BITSAT 2026 May 26 Shift 1

Question Paper (Memory-Based) with Solutions

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General Instructions

(i) **Duration:** The total duration of the examination is 3 hours (180 minutes).

(ii) **Total Marks:** The complete paper carries a maximum of 390 marks.

(iii) **Structure:** The paper has 4 Sections:

- **Part 1:** 30 Multiple Choice Questions (Physics).
- **Part 2:** 30 Multiple Choice Questions (Chemistry).
- **Part 3:** 10 Multiple Choice Questions (English Proficiency), 20 Multiple Choice Questions (Logical Reasoning)
- **Part 4:** 40 Multiple Choice Questions (Mathematics/Biology)

(iv) **Compulsory Questions:** All 130 questions are compulsory,and +12 Questions(Optional Extra Questions)

(v) Each question has four options. Only **one** option is correct.

(vi) **Correct Answer:** +3 marks.

(vii) **Incorrect Answer:** −1 (Negative marking).

(viii) **Unanswered/Marked for Review:** 0 marks.

PHYSICS

1. A particle moves along a circle of radius R with a constant angular acceleration α. If the initial angular velocity is zero, the total acceleration of the particle at time t is:

(A) $R\alpha$

(B) $R\alpha^2 t^2$

(C) $R\alpha\sqrt{1+\alpha^2 t^4}$

(D) $R\alpha t$

Correct Answer: (C) $R\alpha\sqrt{1+\alpha^2 t^4}$

Solution:

Concept: When a particle moves along a circular path under non-uniform rotational motion (i.e., with an angular acceleration), it experiences two distinct, mutually perpendicular components of acceleration:

1. **Tangential Acceleration (a_t):** Responsible for changing the magnitude of the linear velocity. It is given by:

$$a_t = R\alpha$$

2. **Centripetal (or Radial) Acceleration (a_c):** Responsible for changing the direction of the velocity vector, pointing toward the center of the circular path. It is given by:

$$a_c = \omega^2 R$$

Since these two components are orthogonal ($a_t \perp a_c$), the magnitude of the net total acceleration vector (a_{total}) is found using the Pythagorean theorem:

$$a_{\text{total}} = \sqrt{a_t^2 + a_c^2}$$

Step 1: Determining the angular velocity (ω) at time t.

We can apply the rotational kinematic equation for constant angular acceleration, analogous to the linear equation $v = u + at$:

$$\omega = \omega_0 + \alpha t$$

Given that the initial angular velocity is zero ($\omega_0 = 0$):

$$\omega = 0 + \alpha t = \alpha t$$

Step 2: Calculating the individual acceleration components.

- The tangential acceleration component remains constant over time:

$$a_t = R\alpha$$

- The centripetal acceleration component at time t is evaluated by substituting our derived ω:

$$a_c = \omega^2 R = (\alpha t)^2 R = \alpha^2 t^2 R$$

Step 3: Evaluating the net total acceleration magnitude.

Substitute both component expressions into our vector addition layout:

$$a_{\text{total}} = \sqrt{(R\alpha)^2 + (\alpha^2 t^2 R)^2}$$

$$a_{\text{total}} = \sqrt{R^2\alpha^2 + \alpha^4 t^4 R^2}$$

Factoring out the shared common terms $R^2\alpha^2$ inside the square root radical:

$$a_{\text{total}} = \sqrt{R^2\alpha^2 \cdot (1 + \alpha^2 t^4)}$$

Taking $R^2\alpha^2$ cleanly out of the radical yields the final expression:

$$a_{\text{total}} = R\alpha\sqrt{1 + \alpha^2 t^4}$$

Quick Tip: To verify your expression instantly during an exam, test the initial boundary condition at $t = 0$. At the absolute start of the motion, the particle isn't spinning yet ($\omega = 0$), so its centripetal component must be zero, leaving only the pure tangential kick-start acceleration ($a = R\alpha$). Substituting $t = 0$ into Option C gives $R\alpha\sqrt{1+0} = R\alpha$, matching the physical behavior perfectly!

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2. The focal length of a convex lens is f in air. When it is completely immersed in water of refractive index $\frac{4}{3}$, its focal length becomes (take refractive index of glass = 1.5):

(A) f

(B) $2f$

(C) $4f$

(D) $\frac{f}{2}$

Correct Answer: (C) $4f$

Solution:

Concept: The focal length (f) of a thin spherical lens depends on the radii of curvature of its two surfaces (R_1 and R_2) as well as the relative refractive index of the lens material with respect to its surrounding medium. This relationship is defined by the **Lens Maker's Formula**:

$$\frac{1}{f} = \left(\frac{\mu_{\text{lens}}}{\mu_{\text{medium}}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

When a lens is immersed in a liquid medium like water instead of air, the relative refractive index decreases, which reduces the bending power of the lens interfaces and subsequently increases its focal length.

Step 1: Writing the Lens Maker's Formula for the lens in air.

