b) 0.125 V (c) 0.5 V (d) zero

SOLUTIONS

1. **(c) :** Quality factor of an L-C-R circuit is given by,

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$Q_1 = \frac{1}{20}\sqrt{\frac{1.5}{35\times10^{-6}}} = 50\times\sqrt{\frac{3}{70}} = 10.35$$

$$Q_2 = \frac{1}{25}\times\sqrt{\frac{2.5}{45\times10^{-6}}} = 40\times\sqrt{\frac{5}{90}} = 9.43$$

$$Q_3 = \frac{1}{15}\sqrt{\frac{3.5}{30\times10^{-6}}} = \frac{100}{15}\sqrt{\frac{35}{3}} = 22.77$$

$$Q_4 = \frac{1}{25}\times\sqrt{\frac{1.5}{45\times10^{-6}}} = \frac{40}{\sqrt{30}} = 7.30$$

Clearly Q_3 is maximum out of Q_1, Q_2, Q_3, and Q_4.
Hence, option (c) should be selected for better tuning of an L-C-R circuit.

2. (a) : Since galvanometer shows no deflection, thus voltage across R is 2V.

Now, voltage across R is, $V = \frac{10R}{400+R}$

or $2 = \frac{10R}{400+R} \Rightarrow R = 100\,\Omega$

3. (a) : $\lambda = 6670$ Å

E of a photon $= \frac{12400 \text{ eVÅ}}{6670 \text{ Å}} = \frac{12400}{6670} \times 1.6 \times 10^{-19}$ J.

Energy emitted per second, power, $P = 9 \times 10^{-3}$ J

$\therefore$ Number of photons incident $= \frac{\text{Power}}{\text{Energy}} = \frac{P}{E}$

$= \frac{9\times10^{-3}\times6670}{12400\times1.6\times10^{-19}} = 3\times10^{16}$

4. (c)

5. (b): Here, $r = 10$ cm, $q = 3.2 \times 10^{-7}$ C

$E = \frac{kq}{r^2} = \frac{9\times10^{9}\times3.2\times10^{-7}}{225\times10^{-4}}$

$E = 1.28 \times 10^5$ N/C

6. (a) : Given : Pitch = 1 mm, Number of division on circular scale, $N = 100$

Least count, L.C. $= \frac{\text{Pitch}}{N} = \frac{1}{100} = 0.01$ mm

So, diameter, d = main scale reading + (circular scale reading × least count)

$d = 0 + 52 \times 0.01$ or $d = 0.52$ mm or $d = 0.052$ cm

7. (d): Work done in a coil

$W = mB(\cos\theta_1 - \cos\theta_2)$

When it is rotated by angle 180° then

$W = 2mB = 2(NIA)B$ ...(i)

Given: $N = 250$, $I = 85\ \mu\text{A} = 85 \times 10^{-6}$ A

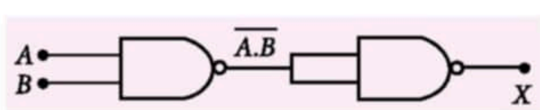
$A = 1.25 \times 2.1 \times 10^{-4}\ \text{m}^2 \approx 2.6 \times 10^{-4}\ \text{m}^2$

$B = 0.85$ T

Putting these values in eqn. (i), we get

$W = 2 \times 250 \times 85 \times 10^{-6} \times 2.6 \times 10^{-4} \times 0.85$

$\approx 9.1 \times 10^{-6}$ J = 9.1 μJ

8. (a) : 

The output of the given logic circuit is

$X = \overline{\overline{A.B}} = A.B$

9. (c) : Given, there is no initial phase difference.

$\therefore$ Initial phase = δ = 0

Again, phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Rightarrow \delta' = \frac{2\pi}{\lambda}\times\Delta x \Rightarrow \Delta x = \frac{\lambda}{2\pi}\times\delta'$

Now, for the fifth minima we will consider $n = 4$ as initial phase difference is zero.

$\therefore$ For fifth minimum, $\delta' = (8 + 1)\pi = 9\pi$

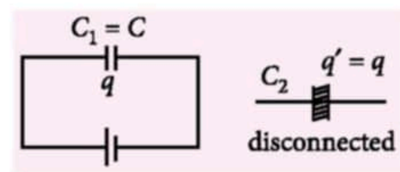
$\therefore$ Path difference, $\Delta x = \frac{\lambda}{2\pi}\times 9\pi = \frac{9\lambda}{2}$

10. (a) : Ultraviolet rays – Sterilizing surgical instrument
Microwaves – Radar system
Infrared waves – Greenhouse effect
X-rays – Study crystal structure

11. (b): $q = CV \Rightarrow V = q/C$

Due to dielectric insertion, new capacitance

$C_2 = CK$



Initial energy stored in capacitor, $U_1 = \frac{q^2}{2C}$

Final energy stored in capacitor, $U_2 = \frac{q^2}{2KC}$

Change in energy stored, $\Delta U = U_2 - U_1$

$\Delta U = \frac{q^2}{2C}\left(\frac{1}{K}-1\right) = \frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$

New potential difference between plates $V' = \frac{q}{CK} = \frac{V}{K}$

12. (d): Energy of electron in He^+ 3rd orbit

$E_3 = -13.6\times\frac{Z^2}{n^2}\text{ eV} = -13.6\times\frac{4}{9}\text{ eV}$

$= -13.6\times\frac{4}{9}\times1.6\times10^{-19}\text{ J} \simeq -9.7\times10^{-19}\text{ J}$

As per Bohr's model,

Kinetic energy of electron in the 3rd orbit = $-E_3$

$\therefore\ 9.7\times10^{-19} = \frac{1}{2}m_e v^2$

$\Rightarrow v = \sqrt{\frac{2\times9.7\times10^{-19}}{9.1\times10^{-31}}} = 1.46\times10^{6}\text{ m s}^{-1}$

13. (c)

14. (c) : Statement I is correct, but statement II is incorrect because, the magnetic field is produced by vector source Idl and the coulomb's force is produced by scalar source q.

15. (b): Here, $B = 0.1$ T, $r = 0.5$ m, $\omega = 10$ rad/s

So, the emf generated between its centre and rim is,

$\varepsilon = \frac{1}{2}B\omega r^2 = \frac{1}{2}\times0.1\times10\times(0.5)^2 = 0.125$ V

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Class XII

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Series 4

Moving Charges and Magnetism

Magnetic Fields and its Source

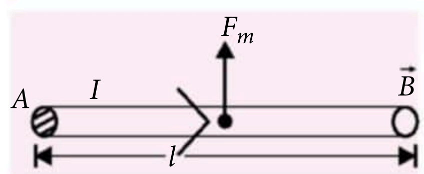
- The magnetic field is the region around the source of the magnetic field (magnetic material, bar magnet, current loop etc.)
- Electric currents or moving charges produce a magnetic field.
- A dot (⊙) represents a current or magnetic field emerging out of the plane of the paper and a cross (⊗) represents a current or magnetic field going into the plane of the paper.

Lorentz Force

- The force observed by Lorentz in electric and magnetic field on a moving charge is given by
  $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) = \vec{F}_e + \vec{F}_m$
- Magnetic force, $|\vec{F}_m| = qvB\sin\theta$, θ is the angle between $\vec{B}$ and $\vec{v}$.
- Features of magnetic force :
  - It depends on $q, \vec{v}$ and $\vec{B}$.
  - If $\vec{v}$ is perpendicular to $\vec{B}$, then magnetic force (F_m) will be maximum.
  - If $\vec{v}$ and $\vec{B}$ are parallel or anti-parallel, the magnetic force (F_m) will be zero.
  - If $\vec{v} = 0$, then $|\vec{F}_m| = 0$, moving charges only experience the Electric force.

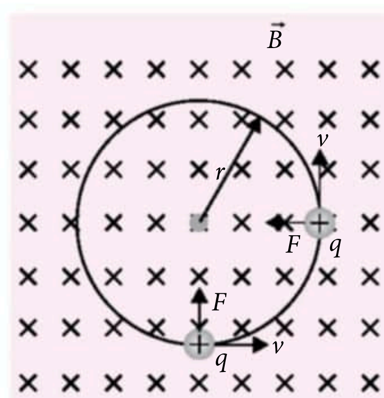
Magnetic Force on a Current Carrying Conductor

- Net mobile charge carrier in a conductor, $q = nAle$
  Average drift velocity of electron = v_d
- Magnetic force on charge
  $\vec{F}_m = (nAl)e(\vec{v}_d \times \vec{B}) = [(ne\vec{v}_d)Al] \times \vec{B}$
  $= (\vec{J}Al) \times \vec{B} = I(\vec{l} \times \vec{B})$
- For an arbitrary shape of wire
  $\vec{F} = \sum_k I(d\vec{l}_k \times \vec{B})$
- This force acts through the centre of the rod of length (l).



Motion of a Charged Particle in a Magnetic Field

- If $\vec{v} \perp \vec{B}$ then the particle will describe a circle.
  - Radius of the circle,
    $\frac{mv^2}{r} = qvB$
    $\therefore \; r = \frac{mv}{qB}$
  - Angular frequency of charged particle,
    $\omega = \frac{v}{r} = \frac{qB}{m}$



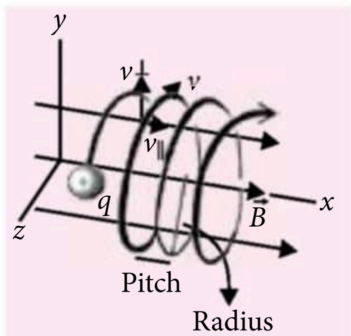
Circular motion of charge

– Time period of charge particle, $T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$

– T and ω are independent of velocity or energy.

- If $\vec{v}$ is not perpendicular to $\vec{B}$, then velocity has two components, one along $\vec{B}$ and other one perpendicular to $\vec{B}$. Hence, the particle will follow a helical path.
  – The linear distance moved along the magnetic field in one rotation is called pitch (p).

$$p = v_{||}T = \frac{2\pi m v_{||}}{qB} = \frac{2\pi m v\cos\theta}{qB}$$



Helical motion of charge

– Radius of helix,

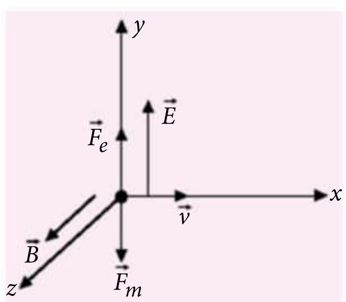
$$r = \frac{mv_{\perp}}{qB} = \frac{mv\sin\theta}{qB}$$

Motion of a Charged Particle in Combined Electric and Magnetic Fields

Velocity selector : The arrangement of adjusting electric and magnetic fields so that the net force on the charged particle becomes zero is called velocity selector. It is employed in mass spectrometers.

For combined fields,

$$\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$$



For equilibrium of charged particle,

$|\vec{F}| = 0$, so, $|q\vec{E}| = q|\vec{v}\times\vec{B}|$

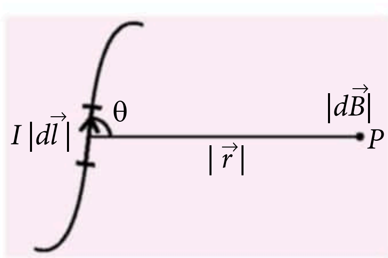
or, $E = vB \qquad (\because \vec{v}\perp\vec{B})$

$\therefore v = \frac{E}{B}$

Biot-Savart Law

- Magnetic field at a point P due to a current element Idl depends as $dB \propto I$, $dB \propto dl$

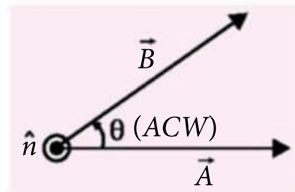
  $dB \propto \sin\theta$, $dB \propto \frac{1}{r^2}$

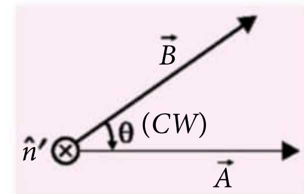


On combining, $dB \propto \frac{Idl\ \sin\theta}{r^2}$

$$\Rightarrow dB = \frac{kIdl\ \sin\theta}{r^2}, \text{ where } k = \begin{cases} \frac{\mu_0}{4\pi} = 10^{-7}\ (\text{S.I.}) \\ = 1\ (\text{C.G.S.}) \end{cases}$$

- Vector cross product





$\vec{C} = \vec{A}\times\vec{B}$; $\vec{C}' = \vec{B}\times\vec{A}$

$\vec{C} = AB\sin\theta\,\hat{n}$; $\vec{C}' = BA\sin\theta\,\hat{n}'$

$\hat{n} \rightarrow$ out of paper ; $\hat{n}' \rightarrow$ into the paper

- Vector form of Biot-Savart Law

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$$

Magnetic Field on the Axis of a Circular Current Loop

$|d\vec{B}|$ due to small element $Id\vec{l}$, is given by

$$dB = \frac{\mu_0}{4\pi}\frac{I|d\vec{l}\times\vec{r}|}{r^3} = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dl}{(x^2+R^2)}$$

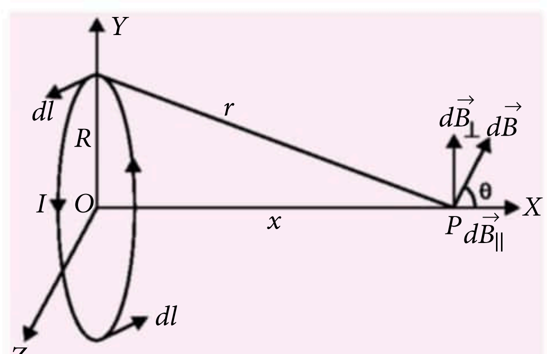
Due to symmetry of loop only x-component of the field will survive.

i.e., $dB_x = dB\cos\theta$; $dB_x = \frac{\mu_0 I\,dl}{4\pi}\frac{R}{(x^2+R^2)^{3/2}}$

Net magnetic field at point P due to entire circular loop,

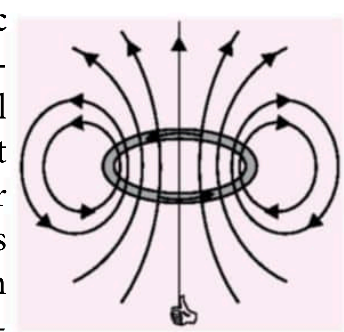
$$\vec{B} = B_x\hat{i} = \frac{\mu_0 I R}{4\pi(x^2+R^2)^{3/2}}\int dl\,(\hat{i})$$

$$\vec{B} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\hat{i}$$



Magnetic field on the axis of current carrying circular loop of radius R.

- **Direction of the magnetic field is given by right-hand thumb rule :** Curl the palm of your right hand around the circular wire with the fingers pointing in the direction of the current. The right-



hand thumb gives the direction of the magnetic field. In the given figure, the upper side of the loop may be thought of as the north pole and the lower side as the south pole of a magnet.

