

JEE Main Physics Sample Paper-18

Duration: 1 Hour

Maximum Marks: 100

Instructions

- This paper contains TWO sections: **Section A** (MCQs) and **Section B** (Numerical).
- Section A contains 20 Multiple Choice Questions.
- Section B contains 5 Numerical Value Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Section A — Multiple Choice Questions

Q1. The frequency of revolution of the electron in Bohr's orbit varies with n , the principal quantum number, as per the relation: [JEE Main 2021]

- (A) n
- (B) $\frac{1}{n^4}$
- (C) $\frac{1}{n^2}$
- (D) $\frac{1}{n^3}$

Q2. A parallel-plate capacitor is filled equally with two dielectrics of constants ε_1 and ε_2 . In configuration 1, they are side-by-side (series-like split of d). In configuration 2, they are layered (parallel-like split of A). If C_1 and C_2 are the capacitances, find $\frac{C_2}{C_1}$. [JEE Main 2022]

- (A) $\frac{\varepsilon_1 + \varepsilon_2}{2\varepsilon_1\varepsilon_2}$
- (B) $\frac{2}{\varepsilon_1 + \varepsilon_2}$
- (C) $\frac{(\varepsilon_1 + \varepsilon_2)^2}{\varepsilon_1\varepsilon_2}$



$$(D) \frac{(\varepsilon_1 + \varepsilon_2)^2}{4\varepsilon_1\varepsilon_2}$$

- Q3.** An electron of mass m with initial velocity $\vec{v} = v_0\hat{i}$ enters an electric field $\vec{E} = -E_0\hat{k}$. If the initial de Broglie wavelength is λ_0 , the wavelength after time t is: [JEE Main 2019]

(A) λ_0

(B) $\lambda_0\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}$

(C) $\frac{\lambda_0}{\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}}$

(D) $\lambda_0\left(1 + \frac{eE_0t}{mv_0}\right)$

- Q4.** A coil of area A and N turns rotates with angular velocity ω in a uniform magnetic field B about an axis perpendicular to B . When the plane of the coil is parallel to B , the magnetic flux ϕ and induced emf ε are:

[JEE Main 2023]

(A) $\phi = AB, \varepsilon = 0$

(B) $\phi = 0, \varepsilon = 0$

(C) $\phi = NAB, \varepsilon = NAB\omega$

(D) $\phi = 0, \varepsilon = NAB\omega$

- Q5.** Two monochromatic light beams have intensities in the ratio 1 : 9. After interference, the ratio of maximum to minimum intensity ($I_{\max} : I_{\min}$) is:

[JEE Main 2020]

(A) 9 : 1

(B) 4 : 1

(C) 16 : 9

(D) 3 : 1

- Q6.** A material used to harvest heat energy via the Seebeck effect should ideally possess which combination of properties? [JEE Main 2021]



- (A) High thermal conductivity and low electrical conductivity
- (B) High thermal conductivity and high electrical conductivity
- (C) Low thermal conductivity and low electrical conductivity
- (D) Low thermal conductivity and high electrical conductivity

Q7. An alternating current is given by $I = I_A \sin \omega t + I_B \cos \omega t$. The r.m.s. current is:

[JEE Main 2022]

- (A) $\frac{I_A + I_B}{\sqrt{2}}$
- (B) $\sqrt{I_A^2 + I_B^2}$
- (C) $\sqrt{\frac{I_A^2 + I_B^2}{2}}$
- (D) $\sqrt{2(I_A^2 + I_B^2)}$

Q8. In an isothermal process, the volume of an ideal gas is halved. The pressure of the gas becomes:

[JEE Main 2023]

- (A) Half
- (B) Four times
- (C) Double
- (D) Unchanged

Q9. If the mass of Earth remains the same but its radius shrinks by 1%, the acceleration due to gravity g on its surface would:

[JEE Main 2021]

- (A) Decrease by 2%
- (B) Remain the same
- (C) Increase by 1%
- (D) Increase by 2%

Q10. Which of the following pairs of physical quantities does NOT have the same dimensions?

