GATE 2026 Metallurgical Engineering Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total Questions :**65

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Each GATE 2024 paper consists of a total of 100 marks. The examination is divided into two sections – General Aptitude (GA) and the Candidate's Selected Subjects. General Aptitude carries 15 marks, while the remaining 85 marks are dedicated to the candidate's chosen test paper syllabus.
2. GATE 2024 will be conducted in English as a Computer Based Test (CBT) at select centres in select cities. The duration of the examination is 3 hours.
3. MCQs carry 1 mark or 2 marks.
4. For a wrong answer in a 1-mark MCQ, 1/3 mark is deducted.
5. For a wrong answer in a 2-mark MCQ, 2/3 mark is deducted.
6. No negative marking for wrong answers in MSQ or NAT questions.

1. For laminar fluid flow through a smooth circular tube, the relation between friction factor (f) and Reynolds number (Re) is

(A) $f = \frac{16}{Re}$
(B) $f = \frac{24}{Re}$
(C) $f = \frac{16}{\sqrt{Re}}$
(D) $f = \frac{24}{\sqrt{Re}}$

Correct Answer: (A) $f = \frac{16}{Re}$

Solution:

Step 1: Understanding the Question:
The question asks for the mathematical relationship between the Fanning friction factor (f) and the Reynolds number (Re) for a specific flow condition: laminar flow in a smooth circular tube.

Step 2: Key Formula or Approach:
For laminar flow in a circular pipe, the velocity profile is parabolic, and this is described by the Hagen-Poiseuille equation. The friction factor can be derived from the pressure drop given by this equation. The Reynolds number for flow in a pipe is defined as $Re = \frac{\rho v D}{\mu}$, where ρ is the fluid density, v is the average velocity, D is the pipe diameter, and μ is the dynamic viscosity. Laminar flow typically occurs when $Re < 2100$.

Step 3: Detailed Explanation:
The Fanning friction factor (f) is defined as the ratio of the wall shear stress (τ_w) to the kinetic energy per unit volume of the fluid, $f = \frac{\tau_w}{\frac{1}{2}\rho v^2}$.
From the Hagen-Poiseuille equation for laminar flow, the wall shear stress is given by $\tau_w = \frac{8\mu v}{D}$.
Substituting this into the definition of the friction factor:

$$f = \frac{8\mu v/D}{\frac{1}{2}\rho v^2} = \frac{16\mu}{\rho v D}$$

Recognizing that the Reynolds number is $Re = \frac{\rho v D}{\mu}$, we can substitute it into the equation for f:

$$f = \frac{16}{Re}$$

This relationship is a fundamental result in fluid mechanics for laminar flow in pipes.
It is important to distinguish the Fanning friction factor (f) from the Darcy-Weisbach friction factor (f_D), where $f_D = 4f$. For the Darcy factor, the relationship would be $f_D = \frac{64}{Re}$. Since $\frac{64}{Re}$ is not an option, the question is referring to the Fanning friction factor.

Step 4: Final Answer:
The correct relation is $f = \frac{16}{Re}$.

Quick Tip

For fluid dynamics problems, always identify the flow regime (laminar or turbulent) using the Reynolds number. Memorize the friction factor formula for laminar flow ($f = 16/Re$) as it's a frequently tested concept.

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2. Among the following options, a process for liquid-liquid separation is

(A) Smelting
(B) Roasting
(C) Sintering
(D) Calcination

Correct Answer: (A) Smelting

Solution:

Step 1: Understanding the Question:
The question asks to identify which of the given metallurgical processes involves the separation of two immiscible liquids.

Step 2: Detailed Explanation:
Let's analyze each option:

- **Smelting:** This is a high-temperature process used to extract a metal from its ore. During smelting, the ore is heated with a reducing agent (like coke) and a flux. This results in the formation of two immiscible liquid layers: the molten metal and a lighter molten slag (composed of impurities and flux). The molten metal is then separated from the slag by tapping them off at different levels. This is a clear example of a liquid-liquid separation.

- **Roasting:** This process involves heating a solid ore (often a sulfide) in the presence of air to convert it into a more manageable form, typically an oxide. This is a gas-solid reaction and does not involve liquid-liquid separation.

- **Sintering:** This process involves heating fine particles of ore at a temperature just below their melting point to cause them to agglomerate into a porous solid mass called sinter. This is a solid-state process.

- **Calcination:** This involves heating an ore (like a carbonate or hydroxide) in the absence or limited supply of air to decompose it and drive off a volatile component, such as carbon dioxide or water. This is a thermal decomposition process, a solid-gas reaction.

Step 3: Final Answer:
Based on the analysis, smelting is the only process among the options that involves the separation of two immiscible liquids (molten metal and molten slag).

> Quick Tip
>
> Associate key transformations with each metallurgical process: Smelting $\rightarrow$ Melting & Reduction (liquid metal + liquid slag); Roasting $\rightarrow$ Oxidation (solid + gas); Calcination $\rightarrow$ Decomposition (solid + gas); Sintering $\rightarrow$ Agglomeration (solid).

