

AP PGECET 2025 Nano Technology Question Paper with Solutions

Time Allowed :2 Hour	Maximum Marks :120	Total Questions :120
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General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 2 hour duration.
2. The question paper consists of 120 questions. The maximum marks are 120.
3. The questions are related to Nano Technology.

1. The shape of first Brillouin zone of an FCC lattice is?

- (A) Tetrahedral
- (B) Triagonal
- (C) Truncated hexagon
- (D) Truncated octahedron

Correct Answer: (D) Truncated octahedron

Solution:

Step 1: Understanding the Question:

The question asks for the geometric shape of the first Brillouin zone for a face-centered cubic (FCC) crystal lattice.

Step 2: Key Formula or Approach:

The first Brillouin zone is defined as the Wigner-Seitz cell of the reciprocal lattice. Therefore, to find the shape of the first Brillouin zone for an FCC lattice, we must first determine its reciprocal lattice structure. It is a standard result in solid-state physics that the reciprocal lattice of an FCC lattice is a body-centered cubic (BCC) lattice.

Step 3: Detailed Explanation:

1. The real space lattice is Face-Centered Cubic (FCC).
2. The reciprocal lattice of an FCC lattice is a Body-Centered Cubic (BCC) lattice.
3. The first Brillouin zone of the FCC lattice is, by definition, the Wigner-Seitz cell of its BCC reciprocal lattice.
4. A Wigner-Seitz cell is constructed by taking a central lattice point and drawing perpendicular bisector planes to the lines connecting this point to all its nearest and next-nearest neighbors. The smallest enclosed volume is the Wigner-Seitz cell.
5. For a BCC lattice, the central point has 8 nearest neighbors at the corners of a cube and 6 next-nearest neighbors at the centers of adjacent cubes. Constructing the Wigner-Seitz cell by drawing perpendicular bisectors to these vectors results in a polyhedron with 14 faces, known

as a **truncated octahedron**.

Step 4: Final Answer:

The reciprocal lattice of FCC is BCC. The Wigner-Seitz cell of a BCC lattice is a truncated octahedron. Therefore, the first Brillouin zone of an FCC lattice is a truncated octahedron. This corresponds to option (D).

💡 Quick Tip

It's crucial for exams to memorize the reciprocal lattice pairs and their corresponding first Brillouin zone shapes:

- **Simple Cubic (SC)** → Reciprocal is **SC** → Zone is a **Cube**.
- **Body-Centered Cubic (BCC)** → Reciprocal is **FCC** → Zone is a **Rhombic Dodecahedron**.
- **Face-Centered Cubic (FCC)** → Reciprocal is **BCC** → Zone is a **Truncated Octahedron**.

2. For a body to be in equilibrium under concurrent coplanar forces, the sum of:

- (A) Moments must be zero
- (B) Forces in vertical direction must be zero
- (C) All forces must be zero
- (D) Horizontal and vertical components of forces must each be zero

Correct Answer: (D) Horizontal and vertical components of forces must each be zero

Solution:

Step 1: Understanding the Question:

The question asks for the conditions of equilibrium for a body subjected to a system of forces that are both concurrent (all forces pass through a single point) and coplanar (all forces lie in the same plane).

Step 2: Key Formula or Approach:

The general conditions for static equilibrium of a rigid body are:

1. The vector sum of all external forces is zero ($\sum \vec{F} = 0$).
2. The sum of moments of all external forces about any point is zero ($\sum \vec{M} = 0$).

Step 3: Detailed Explanation:

The forces are described as **concurrent**. This means all forces intersect at a single point. The moment of a force about a point is the force multiplied by the perpendicular distance. If we calculate the moments about the point of concurrency, the distance for every force is zero, so the sum of moments ($\sum \vec{M}$) is automatically zero. Therefore, the moment equilibrium condition is trivially satisfied for concurrent force systems.

This leaves only the force equilibrium condition: $\sum \vec{F} = 0$.

For a **coplanar** (2D) system of forces, the vector equation $\sum \vec{F} = 0$ can be broken down into two scalar equations by resolving the forces into orthogonal components (typically horizontal, x, and vertical, y):

$$\sum F_x = 0$$
$$\sum F_y = 0$$

This means the sum of the horizontal components of forces must be zero, and the sum of the vertical components of forces must also be zero. Option (D) states this precisely. Option (C) is also technically correct, but (D) is the practical and explicit method for applying the condition.

Step 4: Final Answer:

For a concurrent coplanar force system, equilibrium is achieved when the net force is zero, which is ensured by making the sum of horizontal and vertical components of the forces each equal to zero. This corresponds to option (D).

💡 Quick Tip

Remember the key terms for equilibrium conditions:

- For **any** system: $\sum \vec{F} = 0$ and $\sum \vec{M} = 0$.
- For a **concurrent** system: Only $\sum \vec{F} = 0$ needs to be checked, as $\sum \vec{M} = 0$ is automatic about the point of concurrency.

3. A metal nanopowder is produced by four different process as given below. Spherical morphology of the powder is more likely in?

- (A) Electrolytic reduction process
- (B) Water atomization process
- (C) Machining process
- (D) Air atomization process

Correct Answer: (D) Air atomization process

Solution:

Step 1: Understanding the Question:

The question asks which of the listed synthesis methods is most likely to produce nanopowders with a spherical shape. Spherical morphology is often desired as it minimizes surface area for a given volume and improves flowability.

Step 2: Detailed Explanation:

Let's analyze the typical particle morphology produced by each process:

- **Machining process:** This is a top-down mechanical attrition method (e.g., ball milling). It

involves grinding and fracturing bulk material, which results in irregular, angular, and work-hardened particles.

- **Electrolytic reduction process:** This is a bottom-up chemical method. The morphology can be controlled to some extent, but it often produces dendritic (tree-like) or spongy, irregular structures.

- **Atomization processes:** In these methods, a stream of molten metal is broken into fine droplets by a high-velocity fluid. Due to surface tension, liquid droplets naturally tend to form a spherical shape to minimize their surface energy.

- **Water atomization:** Uses high-pressure water jets. The cooling rate is very high ($\sim 10^4 - 10^6$ K/s). This rapid solidification can "freeze" the droplets in an irregular or ligamental shape before they have sufficient time to become fully spherical.

- **Air (or gas) atomization:** Uses high-velocity air or inert gas. The cooling rate is significantly lower than water atomization ($\sim 10^2 - 10^4$ K/s). This slower cooling allows the molten droplets more time to form a stable, low-energy spherical shape before they solidify.

Step 3: Final Answer:

Comparing the methods, air atomization provides the necessary conditions (liquid droplets and sufficient time before solidification) to produce a predominantly spherical powder morphology. This corresponds to option (D).

💡 Quick Tip

To get spherical particles, you generally need a process where the material passes through a liquid or gas phase and solidifies slowly enough for surface tension to pull it into a sphere. Faster cooling or purely mechanical processes tend to create irregular shapes.

4. In a simply supported beam, where does maximum bending moment occur under a point load?

- (A) At the support
- (B) At the point load
- (C) Mid-span
- (D) Uniform throughout

Correct Answer: (B) At the point load

Solution:

Step 1: Understanding the Question:

The question asks for the location of the maximum bending moment in a simply supported beam that is subjected to a single concentrated force (a point load).

Step 2: Key Formula or Approach:

The relationship between Shear Force (V) and Bending Moment (M) in a beam is fundamental:

$$V = \frac{dM}{dx}$$

This mathematical relationship implies that the bending moment M will be at a local maximum or minimum when its derivative, the shear force V, is equal to zero. Therefore, to find the location of the maximum bending moment, we must find where the shear force is zero or changes its sign.

Step 3: Detailed Explanation:

Consider a simply supported beam of length L with a point load P at a distance 'a' from the left support.

1. First, calculate the support reactions. Let R_A and R_B be the reactions at the left and right supports. $R_A = Pb/L$ and $R_B = Pa/L$.
2. Now, analyze the shear force along the beam.
 - In the section to the left of the load ($0 < x < a$), the shear force is constant and equal to R_A .
 - In the section to the right of the load ($a < x < L$), the shear force is constant and equal to $R_A - P = -R_B$.
3. The shear force diagram shows that the shear force is positive from the left support up to the point load, and then it abruptly drops by the magnitude of the load P, becoming negative. The shear force diagram crosses the zero axis precisely at the location where the point load is applied.
4. Since the maximum bending moment occurs where the shear force is zero, the maximum bending moment must occur directly under the point load.

Step 4: Final Answer:

The maximum bending moment in a simply supported beam under a point load occurs at the location of the point load itself. This corresponds to option (B).

💡 Quick Tip

A key rule in beam analysis is: **Maximum bending moment occurs where the shear force is zero or changes sign.** For a point load on a simply supported beam, this always happens at the point load.

5. Which mathematical method is used in X-ray crystallography?

- (A) Fourier Transformation
- (B) Partial Differentiation
- (C) Geiger Method
- (D) Permutation

Correct Answer: (A) Fourier Transformation

Solution:

Step 1: Understanding the Question:

The question asks for the core mathematical technique that underpins the analysis of data in X-ray crystallography to determine crystal structures.

Step 2: Detailed Explanation:

X-ray crystallography is a technique used to determine the atomic and molecular structure of a crystal. The process works as follows:

1. A beam of X-rays is directed at a crystal. The X-rays are diffracted by the periodic arrangement of atoms (specifically, the electron clouds) within the crystal lattice.
2. The diffracted X-rays produce a pattern of spots of varying intensities on a detector. This diffraction pattern is a representation of the crystal structure in **reciprocal space**.
3. The goal is to determine the electron density map, which shows the positions of atoms in **real space**.
4. The mathematical relationship between the electron density in real space and the diffraction pattern in reciprocal space is the **Fourier transform**. The electron density function and the structure factor amplitudes (derived from the diffraction pattern) are a Fourier transform pair. Therefore, to reconstruct the crystal structure from the diffraction data, an inverse Fourier transform is performed.

The other options are not relevant: Partial differentiation is a general calculus tool, the Geiger method refers to radiation detection (like a Geiger counter), and permutation is a concept from combinatorics.

Step 3: Final Answer:

The Fourier transform is the fundamental mathematical method used to convert X-ray diffraction data into a 3-D model of electron density, and thus determine the crystal structure. This corresponds to option (A).

💡 Quick Tip

Remember the central relationship in crystallography:
The crystal structure (in real space) and its diffraction pattern (in reciprocal space) are related by the Fourier transform. To get the structure from the pattern, you perform an inverse Fourier transform.

6. In 2D viscous incompressible flow, the continuity equation is:

- (A) $\partial u / \partial x + \partial v / \partial y = 0$
- (B) $\partial u / \partial x + \partial v / \partial x = 0$
- (C) $\partial u / \partial y = \partial v / \partial x$
- (D) $\partial^2 u / \partial x^2 = \partial^2 v / \partial y^2$

Correct Answer: (A) $\partial u/\partial x + \partial v/\partial y = 0$

Solution:

Step 1: Understanding the Question:

The question asks for the mathematical form of the continuity equation for a two-dimensional (2D), viscous, incompressible fluid flow.

Step 2: Key Formula or Approach:

The continuity equation is a mathematical statement of the principle of **conservation of mass**. In its general differential form, it is:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{V}) = 0$$

where ρ is the fluid density, t is time, and $\vec{V}$ is the velocity vector.

