CUET 2026 May 19 Shift 2 Physics

Question Paper (Memory-Based) with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) The examination will be conducted in Computer-Based Test (CBT) mode.

(ii) Each question carries +5 marks for correct answer and -1 mark for wrong answer.

(iii) The total number of questions are 50.

(iv) Duration of the exam is 1 hour (60 minutes).

1. A balanced Wheatstone bridge consists of four resistances $P = 10\,\Omega$, $Q = 20\,\Omega$, $R = 15\,\Omega$, and S. If the positions of the galvanometer and the battery are interchanged, the balancing condition will remain valid. What is the value of the unknown resistance S under the balanced condition?

(A) $15\,\Omega$

(B) $30\,\Omega$

(C) $45\,\Omega$

(D) $60\,\Omega$

Correct Answer: (B) 30 Ω

Solution:

Concept:

A Wheatstone bridge is an electrical circuit configuration used to measure an unknown electrical resistance by balancing two legs of a bridge circuit. The network consists of four resistors arranged in a closed loop (a diamond shape) with a voltage source connected across one pair of opposite vertices and a sensitive galvanometer connected across the remaining two vertices.

When the bridge is perfectly balanced, the electrical potential at both terminals of the galvanometer becomes exactly equal. Because there is zero potential difference across it, no current flows through the galvanometer branch ($I_g = 0$). The mathematical condition governing this state of balance is given by the ratio of adjacent arms:

$$\frac{P}{Q} = \frac{R}{S}$$

An interesting property of this network is its conjugate nature. If you interchange the positions of the input battery source and the null-detecting galvanometer, the fundamental ratio that determines the balance remains totally unaffected. The condition for zero deflection stays exactly the same.

Step 1: Substitute the given values into the balancing ratio.

We are given the values for three of the circuit arms:

- Resistor $P = 10\,\Omega$
- Resistor $Q = 20\,\Omega$
- Resistor $R = 15\,\Omega$

Plugging these parameters directly into our null-balance equation:

$$\frac{10}{20} = \frac{15}{S}$$

Step 2: Isolate and solve for the unknown resistance S.

First, simplify the fraction on the left side of the equation:

$$\frac{1}{2} = \frac{15}{S}$$

Now, cross-multiply to solve for the value of S:

$$S \cdot 1 = 15 \cdot 2$$

$$S = 30\,\Omega$$

Thus, the value of the unknown resistor must be exactly $30\,\Omega$ to maintain a state of zero current through the central galvanometer branch.

Quick Tip: To avoid basic algebraic cross-multiplication errors under time pressure, remember that if the bottom resistor on the left side (Q) is double the top resistor (P), then the bottom resistor on the right side (S) must simply be double its corresponding top resistor (R).

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2. Three point charges $+q$, $+q$, and $-q$ are placed at the vertices of an equilateral triangle of side length L. The net electrostatic potential energy of this system of charges is given by:

(A) $\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$

(B) $-\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$

(C) $-\frac{3}{4\pi\varepsilon_0}\frac{q^2}{L}$

(D) 0

Correct Answer: (B) $-\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$

Solution:

Concept:

The electrostatic potential energy of a collection of stationary point charges represents the total external work done to bring these charges from an infinite separation to their specific coordinates in space without accelerating them.

Based on the fact that electrostatic forces are conservative, the potential energy depends strictly on the final configuration, not the path taken. For a pair of point charges q_i and q_j separated by a spatial distance r_{ij}, the mutual potential energy is a scalar value given by Coulomb's law derivation:

$$U_{ij} = \frac{1}{4\pi\varepsilon_0}\frac{q_i q_j}{r_{ij}}$$

When dealing with a system containing more than two charges, the net electrostatic potential energy is computed by taking the algebraic sum of the potential energies of every single unique pair configuration. For a system of three charges, this translates to:

$$U_{\text{total}} = U_{12} + U_{23} + U_{13}$$

Step 1: Identify the individual charges and their geometric separations.