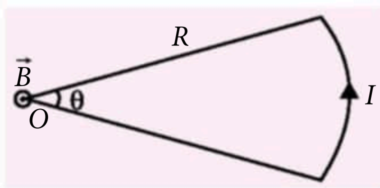
– Magnetic field at the centre of the loop ($x = 0$)

$$\therefore\ B = \frac{\mu_0 I R}{4\pi\,(0+R^2)^{3/2}}\int dl = \frac{\mu_0 I}{4\pi R^2}\times 2\pi R = \frac{\mu_0 I}{2R}$$

– Magnetic field at the centre due to current carrying arc of a circle

Here, $\int dl = R\theta$

$$\therefore\ B = \frac{\mu_0 I\,\theta}{4\pi R}$$



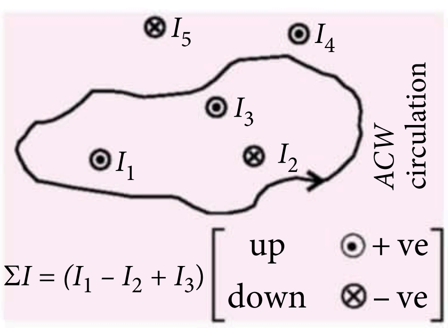
– When $x >> R$, points close to the loop are not considered, $B = \frac{\mu_0 I R^2}{2x^3} \Rightarrow B \propto \frac{1}{x^3}$

So, current loop is equivalent to a magnetic dipole.

Ampere's Circuital Law

- It states that line integral of the magnetic field along any closed path in free space is equal to μ_0 times of net current, which is passing through area bounded by the closed path. Mathematically,

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \sum I$$



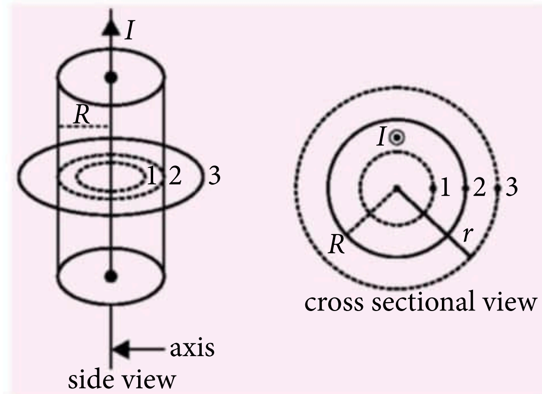
- **Limitations**
  – This law is suitable for infinite long and symmetrical current distribution.
  – Radius of cross section of thick cylindrical wire and current density must be given to apply this law.
  – Current density in a thick cylindrical wire must be constant.

Magnetic Field due to Infinite Long Solid Cylindrical Conductor or Wire

- Current density, $J = \frac{I}{\pi R^2} =$ constant; $A = \pi R^2$
- Magnetic field at specific positions :

– For $r < R$, $B_{in}(2\pi r) = \mu_0 I_{enc} = \mu_0 \frac{Ir^2}{R^2}$

$$B_{in} = \frac{\mu_0 I r}{2\pi R^2} \Rightarrow B_{in} \propto r$$



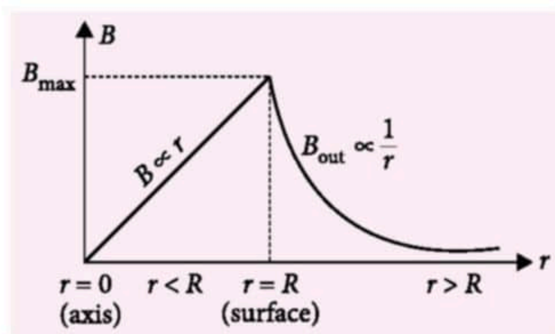
– For $r = R$, $B_s\,(2\pi R) = \mu_0 I$

$$B_s = \frac{\mu_0 I}{2\pi R}\quad \text{(maximum)}$$

– For $r > R$, $B_{out}\,(2\pi r) = \mu_0 I$

$$B_{out} = \frac{\mu_0 I}{2\pi r} \Rightarrow B_{out} \propto \frac{1}{r}$$

– For $r = 0$, $B_{axis} = 0$



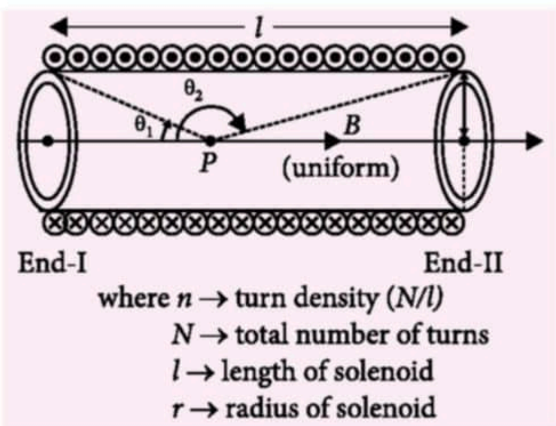
The Solenoid

- It is a coil which has length and used to produce uniform magnetic field of long range.
- It consists a conducting wire which is tightly wound over a cylindrical frame in the form of identical circular turns.
- The magnetic field at a point on the axis of a solenoid can be obtained by superposition of field due to large number of identical circular turns having their centres on the axis of solenoid.
- Magnetic field on the an axial point inside of solenoid of finite length, $B = \frac{\mu_0 nI}{2}(\cos\theta_1 - \cos\theta_2)$
- If solenoid length is infinite then

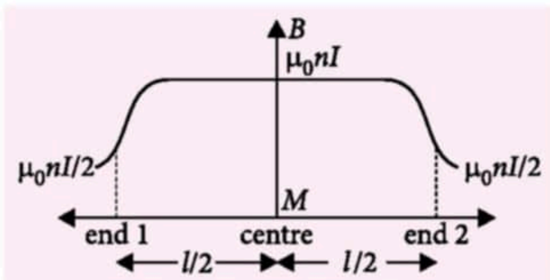
$$B = \frac{\mu_0 nI}{2}(\cos 0° - \cos 180°) = \mu_0 nI \quad \text{(unifrom)}$$

- Magnetic field at end point of infinite solenoid

$$B = \frac{\mu_0 nI}{2}(\cos 90° - \cos 180°) = \frac{\mu_0 nI}{2}$$



- Magnetic field outside the volume of the infinite solenoid approaches to zero.
- If magnetic permeability of solenoid frame is μ_r then field produced by the solenoid $B = \mu_0 \mu_r nI$



Force Between Two Parallel Currents

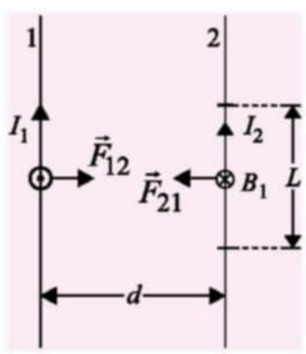
Magnetic field B_1 due to current I_1 at the location of second wire,

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

A length L of wire 2 experiences a magnetic force,

$$\vec{F}_{21} = I_2(\vec{L} \times \vec{B}_1) = -\vec{F}_{12}$$

$$F_{21} = \frac{\mu_0 L I_1 I_2}{2\pi d} = F_{12}$$



- Magnetic force per unit length, $F = \dfrac{\mu_0 I_1 I_2}{2\pi d}$
- Parallel currents attract and antiparallel currents repel.
- It gives definition of ampere and force experienced by each wire per unit length in this case is 2×10^{-7} N m^{-1}.

Torque on a Rectangular Current Loop

When a rectangular current loop is placed in a uniform magnetic field in a particular orientation then it will experience only torque.

$$\vec{\tau} = \vec{m} \times \vec{B} = mB \sin\theta \hat{n}$$

Here, $\vec{m} = N I \vec{A} = NI(ab)\hat{A}$

= magnetic moment of current in loop

$A = ab$ = area of rectangular loop

θ = angle between $\vec{m}$ and $\vec{B}$

Circular Current Loop as a Magnetic Dipole

- Magnetic moment of circular current loop, $m = IA = I\pi R^2$
- Magnetic field perpendicular to the loop,

$$B_\perp = \frac{\mu_0 I R^2}{2x^3} \quad (\text{For } x >> R) \; ; \; B_\perp = \frac{\mu_0}{4\pi} \cdot \frac{2m}{x^3}$$

- Magnetic field in the plane of the loop

$$B_\parallel = \frac{\mu_0}{4\pi} \frac{m}{x^3} \quad (x >> R) \qquad \text{Also, } B_\perp = 2 \times B_\parallel$$

- These expressions are analogous to the electric field due to short dipole.

The Moving Coil Galvanometer

- **Principle :** When a current carrying coil is placed in a magnetic field, it experiences a torque. In moving coil galvanometer the current I passing through the galvanometer is directly proportional to its deflection (ϕ).

  $I \propto \phi$ or $I = G\phi$,

  where, $G = \dfrac{k}{NAB}$ = galvanometer constant

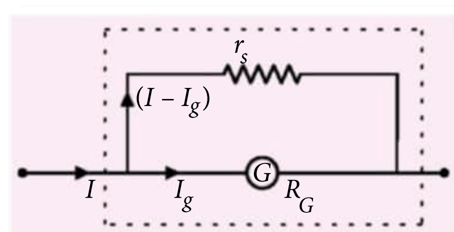
  A = area of a coil, N = number of turns in the coil, B = strength of magnetic field, k = torsional constant of the spring *i.e.*, restoring torque per unit twist.

- Voltage sensitivity, $\dfrac{\phi}{V} = \left(\dfrac{NAB}{k}\right)\dfrac{I}{V} = \left(\dfrac{NAB}{k}\right)\dfrac{1}{R}$

- **Conversion of galvanometer into ammeter (Shunt is connected in parallel):**

  r_s is a very small resistance ($r_s << R_G$)

$$\frac{r_s}{R_G} = \frac{I_g}{I - I_g} \quad \therefore \quad r_s = \left(\frac{I_g}{I - I_g}\right) R_G$$



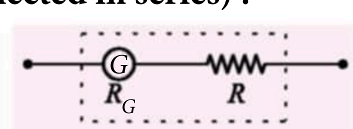
Ammeter

- **Conversion of galvanometer into voltmeter (A large resistance is connected in series) :**

  R is a large resistance

  ($R >> R_G$) $V = I_g(R_G + R)$

$$\therefore \quad R = \frac{V}{I_g} - R_G$$

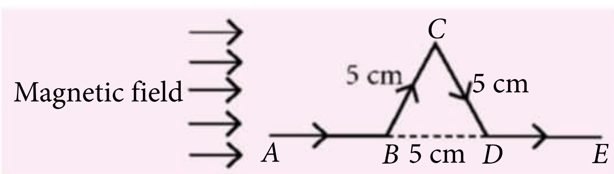


Voltmeter

WRAP it up!

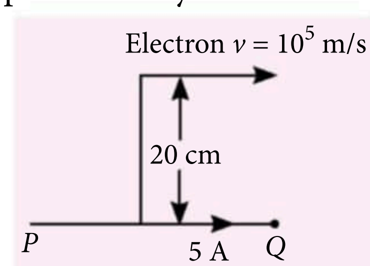
1. A proton and an alpha particle both enter a region of uniform magnetic field B, moving at right angles to the field B. If the radius of circular orbits for both the particles is equal and the kinetic energy acquired by proton is 1 MeV, the energy acquired by the alpha particle will be
   (a) 1.5 MeV (b) 1 MeV
   (c) 4 MeV (d) 0.5 MeV

2. A triangular shaped wire carrying 10 A current is placed in a uniform magnetic field of 0.5 T, as shown in figure. The magnetic force on segment CD is (Given $BC = CD = BD = 5$ cm.)



   (a) 0.126 N (b) 0.312 N
   (c) 0.216 N (d) 0.245 N

3. An infinitely long straight conductor carries a current of 5 A as shown. An electron is moving with a speed of 10^5 m/s parallel to the conductor. The perpendicular distance between the electron and the conductor is 20 cm at an instant. Calculate the magnitude of the force experienced by the electron at that instant.
   Electron $v = 10^5$ m/s



   (a) 8×10^{-20} N
   (b) 4×10^{-20} N
   (c) $8\pi \times 10^{-20}$ N
   (d) $4\pi \times 10^{-20}$ N

4. The electric current in a circular coil of 2 turns produces a magnetic induction B_1 at its centre. The coil is unwound and is rewound into a circular coil of 5 turns and the same current produces a magnetic induction B_2 at its centre. The ratio of B_2/B_1 is
   (a) 5/2 (b) 25/4 (c) 5/4 (d) 25/2

5. A long straight wire carries a certain current and produces a magnetic field 2×10^{-4} Wb m^{-2} at a perpendicular distance of 5 cm from the wire. An electron situated at 5 cm from the wire moves with a velocity 10^7 m/s towards the wire along perpendicular to it. The force experienced by the electron will be (charge on electron 1.6×10^{-19} C)
   (a) 3.2 N (b) 3.2×10^{-16} N
   (c) 1.6×10^{-16} N (d) zero

6. A square loop of side $2a$, and carrying current I, is kept in XZ plane with its centre at origin. A long wire carrying the same current I is placed parallel to the z-axis and passing through the point $(0, b, 0)$, $(b >> a)$. The magnitude of the torque on the loop about Z-axis is given by
   (a) $\dfrac{\mu_0 I^2 a^2}{2\pi b}$ (b) $\dfrac{\mu_0 I^2 a^3}{2\pi b^2}$
   (c) $\dfrac{2\mu_0 I^2 a^2}{\pi b}$ (d) $\dfrac{2\mu_0 I^2 a^3}{\pi b^2}$

7. An electron is moving along the positive x-axis. If the uniform magnetic field is applied parallel to the negative z-axis, then
   A The electron will experience magnetic force along positive y-axis.
   B. The electron will experience magnetic force along negative y-axis.
   C. The electron will not experience any force in magnetic field.
   D. The electron will continue to move along the positive x-axis.
   E. The electron will move along circular path in magnetic field.
   Choose the correct answer from the options given below.
   (a) B and E only (b) A and E only
   (c) B and D only (d) C and D only

8. A long wire carrying a steady current is bent into a circular loop of one turn. The magnetic field at the centre of the loop is B. It is then bent into a circular coil of n turns. The magnetic field at the centre of this coil of n turns will be
   (a) nB (b) n^2B (c) $2nB$ (d) $2n^2B$.

9. Given below are two statements : One is labelled as Assertion (A) and the other is labelled as Reason (R).
   Assertion (A) : For measuring the potential difference across a resistance of 600 Ω, the voltmeter with resistance 1000 Ω will be preferred over voltmeter with resistance 4000 Ω.

Reason (R) : Voltmeter with higher resistance will draw smaller current than voltmeter with lower resistance.

In the light of above statements, choose the most appropriate answer the from options given below

(a) Both A and R are correct and R is not the correct explanation of A.

(b) Both A and R are correct but R is the correct explanation of A.

(c) A is incorrect but R is correct.

(d) A is correct but R is incorrect.

10. A current loop in a magnetic field

(a) can be in equilibrium in two orientations, both the equilibrium states are unstable.

(b) can be in equilibrium in two orientations, one stable while the other is unstable.

(c) experiences a torque whether the field is uniform or non uniform in all orientations.

(d) can be in equilibrium in one orientations.

