

PGECET 2024 Metallurgical Engineering Question with Solutions

Duration :120 minutes	Total Marks :120	Total Questions :120
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Important Instructions

Read the following instructions carefully:

1. The Answer Sheet is inside this Test Booklet. Fill in the details in the provided columns with a blue or black ballpoint pen.
2. The test duration is 120 minutes, covering Nano Technology with 120 multiple-choice questions.
3. Each correct response awards 4 marks; each incorrect response deducts 1 mark. Total marks: 120.
4. Candidates should mark answers clearly on the Answer Sheet.
5. Rough work should be done on the provided rough sheets only.
6. The code for this booklet is F1. Ensure it matches the code on your Answer Sheet.
7. Do not leave the hall without handing over the Answer Sheet to the Invigilator.
8. Violation of rules will lead to disqualification.
9. Do not mark anything on the Answer Sheet other than the answers.

1. If $X_1 = \begin{bmatrix} 1 \\ i \end{bmatrix}$, $X_2 = \begin{bmatrix} i \\ 1 \end{bmatrix}$ are given vectors and $A = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix}$.

If $P = [X_1, X_2]$, then $P^{-1}AP$ is: (A) $\begin{bmatrix} e^{i\theta} & 0 \\ 0 & e^{-i\theta} \end{bmatrix}$

(B) $\begin{bmatrix} e^\theta & 0 \\ 0 & e^\theta \end{bmatrix}$

$$(C) \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$$

$$(D) \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Correct Answer: (A) $\begin{bmatrix} e^{i\theta} & 0 \\ 0 & e^{-i\theta} \end{bmatrix}$

Solution:

We are given:

$$A = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \quad \text{and} \quad P = [X_1 \ X_2] = \begin{bmatrix} 1 & i \\ i & 1 \end{bmatrix}$$

We need to compute $P^{-1}AP$, which is a similarity transformation.

Step 1: Interpret the matrix A

Matrix A is a rotation matrix in 2D space. It represents a counterclockwise rotation by angle θ , and its eigenvalues are:

$$\lambda_1 = e^{i\theta}, \quad \lambda_2 = e^{-i\theta}$$

So, if we can find a basis of eigenvectors for A , we can diagonalize it. That is:

$$P^{-1}AP = D = \text{diag}(\lambda_1, \lambda_2)$$

Step 2: Confirm that X_1 and X_2 are eigenvectors

Let us apply A to $X_1 = \begin{bmatrix} 1 \\ i \end{bmatrix}$:

$$AX_1 = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} 1 \\ i \end{bmatrix} = \begin{bmatrix} \cos \theta + i \sin \theta \\ -\sin \theta + i \cos \theta \end{bmatrix} = e^{i\theta} \begin{bmatrix} 1 \\ i \end{bmatrix} = e^{i\theta} X_1$$

So X_1 is an eigenvector with eigenvalue $e^{i\theta}$.

Similarly, apply A to $X_2 = \begin{bmatrix} i \\ 1 \end{bmatrix}$:

$$AX_2 = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} i \\ 1 \end{bmatrix} = \begin{bmatrix} i \cos \theta + \sin \theta \\ -i \sin \theta + \cos \theta \end{bmatrix} = e^{-i\theta} \begin{bmatrix} i \\ 1 \end{bmatrix} = e^{-i\theta} X_2$$

Thus, X_2 is an eigenvector with eigenvalue $e^{-i\theta}$.

Step 3: Diagonalizing the matrix

The matrix $P = [X_1 \ X_2]$ contains the eigenvectors of A , so the similarity transformation:

$$P^{-1}AP = \begin{bmatrix} e^{i\theta} & 0 \\ 0 & e^{-i\theta} \end{bmatrix}$$

This is the diagonal matrix with the eigenvalues of A .

Quick Tip

If a matrix has complex eigenvectors, you can still diagonalize it using the eigenvector matrix P . For 2D rotation matrices, the eigenvalues are $e^{i\theta}$ and $e^{-i\theta}$, and the eigenvectors are complex-conjugate pairs.

2. The rank of the matrix $A = \begin{bmatrix} 1 & 2 & 3 & 0 \\ 0 & -4 & -8 & 3 \\ 2 & 4 & 3 & 2 \\ 0 & -4 & -11 & 5 \end{bmatrix}$ is:

- (A) 4
- (B) 2
- (C) 1
- (D) 3

Correct Answer: (D) 3

Solution:

We aim to compute the **rank** of matrix A , which is the maximum number of linearly independent rows (or columns).

Start with:

$$A = \begin{bmatrix} 1 & 2 & 3 & 0 \\ 0 & -4 & -8 & 3 \\ 2 & 4 & 3 & 2 \\ 0 & -4 & -11 & 5 \end{bmatrix}$$

Step 1: Apply row operations to simplify.

Let $R_3 \leftarrow R_3 - 2R_1$

$$R_3 = [2, 4, 3, 2] - 2 \cdot [1, 2, 3, 0] = [0, 0, -3, 2]$$

Matrix becomes:

$$\begin{bmatrix} 1 & 2 & 3 & 0 \\ 0 & -4 & -8 & 3 \\ 0 & 0 & -3 & 2 \\ 0 & -4 & -11 & 5 \end{bmatrix}$$

Step 2: Eliminate the second column below R_2

Let $R_4 \leftarrow R_4 - R_2$

$$R_4 = [0, -4, -11, 5] - [0, -4, -8, 3] = [0, 0, -3, 2]$$

Now:

$$\begin{bmatrix} 1 & 2 & 3 & 0 \\ 0 & -4 & -8 & 3 \\ 0 & 0 & -3 & 2 \\ 0 & 0 & -3 & 2 \end{bmatrix}$$

Step 3: Eliminate $R_4 \leftarrow R_4 - R_3$

$$R_4 = [0, 0, -3, 2] - [0, 0, -3, 2] = [0, 0, 0, 0]$$

Final matrix:

$$\begin{bmatrix} 1 & 2 & 3 & 0 \\ 0 & -4 & -8 & 3 \\ 0 & 0 & -3 & 2 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

This matrix has ****3 non-zero rows**** \Rightarrow **Rank = 3**

Quick Tip

To find the rank of a matrix, perform row reduction (Gaussian elimination) to row echelon form. The number of non-zero rows gives the rank.

3. If $x > 0$, the series $x + 2x^2 + 3x^3 + \dots$ is:

- (A) convergent if $x > 1$ and divergent $x \geq 1$
- (B) convergent if $x < 1$ and divergent $x \geq 1$
- (C) divergent if $x > 1$ and convergent $x > 1$
- (D) convergent if $x \leq 1$ and convergent $x \geq 1$

Correct Answer: (B) convergent if $x < 1$ and divergent $x \geq 1$

Solution:

We are given the series:

$$x + 2x^2 + 3x^3 + 4x^4 + \dots = \sum_{n=1}^{\infty} nx^n$$

This is a power series of the form:

$$\sum_{n=1}^{\infty} nx^n$$

To test for convergence, we apply the ****Ratio Test****: Let $a_n = nx^n$

Then:

$$\left| \frac{a_{n+1}}{a_n} \right| = \left| \frac{(n+1)x^{n+1}}{nx^n} \right| = \left| \frac{n+1}{n} \cdot x \right| = \left(1 + \frac{1}{n} \right) x$$

Now take the limit as $n \rightarrow \infty$:

$$\lim_{n \rightarrow \infty} \left| \frac{a_{n+1}}{a_n} \right| = x$$

So: - The series converges if $x < 1$ - The series diverges if $x \geq 1$

Quick Tip

For series of the form $\sum nx^n$, use the ratio test and note that such series diverge at $x = 1$. Always examine endpoints separately.

4. If $u = \sin^{-1} \left(\frac{x}{y} \right) + \tan^{-1} \left(\frac{y}{x} \right)$, then the value of $x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y}$ is:

- (A) $\frac{1}{\sqrt{y^2 - x^2}}$
- (B) $\frac{-1}{y^2 - x^2}$

(C) 0

(D) 1

Correct Answer: (C) 0

Solution:

We are given:

$$u = \sin^{-1}\left(\frac{x}{y}\right) + \tan^{-1}\left(\frac{y}{x}\right)$$

Let us compute:

$$x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y}$$

We use the chain rule.

First, define:

$$u_1 = \sin^{-1}\left(\frac{x}{y}\right), \quad u_2 = \tan^{-1}\left(\frac{y}{x}\right)$$

So,

$$\frac{\partial u_1}{\partial x} = \frac{1}{\sqrt{1 - \left(\frac{x}{y}\right)^2}} \cdot \frac{1}{y} = \frac{1}{\sqrt{y^2 - x^2}}, \quad \frac{\partial u_1}{\partial y} = \frac{-x}{y^2 \sqrt{1 - \left(\frac{x}{y}\right)^2}} = \frac{-x}{y \sqrt{y^2 - x^2}}$$

$$\frac{\partial u_2}{\partial x} = \frac{-y}{x^2 + y^2}, \quad \frac{\partial u_2}{\partial y} = \frac{x}{x^2 + y^2}$$

Now summing the total derivatives:

$$\frac{\partial u}{\partial x} = \frac{1}{\sqrt{y^2 - x^2}} - \frac{y}{x^2 + y^2}$$

$$\frac{\partial u}{\partial y} = \frac{-x}{y \sqrt{y^2 - x^2}} + \frac{x}{x^2 + y^2}$$

Now compute:

$$x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y} = x \left(\frac{1}{\sqrt{y^2 - x^2}} - \frac{y}{x^2 + y^2} \right) + y \left(\frac{-x}{y \sqrt{y^2 - x^2}} + \frac{x}{x^2 + y^2} \right)$$

Simplifying:

$$= \frac{x}{\sqrt{y^2 - x^2}} - \frac{xy}{x^2 + y^2} - \frac{x}{\sqrt{y^2 - x^2}} + \frac{xy}{x^2 + y^2} = 0$$

Hence,

$$x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y} = 0$$

Quick Tip

When computing $x \frac{\partial u}{\partial x} + y \frac{\partial u}{\partial y}$, consider using Euler's theorem if the function is homogeneous, or apply the chain rule carefully for each term.

5. If $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is the position vector of a point, then $\text{curl}(\vec{r})$ is:

- (A) null vector
- (B) 0
- (C) $\hat{i} + \hat{j} + \hat{k}$
- (D) $\hat{i} - \hat{j}$

Correct Answer: (A) null vector

Solution:

We are given the position vector:

$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

We are asked to compute:

$$\text{curl}(\vec{r}) = \nabla \times \vec{r}$$

Recall the formula for the curl of a vector field:

$$\nabla \times \vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ x & y & z \end{vmatrix}$$

Now expand the determinant:

$$= \hat{i} \left(\frac{\partial z}{\partial y} - \frac{\partial y}{\partial z} \right) - \hat{j} \left(\frac{\partial z}{\partial x} - \frac{\partial x}{\partial z} \right) + \hat{k} \left(\frac{\partial y}{\partial x} - \frac{\partial x}{\partial y} \right)$$

Each of these partial derivatives is zero:

$$\frac{\partial z}{\partial y} = \frac{\partial y}{\partial z} = \frac{\partial z}{\partial x} = \frac{\partial x}{\partial z} = \frac{\partial y}{\partial x} = \frac{\partial x}{\partial y} = 0$$

Therefore:

$$\nabla \times \vec{r} = \vec{0}$$

Hence, the curl is a **null vector**.

Quick Tip

The curl of the position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ is always the null vector because its components are linear and partial cross derivatives vanish.

6. Laplace transform of $\frac{e^{-at} - e^{-bt}}{t}$ is:

- (A) $\log\left(\frac{s+a}{s+b}\right)$
- (B) $\log\left(\frac{s+b}{s+a}\right)$
- (C) $\frac{\pi}{2} - \tan^{-1}(s)$
- (D) $\frac{\pi}{2} - \cot^{-1}(s)$

Correct Answer: (B) $\log\left(\frac{s+b}{s+a}\right)$

Solution:

We are given the function:

$$f(t) = \frac{e^{-at} - e^{-bt}}{t}$$

This is a standard Laplace transform result.

Formula:

$$\mathcal{L}\left\{\frac{e^{-at} - e^{-bt}}{t}\right\} = \log\left(\frac{s+b}{s+a}\right), \quad \text{for } s > -\min(a, b)$$

This result comes from the integral identity:

$$\int_0^{\infty} \frac{e^{-at} - e^{-bt}}{t} e^{-st} dt = \log\left(\frac{s+b}{s+a}\right)$$

Thus, the Laplace transform directly yields:

$$\boxed{\log\left(\frac{s+b}{s+a}\right)}$$

Quick Tip

Memorize special Laplace transforms involving exponential terms divided by t . They frequently result in logarithmic expressions.

7. The particular integral of $(D^2 + 4)y = \cos 3x + \sin 2x$ is:

(A) $\frac{1}{20}(\cos 3x + 5x \cos 2x)$

(B) $\frac{1}{20}(4 \cos 3x + 5x \cos 2x)$

(C) $\frac{-1}{20}(4 \cos 3x + 5x \cos 2x)$

(D) $\frac{1}{20}(4 \cos 3x + x \cos 2x)$

Correct Answer: (C) $\frac{-1}{20}(4 \cos 3x + 5x \cos 2x)$

Solution:

We are given the differential equation:

$$(D^2 + 4)y = \cos 3x + \sin 2x$$

We need to find the particular integral (P.I.).

Break into two parts:

$$\text{P.I.} = \frac{1}{D^2 + 4}(\cos 3x + \sin 2x) = \frac{1}{D^2 + 4}(\cos 3x) + \frac{1}{D^2 + 4}(\sin 2x)$$

Part 1: $\frac{1}{D^2 + 4}(\cos 3x)$

Since $D^2(\cos 3x) = -9 \cos 3x$, the operator becomes:

$$= \frac{1}{-9 + 4} \cos 3x = \frac{1}{-5} \cos 3x = -\frac{1}{5} \cos 3x$$

Part 2: $\frac{1}{D^2 + 4}(\sin 2x)$

Here, $D^2(\sin 2x) = -4 \sin 2x$. Hence,

$$D^2 + 4 = 0 \Rightarrow \text{Resonance Case (failure)}$$

So we multiply by x and differentiate:

$$\frac{1}{(D^2 + 4)}(\sin 2x) = x \cdot \frac{1}{2D}(\sin 2x)$$

Now $D(\sin 2x) = 2 \cos 2x$, so:

$$\frac{1}{2D}(\sin 2x) = \frac{1}{2 \cdot 2 \cos 2x} = \frac{1}{4} \cos 2x \Rightarrow x \cdot \frac{1}{4} \cos 2x = \frac{x}{4} \cos 2x$$

Final Result:

$$\text{P.I.} = -\frac{1}{5} \cos 3x + \frac{x}{4} \cos 2x = \frac{-4 \cos 3x + 5x \cos 2x}{20} = \boxed{\frac{-1}{20}(4 \cos 3x + 5x \cos 2x)}$$

Quick Tip

For non-homogeneous linear differential equations with trigonometric inputs, remember to handle resonance cases (when the operator evaluates to zero) by multiplying the input by x and proceeding with inverse differential operators.

8. The table below gives the values of $f(x)$ at five equidistant points of x :

x	0	0.5	1.0	1.5	2.0
$f(x)$	0	0.25	1	2.25	4

Then the approximate value of $\int_0^2 f(x) dx$ by Trapezoidal Rule is:

- (A) 1.75
- (B) 2
- (C) 2.5
- (D) 2.75

Correct Answer: (D) 2.75

Solution:

Using the **Trapezoidal Rule** formula:

$$\int_a^b f(x) dx \approx \frac{h}{2} [f(x_0) + 2f(x_1) + 2f(x_2) + 2f(x_3) + f(x_4)]$$

Here, $h = 0.5$ (since x increments by 0.5), $x_0 = 0, x_1 = 0.5, x_2 = 1, x_3 = 1.5, x_4 = 2$,
 $f(x_0) = 0, f(x_1) = 0.25, f(x_2) = 1, f(x_3) = 2.25, f(x_4) = 4$

Substituting into the formula:

$$\begin{aligned} \int_0^2 f(x) dx &\approx \frac{0.5}{2} [0 + 2(0.25) + 2(1) + 2(2.25) + 4] \\ &= \frac{0.5}{2} [0 + 0.5 + 2 + 4.5 + 4] = \frac{0.5}{2} \cdot 11 = 0.25 \cdot 11 = \boxed{2.75} \end{aligned}$$

Quick Tip

The Trapezoidal Rule is especially useful when values of $f(x)$ are given at equidistant points. Always remember the endpoints are taken once, and interior points are doubled in the formula.

9. If $2Y - X - 50 = 0$, $3Y - 2X - 10 = 0$ are the two regression equations, then the mean values of the variables X and Y respectively are:

- (A) 80 and 90
- (B) 130 and 90
- (C) 96 and 130
- (D) 90 and 80

Correct Answer: (B) 130 and 90

Solution:

To find the mean values of X and Y , we solve the given regression equations simultaneously:

1st equation:

$$2Y - X = 50 \Rightarrow X = 2Y - 50 \quad \dots (1)$$

2nd equation:

$$3Y - 2X = 10 \Rightarrow 3Y = 2X + 10 \quad \dots (2)$$

Substitute equation (1) into equation (2):

$$3Y = 2(2Y - 50) + 10 \Rightarrow 3Y = 4Y - 100 + 10 \Rightarrow 3Y = 4Y - 90 \Rightarrow Y = 90$$

Now substitute $Y = 90$ into equation (1):

$$X = 2(90) - 50 = 180 - 50 = 130$$

So, the mean values are:

$$\boxed{X = 130, \quad Y = 90}$$

Quick Tip

When two regression lines are given, their point of intersection gives the mean values of X and Y . Always solve them simultaneously.

