<table>
<thead>
<tr>
<th>S. No</th>
<th>Questions</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| Q.1   | A rectangular loop has a sliding connector PQ of length ℓ and resistance R Ω and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents I₁, I₂ and I are | Sol: 1 (b) A moving conductor is equivalent to a battery of emf = v B ℓ (motion emf)
Equivalent circuit
I = I₁ + I₂
Applying Kirchoff’s law
I₁ R + IR - vB ℓ = 0 ..........................(1)
I₂ R + IR - vB ℓ = 0 ..........................(2)
adding (1) & (2)
2IR = 2vB ℓ
I = \(\frac{2vB \ell}{3R}\)
I₁ = I₂ = \(\frac{vB \ell}{3R}\) |
|       | (a) \(I₁ = -I₂ = \frac{B \ell v}{R}, I = \frac{2B \ell v}{R}\) |           |
|       | (b) \(I₁ = I₂ = \frac{B \ell v}{3R}, I = \frac{2B \ell v}{3R}\) |           |
|       | (c) \(I₁ = I₂ = \frac{B \ell v}{R}, I = \frac{2B \ell v}{3R}\) |           |
|       | (d) \(I₁ = I₂ = \frac{B \ell v}{6R}, I = \frac{2B \ell v}{3R}\) |           |
| Q.2   | Let C be the capacitance of a capacitor discharging through a resistor R. Suppose \(t₁\) is the time taken for the energy stored in the capacitor to reduce to half its initial value and \(t₂\) is the time taken for the charge to reduce to one-fourth its initial value. Then the ratio \(t₁/t₂\) will be | Sol: 2 (c) |
|       | (a) \(1\) | U = \(\frac{1}{2} C \left(\frac{q₀ e^{-t/T}}{2}\right)^2 = \frac{q₀}{2} e^{-2t/T}\) (where \(T = CR\))
\[U = \frac{1}{2} U₁ e^{-2t₁/T}\]
\[\frac{1}{2} U₁ = U₁ e^{-2t₁/T}\]
\[\frac{1}{2} e^{-2t₁/t} = t₁ = \frac{T}{2} \ln 2\]
Now \(q = q₀ e^{-t/T}\)
\[\frac{1}{4} q₀ = q₀ e^{-t/2T}\]
\[t₂ = T \ln 4 = 2T \ln 2\]
∴ \(\frac{t₁}{t₂} = \frac{1}{4}\) |
|       | (b) \(\frac{1}{2}\) |           |
|       | (c) \(\frac{1}{4}\) |           |
|       | (d) \(2\) |           |
| Q.3   | **Statement-1**: Two particles moving in the same direction do not lose all their energy in a completely inelastic collision. **Statement-2**: Principle of conservation of momentum holds true for all kinds of collisions. (a) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1. (b) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1 (c) Statement-1 is false, Statement-2 is true. (d) Statement-1 is true, Statement-2 is false. | Sol: 3 (a) If \(m₁v₁ + m₂v₂ = m₁v₁' + m₂v₂'\) it is a completely inelastic collision then
\[m₁v₁ + m₂v₂ = m₁v₁' + m₂v₂'\]
\[v = \frac{m₁v₁' + m₂v₂'}{m₁ + m₂}\]
K.E = \(\frac{p₁^2}{2m₁} + \frac{p₂^2}{2m₂}\)
as \(p₁'\) and \(p₂'\) both simultaneously cannot be zero therefore total KE cannot be lost. |
Q.4 Statement-1 : When ultraviolet light is incident on a photocell, its stopping potential is \( V_0 \) and the maximum kinetic energy of the photoelectrons is \( K_{\text{max}} \). When the ultraviolet light is replaced by X-rays, both \( V_0 \) and \( K_{\text{max}} \) increase.

Statement-2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.

(a) Statement-1 is true, Statement-2 is true; Statement-2 is the Correct explanation of Statement-1.
(b) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is false, Statement-2 is true.
(d) Statement-1 is true, Statement-2 is false.