11. A particle having a mass of 10^{-2} kg carries a charge of 5×10^{-8} C. The particle is given an initial horizontal velocity of 10^5 m s^{-1} in the presence of electric field $\vec{E}$ and magnetic field $\vec{B}$. To keep the particle moving in a horizontal direction, it is necessary that

(1) $\vec{B}$ should be perpendicular to the direction of velocity and $\vec{E}$ should be along the direction of velocity

(2) Both $\vec{B}$ and $\vec{E}$ should be along the direction of velocity

(3) Both $\vec{B}$ and $\vec{E}$ are mutually perpendicular and perpendicular to the direction of velocity.

(4) $\vec{B}$ should be along the direction of velocity and $\vec{E}$ should be perpendicular to the direction of velocity

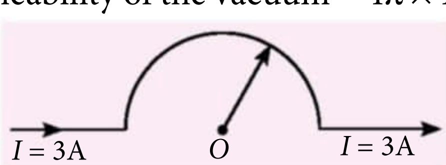
Which one of the following pairs of statements is possible?

(a) (1) and (3) (b) (3) and (4)

(c) (2) and (3) (d) (2) and (4)

12. As shown in the figure, a long straight conductor with semi-circular arc of radius $\pi/10$ m is carrying current $I = 3$ A. The magnitude of the magnetic field at the center O of the arc is

(The permeability of the vacuum = $4\pi \times 10^{-7}$ NA^{-2})



(a) 6 μT (b) 4 μT (c) 3 μT (d) 1 μT

13. A long solenoid of radius 1 mm has 100 turns per mm. If 1 A current flows in the solenoid, the magnetic field strength at the centre of the solenoid is

(a) 6.28×10^{-2} T (b) 12.56×10^{-2} T

(c) 12.56×10^{-4} T (d) 6.28×10^{-4} T

14. Two coaxial solenoids of different radii carry current I in the same direction. Let $\vec{F}_1$ be the magnetic force on the inner solenoid due to the outer one and $\vec{F}_2$ be the magnetic force on the outer solenoid due to the inner one. Then

(a) $\vec{F}_1$ is radially inwards and $\vec{F}_2 = 0$

(b) $\vec{F}_1$ is radially outwards and $\vec{F}_2 = 0$

(c) $\vec{F}_1 = \vec{F}_2 = 0$

(d) $\vec{F}_1$ is radially inwards and $\vec{F}_2 = 0$ is radially outwards

15. A solenoid of 1000 turns per metre has a core with relative permeability 500. Insulated windings of the solenoid carry an electric current of 5 A. The magnetic flux density produced by the solenoid is (permeability of free space = $4\pi \times 10^{-7}$ H/m)

(a) $2 \times 10^{-3}\pi$ T (b) π T

(c) $10^{-4}\pi$ T (d) $\frac{\pi}{5}$ T

16. Given below are two statements :

Statement I : Biot-Savart's law gives us the expression for the magnetic field strength of an infinitesimal current element (Idl) of a current carrying conductor only.

Statement II : Biot-Savart's law is analogous to Coulomb's inverse square law of charge q, with the former being related to the field produced by a scalar source, Idl while the latter being produced by a vector source, q.

In light of above statements choose the most appropriate answer from the options given below.

(a) Both Statement I and Statement II are correct.

(b) Both Statement I and Statement II are incorrect.

(c) Statement I is correct and Statement II is incorrect.

(d) Statement I is incorrect and Statement II is correct.

17. A 72 Ω galvanometer is shunted by a resistance of 8 Ω. The percentage of the total current which passes through the galvanometer is

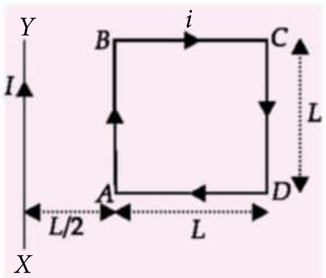
(a) 0.1% (b) 10%

(c) 25% (d) 0.25%

18. A galvanometer of resistance 50 Ω is connected to a battery of 3 V along with a resistance of 2950 Ω in series. A full scale deflection of 30 divisions is obtained in the galvanometer. In order to reduce this deflection to 20 divisions, the resistance in series should be

(a) 6050 Ω (b) 4450 Ω
(c) 5050 Ω (d) 5550 Ω

19. A square loop $ABCD$ carrying a current i, is placed near and coplanar with a long straight conductor XY carrying a current I, the net force on the loop will be



(a) $\frac{2\mu_0 IiL}{3\pi}$ (b) $\frac{\mu_0 IiL}{2\pi}$ (c) $\frac{2\mu_0 Ii}{3\pi}$ (d) $\frac{\mu_0 Ii}{2\pi}$

20. A proton, a deuteron and an α-particle are moving with same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them is ______ and their speed is _______, in the ratio.

(a) 4 : 2 : 1 and 2 : 1 : 1 (b) 1 : 2 : 4 and 1 : 1 : 2
(c) 2 : 1 : 1 and 4 : 2 : 1 (d) 1 : 2 : 4 and 2 : 1 : 1

SOLUTIONS

1. (b) : The kinetic energy acquired by a charged particle in a uniform magnetic field B is

$$K = \frac{q^2 B^2 R^2}{2m} \qquad \left(\text{as} \quad R = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}\right)$$

where q and m are the charge and mass of the particle and R is the radius of circular orbit.

∴ The kinetic energy acquired by proton is

$$K_p = \frac{q_p^2 B^2 R_p^2}{2m_p}$$

and that by the alpha particle is, $K_\alpha = \frac{q_\alpha^2 B^2 R_\alpha^2}{2m_\alpha}$

$$\text{Thus, } \frac{K_\alpha}{K_p} = \left(\frac{q_\alpha}{q_p}\right)^2 \left(\frac{m_p}{m_\alpha}\right)\left(\frac{R_\alpha}{R_p}\right)^2$$

$$\text{or } K_\alpha = K_p \left(\frac{q_\alpha}{q_p}\right)^2 \left(\frac{m_p}{m_\alpha}\right)\left(\frac{R_\alpha}{R_p}\right)^2$$

Here, $K_p = 1$ MeV, $\frac{q_\alpha}{q_p} = 2$, $\frac{m_p}{m_\alpha} = \frac{1}{4}$ and $\frac{R_\alpha}{R_p} = 1$

$$\therefore K_\alpha = (1 \text{ MeV})(2)^2 \left(\frac{1}{4}\right)(1)^2 = 1 \text{ MeV}$$

2. (c) : Here, $I = 10$A, $l = 5$ cm $= \frac{5}{100}$ m, $B = 0.5$ T, $\theta = 60°$

$$F = IlB\sin\theta = 10 \times \frac{5}{100} \times 0.5 \times \sin 60° = 0.216 \text{ N}$$

3. (a)

4. (b) : Let the radius of coils is R_1 and R_2

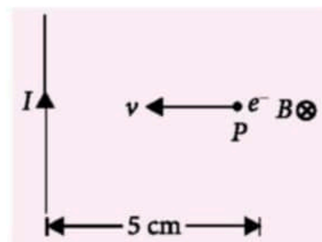
$2 \times 2\pi R_1 = 5 \times 2\pi R_2$

$2R_1 = 5R_2$ ...(i)

$$B_1 = 2 \times \frac{\mu_0 I}{2R_1}, B_2 = \frac{5\mu_0 I}{2R_2}; \frac{B_2}{B_1} = \frac{5}{2}\frac{R_1}{R_2} = \frac{5}{2} \times \frac{5}{2} \text{ (from (i))}$$

$$\frac{B_2}{B_1} = \frac{25}{4}$$

5. (b) : The situation is as shown in the figure.



Here, $v = 10^7$ m/s,

$B = 2 \times 10^{-4}$ Wb/m^2

The magnitude of the force experienced by the electron is

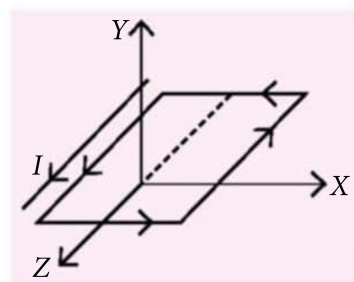
$F = evB\sin\theta$

(∵ $\vec{v}$ and $\vec{B}$ are perpendicular to each other)

$= evB \sin 90° = 1.6 \times 10^{-19} \times 10^7 \times 2 \times 10^{-4} \times 1$

$= 3.2 \times 10^{-16}$ N

6. (c) : The magnitude of torque on the loop is given by,



$\tau = MB \sin\theta$ ...(i)

Here, $M = IA = I(2a)^2$

and $B = \frac{\mu_0 I}{2\pi d} = \frac{\mu_0 I}{2\pi b}$ (∵ $d = b$)

From equation (i), $\tau = MB \sin 90°$

$$\tau = 4a^2 I \times \frac{\mu_0 I}{2\pi b} = \frac{2\mu_0 a^2 I^2}{\pi b}$$

7. (a) : As, the electron is moving in +x-axis and uniform magnetic field is in negative z-axis. So, electron will experience magnetic force along negative y-axis.

As, $\vec{F} = -e(\vec{v} \times \vec{B})$

Electron will move in a circular path in magnetic field.

8. (b) : Let l be the length of the wire. Magnetic field at the centre of the loop is

$$B = \frac{\mu_0 I}{2R} \quad \therefore \quad B = \frac{\mu_0 \pi I}{l} \quad (\because l = 2\pi R) \qquad \text{...(i)}$$

$$B' = \frac{\mu_0 nI}{2r} = \frac{\mu_0 nI}{2\left(\frac{l}{2n\pi}\right)} \text{ or } B' = \frac{\mu_0 n^2 \pi I}{l} \qquad \text{...(ii)}$$

From eqns. (i) and (ii), we get $B' = n^2 B$

9. (c) : Assertion A is incorrect because a voltmeter should have very high resistance.

10. (b) : When a current loop is placed in a magnetic field it experiences a torque. It is given by $\vec{\tau}=\vec{M}\times\vec{B}$ where, $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.
$\tau = MB\sin\theta$ where, θ is angle between $\vec{M}$ and $\vec{B}$
When $\vec{M}$ and $\vec{B}$ and are parallel (*i.e.*, $\theta = 0°$) the equilibrium is stable and when they are antiparallel (*i.e.*, $\theta = \pi$) the equilibrium is unstable.

11. (c)

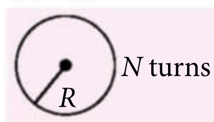
12. (c) : $I = 3\text{ A}, r=\frac{\pi}{10}\text{m}$

$B_1 = B_3 = 0$

$$B_2=\frac{\mu_0}{4\pi}\cdot\frac{\pi I}{r}=10^{-7}\times\frac{\pi\times 3}{\pi}\times 10=3\times 10^{-6}\text{ T}$$

$B_{net} = B_2 = 3\,\mu\text{T}$.

13. (b) : Here, number of turns in the solenoid,
$n = 100/1\text{ mm} = 100\times 10^3\text{ /m}$
Current in the solenoid, $I = 1$ A
Magnetic field strength at the centre of the solenoid, $B = \mu_0 nI$



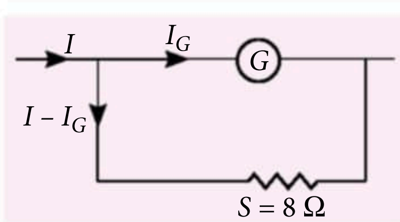
$$=4\pi\times 10^{-7}\times 10^5\times 1=12.56\times 10^{-2}\text{ T}$$

14. (c)

15. (b) : Number of turns per metre, $n = 1000$
Relative permeability, $\mu_r = 500$; Current, $I = 5$ A
Magnetic flux density produced by solenoid
$B = \mu_0\mu_r nI = 500\times 4\pi\times 10^{-7}\times 1000\times 5$
$= 10^7\times\pi\times 10^{-7} = \pi$ T

16. (c) : Statement I is correct, but statement II is incorrect because, the magnetic field is produced by vector source *Idl* and the coulomb's force is produced by scalar source *q*.

17. (b) : Given, $S = 8\ \Omega$ and $G = 72\ \Omega$
Therefore, equivalent circuit is shown in the figure.



Shunt resistance is given by,

$$S=\left(\frac{I_G}{I-I_G}\right)\times G$$

Total current passing the galvanometer,

$$\frac{I_G}{I}=\left(\frac{S}{G+S}\right)=\left(\frac{8}{72+8}\right)=\frac{1}{10}$$

$$\therefore\ \frac{I_G}{I}\times 100=\frac{1}{10}\times 100=10\%$$

18. (b)

19. (c) : Force on arm *AB* due to current in conductor *XY* is

$$F_1=\frac{\mu_0}{4\pi}\frac{2IiL}{(L/2)}=\frac{\mu_0 Ii}{\pi}$$

acting towards *XY* in the plane of loop.
Force on arm *CD* due to current in conductor *XY* is

$$F_2=\frac{\mu_0}{4\pi}\frac{2IiL}{3(L/2)}=\frac{\mu_0 Ii}{3\pi}$$

acting away from *XY* in the plane of loop.

$\therefore$ Net force on the loop $= F_1 - F_2$

$$=\frac{\mu_0 Ii}{\pi}\left[1-\frac{1}{3}\right]=\frac{2}{3}\frac{\mu_0 Ii}{\pi}$$

20. (c) :

	Charge	Mass
Proton	e	m
α-particle	$2e$	$4m$
Deuteron	e	$2m$

speed, $v = P/m$

$$v_1=\frac{P}{m},\ v_2=\frac{P}{2m},\ v_3=\frac{P}{4m}$$

$$\therefore\ v_1:v_2:v_3=4:2:1;\ F=qvB=\frac{qPB}{m}$$

$$F_1=\frac{qPB}{m},\ F_2=\frac{q\times P\times B}{2m},\ F_3=\frac{2qPB}{4m}$$

$$\therefore\ F_1:F_2:F_3=4:2:2=2:1:1$$

◈◈

CBSE Warm-up!

CLASS-XII

Chapterwise practice questions for CBSE Exams as per the latest pattern and syllabus by CBSE for the academic session 2024-25.

Series-4 Magnetism and Matter

General Instructions : Read the following instructions very carefully and follow them :

(1) This question paper contains 33 questions. **All questions are compulsory**.
(2) Question paper is divided into **FIVE** section – **Section A, B, C, D** and **E**.
(3) **Section A –** Question number **1** to **16** are Multiple Choice (MCQ) type questions. Each question carries 1 mark.
(4) **Section B –** Question number **17** to **21** are Very Short Answer type questions. Each question carries 2 mark.
(5) **Section C –** Question number **22** to **28** are Short Answer type questions. Each question carries 3 mark.
(6) **Section D –** Question number **29** and **30** are Case-Based questions. Each question carries 4 mark.
(7) **Section E –** Question number **31** to **33** are Long Answer type questions. Each question carries 5 mark.
(8) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section–A.
(9) Kindly note that there is a separate question paper for Visually Impaired candidates.
(10) Use of calculators is **NOT** allowed.
You may use the following values of physical constants wherever necessary :

(i)	$c = 3 \times 10^8$ m/s	(ii)	$h = 6.63 \times 10^{-34}$ Js	(iii)	$e = 1.6 \times 10^{-19}$C
(iv)	$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}	(v)	$\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}	(vi)	$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}
(vii)	Mass of electron (m_e) = 9.1×10^{-31} kg	(viii)	Mass of neutron = 1.675×10^{-27} kg	(ix)	Mass of proton = 1.673×10^{-27} kg
(x)	Avogadro's number = 6.023×10^{23} per gram mole			(xi)	Boltzmann constant = 1.38×10^{-23} JK^{-1}

Time Allowed : 3 hours **Maximum Marks :** 70

SECTION - A

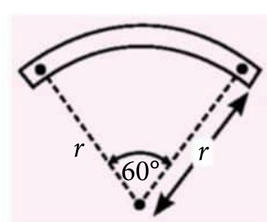
1. A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

(a) $2\sqrt{3}$ J (b) 3 J
(c) $\sqrt{3}$ J (d) $\frac{3}{2}$ J

2. A soft ferromagnetic material is placed in an external magnetic field. The magnetic domains
(a) decrease in size and changes orientation.
(b) increase in size but no change in orientation.
(c) may increase or decrease in size and change its orientation.
(d) have no relation with external magnetic field.