Step 3: Detailed Explanation:

We are given two conditions for the flow:

1. **Incompressible flow:** This means the density ρ is constant. Therefore, its derivative with respect to time and space is zero ($\frac{\partial \rho}{\partial t} = 0$). The continuity equation simplifies to:

$$\nabla \cdot \vec{V} = 0$$

This is the continuity equation for any incompressible flow.

2. **2D flow:** In two-dimensional Cartesian coordinates, the velocity vector is $\vec{V} = u\hat{i} + v\hat{j}$, where u and v are the velocity components in the x and y directions, respectively. The divergence operator $\nabla \cdot$ is $\frac{\partial}{\partial x} + \frac{\partial}{\partial y}$. Applying the divergence operator to the velocity vector:

$$\nabla \cdot \vec{V} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Setting this equal to zero gives the final form of the equation:

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

The term "viscous" is additional information that relates to the momentum equation (Navier-Stokes equation) but does not affect the continuity equation, which is based solely on mass conservation.

Step 4: Final Answer:

The continuity equation for a 2D incompressible flow is $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$. This corresponds to option (A).

💡 Quick Tip

The continuity equation for an incompressible flow is always $\nabla \cdot \vec{V} = 0$ (the divergence of velocity is zero). You just need to know how to write the divergence operator in different coordinate systems (Cartesian, cylindrical, etc.).

7. Grain size distribution in nano material is close to?

- (A) Bimodal
- (B) Parabolic
- (C) Log normal
- (D) Exponential

Correct Answer: (C) Log normal

Solution:

Step 1: Understanding the Question:

The question asks which statistical distribution best describes the variation in the sizes of grains or particles in a typical nanomaterial sample.

Step 2: Detailed Explanation:

The synthesis of nanoparticles often involves nucleation and growth processes. These processes are stochastic (random) in nature, leading to a population of particles with a range of sizes, rather than a single uniform size.

- A normal (Gaussian) distribution is often not suitable because particle growth is a multiplicative process (growth rate is often proportional to the existing surface area or volume), not an additive one. Also, a normal distribution is symmetric and extends to negative infinity, which is physically impossible for particle size.

- A **Log-normal distribution** is a continuous probability distribution of a random variable whose logarithm is normally distributed. This distribution is skewed to the right and is bounded at zero, which accurately reflects the physical constraints of particle sizes. Many natural growth phenomena and particle size distributions resulting from processes like milling or precipitation are well-described by the log-normal distribution. It is the most commonly accepted model for grain size distribution in nanomaterials.

- A bimodal distribution would imply two distinct populations of particle sizes, which is possible but not the typical case. Parabolic and exponential distributions are less common for describing particle sizes.

Step 3: Final Answer:

The grain size distribution in most nanomaterial samples, as a result of nucleation and growth processes, is best approximated by a log-normal distribution. This corresponds to option (C).

Quick Tip

For questions about the statistical distribution of sizes that result from natural growth or breakage processes (like particle sizes, grain sizes, mineral deposits), the log-normal distribution is a very common and often correct answer.

8. The number of dimensionless groups formed using Buckingham's π -theorem is:

- (A) Equal to number of variables
- (B) Equal to number of fundamental dimensions
- (C) Variables minus fundamental dimensions
- (D) Always 3

Correct Answer: (C) Variables minus fundamental dimensions

Solution:

Step 1: Understanding the Question:

The question asks for the rule given by Buckingham's π -theorem to determine the number of independent dimensionless groups (or π terms) in a physical problem.

Step 2: Key Formula or Approach:

Buckingham's π -theorem is the key theorem in dimensional analysis. It states that if a physical process is described by an equation involving 'n' physical variables, which can be expressed in terms of 'm' fundamental dimensions (like mass, length, time, temperature, etc.), then the original equation can be rewritten as an equation of $k = n - m$ independent dimensionless groups ($\pi_1, \pi_2, \dots, \pi_k$).

Step 3: Detailed Explanation:

Let:

- n = the total number of physical variables involved in the problem.
- m = the number of fundamental dimensions required to express these variables (e.g., M, L, T for mechanics problems).

According to the theorem, the number of dimensionless π groups, k , is:

$$k = n - m$$

This means the number of dimensionless groups is the total number of variables minus the number of fundamental dimensions.

Step 4: Final Answer:

The number of dimensionless groups is equal to the number of variables minus the number of fundamental dimensions. This corresponds to option (C).

💡 Quick Tip

Remember the simple formula for Buckingham's π -theorem:

Number of π terms = (Number of variables) - (Number of dimensions).

For example, if you have 5 variables ($n=5$) and they involve mass, length, and time ($m=3$), you will get $5 - 3 = 2$ dimensionless groups.

9. On a Mohr's circle, any point on the circle represents:

- (A) Axial stress only
- (B) Pure shear
- (C) Stress on some inclined plane
- (D) Principle stress

Correct Answer: (C) Stress on some inclined plane

Solution:

Step 1: Understanding the Question:

The question asks for the physical meaning of an arbitrary point on the circumference of a Mohr's circle.

Step 2: Detailed Explanation:

Mohr's circle is a graphical method for representing the state of stress at a single point in a body and for determining stresses on arbitrarily oriented planes.

- The horizontal axis represents normal stress (σ).
- The vertical axis represents shear stress (τ).

Key points on the circle have specific meanings:

- The two points where the circle intersects the horizontal axis represent the **principal stresses** (σ_1 and σ_2). At these points, the shear stress is zero. These correspond to the maximum and minimum normal stresses at the point.
- The highest and lowest points on the circle represent the maximum shear stress (τ_{max}).
- An **arbitrary point** (σ, τ) **on the circumference of the circle** represents the specific combination of normal stress (σ) and shear stress (τ) that acts on a **unique, specific inclined plane** passing through the point in the material. Rotating by an angle 2θ on the Mohr's circle corresponds to rotating the physical plane by an angle θ .

Step 3: Final Answer:

Any point on the circumference of Mohr's circle represents the state of stress (the normal and shear components) on a particular inclined plane. This corresponds to option (C).

💡 Quick Tip

Think of Mohr's circle as a complete "map" of the stress state at a point.

- The horizontal intercepts are the principal stresses (pure normal stress).
- Every other point on the circle shows the combination of normal and shear stress on a plane at a specific angle.

10. The equation which describes the relationship between grain size and the yield of poly crystalline metals is called as?

- (A) Burgers' equation
- (B) Hall-Petch equation
- (C) Boltzmann equation
- (D) Braggs' equation

Correct Answer: (B) Hall-Petch equation

Solution:

Step 1: Understanding the Question:

The question asks for the name of the specific equation that relates the mechanical yield strength of a polycrystalline metal to its average grain size.

Step 2: Key Formula or Approach:

The phenomenon being described is grain boundary strengthening, where smaller grains lead to a stronger material. The equation that quantifies this is the Hall-Petch equation:

$$\sigma_y = \sigma_0 + k_y d^{-1/2}$$

where σ_y is the yield stress, d is the average grain diameter, and σ_0 and k_y are constants specific to the material.

Step 3: Detailed Explanation:

- **Hall-Petch equation:** This empirical equation correctly describes how the yield strength of many materials increases as the grain size decreases. Grain boundaries act as obstacles to dislocation motion, and a material with smaller grains has more grain boundary area, thus providing more resistance to deformation.
- **Burgers' equation:** A fundamental equation in fluid dynamics describing wave propagation and shock formation. It is unrelated to material strength.
- **Boltzmann equation:** A key equation in statistical mechanics that describes the statistical behavior of a thermodynamic system not in a state of equilibrium. It is unrelated to material strength.
- **Bragg's equation (or Bragg's Law):** A fundamental equation in X-ray crystallography that relates the wavelength of X-rays to the angle of diffraction and the lattice spacing in a crystal ($n\lambda = 2d \sin \theta$). It is unrelated to material strength.

Step 4: Final Answer:

The relationship between grain size and yield strength is described by the Hall-Petch equation. This corresponds to option (B).

💡 Quick Tip

For materials science exams, the Hall-Petch relationship is a fundamental concept. Memorize the association: **Hall-Petch = Grain Size $\leftrightarrow$ Strength**. Smaller grains mean higher strength.

11. A method used to produce high quality semiconductor grade material?

- (A) Floating zone refining
- (B) Laser ablation
- (C) Vacuum arc melting
- (D) Vacuum induction melting

Correct Answer: (A) Floating zone refining

Solution:

Step 1: Understanding the Question:

The question asks for a method suitable for producing materials with the extremely high purity required for semiconductor applications (e.g., silicon wafers).

Step 2: Detailed Explanation:

- **Floating zone refining (or Zone melting):** This is a specialized purification technique based on the principle that impurities are generally more soluble in the molten (liquid) phase of a material than in its solid phase. A narrow molten zone is created in a solid rod of material and is slowly moved from one end to the other. As it moves, it "sweeps" the impurities along with it, concentrating them at one end of the rod, which is later discarded. This process can be repeated to achieve extremely high levels of purity (e.g., parts per billion), which is essential for semiconductor grade silicon. It is also a containerless method, preventing contamination from a crucible.

- **Laser ablation:** This is a process for removing material from a surface by irradiating it with a laser beam. It is used for micromachining, thin-film deposition, and creating nanoparticles, not for bulk purification.

- **Vacuum arc melting and Vacuum induction melting:** These are methods for melting and alloying metals under vacuum to prevent oxidation and remove some volatile impurities. However, they do not achieve the ultra-high purity required for semiconductor devices.

Step 3: Final Answer:

Floating zone refining is a key industrial process used to produce high-purity, single-crystal boules of semiconductor materials like silicon. This corresponds to option (A).

💡 Quick Tip

When you see "high purity," "semiconductor grade," or "single crystal" in a question about material processing, zone refining (including floating zone) and the Czochralski method are the most likely correct answers.

12. Laminar flow is characterized by:

- (A) High Reynolds number
- (B) Random particle motion
- (C) Smooth, orderly layers
- (D) Sudden pressure drops

Correct Answer: (C) Smooth, orderly layers

Solution:

Step 1: Understanding the Question:

The question asks for the defining characteristic of laminar fluid flow.

Step 2: Detailed Explanation:

Fluid flow can be classified into two main regimes: laminar and turbulent.

- **Laminar flow:** This regime is characterized by fluid particles moving in smooth, parallel paths or layers (called laminae). There is no mixing between adjacent layers. The flow is orderly, predictable, and occurs at low velocities. The term "laminar" itself comes from "lamina," meaning layer. Therefore, "smooth, orderly layers" is the very definition of laminar flow.
- **Turbulent flow:** This regime is characterized by chaotic, irregular, and random fluid motion with eddies and vortices. There is significant mixing within the fluid.

Let's analyze the options:

- (A) **High Reynolds number:** This is characteristic of turbulent flow. Laminar flow occurs at low Reynolds numbers.
- (B) **Random particle motion:** This describes the chaotic nature of turbulent flow.
- (C) **Smooth, orderly layers:** This is the definition of laminar flow.
- (D) **Sudden pressure drops:** While pressure drops occur in all flow, large and fluctuating pressure drops are more characteristic of turbulent flow.

Step 3: Final Answer:

Laminar flow is characterized by the fluid moving in smooth, orderly layers. This corresponds to option (C).

