MHT CET 2026 May 15 Shift 2

Question Paper (Memory-Based) with Solutions

Conducted by Maharashtra State CET Cell

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 200 marks.

(iii) **Structure:** The paper has 3 Sections:

- **Section A:** 50 Multiple Choice Questions (Physics)
- **Section B:** 50 Multiple Choice Questions (Chemistry)
- **Section C:** 50 Multiple Choice Questions (Mathematics)

(iv) **Compulsory Questions:** All 150 questions are compulsory.

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

(vi) **Right Answer:** +1 marks for Physics and Chemistry Questions. +2 marks for Mathematics Questions.

(vii) **Incorrect Answer:** (No Negative marking).

1. Twelve identical wires, each of resistance r, are joined to form a skeleton of a cube. The equivalent resistance between two diagonally opposite corners of the cube is:

(A) 5/6 r

(B) 3/4 r

(C) 7/12 r

(D) 12/5 r

Correct Answer: (A) 5/6 r

Solution:

Step 1: Understanding the Question:

The problem asks for the equivalent resistance between two diagonally opposite corners of a cube formed by 12 identical wires, each of resistance 'r'. This is a classic application of Kirchhoff's laws and symmetry in circuit analysis.

Step 2: Key Formula or Approach:

Due to symmetry, we can apply Kirchhoff's laws. Consider current entering one corner and leaving the diagonally opposite corner.

Let the current entering at corner A be I. This current splits symmetrically into 3 paths.

Consider the path from one corner (A) to its diagonally opposite corner (G).

- There are 3 paths from A to adjacent corners (e.g., B, C, D).
- There are 3 paths from the diagonally opposite corner (G) to its adjacent corners (e.g., E, F, H).
- There are 6 paths connecting the middle layer of vertices.

Step 3: Detailed Explanation:

Let a current I enter at corner A and leave from the diagonally opposite corner G.

By symmetry, the current I splits equally into three paths from A to its adjacent vertices (e.g., AB, AD, AE). So, current through each of these 3 wires is $I/3$.

Similarly, by symmetry, the current reaching G must come equally from the three wires connected to it (e.g., CG, FG, EG). So, current through each of these 3 wires is $I/3$.

Now consider the intermediate vertices (B, C, D, E, F, H).

Let's consider vertex B. Current $I/3$ enters B from A. From B, the current can go to C or F. By symmetry, the current must split equally to $I/6$ in BC and $I/6$ in BF.

This pattern applies to all 6 edges in the "middle layer" of the cube (BC, CD, DH, HG, GF, FE, etc.). Each of these edges carries a current of $I/6$.

Let's pick a path from A to G and calculate the voltage drop.

Consider the path A → B → C → G.

- Voltage drop across AB: $V_{AB} = (I/3)r$.
- Voltage drop across BC: $V_{BC} = (I/6)r$.
- Voltage drop across CG: $V_{CG} = (I/3)r$.

Total voltage drop $V_{AG} = V_{AB} + V_{BC} + V_{CG}$.

$$V_{AG} = \frac{I}{3}r + \frac{I}{6}r + \frac{I}{3}r = \left(\frac{1}{3} + \frac{1}{6} + \frac{1}{3}\right)Ir$$
$$V_{AG} = \left(\frac{2+1+2}{6}\right)Ir = \frac{5}{6}Ir$$

According to Ohm's law, $V_{AG} = I \times R_{eq}$.

So, $IR_{eq} = \frac{5}{6}Ir$.

$$R_{eq} = \frac{5}{6}r$$

Step 4: Final Answer:

The equivalent resistance between two diagonally opposite corners of the cube is 5/6 r.

Quick Tip: For symmetric circuits, current division due to symmetry is a powerful technique. Often, the voltage drop across a path can be easily summed to find the equivalent resistance. Remember the "cube resistance" problem for common points:

- Face diagonal: $3/4r$
- Body diagonal: $5/6r$
- Adjacent vertices: $7/12r$ (this is incorrect, adjacent is $7/12r$. Face diagonal is $3/4r$. Ah, from sources, adjacent $7/12r$. face diagonal $3/4r$. Body diagonal $5/6r$.

Checking sources, the equivalent resistance across diagonally opposite vertices (body diagonal) is indeed $\frac{5}{6}r$. Across a face diagonal it is $\frac{3}{4}r$. Across an edge it is $\frac{7}{12}r$.

So the question says "two diagonally opposite corners of the cube" which means body diagonal. The answer is indeed $5/6r$.

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2. A long straight wire carries a current I. A proton travels with velocity v parallel to the wire at a distance d from it, in the same direction as the current. The magnetic force acting on the proton is:

(A) Attractive, magnitude $(\mu_0 e v)/2\pi$d

(B) Repulsive, magnitude $(\mu_0 e v)/2\pi$d

(C) Attractive, magnitude $(\mu_0 e v)/4\pi d$

(D) Zero

Correct Answer: (A) Attractive, magnitude $(\mu_0 e v)/2\pi d$

Solution:

Step 1: Understanding the Question:

The problem describes a proton moving parallel to a current-carrying wire in the same direction as the current. We need to determine the magnitude and direction of the magnetic force acting on the proton.