3. The magnetic susceptibility is negative for
(a) ferromagnetic material only
(b) paramagnetic and ferromagnetic materials
(c) diamagnetic material only
(d) paramagnetic material only

4. A bar magnet of length '*l*' and magnetic dipole moment '*M*' is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be



(a) $\frac{2}{\pi}M$ (b) $\frac{M}{2}$ (c) M (d) $\frac{3}{\pi}M$

5. The susceptibility of a magnetic material is 1.9×10^{-5}. The type of magnetic material it represents is

(a) Paramagnetic (b) Diamagnetic
(c) Ferromagnetic (d) Ferrimagnetic

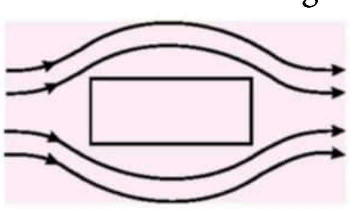
6. The magnetic lines of force inside a bar magnet
(a) are from north-pole to south-pole of the magnet
(b) do not exist
(c) depend upon the area of cross-section of the bar magnet
(d) are from south-pole to north-pole of the magnet.

7. If a diamagnetic substance is brought near the north or the south pole of a bar magnet, it is
(a) repelled by the north pole and attracted by the south pole
(b) attracted by the north pole and repelled by the south pole
(c) attracted by both the poles
(d) repelled by both the poles

8. A bar magnet of magnetic moment M is kept in uniform magnetic field of strength B, making an angle θ with its direction. The torque acting on it is
(a) MB (b) $MB \cos\theta$
(c) $MB(1 - \cos\theta)$ (d) $MB \sin\theta$

9. Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance respectively. A magnet when brought close to them will
(a) attract all three of them
(b) attract N_1 and N_2 strongly but repel N_3
(c) attract N_1 strongly, N_2 weakly and repel N_3 weakly
(d) attract N_1 strongly, but repel N_2 and N_3 weakly.

10. Which of the following cannot modify an external magnetic field as shown in the figure?



(a) Nickel (b) Silicon
(c) Sodium Chloride (d) Copper

11. A diamagnetic material in a magnetic field moves
(a) from stronger to the weaker parts of the field
(b) from weaker to the stronger parts of the field
(c) perpendicular to the field
(d) in none of the above directions.

12. A closely wound solenoid of 2000 turns and area of cross-section 1.5×10^{-4} m^2 carries a current of 2.0 A. It is suspended through its centre and perpendicular to its length, allowing it to turn in a horizontal plane in a uniform magnetic field 5×10^{-2} tesla making an angle of 30° with the axis of the solenoid. The torque on the solenoid will be
(a) 3×10^{-3} N m (b) 1.5×10^{-3} N m
(c) 1.5×10^{-2} N m (d) 3×10^{-2} N m

For Questions number 13 to 16, two statements are given –one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:
(a) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(b) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).
(c) If Assertion (A) is true and Reason (R) is false.
(d) If both Assertion (A) and Reason (R) are false.

13. Assertion : The properties of paramagnetic and ferromagnetic substance are not effected by heating.
Reason : As temperature rises, the alignment of molecular magnets gradually increases.

14. Assertion : Torque experience by the bar magnet is maximum when field is applied perpendicular to magnetic moment.
Reason : Torque on a bar magnet depends on the angle between applied magnetic field and magnetic dipole moment.

15. Assertion : For a perfectly diamagnetic substance permeability is zero.
Reason : The ability of a material to permit the passage of magnetic lines of force through it is called magnetic permeability.

16. Assertion : An unmagnetised piece of iron is attracted to a bar magnet.
Reason : An atom is equivalent to a current loop.

SECTION - B

17. (a) What is a magnetic dipole?
(b) A bar magnet of magnetic moment of 200 Am^2 suspended in a magnetic field of intensity 0.25 N/Am. Find the couple required to deflect it through 30°.

18. What are behaviour of magnetic field lines due to diamagnetic material?

OR

Three identical specimens of magnetic material nickel, antimony and aluminum are kept in a non-uniform magnetic field. Draw the modifications in the field lines in each case. Justify your answer.

19. What is Gauss's law of magnetism? What does it signify?

20. Is magnetic susceptibility of a diamagnetic substances depend upon temperature?

21. Draw the magnetic field lines for a U-shaped magnet.

SECTION - C

22. In what way is the behaviour of a diamagnetic material different from that of paramagnetic, when kept in an external magnetic field?

23. **(a)** Does every configuration have a north pole and a south pole?

(b) The force on a north pole, $\vec{F} = m\vec{B}$, is parallel to the field $\vec{B}$. Does it contradict our earlier knowledge that a magnetic field can exert forces only perpendicular to itself?

(c) Write two properties of magnetic field lines.

24. **(a)** The magnetic susceptibility of a paramagnetic substance at –173°C is 1.5×10^{-2} then what will be its value at –73°C ?

(b) From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism and ferromagnetism.

25. Two magnets are suspended by a given wire one by one. In order of deflect the first magnet through 45°, the wire has to be twisted through 540°, whereas with the second magnet, the wire requires a twist of 360° for the same deflection. Determine the ratio of magnetic moments of the two magnets.

OR

Two bar magnets are placed closed to each other with their opposite poles facing each other. In the absence of other forces, the magnets are pulled towards each other and their kinetic energy increases. Does it contradict our earlier knowledge that magnetic forces cannot do any work and hence cannot increase the kinetic energy of a system?

26. Explain the end effect in magnetism.

27. **(a)** Explain how magnetic dipole differ from electric dipole.

(b) Gauss law of magnetic states that net flux of magnetic field out any closed surface is always zero. But it is not necessarily zero for disk or square surface. Explain why?

28. **(a)** What are magnetic lines of force? Give their important properties.

(b) An iron needle is attracted to the ends of a bar magnet but not to the middle region of the magnet. Is the material making up the ends of a bar magnet different from that of the middle region?

SECTION - D

Case Study Based Questions

Question no. 29 to 30 are case based questions. Read the following paragraph and answer the questions that follow.

29. When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction of the field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called magnetic intensity (H).

$$H = \frac{B}{\mu_0} - M$$

where, M is the magnetisation of the material, μ_0 is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity appropriately called the magnetic susceptibility. For a certain class of magnetic materials, intensity of magnetisation is directly proportional to the magnetic intensity.

(i) Magnetization of a sample is

(a) volume of sample per unit magnetic moment
(b) net magnetic moment per unit volume
(c) ratio of magnetic moment and pole strength
(d) ratio of pole strength to magnetic moment.

(ii) Identify the wrongly matched quantity and unit pair.

(a) Pole strength – A m
(b) Magnetic susceptibility – Dimensionless
(c) Intensity of magnetisation – A m^{-1}
(d) Magnetic permeability – Henry m

(iii) A bar magnet has length 3 cm, cross-sectional area 2 cm^2 and magnetic moment 3 A m^2. The intensity of magnetisation of bar magnet is

(a) 2×10^5 A/m (b) 3×10^5 A/m
(c) 4×10^5 A/m (d) 5×10^5 A/m

(iv) The susceptibility of a ferromagnetic substance is

(a) > 1 (b) Zero (c) >>1 (d) < 1

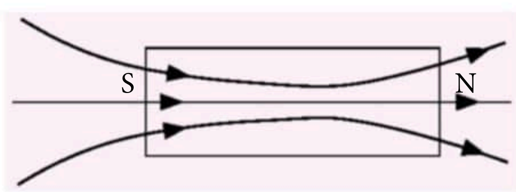
OR

The magnetic susceptibility of a paramagnetic material at −73°C is 0.0075 and its value at −173°C will be

(a) 0.0030 (b) 0.0075 (c) 0.0045 (d) 0.015

30. By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B} \cdot d\vec{s} = \mu_0 m_{\text{inside}}$ where $\oint \vec{B} \cdot d\vec{s}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface.

We do not have an isolated magnetic pole in nature. At least none has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



(i) Consider the two idealised systems

I. a parallel plate capacitor with large plates and small separation and

II. a long solenoid of length $L >> R$, radius of cross-section.

In I $\vec{E}$ is ideally treated as a constant between plates and zero outside. In II magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below

(a) case I contradicts Gauss's law for electrostatic fields.
(b) case II contradicts Gauss's law for magnetic fields.
(c) case I agrees with $\oint \vec{E} \cdot \vec{dl} = 0$.
(d) case II contradicts $\oint \vec{H} \cdot \vec{dl} = I_{en}$.

(ii) The net magnetic flux through any closed surface, kept in a magnetic field is

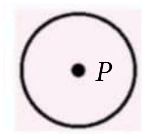
(a) zero (b) $\frac{\mu_0}{4\pi}$ (c) $4\pi\mu_0$ (d) $\frac{4\mu_0}{\pi}$

(iii) Which of the following is not a consequence of Gauss's law?

(a) The magnetic poles always exist as unlike pairs of equal strength.
(b) If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.
(c) There are abundant sources or sinks of the magnetic field inside a closed surface.
(d) Isolated magnetic poles do not exist.

OR

A perfectly diamagnetic sphere has a small spherical cavity at its centre, which is filled with a paramagnetic substance. The whole system is placed in a uniform magnetic field $\vec{B}$. Then the field inside the paramagnetic substance is



(a) $\vec{B}$ (b) Zero
(c) much large than $|\vec{B}|$ and parallel to $\vec{B}$
(d) much large than $|\vec{B}|$ but opposite to $\vec{B}$.

(iv) Which of the following statements is not correct about the magnetic field?

(a) Magnetic line of force don't cut each other
(b) Inside the magnet, the lines go from north to south pole of the magnet.
(c) The magnetic field lines form a closed loop.
(d) Tangents to the magnetic field lines give the direction of the magnetic field.

SECTION - E

31. (a) Write the four important properties of a bar magnet.

(b) A bar magnet of magnetic moment 6 J T^{-1} is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate (I) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (II) the torque on the magnet in the final orientation in case (ii).

OR

Write down the comparision between dia, para and ferromagnetic substance.

32. **(a)** (i) Can we have magnetic hysteresis in paramagnetic or diamagnetic substances?

(ii) State curie law in magnetism.

OR

(b) What are the dimensions of χ, the magnetic susceptibility? Consider an H-atom. Guess an expression for χ, upto a constant by constructing a quantity of dimensions of χ, out of parameters of the atom: e, m, v, R and μ_0. Here, m is the electronic mass, v is electronic velocity, R is Bohr radius. Estimate the number so obtained and compare with the value of $|\chi| \sim 10^{-5}$ for many solid materials.

33. **(a)** Derive the expression for the force acting between two long parallel current carrying conductors. Hence, define 1 A current.

(b) A bar magnet of dipole moment 3 Am^2 rests with its centre on a frictionless pivot. A force F is applied at right angles to the axis of the magnet, 10 cm from the pivot. It is observed that an external magnetic field of 0.25 T is required to hold the magnet in equilibrium at an angle of 30° with the field.

Calculate the value of F.

How will the equilibrium be effected if F is withdrawn ?

OR

(a) Show that a current carrying solenoid behaves like a small bar magnet. Obtain the expression for the magnetic field at an external point lying on its axis.

(b) A steady current of 2 A flows through a circular coil having 5 turns of radius 7 cm. The coil lies in X-Y plane with its centre at the origin. Find the magnitude and direction of the magnetic dipole moment of the coil.

SOLUTIONS

1. **(b) :** Work done in changing the orientation of a magnetic needle of magnetic moment M in a magnetic field B from position θ_1 to θ_2 is given by

$W = MB(\cos\theta_1 - \cos\theta_2)$

Here, $\theta_1 = 0°$, $\theta_2 = 60°$

$$= MB\left(1 - \frac{1}{2}\right) = \frac{MB}{2} \quad ...(i)$$

The torque on the needle is $\vec{\tau} = \vec{M} \times \vec{B}$

In magnitude,

$$\tau = MB\sin\theta = MB\sin 60° = \frac{\sqrt{3}}{2}MB \quad ...(ii)$$

Dividing (ii) by (i), we get

$$\frac{\tau}{W} = \sqrt{3} \text{ or } \tau = \sqrt{3}W = \sqrt{3} \times \sqrt{3}\text{ J} = 3\text{ J}$$

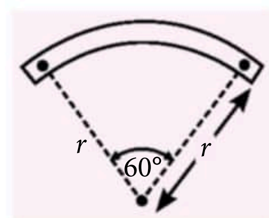
2. **(c) :** Soft ferromagnetic materials can easily magnetised and demagnetised. These materials, when placed in an external magnetic field, experiences net torque which can change the orientation. Also, when the domains are aligned along the magnetic field, the size will increase and when they are aligned opposite to the field the size will decrease.

3. **(c) :** Magnetic susceptibility is negative for diamagnetic material only.

4. **(d) :** Let m be strength of each pole of bar magnet of length l. Then,

$M = m \times l \quad ...(i)$

When the bar magnet is bent in the form of an arc as shown in figure. Then,



$$l = \frac{\pi}{3} \times r = \frac{\pi r}{3} \text{ or } r = \frac{3l}{\pi}$$

New magnetic dipole moment,

$M' = m \times 2r\sin 30°$

$$= m \times 2 \times \frac{3l}{\pi} \times \frac{1}{2} = \frac{3ml}{\pi} = \frac{3M}{\pi} \quad \text{(Using (i))}$$

5. **(a) :** It represents paramagnetic substance.

6. **(d) :** The magnetic lines of force inside a bar magnet are from south pole to north pole of magnet.

7. **(d) :** A diamagnet is always repelled by a magnetic field. Therefore, it is repelled by both the north pole as well as the south pole.

8. **(d) :** $\tau = MB\sin\theta$

9. **(c) :** Magnet will attract N_1 strongly, N_2 weakly and repel N_3 weakly.

10. **(d) :** As copper is diamagnetic, so the magnetic field lines do not pass through it.