 Quick Tip

Remember the key distinction based on the Reynolds number (Re), which compares inertial forces to viscous forces:

- **Low Re** $\rightarrow$ Viscous forces dominate $\rightarrow$ **Laminar Flow** (smooth and orderly).
- **High Re** $\rightarrow$ Inertial forces dominate $\rightarrow$ **Turbulent Flow** (chaotic and random).

13. Differential scanning calorimetry is used for the determination of?

- (A) Surface topography
- (B) Co-efficient of thermal expansion
- (C) Phase transformations
- (D) Grain boundary chemical analysis

Correct Answer: (C) Phase transformations

Solution:

Step 1: Understanding the Question:

The question asks for the primary application of the thermal analysis technique known as Differential Scanning Calorimetry (DSC).

Step 2: Detailed Explanation:

Differential Scanning Calorimetry (DSC) is a thermoanalytical technique in which the difference in the amount of heat required to increase the temperature of a sample and a reference is measured as a function of temperature. Both the sample and reference are maintained at nearly the same temperature throughout the experiment.

The main purpose of DSC is to observe thermal events in a material as it is heated or cooled. When a material undergoes a **phase transformation** (such as melting, crystallization, or a glass transition), it is accompanied by a change in enthalpy, meaning heat is either absorbed (endothermic) or released (exothermic). DSC is extremely sensitive to these changes in heat flow. The output of a DSC experiment is a thermogram, which shows peaks or shifts in the baseline at the temperatures where these transformations occur.

Let's look at the other options:

- **Surface topography** is studied using microscopy techniques like Scanning Electron Microscopy (SEM) or Atomic Force Microscopy (AFM).
- **Co-efficient of thermal expansion** is measured using a technique called thermomechanical analysis (TMA) or dilatometry.
- **Grain boundary chemical analysis** is performed using techniques like Energy-dispersive X-ray spectroscopy (EDS) or Auger electron spectroscopy (AES).

Step 3: Final Answer:

DSC is a primary tool for determining the temperatures and enthalpies of phase transformations in materials. This corresponds to option (C).

 Quick Tip

The name "calorimetry" is the biggest clue. A calorimeter measures heat (*calor*). Differential Scanning Calorimetry (DSC) measures the *difference* in heat flow as you *scan* the temperature. This is ideal for detecting any process that involves heat, like phase changes.

14. In Joule's experiment, heat is converted into:

- (A) Light
- (B) Work
- (C) Entropy
- (D) Internal energy

Correct Answer: (D) Internal energy

Solution:

Step 1: Understanding the Question:

The question asks about the energy conversion that occurs in the context of Joule's experiment.

Step 2: Detailed Explanation:

Joule's famous paddle wheel experiment demonstrated the mechanical equivalent of heat.

In this experiment, mechanical work was performed on a thermally insulated container of water by a paddle wheel driven by falling weights.

This work resulted in an increase in the water's temperature.

The key finding was that the work done on the system was directly proportional to the increase in its thermal energy.

This established that work can be converted into heat, or more precisely, that both work and heat are forms of energy transfer that change the internal energy of a system.

The first law of thermodynamics states $\Delta U = Q - W$, where ΔU is the change in internal energy, Q is the heat added to the system, and W is the work done by the system.

In a process where heat is added to a system ($Q > 0$) without any work being done ($W = 0$), the heat energy is directly converted into the internal energy of the system ($\Delta U = Q$).

Therefore, heat is fundamentally converted into internal energy.

Step 3: Final Answer:

Based on the principles of thermodynamics demonstrated by Joule, heat supplied to a system increases its internal energy.

Therefore, heat is converted into internal energy.

💡 Quick Tip

Remember the first law of thermodynamics: $\Delta U = Q - W$. This equation is the foundation for understanding energy conversions. Joule's experiment established the link between mechanical work and internal energy, proving they are interconvertible forms of energy.

15. Inert gas used in Brunauer - Emmet - Teller (BET) surface area analysis for measuring low surface area values is:

- (A) N_2
- (B) Ar
- (C) Kr
- (D) Xe

Correct Answer: (C) Kr

Solution:

Step 1: Understanding the Question:

The question asks which inert gas is most suitable for BET analysis of materials with low surface areas.

Step 2: Detailed Explanation:

The Brunauer-Emmett-Teller (BET) method is a widely used technique for measuring the specific surface area of materials.

It works by measuring the amount of gas that physically adsorbs onto the surface of a material at cryogenic temperatures (typically that of liquid nitrogen, 77 K).

Nitrogen (N_2) is the most common gas used for BET analysis.

However, for materials with very low surface areas (e.g., $< 1 \text{ m}^2/\text{g}$), the amount of adsorbed nitrogen is extremely small.

At 77 K, nitrogen has a high saturation vapor pressure (approx. 760 torr).

This makes it difficult to accurately measure the small pressure changes associated with the small amount of gas adsorption, leading to large errors.

Krypton (Kr) has a much lower saturation vapor pressure at 77 K (approx. 2.5 torr).

This lower vapor pressure allows for much more sensitive and accurate measurements of the small quantities of gas adsorbed on low-surface-area samples.

Therefore, Krypton is the preferred adsorbate for such measurements.

Step 3: Final Answer:

Due to its low saturation vapor pressure at liquid nitrogen temperature, Krypton (Kr) allows for more precise measurements of adsorption on low-surface-area materials.

💡 Quick Tip

For BET analysis, remember the rule: use Nitrogen (N_2) for general-purpose/high surface area measurements and Krypton (Kr) for low surface area measurements. The choice of gas is dictated by its saturation vapor pressure at the analysis temperature.

16. An Ellingham diagram is used to:

- (A) Calculate melting points
- (B) Determine gas fugacity
- (C) Predict reduction feasibility of metal oxides
- (D) Evaluate activity coefficients

Correct Answer: (C) Predict reduction feasibility of metal oxides

Solution:

Step 1: Understanding the Question:

The question asks for the primary application of an Ellingham diagram.

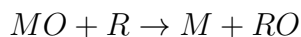
Step 2: Detailed Explanation:

An Ellingham diagram is a graph that plots the standard Gibbs free energy of formation (ΔG°) of oxides (and sulfides, etc.) as a function of temperature.

The primary use of this diagram is in extractive metallurgy.

A chemical reaction is thermodynamically feasible if the change in Gibbs free energy (ΔG) for the overall reaction is negative.

In the context of reducing a metal oxide (MO) with a reducing agent (R), the overall reaction is:



The Ellingham diagram allows for a quick visual assessment of this feasibility.

Any element's line on the diagram represents the oxidation reaction.

For a reduction to occur, the line for the reducing agent must lie below the line for the metal oxide being reduced at a given temperature.

This geometric condition ensures that the overall ΔG for the reduction reaction is negative.

Step 3: Final Answer:

The diagram is a thermodynamic tool used to predict the temperature at which a metal oxide can be reduced by a specific reducing agent (like carbon, carbon monoxide, or another metal).

Therefore, its main purpose is to predict the feasibility of the reduction of metal oxides.

Quick Tip

On an Ellingham diagram, remember the rule: "The lower element can reduce the oxide of the higher element." The intersection of two lines indicates the temperature at which the reduction potential reverses.

17. In the case of nanostructures, the ratio of number of atoms on the surface to the number of atoms in the interior is -----

- (A) exactly zero because the total tends to infinity
- (B) may be of the order of unity
- (C) always 0.5
- (D) tends to infinity because the surface energy tends to infinity

Correct Answer: (B) may be of the order of unity

Solution:

Step 1: Understanding the Question:

The question asks about the relationship between surface atoms and interior (bulk) atoms in nanostructures.

Step 2: Detailed Explanation:

Nanostructures are materials with at least one dimension in the nanoscale range (typically 1-100 nm).

A key characteristic of these materials is their extremely high surface-area-to-volume ratio.

As a particle's size decreases, the fraction of atoms located on its surface increases dramatically compared to the atoms in its interior (the bulk).

For a macroscopic object, the number of surface atoms is negligible compared to the number of bulk atoms, so the ratio is close to zero.

However, for a very small nanoparticle (e.g., a few nanometers in diameter), a significant percentage of its total atoms are on the surface.

For instance, in a 3 nm gold nanoparticle, approximately 50% of the atoms are on the surface.

In such cases, the number of surface atoms can be comparable to the number of interior atoms.

When two numbers are comparable, their ratio is of the order of unity (i.e., around 1).

The ratio is not a fixed value like 0.5 and certainly not zero or tending to infinity.

Step 3: Final Answer:

For very small nanoparticles, the number of surface atoms can be similar to the number of interior atoms.

Therefore, their ratio can be on the order of unity.

💡 Quick Tip

Think about a cube. As you make the cube smaller, the volume (number of interior atoms) decreases faster (L^3) than the surface area (number of surface atoms, $\propto L^2$). This is why the surface-to-volume ratio ($L^2/L^3 = 1/L$) increases, and the properties of nanomaterials are dominated by surface effects.

18. A quantum dot emits light at 600 nm. If the particle size is reduced, the emitted wavelength will:

- (A) Increase
- (B) Decrease
- (C) Remain same
- (D) First increase, then decrease

Correct Answer: (B) Decrease

Solution:

Step 1: Understanding the Question:

The question describes the effect of changing the size of a quantum dot on the wavelength of light it emits.

This relates to the phenomenon of quantum confinement.

Step 2: Key Formula or Approach:

The energy of an emitted photon is related to its wavelength by the Planck-Einstein relation:

$$[E = hc/\lambda]$$

where E is the energy, h is Planck's constant, c is the speed of light, and λ is the wavelength.

Step 3: Detailed Explanation:

Quantum dots are semiconductor nanocrystals whose excitons (electron-hole pairs) are confined in all three spatial dimensions.

Due to this quantum confinement, the energy levels of the quantum dot are discrete and size-dependent, unlike the continuous bands in a bulk semiconductor.

The energy gap (bandgap) between the valence and conduction bands increases as the size of the quantum dot decreases.

This is because the charge carriers are more tightly confined in a smaller space, which, according to the "particle in a box" model from quantum mechanics, leads to higher energy levels and a larger energy separation.

Since the emitted photon's energy (E) corresponds to this bandgap energy, a smaller particle size leads to a larger bandgap (E increases).

From the formula $E = hc/\lambda$, we can see that energy and wavelength are inversely proportional.

Therefore, as the energy (E) increases, the wavelength (λ) must decrease.

This shift to a shorter wavelength is known as a blueshift.

Step 4: Final Answer:

Reducing the particle size increases the quantum confinement, which increases the bandgap energy.

An increase in energy results in a decrease in the emitted wavelength.

Thus, the emitted wavelength will decrease.

💡 Quick Tip

For quantum dots, remember this simple relationship: Smaller Size $\rightarrow$ Stronger Confinement $\rightarrow$ Larger Bandgap Energy $\rightarrow$ Shorter Wavelength (Blueshift). Conversely, Larger Size $\rightarrow$ Weaker Confinement $\rightarrow$ Smaller Bandgap Energy $\rightarrow$ Longer Wavelength (Redshift).

19. The primary mode of heat transfer in solids is:

- (A) Conduction
- (B) Convection
- (C) Radiation
- (D) All modes equally

Correct Answer: (A) Conduction

Solution:

Step 1: Understanding the Question:

The question asks to identify the main mechanism of heat transfer within solid materials.