Sol: 4 (d)
Since the frequency of ultraviolet light is less than the frequency of X-rays, the energy of each incident photon will be more for X-rays
\[ K.E_{\text{photon}} = h \nu - \varphi \]
Stopping potential is to stop the fastest photoelectron
\[ V_0 = \frac{h \nu}{e} - \frac{\varphi}{e} \]
so, \( K.E_{\text{max}} \) and \( V_0 \) both increases.
But K.E ranges from zero to \( K.E_{\text{max}} \) because of loss of energy due to subsequent collisions before getting ejected and not due to range of frequencies in the incident light.

Q.5 A ball is made of a material of density \( \rho \) where \( \rho_{\text{oil}} < \rho < \rho_{\text{water}} \) with \( \rho_{\text{oil}} \) and \( \rho_{\text{water}} \) representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position?

Sol: 5 (b)
\( \rho_{\text{oil}} < \rho < \rho_{\text{water}} \)
Oil is the least dense of them so it should settle at the top with water at the base. Now the ball is denser than oil but less denser than water. So, it will sink through oil but will not sink in water. So it will stay at the oil–water interface.

Q.6 A particle is moving with velocity \( \vec{v} = K(y \, \hat{i} + x \, \hat{j}) \), where \( K \) is a constant. The general equation for its path is

(a) \( y = x^2 + \text{constant} \)
(b) \( y^2 = x + \text{constant} \)
(c) \( xy = \text{constant} \)
(d) \( y^2 = x^2 + \text{constant} \)

Sol: 6 (d)
\[ \vec{v}' = Ky \, \hat{i} + Kx \, \hat{j} \]
\[ \frac{dy}{dx} = \frac{dy}{dt} \times \frac{dt}{dx} = \frac{Kx}{Ky} \]
\[ y \, dy = x \, dx \]
\[ y^2 = x^2 + c. \]

Q.7 Two long parallel wires are at a distance \( 2d \) apart. They carry steady equal current flowing out of the plane of the paper as shown. The variation of the magnetic field along the line \( XX' \) is given by

Sol: 7 (a)
The magnetic field in between because of each will be in opposite direction
\[ B_{\text{in between}} = \frac{\mu_0 I}{2\pi} \left[ \frac{1}{2d-x} - \frac{1}{2d+x} \right] (-\hat{j}) \]
at \( x=d \), \( B_{\text{in between}} = 0 \) for \( x<d \), \( B_{\text{in between}} = (\hat{j}) \)
for \( x>d \), \( B_{\text{in between}} = (-\hat{j}) \)
towards \( x \) net magnetic field will add up and direction will be \((-\hat{j})\)
towards \( x' \) net magnetic field will add up and direction will be \( (\hat{j}) \).
Q.8 In the circuit shown below, the key K is closed at \( t = 0 \). The current through the battery is

\[
\begin{align*}
(\text{a}) & \quad \frac{V_{R_1R_2}}{R_1^2+R_2^2} \text{ at } t = 0 \text{ and } \frac{V}{R_2} \text{ at } t = \infty \\
(\text{b}) & \quad \frac{V}{R_2} \text{ at } t = 0 \text{ and } \frac{V(R_1+R_2)}{R_1R_2} \text{ at } t = \infty \\
(\text{c}) & \quad \frac{V}{R_2} \text{ at } t = 0 \text{ and } \frac{V(R_1+R_2)}{R_1R_2} \text{ at } t = \infty \\
(\text{d}) & \quad \frac{V(R_1+R_2)}{R_1R_2} \text{ at } t = 0 \text{ and at } t = \infty \\
\end{align*}
\]

Sol: 8 (b)
At \( t = 0 \), inductor behaves like an infinite resistance So at \( t = 0 \), \( i = \frac{V}{R_2} \)
So at \( t = 0 \), \( i = \frac{V}{R_2} \)
and at \( t = \infty \), inductor behaves like a conducting wire
\[
i = \frac{V}{R_{eq}} = \frac{V(R_1+R_2)}{R_1R_2}
\]