[JEE Main 2018]

- (A) Angular Momentum and Planck's Constant



- (B) Pressure and Young's Modulus
- (C) Surface Tension and Impulse
- (D) Torque and Energy

Q11. For a nucleus of mass number A and radius R , the mass density of the nucleus is: [JEE Main 2021]

- (A) Proportional to $A^{1/3}$
- (B) Inversely proportional to A
- (C) Proportional to A
- (D) Independent of A

Q12. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 40 cm. The power of the combination is: [JEE Main 2022]

- (A) +7.5 D
- (B) +5 D
- (C) +2.5 D
- (D) -2.5 D

Q13. A block of mass 5 kg is pulled along a horizontal frictionless surface by a force of 20 N at an angle of 60° to the horizontal. The acceleration of the block is: [JEE Main 2023]

- (A) 2 m/s^2
- (B) 1.73 m/s^2
- (C) 4 m/s^2
- (D) 1 m/s^2

Q14. At what distances from the center of a long straight wire (radius a) carrying uniform current is the magnetic field half of its maximum value? [JEE Main 2019]

- (A) $\frac{a}{2}$ and a
- (B) $\frac{a}{4}$ and $4a$



- (C) $\frac{a}{2}$ and $2a$
(D) a and $2a$

Q15. A particle executing SHM has a maximum velocity v_0 and maximum acceleration a_0 . Its time period is: [JEE Main 2022]

- (A) $2\pi \frac{v_0}{a_0}$
(B) $2\pi \frac{v_0}{a_0}$
(C) $\frac{v_0}{a_0}$
(D) $2\pi \frac{a_0}{v_0}$

Q16. A metallic ring is uniformly charged. The electric field due to arc AB at the center O is E . What is the magnitude of the electric field at O due to arc ABC ($90^\circ + 90^\circ$)? [JEE Main 2021]

- (A) E
(B) $\sqrt{2} E$
(C) 0
(D) $2E$

Q17. A thin uniform rod of length L and mass M is bent into a circle. Its moment of inertia about an axis passing through its center and perpendicular to its plane is: [JEE Main 2020]

- (A) $\frac{ML^2}{12}$
(B) $\frac{ML^2}{2\pi^2}$
(C) $\frac{ML^2}{4\pi^2}$
(D) $\frac{ML^2}{8\pi^2}$

Q18. In the photoelectric effect, the stopping potential V_s is: [JEE Main 2023]

- (A) Independent of the frequency of incident light



- (B) Directly proportional to the intensity of light
- (C) Inversely proportional to the intensity of light
- (D) $\frac{1}{e}$ times the maximum kinetic energy of emitted photoelectrons

Q19. The average kinetic energy of a gas molecule at temperature T is E . If the temperature is doubled to $2T$, the new average kinetic energy is:
[JEE Main 2019]

- (A) $\sqrt{2} E$
- (B) $\frac{E}{2}$
- (C) $2E$
- (D) $4E$

Q20. Three resistors of 2Ω , 4Ω , and 6Ω are connected in parallel. The equivalent resistance is: [JEE Main 2022]

- (A) 0.5Ω
- (B) 12Ω
- (C) 1.09Ω
- (D) 3Ω



Section B — Numerical Questions

Q21. A parallel plate capacitor ($C = 2.5 \mu\text{F}$) has a displacement current of 0.25 mA. The rate of change of potential difference $\left(\frac{dV}{dt}\right)$ in V/s is:

[JEE Main 2023]

Q22. The ratio of the shortest wavelength of the Balmer series to the shortest wavelength of the Lyman series for hydrogen is:

[JEE Main 2021]

Q23. Two strings of same material and tension have radii R and $\frac{R}{2}$. If the wave velocity in the first string is v_1 and in the second is v_2 , the ratio $\frac{v_2}{v_1}$ is:

[JEE Main 2022]

Q24. A point charge q is placed at the center of a cube of side L . The electric flux through one face of the cube is $\frac{q}{k\epsilon_0}$. The value of k is:

[JEE Main 2020]

Q25. In YDSE, if the slit width ratio is 4 : 9, the ratio of maximum to minimum intensity is $\frac{I_{\max}}{I_{\min}} = \frac{25}{k}$. The value of k is:

[JEE Main 2023]



Detailed Solutions

Q1.