MONTHLY TEST DRIVE CLASS XI ANSWER KEY

1. (d)	2. (d)	3. (c)	4. (b)	5. (a)
6. (b)	7. (a)	8. (b)	9. (a)	10. (d)
11. (a)	12. (d)	13. (a)	14. (a)	15. (c)
16. (d)	17. (c)	18. (b)	19. (a,b,c,d)	20. (a,b,d)
21. (b,d)	22. (a,b,c)	23. (b)	24. (3)	25. (3)
26. (0.95)	27. (c)	28. (d)	29. (b)	30. (a)

11. (a)

12. (c) : Magnetic moment of the loop

$M = NIA = 2000 \times 2 \times 1.5 \times 10^{-4} = 0.6$ J/T

Torque $\tau = MB\sin 30°$

$$= 0.6 \times 5 \times 10^{-2} \times \frac{1}{2} = 1.5 \times 10^{-2} \text{ Nm}$$

13. (d) : The properties of substance is due to alignment of molecules in it. When these substance are heated, molecules acquire some kinetic energy. Some of molecules may get back to the closed chain arrangement (produce zero resultant). So, they lose their magnetic property or magnetism. Therefore, the properties of both ferromagnetic and paramagnetic are effected by heating.

14. (a) : The torque on a bar magnet is given by

$\tau = MB \sin\theta$

where, M = magnetic dipole moment, B = uniform magnetic field. When $\theta = 90°$ then magnitude of the torque is maximum.

15. (b) : For a perfectly diamagnetic substance,

$B = \mu_0(H + I) = 0 \quad \therefore \quad I = -H$

$$\Rightarrow \chi_m = \frac{I}{H} = -1$$

Therefore, relative permeability

$\mu_r = 1 + \chi_m = 1 - 1 = 0$

$\therefore \ \mu = \mu_0\mu_r = \text{zero}.$

i.e. for a perfectly diamagnetic material permeability is zero.

16. (b) : Each atom behave as tiny magnet. In iron these atoms are randomly oriented, so that there is no net magnetism. But when unmagnetised iron is brought near the bar magnet, the current loops located at the ends of the bar magnet and the iron piece facing each other align themselves. When they do so, the currents in the current loops happen to be in the same direction and as a consequence, the attractive force occurs between the two.

17. (a) Two unlike poles of equal strength separated by some distance form a magnetic dipole.

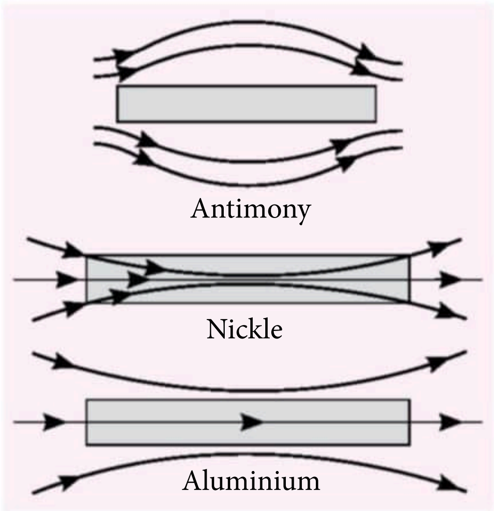
(b) Torque, $\tau = MB \sin\theta$

$= (200)\,(0.25) \sin 30° = 25$ Nm

18. A diamagnetic material tends to move from stronger to weaker regions of the magnetic field and hence, decreases the number of lines of magnetic field passing through it. Relative permeability is 1.

OR

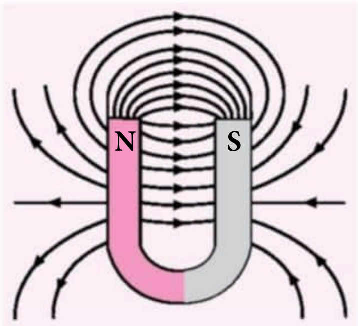
The modifications in field lines are shown in figure. This is because, Nickle is ferromagnetic, Antimony is diamagnetic and aluminum is paramagnetic.



19. The Gauss's law in magnetism states that the surface integral of a magnetic field over a closed surface is zero. Significance: Monopole does not exist.

20. Magnetic susceptibility of diamagnetic substances does not depend upon the temperature. Hence, it remain constant with the change in temperature.

21. The magnetic field lines due to a U-shaped magnet is shown in figure.



22. (i) A diamagnetic specimen would move towards the stronger to weaker region of the field, while a paramagnetic specimen would move towards the weaker to stronger region.

(ii) A diamagnetic specimen is repelled by a magnet while a paramagnetic specimen moves towards the magnet.

(iii) The paramagnetic gets aligned along the field and the diamagnetic is perpendicular to the field.

23. (a) Not necessarily, if the source of the field has a net non-zero magnetic moment.

(b) Yes, it seems to contradict with our earlier knowledge that a magnetic field can exert forces only perpendicular to it self.

Force, $\vec{F} = m\vec{B}$,

where, B is magnetic field and m is the magnetic charge. For a positive magnetic charge, force is along the magnetic field and for a negative magnetic charges, forces is opposite to the magnetic field. Thus, it contradicts the notion that a magnetic field can exert force only perpendicular to itself.

(c) (i) Two lines of force can never intersect each other. If they do so, then at point of intersection there will be two tangents which give two direction of magnetic field at same point which is practically not possible.

(ii) The lines of force behave like stretched rubber bands under tension *i.e.*, they have a tendency to contract longitudinally. The attraction between two unlike poles can be explained with the help of this property.

24. (a) For a paramagnetic substance, the magnetic susceptibility

$$\chi = \frac{C}{T} \Rightarrow \frac{\chi_1}{\chi_2} = \frac{T_2}{T_1}$$

Then, $\chi_2 = \chi_1 \frac{T_1}{T_2}$

Here, $\chi_1 = 1.5 \times 10^{-2}$,

$T_1 = 273 + 173 = 100$ K

$T_2 = 273 - 73 = 200$ K

$$\therefore \quad \chi_2 = 1.5 \times 10^{-2} \times \frac{100}{200} = 7.5 \times 10^{-3}$$

(b) Diamagnetism is due to orbital motion of electrons developing magnetic moments opposite to applied field and hence is not much affected by temperature.

Paramagnetism and ferromagnetism is due to alignment of atomic magnetic moments in the direction of the applied field. As temperature increases, this alignment is disturbed and hence susceptibilities of both decreases as temperature increases.

25. If C is torque per unit angular twist of the wire, then for a twist ϕ,

$\tau = C\phi = MB \sin\theta$

In the first case, $\theta = 540° - 45° = 495°$, $\theta_1 = 45°$

In the second case, $\theta = 360° - 45° = 315°$, $\theta_2 = 45°$

$\therefore \quad C(495°) = M_1 B \sin 45°$ ...(i)

and $C(315°) = M_2 B \sin 45°$ ...(ii)

Dividing (i) by (ii), we get $\frac{M_1}{M_2} = \frac{495}{315} = \frac{11}{7}$

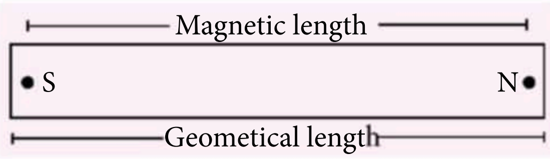
OR

Yes, it contradicts our earlier knowledge that negative forces cannot do any work and hence cannot increase the kinetic energy of the system. When opposite poles are facing each other, an attractive force acts between them so the magnets are pulled towards each other.

As the two magnets come close to each other so the force between them increases hence, the kinetic energy also increases.

26. At the two ends of the magnet, the current behaves differently. Because of this effect, the magnetic poles appear slightly inside the bar. The distance between the locations of the assumed poles is called the magnetic length of the magnet. The distance between the ends is called the geometrical length. It is found that

$$= \frac{\text{magnetic length}}{\text{geometrical length}} \approx 0.84$$



The magnetic moment of a bar magnet is conventionally denoted by M. Also, the magnetic length of a bar magnet is written as $2l$. If m be the pole strength and $2l$ the magnetic length of a bar magnet its magnetic moment is, $M = 2ml$

27. (a)

Magnetic dipole	Electric dipole
It consists of two equal and opposite poles which do not have separate existence.	It consists of two equal and opposite poles which do have separate existence.
Poles of a magnetic dipole not move independently.	Charges of an electric dipole can move independently.

(b) (i) Some examples of closed surfaces include the surface of a sphere, surface of a toroid and surface of a cube. The magnetic flux through any of these surfaces is zero. (ii) Some examples of non-closed surfaces include the disk surface, square surface or hemisphere surface. They all have boundaries and they do not fully enclosed in three dimensional. The magnetic flux through these surfaces is not necessarily zero.

28. (a) Magnetic line of force is an imaginary line representing the direction of magnetic field such that the target at any point is the direction of field vector at that point.

Properties:

(i) They choose, the path of least resistance between opposite magnetic poles.
(ii) In a single bar they form a closed loop from pole to pole.
(iii) They never cross one another.

(b) No, the material making up the middle region of a magnet is the same as that of material making up its end. When an iron needle is take closer to one of the ends of a magnet, the pole of the magnet induces opposite polarity on the needle.
But if we bring the needle closer to the centre of the magnet, then both the poles of the magnet will induce opposite polarity on the needle. As a result, the needles will not get attracted towards the centre of the magnet.

29. (i) (b) : $M = \frac{m(2l)}{V}$

(ii) (d) : Magnetic permeability - Henry m^{-1}.

(iii) (d) : Given, $l = 3$ cm, $A = 2$ cm^2, $M = 3$ A m^2

Intensity of magnetisation $= \frac{M}{lA}$

$$= \frac{3}{3\times10^{-2}\times2\times10^{-4}} = \frac{1}{2\times10^{-6}} = 0.5\times10^6 = 5\times10^5$$

(iv) (c) : For ferromagnetic substances, susceptibility is a large and positive value, *i.e.*, $\chi >> 1$

OR

(d) : The magnetic susceptibility (χ_m) of a paramagnetic substance is inversely proportional to absolute temperature T

$$\therefore \quad \chi_2 = \chi_1 \quad \therefore \quad \chi_2 = \chi_1 \frac{T_1}{T_2}$$

Here, $\chi_1 = 0.0075$

$T_1 = -73°C = (273 - 73)$ K $= 200$ K

$T_2 = -173°C = (273 - 173)$ K $= 100$ K

$$\therefore \quad \chi_2 = (0.0075)\left(\frac{200\text{ K}}{100\text{ K}}\right) = 0.015$$

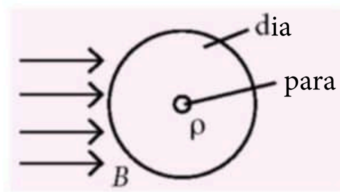
30. (i) (b) : According to Gauss's law in magnetism $\oint \vec{B}\cdot\vec{dS} = 0$, which implies that number of magnetic field lines entering the Gaussian surface is equal to the number of magnetic field lines leaving it. Therefore, case II is not possible.

(ii) (a) : The net magnetic flux through a closed surface will be zero, *i.e.* $\oint \vec{B}\cdot d\vec{s} = 0$, because there are no magnetic monopoles.

(iii) (c) : Gauss's law indicates that there are no sources or sinks of the magnetic field inside a closed surface. In other words, there are no free magnetic charges.

OR

(b) : When the magnetic field is applied across a diamagnetic substance, the magnetic field is produced in opposite direction, so the field inside the paramagnetic substance is zero.



(iv) (b) : Inside the magnet, the field line go from south pole to the north pole.

31. (a) : *Refer solution no. 23, Page no. 231, Class-12, MTG 100 percent Physics 2024-2025.*

OR

(b) *Refer solution no. 16, Page no. 241, Class-12, MTG 100 percent Physics 2024-2025.*

32. (a) : *Refer solution no. 15, Page no. 240-241, Class-12, MTG 100 percent Physics 2024-2025.*

OR

(b) *Refer solution no. 17, Page no. 241, Class-12, MTG 100 percent Physics 2024-2025.*

33. (a) : *Refer solution no. 6, Page no. 136, Class-12, MTG CBSE Champion Physics 2025.*

OR

(b) *Refer solution no. 7, Page no. 136, Class-12, MTG CBSE Champion Physics 2025.*

SOLUTIONS TO AUGUST 2024 QUIZ CLUB

1. Heinrich Hertz
2. Nuclear Fission
3. Mercury vapor and argon gas
4. Bernoulli's principle
5. High refractive index
6. it has no atmosphere
7. Increases
8. Ultra violet radiation
9. North-South
10. Outer zone
11. Faraday's law of electromagnetic induction
12. Doppler's effect
13. Solar cells
14. to flow in one direction
15. Graphite
16. Pumping
17. Gramophone
18. 54 MHz to 890 MHz
19. Cassini
20. Black
21. Crystal oscillator

Winner : *Prakash chugh, Uttar pradesh*

Class XII

Monthly test drive

This specially designed column enables students to self analyse their extent of understanding of specific chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Electrostatics

Time : 60 Min **Total Marks :** 120

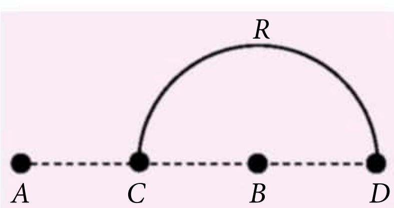
NEET

Only One Option Correct Type

1. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre

(a) decreases as r increases for $r < R$ and for $r > R$
(b) increases as r increases for $r < R$ and for $r > R$
(c) zero as r increases for $r < R$, decreases as r increases for $r > R$
(d) zero as r increases for $r < R$, increases as r increases for $r > R$.

2. Charges $+q$ and $-q$ are placed at points A and B respectively which are at distance $2L$ apart, C is the midpoint between A and B. The work done in moving a charge $+Q$ along the semicircle CRD is



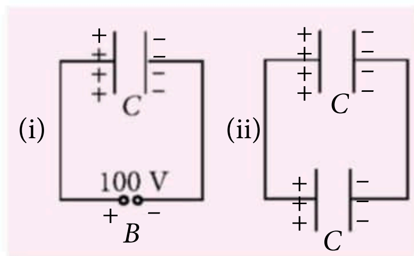
(a) $\frac{qQ}{2\pi\varepsilon_0 L}$ (b) $\frac{qQ}{6\pi\varepsilon_0 L}$

(c) $-\frac{qQ}{6\pi\varepsilon_0 L}$ (d) $\frac{qQ}{4\pi\varepsilon_0 L}$

3. Two charged spherical conductors of radius R_1 and R_2 are connected by a wire. Then the ratio of surface charge densities of the spheres (σ_1/σ_2) is

(a) $\frac{R_1^2}{R_2^2}$ (b) $\frac{R_1}{R_2}$ (c) $\frac{R_2}{R_1}$ (d) $\sqrt{\left(\frac{R_1}{R_2}\right)}$

4. A capacitor of capacitance C = 900 pF is charged fully by 100 V battery B as shown in figure (i). Then it is disconnected from the battery and connected to another uncharged capacitor of capacitance C = 900 pF as shown in figure (ii). The electrostatic energy stored by the system (ii) is



(a) 4.5×10^{-6} J (b) 3.25×10^{-6} J
(c) 2.25×10^{-6} J (d) 1.5×10^{-6} J

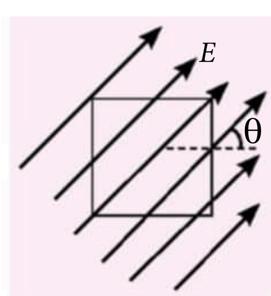
5. An electric dipole is placed at an angle of 30° with an electric field of intensity 2×10^5 N C^{-1}. It experiences a torque equal to 4 Nm. Calculate the magnitude of charge on the dipole, if the dipole length is 2 cm.