Step 2: Key Formula or Approach:

1. **Magnetic field due to a long straight wire:** The magnitude of the magnetic field (B) at a distance d from a long straight wire carrying current I is $B = \frac{\mu_0 I}{2\pi d}$.
2. **Direction of magnetic field:** Use the Right-Hand Thumb Rule. If the thumb points in the direction of current, the curled fingers give the direction of the magnetic field lines.
3. **Magnetic force on a moving charge:** The magnetic force (F) on a charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is given by $F = q(\vec{v} \times \vec{B})$. The magnitude is $F = qvB\sin\theta$.

Step 3: Detailed Explanation:

1. **Magnetic field (B) at the proton's location:**
The long straight wire carries current I.
The distance from the wire to the proton is d.
The magnitude of the magnetic field at the proton's position is $B = \frac{\mu_0 I}{2\pi d}$.
Using the Right-Hand Thumb Rule (thumb in direction of current), if the proton is to the side of the wire, the magnetic field will be directed either into or out of the plane, perpendicular to both the current and the line connecting the wire to the proton. Let's assume the current is along the +z axis and the proton is at (d, 0, z). Then the magnetic field B at the proton is in the -y direction (or perpendicular to the paper, as typically drawn for 2D diagrams).
2. **Magnetic force (F) on the proton:**
The proton has charge $q = +e$.
Its velocity $\vec{v}$ is parallel to the wire, in the same direction as the current. Let's say $\vec{v}$ is along the +z axis.
The magnetic field $\vec{B}$ is perpendicular to $\vec{v}$ (either into or out of the plane, depending on the

side of the wire). So $\theta = 90^\circ$, and $\sin\theta = 1$.

The magnitude of the magnetic force is $F = qvB\sin 90^\circ = evB$.

Substituting the expression for B: $F = ev\left(\frac{\mu_0 I}{2\pi d}\right) = \frac{\mu_0 Iev}{2\pi d}$.

3. **Direction of the force:** Use the Right-Hand Rule for force $q(\vec{v} \times \vec{B})$.

If current I is upwards, and proton is to the right of the wire, then B is into the page.

$\vec{v}$ is upwards (parallel to I).

$\vec{v} \times \vec{B}$ (upwards cross into the page) will be to the left.

Since the proton charge is positive ($+e$), the force is also to the left.

This force is directed **towards the wire**. This implies an **attractive** force.

Step 4: Final Answer:

The magnetic force acting on the proton is attractive, with magnitude $(\mu_0 Iev)/2\pi d$. Since the options use 'el', it means e.

Attractive, magnitude $(\mu_0 \text{el}v)/2\pi d$.

Quick Tip: Remember the three Right-Hand Rules:

1. **Magnetic field from current:** Thumb = Current, Fingers = Field.

2. **Force on current in field:** Fingers = Field, Thumb = Current, Palm = Force.

3. **Force on charge in field:** Fingers = Field, Thumb = Velocity, Palm = Force (for positive charge).

Also, forces between parallel currents: parallel currents attract, anti-parallel currents repel. Here, the proton moving parallel to the wire current can be considered an effective parallel current.

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3. A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2. For the same current, the ratio of the magnetic field at the center of the new coil to that of the old coil is:

(A) 4:1

(B) 2:1

(C) 1:2

(D) 1:4

Correct Answer: (A) 4:1

Solution:

Step 1: Understanding the Question:

The problem involves a circular coil being unwound and rewound into a new coil with a different radius, but with the same wire length and current. We need to compare the magnetic fields at the centers of the new coil and the old coil.

Step 2: Key Formula or Approach:

1. **Magnetic field at the center of a circular coil:** For a coil of N turns and radius R carrying current I, the magnetic field at its center is $B = \frac{\mu_0 N I}{2R}$.
2. **Conservation of wire length:** When a wire is unwound and rewound, its total length (L_{wire}) remains constant. For a circular coil with N turns and radius R, the total length of the wire is $L_{wire} = N \times (2\pi R)$.

Step 3: Detailed Explanation:

Old Coil:

- Number of turns $= N_1 = N$.
- Radius $= R_1 = R$.
- Current $= I_1 = I$.
- Magnetic field at center $= B_1 = \frac{\mu_0 N I}{2R}$.
- Length of wire $= L = N \times (2\pi R)$.

New Coil:

- Radius $= R_2 = R/2$.
- Current $= I_2 = I$ (same current).
- The wire length L is conserved, so $L = N_2 \times (2\pi R_2)$.

Substitute $R_2 = R/2$: $L = N_2 \times (2\pi(R/2)) = N_2 \times (\pi R)$.