Step 2: Detailed Explanation:

There are three modes of heat transfer:

1. Conduction: Heat transfer through direct molecular collision without bulk movement of matter.

In solids, energy is transferred via lattice vibrations (phonons) and, in the case of metals, through the movement of free electrons.

This is the defining mode of heat transfer in solids.

2. Convection: Heat transfer by the bulk movement of fluids (liquids or gases).

Since the atoms in a solid are fixed in a lattice and cannot move freely, convection cannot occur within a solid.

3. Radiation: Heat transfer through electromagnetic waves.

All objects with a temperature above absolute zero emit thermal radiation.

While radiation does occur from the surface of a solid, it is generally not the primary mode of heat transfer through the bulk of the solid, especially for opaque materials at moderate temperatures, compared to conduction.

Step 3: Final Answer:

Because heat transfer in solids occurs primarily through the vibration and collision of tightly packed particles (and free electrons in conductors), conduction is the primary mode.

💡 Quick Tip

Associate each mode of heat transfer with a state of matter for easy recall:

- **Conduction** → Solids (primary)
- **Convection** → Fluids (liquids and gases)
- **Radiation** → Can travel through vacuum; occurs in all states.

20. How many number of Bravais lattices are there in the monoclinic crystal system?

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

Correct Answer: (D) 2

Solution:

Step 1: Understanding the Question:

The question asks for the number of distinct Bravais lattices that belong to the monoclinic crystal system.

Step 2: Detailed Explanation:

In crystallography, the 14 Bravais lattices describe the 14 unique ways that points can be arranged in a periodic three-dimensional array.

These 14 lattices are grouped into 7 crystal systems based on their lattice parameters ($a, b, c, \alpha, \beta, \gamma$).

The monoclinic crystal system is defined by lattice parameters where $a \neq b \neq c$, and $\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$.

Within this system, there are two possible Bravais lattices:

1. Simple (or Primitive) Monoclinic (mP): Lattice points are only at the corners of the unit cell.

2. Base-Centered (or C-Centered) Monoclinic (mC): Lattice points are at the corners and at the center of two opposite faces (the 'C' faces).

It can be shown through symmetry operations that other potential centerings (like body-centered or face-centered) in the monoclinic system are equivalent to one of these two.

Step 3: Final Answer:

The monoclinic crystal system has two Bravais lattices: simple monoclinic and base-centered monoclinic.

💡 Quick Tip

Remember the number of Bravais lattices for the 7 crystal systems. A useful mnemonic is C-T-O-R-H-M-T: Cubic (3), Tetragonal (2), Orthorhombic (4), Rhombohedral (1), Hexagonal (1), Monoclinic (2), Triclinic (1). The total is $3+2+4+1+1+2+1 = 14$.

21. Displacement thickness in boundary layer theory represents:

- (A) Thickness of wall
- (B) Distance where velocity is zero
- (C) Shift in outer inviscid flow due to boundary layer
- (D) Distance of maximum shear

Correct Answer: (C) Shift in outer inviscid flow due to boundary layer

Solution:

Step 1: Understanding the Question:

The question asks for the physical meaning of displacement thickness (δ) in the context of fluid dynamics boundary layer theory.

Step 2: Detailed Explanation:

When a fluid flows over a surface, a thin region called the boundary layer forms near the surface due to viscosity.

Inside this layer, the fluid velocity is reduced from the free-stream velocity (U_∞) down to zero at the wall (the no-slip condition).

This reduction in velocity within the boundary layer means that the mass flow rate is less than what it would be if the flow were frictionless (inviscid) right up to the wall.

The **displacement thickness** (δ) is a concept used to quantify this effect.

It is defined as the distance by which the streamlines of the external, inviscid flow are displaced or shifted away from the surface.

This imaginary shift accounts for the mass flow deficit caused by the presence of the boundary layer.

In other words, if the real fluid with the boundary layer were replaced by an inviscid fluid, the solid boundary would have to be thickened by an amount δ to produce the same mass flow rate at a given cross-section.

Step 3: Final Answer:

Displacement thickness represents the outward shift of the external inviscid flow streamlines due to the velocity deficit within the boundary layer.

💡 Quick Tip

Think of displacement thickness (δ) as the "missing flow" converted into a thickness. It's the amount the wall would need to "thicken" to cause the same blockage effect in an ideal, frictionless flow. This is distinct from momentum thickness (θ), which relates to the loss of momentum.

22. The Navier-Stokes equation is based on:

- (A) Conservation of mass only
- (B) Newton's second law for fluids
- (C) Bernoulli's principle
- (D) Pascal's law

Correct Answer: (B) Newton's second law for fluids

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental physical principle upon which the Navier-Stokes equations are derived.

Step 2: Detailed Explanation:

The Navier-Stokes equations are a set of partial differential equations that describe the motion of viscous fluid substances.

They are the cornerstone of fluid dynamics.

The derivation of these equations involves applying **Newton's second law of motion** ($F = ma$) to an infinitesimal fluid element.

This law is a statement of the **conservation of momentum**.

The terms in the equation represent:

- **Inertia (mass $\times$ acceleration):** This is the ' ma ' part, describing the rate of change of momentum of the fluid particle.
- **Forces (F):** These are the forces acting on the fluid particle, which include:
 - **Pressure forces:** Arising from the pressure gradient.
 - **Viscous forces:** Arising from friction within the fluid (shear stresses).
 - **Body forces:** External forces like gravity that act on the entire volume of the fluid element.

While conservation of mass (the continuity equation) is also needed to solve fluid flow problems, the Navier-Stokes equation itself is the expression of momentum conservation, i.e., Newton's second law. Bernoulli's principle is a simplified result derived from the Navier-Stokes equation for inviscid, steady flow. Pascal's law relates to pressure in a static fluid.

Step 3: Final Answer:

The Navier-Stokes equation is a direct application of Newton's second law (conservation of momentum) to a fluid element, balancing inertial forces with pressure, viscous, and body forces.

💡 Quick Tip

To remember the foundations of fluid dynamics, associate the core equations with conservation principles:

- **Continuity Equation** → Conservation of Mass
- **Navier-Stokes Equation** → Conservation of Momentum (Newton's 2nd Law)
- **Energy Equation** → Conservation of Energy (1st Law of Thermodynamics)

23. For the emission of characteristic X-rays from the K-shell of an element, the incident energy should be?

- (A) Less than the corresponding ionization potential
- (B) Greater than the corresponding ionization potential
- (C) Greater than the bond energy
- (D) Less than the bond energy

Correct Answer: (B) Greater than the corresponding ionization potential

Solution:

Step 1: Understanding the Question:

The question asks about the energy requirement for an incident particle (like an electron or photon) to cause the emission of a characteristic K-shell X-ray.

Step 2: Detailed Explanation:

Characteristic X-rays are produced through a two-step process:

1. Ionization: An incident particle with high energy collides with an atom and ejects an electron from one of its inner electron shells (e.g., the K-shell, which is the innermost shell).

To eject this electron, the incident particle must transfer an amount of energy to it that is at least equal to its binding energy.

The binding energy of an electron in a specific shell is also known as its ionization potential or ionization energy for that shell.

Therefore, the incident energy must be greater than the K-shell ionization potential.

2. Relaxation: The atom is now in an unstable, excited state with a vacancy in the K-shell.

An electron from a higher energy shell (like the L or M shell) "falls down" to fill this vacancy.

In doing so, it releases energy equal to the difference in binding energies between the two shells.

This energy is emitted as an X-ray photon with a specific, characteristic energy (and thus wavelength).

Step 3: Final Answer:

The initial and necessary step for producing a K-shell characteristic X-ray is to remove an electron from the K-shell.

This requires the incident energy to be greater than the binding energy of the K-shell electron, which is its ionization potential.

Quick Tip

Think of it like knocking a ball out of a deep hole. You must give the ball enough energy to get over the edge of the hole. The "depth" of the hole is the binding energy or ionization potential. Any less energy, and the ball (electron) stays put.

24. A material shows the following stress strain data: Stress = 400 MPa at strain = 0.002. Find modulus of elasticity.

- (A) 200 GPa
- (B) 100 GPa
- (C) 300 GPa
- (D) 250 GPa

Correct Answer: (A) 200 GPa

Solution:

Step 1: Understanding the Question:

The question asks to calculate the modulus of elasticity (also known as Young's Modulus) given a single data point of stress and strain, assuming the material is behaving elastically.

Step 2: Key Formula or Approach:

The modulus of elasticity, E , is defined by Hooke's Law as the ratio of stress (σ) to strain (ϵ) within the elastic limit of a material.

$$[E = \sigma / \epsilon]$$

Step 3: Detailed Explanation:

We are given the following values:

- Stress, $\sigma = 400 \text{ MPa}$
- Strain, $\epsilon = 0.002$ (strain is dimensionless)

Now, we can substitute these values into the formula:

$$\begin{aligned} [E &= 400 \text{ MPa} \cdot \frac{1}{0.002}] \\ [E &= 200,000 \text{ MPa}] \end{aligned}$$

The options are given in Gigapascals (GPa).

We need to convert MPa to GPa.

The conversion factor is:

$$1 \text{ GPa} = 1000 \text{ MPa}$$

So, we divide the result in MPa by 1000:

$$[E = 200,000 \text{ MPa} \cdot \frac{1}{1000 \text{ MPa/GPa}} = 200 \text{ GPa}]$$

Step 4: Final Answer:

The calculated modulus of elasticity is 200 GPa.

💡 Quick Tip

Be very careful with units in materials science problems. Stress is often given in MPa, while the modulus of elasticity is typically expressed in GPa. Remember that Giga is 10^9 and Mega is 10^6 , so $1 \text{ GPa} = 1000 \text{ MPa}$.

25. Surface area per gram of the adsorbent is called?

- (A) Molar surface area
- (B) Normal surface area
- (C) Specific surface area
- (D) Equivalent surface area

Correct Answer: (C) Specific surface area

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking for the term used to describe the surface area of a material normalized by its mass.

Step 2: Detailed Explanation:

In materials science, chemistry, and physics, the term "**specific**" is used to denote a property per unit mass.

For example, specific heat is heat capacity per unit mass, and specific volume is volume per unit mass.

Following this convention, the surface area per unit mass (typically per gram) of a material is called the **specific surface area**.

This is a crucial property for adsorbents, catalysts, and porous materials, as it quantifies the amount of surface available for chemical reactions or physical adsorption.

The standard units are meters squared per gram (m^2/g).

- Molar surface area would be area per mole.
- Normal surface area is not a standard term.
- Equivalent surface area relates to the surface area of a sphere with the same volume as the particle, but it is not a term for area per gram.

Step 3: Final Answer:

The correct term for surface area per gram of an adsorbent is specific surface area.

💡 Quick Tip

In science, whenever you see the word "specific" in front of a physical quantity (like specific heat, specific gravity, specific energy), it almost always means that the quantity has been divided by mass.

26. Reynolds stresses arise due to:

- (A) Laminar sublayer
- (B) Density variation
- (C) Mean flow gradients

(D) Turbulent fluctuations

Correct Answer: (D) Turbulent fluctuations

Solution:

Step 1: Understanding the Question:

The question asks for the physical origin of Reynolds stresses in fluid flow.

Step 2: Detailed Explanation:

In a turbulent flow, fluid properties like velocity and pressure fluctuate randomly and chaotically over time and space.