Let us map out our three point charges sitting at the corners of the equilateral triangle:

- $q_1 = +q$
- $q_2 = +q$
- $q_3 = -q$

Since they occupy the vertices of an equilateral triangle, every single pair is separated by the exact same side length, meaning:

$$r_{12} = r_{23} = r_{13} = L$$

Step 2: Calculate the scalar interaction energy for each individual pair.

Let us write out the explicit energy expression for each pair, keeping careful track of the algebraic signs:

1. Interaction between charge 1 and charge 2 (both positive):

$$U_{12} = \frac{1}{4\pi\varepsilon_0}\frac{(+q)(+q)}{L} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$$

2. Interaction between charge 2 and charge 3 (one positive, one negative):

$$U_{23} = \frac{1}{4\pi\varepsilon_0}\frac{(+q)(-q)}{L} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$$

3. Interaction between charge 1 and charge 3 (one positive, one negative):

$$U_{13} = \frac{1}{4\pi\varepsilon_0}\frac{(+q)(-q)}{L} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$$

Step 3: Algebraically sum up the pair energies to find the net system energy.

Now, add the three scalar parts together:

$$U_{\text{total}} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q^2}{L} + \left(-\frac{q^2}{L}\right) + \left(-\frac{q^2}{L}\right)\right]$$

Combining the common terms inside the bracket:

$$U_{\text{total}} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q^2}{L} - \frac{q^2}{L} - \frac{q^2}{L}\right]$$

$$U_{\text{total}} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{L}$$

The negative sign indicates that the system is bound; external work must be put into the configuration to completely pull these charges infinitely far apart from each other.

Quick Tip: Potential energy is a scalar quantity, not a vector! Never split it into horizontal or vertical components. Simply carry the sign of the charges through the equations and sum them up using basic arithmetic.

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3. A particle carrying a positive charge q moves with a velocity vector $\vec{v} = v\hat{i}$ into a uniform magnetic field region specified by $\vec{B} = B\hat{j}$. What is the vector direction of the magnetic Lorentz force acting on this particle at that instant?

(A) $+\hat{k}$

(B) $-\hat{k}$

(C) $+\hat{i}$

(D) $-\hat{j}$

Correct Answer: (A) $+\hat{k}$

Solution:

Concept:

When an electrically charged particle moves through a magnetic field, it experiences a deflecting force known as the magnetic component of the Lorentz Force. This force relies fundamentally on the relative orientation of the particle's velocity vector and the surrounding magnetic field lines.

The exact vector equation mapping this physical interaction is given by:

$$\vec{F} = q(\vec{v} \times \vec{B})$$

This mathematical cross product dictates two critical physical rules:

1. The resulting magnetic force vector $\vec{F}$ is always simultaneously perpendicular to both the velocity vector $\vec{v}$ and the magnetic field vector $\vec{B}$.

2. The direction depends strictly on the sign of the net charge q. If the charge is positive, the force matches the direction of $\vec{v} \times \vec{B}$. If the charge is negative, the force points in the exact opposite direction $(-\vec{v} \times \vec{B})$.

Step 1: Substitute the given vector components into the Lorentz law.

Let's look at our given values:

- Net charge of the particle $= +q$ (positive sign)
- Velocity vector $\vec{v} = v\hat{i}$ (moving along the positive x-axis)
- Magnetic field vector $\vec{B} = B\hat{j}$ (pointing along the positive y-axis)

Substituting these into the cross-product equation:

$$\vec{F} = q \cdot (v\hat{i} \times B\hat{j})$$

Step 2: Use scalar and vector properties to evaluate the cross product.

Pull the scalar magnitudes (v and B) out in front of the vector cross product:

$$\vec{F} = qvB \cdot (\hat{i} \times \hat{j})$$

According to the properties of orthogonal unit vectors in a right-handed Cartesian coordinate system, the cross product of the unit vector along the x-axis ($\hat{i}$) and the unit vector along the y-axis ($\hat{j}$) yields the positive unit vector along the z-axis ($\hat{k}$):

$$\hat{i} \times \hat{j} = \hat{k}$$

Substituting this back into our expression gives:

$$\vec{F} = qvB\hat{k}$$

Since the unit vector is $\hat{k}$, the mechanical force points straight along the positive z-direction.