Solution

Concept: In Bohr's model:

- Radius of orbit: $r_n \propto n^2$
- Velocity of electron: $v_n \propto \frac{1}{n}$

Time period:

$$T = \frac{2\pi r}{v}$$

Frequency:

$$f = \frac{1}{T}$$

Solution:

Using proportional relations:

$$T \propto \frac{r}{v} \propto \frac{n^2}{1/n} = n^3$$

Thus:

$$f = \frac{1}{T} \propto \frac{1}{n^3}$$

Hence, frequency varies as:

$$f \propto \frac{1}{n^3}$$

Answer: (D)

Solution

Equivalent capacitance:

$$\frac{1}{C_1} = \frac{1}{C_a} + \frac{1}{C_b} = \frac{d}{2A} \left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} \right)$$

$$C_1 = \frac{2A}{d} \cdot \frac{\varepsilon_1 \varepsilon_2}{\varepsilon_1 + \varepsilon_2}$$

Configuration 2 (parallel-like split of A):

Each dielectric occupies area $A/2$.

$$C_a = \frac{\varepsilon_1(A/2)}{d}, \quad C_b = \frac{\varepsilon_2(A/2)}{d}$$

$$C_2 = C_a + C_b = \frac{A}{2d}(\varepsilon_1 + \varepsilon_2)$$

Ratio:

$$\frac{C_1}{C_2} = \frac{\frac{2A}{d} \cdot \frac{\varepsilon_1 \varepsilon_2}{\varepsilon_1 + \varepsilon_2}}{\frac{A}{2d}(\varepsilon_1 + \varepsilon_2)} = \frac{4\varepsilon_1 \varepsilon_2}{(\varepsilon_1 + \varepsilon_2)^2}$$

$$\boxed{\frac{C_1}{C_2} = \frac{4\varepsilon_1 \varepsilon_2}{(\varepsilon_1 + \varepsilon_2)^2}}$$

Answer: (D)



Q3.

Solution**Concept:** De Broglie wavelength:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

If velocity has components, then:

$$v = \sqrt{v_x^2 + v_z^2}$$

Solution:

Initial velocity:

$$\vec{v} = v_0 \hat{i}$$

Electric field is along $-\hat{k}$, so acceleration is:

$$a_z = \frac{-eE_0}{m}$$

Thus, velocity components after time t :

$$v_x = v_0, \quad v_z = \frac{eE_0 t}{m}$$

Net speed:

$$v = \sqrt{v_0^2 + \left(\frac{eE_0 t}{m}\right)^2}$$

Initial wavelength:

$$\lambda_0 = \frac{h}{mv_0}$$

New wavelength:

$$\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{v_0^2 + \left(\frac{eE_0 t}{m}\right)^2}}$$

$$\lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$$

$$\lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2 E_0^2 t^2}{m^2 v_0^2}}}$$

Answer: (B)

Q4.

Solution**Concept:** Magnetic flux:

$$\phi = NAB \cos \theta$$

Induced emf:

$$\varepsilon = -\frac{d\phi}{dt} = NAB\omega \sin \theta$$

Solution:When the plane of the coil is parallel to B , the normal to the coil is perpendicular to B .

$$\theta = 90^\circ$$

Thus,

$$\phi = NAB \cos 90^\circ = 0$$

$$\varepsilon = NAB\omega \sin 90^\circ = NAB\omega$$

$$\boxed{\phi = 0, \quad \varepsilon = NAB\omega}$$

Answer: (D)

Q5.