10. Which of the following cannot be the probability mass function of any discrete random variable X ?

(A) $P(X = x) = \frac{1}{6}$ for $x = 1, 2, 3, 4, 5, 6$

(B) $P(X = x) = \frac{1}{3}$ for $x = 1, 2, 3$

(C) $P(X = x) = \frac{1}{2}$ for $x = 1, 2$

(D) $P(X = x) = \frac{1}{4}$ for $x = 1, 2$

Correct Answer: (D) $P(X = x) = \frac{1}{4}$ for $x = 1, 2$

Solution:

A probability mass function (PMF) must satisfy the condition:

$$\sum P(X = x_i) = 1$$

Let us examine each option:

Option A:

$$P(X = x) = \frac{1}{6} \text{ for } x = 1, 2, 3, 4, 5, 6 \Rightarrow \sum P(X = x) = 6 \times \frac{1}{6} = 1 \quad (\text{Valid})$$

Option B:

$$P(X = x) = \frac{1}{3} \text{ for } x = 1, 2, 3 \Rightarrow \sum P(X = x) = 3 \times \frac{1}{3} = 1 \quad (\text{Valid})$$

Option C:

$$P(X = x) = \frac{1}{2} \text{ for } x = 1, 2 \Rightarrow \sum P(X = x) = 2 \times \frac{1}{2} = 1 \quad (\text{Valid})$$

Option D:

$$P(X = x) = \frac{1}{4} \text{ for } x = 1, 2 \Rightarrow \sum P(X = x) = 2 \times \frac{1}{4} = \frac{1}{2} \neq 1 \quad (\text{Invalid})$$

Hence, option (D) cannot be a valid PMF.

Quick Tip

Always verify that the sum of probabilities across all values of the random variable equals 1 for a valid PMF.

11. “It is impossible for a heat engine to be 100% efficient.” This statement is related to:

- (A) First law of thermodynamics
- (B) Second law of thermodynamics
- (C) Enthalpy
- (D) Diffusion

Correct Answer: (2) Second law of thermodynamics

Solution:

Step 1: The statement refers to the efficiency of a heat engine, which is fundamentally limited by the laws of thermodynamics.

Step 2: The **Second Law of Thermodynamics** states that it is impossible for any heat engine to convert all the heat it absorbs into work — some energy must always be lost to a sink. This implies no engine can be 100% efficient.

Step 3: The **First Law of Thermodynamics** only deals with conservation of energy and doesn't restrict efficiency. Concepts like enthalpy and diffusion are unrelated to the maximum efficiency of heat engines.

Conclusion: The impossibility of 100% efficiency directly follows from the **Second Law of Thermodynamics**.

Quick Tip

The Second Law of Thermodynamics limits the efficiency of all heat engines — always link efficiency-related impossibilities to this law, not the first law or enthalpy.

12. If a system is completely ordered and the atoms are at rest at zero Kelvin, then the entropy of the system is:

- (A) Zero
- (B) Positive
- (C) Negative
- (D) Cannot be defined

Correct Answer: (1) Zero

Solution:

Step 1: Understanding Entropy and Absolute Zero

Entropy is a measure of the disorder or randomness of a system. The more disordered the system, the higher the entropy. When a system is said to be *completely ordered*, it means all the particles are in a definite and predictable state — there's no randomness in their arrangement.

Step 2: Third Law of Thermodynamics

The Third Law of Thermodynamics states that:

"The entropy of a perfect crystalline substance is zero at absolute zero temperature (0 Kelvin)."

At absolute zero, the thermal motion of atoms theoretically ceases. In a perfect crystal, each atom is perfectly arranged, and there is only one microstate possible. Since entropy (S) is given by Boltzmann's formula:

$$S = k \ln W$$

where k is Boltzmann's constant and W is the number of microstates. For a perfectly ordered system, $W = 1$, so:

$$S = k \ln(1) = 0$$

Step 3: Why Other Options Are Incorrect

- **(B) Positive:** Entropy becomes positive only if there's some degree of disorder, which is not the case here.
- **(C) Negative:** Entropy can never be negative because $\ln W \geq 0$ for $W \geq 1$.
- **(D) Cannot be defined:** Entropy is well-defined for such ideal conditions as described by the third law.

Conclusion: Since the system is completely ordered and at 0 K, its entropy is exactly **zero**.

Quick Tip

When a question involves absolute zero temperature and complete order, apply the **Third Law of Thermodynamics**: Entropy becomes zero for a perfectly crystalline system at 0 K.

13. Electrodes used in anodizing process are:

- (A) Iron as cathode and work piece as anode
- (B) Lead as cathode and work piece as anode
- (C) Work piece as cathode and copper as anode
- (D) Work piece as cathode and zinc as anode

Correct Answer: (2) Lead as cathode and work piece as anode

Solution:

Step 1: Understanding Anodizing

Anodizing is an electrolytic process used to increase the thickness of the natural oxide layer on the surface of metal parts, most commonly aluminum. The purpose is to enhance corrosion resistance, surface hardness, and aesthetic appearance.

Step 2: Electrode Configuration in Anodizing

In anodizing, the metal work piece (usually aluminum) is connected to the **anode** of the power supply, meaning it loses electrons and undergoes oxidation. A suitable inert or corrosion-resistant material is chosen as the **cathode**, which does not dissolve into the electrolyte. Lead is often used for this purpose due to its resistance to corrosion and chemical inertness.

Step 3: Evaluating the Options

- (A) Iron as cathode may corrode or react, which is not ideal.
- (B) **Correct:** Lead is inert and ideal as the cathode. The work piece is correctly used as anode.
- (C) Wrong polarity — work piece should be anode.
- (D) Again, wrong polarity — work piece should not be cathode.

Conclusion: For the anodizing process, the **work piece acts as the anode**, and a material like **lead acts as the cathode**.

Quick Tip

In anodizing, always remember: **work piece = anode** (undergoes oxidation), and the cathode must be inert — often lead is used.

14. Units for quantity of electricity are:

- (A) Volt
- (B) Ampere
- (C) Joule
- (D) Coulomb

Correct Answer: (4) Coulomb

Solution:

Step 1: Understanding the Quantity of Electricity

The **quantity of electricity** refers to the total electric charge transferred through a circuit. It is represented by the symbol Q and is mathematically defined as:

$$Q = I \times t$$

where I is the current in amperes, and t is the time in seconds.

Step 2: SI Unit of Charge

The SI unit of electric charge is the **Coulomb (C)**. One coulomb is defined as the quantity of charge transported by a current of one ampere in one second.

Step 3: Explanation of Other Options

- (A) **Volt:** Unit of electric potential or potential difference.
- (B) **Ampere:** Unit of electric current, not charge.
- (C) **Joule:** Unit of energy or work.

Conclusion: Among the given options, the correct SI unit for quantity of electricity is the **Coulomb**.

Quick Tip

Remember: Quantity of electricity = Charge = $Q = I \times t$. Its SI unit is **Coulomb (C)**.

15. Identify the wrong statement:

- (A) Alkali halides are highly conductive
- (B) Mercury chloride is very good conductor of electricity
- (C) Fused salts are good conductor of electricity
- (D) Easily polarizable ions in the fused salt mixtures reduces the ionic mobility

Correct Answer: (2) Mercury chloride is very good conductor of electricity

Solution:

Step 1: Understanding the properties of the given substances

- **Alkali halides** (such as NaCl, KCl) are ionic compounds. In molten or aqueous form, they conduct electricity well due to the presence of free-moving ions. Hence, statement (A) is correct.

- **Mercury(II) chloride (HgCl_2)** is a covalent compound. It does not dissociate well in aqueous solution and hence, is a poor conductor of electricity. This makes statement (B) incorrect.

- **Fused salts**, when melted, release free ions and act as good conductors of electricity. This makes statement (C) correct.

- **Easily polarizable ions** can distort the ionic cloud, leading to reduced mobility of the ions in fused salts. This reduces the conductivity, so statement (D) is also correct.

Step 2: Identifying the incorrect statement

Only statement (B) is scientifically inaccurate. Mercury chloride is not a good conductor of electricity.

Conclusion: The incorrect statement is (B) Mercury chloride is very good conductor of electricity.

Quick Tip

Poor electrical conductivity is a characteristic of covalent compounds like HgCl_2 , unlike ionic substances that conduct in molten or dissolved form.

16. Identify the noble metal:

- (A) Silver
- (B) Lead
- (C) Zinc
- (D) Platinum

Correct Answer: (4) Platinum

Solution:

Step 1: Understanding Noble Metals

Noble metals are metals that resist oxidation and corrosion in moist air, unlike most base metals. They are chemically inert and are often found in their pure or metallic form in nature. These metals are typically used in jewelry, electronics, and catalysis due to their stability and resistance to tarnish.

Step 2: List of Common Noble Metals

The noble metals include: Gold (Au), Platinum (Pt), Palladium (Pd), Rhodium (Rh), Ruthenium (Ru), Osmium (Os), and Iridium (Ir). While silver is relatively resistant to corrosion, it tarnishes upon exposure to air and is not always classified as a noble metal in the strictest sense.

Step 3: Evaluating the Options

- (A) **Silver:** Semi-noble metal; tarnishes due to reaction with sulfur in the air.
- (B) **Lead:** Base metal; not inert, corrodes over time.
- (C) **Zinc:** Highly reactive; used as a sacrificial anode, not a noble metal.
- (D) **Platinum: Correct;** highly inert, does not oxidize easily, true noble metal.

Conclusion: Among the given options, only **Platinum** meets the criteria of a true noble metal.

Quick Tip

Noble metals like **Platinum** and **Gold** resist corrosion and oxidation — they are stable, chemically inert, and often used in high-end industrial and decorative applications.

17. Hydrogen overvoltage is observed in:

- (A) Oxidation processes
- (B) Cathodic processes
- (C) Anodic processes
- (D) Smelting processes

Correct Answer: (2) Cathodic processes

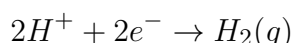
Solution:

Step 1: Understanding Hydrogen Overvoltage

Hydrogen overvoltage (or hydrogen overpotential) refers to the extra voltage required beyond the theoretical voltage to produce hydrogen gas at the cathode during electrolysis. This phenomenon arises due to the slow kinetics of the hydrogen evolution reaction on certain electrodes.

Step 2: Where Hydrogen Evolution Occurs

Hydrogen gas is liberated at the cathode during electrolysis as per the reaction:



The electrode material and the electrolyte conditions can affect the rate and efficiency of this hydrogen evolution. Due to energy losses, a higher voltage (overvoltage) than theoretically required is needed to drive the reaction.

Step 3: Evaluating the Options

- **(A) Oxidation processes:** These occur at the anode, not relevant to hydrogen evolution.
- **(B) Cathodic processes:** **Correct**, as hydrogen gas is released at the cathode during electrolysis.
- **(C) Anodic processes:** Involve oxidation (e.g., of anions or metal), not H₂ gas evolution.
- **(D) Smelting processes:** These are metallurgical and thermal processes, unrelated to overvoltage.

Conclusion: Hydrogen overvoltage is specifically observed during **cathodic processes** where hydrogen gas is produced.

Quick Tip

Hydrogen overvoltage occurs during **hydrogen evolution** at the cathode — it's the extra voltage needed to overcome slow reaction kinetics on some electrode surfaces.

18. Tafel equation defines the relation between:

- (A) Oxygen overvoltage and current density
- (B) Hydrogen overvoltage and current density
- (C) Decomposition voltage and current density
- (D) Cell voltage and current density

Correct Answer: (2) Hydrogen overvoltage and current density

Solution:

Step 1: Understanding the Tafel Equation

The **Tafel equation** is an empirical relationship that describes how the rate of an electrochemical reaction (expressed as current density) is related to the overpotential (extra voltage required beyond the equilibrium potential) at the electrode. It is especially used for reactions involving hydrogen evolution.

Tafel equation:

$$\eta = a + b \log i$$

where:

- η = overpotential (in volts),
- i = current density (in A/m²),
- a and b = Tafel constants specific to the system and electrode.

Step 2: Relevance to Hydrogen Overvoltage

Tafel equation is most commonly applied to describe the kinetics of the hydrogen evolution

reaction at the cathode, where hydrogen gas is generated. The equation links hydrogen overvoltage (extra potential required for hydrogen gas evolution) with the current density.

Step 3: Evaluating the Options

- (A) Oxygen overvoltage: While similar in concept, Tafel equation is not specifically defined for it.
- (B) **Correct:** Hydrogen overvoltage and current density are directly related using the Tafel equation.
- (C) Decomposition voltage: This is unrelated to Tafel analysis.
- (D) Cell voltage includes multiple contributions; Tafel specifically relates overpotential to current density.

Conclusion: Tafel equation specifically correlates **hydrogen overvoltage** with **current density**.

Quick Tip

Tafel equation helps analyze electrochemical kinetics by relating **hydrogen overvoltage** with **logarithm of current density**, especially in hydrogen evolution reactions.

19. Second law of thermodynamics can be stated as:

- (A) Work done by the system is zero
- (B) $\Delta H = 0$
- (C) $\Delta U_{\text{cycle}} = 0$
- (D) $dS = \frac{\delta q_{\text{rev}}}{T}$

Correct Answer: (4) $dS = \frac{\delta q_{\text{rev}}}{T}$

Solution:

Step 1: Understanding the Second Law of Thermodynamics

The Second Law introduces the concept of entropy and states that in a reversible process, the change in entropy dS is equal to the heat exchanged reversibly (δq_{rev}) divided by the absolute temperature T :

$$dS = \frac{\delta q_{\text{rev}}}{T}$$

Step 2: Implications of the Law

This equation expresses that entropy change depends on the reversible transfer of heat. It signifies that for any spontaneous (irreversible) process, the entropy of the universe increases, while for a reversible process, entropy remains constant.

Step 3: Evaluation of Options

- (A) "Work done by the system is zero" is unrelated to the second law; this may refer to isolated systems, not thermodynamic laws.
- (B) $\Delta H = 0$ is not a general statement of the second law; it may apply to specific processes.
- (C) $\Delta U_{\text{cycle}} = 0$ is from the First Law — in cyclic processes, internal energy change is zero.
- (D) **Correct:** This is the mathematical statement of the second law for reversible processes.

Conclusion: The correct thermodynamic expression of the second law is:

$$dS = \frac{\delta q_{\text{rev}}}{T}$$

Quick Tip

The second law of thermodynamics introduces entropy. For reversible processes, remember the formula: $dS = \frac{\delta q_{\text{rev}}}{T}$.

20. An expression for Gibbs free energy is:

- (A) $H - TS$
- (B) $U - TS$
- (C) $dS_{\text{system}} + dS_{\text{surroundings}}$
- (D) $dU = TdS - PdV$

Correct Answer: (1) $H - TS$

Solution:

Step 1: Definition of Gibbs Free Energy

Gibbs free energy (G) is a thermodynamic potential that measures the maximum reversible work that a thermodynamic system can perform at constant temperature and pressure. It helps predict the spontaneity of a process.

Step 2: Expression

The formula for Gibbs free energy is:

$$G = H - TS$$

where:

- G = Gibbs free energy
- H = Enthalpy of the system
- T = Absolute temperature in Kelvin
- S = Entropy of the system

Step 3: Evaluating Other Options

- **(B)** $U - TS$: This is not the standard Gibbs free energy relation; it resembles Helmholtz free energy $A = U - TS$.
- **(C)** $dS_{\text{system}} + dS_{\text{surroundings}}$: Represents total entropy change, related to the second law, not Gibbs energy.
- **(D)** $dU = TdS - PdV$: This is a thermodynamic identity for internal energy, not Gibbs free energy.

Conclusion: The correct expression for Gibbs free energy is $G = H - TS$.

Quick Tip

Gibbs free energy: $G = H - TS$. It predicts spontaneity at constant temperature and pressure — a negative ΔG implies a spontaneous process.

21. Identify the incorrect statement:

- (A) $dH = VdP - TdS$
- (B) $\frac{d\left(\frac{G}{T}\right)}{d\left(\frac{1}{T}\right)} = H$
- (C) $\frac{d\left(\frac{\Delta G}{T}\right)}{d\left(\frac{1}{T}\right)} = \Delta H$
- (D) $TdG - GdT = -HdT$

Correct Answer: (1) $dH = VdP - TdS$

Solution:

Step 1: Understanding Enthalpy Differential

The total differential of enthalpy H , using its definition $H = U + PV$, is given by:

$$dH = dU + PdV + VdP$$

Using the First Law of Thermodynamics and assuming reversible processes:

$$dU = TdS - PdV$$

Substituting into dH , we get:

$$dH = TdS + VdP$$

So the correct expression is:

$$dH = TdS + VdP$$

Therefore, option (A): $dH = VdP - TdS$ is **incorrect**.

Step 2: Verifying Other Options

- (B) and (C) are known thermodynamic identities derived from the Gibbs-Helmholtz equation.
- (D) is a correctly rearranged form of the temperature differential of Gibbs free energy.

Conclusion: Among the options, only option (A) presents an incorrect expression for dH .

Quick Tip

The correct differential for enthalpy is: $dH = TdS + VdP$. Always double-check signs when working with thermodynamic identities.

22. “The heat capacity of a solid compound is equal to the sum of the heat capacities of its constituent elements”. This statement is known as:

- (A) Trouton’s rule
- (B) Dulong and Petit’s law
- (C) Kirchhoff’s law
- (D) Neumann–Kopps rule

Correct Answer: (4) Neumann–Kopps rule

Solution:**Step 1: Understanding the Statement**

The statement implies that the molar heat capacity of a solid compound can be estimated by summing the atomic heat capacities of the individual elements that make up the compound.