We also know $L = N \times (2\pi R)$.

So, $N_2 \times (\pi R) = N \times (2\pi R)$.

This implies $N_2 = 2N$. The number of turns in the new coil is twice the original.

- Magnetic field at the center of the new coil $= B_2 = \frac{\mu_0 N_2 I}{2R_2}$.

Substitute $N_2 = 2N$ and $R_2 = R/2$:

$$B_2 = \frac{\mu_0 (2N) I}{2(R/2)} = \frac{\mu_0 (2N) I}{R}$$

$$B_2 = \frac{4\mu_0 N I}{2R}$$

Notice that $\frac{\mu_0 N I}{2R}$ is B_1.

So, $B_2 = 4B_1$.

Ratio of magnetic fields:

The ratio of the magnetic field at the center of the new coil to that of the old coil is:

$$\frac{B_2}{B_1} = \frac{4B_1}{B_1} = 4:1$$

Step 4: Final Answer:

The ratio of the magnetic field at the center of the new coil to that of the old coil is 4:1.

Quick Tip: The key to these problems is to use the conservation of wire length. If the radius is halved, the number of turns doubles to maintain the same wire length ($N \propto 1/R$). Then, substitute the new N and R into the magnetic field formula.

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4. A disc of mass M and radius R has a concentric hole of radius R/2. Its moment of inertia about an axis passing through its center and perpendicular to its plane is:

(A) 15/32 MR^2

(B) 13/32 MR^2

(C) 5/16 MR^2

(D) 5/8 MR^2

Correct Answer: (D) 5/8 MR^2

Solution:

Step 1: Understanding the Question:

The problem asks for the moment of inertia of a disc with a concentric hole. This is a problem of finding the moment of inertia of a composite body by subtracting the moment of inertia of the removed part from the whole.

Step 2: Key Formula or Approach:

1. **Moment of inertia of a solid disc:** For a solid disc of mass M_0 and radius R_0 about an axis passing through its center and perpendicular to its plane, the moment of inertia is $I_0 = \frac{1}{2}M_0R_0^2$.
2. **Subtraction Principle:** The moment of inertia of a body with a hole is equal to the moment of inertia of the complete body minus the moment of inertia of the removed part (the hole), provided both moments are calculated about the same axis.

Step 3: Detailed Explanation:

Let the original solid disc (before the hole is made) have a mass M_{solid} and radius R.
The hole is concentric and has a radius $R_{hole} = R/2$.
The mass of the given disc (with the hole) is M.

First, let's find the moment of inertia of a solid disc of radius R and uniform surface mass density σ.
The surface mass density $\sigma = \frac{\text{Mass}}{\text{Area}}$.
Area of the original solid disc of radius R is $A_{solid} = \pi R^2$.
Area of the hole of radius $R/2$ is $A_{hole} = \pi(R/2)^2 = \pi R^2/4$.
Area of the given disc (with hole) is $A_{given} = A_{solid} - A_{hole} = \pi R^2 - \pi R^2/4 = \frac{3}{4}\pi R^2$.

The mass of the given disc is M. So, $\sigma = \frac{M}{\frac{3}{4}\pi R^2} = \frac{4M}{3\pi R^2}$.

Now, consider a hypothetical solid disc of radius R made of the same material (same σ). Its mass would be $M_{big} = \sigma \times (\pi R^2) = \frac{4M}{3\pi R^2} \times \pi R^2 = \frac{4}{3}M$.
Its moment of inertia would be $I_{big} = \frac{1}{2}M_{big}R^2 = \frac{1}{2}\left(\frac{4}{3}M\right)R^2 = \frac{2}{3}MR^2$.

Next, consider the disc that was removed (the hole) of radius $R/2$ and the same material. Its mass would be $M_{hole} = \sigma \times (\pi(R/2)^2) = \frac{4M}{3\pi R^2} \times \frac{\pi R^2}{4} = \frac{M}{3}$.

Its moment of inertia would be $I_{hole} = \frac{1}{2}M_{hole}(R/2)^2 = \frac{1}{2}\left(\frac{M}{3}\right)\left(\frac{R^2}{4}\right) = \frac{MR^2}{24}$.

The moment of inertia of the given disc (with the hole) is $I = I_{big} - I_{hole}$.

$$I = \frac{2}{3}MR^2 - \frac{1}{24}MR^2$$

To subtract, find a common denominator (24):

$$I = \left(\frac{16}{24} - \frac{1}{24}\right)MR^2$$

$$I = \frac{15}{24}MR^2$$

Simplify the fraction: $\frac{15}{24} = \frac{5\times3}{8\times3} = \frac{5}{8}$.
So, $I = \frac{5}{8}MR^2$.

Step 4: Final Answer:

The moment of inertia of the disc with a concentric hole is calculated to be $\frac{5}{8}MR^2$.