Q.9 The figure shows the position – time (x – t) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is

\[
\begin{align*}
(\text{a}) & \quad 0.4 \text{ Ns} \\
(\text{b}) & \quad 0.8 \text{ Ns} \\
(\text{c}) & \quad 1.6 \text{ Ns} \\
(\text{d}) & \quad 0.2 \text{ Ns}
\end{align*}
\]

Sol: 9 (b)
From the graph, it is a straight line so, uniform motion. Because of impulse direction of velocity changes as can be seen from the slope of the graph.
Initial velocity \( = \frac{\Delta x}{\Delta t} = \frac{2}{2} = 1 \text{ m/s} \) Final velocity = \( -\frac{2}{2} = -1 \text{ m/s} \)
\[
\vec{P}_1 = 0.4 \text{ N} - \text{s} \quad \vec{P}_2 = -0.4 \text{ N} - \text{s}
\]
\[
\vec{J} = \vec{P}_2 - \vec{P}_1 = -0.4 - 0.4 = -0.8 \text{ N} - \text{s} \text{ (} \vec{J} = \text{ impulse} \text{)} \quad ||\vec{J}|| = 0.8 \text{ N - s}
\]

Directions: Questions number 10 – 11 are based on the following paragraph.

A nucleus of mass \( M + \Delta m \) is at rest and decays into two daughter nuclei of equal mass \( \frac{M}{2} \) each. Speed of light is \( c \).

Q.10 The binding energy per nucleon for the parent nucleus is \( E_1 \) and that for the daughter nuclei is \( E_2 \). Then

\[
\begin{align*}
(1) & \quad E_2 = 2E_1 \\
(2) & \quad E_1 > E_2 \\
(3) & \quad E_2 > E_1 \\
(4) & \quad E_1 = 2E_2
\end{align*}
\]

Sol: 10 (c)
After decay, the daughter nuclei will be more stable hence binding energy per nucleon will be more than that of their parent nucleus.

Q.11 The speed of daughter nuclei is

\[
\begin{align*}
(\text{a}) & \quad \frac{\Delta m}{M+\Delta m} \\
(\text{b}) & \quad \sqrt{\frac{2\Delta m}{M}} \\
(\text{c}) & \quad \sqrt{\frac{\Delta m}{M}} \\
(\text{d}) & \quad \sqrt{\frac{\Delta m}{M+\Delta m}}
\end{align*}
\]

Sol: 11 (b)
Conserving the momentum
\[
0 = \frac{M}{2}v_1 - \frac{M}{2}v_2
\]
\[
v_1 = v_2 \quad \text{..............(1)}
\]
\[
\Delta m c^2 = \frac{1}{2} \cdot \frac{M}{2} v_1^2 + \frac{1}{2} \cdot \frac{M}{2} v_2^2 \quad \text{..........(2)}
\]
\[
\Delta m c^2 = \frac{M}{2} v_1^2
\]
\[
\Delta m c^2 = \frac{M}{2} v_2^2
\]
\[
\Delta m c^2 = \frac{2 \Delta m}{M} v_1^2
\]
\[
v_1 = c \sqrt{\frac{2 \Delta m}{M}}
Q.12
A radioactive nucleus (initial mass number A and atomic number Z) emits 3 α-particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be

(a) \( \frac{A-Z-8}{Z-4} \)  
(b) \( \frac{A-Z-4}{Z-8} \)  
(c) \( \frac{A-Z-12}{Z-4} \)  
(d) \( \frac{A-Z-4}{Z-2} \)

Sol: 12 (b)
In positive beta decay a proton is transformed into a neutron and a positron is emitted. 
\[ p^+ \rightarrow n^0 + e^+ \]
no. of neutrons initially was \( A-Z \)  
no. of neutrons after decay \( (A-Z) - 3 \times 2 \) (due to alpha particles) + \( 2 \times 1 \) (due to positive beta decay)  
The no. of proton will reduce by 8. [as \( 3 \times 2 \) (due to alpha particles) + \( 2 \) (due to positive beta decay)]
Hence atomic number reduces by 8.