Step 2: Neumann–Kopps Rule

The **Neumann–Kopps rule** specifically states that:

“The molar heat capacity of a crystalline solid compound is approximately equal to the sum of the molar heat capacities of its constituent atoms.”

This empirical rule is useful for estimating the heat capacity of solid compounds based on elemental data.

Step 3: Other Options

- (A) **Trouton’s rule:** Relates to the entropy of vaporization of liquids, not solids.
- (B) **Dulong and Petit’s law:** Estimates the molar heat capacity of individual elements (typically metals), not compounds.
- (C) **Kirchhoff’s law:** Concerns the temperature dependence of reaction enthalpy.

Conclusion: The correct law associated with the additive heat capacities of elements in a solid compound is **Neumann–Kopps rule**.

Quick Tip

Use Neumann–Kopps rule to estimate the molar heat capacity of a solid compound by summing the capacities of its constituent atoms.

23. The difference of C_P and C_V of a substance is:

- (A) Positive, finite and variable quantity
- (B) Negative, finite and constant quantity
- (C) Positive, finite and constant quantity
- (D) Negative, finite and variable quantity

Correct Answer: (3) Positive, finite and constant quantity

Solution:

Step 1: Definitions of Heat Capacities

- C_P : Heat capacity at constant pressure.
- C_V : Heat capacity at constant volume.

For any substance, especially gases, C_P is always greater than C_V , because at constant pressure, the system also performs expansion work, requiring more heat input.

Step 2: Theoretical Relationship

For an ideal gas, the relationship between C_P and C_V is given by:

$$C_P - C_V = nR$$

where:

- n is the number of moles of the gas, and
- R is the universal gas constant.

Thus, the difference is **positive**, **finite**, and for an ideal gas, **constant** (as R is constant and n is fixed).

Step 3: Evaluating the Options

- (A) Incorrect — it's not variable for ideal gases.
- (B) Incorrect — the difference is not negative.
- (C) **Correct** — matches theoretical result.
- (D) Incorrect — wrong in sign and variability.

Conclusion: The difference $C_P - C_V$ is a **positive, finite, and constant quantity** for an ideal gas.

Quick Tip

For ideal gases, always remember: $C_P - C_V = R$. The difference is constant and positive.

24. Ellingham diagram for metal–oxide system doesn't give idea about:

- (A) Kinetics of the oxidation reaction
- (B) Oxidation of metals

(C) Value of partial pressure of oxygen for the reactions shown in a diagram

(D) Reduction of metal oxides

Correct Answer: (3) Value of partial pressure of oxygen for the reactions shown in a diagram

Solution:

Step 1: What is an Ellingham Diagram?

An **Ellingham diagram** plots the standard Gibbs free energy change (ΔG°) for various oxidation reactions (mostly metal to metal oxide) versus temperature. It is primarily used in metallurgy to predict the feasibility of reduction reactions.

Step 2: Information Provided

From an Ellingham diagram, you can infer: - The temperature above which one metal can reduce the oxide of another metal. - The stability of oxides. - Thermodynamic feasibility (not kinetics).

Step 3: What It Does Not Show

- It does **not** provide information about the **rate** (kinetics) of the reaction. However, this is still sometimes misunderstood as being partially inferable. - Importantly, **it does not give the exact partial pressure of oxygen** unless extra data is provided or derived. The diagram shows ΔG° trends but not actual gas pressures.

Conclusion: The Ellingham diagram does not provide direct information about the **value of partial pressure of oxygen**, making option (3) correct.

Quick Tip

Ellingham diagrams help assess thermodynamic feasibility (via ΔG) but not reaction kinetics or actual gas pressures like p_{O_2} .

25. In a reversible cycle, the sum of change in $\frac{q}{T}$ is

(where q is heat absorbed and T is absolute temperature):

(A) Zero

(B) One

(C) Two

(D) Three

Correct Answer: (1) Zero

Solution:

Step 1: Apply Clausius' Theorem

According to Clausius' theorem, the entropy change in a reversible cycle is given by:

$$\oint \frac{\delta q_{\text{rev}}}{T} = 0$$

This implies that over the course of a full reversible cycle, the net entropy change is zero.

Step 2: Entropy as a State Function

Entropy is a state function, meaning its total change in a cyclic process (returning to the same state) is zero, just like internal energy. This is why the sum of $\frac{q}{T}$ over a reversible cycle is also zero.

Step 3: Misleading Alternatives

- **Option B:** Would imply non-zero entropy generation, which occurs in irreversible processes.
- **Options C and D:** Have no basis in thermodynamic theory.

Conclusion: In a reversible cycle, $\sum \frac{q}{T} = 0$, in accordance with Clausius' formulation of the second law.

Quick Tip

In reversible cycles, always remember: $\oint \frac{\delta q_{\text{rev}}}{T} = 0$. This reflects the fact that entropy is a state function and there's no net change over a closed loop.

26. With increase in pressure, the bulk diffusion in catalyst pore:

- (A) Decreases
- (B) Increases
- (C) Increases exponentially
- (D) Remains unchanged

Correct Answer: (1) Decreases

Solution:

Step 1: Understanding Bulk Diffusion

Bulk diffusion refers to the movement of gas molecules through a medium under a concentration gradient, typically governed by Fick's Law. In porous solids like catalysts, this diffusion can be significantly influenced by pressure.

Step 2: Effect of Pressure on Diffusivity

According to the kinetic theory of gases, diffusivity D is inversely proportional to pressure P :

$$D \propto \frac{1}{P}$$

This occurs because as pressure increases, gas molecules become more densely packed, leading to more frequent collisions and hence reduced mobility.

Step 3: Implications for Catalyst Pores

Inside catalyst pores, bulk diffusion becomes slower at higher pressures because of restricted movement and increased molecular interactions. Thus, increasing pressure leads to a decrease in diffusion rates.

Conclusion: As pressure increases, bulk diffusion in catalyst pores **decreases**.

Quick Tip

For gases, bulk diffusion $D \propto \frac{1}{P}$. In catalyst pores, higher pressure means more collisions and slower diffusion.

27. Equilibrium of a chemical reaction as viewed by kinetics is in a:

- (A) Static steady state
- (B) Dynamic steady state
- (C) Dynamic unsteady state
- (D) Static unsteady state

Correct Answer: (2) Dynamic steady state

Solution:

Step 1: Understanding Chemical Equilibrium from a Kinetics Viewpoint

From a kinetic perspective, chemical equilibrium does not mean that the reactants and prod-

ucts stop reacting. Instead, it means that the rates of the forward and reverse reactions are equal, so the concentrations of the species remain constant over time.

Step 2: Dynamic vs Static

- **Dynamic:** Because both forward and reverse reactions are continuously occurring.
- **Static:** Would imply no molecular activity — incorrect for equilibrium.

Step 3: Steady State vs Unsteady State

- **Steady state:** The macroscopic properties (concentration, pressure, etc.) remain constant with time.
- **Unsteady state:** Variables change over time.

Conclusion: Since equilibrium involves ongoing (dynamic) molecular activity while the overall system properties remain constant (steady), it is a **dynamic steady state**.

Quick Tip

Chemical equilibrium is not static — it's dynamic with equal rates in both directions. Thus, it's a **dynamic steady state**.

28. The rate of homogeneous reaction is a function of:

- (A) Pressure and composition only
- (B) Temperature and pressure only
- (C) Composition and temperature only
- (D) Temperature, pressure and composition

Correct Answer: (4) Temperature, pressure and composition

Solution:

Step 1: Understanding Homogeneous Reactions

A homogeneous reaction occurs in a single phase (usually gas or liquid). The rate of such a reaction depends on how frequently the reactant molecules collide and how energetically they do so.

Step 2: Key Factors Affecting Rate

The reaction rate r of a homogeneous reaction depends on:

- **Temperature:** Influences the kinetic energy and activation energy barrier (Arrhenius equation).
- **Pressure:** Especially for gaseous systems, increasing pressure increases concentration and thus the collision frequency.
- **Composition:** The concentration of the reacting species directly impacts the reaction rate (as seen in rate laws like $r = k[A]^m[B]^n$).

Step 3: Evaluating Options

Only option (D) includes all three relevant variables: **temperature, pressure, and composition**. The other options omit one of the key parameters.

Conclusion: The rate of a homogeneous reaction is a function of **temperature, pressure, and composition**.

Quick Tip

For homogeneous reactions, remember that **temperature, pressure, and composition** all influence the reaction rate.

29. The reactions with low activation energy are:

- (A) Slow
- (B) Fast
- (C) Non-spontaneous
- (D) Always spontaneous

Correct Answer: (2) Fast

Solution:

Step 1: Understanding Activation Energy

Activation energy (E_a) is the minimum energy required for reactants to transform into products by crossing the energy barrier. The lower the E_a , the more readily the molecules can overcome this barrier.

Step 2: Link to Reaction Rate

According to the **Arrhenius equation**:

$$k = Ae^{-E_a/RT}$$

where:

- k : rate constant,
- E_a : activation energy,
- R : gas constant,
- T : temperature.

From this relation, a lower E_a leads to a larger k , resulting in a faster reaction rate.

Step 3: Clarifying Misconceptions

- **Spontaneity** is determined by Gibbs free energy change (ΔG), not activation energy.
- A fast reaction doesn't mean it's spontaneous, and a spontaneous reaction might still be slow if E_a is high.

Conclusion: Reactions with low activation energy tend to be **fast**, regardless of spontaneity.

Quick Tip

Low activation energy \Rightarrow high rate constant $k \Rightarrow$ faster reaction. Spontaneity depends on ΔG , not E_a .

30. Arrhenius equation represents graphically the variation between the:

- (A) Rate constant and temperature
- (B) Rate of reaction and temperature
- (C) Activation energy and temperature
- (D) Frequency factor and temperature

Correct Answer: (1) Rate constant and temperature

Solution:

Step 1: Arrhenius Equation

The Arrhenius equation provides a quantitative relationship between the rate constant k of a reaction and the absolute temperature T :

$$k = Ae^{-E_a/RT}$$

Taking natural logarithm on both sides:

$$\ln k = \ln A - \frac{E_a}{R} \cdot \frac{1}{T}$$

This is a linear equation of the form $y = mx + c$, where:

- $y = \ln k$
- $x = \frac{1}{T}$
- Slope $m = -\frac{E_a}{R}$
- Intercept $c = \ln A$

Step 2: What It Graphically Represents

A plot of $\ln k$ versus $\frac{1}{T}$ yields a straight line. Therefore, the Arrhenius equation graphically represents the relationship between: - **Rate constant k** and - **Temperature T**

Step 3: Eliminating Incorrect Options

- (B) and (C): Refer to different dependencies, not directly plotted in the Arrhenius form.
- (D): Frequency factor A is a constant at a given temperature, not plotted against T .

Conclusion: The Arrhenius equation graphically shows the variation between the **rate constant** and **temperature**.

Quick Tip

Plotting $\ln k$ vs $\frac{1}{T}$ gives a straight line — this is the graphical form of the Arrhenius equation, linking rate constant and temperature.

31. Xanthates are used as:

- (A) Collectors
- (B) pH reagents

(C) Moderators

(D) Frothers

Correct Answer: (1) Collectors

Solution:

Step 1: Understanding Froth Flotation and Reagents

In the froth flotation process used in mineral processing, various reagents are added to selectively separate hydrophobic (valuable) and hydrophilic (waste) particles. These include:

- **Collectors:** Increase the hydrophobicity of mineral particles.
- **Frothers:** Help stabilize the froth.
- **pH Modifiers:** Adjust the solution pH.
- **Depressants and Activators:** Modify the surface properties for selective separation.

Step 2: Role of Xanthates

Xanthates (such as potassium ethyl xanthate) are widely used as **collectors** in the flotation of sulphide ores like galena (PbS) and sphalerite (ZnS). They adsorb onto the surface of the mineral particles, making them water-repellent and promoting their attachment to air bubbles.

Step 3: Eliminating Other Options

- **pH reagents** and **Moderators** serve different purposes.
- **Frothers** stabilize the froth but xanthates do not function this way.

Conclusion: Xanthates are used as **collectors** in froth flotation.

Quick Tip

Xanthates are key reagents in froth flotation — they act as **collectors** to selectively bind to sulphide ores and aid in their separation.

32. Primary step of ore processing is:

(A) Grinding

(B) Crushing

(C) Magnetic separation

(D) Jigging

Correct Answer: (2) Crushing

Solution:

Step 1: Sequence of Ore Processing

Ore processing begins with the physical methods of size reduction. The goal is to liberate valuable minerals from the gangue. The standard sequence includes:

1. **Crushing:** The first mechanical step, used to break large ore chunks into smaller pieces.
2. **Grinding:** Follows crushing; reduces ore to finer particles for further concentration.
3. **Concentration methods:** Techniques like magnetic separation, froth flotation, and gravity separation follow to enrich the ore.

Step 2: Evaluating the Options

- **Crushing** is the **primary step** to reduce ore size initially.
- **Grinding** occurs after crushing to further reduce size.
- **Magnetic separation** and **Jigging** are concentration methods, not primary steps.

Conclusion: The first or primary step in ore processing is **crushing**.

Quick Tip

In metallurgy, **crushing** is the very first step to reduce the size of ore before any concentration or refinement can take place.

33. Liberation is done for:

- (A) Separation of particles
- (B) Sizing of the ore
- (C) Concentration of the ore
- (D) Oxidising the ores

Correct Answer: (1) Separation of particles

Solution:

Step 1: What is Liberation?

Liberation in metallurgy refers to the process of breaking down ore particles so that the valuable minerals are freed from the surrounding gangue material. This step is essential before concentration can be performed effectively.

Step 2: Purpose of Liberation

The goal of liberation is to ensure that: - Each particle contains predominantly one mineral phase. - The separation (concentration) techniques such as froth flotation or magnetic separation can efficiently isolate the desired component.

Step 3: Misinterpretation of Other Options

- **(B) Sizing** refers to screening or classification after crushing/grinding.
- **(C) Concentration** is the step that follows liberation.
- **(D) Oxidising** is a chemical treatment, not a mechanical separation process.

Conclusion: Liberation is specifically aimed at the **separation of particles**, especially valuable minerals from gangue.

Quick Tip

Liberation is the mechanical process to separate valuable mineral particles from gangue, enabling effective downstream concentration.

34. Direct coal is charged as fuel in:

- (A) SR process
- (B) COREX process
- (C) ELRED process
- (D) MIDREX process

Correct Answer: (2) COREX process

Solution:

Step 1: Understanding the COREX Process

The **COREX process** is a smelting reduction method used for ironmaking. It is a more

environmentally friendly alternative to the traditional blast furnace. One of the key features of the COREX process is that it uses **non-coking (direct) coal** directly as a reducing agent and energy source — eliminating the need for coke ovens.

Step 2: Evaluation of Other Options

- (A) **SR process (Smelting Reduction)**: A general category; may or may not use direct coal depending on the variant.
- (C) **ELRED process**: Involves electric reduction and does not utilize direct coal.
- (D) **MIDREX process**: Uses natural gas (not coal) as the primary reducing agent.

Step 3: Advantages of COREX

- Utilizes direct coal, reducing environmental pollution from coke production.
- Economically viable where non-coking coal is abundantly available.

Conclusion: Among the listed options, only the **COREX process** uses direct coal as fuel.

Quick Tip

The COREX process is a cleaner alternative to the blast furnace, using **non-coking coal directly** — a major cost and environmental advantage.

35. TISCO located at:

- (A) Hazira
- (B) Vijayanagaram
- (C) Raigarh
- (D) Jamshedpur

Correct Answer: (4) Jamshedpur

Solution:

Step 1: About TISCO

TISCO stands for **Tata Iron and Steel Company Limited**, now known as **Tata Steel**. It was established in 1907 and is one of India's largest and oldest steel manufacturing companies.

Step 2: Location

TISCO's main plant is located at **Jamshedpur** in the state of Jharkhand. It was the first

integrated steel plant in India and was set up because of proximity to raw materials like iron ore, coal, and water from the Subarnarekha and Kharkai rivers.

Step 3: Eliminating Other Options

- **Hazira:** Known for Essar Steel.
- **Vijayanagaram:** Associated with RINL (Vizag Steel).
- **Raigarh:** Hosts JSPL's (Jindal) operations.

Conclusion: TISCO (Tata Steel) is located at **Jamshedpur**, Jharkhand.

Quick Tip

TISCO, India's first integrated steel plant, is located at **Jamshedpur**, Jharkhand — established by the Tata Group in 1907.

36. In Indian blast furnaces for iron production, the oxygen enrichment is done up to:

- (A) 12% of oxygen
- (B) 20% of oxygen
- (C) 25% of oxygen
- (D) 40% of oxygen

Correct Answer: (3) 25% of oxygen

Solution:

Step 1: What is Oxygen Enrichment?

Oxygen enrichment in blast furnaces refers to increasing the oxygen content in the hot blast air blown into the furnace. The goal is to enhance combustion efficiency, reduce coke consumption, and improve the productivity of the furnace.

Step 2: Industrial Standard

In Indian blast furnaces, oxygen enrichment is typically carried out up to about **25% oxygen by volume** in the blast air. This level balances operational efficiency and safety.

Step 3: Benefits of Oxygen Enrichment

- Increases flame temperature.
- Enhances reduction reactions.

- Reduces nitrogen load in the blast, which improves thermal efficiency.

Step 4: Evaluating Options

- **12% and 20%** are lower than the industrial norm for peak enrichment.
- **40%** is too high and may lead to operational hazards or inefficiencies.
- **25%** is the widely adopted and optimized figure for industrial use in India.

Conclusion: In Indian blast furnaces, oxygen enrichment is done up to **25%**.