To analyze such flows, we use a technique called Reynolds decomposition, where the instantaneous velocity (u) is split into a time-averaged mean component ($\bar{u}$) and a fluctuating component (u').

$$u(t) = \bar{u} + u'(t)$$

When this decomposition is substituted into the Navier-Stokes equations (which represent momentum conservation) and then time-averaged, new terms appear.

These terms, of the form $-\rho\overline{u'v'}$, are called the **Reynolds stresses** or turbulent stresses.

These are not true stresses caused by molecular viscosity, but rather they represent the net transfer of momentum due to the chaotic swirling motions (**turbulent fluctuations** or eddies) of the fluid.

The correlation between fluctuating velocity components ($\overline{u'v'}$) indicates that momentum is being transported across the mean flow streamlines by the turbulence.

This momentum transport acts mathematically like an additional stress on the fluid.

Step 3: Final Answer:

Reynolds stresses are the apparent shear stresses in a turbulent fluid flow that arise directly from the time-averaged effect of the turbulent fluctuations in velocity.

💡 Quick Tip

Associate "Reynolds stresses" with "turbulence." They are a mathematical consequence of trying to describe a chaotic, fluctuating flow with time-averaged equations. They represent the momentum transport by eddies, which is a defining feature of turbulence.

27. Optical fibers rely primarily on:

- (A) Electron tunneling
- (B) Magnetic hysteresis
- (C) Total internal reflection
- (D) Photoluminescence

Correct Answer: (C) Total internal reflection

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental physical principle that allows optical fibers to guide light over long distances.

Step 2: Detailed Explanation:

An optical fiber consists of a central core made of a material with a higher refractive index (n_1) surrounded by a cladding with a slightly lower refractive index (n_2).

Light is transmitted through the fiber by undergoing a phenomenon called **Total Internal Reflection (TIR)**.

TIR occurs when light travels from a denser medium (higher refractive index, the core) to a less dense medium (lower refractive index, the cladding) at an angle of incidence greater than a specific critical angle (θ_c).

When this condition is met, the light does not refract out into the cladding but is instead completely reflected back into the core.

This process repeats along the length of the fiber, effectively trapping the light signal within the core and guiding it with minimal loss.

Step 3: Final Answer:

The guiding of light in optical fibers is achieved through the repeated process of total internal reflection at the core-cladding interface.

💡 Quick Tip

Remember the two conditions for Total Internal Reflection (TIR): 1. Light must travel from a medium with a higher refractive index to one with a lower refractive index. 2. The angle of incidence must be greater than the critical angle.

28. Electron backscattered diffraction is a technique based on?

- (A) Optical microscopy
- (B) Scanning electron microscopy
- (C) Atomic force microscopy
- (D) X-ray diffraction

Correct Answer: (B) Scanning electron microscopy

Solution:

Step 1: Understanding the Question:

The question asks to identify the parent microscopy technique on which Electron Backscatter Diffraction (EBSD) is based.

Step 2: Detailed Explanation:

Electron Backscatter Diffraction (EBSD) is a microstructural-crystallographic characterization technique.

It is performed using a **Scanning Electron Microscope (SEM)** equipped with an EBSD detector.

In this technique, a stationary electron beam from the SEM is focused onto a highly tilted crystalline sample.

The electrons in the beam interact with the sample and are diffracted by the crystallographic planes.

These diffracted electrons travel to a fluorescent screen, forming a pattern of intersecting bands known as Kikuchi patterns.

The geometry of these patterns is directly related to the crystal orientation at the point where the beam hits the sample.

By scanning the beam across the sample surface, a map of the crystal orientation can be created.

Step 3: Final Answer:

EBSD is fundamentally an accessory technique for a Scanning Electron Microscope, as it relies on the SEM's focused electron beam to generate the diffraction patterns.

💡 Quick Tip

Always associate EBSD with SEM. EBSD provides crystallographic information (like grain orientation, phase identification, texture), while the SEM provides morphological and topographical information. Together, they offer a comprehensive microstructural analysis.

29. A polymer shows a glass transition temperature (T_g) of 100°C . If modified with nanofillers, T_g increases by 15%. What is the new T_g ?

- (A) 110°C
- (B) 115°C
- (C) 120°C
- (D) 130°C

Correct Answer: (B) 115°C

Solution:

Step 1: Understanding the Question:

The question asks for the new glass transition temperature (T_g) of a polymer after it has been increased by a certain percentage.

Step 2: Key Formula or Approach:

To find the new value after a percentage increase, we can use the formula:

$$\text{New Value} = \text{Original Value} \times (1 + \text{Percentage Increase} / 100)$$

Step 3: Detailed Explanation:

We are given:

- Original $T_g = 100^\circ\text{C}$
- Percentage increase = 15%

First, calculate the amount of increase in T_g :

Increase in $T_g = 15\%$ of 100°C

$$\text{Increase} = \frac{15}{100} \times 100^\circ\text{C} = 15^\circ\text{C}$$

Next, add this increase to the original T_g to find the new T_g :

New $T_g = \text{Original } T_g + \text{Increase in } T_g$

$$\text{New } T_g = 100^\circ\text{C} + 15^\circ\text{C} = 115^\circ\text{C}$$

Step 4: Final Answer:

The new glass transition temperature of the polymer is 115°C .

💡 Quick Tip

Adding nanofillers to a polymer often increases its T_g . The fillers restrict the mobility of the polymer chains, meaning more thermal energy (a higher temperature) is required for the chains to move and transition from a glassy state to a rubbery state.

30. Thermodynamically stable defects are?

- (A) Point defects
- (B) Line defects
- (C) Surface defects
- (D) Volume defects

Correct Answer: (A) Point defects

Solution:

Step 1: Understanding the Question:

The question asks to identify which class of crystal defects is considered thermodynamically stable, meaning their presence is favored by thermodynamics above absolute zero.

Step 2: Detailed Explanation:

A defect is thermodynamically stable if its formation leads to a decrease in the Gibbs free energy (G) of the crystal, where $G = H - TS$. Here, H is enthalpy, T is temperature, and S is entropy.

Point defects, such as vacancies (missing atoms), are unique among crystal defects because their formation increases the configurational entropy of the crystal.

While creating a vacancy requires energy (an increase in enthalpy, ΔH), the increase in randomness (entropy, ΔS) it introduces can offset this energy cost at temperatures above absolute zero.

The free energy change due to forming n vacancies is $\Delta G = n\Delta H - T\Delta S$. The entropy term ($-T\Delta S$) becomes more significant as temperature increases, making ΔG negative.

This means there is an equilibrium concentration of point defects that is thermodynamically stable at any given temperature above 0 K.

Line, surface, and volume defects have a much higher formation enthalpy and do not provide a comparable increase in configurational entropy, so they are not thermodynamically stable and are generally introduced by non-equilibrium processes like deformation or solidification.

Step 3: Final Answer:

Point defects are the only class of defects that are thermodynamically stable because their formation increases the entropy of the system, which lowers the Gibbs free energy at non-zero temperatures.

💡 Quick Tip

Remember that only point defects have an equilibrium concentration that depends on temperature. All other defects (dislocations, grain boundaries, voids) are considered non-equilibrium defects.

31. Enthalpy and temperature are?

- (A) Both extensive properties
- (B) Both intensive properties
- (C) Extensive and intensive properties, respectively
- (D) Intensive and extensive properties, respectively

Correct Answer: (C) Extensive and intensive properties, respectively

Solution:

Step 1: Understanding the Question:

The question asks to classify enthalpy and temperature as either extensive or intensive thermodynamic properties.

Step 2: Detailed Explanation:

Thermodynamic properties are classified as follows:

Extensive Properties: These properties depend on the amount of matter or the size of the system. If you combine two identical systems, the value of an extensive property doubles. Examples include mass, volume, energy, and **enthalpy**. The enthalpy of 2 kg of water is twice the enthalpy of 1 kg of water at the same state.

Intensive Properties: These properties are independent of the amount of matter or the size of the system. If you divide a system in half, the value of an intensive property remains the same in each half. Examples include pressure, density, and **temperature**. The temperature of a cup of water is the same as the temperature of a bucket of water from the same source.

Step 3: Final Answer:

Enthalpy is an extensive property because it scales with the size of the system. Temperature is an intensive property because it does not depend on the size of the system. Therefore, they are extensive and intensive properties, respectively.

💡 Quick Tip

A simple test to distinguish between extensive and intensive properties is to imagine dividing the system in half. If the property's value is also halved, it's extensive. If it stays the same, it's intensive.

32. In laminar boundary layer flow over a flat plate, wall shear stress:

- (A) Constant
- (B) Decreases with distance
- (C) Increases with distance
- (D) Zero

Correct Answer: (B) Decreases with distance

Solution:

Step 1: Understanding the Question:

The question asks how the wall shear stress (τ_w) changes along the length of a flat plate in a laminar boundary layer flow.

Step 2: Key Formula or Approach:

For a laminar boundary layer on a flat plate (Blasius solution), the wall shear stress at a distance x from the leading edge is given by:

$$\tau_w(x) = \frac{0.332\rho U^2}{\sqrt{Re_x}}$$

where $Re_x = \frac{\rho U x}{\mu}$ is the local Reynolds number. Substituting Re_x into the equation for τ_w :

$$\tau_w(x) \propto \frac{1}{\sqrt{x}}$$

Step 3: Detailed Explanation:

The boundary layer thickness (δ) grows with the distance x from the leading edge ($\delta \propto \sqrt{x}$).

Wall shear stress is related to the velocity gradient at the wall ($\tau_w = \mu(\frac{\partial u}{\partial y})_{y=0}$).

As the boundary layer grows thicker, the velocity gradient at the wall becomes less steep.

A smaller velocity gradient results in a lower shear stress.

Based on the formula $\tau_w(x) \propto \frac{1}{\sqrt{x}}$, as the distance x increases, the wall shear stress τ_w decreases.

Step 4: Final Answer:

In a laminar boundary layer flow over a flat plate, the wall shear stress is highest at the leading edge ($x = 0$) and decreases with increasing distance along the plate.

💡 Quick Tip

Remember the dependencies for a laminar flat plate boundary layer: - Boundary layer thickness, $\delta \propto \sqrt{x}$ (grows) - Wall shear stress, $\tau_w \propto 1/\sqrt{x}$ (decreases)

33. The third law of thermodynamic states that in the limit $T \rightarrow 0$?

- (A) $U = 0$
- (B) $S = 0$
- (C) $H = 0$
- (D) $G = 0$

Correct Answer: (B) $S = 0$

Solution:

Step 1: Understanding the Question:

The question asks for the statement of the third law of thermodynamics as the temperature (T) approaches absolute zero (0 Kelvin).

Step 2: Detailed Explanation:

The third law of thermodynamics deals with the behavior of entropy as the temperature approaches absolute zero.

It states: **The entropy (S) of a perfect, pure crystalline substance approaches a constant value as the temperature approaches absolute zero.**

By convention, this constant minimum entropy is defined as zero.

This means that at absolute zero, a perfect crystal would be in its most ordered state (a single, unique ground state), and therefore, its entropy would be zero ($S = 0$).

The other thermodynamic potentials (Internal Energy U , Enthalpy H , Gibbs Free Energy G) do not necessarily go to zero at $T=0$. They approach a minimum value known as the zero-point energy.