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3. The most effective concentration step for sulfide ores is

(A) Froth flotation
(B) Magnetic separation
(C) Gravity separation
(D) Electrostatic separation

Correct Answer: (A) Froth flotation

Solution:

Step 1: Understanding the Question:
The question asks for the most effective method for the concentration of sulfide ores. Concentration (or ore dressing) is the process of removing the unwanted gangue particles from the ore.

Step 2: Detailed Explanation:
Let's evaluate the suitability of each method for sulfide ores:

- **Froth Flotation:** This method is based on the principle of selectively wetting mineral particles. Sulfide ores are generally hydrophobic (water-repelling), or can be made so by adding 'collectors'. When air is bubbled through a slurry of the powdered ore, the hydrophobic sulfide particles attach to the air bubbles and rise to the surface to form a froth, which is then skimmed off. The hydrophilic gangue particles are wetted by water and settle at the bottom. This method is highly effective and widely used for concentrating sulfide ores like galena (PbS), chalcopyrite ($CuFeS_2$), and sphalerite (ZnS).

- **Magnetic Separation:** This method separates minerals based on differences in their magnetic properties. It is effective for ferromagnetic ores like magnetite (Fe_3O_4) or for separating magnetic impurities like wolframite from cassiterite. Most sulfide ores are not sufficiently magnetic for this process to be effective.

- **Gravity Separation:** This method relies on the difference in specific gravity between the ore and the gangue. It works well for heavy oxide ores like cassiterite (SnO_2) and hematite (Fe_2O_3). While there is a density difference for sulfide ores, froth flotation is generally far more efficient and selective.

- **Electrostatic Separation:** This method separates particles based on their electrical conductivity. It is used in specific applications, like separating conducting minerals from non-conducting ones, but it is not the primary or most effective method for sulfide ores in general.

Step 3: Final Answer:
The froth flotation process is uniquely suited to the surface properties of sulfide minerals and is the most common and effective industrial method for their concentration.

Quick Tip

Remember the specific ore types associated with each concentration method: Froth flotation for sulfide ores, magnetic separation for magnetic ores, and gravity separation for dense oxide ores.

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4. Both creep resistance and tensile strength of a metal can be enhanced by

(A) increase in the grain size
(B) decrease in the grain size
(C) addition of dispersoids

(D) annealing

Correct Answer: (C) addition of dispersoids

Solution:

Step 1: Understanding the Question:
The question asks which of the given options can simultaneously increase both the tensile strength (resistance to deformation at lower temperatures) and the creep resistance (resistance to deformation at high temperatures under a constant load) of a metal.

Step 2: Detailed Explanation:
Let's analyze the effect of each option on mechanical properties:

- **(A) Increase in the grain size:** A larger grain size generally decreases tensile strength at room temperature (contrary to the Hall-Petch relationship). However, at high temperatures where creep is dominated by grain boundary sliding, larger grains can improve creep resistance. Since it decreases tensile strength, this option is incorrect.

- **(B) Decrease in the grain size:** According to the Hall-Petch relationship, decreasing the grain size increases the tensile strength by increasing the number of grain boundaries that impede dislocation motion. This also improves creep resistance at lower temperatures. However, at very high temperatures, a fine grain structure can lead to faster creep due to increased grain boundary sliding. Therefore, it does not reliably enhance both properties under all conditions.

- **(C) Addition of dispersoids:** Dispersoids are fine, stable, and non-coherent particles (e.g., oxides, carbides) distributed within the metal matrix. This process is known as dispersion strengthening. These particles act as very effective obstacles to dislocation motion at both room temperature and elevated temperatures. This significantly increases both tensile strength and creep resistance, as the dislocations must climb over or bypass these particles, a process that requires high energy.

- **(D) Annealing:** This is a heat treatment process that typically involves heating a metal to a specific temperature and then cooling it slowly. The primary purpose of annealing is to relieve internal stresses, increase ductility and toughness, and produce a specific microstructure. It generally results in a softer material with lower tensile strength and hardness. Thus, it is the opposite of what is required.

Step 3: Final Answer:
The addition of dispersoids is the most effective method among the choices for simultaneously enhancing both tensile strength and high-temperature creep resistance.

Quick Tip

Remember that strengthening mechanisms that hinder dislocation motion (like precipitation and dispersion strengthening) are effective at both low and high temperatures, thus improving both tensile strength and creep resistance.

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5. A rod is elastically deformed by a uniaxial stress resulting in a strain of 0.02. If the Poisson's ratio is 0.3, the volumetric strain is _______________ (answer up to three decimal places)

Correct Answer: 0.008

Solution:

Step 1: Understanding the Question:
The problem provides the axial strain (ϵ_z) on a rod under uniaxial stress and the material's Poisson's ratio (ν). We need to calculate the resulting volumetric strain (ϵ_V).