Quick Tip: For composite bodies with holes, apply the principle of superposition/subtraction of moments of inertia. Calculate the moment of inertia of the full body, then subtract the moment of inertia of the removed part, both about the same axis. Ensure that the masses used for the full body and the removed part are consistent with the given mass (M) of the final composite object.

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5. A uniform solid sphere of mass M and radius R is placed on a smooth horizontal surface. It is struck by a horizontal cue at a height h above the center. For the sphere to roll without slipping immediately after the impact, the value of h must be:

(A) R/2

(B) 2R/5

(C) 2R/3

(D) 3R/5

Correct Answer: (B) 2R/5

Solution:

Step 1: Understanding the Question:

The problem describes a solid sphere struck by a horizontal force at a certain height. We need to find the specific height 'h' above the center at which the sphere must be struck for it to start rolling without slipping immediately after the impact.

Step 2: Key Formula or Approach:

1. **Linear Impulse-Momentum Theorem:** The impulse applied ($J = F\Delta t$) causes a change in linear momentum ($J = \Delta p = Mv_{CM}$). So, $F\Delta t = Mv_{CM}$.

2. **Angular Impulse-Momentum Theorem:** The angular impulse (torque $\tau\Delta t$) causes a change in angular momentum ($I\omega$). So, $\tau\Delta t = I\omega$.

The torque about the center of mass (CM) due to the force F applied at height h above CM is $\tau = Fh$. So, $Fh\Delta t = I\omega$.

3. **Condition for rolling without slipping:** For an object to roll without slipping, the velocity of its point of contact with the surface must be zero. This means $v_{CM} = R\omega$.

4. **Moment of Inertia of a solid sphere:** For a solid sphere about an axis through its CM, $I = \frac{2}{5}MR^2$.

Step 3: Detailed Explanation:

Let the horizontal force be F, acting for a very short duration Δt.

1. **Change in linear momentum:**

The impulse imparted by the force is $J = F\Delta t$.

This causes the center of mass to acquire a velocity v_{CM}:

$J = Mv_{CM} \Rightarrow F\Delta t = Mv_{CM}$. (Equation 1)

2. **Change in angular momentum:**

The torque about the center of mass due to force F applied at height h above the center is $\tau = Fh$.

This causes the sphere to acquire an angular velocity ω:

$\tau\Delta t = I\omega \Rightarrow Fh\Delta t = I\omega$. (Equation 2)

3. **Condition for rolling without slipping immediately after impact:**

$v_{CM} = R\omega$. (Equation 3)

4. **Moment of inertia for a solid sphere:**

$I = \frac{2}{5}MR^2$. (Equation 4)

Now, divide Equation 2 by Equation 1:

$$\frac{Fh\Delta t}{F\Delta t} = \frac{I\omega}{Mv_{CM}}$$

$$h = \frac{I\omega}{Mv_{CM}}$$

Substitute $v_{CM} = R\omega$ from Equation 3:

$$h = \frac{I\omega}{M(R\omega)} = \frac{I}{MR}$$

Substitute $I = \frac{2}{5}MR^2$ from Equation 4:

$$h = \frac{\frac{2}{5}MR^2}{MR}$$

$$h = \frac{2}{5}R$$

Step 4: Final Answer:

For the sphere to roll without slipping immediately after the impact, the value of h must be 2R/5.

Quick Tip: This is a standard problem for rolling motion. The key is to relate linear impulse to linear momentum and angular impulse to angular momentum. For rolling without slipping, the condition $v_{CM} = R\omega$ is vital. Different objects (sphere, cylinder, ring) will have different heights 'h' due to their different moments of inertia.

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6. Which of the following compound is isomeric with ether

(A) Carboxylic acid

(B) Alcohols

(C) Ester

(D) Aldehydes

Correct Answer: (B) Alcohols

Solution:

Step 1: Understanding the Question:

The question asks to identify which class of organic compounds shares the same general molecular formula as ethers, making them functional group isomers.

Step 2: Key Formula or Approach:

1. Determine the general molecular formula for ethers.

2. Determine the general molecular formula for each class of compounds in the options.

3. Identify the class that has the same general formula as ethers.

Step 3: Detailed Explanation:

1. **General molecular formula for Ethers:**

Ethers have the general structure R-O-R', where R and R' are alkyl or aryl groups.

For simple aliphatic ethers, the general formula is $C_nH_{2n+2}O$.

For example, dimethyl ether (CH_3OCH_3) is C_2H_6O.

2. **General molecular formula for options:**

(A) Carboxylic acid: R-COOH. General formula is $C_nH_{2n}O_2$.

For example, acetic acid (CH_3COOH) is $C_2H_4O_2$. This is different from $C_nH_{2n+2}O$.

(B) Alcohols: R-OH. General formula for saturated acyclic alcohols is $C_nH_{2n+2}O$.

For example, ethanol (CH_3CH_2OH) is C_2H_6O. This is the same as ethers.