Quick Tip: You can verify cross-product directions using a simple clockwise circle memory aid: if you go from $\hat{i} \to \hat{j}$, you get positive $\hat{k}$. If you reverse the order to $\hat{j} \to \hat{i}$, you get negative $-\hat{k}$. Always check the sign of the charge first!

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4. A material specimen exhibits a small, negative magnetic susceptibility ($\chi < 0$) at room temperature. When placed inside a non-uniform magnetic field, this specimen experiences a net force pushing it. How will this material behave?

(A) It will be strongly attracted toward the stronger fields.

(B) It will be weakly attracted toward the stronger fields.

(C) It will be weakly repelled away from the stronger field regions.

(D) Its properties change completely above its Curie temperature.

Correct Answer: (C) It will be weakly repelled away from the stronger field regions.

Solution:

Concept:

Magnetic susceptibility, denoted by the Greek letter χ (chi), is a dimensionless proportionality constant that tells us exactly how easily a given material becomes magnetized when exposed to an external magnetic field. It forms the relationship:

$$\vec{M} = \chi \vec{H}$$

where $\vec{M}$ is the induced magnetization density, and $\vec{H}$ is the applied magnetic field intensity.

Based on the value of magnetic susceptibility, materials are classified into three primary groups:

- **Diamagnetic Materials:** Characterized by a small, negative susceptibility ($-1 \leq \chi < 0$).
- **Paramagnetic Materials:** Characterized by a small, positive susceptibility ($0 < \chi < 1$).
- **Ferromagnetic Materials:** Characterized by an incredibly large, positive susceptibility ($\chi \gg 1$).

Step 1: Match the given property to the correct material group.

The problem states that the specimen has a small, negative magnetic susceptibility ($\chi < 0$). This instantly identifies the specimen as a diamagnetic material.

Step 2: Analyze the structural magnetic response of this group.

When a diamagnetic material is introduced to an external field lines, its atomic electrons shift their orbital paths. This induces an internal magnetic dipole moment that directly opposes the applied external field direction (Lenz's law behavior at the atomic scale).

Because this induced magnetization runs counter to the external magnetic field lines, the material experiences a net mechanical force pushing it away.

Step 3: Determine the behavior inside a non-uniform spatial gradient field.

In a uniform magnetic field, a diamagnetic object experiences an alignment torque but zero net translational force. However, inside a non-uniform (gradient) magnetic field, the field strength varies across different regions of space.

Because the induced dipoles oppose the external field lines, the material is mechanically repelled by areas of high magnetic flux density. This creates a net translational migration force, shifting the material out of high-intensity zones into weaker field regions.

Therefore, it will be weakly repelled away from the stronger field regions.

Quick Tip: Diamagnetism is a fundamental property found in all materials, but it is often covered up by much stronger paramagnetic or ferromagnetic effects. Unlike those two classes, a material's diamagnetic response remains completely independent of temperature changes.

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5. A straight metallic rod of length L is oriented horizontally and dropped vertically downward with a speed v perpendicular to the horizontal component of the Earth's uniform magnetic field B_H. The instantaneous motional electromotive force (EMF) induced across the two ends of this rod is:

(A) $\frac{1}{2}B_H v L^2$

(B) $B_H v L$

(C) $\frac{B_H v}{L}$

(D) 0

Correct Answer: (B) $B_H v L$

Solution:

Concept:

Motional electromotive force (EMF) is an electrical potential difference induced across a conductor that is actively moving through a magnetic field region.

At the microscopic level, as the metallic conductor moves through the field, the free conduction electrons inside the metal move along with it at velocity $\vec{v}$. Because these charges are moving within an external magnetic field $\vec{B}$, they experience a magnetic Lorentz force ($\vec{F} = q(\vec{v} \times \vec{B})$) that pushes them along the length of the conductor.