Q.13
A thin semi-circular ring of radius \( r \) has a positive charge \( q \) distributed uniformly over it. The net field \( E \) at the centre \( O \) is

(a) \( \frac{q}{4\pi\epsilon_0 r^2} \)  
(b) \( -\frac{q}{4\pi\epsilon_0 r^2} \)  
(c) \( -\frac{q}{2\pi\epsilon_0 r^2} \)  
(d) \( \frac{q}{2\pi\epsilon_0 r^2} \)

Sol: 13 (c)
Linear charge density \( \lambda = \frac{q}{\pi r} \)
\[ E = \int dE \sin \theta = \int \frac{K dq}{r^2 \sin \theta} \]
\[ E = \frac{K}{r^2} \int_0^{\pi} \frac{q d\theta}{\sin \theta} \]
\[ = \frac{Kq}{r^2} \int_0^{\pi} \sin \theta \sin \theta \]
\[ = \frac{q}{2\pi \epsilon_0 r^2} \]

Q.14
The combination of shown below yields

(a) OR gate  
(b) NOT gate  
(c) XOR gate  
(d) NAND gate

Sol: 14 (a)
Truth table for given combination is

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

This comes out to be truth table of OR gate

Q.15
A diatomic ideal gas is used in a Car engine as the working substance. If during the adiabatic expansion part of the cycle, volume of the gas increases from \( V \) to \( 32V \) the efficiency of the engine is

(a) 0.5  
(b) 0.75  
(c) 0.99  
(d) 0.25

Sol: 15 (b)
The efficiency of cycle is
\[ \eta = 1 - \frac{T_2}{T_1} \]
for adiabatic process
\[ TV^{y-1} = \text{constant} \]
For diatomic gas \( y = \frac{7}{5} \)
\[ T_1 V_1^{y-1} = T_2 V_2^{y-1} \]
\[ T_1 = T_2 \left( \frac{V_2}{V_1} \right)^{y-1} \]
\[ T_1 = T_2 (32)^{7/5-1} = T_2 (2^5)^{2/5} \]
\[ = T_2 \times 4 \]
\[ T_1 = 4T_2 \]
\[ \eta = \left(1 - \frac{1}{4}\right) = \frac{3}{4} = 0.75 \]
Q.16 If a source of power 4 kW produces $10^{20}$ photons/second, the radiation belong to a part of the spectrum called
(a) X–rays
(b) ultraviolet rays
(c) microwaves
(d) g–rays

Sol: 16 (a)

\[
4 \times 10^3 = 10^{20} \times hf
\]

\[
f = \frac{4 \times 10^3}{10^{20} \times 6.023 \times 10^{-34}}
\]

\[
f = 6.03 \times 10^{16} \text{ Hz}
\]

The obtained frequency lies in the band of X – rays.

Q.17 The respective number of significant figures for the numbers 23.023, 0.0003 and $2.1 \times 10^{-3}$ are
(a) 5, 1, 2
(b) 5, 1, 5
(c) 5, 5, 2
(d) 4, 4, 2

Sol: 17 (a)

Q.18 In a series LCR circuit $R = 200 \Omega$ and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30°. On taking out the inductor from the circuit the current leads the voltage by 30°. The power dissipated in the LCR circuit is
(a) 305 W
(b) 210 W
(c) Zero W
(d) 242 W

Sol: 18 (d)

The given circuit is under resonance as $X_L = X_C$

Hence power dissipated in the circuit is

\[
P = \frac{V^2}{R} = 242 \text{ W}
\]