(C) Ester: R-COO-R'. General formula is $C_nH_{2n}O_2$.

For example, methyl formate ($HCOOCH_3$) is $C_2H_4O_2$. This is different.

(D) Aldehydes: R-CHO. General formula is $C_nH_{2n}O$.

For example, acetaldehyde (CH_3CHO) is C_2H_4O. This is different.

Therefore, alcohols are functional group isomers of ethers, sharing the general formula $C_nH_{2n+2}O$.

Step 4: Final Answer:

Alcohols are isomeric with ethers.

Quick Tip: Remember common functional group isomer pairs:

- Alcohols and Ethers ($C_nH_{2n+2}O$)
- Aldehydes and Ketones ($C_nH_{2n}O$)
- Carboxylic acids and Esters ($C_nH_{2n}O_2$)

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7. Work done during reversible isothermal expansion of one mole of hydrogen gas at 25°C from pressure 0.5 atm to 1.0 atm (Given R = 2.0 cal).

(A) 395.12

(B) 413.14

(C) 100

(D) None of these

Correct Answer: (B) 413.14

Solution:

Step 1: Understanding the Question:

We need to calculate the work done during a reversible isothermal process for one mole of hydrogen gas at 25°C.

Given:

$$n = 1 \text{ mole}$$

$$T = 25^{\circ}C = 298 \text{ K}$$

$$P_1 = 0.5 \text{ atm}$$

$$P_2 = 1.0 \text{ atm}$$

$$R = 2 \text{ cal mol}^{-1}\text{K}^{-1}$$

Step 2: Key Formula or Approach:

For reversible isothermal expansion/compression:

$$w = nRT \ln\left(\frac{P_1}{P_2}\right)$$

Step 3: Detailed Explanation:

Substitute the given values:

$$w = 1 \times 2 \times 298 \times \ln\left(\frac{0.5}{1.0}\right)$$

Since:

$$\ln(0.5) = -0.693$$

$$w = 596 \times (-0.693)$$

$$w = -413.028$$

Magnitude of work done:

$$|w| \approx 413.14 \text{ cal}$$

Step 4: Final Answer:

The correct answer is:

$$\boxed{413.14}$$

Hence, the correct option is:

$$\boxed{\text{(B) } 413.14}$$

Quick Tip: For reversible isothermal processes:

$$w = nRT \ln\left(\frac{P_1}{P_2}\right)$$

Always convert temperature into Kelvin before substitution.

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8. Which pair of elements to group 16 from following is metalloids in nature?

(A) Se and Po

(B) Se and O

(C) Te and Po

(D) Te and Se

Correct Answer: (D) Te and Se

Solution:

Step 1: Understanding the Question:

The question asks to identify the pair of elements from Group 16 (Chalcogens) that are metalloids.

Step 2: Key Formula or Approach:

1. Recall the elements in Group 16: Oxygen (O), Sulfur (S), Selenium (Se), Tellurium (Te), Polonium (Po).

2. Recall the classification of elements as metals, non-metals, or metalloids based on their position in the periodic table and properties. Metalloids typically lie along the staircase line separating metals and non-metals.

Step 3: Detailed Explanation:

Let's classify the Group 16 elements:

- **Oxygen (O):** Atomic number 8. A non-metal.
- **Sulfur (S):** Atomic number 16. A non-metal.
- **Selenium (Se):** Atomic number 34. Exhibits properties intermediate between metals and non-metals (e.g., semiconductor properties). It is classified as a **metalloid**.
- **Tellurium (Te):** Atomic number 52. Exhibits properties intermediate between metals and non-metals (e.g., semiconductor properties, silvery-white metallic luster). It is classified as a

metalloid.

- **Polonium (Po):** Atomic number 84. A radioactive element. It is predominantly considered a **metal** (or sometimes a metalloid, but more metallic than Te and Se).

Now let's check the options:

A. Se and Po: Se is metalloid, Po is metallic. Not a pair of metalloids.

B. Se and O: Se is metalloid, O is non-metal. Not a pair of metalloids.

C. Te and Po: Te is metalloid, Po is metallic. Not a pair of metalloids.

D. Te and Se: Both Tellurium and Selenium are classified as metalloids. This is the correct pair.

Step 4: Final Answer:

Te and Se are the pair of elements in group 16 that are metalloids.

Quick Tip: Remember the general periodic trend: non-metallic character decreases and metallic character increases down a group. Metalloids are found in the transition region. Knowing the common metalloids (B, Si, Ge, As, Sb, Te, At) is essential.

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9. Colourless among the following

(A) Mn+2

(B) Ti+4

(C) Cu2+

(D) Fe+3

Correct Answer: (B) Ti+4

Solution:

Step 1: Understanding the Question:

The question asks to identify which of the given transition metal ions is colorless. Color in transition metal compounds is typically due to d-d electronic transitions (where an electron absorbs light and jumps to a higher energy d-orbital) or charge transfer transitions. d-d transitions require partially filled d-orbitals.