Quick Tip

Oxygen enrichment in blast furnaces improves efficiency and is typically done up to **25% oxygen** in Indian steel plants.

37. Bleeder valves in the blast furnace is provided at:

- (A) Below mantle region
- (B) Below stack region
- (C) Top of stack region
- (D) Top of uptakes

Correct Answer: (4) Top of uptakes

Solution:

Step 1: Purpose of Bleeder Valves in Blast Furnaces

Bleeder valves are safety devices installed in blast furnaces to release excess pressure or gas in emergency situations. They help prevent structural damage or explosions by allowing sudden venting of gas buildup.

Step 2: Location of Bleeder Valves

Bleeder valves are specifically located at the **top of the uptakes**, which are the ducts that carry gas from the top of the furnace to the gas cleaning system. This location allows: - Immediate release of excess gas pressure from the furnace top. - Safe management of sudden pressure surges during irregular operation.

Step 3: Elimination of Other Options

- **Below mantle or stack regions** are not suitable for gas pressure relief.

- **Top of stack** is not the correct position for emergency venting — it is the uptakes that carry gases from the stack.

Conclusion: Bleeder valves are provided at the **top of the uptakes** in a blast furnace for emergency pressure relief.

Quick Tip

Bleeder valves act as safety vents in blast furnaces and are located at the **top of the uptakes** to release excess gas pressure.

38. The important reactions that occur in tuyeres region in blast furnace is:

- (A) Slag melting
- (B) Combustion of coke
- (C) Reduction of iron oxides
- (D) Solution loss reaction

Correct Answer: (2) Combustion of coke

Solution:

Step 1: Understanding the Tuyeres Region

The tuyeres region in a blast furnace is the zone just above the hearth where hot air (blast) is injected into the furnace through tuyeres. This region is extremely hot and plays a critical role in fuel combustion and gas generation.

Step 2: Key Reaction — Combustion of Coke

In this high-temperature zone, **coke undergoes combustion** with the oxygen in the blast air:



This reaction is exothermic and releases a large amount of heat, raising the temperature to about 1900–2000°C. This is essential for melting iron and slag lower in the furnace.

Step 3: Evaluating Other Options

- (A) **Slag melting:** Occurs lower in the hearth.
- (C) **Reduction of iron oxides:** Primarily happens in the upper and middle zones.
- (D) **Solution loss reaction:** Occurs above the tuyeres zone at slightly lower temperatures.

Conclusion: The main reaction in the tuyeres region is the **combustion of coke**.

Quick Tip

The tuyeres region is the hottest zone in a blast furnace where **coke burns in oxygen** to generate the heat needed for downstream reactions.

39. JFN number in LD converter process is defined as:

- (A) $JFN = \text{Gas pressure} \times \left(\frac{\text{Lance height}}{\text{Nozzle diameter}} \right)$
(B) $JFN = \text{Nozzle diameter} \times \left(\frac{\text{Lance height}}{\text{Gas pressure}} \right)$
(C) $JFN = \text{Gas pressure} \times \left(\frac{\text{Nozzle diameter}}{\text{Lance height}} \right)$
(D) $JFN = (\text{Gas pressure} + \text{Lance height}) \times \text{Nozzle diameter}$

Correct Answer: (3) $JFN = \text{Gas pressure} \times \left(\frac{\text{Nozzle diameter}}{\text{Lance height}} \right)$

Solution:

Step 1: What is JFN Number?

In steelmaking using the LD (Linz-Donawitz) converter process, the JFN (Jet Force Number) is an empirical parameter that governs the force exerted by the gas jet on the molten metal surface. It plays a crucial role in determining the depth of penetration and mixing in the bath.

Step 2: Formula

The correct expression for the Jet Force Number is:

$$JFN = \text{Gas pressure} \times \left(\frac{\text{Nozzle diameter}}{\text{Lance height}} \right)$$

This shows that the force of the oxygen jet increases with: - Higher gas pressure, - Larger nozzle diameter, and - Decreases with greater lance height (more distance from the bath).

Step 3: Elimination of Incorrect Options

- (A), (B), and (D) are all dimensionally or conceptually incorrect in terms of flow dynamics and energy transfer.

Conclusion: JFN is defined as **Gas pressure × (Nozzle diameter / Lance height)**.

Quick Tip

Jet Force Number (JFN) in LD steelmaking helps optimize the oxygen jet impact — it increases with pressure and nozzle size, but decreases with higher lance height.

40. First element to be removed during steel making by BOF method is:

- (A) Cadmium
- (B) Carbon
- (C) Silicon
- (D) Manganese

Correct Answer: (3) Silicon

Solution:

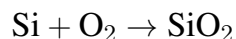
Step 1: Understanding BOF Method

The Basic Oxygen Furnace (BOF) process is a primary method used in steelmaking. In this process, pure oxygen is blown at high velocity over molten pig iron to oxidize impurities.

Step 2: Oxidation Sequence of Elements

In the BOF process, elements in the molten pig iron are oxidized based on their **affinity for oxygen**: - **Silicon** has the highest affinity and gets oxidized first to form SiO_2 (slag). - **Manganese** and **carbon** are oxidized later as the reaction proceeds. - **Cadmium** is not a major constituent in steel and is irrelevant in this context.

Step 3: Reaction of Silicon



This reaction occurs at the initial stage of blowing due to silicon's high reactivity.

Conclusion: The first element to be removed in the BOF process is **silicon**.

Quick Tip

In the BOF steelmaking process, **silicon is oxidized first** due to its strong affinity for oxygen — forming silica that enters the slag.

41. Calamine is an ore of:

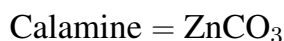
- (A) Lead
- (B) Iron
- (C) Copper
- (D) Zinc

Correct Answer: (4) Zinc

Solution:

Step 1: Understanding Calamine

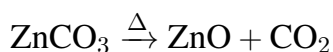
Calamine is a naturally occurring mineral form of zinc carbonate:



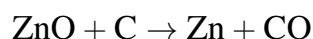
It is one of the important ores used for the commercial extraction of zinc.

Step 2: Extraction of Zinc from Calamine

Calamine is typically concentrated and then subjected to calcination:



The zinc oxide formed is then reduced with carbon to produce metallic zinc:



Step 3: Elimination of Incorrect Options

- **Lead:** Extracted from galena (PbS).
- **Iron:** Obtained from hematite and magnetite.
- **Copper:** Extracted from ores like chalcopyrite (CuFeS₂).

Conclusion: Calamine is an ore of **zinc**.

Quick Tip

Remember: Calamine (ZnCO₃) is a carbonate ore used to extract **zinc** — often via calcination followed by reduction.

42. VAD process is a:

- (A) Iron extraction process
- (B) Reduction process
- (C) Secondary refining process
- (D) Concentration process

Correct Answer: (3) Secondary refining process

Solution:

Step 1: What is the VAD Process?

VAD stands for **Vacuum Arc Degassing**. It is a type of **secondary steel refining process** used after the primary steelmaking in the electric arc furnace (EAF) or basic oxygen furnace (BOF).

Step 2: Purpose of VAD

The VAD process is designed to: - Remove dissolved gases like hydrogen, oxygen, and nitrogen under vacuum. - Allow alloying under controlled temperature and pressure. - Improve steel purity and mechanical properties.

Step 3: Why It's Secondary Refining

Primary steelmaking removes most impurities from molten iron. VAD, as part of the secondary refining, enhances quality and precision in steel chemistry.

Step 4: Elimination of Other Options

- **Iron extraction:** Related to iron ore to pig iron processes.
- **Reduction process:** General term; not specific to VAD.
- **Concentration:** Applies to ore beneficiation, not steel refining.

Conclusion: The VAD process is a **secondary refining process** used for high-grade steel-making.

Quick Tip

The VAD (Vacuum Arc Degassing) process is used in **secondary refining** of steel to remove dissolved gases and control composition.

43. Sulphide shape control in steel making is done by adding:

- (A) Copper
- (B) Argon
- (C) Zinc
- (D) Nickel

Correct Answer: (2) Argon

Solution:

Step 1: What is Sulphide Shape Control?

In steelmaking, **sulphide inclusions** (primarily MnS) can adversely affect the mechanical properties of steel, especially ductility and toughness. Sulphide shape control involves modifying the shape of these inclusions from elongated (detrimental) to globular (harmless).

Step 2: Role of Argon in Shape Control

Argon gas stirring is used during secondary steelmaking to homogenize temperature and composition. It plays a critical role in: - Modifying sulphide morphology, - Promoting inclusion flotation and removal, - Ensuring cleaner and tougher steel.

Step 3: Evaluating Other Options

- **Copper, Zinc, and Nickel** are alloying elements but do not contribute to sulphide shape control. - **Argon** is chemically inert but physically effective due to its agitation and stirring effect.

Conclusion: Sulphide shape control in steelmaking is achieved by the addition of **argon gas** during secondary refining.

Quick Tip

Sulphide inclusions are controlled using **argon gas stirring**, which modifies their shape and improves steel toughness.

44. Hoopes' process used for:

- (A) Extraction of copper
- (B) Concentration of lead ore

- (C) Refining of aluminium
- (D) Refining of titanium

Correct Answer: (3) Refining of aluminium

Solution:

Step 1: What is Hoopes' Process?

Hoopes' process is an **electrolytic refining method** used for the purification of aluminium. It was developed by William Hoopes and is specifically used to obtain **ultra-pure aluminium** (about 99.99%).

Step 2: Working Principle

The setup involves: - A three-layered cell: - Top layer: Pure aluminium (cathode), - Middle layer: Electrolyte (a mixture of molten salts like BaCl_2 , NaCl , and AlF_3), - Bottom layer: Impure aluminium (anode).

When current is passed: - Aluminium ions from the impure bottom layer migrate through the electrolyte and deposit as pure aluminium in the top layer.

Step 3: Elimination of Incorrect Options

- **Copper:** Refined using the electrolytic method, not Hoopes'.
- **Lead ore:** Concentration uses methods like froth flotation.
- **Titanium:** Refined using the Kroll process, not Hoopes'.

Conclusion: Hoopes' process is used exclusively for the **refining of aluminium**.

Quick Tip

Hoopes' process refines aluminium electrolytically using a 3-layered cell, producing 99.99% pure aluminium.

45. Metallurgical coke is charged to:

- (A) LD convertor
- (B) Secondary steel making
- (C) Iron blast furnace
- (D) Bayer process

Correct Answer: (3) Iron blast furnace

Solution:

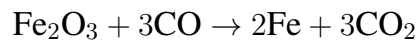
Step 1: What is Metallurgical Coke?

Metallurgical coke is a carbon-rich solid derived from coal through destructive distillation. It is: - Highly porous, - Strong, and - Essential as a reducing agent and fuel in metallurgical operations.

Step 2: Use in Iron Blast Furnace

In the **iron blast furnace**, coke serves two primary functions:

- **Fuel:** Provides heat energy for the reduction reactions.
- **Reducing agent:** Reduces iron ore (Fe_2O_3 or Fe_3O_4) to metallic iron.



Step 3: Elimination of Other Options

- **LD converter:** Uses pure oxygen, not coke.
- **Secondary steel making:** Involves ladle refining, not combustion.
- **Bayer process:** Extracts alumina from bauxite; coke is not involved.

Conclusion: Metallurgical coke is primarily charged into the **iron blast furnace** during pig iron production.

Quick Tip

Metallurgical coke is essential in a **blast furnace** — it acts as both a fuel and reducing agent to extract iron from its ores.

46. Ladle metallurgy does not include the following operation:

- (A) Deoxidation
- (B) Decarburisation
- (C) Desulphurisation
- (D) Sulphide shape control

Correct Answer: (2) Decarburisation

Solution:

Step 1: What is Ladle Metallurgy?

Ladle metallurgy is a set of refining operations carried out in the ladle after the steel is tapped from the primary furnace (like BOF or EAF). It enhances steel quality before casting.

Step 2: Operations Included in Ladle Metallurgy Common ladle metallurgy operations include: - **Deoxidation:** Addition of elements like Si, Al to remove dissolved oxygen. - **Desulphurisation:** Removal of sulfur by adding calcium or fluxes. - **Sulphide shape control:** Use of argon or rare earths to modify MnS inclusion shape.

Step 3: Decarburisation is Excluded

Decarburisation (removal of carbon) is a primary furnace operation, carried out in: - BOF (Basic Oxygen Furnace) by oxygen blowing, or - EAF (Electric Arc Furnace) during oxidation.

Ladle metallurgy does not focus on significant carbon removal.

Conclusion: The operation not included in ladle metallurgy is **decarburisation**.

Quick Tip

Decarburisation is done in the main furnace (BOF/EAF), not in ladle metallurgy, which focuses on deoxidation, desulphurisation, and inclusion control.

47. Titanium is produced by:

- (A) Magnesium reduction of TiCl_4
- (B) Electrolytic reduction of TiCl_4
- (C) Thermal dissociation of TiCl_4
- (D) Calcium reduction of TiCl_4

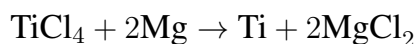
Correct Answer: (1) Magnesium reduction of TiCl_4

Solution:

Step 1: Kroll Process — Titanium Extraction

Titanium is primarily extracted using the **Kroll process**, in which: - Titanium tetrachloride (TiCl_4) is reduced by **magnesium** metal, - This reduction is carried out in an inert atmosphere

(usually argon) at high temperature (800–850°C).



Step 2: Why Magnesium is Used

Magnesium has a strong affinity for chlorine and can effectively reduce TiCl_4 to pure titanium metal. The process avoids the use of carbon, which could form titanium carbide and contaminate the product.

Step 3: Elimination of Incorrect Options

- **Electrolytic reduction:** Not used for titanium due to its high reactivity.
- **Thermal dissociation:** TiCl_4 is thermally stable; dissociation is not feasible.
- **Calcium reduction:** Used in laboratory-scale methods, not commercial production.

Conclusion: Titanium is commercially produced by **magnesium reduction of TiCl_4** in the Kroll process.

Quick Tip

Titanium is extracted via the **Kroll process** by reducing TiCl_4 with magnesium — not by electrolysis or thermal dissociation.

48. Which of the following is a suitable method to remove hydrogen from molten aluminium?

- (A) Cover melt surface with a flux
- (B) Increase melt temperature
- (C) Expose flowing melt to vacuum
- (D) Bubble humidified argon gas through the melt

Correct Answer: (4) Bubble humidified argon gas through the melt

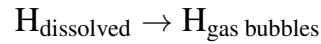
Solution:

Step 1: Hydrogen Problem in Aluminium

Hydrogen is the only gas that is significantly soluble in molten aluminium. If not removed, it forms pores in solidified metal, degrading mechanical properties and surface finish.

Step 2: Removal via Degassing

The most effective industrial method is to **bubble dry or humidified inert gas** (commonly argon or nitrogen) through the molten aluminium. This works on the principle of partial pressure difference, helping hydrogen diffuse out of the melt.



Step 3: Why Argon?

Argon is chemically inert and does not react with the aluminium melt. Bubbling it through the melt provides nucleation sites for hydrogen to escape and is safer and more efficient than vacuum or flux methods for hydrogen.

Step 4: Eliminating Other Options

- **Flux covering** helps prevent oxidation but doesn't remove dissolved hydrogen.
- **Increasing temperature** can increase hydrogen solubility — worsening the problem.
- **Vacuum degassing** is less effective and costly for aluminium compared to argon purging.

Conclusion: The best method to remove hydrogen from molten aluminium is to **bubble humidified argon gas** through the melt.

Quick Tip

Hydrogen in molten aluminium is best removed by **argon degassing** — a standard practice in foundries to prevent porosity.

49. Aluminium is not commercially produced by carbo-thermic reduction because:

- (A) It melts at a low temperature
- (B) It does not vaporise at reasonable temperature
- (C) Al–Al₂O₃ line is too low in the Ellingham diagram and need excessively high temperature
- (D) Aluminium metal will have excessive dissolved oxygen

Correct Answer: (3) Al–Al₂O₃ line is too low in the Ellingham diagram and need excessively high temperature

Solution:

Step 1: Understanding Carbo-Thermic Reduction

Carbo-thermic reduction involves reducing metal oxides using carbon as the reducing agent. However, not all metals can be commercially extracted this way due to thermodynamic limitations.

Step 2: Role of the Ellingham Diagram

The **Ellingham diagram** is a graph of Gibbs free energy (ΔG) vs. temperature for various metal oxides. A more negative line indicates a more stable oxide and harder reduction.

In the case of aluminium: - The **Al–Al₂O₃** line lies far below the carbon–CO and carbon–CO₂ lines. - This means carbon cannot reduce Al₂O₃ because the reaction is not thermodynamically favourable at practical temperatures.

Step 3: Alternative Method — Electrolytic Reduction

Due to this, aluminium is commercially extracted by **electrolysis of alumina** (Hall-Héroult process), not by carbo-thermic methods.

Conclusion: Aluminium is not reduced by carbon because the **Al–Al₂O₃** line is too low in the Ellingham diagram and would require **excessively high temperature** for reduction.

Quick Tip

The Al–Al₂O₃ line lies below the C–CO and C–CO₂ lines in the Ellingham diagram, making carbon reduction of Al₂O₃ thermodynamically unfeasible.

50. The process of cementation involves:

- (A) Elimination of a more reactive metal from molten metal by preferential oxidation
- (B) Refining by preferential dissolution of the desired metal in an organic solvent
- (C) Extraction by selective dissolution of the desired metal in an inorganic solvent
- (D) Separation of the desired metal by adding a more reactive metal

Correct Answer: (1) Elimination of a more reactive metal from molten metal by preferential oxidation

Solution:

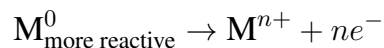
Step 1: Understanding Cementation

Cementation is a **metallurgical purification process** where a more reactive metal is removed or precipitated from a solution or molten phase by chemical displacement or oxidation.