Solution**Concept:** For interference:

$$I_{\max} = (\sqrt{I_1} + \sqrt{I_2})^2, \quad I_{\min} = (\sqrt{I_1} - \sqrt{I_2})^2$$

Solution:

Given:

$$I_1 : I_2 = 1 : 9 \Rightarrow I_1 = 1, \quad I_2 = 9$$

$$\sqrt{I_1} = 1, \quad \sqrt{I_2} = 3$$

$$I_{\max} = (1 + 3)^2 = 16$$

$$I_{\min} = (3 - 1)^2 = 4$$

$$\frac{I_{\max}}{I_{\min}} = \frac{16}{4} = 4$$

$$I_{\max} : I_{\min} = 4 : 1$$

Answer: (B)

Q6.

Solution

Concept: For efficient thermoelectric (Seebeck effect) materials, the figure of merit is:

$$Z = \frac{S^2 \sigma}{\kappa}$$

where S is Seebeck coefficient, σ is electrical conductivity, and κ is thermal conductivity. To maximize Z :

- Electrical conductivity should be high
- Thermal conductivity should be low

Solution:

A good thermoelectric material should:

- Allow charge carriers to move easily \Rightarrow high electrical conductivity
- Prevent heat flow \Rightarrow low thermal conductivity

Low thermal conductivity and high electrical conductivity

Answer: (D)



Q7.

Solution**Concept:** RMS value of current:

$$I_{\text{rms}} = \sqrt{\langle I^2 \rangle}$$

Also,

$$\langle \sin^2 \omega t \rangle = \langle \cos^2 \omega t \rangle = \frac{1}{2}, \quad \langle \sin \omega t \cos \omega t \rangle = 0$$

Solution:

Given:

$$I = I_A \sin \omega t + I_B \cos \omega t$$

$$I^2 = I_A^2 \sin^2 \omega t + I_B^2 \cos^2 \omega t + 2I_A I_B \sin \omega t \cos \omega t$$

Taking mean:

$$\langle I^2 \rangle = \frac{I_A^2}{2} + \frac{I_B^2}{2}$$

$$I_{\text{rms}} = \sqrt{\frac{I_A^2 + I_B^2}{2}}$$

$$I_{\text{rms}} = \sqrt{\frac{I_A^2 + I_B^2}{2}}$$

Answer: (D)

Q8.

Solution**Concept:** In an isothermal process for an ideal gas:

$$PV = \text{constant}$$

Solution:

$$P_1V_1 = P_2V_2$$

Given:

$$V_2 = \frac{V_1}{2}$$

$$P_1V_1 = P_2 \left(\frac{V_1}{2} \right)$$

$$P_2 = 2P_1$$

Thus, pressure becomes double.

Pressure becomes double

Answer: (C)

Q9.

Solution**Concept:** Acceleration due to gravity:

$$g = \frac{GM}{R^2}$$

Solution:Let initial radius be R .

New radius:

$$R' = 0.99R$$

$$g' = \frac{GM}{(0.99R)^2} = \frac{GM}{R^2} \cdot \frac{1}{(0.99)^2}$$

$$g' = g \cdot \frac{1}{0.9801} \approx 1.02g$$

Thus, g increases by approximately 2%. g increases by 2%

Answer: (D)



Q10.

Solution**Concept:** Compare dimensions of given physical quantities.

- Angular momentum = $[ML^2T^{-1}]$
- Planck's constant = $[ML^2T^{-1}]$
- Pressure = $[ML^{-1}T^{-2}]$
- Young's modulus = $[ML^{-1}T^{-2}]$
- Surface tension = $[MT^{-2}]$
- Impulse = $[MLT^{-1}]$
- Torque = $[ML^2T^{-2}]$
- Energy = $[ML^2T^{-2}]$

Solution:

Comparing:

- Angular momentum and Planck's constant \rightarrow same
- Pressure and Young's modulus \rightarrow same
- Torque and Energy \rightarrow same
- Surface tension and Impulse \rightarrow different

Surface tension and Impulse

Answer: (C)

Q11.