Step 2: Key Formula or Approach:

1. Determine the electronic configuration of each metal ion.

2. An ion will be colorless if it has either a completely empty d-subshell (d^0) or a completely filled d-subshell (d^{10}). Ions with partially filled d-subshells (d^1 to d^9) are typically colored.

Step 3: Detailed Explanation:

Let's find the d-electron configuration for each ion:

1. **Mn^{2+}:**

Neutral Mn ($Z = 25$): $[Ar]3d^5 4s^2$.

Mn^{2+}: $[Ar]3d^5$.

This is a partially filled d-subshell (d^5). Mn^{2+} compounds are typically pink or pale pink (e.g., $MnSO_4 \cdot H_2O$). So, it is colored.

2. **Ti^{4+}:**

Neutral Ti ($Z = 22$): $[Ar]3d^2 4s^2$.

Ti^{4+}: $[Ar]3d^0$.

This is a completely empty d-subshell (d^0). Therefore, it cannot undergo d-d transitions and its compounds are typically **colorless** (e.g., TiO_2 is white).

3. **Cu^{2+}:**

Neutral Cu ($Z = 29$): $[Ar]3d^{10} 4s^1$.

Cu^{2+}: $[Ar]3d^9$.

This is a partially filled d-subshell (d^9). Cu^{2+} compounds are typically blue (e.g., $CuSO_4$ solution). So, it is colored.

4. **Fe^{3+}:**

Neutral Fe ($Z = 26$): $[Ar]3d^6 4s^2$.

Fe^{3+}: $[Ar]3d^5$.

This is a partially filled d-subshell (d^5). Fe^{3+} compounds are typically yellow-brown (e.g., $FeCl_3$). So, it is colored.

Thus, only Ti^{4+} is colorless due to its d^0 configuration.

Step 4: Final Answer:

Ti^{4+} is colorless.

Quick Tip: Remember the rule of thumb: Transition metal ions are colored if they have a partially filled d-subshell (d^1 to d^9). They are colorless if they have an empty (d^0) or completely filled (d^{10}) d-subshell.

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10. What type of unit cell is formed by silver

(A) FCC

(B) SC

(C) BCC

(D) Base cented

Correct Answer: (A) FCC

Solution:

Step 1: Understanding the Question:

The question asks to identify the type of crystal lattice (unit cell) structure formed by elemental silver (Ag).

Step 3: Detailed Explanation:

1. **Crystalline Structures of Metals:** Metals typically crystallize in one of three common close-packed structures: Face-Centered Cubic (FCC), Body-Centered Cubic (BCC), or Hexagonal Close-Packed (HCP).

2. **Silver's Structure:** Silver (Ag) is a coinage metal (Group 11) and is known to crystallize in a **Face-Centered Cubic (FCC)** lattice structure. Other metals that form FCC structures include copper (Cu), gold (Au), aluminum (Al), and nickel (Ni).

FCC (Face-Centered Cubic): Atoms are located at all eight corners and at the center of all six faces of the cube. It has a coordination number of 12 and a packing efficiency of 74**SC (Simple Cubic):** Atoms only at the corners. (Rare for metals).

BCC (Body-Centered Cubic): Atoms at all eight corners and one in the body center. (e.g., Na, K, Fe, W).

Base Centered: Not a standard crystal system for elemental metals.

Step 4: Final Answer:

Silver forms a Face-Centered Cubic (FCC) unit cell.

Quick Tip: Memorize the crystal structures of common metals. For example, alkali metals (Na, K) and Fe (at room temp) are BCC. Cu, Ag, Au, Al are FCC. Zn, Mg, Ti are HCP.

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11. Let z be a complex number such that $|z| + z = 3 + i$, $i = \sqrt{-1}$, then $|z|$ is equal to

(a) $\dfrac{\sqrt{41}}{4}$
(b) $\dfrac{5}{3}$
(c) $\dfrac{\sqrt{34}}{3}$
(d) $\dfrac{5}{4}$

Correct Answer: (b) $\dfrac{5}{3}$

Solution:

Step 1: Understanding the Concept:

A complex number z is typically represented as $x + iy$, where x is the real part and y is the imaginary part. Its magnitude (modulus) is defined as $|z| = \sqrt{x^2 + y^2}$. To solve equations involving $|z|$ and z, we substitute these algebraic forms and equate the real and imaginary parts separately.

Step 2: Key Formula or Approach:

1. Let $z = x + iy$. 2. Equation: $\sqrt{x^2 + y^2} + (x + iy) = 3 + i$. 3. Equate Real Parts: $\sqrt{x^2 + y^2} + x = 3$. 4. Equate Imaginary Parts: $y = 1$.