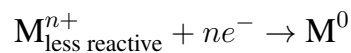
In hydrometallurgy, cementation is often used to: - **Eliminate more reactive metals** through selective oxidation, - Recover less reactive metals like copper by using zinc as a sacrificial metal.

Step 2: Mechanism of Cementation

A more reactive metal is oxidized:



This displaces a less reactive metal from its ionic form:



However, when considering **molten metal**, cementation implies selective oxidation to remove more reactive impurities.

Step 3: Clarifying the Misleading Options

- (B) and (C) refer to solvent extraction processes, not cementation.
- (D) misstates the process — in cementation, the more reactive metal is removed, not the desired metal added.

Conclusion: Cementation in molten systems involves **elimination of more reactive metals via preferential oxidation**.

Quick Tip

Cementation purifies metals by **removing more reactive elements**, especially via **preferential oxidation** in molten phases.

51. Ratio of packing factor of an FCC crystal to the packing factor of a simple cubic crystal is:

- (A) 1.0
- (B) 0.702
- (C) 1.423
- (D) 2.502

Correct Answer: (3) 1.423

Solution:

Step 1: Understanding Packing Factor (PF)

Packing factor or packing efficiency is defined as the fraction of volume in a crystal structure that is occupied by constituent particles (atoms).

Step 2: PF for Simple Cubic (SC)

- Number of atoms per unit cell: 1
- $PF = \frac{\text{Volume occupied by atoms}}{\text{Volume of unit cell}} = \frac{\pi}{6} \approx 0.52$

Step 3: PF for Face-Centered Cubic (FCC)

- Number of atoms per unit cell: 4
- $PF = \frac{4 \times \frac{4}{3} \pi r^3}{a^3} = \frac{\pi\sqrt{2}}{6} \approx 0.74$

Step 4: Finding the Ratio

$$\text{Ratio} = \frac{\text{PF of FCC}}{\text{PF of SC}} = \frac{0.74}{0.52} \approx 1.423$$

Conclusion: The ratio of the packing factor of FCC to SC is approximately **1.423**.

Quick Tip

FCC has a packing efficiency of about 74

52. Interplanar spacing between parallel planes can be determined by:

- (A) Scanning Electron Microscope
- (B) Transmission Electron Microscope
- (C) Spectrophotometer
- (D) Thermogravimetric Analyser

Correct Answer: (2) Transmission Electron Microscope

Solution:

Step 1: Understanding Interplanar Spacing

Interplanar spacing refers to the distance between parallel atomic planes in a crystal lattice. It is a critical structural parameter used in materials science and solid-state physics.

Step 2: Why Use a Transmission Electron Microscope (TEM)?

The **Transmission Electron Microscope (TEM)** can provide high-resolution images at the atomic scale due to: - Very short electron wavelengths, - Capability to produce **electron diffraction patterns**, which can be analyzed using Bragg's Law:

$$n\lambda = 2d \sin \theta$$

where d is the interplanar spacing.

Step 3: Elimination of Other Instruments

- **Scanning Electron Microscope (SEM)**: Provides surface topology, not interplanar distances.
- **Spectrophotometer**: Measures light absorption, used in chemical analysis.
- **Thermogravimetric Analyser (TGA)**: Measures mass change with temperature; unrelated to crystal structure.

Conclusion: TEM is the appropriate tool for measuring interplanar spacing due to its diffraction and atomic resolution capabilities.

Quick Tip

TEM allows measurement of interplanar spacing by analyzing diffraction patterns using Bragg's law.

53. Thin sheets of ceramic material is produced by:

- (A) Tape casting
- (B) Rolling
- (C) Forging
- (D) Injection molding

Correct Answer: (1) Tape casting

Solution:

Step 1: What is Tape Casting?

Tape casting is a widely used technique for producing thin, flexible sheets of ceramic materials. It is primarily used in electronics and ceramic capacitor manufacturing.

Step 2: Process Description

- A slurry of ceramic powder, solvents, binders, and plasticizers is prepared. - The slurry is cast onto a flat surface using a **doctor blade**. - The sheet is dried to remove the solvent, resulting in a thin ceramic "green" tape.

Step 3: Applications of Tape Casting

- Used for multilayer ceramic capacitors (MLCCs), - Fuel cell electrolytes, - Substrates in microelectronics.

Step 4: Elimination of Incorrect Options

- **Rolling and Forging:** Suitable for metals, not ceramics.
- **Injection Molding:** Used for complex 3D ceramic shapes, not thin sheets.

Conclusion: Thin ceramic sheets are produced using the **tape casting** process.

Quick Tip

Tape casting is a key technique for fabricating thin ceramic sheets used in capacitors and electronics.

54. Which one of the following is used as solder in an electronic industry?

- (A) Pb–Cu
- (B) Cu–Sn
- (C) Sn–Sb
- (D) Pb–Sn

Correct Answer: (4) Pb–Sn

Solution:

Step 1: What is Solder?

Solder is a fusible metal alloy used to join metal surfaces, especially in electronic circuit boards. It must have: - A low melting point, - Good electrical conductivity, - Strong adhesion properties.

Step 2: Lead-Tin (Pb–Sn) Alloy in Electronics

The most widely used solder alloy in traditional electronics is **Pb–Sn**, typically in the ratio

60:40 or 63:37. This alloy: - Melts at around 183–190°C, - Offers excellent wetting and adhesion on copper pads, - Has good mechanical strength and fatigue resistance.

Step 3: Evaluation of Other Options

- **Pb–Cu**: Not a typical soldering alloy.
- **Cu–Sn (bronze)**: Used in structural alloys, not as solder.
- **Sn–Sb**: Used in some high-temperature solders, but not common in general electronic applications.

Conclusion: The standard and widely used solder alloy in the electronic industry is **Pb–Sn**.

Quick Tip

Pb–Sn alloy is the traditional solder in electronics due to its low melting point and excellent conductivity.

55. Reinforcing material which possesses highest tensile strength from the following is:

- (A) Si_3N_4 fiber
- (B) S-glass fiber
- (C) SiC fiber
- (D) Graphite fiber

Correct Answer: (4) Graphite fiber

Solution:

Step 1: Understanding Reinforcing Materials

Reinforcing fibers are used in composite materials to enhance mechanical properties such as tensile strength, modulus, and thermal stability.

Step 2: Tensile Strength Comparison

Among the options: - **Graphite fiber** (also known as carbon fiber) is known for its **exceptionally high tensile strength**, often exceeding 4000 MPa. - **Si_3N_4** and **SiC** fibers are strong ceramics, but typically lower in tensile strength compared to graphite. - **S-glass fiber** has high strength and is used in aerospace, but graphite fibers outperform it in tensile performance.

Step 3: Applications of Graphite Fiber

Graphite fibers are widely used in: - Aerospace and defense, - High-performance sports equipment, - Automotive lightweight structures.

Conclusion: Graphite fiber exhibits the highest tensile strength among the listed options.

Quick Tip

Graphite (carbon) fibers offer the highest tensile strength and are essential in lightweight, high-strength composite applications.

56. Composite products such as pressure vessels, liquid storage tanks and rocket motor castings are made by:

- (A) Pultrusion
- (B) Resin transfer molding
- (C) Vacuum bagging
- (D) Filament winding

Correct Answer: (4) Filament winding

Solution:

Step 1: Understanding Filament Winding

Filament winding is a fabrication technique used to manufacture **high-strength, hollow composite structures**. In this process: - Continuous fiber filaments (like glass, carbon, or aramid) are soaked in resin and wound under tension over a rotating mandrel. - The resin is then cured (hardened), and the mandrel is removed.

Step 2: Applications of Filament Winding

This method is ideal for producing: - **Pressure vessels**, - **Storage tanks**, - **Rocket motor casings**, - Pipes and gas cylinders.

Step 3: Why Other Methods are Incorrect

- **Pultrusion:** Used for constant cross-section profiles (like rods, beams), not tanks. - **Resin transfer molding (RTM):** Suitable for complex closed-mold shapes, not large cylindrical vessels. - **Vacuum bagging:** A curing technique used in laminates, not for hollow cylindrical casting.

Conclusion: The most suitable and widely used method for manufacturing pressure vessels and similar components is **filament winding**.

Quick Tip

Filament winding is ideal for making strong, hollow, cylindrical composites like **pressure vessels and rocket casings**.

57. Which of the following is not the characteristics of a gray cast iron?

- (A) Brittle
- (B) Breaks preferentially along the graphite flakes
- (C) Produce a white fracture surface
- (D) Good damping property

Correct Answer: (3) Produce a white fracture surface

Solution:

Step 1: Properties of Gray Cast Iron

Gray cast iron is a type of cast iron that contains: - Flake graphite in its microstructure, - High carbon content (3–4%).

Key characteristics: - Appears gray due to the graphite flakes, - **Brittle**, due to stress concentration around flakes, - Has excellent **damping properties**, - Fractures preferentially along the graphite flakes, - **Produces a gray fracture surface**, not white.

Step 2: Contrast with White Cast Iron

- White cast iron has cementite (Fe_3C) instead of graphite. - It fractures with a white, shiny surface due to absence of graphite. - Gray cast iron has a dull gray surface when fractured due to presence of graphite flakes.

Conclusion: The statement ”**Produce a white fracture surface**” is not true for gray cast iron.

Quick Tip

Gray cast iron fractures with a **gray surface** due to graphite — unlike white cast iron, which produces a white surface.

58. Identify the element which increases the Ms temperature of a steel containing 1.0%

C:

- (A) Chromium
- (B) Copper
- (C) Manganese
- (D) Aluminium

Correct Answer: (4) Aluminium

Solution:

Step 1: Understanding Ms Temperature

The **Ms (Martensite start)** temperature is the point at which transformation from austenite to martensite begins during cooling. The Ms temperature is sensitive to: - Carbon content, - Alloying elements.

Step 2: Role of Alloying Elements

Most alloying elements such as Chromium, Manganese, and Nickel tend to **decrease the Ms temperature** because they stabilize austenite.

Step 3: Aluminium's Effect

- Aluminium is a **ferrite stabilizer**, meaning it promotes the formation of ferrite and destabilizes austenite. - This leads to an **increase in Ms temperature**. - Aluminium also refines grain size and enhances toughness in some grades of steel.

Step 4: Elimination of Incorrect Options

- **Chromium, Copper, Manganese:** All these elements tend to lower the Ms temperature by stabilizing the austenite phase.

Conclusion: The element that increases the Ms temperature in steel with 1.0% C is **Aluminium**.

Quick Tip

Aluminium is a ferrite stabilizer and increases M_s temperature, while most transition metals lower it by stabilizing austenite.

59. Bain distortion model explains:

- (A) The atomic movement involved in martensitic transformation
- (B) Formation of bainite by isothermal transformation
- (C) Formation of pearlite by eutectoid transformation
- (D) Formation of ledeburite by eutectic transformation

Correct Answer: (1) The atomic movement involved in martensitic transformation

Solution:

Step 1: What is the Bain Distortion Model?

The Bain distortion model describes the **mechanism of atomic movement** during the transformation of **austenite (FCC)** to **martensite (BCT)** in steel.

Step 2: Nature of Martensitic Transformation

- It is a diffusionless transformation, - Occurs by a coordinated shear-like movement of atoms,
- Results in a rapid, hard, and brittle microstructure.

Step 3: Bain's Proposal

Bain proposed that: - The FCC lattice of austenite contracts in one direction and expands in the other two directions, - This distortion transforms the structure into a **body-centered tetragonal (BCT)** lattice, representing martensite.

Step 4: Elimination of Incorrect Options

- **Bainite, Pearlite, and Ledeburite** all form through **diffusional transformations**, not via the coordinated distortion model.

Conclusion: The **Bain distortion model** explains the atomic mechanism of **martensitic transformation**.

Quick Tip

The Bain distortion model describes how FCC austenite transforms into BCT martensite without diffusion — via lattice distortion.

60. Stepped quenching process is also called as:

- (A) Austempering
- (B) Self tempering
- (C) Martempering
- (D) Spray quenching

Correct Answer: (3) Martempering

Solution:

Step 1: What is Stepped Quenching?

Stepped quenching, or **martempering**, is a heat treatment process where: - The steel is heated above the austenitizing temperature, - Then quenched rapidly to a temperature just above the martensite start (M_s) temperature, - Held isothermally to equalize temperature throughout the part, - Finally, cooled in air to form martensite.

Step 2: Purpose of Martempering

This technique: - Reduces internal stresses and distortion, - Avoids cracking in hardened parts, - Is especially useful for thick sections.

Step 3: Distinguishing from Other Options

- **Austempering:** Leads to bainite formation, not martensite. - **Self tempering:** A general term, not a controlled process. - **Spray quenching:** A method of cooling, not a specific stepped process.

Conclusion: The stepped quenching process is technically and correctly referred to as **martempering**.

Quick Tip

In **martempering**, steel is quenched just above M_s , held, then cooled — reducing cracking and distortion.

61. Grossman's critical diameter method is adopted to determine:

- (A) Case depth in carburising methods
- (B) Percentage of ductility
- (C) Percentage of carbon in steel
- (D) Hardenability of steel

Correct Answer: (4) Hardenability of steel

Solution:

Step 1: Understanding Hardenability

Hardenability refers to the ability of steel to harden in depth under a given set of conditions — it is not the same as hardness. High hardenability means a larger portion of the material can transform to martensite upon quenching.

Step 2: Grossman's Critical Diameter Method

This method determines the **critical diameter (D_c)**: - D_c is the diameter of a round bar that just fully hardens to 50% martensite at its center upon quenching. - It is used to compare and classify steels based on their hardenability.

Step 3: Key Concept

- A larger critical diameter indicates higher hardenability. - The method considers the cooling rate and alloying elements affecting transformation.

Step 4: Elimination of Other Options

- (A) relates to case hardening, not bulk hardenability.
- (B) and (C) are mechanical or compositional properties not evaluated by this method.

Conclusion: Grossman's critical diameter method is a standard approach to evaluating the **hardenability of steel**.

Quick Tip

The **Grossman method** uses the **critical diameter** to quantify the **hardenability** of steel, essential in heat treatment design.

62. Permanent magnets are made of:

- (A) High energy hard magnetic material
- (B) Ti–Al–V alloy
- (C) Commercial iron
- (D) Copper–Zinc alloy

Correct Answer: (1) High energy hard magnetic material

Solution:

Step 1: Characteristics of Permanent Magnets

Permanent magnets are materials that retain a significant magnetic field after magnetization. Their performance depends on: - High coercivity (resistance to demagnetization), - High remanence (residual magnetism), - High magnetic energy product (BH_{\max}).

Step 2: High Energy Hard Magnetic Materials

These include: - Alnico (Al–Ni–Co alloys), - Ferrites (ceramic magnets), - Rare-earth magnets (e.g., NdFeB, SmCo).

Such materials are called **hard magnetic materials** and are used in: - Motors and generators, - Magnetic sensors, - Audio devices and permanent magnet-based assemblies.

Step 3: Elimination of Incorrect Options

- **Ti–Al–V:** Typically used in aerospace alloys, not magnetic.
- **Commercial iron:** Soft magnetic, easily magnetized and demagnetized.
- **Cu–Zn (brass):** Non-magnetic.

Conclusion: Permanent magnets are made from **high energy hard magnetic materials**.

Quick Tip

Permanent magnets require **hard magnetic materials** like ferrites or rare-earth alloys due to their high coercivity and BH_{\max} .

63. Nitriding of the steel is done at low temperatures because:

- (A) To favour nitrogen diffusion
- (B) To favour carbon diffusion

- (C) To minimize thermal cracks
- (D) To soften the ferrite phase

Correct Answer: (1) To favour nitrogen diffusion

Solution:

Step 1: What is Nitriding?

Nitriding is a surface hardening heat treatment process that introduces **nitrogen atoms** into the surface of steel to form hard nitrides. It enhances: - Surface hardness, - Wear resistance, - Fatigue strength.

Step 2: Temperature Range

- Nitriding is conducted at relatively **low temperatures**, typically between **500–550°C**. - At these temperatures, **nitrogen has optimal diffusivity** without altering the microstructure significantly.

Step 3: Why Not Carbon Diffusion?

- Carbon diffusion requires higher temperatures (as in carburizing). - Nitriding specifically targets nitrogen atoms for diffusion, not carbon.

Step 4: Elimination of Other Options

- **Thermal cracks** are not a dominant concern at nitriding temperatures. - Nitriding is intended to **harden** the ferrite phase, not soften it.

Conclusion: The main reason nitriding is performed at lower temperatures is to **favor nitrogen diffusion** into the steel matrix.

Quick Tip

Nitriding enhances surface hardness by diffusing **nitrogen** at low temperatures, avoiding phase transformations.

64. Minimum percent of nickel needed in stainless steel to stabilize the austenitic FCC phase is:

- (A) 2
- (B) 4

(C) 9

(D) 16

Correct Answer: (3) 9

Solution:

Step 1: Austenitic Stainless Steel

- Austenitic stainless steels have a **face-centered cubic (FCC)** crystal structure at room temperature. - Nickel is a **strong austenite stabilizer**, meaning it retains the FCC phase even after cooling.

Step 2: Nickel Requirement

- For a steel to be classified as fully austenitic, at least **8–10% nickel** is typically needed. - **9%** is widely accepted as the **minimum** content to ensure stabilization of the FCC phase, particularly in grades like AISI 304.

Step 3: Role of Nickel

- Nickel lowers the martensite start temperature, - Prevents ferrite and martensite formation during cooling, - Enhances corrosion resistance and ductility.