Step 3: Final Answer:

According to the third law of thermodynamics, the entropy (S) of a perfect crystal is zero at absolute zero temperature ($T \rightarrow 0$).

💡 Quick Tip

Associate the third law of thermodynamics directly with entropy and absolute zero. It essentially provides a baseline for entropy calculations, stating $S=0$ at $T=0$ for a perfect crystal.

34. Turbulent flow is generally observed when Reynolds number is:

- (A) ≤ 2000
- (B) ≥ 4000
- (C) ≤ 500
- (D) Between 500-1000

Correct Answer: (B) ≥ 4000

Solution:

Step 1: Understanding the Question:

The question asks for the range of Reynolds number (Re) that typically corresponds to turbulent flow.

Step 2: Detailed Explanation:

The Reynolds number is a dimensionless quantity used to predict fluid flow patterns. It represents the ratio of inertial forces to viscous forces. The context (e.g., flow in a pipe, over a plate) is important, but for internal flow in a circular pipe, the conventions are:

- **Laminar Flow ($Re \leq 2300$):** A smooth, orderly flow where viscous forces are dominant. The option ' ≤ 2000 ' falls in this category.
- **Transitional Flow ($2300 < Re < 4000$):** An unstable flow regime that can exhibit characteristics of both laminar and turbulent flow.
- **Turbulent Flow ($Re \geq 4000$):** A chaotic, disorderly flow with eddies and swirls, where inertial forces are dominant.

The options ' ≤ 500 ' and 'Between 500-1000' represent low Reynolds numbers, which are firmly in the laminar regime.

The option ' ≥ 4000 ' is the standard and unambiguous range for fully developed turbulent flow in a pipe.

Step 3: Final Answer:

Turbulent flow is generally observed when the Reynolds number is greater than 4000.

 Quick Tip

For internal pipe flow, memorize these critical Reynolds numbers: - $Re < 2300$: Laminar - $2300 < Re < 4000$: Transitional - $Re > 4000$: Turbulent While the exact transition value can vary, these are the widely accepted engineering approximations.

35. The product of electron and hole concentration in an extrinsic semiconductor is?

- (A) Infinity
- (B) Dependent of impurity concentration
- (C) Independent of impurity concentration
- (D) Zero

Correct Answer: (C) Independent of impurity concentration

Solution:

Step 1: Understanding the Question:

The question asks about the nature of the product of electron (n) and hole (p) concentrations in an extrinsic (doped) semiconductor under thermal equilibrium.

Step 2: Key Formula or Approach:

This is governed by the **Law of Mass Action** for semiconductors, which states:

$$n \cdot p = n_i^2$$

Step 3: Detailed Explanation:

- n is the concentration of electrons in the conduction band.
- p is the concentration of holes in the valence band.
- n_i is the intrinsic carrier concentration, which is the concentration of electrons (or holes) in a pure, undoped semiconductor.

The intrinsic concentration n_i is a property of the semiconductor material itself and is strongly dependent on temperature, but it is **not** dependent on the concentration of dopant impurities.

In an extrinsic semiconductor, doping increases one type of carrier (e.g., electrons in n-type) while decreasing the other (holes in n-type), but their product remains constant and equal to n_i^2 at a given temperature.

Therefore, the product $n \cdot p$ is independent of the impurity concentration.

Step 4: Final Answer:

The product of electron and hole concentration in an extrinsic semiconductor is equal to the square of the intrinsic carrier concentration (n_i^2) and is therefore independent of the impurity

concentration.

 Quick Tip

Remember the Law of Mass Action: $np = n_i^2$. This relationship is fundamental to semiconductor physics. Doping throws the balance of n and p way off, but their product always remains the same constant (n_i^2) at a given temperature.

36. The susceptibility of a diamagnetic material is essentially independent of temperature.

- (A) At very high temperatures
- (B) As long as the electronic structure is independent of temperature
- (C) At very low temperature of the order 10 K
- (D) Under all circumstances

Correct Answer: (B) As long as the electronic structure is independent of temperature

Solution:

Step 1: Understanding the Question:

The question asks under what conditions the magnetic susceptibility (χ) of a diamagnetic material is independent of temperature.

Step 2: Detailed Explanation:

Diamagnetism is a fundamental property of all matter that arises from the change in the orbital motion of electrons when an external magnetic field is applied (Lenz's Law at the atomic level).

This effect is inherently quantum mechanical and depends on the charge, mass, and orbital radius of the electrons.

The classical Langevin theory of diamagnetism shows that the susceptibility (χ) is negative and does not contain a temperature term.

Thus, to a very good first approximation, diamagnetic susceptibility is independent of temperature.

However, this holds true only as long as the underlying electronic structure of the material (the distribution and radii of electron orbitals) does not change significantly with temperature.

For most materials under normal conditions, the electronic structure is stable, so their diamagnetic susceptibility is considered constant.

Option (B) provides the most accurate and physically correct condition for this independence. The other options are either too restrictive or too general.

Step 3: Final Answer:

The susceptibility of a diamagnetic material is independent of temperature on the condition that the electronic structure of the atoms themselves does not change with temperature.

💡 Quick Tip

Contrast the temperature dependence of different types of magnetism: - **Diamagnetism:** Independent of T. - **Paramagnetism:** Inversely proportional to T (Curie's Law, $\chi = C/T$). - **Ferromagnetism:** Strong dependence, disappears above the Curie Temperature (T_c).

37. A flat plate is placed in an air stream at 20°C. The free stream velocity is 2 m/s. If the kinematic viscosity of air is $1.5 \times 10^{-5} \text{ m}^2/\text{s}$, what is the Reynolds number at a distance of 1 m from the leading edge?

- (A) 1.33×10^5
- (B) 1.00×10^5
- (C) 2.00×10^5
- (D) 2.67×10^5

Correct Answer: (A) 1.33×10^5

Solution:

Step 1: Understanding the Question:

The question asks to calculate the local Reynolds number (Re_x) for flow over a flat plate at a specific distance from its leading edge.

Step 2: Key Formula or Approach:

The formula for the local Reynolds number for a flat plate is:

$$Re_x = \frac{U \cdot x}{\nu}$$

where:

- U is the free stream velocity.
- x is the distance from the leading edge.
- ν is the kinematic viscosity of the fluid.

Step 3: Detailed Explanation:

We are given the following values:

- Free stream velocity, $U = 2 \text{ m/s}$
- Distance from the leading edge, $x = 1 \text{ m}$
- Kinematic viscosity, $\nu = 1.5 \times 10^{-5} \text{ m}^2/\text{s}$

Substitute these values into the Reynolds number formula:

$$\begin{aligned} Re_x &= \frac{(2 \text{ m/s}) \cdot (1 \text{ m})}{1.5 \times 10^{-5} \text{ m}^2/\text{s}} \\ Re_x &= \frac{2}{1.5 \times 10^{-5}} \\ Re_x &= \frac{2}{1.5} \times 10^5 \\ Re_x &= 1.333 \cdots \times 10^5 \end{aligned}$$

Step 4: Final Answer:

The Reynolds number at a distance of 1 m from the leading edge is approximately 1.33×10^5 .

💡 Quick Tip

Always check the characteristic length used for the Reynolds number. For a flat plate, it's the distance from the leading edge (x). For a pipe, it's the diameter (D). Using the wrong length is a common mistake.

38. An elemental superconductor is a perfect?

- (A) Ferromagnetic
- (B) Diamagnetic
- (C) Paramagnetic
- (D) Dielectric

Correct Answer: (B) Diamagnetic

Solution:

Step 1: Understanding the Question:

The question asks to identify the magnetic property of an elemental superconductor in its superconducting state.

Step 2: Detailed Explanation:

Superconductors exhibit two defining properties below their critical temperature (T_c):

1. **Zero Electrical Resistance:** They can conduct electricity with no energy loss.
2. **The Meissner Effect:** They actively expel magnetic fields from their interior.

The Meissner effect means that when a superconductor is placed in a magnetic field, it generates surface currents that create a magnetic field exactly opposite to the external field, canceling it out inside the material.

A material that expels magnetic fields and has a magnetic susceptibility (χ) of -1 is known as a **perfect diamagnet**.

Therefore, a superconductor in its superconducting state is a perfect diamagnetic material.

Step 3: Final Answer:

Due to the Meissner effect, an elemental superconductor is a perfect diamagnet.

💡 Quick Tip

The two pillars of superconductivity are zero resistance and the Meissner effect (perfect diamagnetism). Don't confuse superconductors with perfect conductors, which would only trap existing magnetic fields but not expel them.

39. Maximum shear stress in a circular shaft under torque is at:

- (A) Center
- (B) Surface
- (C) At radius/2
- (D) At neutral axis

Correct Answer: (B) Surface

Solution:

Step 1: Understanding the Question:

The question asks where the shear stress is at its maximum value in a solid circular shaft subjected to a twisting moment (torque).

Step 2: Key Formula or Approach:

The elastic torsion formula relates shear stress (τ) to the applied torque (T), the radial distance from the center (r), and the polar moment of inertia (J) of the shaft's cross-section:

$$\tau = \frac{T \cdot r}{J}$$

Step 3: Detailed Explanation:

From the torsion formula, we can see that for a given shaft (J is constant) and a given torque (T is constant), the shear stress τ is directly proportional to the radial distance r .

$$\tau \propto r$$

This means:

- At the center of the shaft, $r = 0$, so the shear stress is $\tau = 0$.
- As the distance from the center increases, the shear stress increases linearly.
- The shear stress reaches its maximum value where r is maximum. For a circular shaft, the maximum radius is at the outer **surface**.

Step 4: Final Answer:

The shear stress in a circular shaft under torque is zero at the center and increases linearly with the radius, reaching its maximum value at the outer surface.

💡 Quick Tip

Visualize the twisting of a shaft. The material at the center barely rotates relative to itself, while the material at the outer surface undergoes the most deformation (highest strain), and therefore experiences the highest stress.

40. High elastic modulus in material arises from?

- (A) High strength of bonds
- (B) Combination of bonds
- (C) Weak bonds
- (D) No bond

Correct Answer: (A) High strength of bonds

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental origin of a high elastic modulus (also known as Young's Modulus or stiffness) in a material.

Step 2: Detailed Explanation:

The elastic modulus is a measure of a material's resistance to being elastically (non-permanently) deformed when a stress is applied.

At the atomic level, a solid material can be visualized as a lattice of atoms held together by interatomic bonds, which act like tiny springs.

When a force is applied to the material, these bonds are stretched or compressed.

The **strength and stiffness of these interatomic bonds** determine how much they resist this deformation.

Materials with strong, stiff interatomic bonds (like those in ceramics and some metals) require a large force to cause a small amount of stretching. This translates to a high resistance to deformation, and therefore a **high elastic modulus**.

Conversely, materials with weak bonds (like those in polymers) deform easily, resulting in a low elastic modulus.

Step 3: Final Answer:

A high elastic modulus is a direct macroscopic consequence of having strong interatomic bonds at the microscopic level.

💡 Quick Tip

Think of the elastic modulus as the "stiffness" of the atomic bonds. Stronger bonds = Stiffer springs = Higher Modulus. This is why materials like diamond (strong covalent bonds) have an extremely high modulus, while rubber (weak van der Waals forces) has a very low modulus.