Step 2: Key Formula or Approach:
The volumetric strain, ϵ_V, is the sum of the strains in three mutually perpendicular directions:

$$\epsilon_V = \epsilon_x + \epsilon_y + \epsilon_z$$

For a uniaxial stress applied along the z-axis, the strain in that direction is the axial strain, ϵ_z. The strains in the transverse (lateral) directions, ϵ_x and ϵ_y, are related to the axial strain by the Poisson's ratio, ν:

$$\epsilon_x = \epsilon_y = -\nu\epsilon_z$$

Substituting the lateral strains into the volumetric strain equation gives a simplified formula for uniaxial loading:

$$\epsilon_V = (-\nu\epsilon_z) + (-\nu\epsilon_z) + \epsilon_z = \epsilon_z(1 - 2\nu)$$

Step 3: Detailed Explanation:
We are given the following values:

- Axial strain, $\epsilon_z = 0.02$
- Poisson's ratio, $\nu = 0.3$

Now, we substitute these values into the derived formula:

$$\epsilon_V = 0.02 \times (1 - 2 \times 0.3)$$

$$\epsilon_V = 0.02 \times (1 - 0.6)$$

$$\epsilon_V = 0.02 \times (0.4)$$

$$\epsilon_V = 0.008$$

Step 4: Final Answer:
The volumetric strain is 0.008. The answer is already in three decimal places.

Quick Tip

For uniaxial stress problems, the relationship $\epsilon_V = \epsilon_{axial}(1 - 2\nu)$ is a direct and quick way to find volumetric strain from axial strain and Poisson's ratio.

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6. Which one of the following manufacturing techniques is used for making window glass?

(A) Investment casting
(B) Patenting
(C) Spray forming
(D) Float-bath method

Correct Answer: (D) Float-bath method

Solution:

Step 1: Understanding the Question:
The question asks to identify the specific manufacturing process used to produce large, flat sheets of glass, such as those used for windows.

Step 2: Detailed Explanation:
Let's analyze the given options:

- **Investment casting:** This is a process for making complex, intricate metal parts. A wax pattern is created, coated with a ceramic shell (the investment), and then the wax is melted out. Molten metal is then poured into the shell. This is not used for flat glass sheets.

- **Patenting:** This is a specific heat treatment process applied to high-carbon steel wire to produce a fine-grained pearlite structure, which is ideal for drawing into high-strength wires (e.g., for springs or bridge cables). It is unrelated to glass manufacturing.

- **Spray forming:** This is a process for producing semi-finished metal products. A stream of molten metal is atomized by high-velocity gas jets and sprayed onto a substrate, building up a solid deposit. It is used for metals, not glass sheets.

- **Float-bath method:** Also known as the Pilkington process, this is the modern standard for manufacturing high-quality, flat sheet glass. In this method, molten glass is poured from a furnace onto a shallow bath of molten tin. The glass floats on the tin, spreading out to form a flat surface with a uniform thickness. The surface tension of the glass and the perfectly flat surface of the molten tin create a glass sheet with near-perfectly smooth surfaces. This is the method used for making window glass.

Step 3: Final Answer:
The float-bath method is the correct technique used for manufacturing window glass.

> **Quick Tip**
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> Associate "window glass" or "flat glass" with the "float-bath" or "Pilkington" process, which involves floating molten glass on a bed of molten tin.

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7. Dye penetrant test is based on the principle of

(A) polarized sound waves in liquid.
(B) magnetic domain.
(C) absorption of X-rays.
(D) capillary action.

Correct Answer: (D) capillary action.

Solution:

Step 1: Understanding the Question:
The question asks for the fundamental physical principle behind the Dye Penetrant Test, a common non-destructive testing (NDT) method.

Step 2: Detailed Explanation:
The Dye Penetrant Inspection (DPI) method works as follows:

1. A low-viscosity liquid dye (penetrant) is applied to the surface of a non-porous material.
2. Due to **capillary action**, the penetrant is drawn into any surface-breaking defects (like cracks, seams, or porosity).
3. After a sufficient dwell time, the excess penetrant is removed from the surface.
4. A developer is applied, which acts like a blotter, drawing the trapped penetrant out of the defects.
5. The drawn-out penetrant creates a visible indication (often under UV light for fluorescent dyes) that is much larger than the actual flaw, making it easy to detect.

The entire process relies on the ability of the liquid to seep into very fine openings, which is the definition of capillary action.
Let's look at the principles for the other options:

- **Polarized sound waves in liquid:** This is the principle behind Ultrasonic Testing (UT).

- **Magnetic domain:** This is the principle behind Magnetic Particle Testing (MPT), which is used for ferromagnetic materials.

- **Absorption of X-rays:** This is the principle behind Radiographic Testing (RT).

Step 3: Final Answer:
The Dye Penetrant Test is fundamentally based on the principle of capillary action.

Quick Tip

For NDT methods, remember the key principle: Dye Penetrant → Capillary Action; Magnetic Particle → Magnetic Fields; Ultrasonic → Sound Waves; Radiography → X-rays/Gamma rays.