This force drives free electrons toward one end of the rod, leaving behind a net positive charge at the opposite end. This separation of charges creates an internal electric field that opposes the magnetic force. Eventually, a dynamic equilibrium is reached, establishing a stable voltage difference across the ends of the conductor.

The vector equation for this induced potential difference is written as:

$$e = (\vec{v} \times \vec{B}) \cdot \vec{L}$$

When the velocity vector $\vec{v}$, the magnetic field vector $\vec{B}$, and the straight length axis vector $\vec{L}$ are all mutually perpendicular to each other, this scalar triple product simplifies to:

$$e = BvL$$

Step 1: Analyze the geometric alignment of the three key vectors.

Let's look at how the vectors in the problem are oriented relative to each other:

- Magnetic Field Vector ($\vec{B}$): Aligned with the horizontal component of Earth's magnetic field (B_H). Let's say it points along the North-South direction.
- Velocity Vector ($\vec{v}$): The rod is dropped straight down, meaning its velocity vector points vertically downward toward the ground.
- Conductor Length Axis ($\vec{L}$): The rod is held horizontally, running along the East-West direction to cut across the field lines.

This layout confirms that the vertical velocity path, the horizontal North-South field lines, and the horizontal East-West rod length are all perfectly perpendicular to one another (separated by an angle of 90°).

Step 2: Calculate the magnitude of the induced motional EMF.

Since all three components are mutually orthogonal, the sine and cosine parameters from our vector cross and dot products both evaluate to a maximum value of 1:

$$e = B_H \cdot v \cdot L \cdot \sin(90^\circ) \cdot \cos(0^\circ)$$

$$e = B_H v L$$

As a result, a stable potential difference of exactly $B_H v L$ is generated across the tips of the falling rod.

Quick Tip: For motional EMF to exist, the moving conductor must actively cut across magnetic flux lines. If you align the rod along the North-South direction and drop it, its length axis runs parallel to the field lines, which means zero lines are cut and the induced EMF drops to exactly zero.

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6. In a series LCR circuit connected to an AC source of variable frequency, the values are given as $L = 2\,\text{H}$, $C = 32\,\mu\text{F}$, and $R = 10\,\Omega$. What is the resonant angular frequency ω_r of this circuit system?

(A) $125\,\text{rad/s}$

(B) $250\,\text{rad/s}$

(C) $500\,\text{rad/s}$

(D) $1000\,\text{rad/s}$

Correct Answer: (A) 125 rad/s

Solution:

Concept:

In a series electrical circuit containing an inductor (L), a capacitor (C), and a resistor (R), the total opposition to alternating current is called impedance (Z). This impedance is calculated using the formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where $X_L = \omega L$ represents the inductive reactance, and $X_C = \frac{1}{\omega C}$ represents the capacitive reactance.

As you change the driving frequency of the connected AC source, the values of both reactances shift in opposite directions. Electrical resonance happens at a specific frequency where the inductive reactance matches the capacitive reactance exactly:

$$X_L = X_C$$

At this point, the two reactive components cancel each other out completely. This drops the total circuit impedance to its absolute minimum value, which is just equal to the pure thermal resistance ($Z = R$). Consequently, the current amplitude peaks.

Setting these reactances equal lets us isolate the resonant angular frequency (ω_r):

$$\omega_r L = \frac{1}{\omega_r C} \quad \Rightarrow \quad \omega_r^2 = \frac{1}{LC} \quad \Rightarrow \quad \omega_r = \frac{1}{\sqrt{LC}}$$

Step 1: Convert all given metrics into standard SI units.

Before plugging numbers into the formula, ensure all components are in standard units:

- Inductance, $L = 2\,\text{H}$ (already in Henries)
- Capacitance, $C = 32\,\mu\text{F} = 32 \times 10^{-6}\,\text{F}$ (converted from microfarads to Farads)
- Resistance, $R = 10\,\Omega$ (already in Ohms)

Step 2: Calculate the product of inductance and capacitance.

Let's find the value of the LC product under the square root:

$$LC = 2 \times (32 \times 10^{-6})$$

$$LC = 64 \times 10^{-6}\,\text{s}^2$$

Step 3: Calculate the square root of the product.