Conclusion: To stabilize the austenitic (FCC) phase in stainless steel, a minimum of **9% nickel** is required.

Quick Tip

At least **9% Ni** is required to retain the **austenitic FCC phase** in stainless steel such as AISI 304.

65. Cu–Be alloys are strengthened by:

(A) Solid solution strengthening

(B) Dispersion strengthening

(C) Grain refinement

(D) Precipitation strengthening

Correct Answer: (4) Precipitation strengthening

Solution:

Step 1: Nature of Cu–Be Alloys

Copper–beryllium (Cu–Be) alloys are non-ferrous alloys known for: - High strength, - Excellent fatigue resistance, - Good electrical and thermal conductivity.

Step 2: Strengthening Mechanism

Cu–Be alloys are primarily strengthened by **precipitation hardening (age hardening)**, which involves: - Solution treatment at high temperature to dissolve beryllium, - Rapid quenching to retain a supersaturated solid solution, - Ageing (heating) to allow fine beryllide precipitates (CuBe) to form, - These precipitates obstruct dislocation movement, increasing strength.

Step 3: Why Other Options Are Incorrect

- **Solid solution strengthening**: Present in initial phase, but not the dominant hardening mechanism. - **Dispersion strengthening**: Involves stable oxides or ceramic particles, not relevant here. - **Grain refinement**: Affects toughness and ductility more than high-strength enhancement.

Conclusion: Precipitation strengthening is the primary mechanism used to enhance mechanical properties in Cu–Be alloys.

Quick Tip

Cu–Be alloys are classic examples of **precipitation-hardened** materials, strengthened via age-hardening treatments.

66. Polystyrene belongs to:

- (A) Ceramic material
- (B) Composite material
- (C) Thermoplastic material
- (D) Structural material

Correct Answer: (3) Thermoplastic material

Solution:

Step 1: Understanding Polystyrene

Polystyrene is a synthetic aromatic polymer made from the monomer styrene. It is: - Lightweight,

- Rigid, - Easily molded.

Step 2: Classification

Polystyrene is classified as a **thermoplastic**, which means: - It softens upon heating, - Can be reshaped multiple times, - Solidifies upon cooling without chemical change.

Step 3: Applications

Used in: - Packaging (e.g., foam cups, containers), - Disposable cutlery, - CD and DVD cases, - Insulation materials.

Step 4: Elimination of Incorrect Options

- **Ceramic material:** Inorganic and brittle — polystyrene is organic and ductile when heated.
- **Composite material:** Not a combination of distinct phases or reinforcements.
- **Structural material:** Although used in construction, it lacks mechanical robustness to be termed “structural” material.

Conclusion: Polystyrene is a **thermoplastic material** that can be repeatedly heated and molded.

Quick Tip

Polystyrene is a **thermoplastic polymer** — it softens on heating and is used widely in packaging and consumer products.

67. Which of the following are the low molecular weight substances added to polymers to increase plasticity and flexibility?

- (A) Fillers
- (B) Plasticizers
- (C) Inoculants
- (D) Stabilisers

Correct Answer: (2) Plasticizers

Solution:

Step 1: Role of Plasticizers

Plasticizers are **low molecular weight**, often organic compounds, added to polymers to: -

Reduce intermolecular forces between polymer chains, - Increase flexibility and workability,
- Lower the glass transition temperature (T_g).

Step 2: Mechanism of Action

- By embedding between polymer chains, plasticizers reduce stiffness. - Common in PVC, rubber, and cellulose-based plastics.

Step 3: Elimination of Other Options

- **Fillers:** Used to increase bulk or mechanical strength, not flexibility.
- **Inoculants:** Used in metallurgy (e.g., cast iron), not polymers.
- **Stabilisers:** Protect polymers from thermal or UV degradation.

Conclusion: To enhance the flexibility and plasticity of polymers, **plasticizers** are added.

Quick Tip

Plasticizers are added to polymers to **increase flexibility and decrease brittleness**, especially in PVC applications.

68. Hard magnetic material is characterised by:

- (A) Only low coercive force
- (B) High coercive force and low residual magnetic induction
- (C) High coercive force and high residual magnetic induction
- (D) Low coercive force and high residual magnetic induction

Correct Answer: (3) High coercive force and high residual magnetic induction

Solution:

Step 1: Understanding Hard Magnetic Materials

Hard magnetic materials (also called permanent magnets) are those that: - Retain their magnetism after the removal of the external magnetic field, - Are difficult to demagnetize.

Step 2: Key Characteristics

- **High coercive force (H_c):** Resistance to demagnetization, - **High residual magnetic induction (B_r):** Amount of magnetism left in the material after the external field is removed.

These properties ensure that the material maintains strong magnetism in applications like motors, sensors, and permanent magnet generators.

Step 3: Elimination of Incorrect Options

- **Low coercive force:** Characteristic of soft magnetic materials. - **Low residual induction:** Indicates weak permanent magnet capability.

Conclusion: Hard magnetic materials are best characterized by **high coercive force and high residual magnetic induction.**

Quick Tip

Hard magnetic materials are defined by their **high coercivity** and **high remanence**, making them suitable for permanent magnet applications.

69. In a single component system, the maximum number of phases that can co-exist in equilibrium is:

- (A) 0
- (B) 2
- (C) 3
- (D) 4

Correct Answer: (3) 3

Solution:

Step 1: Apply Gibbs Phase Rule

Gibbs phase rule is given by:

$$F = C - P + 2$$

Where:

F = degrees of freedom,

C = number of components,

P = number of phases.

Step 2: For a Single Component System ($C = 1$) and Equilibrium ($F = 0$)

$$0 = 1 - P + 2 \Rightarrow P = 3$$

Step 3: Real Example

The triple point of water is a classic example of 3 phases (solid, liquid, and vapor) co-existing in equilibrium at specific temperature and pressure.

Conclusion: In a single-component system, the maximum number of phases that can co-exist at equilibrium is **3**.

Quick Tip

Use Gibbs phase rule to find maximum equilibrium phases: **Triple point** is the classic case for 3-phase coexistence in a one-component system.

70. Magnetic permeability of iron is increased by:

- (A) Purification
- (B) Decarburising
- (C) Alternating heating and cooling
- (D) Alloying with cobalt

Correct Answer: (4) Alloying with cobalt

Solution:

Step 1: Magnetic Permeability Definition

Magnetic permeability (μ) is a measure of how easily a material can support the formation of a magnetic field within itself.

Step 2: Role of Cobalt in Iron

- Alloying iron with cobalt (Co) significantly increases its magnetic permeability. - Cobalt enhances the magnetic moment and reduces hysteresis losses. - It stabilizes the magnetic domain structure and improves the overall magnetic response of the alloy.

Step 3: Evaluation of Other Options

- **Purification:** Improves electrical conductivity, but effect on permeability is limited. - **Decarburising:** Reduces carbon content but doesn't enhance permeability as effectively. - **Alter-**

nating heating and cooling (annealing): Improves grain structure but has a smaller impact compared to alloying with cobalt.

Conclusion: The most effective way to increase the magnetic permeability of iron is by **alloying it with cobalt.**

Quick Tip

To enhance the magnetic permeability of iron, alloying with **cobalt** is a proven method due to its high magnetic saturation and thermal stability.

71. Plastics as a material of construction suffer from the drawback of low:

- (A) Strength
- (B) Density
- (C) Machinability
- (D) Plastic deformation

Correct Answer: (1) Strength

Solution:

Step 1: Nature of Plastics

Plastics are widely used in construction due to: - Low density, - High corrosion resistance, - Easy fabrication, - Good electrical insulation properties.

Step 2: Drawback – Low Strength

However, compared to traditional materials like steel, aluminum, and concrete, plastics have: - Much lower tensile and compressive strength, - Poor performance under heavy mechanical loading or structural stress.

This limits their use in load-bearing or high-stress applications in construction.

Step 3: Elimination of Other Options

- **Density:** Low density is an advantage, not a drawback. - **Machinability:** Plastics are generally easy to machine or mold. - **Plastic deformation:** Plastics typically show large deformation before fracture, which can be useful.

Conclusion: The primary structural drawback of plastics in construction is their **low strength**.

Quick Tip

Plastics are light and versatile, but their **low mechanical strength** limits structural applications in heavy-duty construction.

72. Machinability of hard alloys and tool steels is improved by:

- (A) Annealing
- (B) Normalising
- (C) Spheroidising
- (D) Tempering

Correct Answer: (1) Annealing

Solution:

Step 1: What is Machinability?

Machinability refers to how easily a material can be cut, shaped, or removed using a cutting tool.

Step 2: Role of Annealing

- Annealing is a heat treatment process that softens the material. - It involves heating the metal to a specific temperature and then cooling it slowly. - This process reduces hardness, refines grain structure, and relieves internal stresses. - As a result, the material becomes less resistant to cutting, hence more machinable.

Step 3: Other Options

- **Normalising:** Increases toughness and strength but doesn't soften the metal significantly. - **Spheroidising:** Mainly used in carbon steels to form globular cementite, improving ductility, but not directly aimed at hard alloys or tool steels. - **Tempering:** Used to reduce brittleness in quenched steels, but not primarily for improving machinability.

Conclusion: Annealing is the most suitable method to **enhance machinability** of hard alloys and tool steels.

Quick Tip

Annealing softens hard steels, making them easier to cut or machine — ideal for improving machinability.

73. Copper is not present as an alloying constituent in:

- (A) Nichrome
- (B) Delta metal
- (C) Silicone bronze
- (D) Constantan

Correct Answer: (1) Nichrome

Solution:

Step 1: Composition of Each Alloy - Nichrome is an alloy of **Nickel (Ni) and Chromium (Cr)**. It typically contains: - 80- 20- No copper content.

- **Delta Metal:** A type of brass (an alloy of Copper and Zinc), also includes a small percentage of iron.

- **Silicon Bronze:** A bronze alloy containing **Copper, Silicon, and sometimes Zinc**.

- **Constantan:** An alloy of **Copper (55%) and Nickel (45%)**.

Step 2: Elimination Copper is a constituent in options (B), (C), and (D), but **not in Nichrome (A)**.

Conclusion: The correct answer is **Nichrome**, as it contains no copper.

Quick Tip

Nichrome is a heat-resistant alloy used in heating elements. It is made of Nickel and Chromium — not copper.

74. In precipitation hardenable alloy, like duralumin, intermediate precipitates can form due to:

- (A) Coherency strains
- (B) Ease of diffusion
- (C) Difficulty of the growth of the final precipitate
- (D) Difficulty of nucleation of the final precipitate

Correct Answer: (1) Coherency strains

Solution:

Step 1: Understanding precipitation hardening

Precipitation hardening involves: - Solution treatment, - Quenching, - Aging (to form fine precipitates that hinder dislocation motion).

Step 2: Role of intermediate precipitates

In alloys like duralumin (Al-Cu), intermediate precipitates such as θ'' and θ' form before the stable θ phase. These intermediate precipitates: - Retain coherent or semi-coherent interfaces with the matrix, - Cause **coherency strains** due to the mismatch in atomic sizes and lattice parameters between the matrix and the precipitate.

Step 3: Impact of coherency strains

These strains: - Increase the driving force for nucleation of intermediate precipitates, - Make intermediate precipitates thermodynamically favorable, - Provide effective strengthening due to lattice distortion.

Hence, the correct answer is **Coherency strains**.

Quick Tip

Coherency strains in a supersaturated solid solution drive the formation of intermediate precipitates, enhancing age-hardening effectiveness.

75. Vanadium in high speed steels:

- (A) Provides high hot hardness
- (B) Promotes retention of austenite
- (C) Increases toughness
- (D) Forms very hard carbides and thus increases wear resistance

Correct Answer: (4) Forms very hard carbides and thus increases wear resistance

Solution:

Step 1: Role of alloying elements in high speed steel

High-speed steels (HSS) contain multiple alloying elements like: - Tungsten, - Molybdenum, - Chromium, - Vanadium.

Each element contributes specific properties. Vanadium is a strong carbide-forming element.

Step 2: Vanadium's influence

Vanadium: - Forms extremely hard vanadium carbides (VC), - These carbides are finely dispersed, - They resist abrasion and maintain cutting edges during service, - This **improves wear resistance** and life of the tool.

Step 3: Conclusion

Thus, vanadium increases wear resistance in HSS by forming very hard carbides.

Quick Tip

In tool steels, vanadium forms hard carbides that increase wear resistance and edge retention — critical for cutting applications.

76. Which of the following is not a point defect?

- (A) Dislocation
- (B) Interstitials
- (C) Vacancies
- (D) Frenkel defect

Correct Answer: (1) Dislocation

Solution:

Step 1: Understanding Point Defects

Point defects are localized disruptions in the perfect regular arrangement of atoms. Common examples include: - **Vacancies:** Missing atoms from lattice sites, - **Interstitials:** Atoms

that occupy positions between regular lattice sites, - **Frenkel Defect:** A combination of a vacancy and an interstitial — an atom moves from its position to an interstitial site.

Step 2: Understanding Dislocation

- **Dislocation** is a type of **line defect**, not a point defect. - It involves a distortion along a line in the crystal lattice, - Most commonly represented by edge or screw dislocations.

Step 3: Conclusion

Since dislocation involves a line of atoms and not just a single site, it is not a point defect.

Quick Tip

Remember: Point defects involve disruptions at individual lattice points (e.g., vacancies), while line defects involve rows of atoms (e.g., dislocations).

77. True strain (ε) and engineering strain (e) are related by

(A) $\varepsilon = 1 + e$

(B) $\varepsilon = \ln(1 + e)$

(C) $e = \ln(1 + \varepsilon)$

(D) $\varepsilon = \frac{1}{1 + e}$

Correct Answer: (2) $\varepsilon = \ln(1 + e)$

Solution:

Step 1: Definitions

- **Engineering strain (e)** is defined as:

$$e = \frac{\Delta L}{L_0}$$

where ΔL is the change in length and L_0 is the original length.

- **True strain (ε)** accounts for the continuous change in length during deformation, and is defined as:

$$\varepsilon = \int_{L_0}^L \frac{dL}{L} = \ln \left(\frac{L}{L_0} \right)$$

Step 2: Relationship Between ε and e

Since:

$$\frac{L}{L_0} = 1 + e$$

Substituting into the true strain formula:

$$\varepsilon = \ln(1 + e)$$

Quick Tip

Use true strain for large deformation problems as it provides more accurate results.

Engineering strain is linear and suitable only for small deformations.

78. Perfect plastic material is

- (A) Rigid
- (B) Exhibits elastic property
- (C) Very hard
- (D) Very brittle

Correct Answer: (1) Rigid

Solution:

Step 1: Understanding Perfect Plasticity

A **perfect plastic material** does not exhibit any elastic behavior. It deforms plastically at a constant stress once yielding begins and continues to do so without any increase in stress. Hence, it lacks an elastic region or strain-hardening.

Step 2: Why it is called "Rigid"

The term "rigid" in this context signifies that the material does not deform elastically (i.e., instantaneously and reversibly), but yields immediately under load and flows plastically at a constant stress level.

Thus, option (A) **Rigid** best describes a perfect plastic material in idealized mechanical models.

Quick Tip

Perfect plasticity is an idealization used in theoretical stress-strain models where no strain hardening occurs. It helps simplify calculations in plasticity theory.

79. The value of Poisson's ratio of most of the metals is

- (A) 0.20
- (B) 0.28
- (C) 0.33
- (D) 1.5

Correct Answer: (3) 0.33

Solution:

Step 1: Understanding Poisson's Ratio

Poisson's ratio is defined as the ratio of lateral strain to longitudinal strain in a material subjected to axial loading. It is given by:

$$\nu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

Step 2: Typical Range for Metals

Most ductile metals, such as aluminum, copper, and mild steel, exhibit a Poisson's ratio in the range of 0.30 to 0.35. Hence, a widely accepted average value for most metals is approximately:

$$\nu \approx 0.33$$

This value indicates that the metal deforms laterally to about one-third of its axial strain.

Quick Tip

For engineering metals, remember that Poisson's ratio is typically around 0.33, indicating moderate lateral contraction relative to axial elongation.

80. Levy–Mises equations are valid for

- (A) Soft material
- (B) Ideal plastic material with elastic region
- (C) Hardened material
- (D) Ideal plastic material

Correct Answer: (4) Ideal plastic material

Solution:

Step 1: Understanding Levy–Mises Equations

The Levy–Mises equations describe the relationship between the plastic strain rate and the deviatoric stress in an ideally plastic, incompressible material. They are used extensively in plasticity theory for materials that yield according to the von Mises yield criterion.

Step 2: Applicability

These equations are derived under the assumption that: - The material is incompressible during plastic deformation. - The material exhibits perfectly plastic behavior (no strain hardening or softening). - There is no elastic strain component during plastic flow.

Hence, Levy–Mises equations are valid for an **ideal plastic material**, which does not exhibit elastic or strain-hardening behavior after yielding.

Quick Tip

Levy–Mises equations are best suited for **ideal plastic materials** under the assumption of incompressibility and perfect plastic flow.

81. Extensive plastic deformation occurs during

- (A) Cold work
- (B) Injection molding
- (C) Casting
- (D) Heat treatment

Correct Answer: (1) Cold work

Solution:

Step 1: Understanding Cold Work

Cold working, also known as cold forming or work hardening, refers to the plastic deformation of metals below their recrystallization temperature. During cold working, dislocations multiply and move, resulting in extensive plastic deformation.

Step 2: Other Processes

- **Injection molding:** primarily involves melting and shaping polymers, not plastic deformation of metals. - **Casting:** involves pouring molten metal into a mold and solidifying it, not deformation. - **Heat treatment:** involves thermal cycles to modify properties; plastic deformation is not a primary mechanism.