For air, the refractive index of the surrounding medium is $\mu_{\text{air}} = 1$. The refractive index of the glass lens is given as $\mu_g = 1.5 = \frac{3}{2}$. Substituting these parameters into the Lens Maker's formula:

$$\frac{1}{f} = \left(\frac{\mu_g}{\mu_{\text{air}}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (1.5 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0.5\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{2}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \cdots(1)$$

Step 2: Writing the Lens Maker's Formula for the lens immersed in water.

Let the new focal length of the lens in water be f_w. The refractive index of water is $\mu_w = \frac{4}{3}$. Substituting these values:

$$\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{1.5}{\frac{4}{3}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{\frac{3}{2}}{\frac{4}{3}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{9}{8} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{8}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \cdots(2)$$

Step 3: Comparing the two conditions to find f_w.

Dividing equation (1) by equation (2) eliminates the structural geometric constant group $\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$:

$$\frac{\left(\frac{1}{f}\right)}{\left(\frac{1}{f_w}\right)} = \frac{\frac{1}{2}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}{\frac{1}{8}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

$$\frac{f_w}{f} = \frac{\frac{1}{2}}{\frac{1}{8}} = \frac{8}{2} = 4$$

Rearranging to solve for the final immersed focal length f_w:

$$f_w = 4f$$

Quick Tip: Keep this highly recurring benchmark result memorized for speed! Whenever a standard glass lens ($\mu = 1.5$) is completely immersed in water ($\mu = 1.33$), its focal length always increases exactly by a factor of **4** ($f_{water} = 4f_{air}$). Remembering this constant numeric multiplier will save you over a minute of algebraic scratchwork during a time-pressured exam.

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3. The stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength λ is V_s. If the intensity of the incident light is doubled while keeping wavelength identical, the stopping potential will be:

(A) $2V_s$

(B) $\frac{V_s}{2}$

(C) V_s

(D) $4V_s$

Correct Answer: (C) V_s

Solution:

Concept: According to **Einstein's Photoelectric Equation**, the maximum kinetic energy (K_{max}) of an emitted photoelectron depends strictly on the energy of the incident photon (E) and the work function (ϕ_0) of the target metal surface:

$$K_{max} = E - \phi_0$$

Expressing the incident photon energy in terms of its wavelength (λ):

$$K_{max} = \frac{hc}{\lambda} - \phi_0$$

The stopping potential (V_s) is the negative potential required to completely halt the fastest moving photoelectrons, meaning:

$$K_{max} = eV_s \implies eV_s = \frac{hc}{\lambda} - \phi_0$$

From this relation, it is clear that the stopping potential is governed purely by the **frequency or wavelength** of the incoming light and the nature of the metal surface.
Intensity, by definition in quantum physics, is a measure of the number of photons striking a unit area per second. Changing the intensity modifies the total number of emitted electrons (the photocurrent) but has absolutely **no effect** on the individual energy configuration of each arriving photon.

Step 1: Analyzing the effect of changing the light intensity.

When the intensity of the incident light is doubled:

- The total number of incident photons striking the metal surface per second is doubled.
- Consequently, the total number of emitted photoelectrons per second (saturation photocurrent) also doubles.

Step 2: Evaluating the final stopping potential.

Because the problem specifies that the wavelength (λ) is kept completely identical, the energy per photon ($E = \frac{hc}{\lambda}$) remains unchanged. Since both the photon energy and the metal's work function are constant, the maximum kinetic energy of the individual photoelectrons remains completely unaffected:

$$K'_{max} = K_{max} \implies eV'_s = eV_s$$

Therefore, the stopping potential remains entirely unchanged:

$$V'_s = V_s$$

Quick Tip: Keep a crystal-clear mental separation between these two quantities in modern physics: **Frequency/Wavelength** controls the **energy** parameters (K_{max}, stopping potential, individual photon speed), whereas **Intensity** controls the **quantity** parameters (number of photons, number of ejected electrons, total circuit current). Changing one leaves the other completely untouched!

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4. The de-Broglie wavelength of an electron accelerated from rest through a potential difference

of 100V is approximately:

(A) 1.227 Å

(B) 12.27 Å

(C) 0.1227 Å

(D) 122.7 Å

Correct Answer: (A) 1.227 Å

Solution:

Concept: According to the **de-Broglie hypothesis**, a moving material particle behaves as a wave, and its dual matter wavelength (λ) is inversely proportional to its linear momentum (p):

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

When a particle of charge q and mass m is accelerated from rest through an electric potential difference V, the work done by the electric field transforms entirely into its translational kinetic energy (K):

$$K = qV$$

Since kinetic energy is related to momentum by $p = \sqrt{2mK}$, substituting this relation into the de-Broglie equation gives:

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

Step 1: Applying the constants for an electron to simplify the radical expression.