Solution**Concept:** Nuclear radius:

$$R = R_0 A^{1/3}$$

Mass of nucleus:

$$M \propto A$$

Density:

$$\rho = \frac{M}{\frac{4}{3}\pi R^3}$$

Solution:

$$R^3 \propto (A^{1/3})^3 = A$$

$$\rho \propto \frac{A}{A} = \text{constant}$$

Thus, density is independent of A .

Independent of A

Answer: (D)



Q12.

Solution

Concept: For lenses in contact, the equivalent focal length F is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Power of a lens:

$$P = 100/f \text{ (if } f \text{ in cm)} \quad \text{or} \quad P = 1/f \text{ (if } f \text{ in m)}$$

Solution:

Given:

$$f_1 = +20 \text{ cm}, \quad f_2 = -40 \text{ cm}$$

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{-40} = \frac{1}{20} - \frac{1}{40} = \frac{1}{40} \text{ cm}^{-1}$$

Power in diopters:

$$P = 100/F = 100/40 = +2.5 \text{ D}$$

$$\boxed{+2.5 \text{ D}}$$

Answer: (C)

Q13.

Solution

Concept: For a block moving on a horizontal surface, only the horizontal component of the applied force contributes to its horizontal acceleration. Horizontal component of force:

$$F_x = F \cos \theta \quad \text{Newton's Second Law: } F_{net} = ma$$

Solution: Given: Mass (m) = 5 kg Applied Force (F) = 20 N Angle (θ) = 60° The horizontal component of the force is:

$$F_x = F \cos 60^\circ$$

$$F_x = 20 \times \frac{1}{2} = 10 \text{ N}$$

Applying Newton's second law in the horizontal direction:

$$a = \frac{F_x}{m}$$

$$a = \frac{10}{5} = 2 \text{ m/s}^2$$

The acceleration of the block is 2 m/s^2 .

Answer: (A)



Q14.

Solution

Concept: For a long straight wire of radius a carrying uniform current I : Inside the wire ($r < a$): $B_{in} = \frac{\mu_0 I r}{2\pi a^2}$ Outside the wire ($r > a$): $B_{out} = \frac{\mu_0 I}{2\pi r}$ Maximum field occurs at $r = a$: $B_{max} = \frac{\mu_0 I}{2\pi a}$

Solution: We seek r such that $B = \frac{1}{2} B_{max} = \frac{\mu_0 I}{4\pi a}$. Case 1: Inside the wire ($r < a$)

$$\frac{\mu_0 I r}{2\pi a^2} = \frac{\mu_0 I}{4\pi a}$$

Solving for r :

$$\frac{r}{a^2} = \frac{1}{2a} \implies r = \frac{a}{2}$$

Case 2: Outside the wire ($r > a$)

$$\frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{4\pi a}$$

Solving for r :

$$\frac{1}{r} = \frac{1}{2a} \implies r = 2a$$

Thus, the magnetic field is half of its maximum value at distances $r = a/2$ and $r = 2a$.

Answer: (C)



Q15.

Solution

Concept: For a particle in SHM with amplitude A and angular frequency ω : Displacement: $x = A \sin(\omega t)$ Velocity: $v = A\omega \cos(\omega t) \implies v_{max} = A\omega$ Acceleration: $a = -A\omega^2 \sin(\omega t) \implies a_{max} = A\omega^2$ Time Period: $T = \frac{2\pi}{\omega}$