41. Nusselt number is a function of:

- (A) Heat capacity
- (B) Conductivity only
- (C) Grashof and Prandtl numbers
- (D) Reynolds number only

Correct Answer: (C) Grashof and Prandtl numbers

Solution:

Step 1: Understanding the Question:

The question asks about the functional dependence of the Nusselt number (Nu). The Nusselt number represents the ratio of convective heat transfer to conductive heat transfer.

Step 2: Detailed Explanation:

The functional dependence of the Nusselt number depends on the mode of convection.

For Forced Convection (where flow is caused by an external source like a fan), the Nusselt number is a function of the Reynolds number (Re) and the Prandtl number (Pr).

$$Nu = f(Re, Pr)$$

For Natural (or Free) Convection (where flow is caused by buoyancy forces due to temperature differences), the Nusselt number is a function of the **Grashof number (Gr)** and the **Prandtl number (Pr)**. The Grashof number represents the ratio of buoyancy forces to viscous forces.

$$Nu = f(Gr, Pr)$$

Since option (C) lists Grashof and Prandtl numbers, it correctly describes the functional dependence for natural convection. Option (D) is incomplete as it omits the Prandtl number for forced convection.

Step 3: Final Answer:

The Nusselt number is a function of the Grashof and Prandtl numbers in the case of natural convection. This is one of the primary relationships defining convective heat transfer.

💡 Quick Tip

To remember the key dimensionless numbers in heat transfer: - Forced Convection: $Nu = f(Re, Pr)$ - Natural Convection: $Nu = f(Gr, Pr)$ The Prandtl number (Pr) is a fluid property and appears in both cases.

42. In bending, the stress is maximum at:

- (A) Neutral axis
- (B) Outer fibers
- (C) Midpoint
- (D) At centroid

Correct Answer: (B) Outer fibers

Solution:

Step 1: Understanding the Question:

The question asks where the bending stress (also called flexural stress) is at its maximum value in a beam's cross-section.

Step 2: Key Formula or Approach:

The flexure formula relates the bending stress (σ) to the bending moment (M), the distance from the neutral axis (y), and the moment of inertia of the cross-section (I):

$$\sigma = \frac{M \cdot y}{I}$$

Step 3: Detailed Explanation:

From the flexure formula, for a given bending moment (M) and a constant moment of inertia (I), the stress σ is directly proportional to the distance y from the neutral axis.

- At the **neutral axis**, $y = 0$, which means the bending stress is zero ($\sigma = 0$). The neutral axis is an imaginary line through the centroid where there is no stress or strain.
- As the distance y from the neutral axis increases, the magnitude of the stress increases linearly.
- The maximum distance from the neutral axis occurs at the top and bottom surfaces of the beam, which are known as the **outer fibers**.

Step 4: Final Answer:

The bending stress is zero at the neutral axis and increases linearly with distance from it, reaching its maximum magnitude (one in tension, one in compression) at the outer fibers of the beam.

💡 Quick Tip

Visualize a bending beam. The top surface gets compressed the most, and the bottom surface gets stretched the most. The line in the middle (neutral axis) experiences no change in length. Maximum deformation occurs at the outer surfaces, hence maximum stress.

43. A Salt Bath Furnace provides heat transfer primarily by:

- (A) Conduction
- (B) Radiation
- (C) Immersion (convection + conduction)
- (D) Direct flame contact

Correct Answer: (C) Immersion (convection + conduction)

Solution:

Step 1: Understanding the Question:

The question asks for the primary mechanisms of heat transfer in a salt bath furnace.

Step 2: Detailed Explanation:

A salt bath furnace contains a pot of molten salt heated to a specific temperature for heat treatment processes like annealing, hardening, or tempering.

When a workpiece is submerged (**immersed**) into the molten salt bath:

1. **Convection:** The molten salt, being a fluid, circulates and transfers heat to the surface of the workpiece via natural convection. This is a very efficient way to transfer heat uniformly.
2. **Conduction:** Once the heat reaches the surface of the workpiece, it is transferred into the bulk of the material via conduction. The initial contact between the liquid salt and the solid workpiece surface also involves conduction.

Radiation plays a minor role compared to the dominant immersion-based mechanisms. Direct flame contact is not used, as the part is heated by the salt, not a flame.

Step 3: Final Answer:

Heat transfer in a salt bath furnace is primarily achieved by immersing the workpiece in the molten salt, which involves a combination of convection from the salt to the part's surface and conduction into the part.

 Quick Tip

Salt bath furnaces are known for providing rapid and uniform heating. This is because heat transfer by convection in a liquid is much more efficient than heat transfer by convection in a gas (like in a conventional air furnace).

44. In plane Couette flow, the flow is generated by:

- (A) Pressure gradient
- (B) Gravity
- (C) Relative motion between two plates
- (D) Viscous heating

Correct Answer: (C) Relative motion between two plates

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking for the driving mechanism of plane Couette flow.

Step 2: Detailed Explanation:

Plane Couette flow is a classic problem in fluid dynamics that describes the laminar flow of a viscous fluid confined between two infinite parallel plates.

The defining characteristic of this flow is that one plate is held stationary while the other moves with a constant velocity in its own plane.

The motion of the moving plate drags the fluid along with it due to the no-slip condition at the fluid-plate interface and the fluid's viscosity. This shear action is what generates the flow.

In its simplest form, Couette flow has no pressure gradient and is not driven by gravity.

Step 3: Final Answer:

The flow in a plane Couette flow is generated solely by the shear induced by the relative motion between the two parallel plates.

💡 Quick Tip

Contrast Couette flow with Poiseuille flow. - **Couette Flow:** Driven by the relative motion (shear) of boundaries. Results in a linear velocity profile. - **Poiseuille Flow:** Driven by a pressure gradient between two stationary plates. Results in a parabolic velocity profile.

45. The ceramic that can be used as a cutting tool?

- (A) Magnesita
- (B) Titania
- (C) Alumina
- (D) Yttria

Correct Answer: (C) Alumina

Solution:

Step 1: Understanding the Question:

The question asks to identify which of the listed ceramic materials is commonly used for manufacturing cutting tools.

Step 2: Detailed Explanation:

Ceramic cutting tools are used for high-speed machining of hard materials. They must possess several key properties:

- High hardness and wear resistance
- Chemical stability at high temperatures (hot hardness)
- Sufficient toughness to resist fracture

Alumina (Aluminum Oxide, Al_2O_3) is one of the most widely used ceramics for cutting tools. It has excellent hot hardness and chemical stability, allowing it to cut hardened steels and cast irons at high speeds. It is often reinforced with other materials like silicon carbide whiskers or zirconia to improve its toughness.

While other ceramics listed have industrial applications, they are not primarily used as cutting tool materials. For example, Magnesita is a refractory, and Yttria is used as a stabilizer in zirconia ceramics.

Step 3: Final Answer:

Among the given options, Alumina is the primary ceramic material used for making cutting tools.

💡 Quick Tip

When thinking of ceramic cutting tools, the two most common materials are Alumina (Al_2O_3) and Silicon Nitride (Si_3N_4). Remember Alumina for its excellent hot hardness.

46. Which of the following is a dimensionless number related to heat conduction?

- (A) Fourier Number
- (B) Nusselt Number
- (C) Prandtl Number
- (D) Stanton Number

Correct Answer: (A) Fourier Number

Solution:

Step 1: Understanding the Question:

The question asks to identify the dimensionless number that is primarily associated with heat conduction, specifically in the context of transient (unsteady) heat transfer.

Step 2: Detailed Explanation:

Let's analyze the given dimensionless numbers:

- **Fourier Number (Fo):** It is defined as $Fo = \frac{\alpha t}{L^2}$, where α is the thermal diffusivity, t is time, and L is a characteristic length. It represents the ratio of the rate of heat conduction to the rate of thermal energy storage in a volume. Its presence signifies a transient heat conduction problem.
- **Nusselt Number (Nu):** Represents the ratio of convective to conductive heat transfer across a boundary. It is a measure of the enhancement of heat transfer due to convection.
- **Prandtl Number (Pr):** A fluid property that represents the ratio of momentum diffusivity to thermal diffusivity. It connects the velocity and thermal boundary layers in convection problems.
- **Stanton Number (St):** Represents the ratio of heat transferred into a fluid to the thermal capacity of the fluid. It is a measure of the efficiency of heat transfer in convection.

Step 3: Final Answer:

The Fourier number is the dimensionless parameter that characterizes transient heat conduction. It relates the elapsed time to the time required for heat to penetrate a certain distance within a solid.

💡 Quick Tip

Associate dimensionless numbers with phenomena: - **Fourier (Fo)**: Transient Conduction - **Nusselt (Nu)**: Convection vs. Conduction ratio - **Prandtl (Pr)**: Fluid property (momentum vs. thermal diffusion) - **Biot (Bi)**: Internal conduction resistance vs. external convection resistance

47. The efficiency of a furnace is generally defined as:

- (A) Energy lost / energy input
- (B) Energy input / energy loss
- (C) Useful heat / heat supplied
- (D) Mass of fuel / heat output

Correct Answer: (C) Useful heat / heat supplied

Solution:

Step 1: Understanding the Question:

The question asks for the general definition of the efficiency of a furnace.

Step 2: Detailed Explanation:

The efficiency (η) of any energy conversion device is fundamentally defined as the ratio of the desired useful output to the total required input.

For a furnace, the purpose is to provide heat to a specific object or process (the "load").

- The **useful output** is the amount of heat that is successfully absorbed by the load (**Useful heat**).
- The **total input** is the total amount of heat generated by burning the fuel (**Heat supplied**).

Therefore, the efficiency is:

$$\eta = \frac{\text{Useful Output}}{\text{Total Input}} = \frac{\text{Useful heat absorbed by the load}}{\text{Total heat supplied by the fuel}}$$

The difference between the heat supplied and the useful heat is the heat lost to the surroundings (e.g., through the furnace walls, flue gases).

Step 3: Final Answer:

The efficiency of a furnace is correctly defined as the ratio of the useful heat absorbed by the charge to the total heat supplied by the fuel.

💡 Quick Tip

Remember the universal definition of efficiency: $\eta = \frac{\text{What you want}}{\text{What you pay for}}$. For a furnace, you want useful heat, and you pay for it by supplying fuel (heat supplied).

48. In materials characterization, electron microscopy uses which property of electron?

- (A) Negative charge
- (B) Spin nature
- (C) Wave nature
- (D) Zero

Correct Answer: (C) Wave nature

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental property of electrons that is exploited in electron microscopy to achieve high-resolution imaging.

Step 2: Detailed Explanation:

The ability of a microscope to resolve fine details is limited by diffraction, which depends on the wavelength of the radiation used for imaging. Shorter wavelengths allow for higher resolution.

In 1924, Louis de Broglie proposed that particles, including electrons, exhibit wave-like properties. The de Broglie wavelength (λ) of an electron is inversely proportional to its momentum (p):

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

where h is Planck's constant.

In an electron microscope, electrons are accelerated to very high velocities, giving them extremely high momentum and, consequently, a very short wavelength (much shorter than visible light).

It is this short **wave nature** that allows electron microscopes to overcome the diffraction limit of light microscopes and resolve features at the atomic scale. The electron waves can be focused using magnetic lenses, analogous to how glass lenses focus light waves.

While the negative charge is used to accelerate and focus the electrons, the fundamental principle enabling high-resolution imaging is their wave nature.