For an electron, we substitute the standard known physical constants:

- Planck's constant, $h \approx 6.626 \times 10^{-34}$ J s
- Mass of an electron, $m \approx 9.1 \times 10^{-31}$ kg
- Charge of an electron, $q = e \approx 1.6 \times 10^{-19}$ C

Substituting these constant properties collapses the fixed variables into a highly convenient, condensed shortcut formula specifically calibrated for electrons:

$$\lambda_{\text{electron}} = \frac{12.27}{\sqrt{V}} \text{ Å} \quad \left(\text{where } 1 \text{ Å} = 10^{-10} \text{ m}\right)$$

Step 2: Calculating the wavelength for $V = 100\text{V}$.

Given the accelerating potential difference $V = 100\text{V}$. Substitute this value into our shortcut relation:

$$\lambda_{\text{electron}} = \frac{12.27}{\sqrt{100}}\ \text{Å}$$

Since $\sqrt{100} = 10$:

$$\lambda_{\text{electron}} = \frac{12.27}{10} = 1.227\ \text{Å}$$

Quick Tip: To absolute guarantee you don't misplace a decimal place during choice matching, remember that $\sqrt{100}$ scales exactly by a factor of 10 in the denominator. This shifts the decimal point of your numerator constant (12.27) exactly one spot to the left, pointing directly to 1.227 Å.

CHEMISTRY

5. Balance the following redox reaction in acidic medium and determine the stoichiometric coefficient of H_2O in the final balanced equation.

$$MnO_4^-(aq) + Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + Fe^{3+}(aq)$$

(A) 2

(B) 4

(C) 6

(D) 8

Correct Answer: (B) 4

Solution:

Concept: To balance a redox reaction in an acidic medium, we use the **Ion-Electron Method** (also known as the Half-Reaction Method). This involves breaking the overall chemical skeleton into an oxidation half-reaction and a reduction half-reaction, balancing atoms and charges individually for each half, and then recombining them so that net electrons cancel out completely. The procedural rules for balancing an acidic medium half-reaction are:

1. Balance all atoms except hydrogen (H) and oxygen (O).

2. Balance oxygen atoms by adding water molecules (H_2O) to the deficient side.

3. Balance hydrogen atoms by adding hydrogen ions (H^+) to the deficient side.

4. Balance the net ionic charge by adding electrons (e^-).

Step 1: Separating the reaction into half-reactions and balancing the oxidation part.
Let's look at the change in oxidation states to identify the tracks:

- **Oxidation half-reaction:** Iron changes from a +2 charge to a +3 charge.

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq)$$

Since the iron atoms are already balanced, we only need to balance the charge by adding 1 electron to the product side:

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^- \quad \cdots \text{(Equation 1)}$$

Step 2: Balancing the reduction half-reaction ($MnO_4^- \rightarrow Mn^{2+}$).

- **Reduction half-reaction skeleton:** Manganese goes from a +7 state to a +2 state.

$$MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$$

Now let's apply the acidic balancing guidelines step-by-step:

- **Manganese atoms:** Already balanced (1 on each side).

- **Oxygen atoms:** There are 4 oxygen atoms on the reactant side. To balance them, add 4 water molecules (H_2O) to the product side:

$$MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

- **Hydrogen atoms:** Adding water introduced 8 hydrogen atoms to the product side. Balance this by adding 8 hydrogen ions (H^+) to the reactant side:

$$MnO_4^-(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

- **Charge balancing:** Let's calculate the net charge on both sides:

$$\text{Reactant side charge} = (-1) + 8(+1) = +7$$
$$\text{Product side charge} = (+2) + 0 = +2$$

To bridge the gap from +7 to +2, add 5 electrons (e^-) to the reactant side:

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l) \quad \cdots \text{(Equation 2)}$$

Step 3: Equalizing electrons and combining both halves.

To ensure that no free electrons remain in our final chemical equation, we multiply Equation 1 by **5** so it matches the 5 electrons consumed in Equation 2:

$$5Fe^{2+}(aq) \rightarrow 5Fe^{3+}(aq) + 5e^-$$

Now, add this adjusted oxidation half directly to Equation 2. The 5 electrons on both sides cancel out perfectly:

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

Looking closely at the coefficient attached to the water molecules on the product side, we find it is exactly **4**.

Quick Tip: When an exam problem strictly asks for the coefficient of H_2O in a permanganate (MnO_4^-) reduction, you can bypass balancing the entire equation! Since all oxygens in the reaction come solely from MnO_4^- and end up entirely inside H_2O, the 4 oxygen atoms in MnO_4^- will *always* demand exactly 4 H_2O molecules to balance out, regardless of what species is being oxidized.

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6. Titration of 0.1467 g of primary standard $Na_2C_2O_4$ required 28.85 mL of $KMnO_4$ solution. Calculate the molar concentration of $KMnO_4$ solution.

(A) 0.01518 M

(B) 0.001518 M

(C) 0.15180 M

(D) 1.5180 M

Correct Answer: (A) 0.01518 M

Solution:

Concept: This problem involves an analytical **redox titration** calculation based on the principle of equivalence or stoichiometric molar ratios:

- Potassium permanganate ($KMnO_4$) acts as a powerful oxidizing agent. In its standard lab medium (acidic), the manganese center reduces from an oxidation state of +7 to +2.
- Sodium oxalate ($Na_2C_2O_4$) is a reliable primary standard acting as a reducing agent. The oxalate ion ($C_2O_4^{2-}$) oxidizes into carbon dioxide (CO_2), shifting carbon's oxidation state from +3 to +4.