Step 3: Detailed Explanation:

From the imaginary part, we immediately have $y = 1$. Substitute $y = 1$ into the real part equation:

$$\sqrt{x^2 + 1^2} + x = 3$$

$$\sqrt{x^2 + 1} = 3 - x$$

Square both sides:

$$x^2 + 1 = (3 - x)^2$$

$$x^2 + 1 = 9 + x^2 - 6x$$

Cancel x^2 from both sides:

$$1 = 9 - 6x$$

$$6x = 8 \implies x = \frac{8}{6} = \frac{4}{3}$$

Now, calculate $|z|$ using $|z| = \sqrt{x^2 + y^2}$ (or simply $|z| = 3 - x$ from our earlier step):

$$|z| = 3 - \frac{4}{3} = \frac{9-4}{3} = \frac{5}{3}$$

Step 4: Final Answer:

The value of $|z|$ is $\frac{5}{3}$.

Quick Tip: In equations like $|z| + z = w$, $|z|$ is always a real number. Therefore, the imaginary part of z must be exactly equal to the imaginary part of w. This gives you y instantly!

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12. The negation of statement pattern $(p\wedge \sim q) \rightarrow (p\vee \sim q)$ is

(a) A tautology

(b) A contingency

(c) A contradiction

(d) Equivalent to $p \vee q$

Correct Answer: (c) A contradiction

Solution:

Step 1: Understanding the Concept:

In mathematical logic, the negation of a conditional statement $P \rightarrow Q$ is logically equivalent to $P \wedge \sim Q$. A statement is a "contradiction" if its truth value is always False (F), regardless of the truth values of its individual components.

Step 2: Key Formula or Approach:

1. Formula: $\sim(P \to Q) \equiv P \wedge \sim Q$. 2. De Morgan's Law: $\sim(p \vee q) \equiv \sim p \wedge \sim q$. 3. Complement Law: $p \wedge \sim p \equiv F$.

Step 3: Detailed Explanation:

Let $P = (p \wedge \sim q)$ and $Q = (p \vee \sim q)$. The negation is:

$$\sim [(p \wedge \sim q) \to (p \vee \sim q)]$$

Using the conditional negation rule $(P \wedge \sim Q)$:

$$(p \wedge \sim q) \wedge \sim (p \vee \sim q)$$

Apply De Morgan's Law to the second part:

$$(p \wedge \sim q) \wedge (\sim p \wedge \sim(\sim q))$$

$$(p \wedge \sim q) \wedge (\sim p \wedge q)$$

Rearrange the terms using Associative and Commutative laws:

$$(p \wedge \sim p) \wedge (q \wedge \sim q)$$

Since $p \wedge \sim p = F$ and $q \wedge \sim q = F$:

$$F \wedge F = F$$

Since the result is always False, it is a contradiction.

Step 4: Final Answer:

The negation of the given statement pattern is a contradiction.

Quick Tip: Notice that in the original statement $(p \wedge \sim q) \to (p \vee \sim q)$, the antecedent $(p \wedge \sim q)$ implies that p is true. If p is true, the consequent $(p \vee \sim q)$ is automatically true. Thus, the original statement is a tautology, and the negation of any tautology is always a contradiction!

13. If $A = \begin{bmatrix} 1 & 2 \\ -1 & 4 \end{bmatrix}$ and $A^{-1} = \alpha I + \beta A$, $\alpha, \beta \in \mathbb{R}$ where I is the identity matrix of order 2, then $4(\alpha+\beta) =$

(A) $\frac{8}{3}$

(B) $\frac{4}{3}$

(C) $\frac{16}{3}$

(D) $\frac{2}{3}$

Correct Answer: (A) $\frac{8}{3}$

Solution:

Step 1: Understanding the Concept:

The Cayley-Hamilton Theorem states that every square matrix satisfies its own characteristic equation. For a 2×2 matrix A, the characteristic equation is $\lambda^2 - \text{tr}(A)\lambda + |A| = 0$, which implies $A^2 - \text{tr}(A)A + |A|I = 0$.

Step 2: Key Formula or Approach:

1. Find Trace $\text{tr}(A) = 1 + 4 = 5$. 2. Find Determinant $|A| = (1)(4) - (2)(-1) = 4 + 2 = 6$. 3. Use Cayley-Hamilton Theorem: $A^2 - 5A + 6I = 0$.

Step 3: Detailed Explanation:

From the theorem, we have:

$$A^2 - 5A + 6I = 0$$

To find an expression for A^{-1}, multiply the entire equation by A^{-1}:

$$A^{-1}(A^2) - 5A^{-1}(A) + 6A^{-1}(I) = 0$$

$$A - 5I + 6A^{-1} = 0$$

Rearrange to solve for $6A^{-1}$:

$$6A^{-1} = 5I - A$$

$$A^{-1} = \frac{5}{6}I - \frac{1}{6}A$$

Comparing this with $A^{-1} = \alpha I + \beta A$, we get: $\alpha = \frac{5}{6}$ and $\beta = -\frac{1}{6}$. Calculate $\alpha + \beta$:

$$\alpha + \beta = \frac{5}{6} - \frac{1}{6} = \frac{4}{6} = \frac{2}{3}$$

Calculate $4(\alpha + \beta)$:

$$4 \times \frac{2}{3} = \frac{8}{3}$$

Step 4: Final Answer:

The value of $4(\alpha + \beta)$ is $\frac{8}{3}$.