Q.19 Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0 \left(\frac{5}{4} - \frac{r}{R}\right)$ upto $r = R$, and $\rho(r) = 0$ for $r > R$, where $r$ is the distance from the origin. The electric field at a distance $r (r < R)$ from the origin is given by
(a) $4\pi \rho_0 r^3 / 3\varepsilon_0$
(b) $\rho_0 r / 4 \varepsilon_0$
(c) $4\pi \rho_0 r / 3\varepsilon_0$
(d) $\rho_0 r / 4 \varepsilon_0$

Sol: 19 (b)

Apply shell theorem the total charge upto distance $r$ can be calculated as followed

\[
dq = 4\pi r^2 dr \rho
\]

\[
= 4\pi r^2 dr \rho_0 \left[\frac{5}{4} - \frac{r}{R}\right]
\]

\[
= 4\pi \rho_0 \left[\frac{5}{4} r^2 dr - \frac{3}{R} r^3 dr\right]
\]

\[
= 4\pi \rho_0 \left[\frac{5}{4} r^2 - \frac{3}{R} r^3\right]
\]

\[
E = \frac{\rho_0}{4\pi \varepsilon_0} \left[\frac{5}{4} (\frac{r}{3})^3 - \frac{1}{4} r^4\right]
\]

Q.20 The potential energy function for the force between two atoms in a diatomic molecule is approximately given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$, where $a$ and $b$ are constants and $x$ is the distance between the atoms. If the dissociation energy of the molecule is $D = [U(x = \infty) - U_{\text{at equilibrium}}]$, $D$ is
(a) $\frac{b^2}{2a}$
(b) $\frac{b^2}{12a}$
(c) $\frac{b^2}{4a}$
(d) $\frac{b^2}{6a}$

Sol: 20 (c)

\[
U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}
\]

\[
U(x = \infty) = 0
\]

as, $F = -\frac{dU}{dx} = \left[-\frac{12a}{x^{13}} + \frac{6b}{x^7}\right]$

at equilibrium, $F = 0$

\[
x^6 = \frac{2a}{b}
\]

\[
\therefore U_{\text{at equilibrium}} = \frac{a}{(\frac{2a}{b})^{12}} - \frac{b}{(\frac{2a}{b})^6} = -\frac{b^2}{4a}
\]

\[
\therefore D = [U(x = \infty) - U_{\text{at equilibrium}}] = \frac{b^2}{4a}
\]
Q.21 Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30° with each other. When suspended in a liquid of density 0.8 g cm\(^{-3}\), the angle remains the same. If density of the material of the sphere is 16 g cm\(^{-3}\), the dielectric constant of the liquid is

(a) 4          (b) 3          (c) 2          (d) 1

Sol: 21 (c)

From F.B.D of sphere, using Lami’s theorem
\[ \frac{F}{mg} = \tan \theta \]  
(i)

when suspended in liquid, as \( \theta \) remains same,
\[ \therefore \frac{F'}{mg} = \tan \theta \]  
(ii)

using (i) and (ii)
\[ \frac{F}{mg} = \frac{F'}{mg(1- \frac{\rho}{d})} \]

where \( F' = K \)
\[ \therefore \frac{F}{mg} = \frac{F}{mgK(1 - \frac{\rho}{d})} \]

Q.22 Two conductors have the same resistance at 0° C but their temperature coefficients of resistance are \( a_1 \) and \( a_2 \). The respective temperature coefficients of their series and parallel combinations are nearly

(a) \( \frac{a_1+a_2}{2} \), \( a_1 + a_2 \)          (b) \( a_1 + a_2, \frac{a_1+a_2}{2} \)
(c) \( a_1 + a_2, \frac{a_1+a_2}{2} \)          (d) \( \frac{a_1+a_2}{2}, \frac{a_1+a_2}{2} \)

Sol: 22 (d)