The complete net balanced ionic equation for this specific redox tracking is:

$$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

From the balanced stoichiometry, we establish a direct reacting molar bridge:

$$\text{Moles of } KMnO_4 = \frac{2}{5} \times \text{Moles of } Na_2C_2O_4$$

Step 1: Calculating the number of moles of sodium oxalate ($Na_2C_2O_4$).
First, let's compute the formula mass of the primary standard salt $Na_2C_2O_4$:

$$\text{Molar Mass} = (2 \times 23.00) + (2 \times 12.01) + (4 \times 16.00)$$
$$= 46.00 + 24.02 + 64.00 = 134.02 \text{ g/mol}$$

Using the given experimental mass $m = 0.1467$ g:

$$\text{Moles of } Na_2C_2O_4 = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{0.1467 \text{ g}}{134.02 \text{ g/mol}} \approx 0.0010946 \text{ moles}$$

Step 2: Finding the required moles of potassium permanganate ($KMnO_4$).

Using the stoichiometric relationship from our balanced equation:

$$\text{Moles of } KMnO_4 = \frac{2}{5} \times 0.0010946 = 0.4 \times 0.0010946 \approx 0.00043784 \text{ moles}$$

Step 3: Calculating the molarity of the solution.

Molarity (M) is defined as the total moles of solute divided by the total volume of the solution in liters (L). Convert the given volume from milliliters to liters:

$$V = 28.85 \text{ mL} = \frac{28.85}{1000} \text{ L} = 0.02885 \text{ L}$$

Now, compute the final molar concentration:

$$M = \frac{\text{Moles}}{V(\text{L})} = \frac{0.00043784 \text{ moles}}{0.02885 \text{ L}} \approx 0.015176 \text{ M}$$

Rounding to matching significant figures gives **0.01518 M**.

Quick Tip: To solve analytical titrations significantly faster without worrying about full balanced equations, use the **Normality Law of Equivalents**: $N_1V_1 = N_2V_2$, which expands to $(M \times \text{n-factor})_1 \times V_1 = \left(\frac{\text{mass}}{\text{equivalent mass}}\right)_2$. For this setup, remember that the n-factor of $KMnO_4$ in an acidic medium is *always* **5** and the n-factor of $Na_2C_2O_4$ is **2**. Plugging this in directly gives: $M_{KMnO_4} \times 5 \times 0.02885 = \frac{0.1467}{134.02} \times 2$, isolating your answer in a single step!

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7. A current of 4.0 A is passed through 0.5 L of 0.2 M NaCl solution for 1200s. Calculate the pH of the solution after electrolysis.

(A) 1.3

(B) 13

(C) 7.0

(D) 2.0

Correct Answer: (B) 13

Solution:

Concept: During the electrolysis of an aqueous sodium chloride (NaCl) solution (brine), multiple species compete at the electrodes:

- **At the Cathode (Reduction):** Water has a higher reduction potential than sodium ions (Na^+). Therefore, water is preferentially reduced to produce hydrogen gas (H_2) and hydroxyl ions (OH^-):

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

- **At the Anode (Oxidation):** Chloride ions (Cl^-) are oxidized to form chlorine gas (Cl_2):

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$$

As H_2 and Cl_2 escape, accumulation of OH^- ions together with spectator Na^+ ions converts the remaining liquid environment into basic sodium hydroxide (NaOH), driving up the solution's overall pH. According to Faraday's Laws, the moles of electrons passed dictate the exact moles of OH^- produced in a $1:1$ stoichiometric ratio.

Step 1: Calculating the total charge and moles of electrons passed.

First, find the total electrical charge (Q) passed through the electrolytic cell using $Q = I \cdot t$:

$$Q = 4.0 \text{ A} \times 1200 \text{ s} = 4800 \text{ C}$$

Now, compute the total number of moles of electrons passed by dividing by Faraday's constant ($F \approx 96500$ C/mol):

$$\text{Moles of } e^- = \frac{Q}{F} = \frac{4800}{96500} \approx 0.04974 \text{ moles}$$

Step 2: Checking the limiting reactant condition.

Let's verify if there are enough initial Cl^- ions to sustain this electrolysis runtime:

$$\text{Initial moles of NaCl} = \text{Molarity} \times \text{Volume (L)} = 0.2 \text{ M} \times 0.5 \text{ L} = 0.1 \text{ moles}$$

Since the system requires only 0.04974 moles of electrons to complete the reaction, the initial NaCl supply (0.1 moles) is in excess. The reaction is entirely controlled by the total charge passed.

From the cathode half-reaction, 1 mole of electrons yields exactly 1 mole of OH^- ions:

$$\text{Moles of } OH^- \text{ produced} = \text{Moles of } e^- \approx 0.05 \text{ moles}$$

Step 3: Calculating hydroxyl concentration, pOH, and final pH.