Solution: Given maximum velocity v_0 and maximum acceleration a_0 :

$$v_0 = A\omega \quad \dots (1)$$

$$a_0 = A\omega^2 \quad \dots (2)$$

To find ω , we divide equation (2) by equation (1):

$$\frac{a_0}{v_0} = \frac{A\omega^2}{A\omega} = \omega$$

Now, substitute the value of ω into the formula for the time period T :

$$T = \frac{2\pi}{\omega}$$

$$T = \frac{2\pi}{a_0/v_0}$$

$$T = \frac{2\pi v_0}{a_0}$$

Answer: (B)



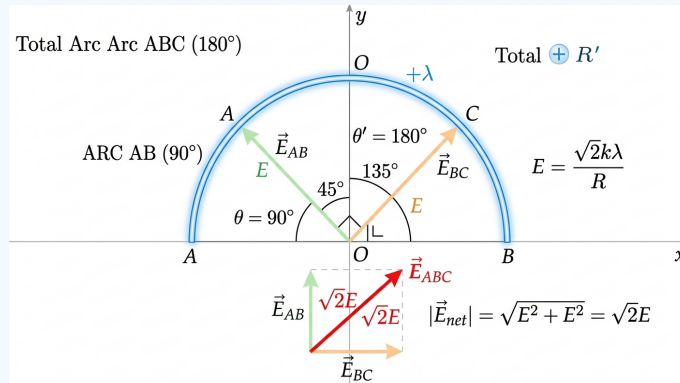
Q16.

Solution

Concept: The electric field at the center of a circular arc of radius R and subtended angle θ is given by:

$$E_{arc} = \frac{2k\lambda}{R} \sin\left(\frac{\theta}{2}\right)$$

The direction of the field is along the angle bisector of the arc.



Solution: Let the electric field due to arc AB (which subtends 90° at the center) be E . Using the formula for $\theta = 90^\circ$:

$$E = \frac{2k\lambda}{R} \sin(45^\circ) = \frac{2k\lambda}{R} \frac{1}{\sqrt{2}} = \frac{\sqrt{2}k\lambda}{R}$$

Now, consider arc ABC . This arc subtends a total angle of $\theta' = 90^\circ + 90^\circ = 180^\circ$ (a semicircle). Using the formula for $\theta' = 180^\circ$:

$$E_{ABC} = \frac{2k\lambda}{R} \sin(90^\circ) = \frac{2k\lambda}{R}$$

To find E_{ABC} in terms of E , we substitute $k\lambda/R = E/\sqrt{2}$ from the first equation:

$$E_{ABC} = 2 \left(\frac{E}{\sqrt{2}} \right) = \sqrt{2}E$$

Alternatively, by vector addition: the fields due to two 90° arcs (each of magnitude E) are perpendicular to each other.

$$E_{net} = \sqrt{E^2 + E^2} = \sqrt{2}E$$

Answer: (B)



Q17.

Solution

Concept: For a thin rod bent into a circle, the length of the rod L becomes the circumference of the circle $2\pi R$. The moment of inertia I of a thin ring (or hoop) about an axis passing through its center and perpendicular to its plane is given by:

$$I = MR^2$$

Solution: Given: Length of rod = L Mass of rod = M Step 1: Relate the length L to the radius R of the circle formed:

$$L = 2\pi R \implies R = \frac{L}{2\pi}$$

Step 2: Substitute R into the formula for the moment of inertia:

$$I = M \left(\frac{L}{2\pi} \right)^2$$

$$I = M \frac{L^2}{4\pi^2}$$

Thus, the moment of inertia is:

$$I = \frac{ML^2}{4\pi^2}$$

Answer: (C)



Q18.

Solution

Concept: The stopping potential V_s is the potential required to stop the fastest-moving photoelectrons. It is related to the maximum kinetic energy by:

$$K_{max} = eV_s$$

Using Einstein's Photoelectric Equation:

$$hf = \Phi + K_{max}$$

Solution: Substituting the expression for kinetic energy into the Einstein equation:

$$hf = \Phi + eV_s$$

Solving for V_s :

$$eV_s = hf - \Phi$$

$$V_s = \frac{h}{e}f - \frac{\Phi}{e}$$

This shows that the stopping potential is: Directly proportional to the frequency of incident light. Independent of the intensity of incident light.