Take the square root of our result:

$$\sqrt{LC} = \sqrt{64 \times 10^{-6}} = \sqrt{64} \times \sqrt{10^{-6}}$$

$$\sqrt{LC} = 8 \times 10^{-3}\,\text{s}$$

Step 4: Invert the result to find the resonant angular frequency (ω_r).

Now, complete the calculation by taking the reciprocal:

$$\omega_r = \frac{1}{8 \times 10^{-3}} = \frac{1000}{8}$$

$$\omega_r = 125\,\text{rad/s}$$

The resonant angular frequency of this system is exactly $125\,\text{rad/s}$. Note that the resistor's value ($10\,\Omega$) has no impact on this frequency point; it only dictates the height and sharpness of the current peak during resonance.

Quick Tip: Always double-check whether a question asks for the angular frequency (ω_r in rad/s) or the linear cyclic frequency (f_r in Hz). If it asks for linear frequency, you must divide your angular result by 2π ($f_r = \frac{\omega_r}{2\pi}$).

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7. Which of the following choices correctly sequences the designated segments of the electromagnetic wave spectrum in an increasing order of their respective photon energies?

(A) Radio waves $<$ Microwaves $<$ Infrared $<$ X-rays

(B) X-rays $<$ Infrared $<$ Microwaves $<$ Radio waves

(C) Microwaves $<$ Radio waves $<$ Infrared $<$ X-rays

(D) Radio waves $<$ X-rays $<$ Infrared $<$ Microwaves

Correct Answer: (A) Radio waves $<$ Microwaves $<$ Infrared $<$ X-rays

Solution:

Concept:

Electromagnetic waves are synchronized oscillations of electric and magnetic fields traveling through space at the speed of light (c). The entire spread of these waves is organized into the

Electromagnetic Spectrum based on wavelength and frequency characteristics.

According to quantum mechanics, the discrete energy (E) carried by an individual photon is directly proportional to its operational frequency (f) and inversely proportional to its spatial wavelength (λ):

$$E = hf = \frac{hc}{\lambda}$$

where h is Planck's constant ($6.626 \times 10^{-34}\,\text{J}\cdot\text{s}$) and c is the speed of light in a vacuum ($3 \times 10^{8}\,\text{m/s}$).

This relationship means that waves with longer wavelengths have lower frequencies and carry less photon energy. Conversely, shorter wavelengths correspond to higher frequencies and much higher photon energies.

Step 1: Chart the complete standard order of the electromagnetic spectrum.

Let's look at the continuous spectrum bands arranged from the longest wavelength (lowest frequency/lowest energy) down to the shortest wavelength (highest frequency/highest energy):

1. Radio Waves: Longest wavelength, lowest photon energy scale.
2. Microwaves: Millimeter wavelength scale.
3. Infrared radiation: Thermal signatures, sits just below visible light.
4. Visible Light: Narrow band visible to human eyes (Red to Violet).
5. Ultraviolet Rays: Ionizing risk potential, sits just above visible light.
6. X-Rays: High penetration capacity, generated via inner shell electron drops.
7. Gamma Rays: Shortest wavelength, highest frequency, highest energy photons.

Step 2: Order the specific options from lowest to highest energy.

Extracting the four specific bands mentioned in the problem options:

- Radio waves $\rightarrow$ Lowest frequency profile $\rightarrow$ Lowest energy.
- Microwaves $\rightarrow$ Intermediate frequency, sits higher than radio waves.
- Infrared $\rightarrow$ High frequency band approaching visible light.

- X-rays → Extremely high frequency profile → Extremely high energy.

Arranging them in a steady, increasing order of photon energy yields:

$$\text{Radio waves} < \text{Microwaves} < \text{Infrared} < \text{X-rays}$$

Quick Tip: To remember this order easily during exams, use a simple mnemonic: Roman Men Invented Very Unusual Xray Guns. This stands for Radio, Microwave, Infrared, Visible, Ultraviolet, X-ray, Gamma.