The molar concentration of hydroxyl ions produced in the 0.5 L container volume is:

$$[OH^-] = \frac{\text{Moles of } OH^-}{\text{Volume (L)}} = \frac{0.05 \text{ moles}}{0.5 \text{ L}} = 0.1 \text{ M} = 10^{-1} \text{ M}$$

Now, computing the alkalinity index (pOH) using its logarithmic rule:

$$pOH = -\log_{10}[OH^-] = -\log_{10}(10^{-1}) = 1$$

Finally, calculating the system's ending chemical balance index (pH) at 25°C:

$$pH = 14 - pOH = 14 - 1 = 13$$

Quick Tip: Whenever you notice that the electrolysis of a neutral salt solution releases OH^- or H^+ ions, look immediately at the order of magnitude of the concentration to eliminate choices! Since $[OH^-] = 0.1$ M, the solution becomes distinctly basic, which means the pH must end up well above 7. This instantly rules out options A, C, and D in under two seconds, making Option B the only physically viable choice.

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8. Using the standard electrode potential, find out the pair between which redox reaction is not feasible.

$$E^\ominus \text{ values: } Fe^{3+}/Fe^{2+} = +0.77 \text{ V}; \quad I_2/I^- = +0.54 \text{ V}; \quad Cu^{2+}/Cu = +0.34 \text{ V}; \quad Ag^+/Ag = +0.80 \text{ V}$$

(A) Fe^{3+} and I^-

(B) Ag^+ and Cu

(C) Fe^{3+} and Cu

(D) Ag and Fe^{3+}

Correct Answer: (D) Ag and Fe^{3+}

Solution:

Concept: For any chemical redox reaction to be thermodynamically spontaneous or **feasible**, the overall standard cell potential (E°_{cell}) calculated from its individual half-reactions

must be strictly **positive** ($E^\circ_{cell} > 0$). This directly relates to a negative change in Gibbs free energy ($\Delta G^\circ = -nFE^\circ_{cell}$).
The standard formula to evaluate cell potential uses the standard reduction potentials (SRP) of the participating electrodes:

$$E^\circ_{cell} = E^\circ_{cathode\ (Reduction)} - E^\circ_{anode\ (Oxidation)}$$

An alternative conceptual rule to remember is: **A species with a higher reduction potential will easily oxidize a species with a lower reduction potential.**
Step 1: Analyzing the chemical behavior of Option D (Ag and Fe^{3+}).
Let's construct the hypothetical redox system for this pair:

- Fe^{3+} is in its highest oxidation state, so it can only undergo **reduction**:

$$Fe^{3+} + e^- \rightarrow Fe^{2+} \quad \left(E^\circ_{red} = +0.77\ V\right)$$

- Ag is in its reduced metallic form, so it can only undergo **oxidation**:

$$Ag \rightarrow Ag^+ + e^- \quad \left(E^\circ_{red} = +0.80\ V\right)$$

Here, the Fe^{3+}/Fe^{2+} system acts as the cathode (reduction) and the Ag^+/Ag system acts as the anode (oxidation).
Step 2: Calculating the cell potential (E°_{cell}) for Option D.
Using the standard formula:

$$E^\circ_{cell} = E^\circ_{Fe^{3+}/Fe^{2+}} - E^\circ_{Ag^+/Ag}$$

$$E^\circ_{cell} = (+0.77\ V) - (+0.80\ V) = -0.03\ V$$

Since E°_{cell} evaluates to a **negative value** (-0.03 V), the forward reaction is entirely non-spontaneous. Therefore, this specific interaction pair is **not feasible**.
Step 3: Verifying why other options are feasible (Optional confirmation).
Let's quickly check the remaining pairs using our core rule:

- **Option A (Fe^{3+} and I^-):** $E^\circ_{Fe^{3+}/Fe^{2+}}(0.77\ V) > E^\circ_{I_2/I^-}(0.54\ V)$. Fe^{3+} successfully reduces while oxidizing I^-. ($E^\circ_{cell} = +0.23\ V \rightarrow$ **Feasible**)
- **Option B (Ag^+ and Cu):** $E^\circ_{Ag^+/Ag}(0.80\ V) > E^\circ_{Cu^{2+}/Cu}(0.34\ V)$. Ag^+ successfully reduces while oxidizing Cu. ($E^\circ_{cell} = +0.46\ V \rightarrow$ **Feasible**)

- **Option C (Fe^{3+} and Cu):** $E^\circ_{Fe^{3+}/Fe^{2+}}(0.77\text{ V}) > E^\circ_{Cu^{2+}/Cu}(0.34\text{ V})$. Fe^{3+} successfully reduces while oxidizing Cu. ($E^\circ_{cell} = +0.43\text{ V} \rightarrow$ **Feasible**)

Quick Tip: To solve electrochemical feasibility questions under ten seconds, arrange the given systems vertically by their reduction potentials from highest to lowest. A species on the **left side (oxidized form)** of a higher system can only react spontaneously with a species on the **right side (reduced form)** of a system located **below it** on your list! Because Ag (0.80V) sits higher up than Fe^{3+} (0.77V), they cannot react.