Let \( R_0 \) be the initial resistance of both conductors

\[ \therefore \] At temperature \( \theta \) their resistance will be,
\[ R_1 = R_0 (1 + a_1 \theta) \quad \text{and} \quad R_2 = (1+a_2 \theta) \]

for, series combination,
\[ R_s = R_1 + R_2 \]

\[ R_{s0} (1+a_s \theta) = (1+a_1 \theta) + R_0 (1+a_2 \theta) \]

where \( R_{s0} = R_0 + R_0 = 2R_0 \)
\[ \therefore 2R_0 (1+a_1 \theta) = 2R_0 + R_0 \theta (a_1 + a_2) \]

or \( a_s = \frac{a_1+a_2}{2} \)

for parallel combination,
\[ R_p = \frac{R_1R_2}{R_1+R_2} \]

\[ R_{p0} (1 + a_p \theta) = \frac{R_0(1+a_1 \theta)R_0(1+a_2 \theta)}{R_0(1+a_1 \theta)+R_0(1+a_2 \theta)} \]

where \( R_{p0} = \frac{R_0}{R_0+R_0} = \frac{R_0}{2} \)
\[ \therefore \frac{R_0}{2} (1 + a_p \theta) = \frac{R_0^2(1+a_1 \theta+a_2 \theta+a_1a_2 \theta)}{R_0(2+a_1 \theta+a_2 \theta)} \]

as \( a_1 \) and \( a_2 \) are small quantities
\[ \therefore a_1 a_2 \] is negligible

or \( a_p = \frac{a_1+a_2}{2} (1 - (a_1 + a_2) \theta) \]

as \( (a_1 + a_2)^2 \) is negligible
\[ \therefore a_p = \frac{a_1+a_2}{2} \]
Q.23  
A point P moves in counter-clockwise direction on a circular path as shown in the figure. The movement of ‘P’ is such that it sweeps out a length \( s = t^3 + 5 \), where \( s \) is in metres and \( t \) is in seconds. The radius of the path is 20 m. The acceleration of ‘P’ when \( t = 2 \) s is nearly

(a) 13 m/s\(^2\)  
(b) 12 m/s\(^2\)  
(c) 7.2 m/s\(^2\)  
(d) 14 m/s\(^2\)

Sol: 23 (d)

\[
S = t^3 + 5 \\
\therefore \text{speed, } v = \frac{ds}{dt} = 3t^2 \\
\text{and rate of change of speed } = \frac{dv}{dt} = 6t \\
\therefore \text{tangential acceleration at } t = 2 \text{ s}, \ a_t = 6 \times 2 = 12 \text{ m/s}^2 \\
\text{at } t = 2 \text{ s, } v = 3(2)^2 = 12 \text{ m/s} \\
\therefore \text{centripetal acceleration, } a_c = \frac{v^2}{R} = \frac{144}{20} \text{ m/s}^2 \\
\therefore \text{net acceleration } = \sqrt{a_t^2 + a_c^2} \\
\approx 14 \text{ m/s}^2
\]

Q.24  
Two fixed frictionless inclined plane making an angle 30° and 60° with the vertical are shown in the figure. Two block A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B ?

(a) 4.9 m/s\(^2\) in horizontal direction  
(b) 9.8 m/s\(^2\) in vertical direction  
(c) zero  
(d) 4.9 m/s\(^2\) in vertical direction

Sol: 24 (d)

\[
mg \sin \theta = ma \\
\therefore a = g \sin \theta \\
\text{where } a \text{ is along the inclined plane} \\
\therefore \text{vertical component of acceleration is } g \sin^2 \theta \\
\therefore \text{relative vertical acceleration of A with respect to B is } g[\sin^2 60 - \sin^2 30] = \frac{g}{2} = 4.9 \text{ m/s}^2 \text{ in vertical direction.}
\]

Q.25  
For a particle in uniform circular motion the acceleration \( \ddot{a} \) at a point P(R, \( \theta \)) on the circle of radius R is (here \( \theta \) is measured from the x–axis)