Thus, the process involving extensive plastic deformation is cold work.

Quick Tip

Cold working increases strength through strain hardening and occurs below the metal's recrystallization temperature.

82. Metals with high monotonic strain-hardening exponents ($n > 0.15$) and those with a low strain-hardening exponent ($n < 0.15$) respectively would undergo

- (A) Ideal plastic, Ideal elastic
- (B) Ideal elastic, Ideal plastic
- (C) Cyclic hardening, cyclic softening
- (D) Cyclic softening, cyclic hardening

Correct Answer: (3) Cyclic hardening, cyclic softening

Solution:

Step 1: Understanding Strain-Hardening Exponent

The strain-hardening exponent (n) characterizes how a metal strengthens as it is plastically deformed. A higher value of n implies better capacity to strain-harden under repeated loading.

- When $n > 0.15$: Materials tend to exhibit **cyclic hardening** due to increased resistance to deformation with repeated loading. - When $n < 0.15$: Materials tend to **cyclically soften**, as

they cannot accumulate as much strain hardening, and internal stresses reduce their ability to resist deformation over time.

Step 2: Linking to Cyclic Loading Behavior

Under fatigue or cyclic loading, high n metals harden, while low n metals soften—this is the critical distinction that governs material selection in applications like springs or rotating machinery.

Quick Tip

High strain-hardening exponent metals ($n > 0.15$) undergo cyclic hardening; low exponent metals ($n < 0.15$) show cyclic softening.

83. Deformation by slip occurs in

- (A) Ceramics
- (B) Composites
- (C) Metals
- (D) Nonmetals

Correct Answer: (3) Metals

Solution:

Step 1: Understanding Slip Mechanism

Slip is the process by which plastic deformation is produced by dislocation motion within a crystal structure. It occurs when sufficient shear stress is applied, and atoms shift from one equilibrium position to another along defined crystallographic planes known as slip planes.

Step 2: Why in Metals?

Metals have:

- Close-packed crystal structures (like FCC, BCC, HCP) with many slip systems.
- Non-directional metallic bonds, allowing atoms to slide over each other easily without breaking bonds.

This makes metals highly ductile and allows them to undergo plastic deformation primarily through slip.

Step 3: Why not in Others?

- *Ceramics*: Brittle due to ionic/covalent bonding; dislocations cannot move easily. - *Composites*: Typically a mix, not pure slip-driven deformation. - *Nonmetals*: Often lack the crystalline structure or bonding nature required for slip.

Quick Tip

Slip deformation primarily occurs in metals due to their crystalline structure and metallic bonding which provide many active slip systems.

84. The Vicker's diamond pyramid method of hardness determination does not give accurate result, when employed for the

- (A) Hard metals
- (B) Forged parts with rough surface
- (C) Soft metals
- (D) Polished and hardened steel surface

Correct Answer: (2) Forged parts with rough surface

Solution:

Step 1: Understanding Vickers Hardness Test

The Vickers hardness test uses a diamond pyramid indenter and is best suited for very small or polished surfaces. It measures the diagonals of the indentation left after applying a known force.

Step 2: Limitation on Rough Surfaces

- The Vickers test assumes a smooth and flat test surface for precise measurement of indentation. - On rough surfaces like forged parts, the irregularities distort the shape of the indentation, making accurate measurement of the diagonal lengths difficult. - This leads to erroneous hardness values due to surface unevenness and scattering of light during optical observation.

Step 3: Other Options Analysis

- *Hard metals*: Vickers test is actually designed for hard materials due to diamond indenter.

- *Soft metals*: Can be tested, although Brinell may be more suitable for some. - *Polished and hardened surfaces*: Ideal for Vickers, providing sharp, measurable indentations.

Quick Tip

The Vickers hardness test is best applied on smooth, polished surfaces—rough surfaces distort the indent shape and lead to inaccurate readings.

85. The yield point in fatigue loading compared to that in static loading is less. The ratio of ultimate tensile strength to endurance limit of a material subjected to fatigue loading is

- (A) 0.5
- (B) 1
- (C) 1.5
- (D) 2

Correct Answer: (4) 2

Solution:

Step 1: Understanding Fatigue Loading and Endurance Limit

Fatigue loading refers to the repetitive application of stress or strain that can lead to failure at stress levels lower than the material's yield strength under static conditions.

Step 2: Definition of Endurance Limit

The endurance limit (or fatigue limit) is the maximum stress level a material can endure for an infinite number of cycles without failure. For most ductile materials, it is typically $\frac{1}{2}$ of the Ultimate Tensile Strength (UTS).

Step 3: Ratio of UTS to Endurance Limit

$$\text{Ratio} = \frac{\text{Ultimate Tensile Strength}}{\text{Endurance Limit}} = \frac{\text{UTS}}{0.5 \cdot \text{UTS}} = 2$$

Quick Tip

For many ductile materials, the endurance limit is roughly half of the ultimate tensile strength, leading to a ratio of about 2.

86. Which of the following mechanical properties of a material is most structure insensitive?

- (A) Toughness
- (B) Tensile strength
- (C) Young's modulus
- (D) Percentage reduction of area

Correct Answer: (3) Young's modulus

Solution:

Step 1: Understanding structure sensitivity

Mechanical properties can be classified based on their sensitivity to a material's microstructure. Properties like toughness, tensile strength, and ductility are influenced by grain size, dislocation density, and phase distribution.

Step 2: Role of Young's modulus

Young's modulus (elastic modulus) represents the stiffness of a material in the elastic region. It is primarily determined by atomic bonding forces and is almost entirely independent of microstructural features.

Conclusion:

Among the given options, Young's modulus is least affected by changes in microstructure and is therefore the most structure-insensitive property.

Quick Tip

Young's modulus depends on atomic bonding and crystal structure, not on grain size or phase distribution—making it structure-insensitive.

87. Decrease in stress at constant deformation under creep conditions is termed as the

- (A) Stress relaxation
- (B) Residual stress
- (C) Stress relief
- (D) Proof stress

Correct Answer: (1) Stress relaxation

Solution:

Step 1: Understanding the condition

Under creep conditions, materials are subjected to constant deformation (strain) over time at elevated temperatures. The internal resistance to this deformation—stress—gradually decreases.

Step 2: Defining stress relaxation

Stress relaxation refers to the phenomenon where the internal stress in a material reduces over time when it is held at a constant strain. This typically happens in viscoelastic and creep-sensitive materials like metals at high temperature or polymers.

Conclusion:

Among the given choices, the correct term that describes this stress reduction behavior at constant deformation is **Stress relaxation**.

Quick Tip

Remember: **Stress relaxation** = stress decreases at constant strain; **Creep** = strain increases at constant stress.

88. Creep resistance can be improved by allowing the

- (A) Fine grains to grow
- (B) Soft particles to precipitate along grain boundaries
- (C) Directional solidification of alloys
- (D) Uniformly dispersed coarse particles precipitation in the metal matrix

Correct Answer: (3) Directional solidification of alloys

Solution:

Step 1: Understanding creep resistance

Creep resistance refers to a material's ability to resist deformation under prolonged exposure to high temperatures and stress. Materials intended for such applications require a microstructure that impedes dislocation movement and diffusion.

Step 2: Role of directional solidification

Directional solidification aligns grains in a preferred direction, typically parallel to the loading axis. This reduces the number of grain boundaries transverse to the applied stress, thus minimizing pathways for creep deformation (especially grain boundary sliding).

Step 3: Why other options are incorrect

- *Option A:* Fine grains promote creep due to increased grain boundary area. - *Option B:* Soft particles are ineffective at blocking dislocation motion. - *Option D:* Coarse particles may not efficiently hinder creep, especially if not finely dispersed or coherent.

Conclusion:

Among the options, **directional solidification of alloys** is the most effective method to enhance creep resistance.

Quick Tip

Creep-resistant alloys often employ **directional solidification** or even **single crystal structures** to reduce grain boundary sliding.

89. The elastic strain energy of a unit length of an edge dislocation as compared to that of a screw dislocation is

- (A) Less
- (B) More
- (C) Equal
- (D) Double

Correct Answer: (2) More

Solution:

Step 1: Understanding dislocations

Dislocations are line defects in crystals. There are primarily two types: - *Edge dislocation*: extra half-plane of atoms inserted into the crystal. - *Screw dislocation*: result of shear distortion.

Step 2: Energy of dislocations

The elastic strain energy per unit length E of a dislocation is given approximately by:

$$E \propto Gb^2$$

where G is the shear modulus and b is the magnitude of the Burgers vector.

For edge dislocations, the energy involves both shear and volumetric (dilatational) components, whereas screw dislocations involve only shear strain.

Conclusion:

Since edge dislocations include both shear and volumetric strain, their total elastic strain energy is **higher** than that of screw dislocations.

Quick Tip

Elastic strain energy of edge dislocations is **slightly more** than screw dislocations due to their extra volumetric distortion component.

90. The yield point phenomenon observed in annealed low carbon steel is due to the presence of the following element

- (A) Silicon
- (B) Chromium
- (C) Carbon
- (D) Phosphorous

Correct Answer: (3) Carbon

Solution:

Step 1: Understanding yield point phenomenon

The yield point in a stress-strain curve of annealed low carbon steel is characterized by an upper yield point followed by a lower yield point and a yield plateau.

Step 2: Role of carbon and nitrogen

The phenomenon is caused by the interaction of dislocations with interstitial atoms, primarily **carbon** and sometimes nitrogen. These atoms pin the dislocations. On application of stress, dislocations break free from these atoms, causing a sudden drop in stress (from upper to lower yield point).

Conclusion:

The yield point phenomenon is primarily due to the presence of **carbon** atoms in the steel that lock the dislocations before yielding.

Quick Tip

The yield point effect in low carbon steel is caused by carbon (or nitrogen) atoms locking dislocations. These are released suddenly, leading to the characteristic yield drop.

91. Stretcher strains found in a low carbon sheet are associated with

- (A) Thickness of the sheet
- (B) Texture
- (C) Dislocation density
- (D) Yield point phenomenon

Correct Answer: (4) Yield point phenomenon

Solution:

Step 1: Understanding stretcher strains

Stretcher strains, also called Luders bands, are visible surface deformations in low carbon steel sheets that occur during plastic deformation.

Step 2: Link with yield point phenomenon

These strains are directly associated with the sudden yielding that occurs in materials exhibiting a yield point phenomenon. As the material deforms beyond the upper yield point, dislocations are released in bands, causing localized stretching—stretcher strains.

Conclusion:

Stretcher strains are a manifestation of the yield point phenomenon in low carbon steels.

Quick Tip

Luders bands or stretcher strains are surface markings in low carbon steels caused by the yield point phenomenon and are visible during early plastic deformation.

92. Movement of jogs can produce

- (A) Interstitials
- (B) Vacancies
- (C) Grain boundary segregation
- (D) Grain boundary sliding

Correct Answer: (2) Vacancies

Solution:

Step 1: Understanding jogs in dislocations

Jogs are steps or irregularities along a dislocation line that can move under stress or temperature.

Step 2: Mechanism of jog movement

When jogs move via the climb mechanism (out of their slip plane), they require the absorption or emission of point defects—typically vacancies.

Conclusion:

Therefore, the movement of jogs leads to the production (or absorption) of vacancies, aiding in dislocation climb.

Quick Tip

Jogs move by climb which involves the diffusion of vacancies. Hence, movement of jogs can produce vacancies in the crystal structure.

93. Von Mises criterion for plastic yielding of a ductile material predicts that the yield stress in uniaxial tension is related to that in pure torsion as

- (A) Equal to each other
- (B) 2 times
- (C) One half
- (D) $\sqrt{3}$ times

Correct Answer: (4) $\sqrt{3}$ times

Solution:

Step 1: According to the Von Mises yield criterion for isotropic ductile materials under complex stress states, the equivalent or effective stress is:

$$\sigma_e = \sqrt{\frac{1}{2} [(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$$

Step 2: For uniaxial tension, let the principal stresses be:

$$\sigma_1 = \sigma, \quad \sigma_2 = 0, \quad \sigma_3 = 0 \Rightarrow \sigma_e = \sigma$$

Step 3: For pure torsion, the only non-zero stress is the shear stress τ . The principal stresses are:

$$\sigma_1 = \tau, \quad \sigma_2 = -\tau, \quad \sigma_3 = 0 \Rightarrow \sigma_e = \sqrt{3}\tau$$

Step 4: Equating the effective stress at yield in both cases:

$$\sigma = \sqrt{3}\tau \Rightarrow \frac{\sigma}{\tau} = \sqrt{3}$$

Therefore, the yield stress in uniaxial tension is $\sqrt{3}$ times that in pure torsion.

Quick Tip

The Von Mises criterion is based on the concept of distortion energy and is often used in design for ductile materials. For pure torsion, the relationship with uniaxial yield stress becomes $\sigma = \sqrt{3}\tau$.

94. Stress intensity factor, K_{IC} , not depends on

- (A) Geometry of the solid containing the crack
- (B) The size and location of the crack

- (C) Magnitude and distribution of the loads imposed on the solid
- (D) Tensile strength of the material

Correct Answer: (4) Tensile strength of the material

Solution:

The stress intensity factor K_{IC} is a parameter used in fracture mechanics to characterize the stress state near the tip of a crack in a material under linear-elastic loading. It primarily depends on:

- The geometry of the component and crack, - The size and position of the crack, - The nature, magnitude, and direction of external loads applied.

However, it **does not** depend on the tensile strength of the material. Tensile strength is a material property that indicates the maximum stress a material can withstand while being stretched or pulled before necking. But K_{IC} is related to how stress is intensified near a crack tip and is not influenced directly by tensile strength.

Quick Tip

Remember, K_{IC} is a function of crack length, geometry, and loading conditions—but not a direct function of material strength properties like tensile strength.

95. The primary strengthening mechanism in 70:30 brass is

- (A) Precipitation hardening
- (B) Dispersion strengthening
- (C) Fiber strengthening
- (D) Solid solution strengthening

Correct Answer: (4) Solid solution strengthening

Solution:

70:30 brass is an alloy of copper and zinc with approximately 70% copper and 30% zinc. In such a binary alloy, the zinc atoms substitute for copper atoms in the crystal lattice, creating lattice distortions.

These distortions hinder the motion of dislocations, which is a fundamental mechanism of plastic deformation. This interference with dislocation motion increases the yield strength and hardness of the alloy.

This mechanism is termed **solid solution strengthening**, where the alloying element (zinc) is completely dissolved in the host metal (copper), and the resulting solid solution offers resistance to deformation.

Other mechanisms like precipitation hardening, dispersion strengthening, and fiber strengthening do not apply to 70:30 brass.

Quick Tip

In substitutional alloys like brass, strengthening typically arises from solid solution hardening due to the atomic size mismatch and lattice distortion.

96. Frank–Read source

- (A) Generates dislocation
- (B) Hinders the movement of dislocation
- (C) Is responsible for polygonization in edge dislocation
- (D) Is responsible for dislocation climb

Correct Answer: (1) Generates dislocation

Solution:

The Frank–Read source is a dislocation multiplication mechanism that explains how a single dislocation can generate additional dislocations under shear stress. This mechanism plays a crucial role in explaining the work hardening and plastic deformation of crystalline materials.

When stress is applied, a segment of a dislocation line pinned at both ends can bow out and loop around, producing additional dislocations in the process. These dislocation loops continue to expand and generate more dislocations, thereby contributing to plastic deformation.

This process does not hinder motion or contribute to polygonization or climb — it primarily **generates dislocations**.

Quick Tip

Frank–Read source is fundamental in crystal plasticity: it explains how materials can undergo large strains due to dislocation multiplication under applied stress.

97. The tensile load-elongation curve of a metal does not describe

- (A) Yield stress
- (B) Necking strain
- (C) Anisotropy index
- (D) Work hardening

Correct Answer: (3) Anisotropy index

Solution:

The tensile load-elongation curve of a metal typically provides information on several mechanical properties such as: - Yield stress (the stress at which permanent deformation begins), - Ultimate tensile strength, - Necking strain (where the specimen begins to narrow), - and Work hardening (the increase in stress with plastic deformation).

However, **anisotropy index** refers to the directional dependence of a material's properties (like different behavior along different axes), and this property **cannot** be directly interpreted or extracted from a standard tensile load-elongation curve.

Quick Tip

Tensile tests reveal mechanical properties such as strength, ductility, and toughness — but not directional properties like anisotropy which require specific directional testing setups.

98. Strain ageing is common in

- (A) High carbon steels
- (B) Low carbon steels
- (C) High manganese steels

(D) High chromium steels

Correct Answer: (2) Low carbon steels

Solution:

Strain ageing is a phenomenon where steel becomes harder and less ductile over time after being plastically deformed. It is primarily caused by the interaction of interstitial atoms like nitrogen and carbon with dislocations. This process is more prominent in:

- **Low carbon steels**, because they contain enough interstitial atoms to cause ageing, - And because they are more susceptible to yield point phenomena and Lüders bands formation after deformation.

High carbon steels are already relatively strong and have different deformation mechanisms, while high manganese and chromium steels are alloyed to reduce effects like strain ageing.

Quick Tip

Strain ageing is particularly a concern in forming operations and sheet metals. It can be mitigated by using aluminum-killed steels or adding stabilizers like titanium or niobium.

99. Which of the following has the lowest tensile strength?

- (A) Cementite
- (B) Bainite
- (C) Martensite
- (D) Ferrite

Correct Answer: (4) Ferrite

Solution:

Ferrite (α -iron) is a relatively soft and ductile phase of iron with a body-centered cubic (BCC) structure. It contains very little carbon and is known for:

- High ductility - Magnetic properties - **Low tensile strength** compared to other microstructural constituents of steel.