Mathematics

9. If p and q be the longest and the shortest distance respectively of the point $(-7,2)$ from any point (α,β) on the curve whose equation is $x^2+y^2-10x-14y-51=0$, then find the Geometric Mean (G.M.) of p and q.

(A) $2\sqrt{11}$

(B) $5\sqrt{5}$

(C) 13

(D) 11

Correct Answer: (A) $2\sqrt{11}$

Solution:

Concept: The given second-degree equation represents a standard circle. For any external point P relative to a circle with center C and radius R:

- The shortest distance (q) from the point to any coordinate on the perimeter lies along the normal line connecting the point to the center:

$$q = PC - R$$

- The longest distance (p) from the point to the circle lies along the diametrically opposite extension of that same normal line:

$$p = PC + R$$

- The Geometric Mean (G.M.) of two quantities p and q is mathematically defined as:

$$\text{G.M.} = \sqrt{p \cdot q}$$

Step 1: Finding the center (C) and radius (R) of the circle.
The general equation of a circle is given by $x^2 + y^2 + 2gx + 2fy + c = 0$. Comparing this standard layout with our problem equation:

$$x^2 + y^2 - 10x - 14y - 51 = 0$$

We identify the standard parameter values:

$$2g = -10 \implies g = -5$$

$$2f = -14 \implies f = -7$$

$$c = -51$$

The center coordinates $C(-g, -f)$ are:

$$\text{Center } C = (5, 7)$$

Now, compute the radius R using the standard formula $R = \sqrt{g^2 + f^2 - c}$:

$$R = \sqrt{(-5)^2 + (-7)^2 - (-51)} = \sqrt{25 + 49 + 51} = \sqrt{125} = 5\sqrt{5} \text{ units}$$

Step 2: Calculating the distance (PC) from the point $P(-7, 2)$ to the center $C(5, 7)$.
Using the standard 2D coordinate distance formula:

$$PC = \sqrt{(5 - (-7))^2 + (7 - 2)^2}$$

$$PC = \sqrt{(5 + 7)^2 + (5)^2} = \sqrt{12^2 + 5^2} = \sqrt{144 + 25} = \sqrt{169} = 13 \text{ units}$$

Since the distance to the center (13) is greater than the radius ($\sqrt{125} \approx 11.18$), the point P lies outside the circle, confirming our geometric assumptions.

Step 3: Determining the Geometric Mean of p and q.

Expressing the longest distance p and shortest distance q:

$$p = PC + R = 13 + R$$

$$q = PC - R = 13 - R$$

Now, let's calculate the product $p \cdot q$ using the algebraic identity $(A+B)(A-B) = A^2 - B^2$:

$$p \cdot q = (13 + R)(13 - R) = 13^2 - R^2$$

Substitute our values for 13^2 and $R^2 = 125$:

$$p \cdot q = 169 - 125 = 44$$

Finally, evaluating the geometric mean definition:

$$\text{G.M.} = \sqrt{p \cdot q} = \sqrt{44} = \sqrt{4 \times 11} = 2\sqrt{11}$$

Quick Tip: Save time by connecting this question to the **Power of a Point** theorem! For an external point P, the product of the maximum and minimum distance lines drawn through the center is identical to the square of the tangent line length (PT^2), which equals the expression $S_1 = x_1^2 + y_1^2 + 2gx_1 + 2fy_1 + c$. Plugging $P(-7, 2)$ directly into the circle equation: $(-7)^2 + (2)^2 - 10(-7) - 14(2) - 51 = 49 + 4 + 70 - 28 - 51 = 44$. Since $\text{G.M.} = \sqrt{p \cdot q} = \sqrt{S_1}$, your answer is immediately $\sqrt{44} = 2\sqrt{11}$ in a single step!

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10. The distance from the origin to the image of $(1, 1)$ with respect to the line $x + y + 5 = 0$ is:

(A) $7\sqrt{2}$

(B) $3\sqrt{2}$

(C) $6\sqrt{2}$

(D) $4\sqrt{2}$

Correct Answer: (C) $6\sqrt{2}$

Solution:

Concept: To find the coordinates of an image point (x_2, y_2) reflected across a mirror line equation $ax + by + c = 0$ from an initial point (x_1, y_1), we use the standard vector coordinate projection identity:

$$\frac{x_2 - x_1}{a} = \frac{y_2 - y_1}{b} = -2\left(\frac{ax_1 + by_1 + c}{a^2 + b^2}\right)$$

Once the explicit coordinate components of the reflection image point are isolated, we determine its geometric distance to the origin $(0, 0)$ using the basic distance formula:

$$D = \sqrt{x_2^2 + y_2^2}$$

Step 1: Calculating the image coordinates (x_2, y_2).

From the problem parameters, the initial point is $(x_1, y_1) = (1, 1)$ and the line equation is $1x + 1y + 5 = 0$, giving coefficients $a = 1, b = 1, c = 5$.