(a) \(-\frac{v^2}{R} \cos \theta \hat{i} + \frac{v^2}{R} \sin \theta \hat{j}\)  
(b) \(-\frac{v^2}{R} \sin \theta \hat{i} + \frac{v^2}{R} \cos \theta \hat{j}\)  
(c) \(-\frac{v^2}{R} \cos \theta \hat{i} - \frac{v^2}{R} \sin \theta \hat{j}\)  
(d) \(\frac{v^2}{R} \hat{i} + \frac{v^2}{R} \hat{j}\)

Sol: 26 (c)

For a particle in uniform circular motion,

\[
\ddot{a} = \frac{v^2}{R} \text{ towards centre of circle} \\
\therefore \ddot{a} = \frac{v^2}{R}(- \cos \theta \hat{i} - \sin \theta \hat{j}) \\
or \ddot{a} = -\frac{v^2}{R} \cos \theta \hat{i} - \frac{v^2}{R} \sin \theta \hat{j}
\]

Directions: Questions number 56 – 58 are based on the following paragraph.

An initially parallel cylindrical beam travels in a medium of refractive index \( \mu (I) = \mu_0 + \mu_2 I \), where \( \mu_0 \) and \( \mu_2 \) are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

Q.26  
As the beam enters the medium, it will

(a) diverge  
(b) converge  
(c) diverge near the axis and converge near the periphery  
(d) travel as a cylindrical beam

Sol: 26 (b)

As intensity is maximum at axis,  
\( \therefore \mu \) will be maximum and speed will be minimum on the axis of the beam.  
\therefore \text{beam will converge.}

Q.27  
The initial shape of the wave front of the beam is

(a) convex  
(b) concave  
(c) convex near the axis and concave near the periphery  
(d) planar

Sol: 27 (d)

For a parallel cylindrical beam, wavefront will be planar.
<table>
<thead>
<tr>
<th>Question</th>
<th>Statement</th>
<th>Option(s)</th>
<th>Solution</th>
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<tr>
<td>Q.28</td>
<td>The speed of light in the medium is</td>
<td>(a) minimum on the axis of the beam (b) the same everywhere in the beam (c) directly proportional to the intensity I (d) maximum on the axis of the beam</td>
<td>Sol: 28 (a)</td>
</tr>
<tr>
<td>Q.29</td>
<td>A small particle of mass m is projected at an angle $\theta$ with the x-axis with an initial velocity $v_0$ in the x-y plane as shown in the figure. At a time $t &lt; \frac{v_0 \sin \theta}{g}$, the angular momentum of the particle is</td>
<td>(a) $-mgv_0 t^2 \cos \theta \hat{j}$ (b) $mgv_0 t \cos \theta \hat{k}$ (c) $\frac{1}{2} mgv_0 t^2 \cos \theta \hat{k}$ (d) $\frac{1}{2} mgv_0 t^2 \cos \theta \hat{i}$</td>
<td>Sol: 29 (c)</td>
</tr>
<tr>
<td></td>
<td>where $\hat{i}$, $\hat{j}$ and $\hat{k}$ are unit vectors along x, y and z-axis respectively.</td>
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<tr>
<td>Q.30</td>
<td>The equation of a wave on a string of linear mass density 0.04 kg m$^{-1}$ is given by $y = 0.02(m) \sin \left[2\pi \left(\frac{\epsilon}{0.04} - \frac{x}{0.50(m)}\right)\right]$. The tension in the string is</td>
<td>(a) 4.0 N (b) 12.5 N (c) 0.5 N (d) 6.25 N</td>
<td>Sol: 30 (d)</td>
</tr>
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<td>$T = \mu v^2 = \mu \frac{a^2}{k^2} = 0.04\left(\frac{2\pi/0.004}{2\pi/0.50}\right)^2 = 6.25$ N</td>
</tr>
</tbody>
</table>