(a) 4 mC (b) 2 mC (c) 8 mC (d) 6 mC

6. The capacitance of a parallel plate capacitor with air as medium is 6 μF. With the introduction of a dielectric medium, the capacitance becomes 30 μF. The permittivity of the medium is
$(\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2})$

(a) $0.44 \times 10^{-13}\ C^2\ N^{-1}\ m^{-2}$
(b) $1.77 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$
(c) $0.44 \times 10^{-10}\ C^2\ N^{-1}\ m^{-2}$
(d) $5.00\ C^2\ N^{-1}\ m^{-2}$

7. A square surface of side L meter in the plane of the paper is placed in a uniform electric field E (volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure.



The electric flux linked to the surface, in units of volt m is

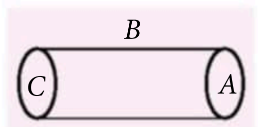
(a) EL^2 (b) $EL^2 \cos\theta$

(c) $EL^2 \sin\theta$ (d) zero

8. An electric dipole of moment $\vec{p}$ is lying along a uniform electric field $\vec{E}$. The work done in rotating the dipole by 90° is

(a) pE (b) $\sqrt{2}pE$ (c) $pE/2$ (d) $2pE$

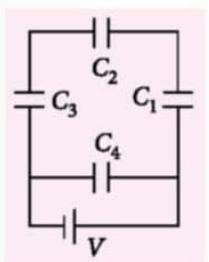
9. A hollow cylinder has a charge q coulomb within it. If ϕ is the electric flux in units of volt meter associated with the curved surface B, the flux linked with the plane surface A in units of V-m will be



(a) $\frac{q}{2\varepsilon_0}$ (b) $\frac{\phi}{3}$

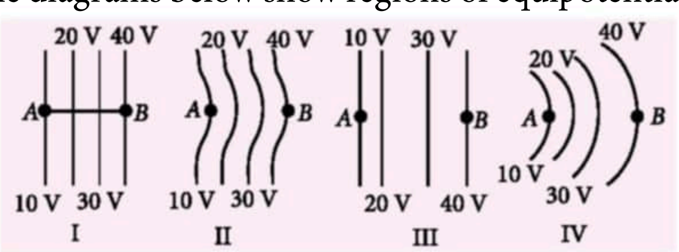
(c) $\frac{q}{\varepsilon_0} - \phi$ (d) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

10. A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are connected to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is



(a) 4/7 (b) 3/22 (c) 7/4 (d) 22/3

11. The diagrams below show regions of equipotentials.



A positive charge is moved from A to B in each diagram.

(a) In all the four cases the work done is the same.

(b) Minimum work is required to move q in figure (I).

(c) Maximum work is required to move q in figure (II).

(d) Maximum work is required to move q in figure (III).

12. Two point charges A and B, having charges $+Q$ and $-Q$ respectively, are placed at certain distance apart and force acting between them is F. If 25% charge of A is transferred to B, then force between the charges becomes

(a) $\frac{4F}{3}$ (b) F (c) $\frac{9F}{16}$ (d) $\frac{16F}{9}$

Assertion & Reason Type

Directions : In questions 13 to 15, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If both assertion and reason are false.

13. Assertion : Three equal charges are situated on a circle of radius r such that they form on equilateral triangle, then the electric field intensity at the centre is zero.

Reason : The force on unit positive charge at the centre, due to the three equal charges are represented by the three sides of a triangle taken in the same order. Therefore, electric field intensity at centre is zero.

14. Assertion : If a dielectric is placed in external field then field inside dielectric will be less than applied field.

Reason : Electric field will induce dipole moment opposite to field direction.

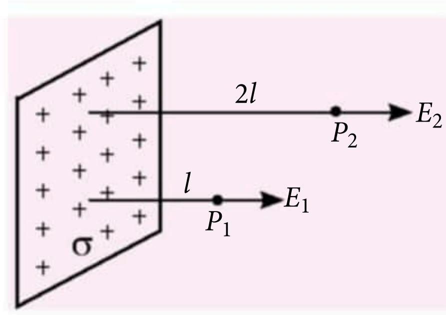
15. Assertion : Two adjacent conductors, carrying the same positive charge have no potential difference between them.

Reason : The potential of a conductor does not depend upon the charge given to it.

JEE (MAIN & ADVANCED)

Only One Option Correct Type

16. In the figure, a very large plane sheet of positive charge is shown. P_1 and P_2 are two points at distance l and $2l$ from the charge distribution. If σ is the surface charge density, then the magnitude of electric fields E_1 and E_2 at P_1 and P_2 respectively are



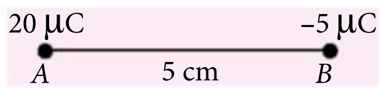
(a) $E_1 = \sigma/\varepsilon_0$, $E_2 = \sigma/2\varepsilon_0$

(b) $E_1 = 2\sigma/\varepsilon_0$, $E_2 = \sigma/\varepsilon_0$

(c) $E_1 = E_2 = \sigma/2\varepsilon_0$

(d) $E_1 = E_2 = \sigma/\varepsilon_0$

17. Two particles A and B having charges 20 μC and −5 μC respectively are held fixed with a separation of 5 cm. At what position a third charged particle should be placed so that it does not experience a net electric force?

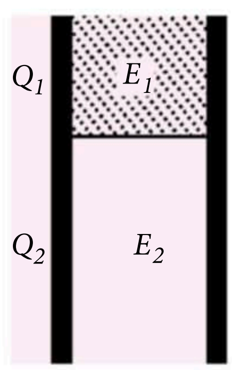


(a) At 5 cm from −5 μC on the right side.
(b) At 5 cm from 20 μC on the left side of system.
(c) At 1.25 cm from a −5 μC between two charges.
(d) At midpoint between two charges.

18. In finding the electric field using Gauss law the formula $|\vec{E}| = \dfrac{q_{enc}}{\varepsilon_0 |A|}$ is applicable. In the formula ε_0 is permittivity of free space, A is the area of Gaussian surface and q_{enc} is charge enclosed by the Gaussian surface. This equation can be used in which of the following situation?
(a) For any choice of Gaussian surface.
(b) Only when the Gaussian surface is an equipotential surface.
(c) Only when the Gaussian surface is an equipotential surface and $|\vec{E}|$ is constant on the surface.
(d) Only when $|\vec{E}|$ = constant on the surface.

More than One Option Correct Type

19. A parallel plate capacitor has a dielectric slab of dielectric constant K between its plates that covers 1/3 of the area of its plates, as shown in the figure. The total capacitance of the capacitor is C while that of the portion with dielectric in between is C_1. When the capacitor is charged, the plate area covered by the dielectric gets charge Q_1 and the rest of the area gets charge Q_2. The electric field in the dielectric is E_1 and that in the other portion is E_2. Choose the correct option/options, ignoring edge effects.

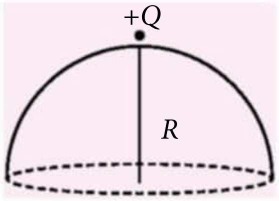


(a) $\dfrac{E_1}{E_2} = 1$ (b) $\dfrac{E_1}{E_2} = \dfrac{1}{K}$
(c) $\dfrac{Q_1}{Q_2} = \dfrac{3}{K}$ (d) $\dfrac{C}{C_1} = \dfrac{2+K}{K}$

20. Two non-conducting solid spheres of radii R and $2R$, having uniform volume charge densities ρ_1 and ρ_2 respectively, touch each other. The net electric field at a distance $2R$ from the centre of the smaller sphere, along the line joining the centres of the spheres, is zero. The ratio $\dfrac{\rho_1}{\rho_2}$ can be
(a) −4 (b) $-\dfrac{32}{25}$ (c) $\dfrac{32}{25}$ (d) 4

21. Two identical non-conducting solid spheres of same mass and charge are suspended in air from a common point by two non-conducting, massless strings of same length. At equilibrium, the angle between the strings is α. The spheres are now immersed in a dielectric liquid of density 800 kg m^{-3} and dielectric constant 21. If the angle between the strings remains the same after the immersion, then
(a) electric force between the spheres remains unchanged
(b) electric force between the spheres reduces
(c) mass density of the spheres is 840 kg m^{-3}
(d) the tension in the strings holding the spheres remains same.

22. A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct?



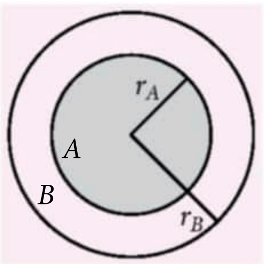
(a) The circumference of the flat surface is an equipotential.

(b) The component of the electric field normal to the flat surface is constant over the surface.

(c) Total flux through the curved and the flat surfaces is $\frac{Q}{\varepsilon_0}$.

(d) The electric flux passing through the curved surface of the hemisphere is $-\frac{Q}{2\varepsilon_0}\left(1-\frac{1}{\sqrt{2}}\right)$.

23. In the figure, the inner (shaded) region A represents a sphere of radius $r_A = 1$, within which the electrostatic charge density varies with the radial distance r from the center as $\rho_A = kr$, where k is positive.



In the spherical shell B of outer radius r_B, the electrostatic charge density varies as $\rho_B = \frac{2k}{r}$.
Assume that dimensions are taken care of. All physical quantities are in their SI units.
Which of the following statement(s) is(are) correct?

(a) If $r_B = \sqrt{\frac{3}{2}}$, then the electric field is zero everywhere outside B.

(b) If $r_B = 3/2$, then the electric potential just outside B is $\frac{k}{\varepsilon_o}$.

(c) If $r_B = 2$, then the total charge of the configuration is $15\pi k$.

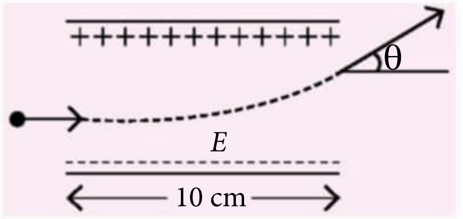
(d) If $r_B = 5/2$, then the magnitude of the electric field just outside B is $\frac{13\pi k}{\varepsilon_o}$.

Integer/Numerical Value Type

24. An electric dipole of dipole moment is 6.0×10^{-6} C m placed in a uniform electric field of 1.5×10^3 N C^{-1} in such a way that dipole moment is along electric field. The work done in rotating dipole by 180° in this field will be ______ m J.

25. Three point charges of magnitude 5 μC, 0.16 μC and 0.3 μC are located at the vertices A, B, C of a right angled triangle whose sides are AB = 3 cm, $BC = 3\sqrt{2}$ cm and CA = 3 cm and point A is the right angle corner. Charge at point A experiences ______ N of electrostatic force due to the other two charges.

26. A uniform electric field of 10 N/C is created between two parallel charged plates (as shown in figure). An electron enters the field symmetrically between the plates with a kinetic energy 0.5 eV. The length of each plate is 10 cm. The angle (θ) of deviation of the path of electron as it comes out of the field is ______ (in degree).



Comprehension Type

Consider a simple RC circuit as shown in figure 1.

Process 1 : In the circuit the switch S is closed at $t = 0$ and the capacitor is fully charged to voltage V_0 (*i.e.*, charging continues for time $T >> RC$). In the process some dissipation (E_D) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is E_C.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time $T >> RC$. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time $T >> RC$. The process is repeated one more time by raising the voltage to V_0 and the capacitor is charged to the same final voltage V_0 as in Process 1.

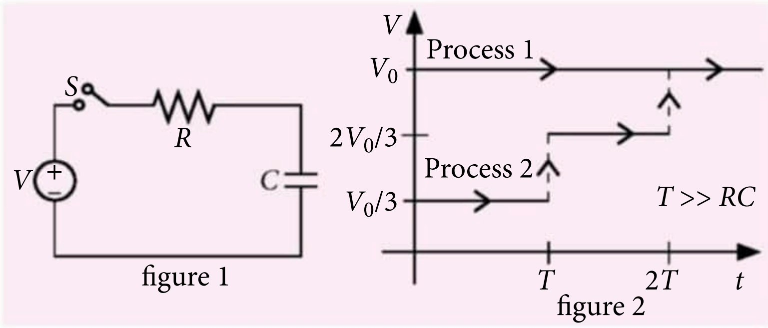
These two processes are depicted in figure 2.

UNSCRAMBLED WORDS

AUGUST 2024

1-c-GEOSTATIONARY	2-h-ISOTROPIC
3-f-COPERNICUS	4-i-CONTINUOUS
5-g-WATT METER	6-a-DOPING
7-j-RAYLEIGH	8-d-CONDUCTANCE
9-e-DEMODULATION	10-b-CONDENSATION

Winner : *Sonam Biswas, Kolkata*



27. In Process 2, total energy dissipated across the resistance E_D is

(a) $E_D = 3\left(\frac{1}{2}CV_0^2\right)$ (b) $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

(c) $E_D = 3CV_0^2$ (d) $E_D = \frac{1}{2}CV_0^2$

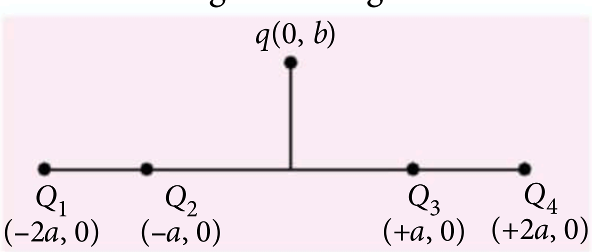
28. In process 1, the energy stored in the capacitor E_C and heat dissipated across resistance E_D are related by

(a) $E_C = E_D$ (b) $E_C = E_D \ln 2$

(c) $E_C = 2E_D$ (d) $E_C = \frac{1}{2}E_D$

Matrix Match Type

29. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x-axis at $x = -2a, -a, +a$ and $+2a$ respectively. A positive charge q is placed on the positive y-axis at a distance $b > 0$. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists.



	List-I		List-II
A.	Q_1, Q_2, Q_3, Q_4 all positive	p.	$+x$
B.	Q_1, Q_2 positive; Q_3, Q_4 negative	q.	$-x$
C.	Q_1, Q_4 positive; Q_2, Q_3 negative	r.	$+y$
D.	Q_1, Q_3 positive; Q_2, Q_4 negative	s.	$-y$

(a) A → r; B → p; C → s; D → q
(b) A → s; B → q; C→ r; D → p
(c) A → r; B → p; C → q; D → s
(d) A → s; B → q; C → p; D → r

30. The electric field E is measured at a point $P(0, 0, d)$ generated due to various charge distributions and the dependence of E on d is found to be different for different charge distributions. List-I contains different relations between E and d. List-II describes different electric charge distributions, along with their locations. Match the functions in List-I with the related charge distributions in List-II.