Let's evaluate the scaling constant on the right side of our vector formula:

$$\text{Scaling Factor} = -2\left(\frac{1(1) + 1(1) + 5}{1^2 + 1^2}\right) = -2\left(\frac{1 + 1 + 5}{1 + 1}\right) = -2\left(\frac{7}{2}\right) = -7$$

Now, equate this scale value separately to find both spatial components:

- **For the x-coordinate:**

$$\frac{x_2 - 1}{1} = -7 \quad \Longrightarrow \quad x_2 - 1 = -7 \quad \Longrightarrow \quad x_2 = -6$$

- **For the y-coordinate:**

$$\frac{y_2 - 1}{1} = -7 \quad \Longrightarrow \quad y_2 - 1 = -7 \quad \Longrightarrow \quad y_2 = -6$$

Thus, the coordinates of the image point are precisely **$(-6, -6)$**.

Step 2: Calculating the distance from the origin $(0, 0)$ to the image point $(-6, -6)$.

Using the standard Euclidean 2D distance formula relative to the origin:

$$D = \sqrt{(-6 - 0)^2 + (-6 - 0)^2}$$

$$D = \sqrt{(-6)^2 + (-6)^2} = \sqrt{36 + 36} = \sqrt{72}$$

Simplifying the radical into its prime factors:

$$D = \sqrt{36 \times 2} = 6\sqrt{2} \text{ units}$$

Quick Tip: Notice that the mirror line $x + y + 5 = 0$ is perfectly symmetric with a slope of -1. Because our starting point $(1, 1)$ lies directly on the diagonal line $y = x$, its reflected image must naturally stay locked along that exact same path where $y = x$. As soon as you discover $x_2 = -6$, you can instantly infer $y_2 = -6$. For any point (k, k), its diagonal distance to the origin is always simply $|k|\sqrt{2}$, which evaluates directly to $6\sqrt{2}$ in under 5 seconds!

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11. General solution of $\tan 5\theta = \cot 2\theta$ is:

(A) $\theta = \frac{n\pi}{7} + \frac{\pi}{14}$
(B) $\theta = \frac{n\pi}{7} + \frac{\pi}{5}$
(C) $\theta = \frac{n\pi}{7} + \frac{\pi}{2}$
(D) $\theta = \frac{n\pi}{7} + \frac{\pi}{3}$

Correct Answer: (A) $\theta = \frac{n\pi}{7} + \frac{\pi}{14}$

Solution:

Concept: To find the general solution of a trigonometric equation involving a mixed pairing like $\tan A = \cot B$, we first transform both sides into matching trigonometric functions using complementary angle properties.
The standard transformations and theorems used are:

- **Complementary Angle Identity:**

$$\cot\alpha = \tan\left(\frac{\pi}{2} - \alpha\right)$$

- **General Solution Theorem for Tangent:** If $\tan\phi = \tan\alpha$, then the general solution is uniquely defined as:

$$\phi = n\pi + \alpha, \quad \text{where } n \in \mathbb{Z}$$

Step 1: Converting the equation to matching tangent terms.

Given the expression:

$$\tan 5\theta = \cot 2\theta$$

Using the complementary conversion rule, rewrite the right-hand side in terms of tangent:

$$\cot 2\theta = \tan\left(\frac{\pi}{2} - 2\theta\right)$$

Substitute this back into the core equation system:

$$\tan 5\theta = \tan\left(\frac{\pi}{2} - 2\theta\right)$$

Step 2: Applying the general solution theorem to isolate the variable.

Equating the arguments through our general tangent theorem:

$$5\theta = n\pi + \left(\frac{\pi}{2} - 2\theta\right)$$

Now, rearrange the terms to group all θ parameters together on the left-hand side:

$$5\theta + 2\theta = n\pi + \frac{\pi}{2}$$

$$7\theta = n\pi + \frac{\pi}{2}$$

Step 3: Solving for θ.

Dividing both sides cleanly by 7 gives our final isolated general solution expression:

$$\theta = \frac{n\pi}{7} + \frac{\pi}{2 \times 7}$$

$$\theta = \frac{n\pi}{7} + \frac{\pi}{14}$$

Quick Tip: When resolving matching expressions like $\tan A = \cot B$, you can bypass writing out the intermediate steps by jumping straight to a handy universal shortcut identity: $A+B = n\pi+\frac{\pi}{2}$. Substituting our specific parameters directly gives $5\theta + 2\theta = n\pi + \frac{\pi}{2} \implies 7\theta = n\pi + \frac{\pi}{2}$, matching our core result in under 5 seconds!