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8. An object is placed at a distance of 20 cm in front of a concave mirror of focal length 15 cm. What is the nature and magnification (m) of the image produced by the mirror?

(A) Virtual, Erect and $m = +3$

(B) Real, Inverted and $m = -3$

(C) Real, Inverted and $m = -0.75$

(D) Virtual, Erect and $m = +0.75$

Correct Answer: (B) Real, Inverted and $m = -3$

Solution:

Concept:

To find the location and properties of an image formed by a spherical mirror, we use the standard mirror formula along with the Cartesian sign convention system:

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

where f is the focal length, u is the object distance, and v is the image distance.

The Cartesian sign convention rules state:

- All distances are measured starting from the pole (P) of the mirror as the origin.
- Distances measured in the direction of the incoming light rays are positive.
- Distances measured against the direction of incoming light rays are negative.
- Consequently, real objects placed in front of a mirror always have a negative distance

$(u < 0)$.

- The focal length of a concave mirror is always negative $(f < 0)$, while the focal length of a convex mirror is always positive $(f > 0)$.

The lateral magnification factor (m) relates the height of the image to the height of the object, and can be calculated using these distances:

$$m = -\frac{v}{u} = \frac{f}{f-u}$$

A negative magnification value $(m < 0)$ means the image is real and inverted, while a positive value $(m > 0)$ means it is virtual and erect.

Step 1: Apply sign conventions to the given values.

From the problem description, we can identify and sign-resolve our key parameters:

- Mirror type: Concave $\rightarrow$ Negative focal length value: $f = -15\,\text{cm}$
- Object location: In front of the mirror $\rightarrow$ Negative object distance value: $u = -20\,\text{cm}$

Step 2: Calculate the magnification factor using the focal length shortcut formula.

Let's plug these values directly into the magnification shortcut equation to save time:

$$m = \frac{f}{f-u}$$

$$m = \frac{-15}{-15-(-20)}$$

Simplify the signs in the denominator:

$$m = \frac{-15}{-15+20}$$

$$m = \frac{-15}{5}$$

$$m = -3$$

Step 3: Interpret the physical characteristics from the magnification value.

We can break down our calculated value of $m = -3$ to find the image properties:

- The negative sign (-): Confirms that the image is real and inverted.
- The absolute value magnitude ($|m| = 3 > 1$): Confirms that the image is magnified to three times the size of the object.

This matches standard optics expectations: since the object is placed at 20 cm, it sits between the focus ($F = 15$ cm) and the center of curvature ($C = 2f = 30$ cm). Any object in this zone forms a real, inverted, and magnified image located beyond C.

Quick Tip: Using the shortcut equation $m = \frac{f}{f-u}$ lets you calculate magnification in one step, bypassing the need to solve for the intermediate image distance variable v first. This saves valuable time during competitive exams.

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9. What is the ratio of the shortest wavelength present in the Lyman series of hydrogen spectral emissions to the shortest wavelength present in the Balmer series?

(A) 1 : 4

(B) 4 : 1

(C) 1 : 2

(D) 2 : 1

Correct Answer: (A) 1 : 4

Solution:

Concept:

The atomic emission spectrum of Hydrogen is split into distinct spectral series. These series describe the light emitted when an excited electron drops from a higher outer energy orbit (n_2) down to a lower inner destination orbit (n_1).

The wavelengths of these emitted photons are predicted by the Rydberg formula:

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

where λ is the emitted wavelength and R_{∞} is the Rydberg constant ($\approx 1.097 \times 10^7\,\text{m}^{-1}$).

The energy of the emitted photon is linked to its wavelength by the equation $E = \frac{hc}{\lambda}$. This inverse relationship means that the shortest wavelength in any series corresponds to the transition with the maximum possible energy change.

The largest energy jump occurs when an electron drops from the farthest possible boundary state—the ionization threshold at infinity ($n_2 = \infty$)—down to the base series level (n_1).

Step 1: Calculate the shortest wavelength limit for the Lyman series.