	List-I		List-II
A.	E is independent of d	p.	A point charge Q at the origin
B.	$E \propto \frac{1}{d}$	q.	A small dipole with point charges Q at $(0, 0, l)$ and $-Q$ at $(0, 0, -l)$. Take $2l << d$
C.	$E \propto \frac{1}{d^2}$	r.	An infinite line charge coincident with the x-axis, with uniform linear charge density λ
D.	$E \propto \frac{1}{d^3}$	s.	Two infinite wires carrying uniform linear charge density parallel to the x- axis. The one along ($y = 0, z = l$) has a charge density $+\lambda$ and the one along ($y = 0, z = -l$) has a charge density $-\lambda$. Take $2l << d$
		t.	Infinite plane charge coincident with the xy-plane with uniform surface charge density

(a) A → t; B → r, s; C → p; D → q
(b) A → t; B → r; C → p, s; D → q
(c) A → t; B → r; C → p, q; D → s
(d) A → s; B → q, r; C → p; D → t

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ……
No. of questions correct ……
Marks scored in percentage ……

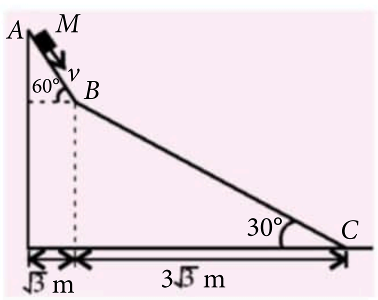
Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

JEE WORK OUTS

COMPREHENSION : PASSAGE TYPE

Passage 1 : A small block of mass M moves on a frictionless surface of an inclined plane, as shown in the figure. The angle of the incline suddenly changes from 60° to 30° at point B. The block is initially at rest at A. Assume that collisions between the block and the incline are totally inelastic ($g = 10$ m/s^2)



1. The speed of the block at point B immediately after it strikes the second incline is
(a) $\sqrt{60}$ m/s (b) $\sqrt{45}$ m/s
(c) $\sqrt{30}$ m/s (d) $\sqrt{15}$ m/s

2. The speed of the block at point C, immediately before it leaves the second incline is
(a) $\sqrt{120}$ m/s (b) $\sqrt{105}$ m/s
(c) $\sqrt{90}$ m/s (d) $\sqrt{75}$ m/s

3. If the collision between the block and the incline is completely elastic, then the vertical (upward) component of the velocity of the block at point B, immediately after it strikes the second incline is
(a) $\sqrt{30}$ m/s (b) $\sqrt{15}$ m/s
(c) 0 (d) $-\sqrt{15}$ m/s

Passage 2 : A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers' usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformers at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers the dissipation is much smaller. In this method, a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers' end, a step-down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with a power factor unity. All the currents and voltages mentioned are rms values.

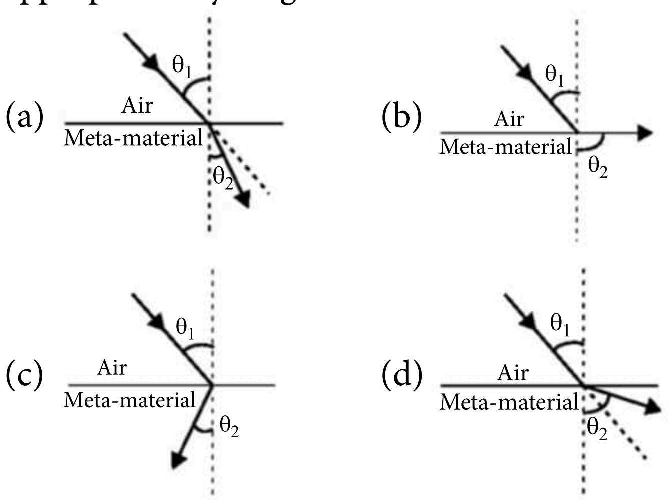
4. In the method using the transformers, assume that the ratio of the number of turns in the primary to that in the secondary in the step-up transformer is 1 : 10. If the power to the consumers has to be supplied at 200 V, the ratio of the number of turns in the primary to that in the secondary in the step-down transformer is
(a) 200 : 1 (b) 150 : 1
(c) 100 : 1 (d) 50 : 1

5. If the direct transmission method with a cable of resistance 0.4 W km^{-1} is used, the power dissipation (in %) during transmission is
(a) 20 (b) 30 (c) 40 (d) 50

Passage 3 : Most materials have the refractive index, $n > 1$. So, when a light ray from air enters a naturally occurring material, then by Snell's law, $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$, it is understood that the refracted ray bends towards the normal. But it never emerges on the same side of the normal as the incident ray. According to electromagnetism, the refractive index of the medium is given by the relation, $n = \left(\frac{c}{v}\right) = \pm\sqrt{\varepsilon_r \mu_r}$, where c is the speed of electromagnetic waves in vacuum, v its speed in the medium, ε_r and μ_r are the relative permittivity and permeability of the medium respectively.

In normal materials, both ε_r and μ_r are positive, implying positive n for the medium. When both ε_r and μ_r are negative, one must choose the negative root of n. Such negative refractive index materials can now be artificially prepared and are called meta-materials. They exhibit significantly different optical behaviour, without violating any physical laws. Since n is negative, it results in a change in the direction of propagation of the refracted light. However, similar to normal materials, the frequency of light remains unchanged upon refraction even in meta-materials.

6. For light incident from air on a meta-material, the appropriate ray diagram is



7. Choose the correct statement.

(a) The speed of light in the meta-material is $v = c|n|$.

(b) The speed of light in the meta-material is $v = \frac{c}{|n|}$.

(c) The speed of light in meta-material is $v = c$.

(d) The wavelength of the light in the meta-material (λ_m) is given by $\lambda_m = \lambda_{air}|n|$, where λ_{air} is the wavelength of the light in air.

Passage 4 : When liquid medicine of density ρ is to be put in the eye, it is done with the help of a dropper. As the bulb on the top of the dropper is pressed, a drop forms at the opening of the dropper. We wish to estimate the size of the drop. We first assume that the drop formed at the opening is spherical because that requires a minimum increase in its surface energy. To determine the size, we calculate the net vertical force due to the surface tension T when the radius of the drop is R. When this force becomes smaller than the weight of the drop, the drop gets detached from the dropper.

8. If the radius of the opening of the dropper is r, the vertical force due to the surface tension on the drop of radius R (assuming $r << R$) is

(a) $2\pi rT$ (b) $2\pi RT$

(c) $\frac{2\pi r^2 T}{R}$ (d) $\frac{2\pi R^2 T}{r}$.

9. If $r = 5 \times 10^{-4}$ m, $\rho = 10^3$ kgm^{-3}, $g = 10$ ms^{-2}, $T = 0.11$ Nm^{-1}, the radius of the drop when it detaches from the dropper is approximately

(a) 1.4×10^{-3} m (b) 3.3×10^{-3} m

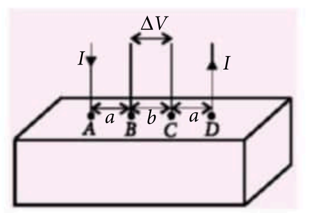
(c) 2.0×10^{-3} m (d) 4.1×10^{-3} m.

10. After the drop detaches, its surface energy is

(a) 1.4×10^{-6} J (b) 2.7×10^{-6} J

(c) 5.4×10^{-6} J (d) 8.1×10^{-6} J.

Passage 5 : Consider a block of conducting material of resistivity ρ shown in the figure. Current I enters at A and leaves from D. We apply superposition principle to find voltage ΔV developed between B and C.



The calculation is done in the following steps :

(i) Take current I entering from A and assume it to spread over a hemispherical surface in the block.

(ii) Calculate field $E(r)$ at distance r from A by using Ohm's law $E = \rho j$, where j is the current per unit area at r.

(iii) From the r dependence of $E(r)$, obtain the potential $V(r)$ at r.

(iv) Repeat (i), (ii) and (iii) for current I leaving D and superpose results for A and D.

11. ΔV measured between B and C is

(a) $\frac{\rho I}{2\pi(a-b)}$ (b) $\frac{\rho I}{\pi a} - \frac{\rho I}{\pi(a+b)}$

(c) $\frac{\rho I}{a} - \frac{\rho I}{(a+b)}$ (d) $\frac{\rho I}{2\pi a} - \frac{\rho I}{2\pi(a+b)}$

12. For current entering at A, the electric field at a distance r from A is

(a) $\frac{\rho I}{4\pi r^2}$ (b) $\frac{\rho I}{8\pi r^2}$

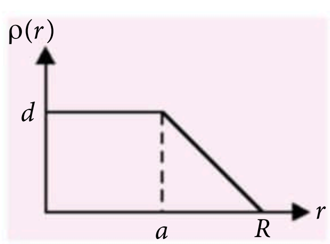
(c) $\frac{\rho I}{r^2}$ (d) $\frac{\rho I}{2\pi r^2}$

Passage 6 : The β-decay process, discovered around 1900, is basically the decay of a neutron (n). In the laboratory, a proton (p) and an electron (e^-) are observed as the decay products of the neutron. Therefore, considering the decay of a neutron as a two-body decay process, it was predicted theoretically that the kinetic energy of the electron should be constant. But experimentally, it was observed that the electron kinetic energy has a continuous spectrum. Considering a three-body decay process, *i.e.*, $n \to p + e^- + \bar{\upsilon}_e$, around 1930, Pauli explained the observed electron energy spectrum. Assuming the anti-neutrino ($\bar{\upsilon}_e$) to be massless and possessing negligible energy, and the neutron to be at rest, momentum and energy conservation principles are applied. From this calculation, the maximum kinetic energy of the electron is 0.8×10^6 eV. The kinetic energy carried by the proton is only the recoil energy.

13. If the anti-neutrino had a mass of 3 eV/c^2 (where c is the speed of light) instead of zero mass, what should be the range of the kinetic energy, K, of the electron?
(a) $0 \le K \le 0.8 \times 10^6$ eV
(b) $3.0 \text{ eV} \le K \le 0.8 \times 10^6$ eV
(c) $3.0 \text{ eV} \le K < 0.8 \times 10^6$ eV
(d) $0 \le K < 0.8 \times 10^6$ eV

14. What is the maximum energy of the anti-neutrino?
(a) Zero
(b) Much less than 0.8×10^6 eV.
(c) Nearly 0.8×10^6 eV.
(d) Much larger than 0.8×10^6 eV.

Passage 7 : The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density $\rho(r)$ (charge per unit volume) is dependent only on the radial distance r from the centre of the nucleus as shown in figure. The electric field is only along the radial direction.



15. The electric field at $r = R$ is
(a) independent of a
(b) directly proportional to a
(c) directly proportional to a^2
(d) inversely proportional to a

16. For $a = 0$, the value d (maximum value of ρ as shown in the figure) is
(a) $\frac{3Ze}{4\pi R^3}$ (b) $\frac{3Ze}{\pi R^3}$ (c) $\frac{4Ze}{3\pi R^3}$ (d) $\frac{Ze}{3\pi R^3}$

17. The electric field within the nucleus is generally observed to be linearly dependent on r. This implies
(a) $a = 0$ (b) $a = \frac{R}{2}$ (c) $a = R$ (d) $a = \frac{2R}{3}$

Passage 8 : Waves $y_1 = A\cos(0.5\pi x - 100\pi t)$ and $y_2 = A\cos(0.46\pi x - 92\pi t)$ are travelling along x-axis. (Here x is in m and t in second)

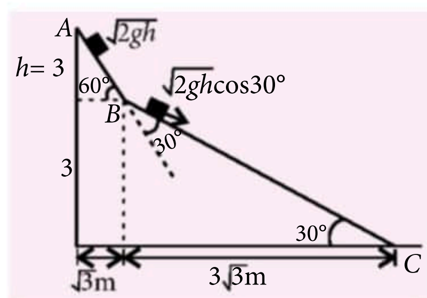
18. Find the number of times intensity is maximum in time interval of 1 sec.
(a) 4 (b) 6 (c) 8 (d) 10.

19. The wave velocity of louder sound is
(a) 100 m/s (b) 192 m/s
(c) 200 m/s (d) 96 m/s.

20. The number of times $y_1 + y_2 = 0$ at $x = 0$ in 1 sec is
(a) 100 (b) 46 (c) 192 (d) 96.

SOLUTIONS

1. (b): At point B the block has an inelastic collision with the incline, so component of velocity perpendicular to incline plane becomes zero and component parallel to second surface is retained.



Velocity immediately after it strikes the second line,

$$v = \sqrt{2gh}\cos 30° = \sqrt{2\times10\times3}\times\frac{\sqrt{3}}{2} = \sqrt{45} \text{ m/s.}$$

2. (b): Mechanical energy conservation between point B and C gives

$$v_C^2 = v_B^2 + 2gh$$

or $v_C^2 = 45 + 2\times10\times3 \Rightarrow v_C = \sqrt{105}$ m/s.

3. (c) : The velocity of the block coming down from the incline AB makes an angle 30° with the incline BC. If the block collides with the incline BC elastically, the angle of velocity of the block after collision with the incline shall be 30°.
Hence, just after collision with incline BC the velocity of block shall be horizontal. So, immediately after the block strikes the second incline, its vertical component of velocity will be zero.

4. (a) : For a step-up transformer,

Here, $\frac{N_p}{N_s} = \frac{1}{10}$, $V_p = 4000$ V

$\therefore \quad V_s = V_p \frac{N_s}{N_p} = (4000 \text{ V}) = 40{,}000$ V

For a step-down transformer,

Here, $\frac{N_p}{N_s} = ?$, $V_p = 40{,}000$ V, Vs = 200 V

$$\therefore \quad \frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{40{,}000 \text{ V}}{200 \text{ V}} = \frac{200}{1}$$

5. (b)

6. (c) : For meta-material, the refractive index is negative. Let n_1 is refractive index of air and n_2 is refractive index of meta-material.

$\therefore$ From Snell's law, $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$

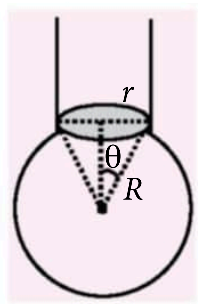
Since, n_2 is negative, therefore θ_2 is also negative. Hence, appropriate diagram (c) is correct.

7. (b): Refractive index for a medium $n = \left(\frac{c}{v}\right)$

For meta material, $n = |n|$ $\quad \therefore \quad v = \frac{c}{|n|}$

8. (c) : The vertical force due to the surface tension on the drop,

$= T2\pi r\sin\theta = T2\pi r\frac{r}{R} = \frac{2\pi r^2 T}{R}$



9. (a) : $\frac{2\pi r^2 T}{R} = mg = \frac{4}{3}\pi R^3 \rho g$

or $\quad R^4 = \frac{3}{2}\frac{r^2 T}{\rho g}$, $R = \left(\frac{3}{2}\frac{r^2 T}{\rho g}\right)^{1/4}$

Substituting the given values, we get

$$R = \left(\frac{3\times5\times10^{-4}\times5\times10^{-4}\times0.11}{2\times10^{3}\times10}\right)^{1/4} = 1.4\times10^{-3} \text{ m}$$

10. (b): Surface energy = $4\pi R^2 T$

Here, $R = 1.4 \times 10^{-3}$ m

$T = 0.11$ N m^{-1} (From the above question)

Surface energy $= 4\times\frac{22}{7}\times1.4\times10^{-3}\times1.4\times10^{-3}\times0.11$

$= 2.7 \times 10^{-6}$ J

11. (d)

12. (d): $j \times \rho = E$ $\quad \therefore \quad E = \frac{I\rho}{2\pi r^2}$

13. (d): Total energy remains conserved. Energy is shared by antineutrino, proton and electron. Kinetic energy of electron has continuous spectrum and it is maximum when antineutrino does not share any kinetic energy.