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12. The sum of the series $\left(x + \frac{1}{x}\right)^2 + \left(x^2 + \frac{1}{x^2}\right)^2 + \left(x^3 + \frac{1}{x^3}\right)^2 \ldots\ldots\ldots$ up to n terms is:

(1) $\frac{x^{2n}-1}{x^2-1} \times \frac{x^{2n+2}+1}{x^{2n}} + 2n$

(2) $\frac{x^{2n}+1}{x^2+1} \times \frac{x^{2n+2}-1}{x^{2n}} - 2n$

(3) $\frac{x^{2n}-1}{x^2-1} \times \frac{x^{2n}-1}{x^{2n}} - 2n$

(4) None of these

Correct Answer: (1) $\frac{x^{2n}-1}{x^2-1} \times \frac{x^{2n+2}+1}{x^{2n}} + 2n$

Solution:

Concept: This problem can be solved analytically by expanding each term algebraically and grouping them into independent **Geometric Progressions (G.P.)**.

The standard sum formula for a geometric progression consisting of n terms with a first term a and common ratio r is given by:

$$S_n = \frac{a(r^n - 1)}{r - 1}$$

Step 1: Expanding the terms and splitting the series.

Let S denote the sum of the series. Expanding each term using the identity $(A+B)^2 = A^2 + 2AB + B^2$:

$$\left(x + \frac{1}{x}\right)^2 = x^2 + 2(x)\left(\frac{1}{x}\right) + \frac{1}{x^2} = x^2 + \frac{1}{x^2} + 2$$
$$\left(x^2 + \frac{1}{x^2}\right)^2 = x^4 + 2(x^2)\left(\frac{1}{x^2}\right) + \frac{1}{x^4} = x^4 + \frac{1}{x^4} + 2$$
$$\left(x^3 + \frac{1}{x^3}\right)^2 = x^6 + 2(x^3)\left(\frac{1}{x^3}\right) + \frac{1}{x^6} = x^6 + \frac{1}{x^6} + 2$$

Summing these expanded expressions together up to n terms:

$$S = \left(x^2 + \frac{1}{x^2} + 2\right) + \left(x^4 + \frac{1}{x^4} + 2\right) + \left(x^6 + \frac{1}{x^6} + 2\right) + \dots \text{ up to } n \text{ blocks}$$

Regrouping the expressions into three separate summation series:

$$S = \underbrace{(x^2 + x^4 + \cdots + x^{2n})}_{\text{Series 1 (G.P.)}}$$
$$+ \underbrace{\left(\frac{1}{x^2} + \frac{1}{x^4} + \cdots + \frac{1}{x^{2n}}\right)}_{\text{Series 2 (G.P.)}}$$
$$+ \underbrace{(2 + 2 + \cdots + 2)}_{n \text{ times}}$$

Step 2: Evaluating each individual sub-series.

- **Series 1:** This is a G.P. with first term $a = x^2$ and common ratio $r = x^2$.

$$S_1 = \frac{x^2((x^2)^n - 1)}{x^2 - 1} = \frac{x^2(x^{2n} - 1)}{x^2 - 1}$$

- **Series 2:** This is a G.P. with first term $a = \frac{1}{x^2}$ and common ratio $r = \frac{1}{x^2}$.

$$S_2 = \frac{\frac{1}{x^2}\left(1 - \left(\frac{1}{x^2}\right)^n\right)}{1 - \frac{1}{x^2}} = \frac{\frac{1}{x^2}\left(1 - \frac{1}{x^{2n}}\right)}{\frac{x^2-1}{x^2}} = \frac{1 - \frac{1}{x^{2n}}}{x^2 - 1} = \frac{x^{2n} - 1}{x^{2n}(x^2 - 1)}$$

- **Series 3:** Summing the constant value 2 exactly n times:

$$S_3 = 2n$$

Step 3: Combining and factoring the expressions.

Adding our three sub-series sums together:

$$S = \frac{x^2(x^{2n} - 1)}{x^2 - 1} + \frac{x^{2n} - 1}{x^{2n}(x^2 - 1)} + 2n$$

Factoring out the shared expression $\frac{x^{2n}-1}{x^2-1}$ from the first two terms:

$$S = \frac{x^{2n} - 1}{x^2 - 1}\left[x^2 + \frac{1}{x^{2n}}\right] + 2n$$

Taking a common denominator inside the square brackets:

$$S = \frac{x^{2n} - 1}{x^2 - 1}\left[\frac{x^2 \cdot x^{2n} + 1}{x^{2n}}\right] + 2n = \frac{x^{2n} - 1}{x^2 - 1} \times \frac{x^{2n+2} + 1}{x^{2n}} + 2n$$

This directly matches the algebraic layout of Option (1).

Quick Tip: When resolving complex progression formula matching, use the **Substitution Strategy** ($n = 1$) to bypass long algebraic layouts entirely! For $n = 1$, the true sum is simply the very first term: $\left(x + \frac{1}{x}\right)^2 = x^2 + \frac{1}{x^2} + 2$. Let's substitute $n = 1$ directly into Option 1:

$$\frac{x^2 - 1}{x^2 - 1} \times \frac{x^{2+2} + 1}{x^2} + 2(1) = 1 \times \left(\frac{x^4 + 1}{x^2}\right) + 2 = x^2 + \frac{1}{x^2} + 2$$

It matches perfectly in less than 15 seconds!