Answer: (D)



Q19.

Solution

Concept: According to the kinetic theory of gases, the average kinetic energy (E) of a gas molecule is directly proportional to its absolute temperature (T). For a molecule with f degrees of freedom, the relation is:

$$E = \frac{f}{2} k_B T$$

where k_B is the Boltzmann constant. For a fixed gas, $E \propto T$.

Solution: Given: Initial average kinetic energy = E Initial temperature = T Final temperature = $2T$ Using the proportionality:

$$\frac{E_1}{T_1} = \frac{E_2}{T_2}$$

Substitute the given values:

$$\frac{E}{T} = \frac{E_{new}}{2T}$$

Solving for E_{new} :

$$E_{new} = E \times \frac{2T}{T}$$
$$E_{new} = 2E$$

Therefore, if the absolute temperature is doubled, the average kinetic energy of the gas molecules also doubles.

Answer: (B)



Q20.

Solution

Concept: When resistors are connected in parallel, the reciprocal of the equivalent resistance (R_{eq}) is the sum of the reciprocals of the individual resistances:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Solution: Given: $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 6\Omega$ Applying the parallel formula:

$$\frac{1}{R_{eq}} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6}$$

To add these fractions, find a common denominator (which is 12):

$$\frac{1}{R_{eq}} = \frac{6}{12} + \frac{3}{12} + \frac{2}{12}$$

$$\frac{1}{R_{eq}} = \frac{11}{12}$$

Taking the reciprocal to find R_{eq} :

$$R_{eq} = \frac{12}{11}\Omega \approx 1.09\Omega$$

As a check, the equivalent resistance in a parallel circuit is always smaller than the smallest individual resistor ($1.09\Omega < 2\Omega$).

Answer: (C)



Q21.

Solution

Concept: Displacement current (I_d) in a capacitor is defined by the rate of change of the electric flux between the plates. It is related to the rate of change of potential difference (V) across the capacitor by the formula:

$$I_d = C \frac{dV}{dt}$$

where C is the capacitance and $\frac{dV}{dt}$ is the rate of change of potential difference.

Solution: Given: Capacitance, $C = 2.5 \mu\text{F} = 2.5 \times 10^{-6} \text{ F}$ Displacement current, $I_d = 0.25 \text{ mA} = 0.25 \times 10^{-3} \text{ A}$ Using the relation:

$$I_d = C \frac{dV}{dt}$$

Rearranging to solve for $\frac{dV}{dt}$:

$$\frac{dV}{dt} = \frac{I_d}{C}$$

Substitute the given values:

$$\frac{dV}{dt} = \frac{0.25 \times 10^{-3}}{2.5 \times 10^{-6}}$$

$$\frac{dV}{dt} = \frac{0.25}{2.5} \times 10^3$$

$$\frac{dV}{dt} = 0.1 \times 1000$$

$$\frac{dV}{dt} = 100 \text{ V/s}$$

$$\boxed{100 \text{ V/s}}$$

Answer: (100)



Q22.

Solution

Concept: The wavelength (λ) of emitted radiation in the hydrogen spectrum is given by the Rydberg formula:

$$\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

The shortest wavelength (series limit) in any series occurs when the electron transitions from $n_2 = \infty$ to the ground state of that series (n_1). For Lyman series: $n_1 = 1$ For Balmer series: $n_1 = 2$

Solution: Step 1: Find the shortest wavelength for the Lyman series (λ_L):

$$\frac{1}{\lambda_L} = R \left(\frac{1}{1^2} - \frac{1}{\infty^2} \right) = R \implies \lambda_L = \frac{1}{R}$$

Step 2: Find the shortest wavelength for the Balmer series (λ_B):

$$\frac{1}{\lambda_B} = R \left(\frac{1}{2^2} - \frac{1}{\infty^2} \right) = \frac{R}{4} \implies \lambda_B = \frac{4}{R}$$

Step 3: Calculate the ratio of λ_B to λ_L :

$$\frac{\lambda_B}{\lambda_L} = \frac{4/R}{1/R} = 4$$

Thus, the ratio is 4 : 1.