So, total energy is shared with proton and electron only.

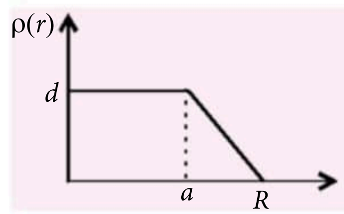
$\therefore \quad K \le 0.8 \times 10^6$ eV

and kinetic energy of electron will be minimum or zero when total energy is shared by proton and antineutrino.

$\therefore \quad 0 \le K \le 0.8 \times 10^6$ eV

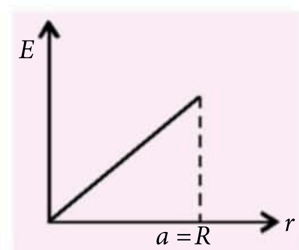
14. (c)

15. (a) : Electric field at a distance R from the centre of the nucleus is, $E = \frac{1}{4\pi\varepsilon_0}\frac{Ze}{R^2}$, which is independent of a.



16. (b)

17. (c) : Electric field inside a uniformly charged sphere is given by, $E = \frac{\rho r}{3\varepsilon_0}$



For $E \propto r$, ρ should be constant throughout the volume of nucleus. This will be possible only when $a = R$.

18. (a)

19. (c) : Wave velocity will be same whether the sound is louder or fainter. Wave travels with same velocity in the same medium.

$\therefore \quad$ Wave velocity $= f_1\lambda_1$

$\quad v = 50 \times 4 = 200$ ms^{-1}

Option (c) represents the answer.

20. (d): Consider $(y_1 + y_2)$ at $x = 0$.

$\therefore \quad y_1 + y_2 = A\cos(100\pi t) + A\cos(92\pi t)$

$\therefore \quad 0 = A\cos(100\pi t) + A\cos(92\pi t)$

or $\quad \cos(100\pi t) = -\cos(92\pi t)$

or $\quad \cos(100\pi t) = \cos[(2n + 1)\pi - 92\pi t]$

where $n = 0, 1, 2, ...$

or $\quad 100\pi t = (2n + 1)\pi - 92\pi t$

or $\quad 192\pi t = (2n + 1)\pi$

or $\quad t = \frac{(2n+1)}{192}$ where $n = 0, 1, 2, ...$

$$\Delta t = t_{n+1} - t_n = \frac{2n+3}{192} - \frac{2n+1}{192} = \frac{2}{192} = \frac{1}{96}$$

$\therefore$ In 1 second, $y_1 + y_2 = 0$ at $x = 0$ for 96 times

WORD GRID

Readers are requested to send their responses of word grid. Be the Winner!

Find and encircle the words in the given grid, running in one of the possible directions; horizontal and vertical by reading the clues given below.

C	O	H	A	N	G	S	T	R	O	M	S	S	T	U	M	S	N
A	M	S	T	U	C	E	N	T	O	O	R	T	S	T	U	M	S
P	Q	R	S	T	A	B	C	D	E	M	A	B	C	C	D	E	F
A	B	C	E	S	M	N	O	P	R	E	W	G	I	J	K	L	M
L	A	S	E	R	O	S	T	U	V	N	X	E	P	R	T	V	X
A	O	P	P	A	G	H	J	K	L	T	Y	N	Q	S	U	W	Y
B	I	E	Q	P	M	N	O	P	Q	A	Z	E	A	A	B	C	D
C	S	C	R	Q	S	T	U	V	W	U	A	R	M	A	M	N	O
D	F	T	S	R	X	Y	Z	A	D	C	M	A	N	O	P	Q	A
S	E	R	T	S	A	R	Y	A	B	H	A	T	T	A	B	C	D
M	D	U	U	T	U	S	M	N	O	P	Q	O	R	S	T	U	A
N	C	M	A	N	T	I	M	A	T	T	E	R	M	N	O	E	F
O	B	N	M	A	D	G	I	G	J	K	L	M	N	O	P	Q	B
P	A	O	P	B	E	N	R	S	T	U	V	W	X	Y	Z	A	C
Q	Z	Q	R	C	F	I	N	D	U	C	T	A	N	C	E	H	I
R	Y	S	T	G	H	T	O	I	L	M	N	O	O	P	Q	R	S
S	X	U	V	I	J	I	P	O	V	W	X	F	J	K	P	Q	T
T	W	W	X	K	L	O	Q	D	Y	A	D	E	I	L	O	R	M
U	V	Y	Z	M	N	N	R	E	Z	B	C	G	H	M	N	S	N

Across

1. A unit of length used for measuring wavelength.
2. A material composed of antiparticles.
3. An Indian scientist who discovered approximation of Pi and trigonometry.
4. The tendency of an electrical conductor to oppose a change in the electric current flowing through it.
5. A device that emits light through a process of optical amplification based on the stimulated emission of EM radiation.

Down

1. A machine that convert one form of energy into another.
2. The process of proceeding the energy that is required to initiate a combustion process.
3. A semiconductor device containing one p-n junction, used in circuits for converting alternating current to direct current.
4. The product of a physical quantity, such as force or mass, and its distance from a fixed reference point.
5. The distribution of colours produced when light passes through a prism.

Note :- Please send entries of solutions both with words and scanned copy of the grid by 10th of every month.

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Those candidates who have the affinity to make a career in industries that rely on nanoscale, critical thinking, innovation and who can bridge the macro and nano can choose to pursue career in nanoscience.

The multidisciplinary field of nanoscience and nanotechnology is considered a building block for tomorrow. The advancement in technology requires experts who have an outstanding knowledge and expertise in nanoscience to create new products. It is poised to bring in ground breaking changes across all fields creating a lot more job opportunities than one can imagine. There is a huge opportunity in the areas of Electronics Industry, Pharmaceutical and Healthcare Industry, Energy and Renewable Energy Sector, Materials Science and Engineering, Aerospace and Defence Industry, Biotechnology and Biomedical Industry, Environmental Science and Technology and Semiconductor Industry.

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- B.Sc. in Nanotechnology
- B.Sc. Nanoscience and Technology
- M.Sc. in Nanoscience
- Ph.D. in Nanotechnology

Job Prospects

Nanoscience offers a wide range of exciting career opportunities across diverse fields, making it an attractive choice for those interested in cutting-edge technology and research. Here are some of the compelling job roles and the areas where nanotechnologists can find meaningful employment as Scientist, Professor, Engineer, Medical Scientist, Food Scientist, Optical Engineer etc.

Listed below are few recruiting companies for nanoscience graduates:

- Adnano technologies Pvt. Ltd.
- Meda Biotech Inc.
- Velbio Nanotech Pvt. Ltd.
- Nilima Nanotechnologies
- Dabur Ltd.
- Micro Materials Ltd.
- Quantum Corporation

Eligibility Criteria

- The eligibility requirement for B.Sc. in Nanoscience requires candidate to have cleared 10+2 level with at least 60% in aggregate from any recognised board or its equivalent with Physics, Chemistry, Mathematics (or Biology) as the main subjects. Many of the colleges require candidates to clear university level entrance exam or personal interview to be able to secure admission in desired college.
- For admissions in M.Sc. in Nanoscience, candidate must have completed Bachelor's degree in science with at least 50-60% aggregate. Some universities require students to qualify entrance exam.
- The eligibility criteria for admission to Ph.D. course is a postgraduation degree. The students are required to qualify GATE/ National entrance exam followed by an interview by concerned universities.

Best Colleges offering B.Sc. in Nanoscience

- **Dr. Shyama Prasad Mukherjee University, Ranchi**
- Swami Vivekanand Subharti University, Meerut
- Parishkar College of Global Excellence, Jaipur
- Yashwantrao Chavan Institute of Science, Satara, Maharashtra
- Amity Institute of Nanotechnology, Noida

College Info

Dr. Shyama Prasad Mukherjee University (DSPMU) an almost 185 years old legacy that traces back to 1839. In 2018, in a landmark development, Ranchi College, Ranchi (RCR), was upgraded to Dr. Shyama Prasad Mukherjee University, encapsulating its rich legacy while embarking on a new era of educational excellence. The transformation from RCR to DSPMU is not just a change of name but a reiteration of the university's pledge to continue being a cradle of higher education, innovation, and societal development. This college is a beacon of higher education and has a vibrant and happening green campus, nestled within the green environs at the heart of the city of Ranchi.

B.Sc. in Nanoscience at Dr. Shyama Prasad Mukherjee University offer students a unique platform of learning, disseminating interdisciplinary knowledge and expertise to the students in various streams of nanoscience with an emphasis on promoting the academia. The course structure is technology-centric where students gain practical skills, critical thinking abilities, and technological research skills. Faculty members are dedicated to addressing individual needs and fostering student potential. The eligibility requirement for admission in B.Sc. in Nanoscience requires candidate to have cleared 10+2 level with at least 60% in aggregate from any recognised board or its equivalent with Physics, Chemistry, Mathematics (or Biology) as the main subjects. The admissions are conducted on merit basis.

GK CORNER

Enhance Your General Knowledge with Current Updates!

STATES IN NEWS

- Former Union Minister Santosh Kumar Gangwar, on July 31, was sworn in as the 12th Governor of Jharkhand and succeeded C.P. Radhakrishnan. He was administered the oath of office by Justice Sujit Narayan Prasad, acting Chief Justice of Jharkhand High Court.
- The Uttar Pradesh Assembly on July 30, passed the Uttar Pradesh Prohibition Unlawful Conversion of Religion (Amendment) Bill 2024, that enhances punishment by providing for a maximum punishment of life imprisonment for those found guilty.
- Telangana launched the 'project Swasthya Nagaram', a model for tuberculosis (TB) free municipalities. This project is a collaborative initiative of State TB cell, Municipal Corporations of Peerzadiguda, Boduppal and Pocharam in Medchal Malkajgiri district along with WHO India, USAID and other stake holders.
- Union Minister of Coal and Mines, Shri G. Kishan Reddy led the launch of the Vriksharopan Abhiyan 2024 at Bharat Coking Coal Limited (BCCL) in Dhanbad. This initiative is part of Prime Minister Narendra Modi's "Ek Ped Maa Ke Naam" campaign, and was simultaneously conducted across 300 places in 47 districts across 11 coal/lignite-bearing states.
- The Atomic Minerals Directorate for Exploration and Research (AMD), a unit of the Department of Atomic Energy (DAE), has identified 1600 tonnes of lithium resources (G3 stage) in the Marlagalla area of Mandya and Yadgiri districts, Karnataka. The announcement came through the Union Minister of the State for Science and Technology Dr. Jitendra Singh.
- The Bihar Assembly passed anti-paper leak bill aimed to curb the malpractices such as leak of question or answer papers, which previously led to the cancellation of several examinations. This bill was introduced by State Minister of Parliamentary Affairs Vijay Kumar Chaudhary and stipulates strict penalties for those involved in such malpractices including prison term of three to five years and a fine of Rs. 10 lakhs.
- In a significant stride towards advancing health research capabilities in Asia, Union Minister Dr. Jitendra Singh inaugurated Asia's first 'Pre-clinical Network Facility' at Translational Health Science & Technology Institute (THSTI), Faridabad. This facility was established under the Coalition of Epidemic Preparedness Innovation (CEPI) and marks a pivotal development in bolstering India's research infrastructure.
- The eSwasthya Dham portal, launched by the Department of Health and Family Welfare, Government of Uttarakhand, has been integrated with the Ayushman Bharat Digital Mission (ABDM) to enhance health infrastructure for monitoring Char Dham Yatra pilgrims while also aligning with India's broader digital health initiatives.
- Bihar has appointed transgender person Manvi Madhu Kashyap as Sub-Inspector of Police, marking a historic first. Her success marks a significant milestone for transgender rights and representation in law enforcement.
- Taking major step towards waste management in Haryana, waste-to-charcoal plants, also known as 'green coal' plants, will be established in the state

with help of central government. A memorandum of understanding (MoU) has been signed between NTPC Vidyut Vyapar Nigam Limited (NVVNL), and the Municipal Corporations of Gurugram and Faridabad for the establishment of these plants which aims to support Prime Minister Narendra Modi's Swachh Bharat campaign, making Gurugram and Faridabad garbage-free.

Test Yourself!

1. The eSwasthya Dham portal, launched by the Government of Uttarakhand aims to
- (a) facilitate digitalization in India.
- (b) facilitate health infrastructure for all citizens.
- (c) facilitate health infrastructure for monitoring Char Dham Yatra pilgrims.
- (d) facilitate healthcare practices advocated by Ayush system.

2. Who introduced anti-paper leak bill in Bihar Assembly?
- (a) Vijay Kumar Chaudhary
- (b) Giriraj Singh
- (c) J. P. Nadda
- (d) Piyush Goyal

3. Which campaign was led by Union Minister of Coal and Mines, Shri G. Kishan Reddy?
- (a) Swachh Bharat Abhiyan 2024
- (b) Atmanirbhar Bharat 2024
- (c) Digital India 2024
- (d) Vriksharopan Abhiyan 2024.

4. Under which initiative Asia's first Pre-clinical Network Facility at Translational Health Science & Technology Institute (THSTI), Faridabad has been established?
- (a) Foundation for Innovative New Diagnostics.
- (b) Coalition of Epidemic Preparedness Innovation.
- (c) International Coalition of Medicines Regulatory Authorities.
- (d) Global Research Collaboration for Infectious Diseases Preparedness.

5. Santosh Kumar Gangwar sworn in as the 12th Governor of which state?
- (a) Maharashtra
- (b) Jharkhand
- (c) Orrisa
- (d) Madhya Pradesh

6. In which district Lithium resources have been identified by the Atomic Minerals Directorate for Exploration and Research (AMD)?
- (a) Mandya and Yadgiri district, Karnataka
- (b) Davangere district, Karnataka
- (c) Koppal district, Karnataka
- (d) Vijayapura and Yadgiri District, Karnataka.

7. The establishment of 'Green Coal' plant in Haryana aims to
- (a) support Make in India campaign.
- (b) support clean-up campaign making Gurugram and Faridabad garbage-free.
- (c) support Breathe Life campaign making Gurugram and Faridabad pollution-free.
- (d) support Prime Swachh Bharat campaign making Gurugram and Faridabad garbage-free.

8. The Uttar Pradesh Unlawful Conversion of Religion (Amendment) Bill, 2024 enhances punishment by
- (a) providing for a maximum punishment of 5 year.
- (b) providing for a maximum punishment of 10 years.
- (c) providing for a maximum punishment of life imprisonment.
- (d) providing for a maximum punishment of 2 years.

9. Who has been appointed as first transgender Sub-Police Inspector in Bihar?
- (a) Manasvi Kumari
- (b) Manvi Madhu Kashyap
- (c) Mrinali Gautam
- (d) Gayatri Abrol

10. Project Swasthya Nagaram is an initiative to eradicate
- (a) Polio
- (b) Malaria
- (c) Cancer
- (d) Tuberculosis.

Answer Key

1. (c) **2.** (a) **3.** (d) **4.** (b) **5.** (b)
6. (a) **7.** (d) **8.** (c) **9.** (b) **10.** (d)

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