In comparison: - **Martensite** is a supersaturated solid solution of carbon in iron, formed by rapid quenching, and is very hard and strong. - **Bainite** is stronger than ferrite due to its fine microstructure and carbon distribution. - **Cementite (Fe_3C)** is a hard, brittle compound with significantly higher hardness and tensile strength than ferrite.

Hence, among all, **ferrite has the lowest tensile strength**.

Quick Tip

Remember: Ferrite is soft and ductile, while martensite and bainite are much stronger due to carbon content and transformation mechanisms.

100. The most serious manufacturing defect from fracture toughness point of view is

- (A) Crack
- (B) Pore
- (C) Surface roughness
- (D) Spherical inclusion

Correct Answer: (1) Crack

Solution:

Cracks are considered the most severe manufacturing defects from the standpoint of fracture toughness because:

- They act as stress concentrators. - The stress intensity factor K near a crack tip increases dramatically. - Even under relatively low applied loads, a crack can propagate rapidly, leading to sudden failure (brittle fracture). - Unlike pores or inclusions, cracks provide a sharp discontinuity that severely lowers the material's ability to withstand tensile stress.

Therefore, the presence of a **crack** in a component is far more critical than other defects like pores, surface roughness, or inclusions.

Quick Tip

Cracks drastically reduce fracture toughness due to high stress concentration at the crack tip. Always inspect and eliminate cracks during quality control.

101. Which of the following occupy maximum percentage of powder metallurgy parts distribution in the engineering industry?

- (A) Hardware
- (B) Household appliances
- (C) Automotive
- (D) Industrial motors

Correct Answer: (3) Automotive

Solution:

Powder metallurgy (PM) is a process widely used in the engineering industry for manufacturing precise and complex components. Among all the sectors utilizing PM components:

- The ****automotive industry**** is the largest consumer, accounting for the highest percentage of total PM parts used. - PM is extensively used in manufacturing gears, bushings, bearings, and structural parts for engines and transmissions in automobiles. - The automotive sector benefits from PM's ability to reduce cost, improve dimensional accuracy, and optimize material usage.

Hence, automotive applications dominate PM usage compared to hardware, household appliances, or industrial motors.

Quick Tip

Powder metallurgy finds maximum usage in automotive industries due to its cost-effectiveness, high precision, and suitability for mass production of complex parts.

102. Which of the following assumptions is not related to continuous casting?

- (A) Solidification begins only when the metal reaches the secondary cooling zone
- (B) The radial temperature gradient in the billet is linear
- (C) The longitudinal heat flow in the billet is significant
- (D) The metal is poured with zero superheat

Correct Answer: (3) The longitudinal heat flow in the billet is significant

Solution:

In continuous casting, several thermal and metallurgical assumptions are considered:

- **Radial heat flow** is predominant due to the geometry of billets and slabs. - Solidification starts quickly as the molten metal comes into contact with the mold and continues in the secondary cooling zone. - Typically, **metal is poured with slight superheat** to maintain fluidity and avoid premature solidification. - A **linear radial temperature gradient** is often assumed for simplification.

However, assuming **significant longitudinal heat flow** contradicts the actual thermal behavior, as heat transfer along the length (longitudinal) is minimal compared to radial cooling.

Quick Tip

In continuous casting, always focus on radial thermal gradients and minimal longitudinal heat flow; the process emphasizes efficient heat extraction radially.

103. The objection with the use of _____ is a tendency for producing a fountain effect in the casting.

- (A) Ring gate
- (B) Horn gate
- (C) Pencil gate
- (D) Top gate

Correct Answer: (2) Horn gate

Solution:

A horn gate is a type of vertical gating system used in casting. One major disadvantage of the horn gate is the **fountain effect** it can produce when molten metal enters the mold cavity. This effect results from the vertical momentum of the metal, which can cause turbulence and entrain air or slag into the casting, leading to defects like blowholes or inclusions.

Other gate types like ring gate, pencil gate, or top gate are either more controlled in terms of flow or serve different gating arrangements that avoid such turbulent entry conditions.

Quick Tip

Avoid horn gates when aiming for defect-free castings in applications sensitive to turbulence. Prefer gating systems that allow smooth, laminar metal flow into the mold cavity.

104. The microsegregation observed in casting is called

- (A) Impurities
- (B) Diffusion
- (C) Dissolution
- (D) Coring

Correct Answer: (4) Coring

Solution:

Coring is a type of microsegregation observed in cast alloys, especially during solidification. It occurs when different regions within a grain solidify at different compositions due to non-uniform cooling. As the temperature drops, the alloying elements are distributed unevenly because diffusion is insufficient to homogenize the structure during the rapid solidification process.

This leads to a **composition gradient** within the grains — richer in solute at the center and leaner at the periphery or vice versa. Coring weakens the mechanical properties and corrosion resistance of the cast material.

Quick Tip

Coring is a common issue in cast alloys and can be reduced or eliminated by post-solidification heat treatment such as homogenization, which allows diffusion to even out composition gradients.

105. Forging is accomplished in drop forging by dropping the

- (A) Work piece at high velocity

- (B) Hammer at high velocity
- (C) Die with hammer at high velocity
- (D) Weight on hammer to produce the required impact

Correct Answer: (3) Die with hammer at high velocity

Solution:

In the drop forging process, the **upper die attached to a hammer** is dropped from a height onto the workpiece placed on the lower die. The impact generated by the high-velocity fall causes plastic deformation of the material into the desired shape.

The phrase “die with hammer” implies the entire impacting assembly that acts at high velocity. It is this impact — involving both the hammer and attached die — that shapes the workpiece.

Quick Tip

Drop forging involves kinetic energy from a falling hammer. Always associate drop forging with **impact** and **die movement** at high velocity — not the workpiece.

106. Hot extrusion of aluminium is done in the temperature range of

- (A) 250°C – 300°C
- (B) 350°C – 500°C
- (C) 600°C – 800°C
- (D) 850°C – 950°C

Correct Answer: (2) 350°C – 500°C

Solution:

Hot extrusion involves heating a metal above its recrystallization temperature to make it easier to deform plastically. For aluminium, this temperature typically falls in the range of:

$$0.6T_m \text{ to } 0.75T_m \quad (\text{in Kelvin}),$$

where T_m for aluminium is approximately 933 K (or 660°C).

$$0.6 \times 933 \approx 560 \text{ K} \quad \text{and} \quad 0.75 \times 933 \approx 700 \text{ K} \Rightarrow \text{in } ^\circ\text{C} : \quad 287^\circ\text{C} \text{ to } 427^\circ\text{C}$$

Hence, $350^\circ\text{C} - 500^\circ\text{C}$ falls within the safe range used for hot extrusion of aluminium, allowing sufficient ductility and reducing the extrusion pressure.

Quick Tip

For hot extrusion of aluminium, remember: temperatures should be significantly above its recrystallization point but below melting. $350^\circ\text{C} - 500^\circ\text{C}$ is an ideal practical range.

107. Which of the following is not a non-destructive test?

- (A) Magnaflux method
- (B) Radiography
- (C) Ultrasonic testing
- (D) Fatigue testing

Correct Answer: (4) Fatigue testing

Solution:

Non-destructive testing (NDT) methods allow inspection and evaluation of materials or components without causing damage.

- **Magnaflux method** is a magnetic particle inspection used for detecting surface and near-surface defects in ferromagnetic materials. - **Radiography** uses X-rays or gamma rays to view internal features of components. - **Ultrasonic testing** uses high-frequency sound waves to detect internal flaws.

Fatigue testing, on the other hand, involves subjecting a specimen to repeated cyclic loading until failure. Hence, it causes damage and ultimately breaks the material, making it a **destructive test**.

Quick Tip

All non-destructive tests preserve the usability of the test object. If a test involves breaking, fracturing, or damaging the material to determine its properties, it's a destructive test.

108. Which of the following is an exclusively cold working process?

- (A) Spinning
- (B) Deep drawing
- (C) Rolling
- (D) Extrusion

Correct Answer: (2) Deep drawing

Solution:

Cold working processes are those performed below the recrystallization temperature of the metal, generally at room temperature. Among the given options:

- **Spinning** can be performed both hot and cold. - **Deep drawing** is a process used to form sheet metal into desired shapes at room temperature, making it exclusively a cold working process. - **Rolling** can be performed both hot (hot rolling) and cold (cold rolling). - **Extrusion** is typically a hot working process but can also be done cold in specific cases.

Thus, **deep drawing** is the only process listed that is exclusively performed in the cold working domain.

Quick Tip

Cold working increases strength through strain hardening but reduces ductility. Deep drawing is a common cold working method for manufacturing cups, shells, and similar shapes from metal sheets.

109. In cold working of steel

- (A) Grain structure does not change
- (B) Internal stresses disappear
- (C) Strength and hardness increases
- (D) It is heated above recrystallisation temperature

Correct Answer: (3) Strength and hardness increases

Solution:

Cold working refers to the plastic deformation of metals below their recrystallization temperature, usually at room temperature. In this process:

- **Grain structure is distorted**, not preserved. - **Internal stresses are introduced**, not eliminated. - **Strength and hardness increase** due to strain hardening. - **It is not heated above the recrystallization temperature** (this would be hot working).

Therefore, among the given options, the only correct statement is that **strength and hardness increases** during cold working.

Quick Tip

Cold working improves strength and hardness through dislocation accumulation, but it reduces ductility and may introduce residual stresses.

110. In two high reversing mill, the rolls used are

- (A) Two vertical
- (B) Two horizontal
- (C) Four vertical
- (D) Four horizontal

Correct Answer: (2) Two horizontal

Solution:

A **two high reversing mill** uses two rolls that rotate in opposite directions. These rolls are arranged **horizontally**, and the direction of rotation can be reversed to allow rolling in both directions without changing the position of the workpiece.

This type of mill is commonly used for initial breakdown of ingots and blooms due to its ability to handle large reductions and high loads. Vertical rolls are typically used in edge rolling or universal mills—not in standard reversing mills.

Quick Tip

In rolling mill classification, “two-high” refers to the number of rolls, while “reversing” indicates the direction of rotation can be switched for back-and-forth rolling.

111. Die casting of aluminium is not done because of the reason that, it is

- (A) Prone to high expansion on solidification
- (B) Having high tendency to react chemically with the die surface
- (C) Strong and light weight
- (D) Having high melting point and cooling time

Correct Answer: (2) Having high tendency to react chemically with the die surface

Solution:

Aluminium is generally avoided in traditional die casting processes because it has a strong tendency to react chemically with the **steel die**. This reaction forms an alloy at the die surface, leading to **soldering** or **sticking** of aluminium to the die, which affects the dimensional accuracy and surface finish of the casting and reduces die life.

While aluminium is commonly used in **pressure die casting** with special coatings and lubricants, in **conventional gravity die casting**, this reactivity presents a significant drawback.

Quick Tip

In casting processes, always consider the chemical compatibility between molten metal and die material to avoid reactions that degrade die surfaces or casting quality.

112. A tooth paste tube can be produced by

- (A) Hollow backward extrusion
- (B) Solid backward extrusion
- (C) Hollow forward extrusion
- (D) Solid forward extrusion

Correct Answer: (1) Hollow backward extrusion

Solution:

Toothpaste tubes are typically hollow, cylindrical shapes with a closed end, which are efficiently manufactured using the **hollow backward extrusion** process. In this process, a punch forces the metal to flow backward around the punch and out through the annular space between the punch and die, forming a seamless hollow product.

This method ensures: - Uniform wall thickness - High dimensional accuracy - No welding or joining required

Thus, it is ideal for manufacturing collapsible tubes like those used for toothpaste.

Quick Tip

Backward extrusion is preferred for hollow components, especially when seamless construction is essential, like in tubes and containers.

113. In casting, to promote / provide unidirectional solidification which of the following are used?

- (A) Cores
- (B) Patterns
- (C) Chills
- (D) Chaplets

Correct Answer: (3) Chills

Solution:

Chills are heat-conducting materials (typically metal) placed in the mold cavity to accelerate the solidification rate of molten metal in specific regions. Their primary function is

to promote unidirectional solidification by quickly extracting heat from critical areas, which helps in:

- Avoiding shrinkage defects
- Directing the solidification front towards the riser
- Ensuring better grain structure and sound casting

Chills can be either internal (embedded) or external (placed against the mold wall).

Quick Tip

To promote unidirectional solidification in casting, use chills to locally increase cooling rates and guide the solidification front effectively.

114. A casting defect, which occurs near the ingates as rough lumps on the surface of a casting is known as

- (A) Swell
- (B) Scab
- (C) Blow hole
- (D) Sand wash

Correct Answer: (4) Sand wash

Solution:

****Sand wash**** is a type of casting surface defect characterized by the presence of rough or scabby surfaces near the ingates. It typically appears as lumps or uneven projections on the casting surface due to erosion of the mold wall during the initial flow of molten metal.

This erosion results in loose sand particles being carried into the casting cavity by the flowing metal, which solidifies along with it and leads to surface irregularities. Causes include:

- High pouring velocity
- Turbulence of molten metal
- Weak mold material strength

This defect is typically found close to the ingates or runners.

Quick Tip

To avoid sand wash defects, ensure proper mold strength and regulate the flow rate of molten metal to minimize erosion near the ingates.

115. Skim bob is attached to

- (A) Along the runner
- (B) Ingates
- (C) Risers
- (D) Pouring cup

Correct Answer: (1) Along the runner

Solution:

A **skim bob** is a type of sand trap used in the gating system of a casting process. It is attached along the **runner** and serves to trap impurities such as slag, oxides, or floating debris in the molten metal before it reaches the mold cavity.

By placing the skim bob at an appropriate location along the runner, the flow of molten metal is directed such that lighter impurities are skimmed off and trapped, thereby preventing their entry into the final casting.

This results in higher quality castings with fewer inclusions and surface defects.

Quick Tip

To improve casting quality, always ensure proper placement of skim bobs along runners to trap slag and floating impurities effectively.

116. Which of the following welding uses consumable electrode?

- (A) Thermit
- (B) MIG
- (C) TIG
- (D) Laser

Correct Answer: (2) MIG

Solution:

MIG welding (Metal Inert Gas welding), also known as **Gas Metal Arc Welding (GMAW)**, uses a **consumable wire electrode** which is continuously fed through the welding gun. This wire melts and becomes part of the weld pool, acting both as the electrode and the filler material.

In contrast: - **TIG welding** uses a **non-consumable tungsten electrode**, and filler may be added separately. - **Laser welding** generally uses no electrode, just focused laser energy. - **Thermit welding** uses a chemical reaction between aluminum and iron oxide; no electrode is used.

Thus, **MIG** is the correct choice where the electrode is **consumable** and actively participates in the weld.

Quick Tip

Remember: MIG and SMAW use consumable electrodes; TIG uses a non-consumable tungsten electrode.

117. Stainless steel is welded using

- (A) Arc welding
- (B) Oxy-acetylene flame
- (C) Inert gas welding
- (D) Oxy-hydrogen flame

Correct Answer: (3) Inert gas welding

Solution:

Inert gas welding, such as **TIG (Tungsten Inert Gas)** or **MIG (Metal Inert Gas)** welding, is ideally suited for stainless steel due to its ability to produce clean, high-quality welds without contamination. These processes use an **inert shielding gas** (like Argon or Helium) that protects the weld area from atmospheric gases such as oxygen and nitrogen, which can cause oxidation or porosity.

Other methods like: - **Arc welding** can introduce impurities. - **Oxy-acetylene** and **oxy-hydrogen flames** are not preferred due to oxidation risks and lack of precise control

over heat.

Quick Tip

For welding stainless steel and non-ferrous metals, prefer TIG or MIG welding due to better shielding and precision.

118. Melting rates of electrodes in manual metal arc welding process is mainly governed by the

- (A) Length of the electrode
- (B) Type of coating
- (C) Welding current
- (D) Arc voltage

Correct Answer: (2) Type of coating

Solution:

In **manual metal arc welding (MMAW)**, the **type of coating on the electrode** significantly affects the melting rate. This is because the coating influences: - The arc stability, - Heat generation near the electrode tip, - Slag formation and, - The metal transfer characteristics.

While welding current and arc voltage influence the energy input, it is the **electrode coating** that controls how this energy is utilized to melt the electrode.

Quick Tip

In arc welding, electrode coating type plays a crucial role in determining the melting rate and overall weld quality.

119. Welds made with high heat input will show reduction in

- (A) Yield strength
- (B) Toughness

- (C) Fatigue strength
- (D) Mechanical strength

Correct Answer: (2) Toughness

Solution:

When welding is performed with **high heat input**, the cooling rate becomes slower. This promotes: - Formation of coarse grain structures in the heat-affected zone (HAZ), - Reduction in microstructural refinement, - Increased susceptibility to cracking.

As a result, **toughness** of the weld decreases significantly, although other properties like yield or fatigue strength may not be as drastically affected.

Quick Tip

High heat input in welding reduces cooling rate and increases grain size, leading to a drop in weld zone toughness.

120. Which of the following is not a solid state metal joining technique?

- (A) Friction welding
- (B) Diffusion welding
- (C) Electroslag welding
- (D) Ultrasonic welding

Correct Answer: (3) Electroslag welding

Solution:

Solid state welding processes are those where coalescence is achieved without melting the base materials. Instead, pressure, time, and sometimes heat below the melting point are used to facilitate bonding.

- **Friction welding**, **diffusion welding**, and **ultrasonic welding** are all solid state joining techniques. - **Electroslag welding (ESW)**, however, is a **fusion welding** process. It involves melting of filler and base material by passing current through molten slag, which acts as the heat source. Hence, ESW is **not** a solid-state welding method.

Quick Tip

Solid state welding avoids melting; fusion welding involves molten phases. Electroslag welding is a fusion process.