Answer: (4)



Q23.

Solution

Concept: The velocity of a transverse wave in a stretched string is given by:

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension and μ is the linear mass density (mass per unit length). Since $\mu = \text{density}(\rho) \times \text{area of cross-section}(A)$:

$$\mu = \rho \cdot \pi R^2$$

Substituting this into the velocity formula:

$$v = \sqrt{\frac{T}{\rho\pi R^2}} = \frac{1}{R} \sqrt{\frac{T}{\rho\pi}}$$

For strings of the same material (ρ) and same tension (T), the velocity is inversely proportional to the radius:

$$v \propto \frac{1}{R}$$

Solution: Given: Radius of first string, $R_1 = R$ Radius of second string, $R_2 = R/2$ Velocity in first string = v_1 Velocity in second string = v_2 Using the inverse proportionality:

$$\frac{v_2}{v_1} = \frac{R_1}{R_2}$$

Substitute the values:

$$\frac{v_2}{v_1} = \frac{R}{R/2}$$

$$\frac{v_2}{v_1} = 2$$

Thus, the ratio v_2/v_1 is 2 : 1.

Answer: (2)



Q24.

Solution

Concept: Gauss's Law states that the total electric flux Φ_{total} through any closed surface is equal to the net charge q_{in} enclosed by the surface divided by the permittivity of free space ϵ_0 :

$$\Phi_{total} = \frac{q_{in}}{\epsilon_0}$$

For a charge placed at the center of a symmetric object like a cube, the flux is distributed equally through all faces.

Solution: The total flux through the entire cube (which has 6 faces) is:

$$\Phi_{total} = \frac{q}{\epsilon_0}$$

Since the charge is at the geometric center, the flux through each of the 6 identical faces is:

$$\Phi_{face} = \frac{1}{6}\Phi_{total} = \frac{q}{6\epsilon_0}$$

Comparing this with the given expression $\frac{q}{k\epsilon_0}$:

$$\frac{q}{6\epsilon_0} = \frac{q}{k\epsilon_0}$$

Thus, the value of k is:

$$k = 6$$

Answer: (6)



Q25.

Solution

Concept: In Young's Double Slit Experiment (YDSE), the intensity I of light from a slit is proportional to its width w . Furthermore, intensity is proportional to the square of the amplitude A :

$$I \propto w \quad \text{and} \quad I \propto A^2 \Rightarrow A \propto \sqrt{I} \propto \sqrt{w}$$

The maximum and minimum intensities are given by:

$$I_{\max} = (A_1 + A_2)^2 \quad \text{and} \quad I_{\min} = (A_1 - A_2)^2$$

Solution: Given the slit width ratio $w_1 : w_2 = 4 : 9$, the intensity ratio is:

$$\frac{I_1}{I_2} = \frac{4}{9}$$

The ratio of amplitudes is:

$$\frac{A_1}{A_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{4}{9}} = \frac{2}{3}$$

Let $A_1 = 2x$ and $A_2 = 3x$. Then:

$$I_{\max} = (2x + 3x)^2 = (5x)^2 = 25x^2$$

$$I_{\min} = (3x - 2x)^2 = (x)^2 = x^2$$

The ratio of maximum to minimum intensity is:

$$\frac{I_{\max}}{I_{\min}} = \frac{25x^2}{x^2} = \frac{25}{1}$$

Comparing this with the given ratio $\frac{25}{k}$:

$$\frac{25}{1} = \frac{25}{k} \Rightarrow k = 1$$

Answer: (1)



Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	100	22	4
23	2	24	6
25	1		