The Lyman series is defined by transitions where electrons drop down to the lowest ground state energy level ($n_1 = 1$).

To find its shortest wavelength limit (λ_L), set the starting orbit to infinity ($n_2 = \infty$):

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

Since $\frac{1}{\infty} = 0$, the equation simplifies to:

$$\frac{1}{\lambda_L} = R_\infty (1 - 0) = R_\infty \quad \Rightarrow \quad \lambda_L = \frac{1}{R_\infty}$$

Step 2: Calculate the shortest wavelength limit for the Balmer series.

The Balmer series covers transitions where electrons drop down to the second energy level ($n_1 = 2$).

Setting the starting level to infinity ($n_2 = \infty$) gives its shortest wavelength limit (λ_B):

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

$$\frac{1}{\lambda_B} = R_\infty \left(\frac{1}{4} - 0 \right) = \frac{R_\infty}{4} \quad \Rightarrow \quad \lambda_B = \frac{4}{R_\infty}$$

Step 3: Calculate the ratio of the two shortest wavelengths.

Now, find the ratio of the shortest Lyman wavelength to the shortest Balmer wavelength:

$$\frac{\lambda_L}{\lambda_B} = \frac{\frac{1}{R_\infty}}{\frac{4}{R_\infty}}$$

Cancel the common Rydberg constant (R_∞) from both the numerator and denominator:

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

Therefore, the ratio of their shortest wavelengths is exactly 1 : 4.

Quick Tip: The shortest wavelength limit for any hydrogen series can be quickly found using the shortcut formula $\lambda_{\text{min}} = \frac{n_1^2}{R_\infty}$. This shows that the minimum wavelength scales directly with the square of the destination orbit number (n_1^2).

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10. When an external operating bias voltage is applied to a standard P-N junction semiconductor diode under a forward bias configuration, how do the width of the internal depletion region and the height of the contact barrier potential change?

(A) The depletion width increases and the barrier height increases.

(B) The depletion width decreases and the barrier height decreases.

(C) The depletion width increases and the barrier height decreases.

(D) The depletion width decreases and the barrier height increases.

Correct Answer: (B) The depletion width decreases and the barrier height decreases.

Solution:

Concept:

A clean P-N junction forms an internal depletion layer at its interface. Free electrons from the n-type region diffuse across the junction into the p-type region, where they recombine with available holes. This migration leaves behind uncompensated positive donor ions on the n-side edge and negative acceptor ions on the p-side edge.

This localized region of uncovered ions is depleted of free charge carriers, creating the depletion region. These opposite ions generate an internal electric field (E_i) pointing from the n-side to the p-side. This field creates a built-in potential barrier (V_0) that stops further diffusion, stabilizing the junction.

Step 1: Analyze how forward biasing affects the internal electric field.

In a forward bias setup, you connect an external battery so its positive terminal attaches to the p-type side and its negative terminal attaches to the n-type side.

This external voltage sets up an electric field (E_e) that points from the p-side to the n-side. Because this external field runs directly opposite to the built-in internal electric field (E_i), it weakens the overall field at the junction.

Step 2: Evaluate changes to the barrier potential height.

Since the external voltage opposes the built-in potential barrier, it lowers the net barrier height. If the built-in barrier potential is V_0 and you apply a forward voltage V, the effective potential barrier drops to:

$$V_{\text{effective}} = V_0 - V$$

This reduction lowers the electrical barrier, making it much easier for majority charge carriers to cross the junction.

Step 3: Evaluate changes to the depletion region width.

The negative terminal of the external battery repels free electrons in the n-region toward the junction, while the positive terminal repels holes in the p-region toward the junction.

This forcing action drives majority carriers into the depletion zone, neutralizing some of the exposed boundary ions. As a result, the width of the depletion layer shrinks.

Consequently, both the depletion region width and the barrier potential height decrease under a forward bias configuration.

Quick Tip: Think of forward bias as an assisting force that compresses the junction: it shrinks the depletion width and lowers the potential barrier. Reverse bias does the opposite, pulling carriers away to widen the depletion layer and raise the barrier.