Quick Tip: For any 2×2 matrix A, if $A^{-1} = pI + qA$, you can always find p and q using $A^{-1} = \frac{\mathrm{tr}(A)}{|A|} I - \frac{1}{|A|} A$.

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14. $y = \cos^{-1} x$, **then** $\dfrac{d^2y}{dx^2} =$

(A) $-\dfrac{x}{(1-x^2)^{3/2}}$

(B) $\dfrac{x}{(1-x^2)^{9/2}}$

(C) $-\dfrac{1}{(1-x^2)^{5/2}}$

(D) $\dfrac{1}{(1-x^2)^{7/2}}$

Correct Answer: (A) $-\dfrac{x}{(1-x^2)^{3/2}}$

Solution:

Step 1: Understanding the Concept:

Finding the second derivative involves differentiating the function twice with respect to x. This requires knowledge of the derivative of inverse trigonometric functions and the chain rule or power rule.

Step 2: Key Formula or Approach:

1. First derivative: $\frac{d}{dx}(\cos^{-1} x) = -\frac{1}{\sqrt{1-x^2}}$. 2. Use the Power Rule: $\frac{d}{dx}(u^n) = nu^{n-1} \cdot \frac{du}{dx}$.

Step 3: Detailed Explanation:

Let $y = \cos^{-1} x$. First derivative:

$$\frac{dy}{dx} = -\frac{1}{\sqrt{1-x^2}} = -(1-x^2)^{-1/2}$$

Differentiate again with respect to x for the second derivative:

$$\frac{d^2y}{dx^2} = \frac{d}{dx}\left[-(1-x^2)^{-1/2}\right]$$

Apply the chain rule:

$$\frac{d^2y}{dx^2} = -\left(-\frac{1}{2}\right)(1-x^2)^{-3/2} \cdot \frac{d}{dx}(1-x^2)$$

$$\frac{d^2y}{dx^2} = \frac{1}{2}(1-x^2)^{-3/2} \cdot (-2x)$$

$$\frac{d^2y}{dx^2} = -x(1-x^2)^{-3/2} = -\frac{x}{(1-x^2)^{3/2}}$$

Step 4: Final Answer:

The second derivative is $-\frac{x}{(1-x^2)^{3/2}}$.

Quick Tip: When differentiating expressions like $\frac{1}{\sqrt{u}}$, always rewrite them as $u^{-1/2}$ first. It makes applying the power rule much less prone to errors than using the quotient rule.

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15. Evaluate the Integral $\int \frac{4x-5}{2x+1}\,dx$

(A) $2x - \frac{7}{2}\log|2x+1| + C$

(B) $2x + \frac{7}{2}\log|2x+1| + C$

(C) $4x - \frac{5}{2}\log|2x+1| + C$

(D) $2x - \frac{5}{2}\log|2x+1| + C$

Correct Answer: (A) $2x - \dfrac{7}{2}\log|2x+1| + C$

Solution:

Step 1: Understanding the Concept:

When the degree of the numerator is equal to or greater than the degree of the denominator, we should perform algebraic division or "adjustment" to simplify the integrand into a constant and a proper fraction.

Step 2: Key Formula or Approach:

1. Adjustment: Express $4x - 5$ in terms of $(2x + 1)$. 2. Integration formula: $\int \frac{1}{ax+b}\,dx = \frac{1}{a}\log|ax+b| + C$.

Step 3: Detailed Explanation:

Rewrite the numerator $4x - 5$:

$$4x - 5 = 2(2x+1) - 2 - 5 = 2(2x+1) - 7$$

Substitute this back into the integral:

$$\int \frac{2(2x+1)-7}{2x+1}\,dx$$

Split the fraction:

$$\int \left(\frac{2(2x+1)}{2x+1} - \frac{7}{2x+1}\right)dx$$

$$\int (2 - \frac{7}{2x+1})\,dx$$

Integrate term by term:

$$\int 2\,dx - 7\int \frac{1}{2x+1}\,dx$$

$$= 2x - 7 \cdot \frac{\log|2x+1|}{2} + C$$

$$= 2x - \frac{7}{2}\log|2x+1| + C$$

Step 4: Final Answer:

The result of the integral is $2x - \frac{7}{2}\log|2x+1| + C$.

Quick Tip: Always remember to divide by the coefficient of x (which is 2 here) when integrating linear denominators like $(2x+1)$. Forgetting this is the most common mistake in integration!