Step 3: Final Answer:

Electron microscopy achieves its high resolving power by utilizing the very short de Broglie wavelength of high-energy electrons, which is a direct consequence of their wave nature.

💡 Quick Tip

Think of it this way: - **Wave Nature**: Allows for high resolution (short wavelength).
- **Negative Charge**: Allows for manipulation (acceleration and focusing with electric/magnetic fields). The core principle of imaging is the wave nature.

49. A particle moves along a straight line with uniformly increasing acceleration. In the first 2 seconds, it covers 10 meters, and in the next 2 seconds it covers 30 meters. Which of the following statements is correct?

- (A) The particle has a constant velocity.
- (B) The particle's acceleration is increasing linearly with time.
- (C) The particle has a constant non-zero acceleration, and the initial velocity is non-zero.
- (D) The particle starts from rest and has constant acceleration.

Correct Answer: (D) The particle starts from rest and has constant acceleration.

Solution:

Step 1: Understanding the Question:

The question provides distance-time data for a moving particle and asks to determine the nature of its motion. There is a contradiction between the question stem ("uniformly increasing acceleration") and the options, which describe constant acceleration. We will solve the problem using the numerical data and assume the text in the stem is a typo.

Step 2: Key Formula or Approach:

We assume constant acceleration, a . The equation for displacement (s) is:

$$s = ut + \frac{1}{2}at^2$$

where u is the initial velocity and t is time.

Step 3: Detailed Explanation:

Case 1: First 2 seconds ($t = 2$ s)

The distance covered is $s_1 = 10$ m.

$$10 = u(2) + \frac{1}{2}a(2)^2$$

$$10 = 2u + 2a$$

$$5 = u + a \quad (\text{Equation 1})$$

Case 2: Total time of 4 seconds ($t = 4$ s)

The distance covered in the "next 2 seconds" is 30 m. So, the total distance from the start is $s_{total} = 10 \text{ m} + 30 \text{ m} = 40 \text{ m}$.

$$40 = u(4) + \frac{1}{2}a(4)^2$$

$$40 = 4u + 8a$$

$$10 = u + 2a \quad (\text{Equation 2})$$

Solving the system of equations:

Subtract Equation 1 from Equation 2:

$$(u + 2a) - (u + a) = 10 - 5$$

$$a = 5 \text{ m/s}^2$$

Now substitute $a = 5$ back into Equation 1:

$$5 = u + 5$$

$$u = 0 \text{ m/s}$$

The results show that the initial velocity is zero (starts from rest) and the acceleration is constant ($a = 5 \text{ m/s}^2$).

Step 4: Final Answer:

The calculations based on the given distances and times confirm that the particle starts from rest and moves with a constant acceleration. This matches option (D).

💡 Quick Tip

In physics problems, if the provided numerical data seems to contradict a statement in the question, trust the numbers. They are likely intended for calculation to find the correct physical scenario among the options.

50. The slope of the stress-strain curve in the elastic deformation region is

- (A) Elastic modulus
- (B) Plastic modulus
- (C) Poisson's ratio
- (D) Bulk modulus

Correct Answer: (A) Elastic modulus

Solution:

Step 1: Understanding the Question:

This is a definition-based question from mechanics of materials asking to identify the physical property represented by the slope of the initial, linear portion of a stress-strain curve.

Step 2: Detailed Explanation:

The stress-strain curve is a fundamental plot describing a material's mechanical properties.

- **Stress** (σ) is the applied force per unit area.
- **Strain** (ϵ) is the fractional change in length.

The initial part of the curve for most metals and many other materials is a straight line. This region is known as the **elastic deformation region**. In this region, the material obeys Hooke's Law, which states that stress is directly proportional to strain.

$$\sigma = E\epsilon$$

Rearranging this equation gives:

$$E = \frac{\sigma}{\epsilon}$$

This constant of proportionality, E , is the slope of the stress-strain curve in the elastic region ($\frac{\text{rise}}{\text{run}} = \frac{\text{stress}}{\text{strain}}$). This value, E , is known as the **Elastic Modulus** or **Young's Modulus**. It represents the material's stiffness.

Step 3: Final Answer:

The slope of the stress-strain curve in the elastic deformation region is the definition of the Elastic Modulus.

💡 Quick Tip

Remember the key features of a stress-strain curve: - **Slope of elastic region:** Elastic Modulus (Stiffness) - **End of elastic region:** Yield Strength - **Highest point of the curve:** Ultimate Tensile Strength (UTS) - **Total area under the curve:** Toughness

51. Boltzmann's equation is:

- (A) $S = kT \ln P$
- (B) $S = k \ln W$
- (C) $S = PV/T$
- (D) $S = Q/T$

Correct Answer: (B) $S = k \ln W$

Solution:

Step 1: Understanding the Question:

The question asks to identify the correct form of Boltzmann's famous entropy formula.

Step 2: Detailed Explanation:

Ludwig Boltzmann established a fundamental connection between the macroscopic property of entropy (S) and the microscopic state of a system.

Boltzmann's equation is:

$$S = k \ln W$$

where:

- **S** is the entropy of the system.
- **k** is the Boltzmann constant (1.38×10^{-23} J/K).
- **W** is the number of microstates (the number of different possible microscopic arrangements of the particles) corresponding to the system's macroscopic state.

This equation provides a statistical interpretation of entropy: a state with higher entropy is a state with a greater number of possible microscopic arrangements, making it more probable.

Let's review the other options: - $S = Q/T$ is the thermodynamic definition of entropy change for a reversible process. - $S = PV/T$ is not a standard form for entropy.

Step 3: Final Answer:

The correct equation is $S = k \ln W$, which relates entropy to the number of microstates.

💡 Quick Tip

This equation is so significant that it is engraved on Ludwig Boltzmann's tombstone. It bridges the gap between macroscopic thermodynamics and microscopic statistical mechanics.

52. Requirement of cross-slip movement of distortion?

- (A) Preferred slip plane
- (B) Preferred slip direction
- (C) No preferred slip plane
- (D) No preferred slip direction

Correct Answer: (C) No preferred slip plane

Solution:

Step 1: Understanding the Question:

The question asks for the requirement that allows for the cross-slip of a dislocation. It is assumed "distortion" is a typo for "dislocation".

Step 2: Detailed Explanation:

Cross-slip is a mechanism of plastic deformation where a **screw dislocation** changes its slip plane to an intersecting slip plane. This is a vital process that allows dislocations to bypass obstacles, leading to work hardening in metals.

There are two main types of dislocations: edge and screw.

- An **edge dislocation** is confined to a single slip plane because its Burgers vector is perpendicular to the dislocation line.
- A **screw dislocation** has its Burgers vector parallel to the dislocation line. This unique geometry means the dislocation line is not confined to a single plane. It can be considered the intersection of multiple planes.

Because the screw dislocation is not restricted to a single plane, it has **no preferred slip plane**. This freedom is precisely what allows it to move from one plane to another (cross-slip), provided the new plane also contains the Burgers vector direction.

Step 3: Final Answer:

The ability for a dislocation to undergo cross-slip relies on it being a screw dislocation, which by its nature has no single preferred slip plane.

💡 Quick Tip

Remember the key difference: - **Edge Dislocation**: Confined to ONE slip plane. Cannot cross-slip. - **Screw Dislocation**: Not confined to one plane. CAN cross-slip. Cross-slip is crucial for understanding plastic deformation and work hardening in FCC and BCC metals.

53. Recuperators are more suitable than regenerators when:

- (A) Fuel is solid
- (B) Operation is continuous
- (C) Fuel cost is negligible
- (D) Space is not an issue

Correct Answer: (B) Operation is continuous

Solution:

Step 1: Understanding the Question:

The question asks to identify the condition under which a recuperator is a more suitable heat exchanger than a regenerator.

Step 2: Detailed Explanation:

Let's compare the two types of heat exchangers:

- **Recuperator:** This is a steady-state heat exchanger where the hot and cold fluids flow simultaneously on opposite sides of a separating wall. Heat is transferred directly from the hot fluid to the cold fluid through this wall. This design is inherently suited for **continuous operation** because the flow does not need to be interrupted. A car radiator is a common example.

- **Regenerator:** This is a transient or periodic heat exchanger. It involves a heat storage medium (like a ceramic matrix). In the first half of a cycle, the hot fluid flows through the medium, heating it up. In the second half, the flow is switched, and the cold fluid flows through the hot medium, picking up the stored heat. This operation is cyclical, not continuous.

Step 3: Final Answer:

Because recuperators are designed for simultaneous and continuous flow of both hot and cold streams, they are the preferred choice for processes that require continuous, steady-state operation.

💡 Quick Tip

- **Recuperator** = Continuous flow, direct transfer through a wall. - **Regenerator** = Cyclical flow, indirect transfer via a storage medium.

54. The first law of thermodynamics is conservation of?

- (A) Momentum
- (B) Energy
- (C) Pressure
- (D) Velocity

Correct Answer: (B) Energy

Solution:

Step 1: Understanding the Question:

This is a fundamental definition question asking for the principle that the first law of thermodynamics represents.

Step 2: Detailed Explanation:

The First Law of Thermodynamics is a statement of the principle of **conservation of energy**.

It states that energy cannot be created or destroyed, only converted from one form to another.

The mathematical expression for a closed system is:

$$\Delta U = Q - W$$

This equation means that the change in the internal energy of a system (ΔU) is equal to the heat added to the system (Q) minus the work done by the system (W). It is an energy balance equation.

Conservation of momentum is related to Newton's laws of motion.

Step 3: Final Answer:

The first law of thermodynamics is the application of the principle of conservation of energy to thermodynamic systems.

💡 Quick Tip

Memorize the fundamental conservation laws in physics: - First Law of Thermodynamics → Conservation of Energy - Newton's Laws → Conservation of Momentum - Continuity Equation (Fluids/Mass Transfer) → Conservation of Mass

55. The role of a reducing agent in metallic nanomaterials synthesis is to?

- (A) Act as a solvent for the reaction
- (B) Donate electrons to the metal ions
- (C) Accept electrons from the metal ions
- (D) Increase the temperature of the reaction mixture

Correct Answer: (B) Donate electrons to the metal ions

Solution:

Step 1: Understanding the Question:

The question asks for the primary function of a reducing agent in the chemical synthesis of metallic nanoparticles.

Step 2: Detailed Explanation:

The chemical synthesis of metallic nanomaterials (like gold or silver nanoparticles) typically starts with a precursor, which is a salt of the metal dissolved in a solvent. In this dissolved state, the metal exists as positive ions (cations), for example, Au^{3+} or Ag^{+} .

To form metallic nanoparticles, these ions must be converted into neutral metal atoms (Au^0 or Ag^0). This process is a chemical **reduction**, which involves the gain of electrons.

The role of the **reducing agent** (e.g., sodium borohydride, sodium citrate) is to **donate electrons** to the metal ions, thereby reducing them to their zero-valent (metallic) state.



Once a sufficient number of neutral metal atoms are formed, they nucleate and grow into nanoparticles. An agent that accepts electrons would be an oxidizing agent, not a reducing agent.

Step 3: Final Answer:

The primary role of a reducing agent in the synthesis of metallic nanomaterials is to donate electrons to the metal ions, reducing them into neutral metal atoms which then form the nanoparticles.

💡 Quick Tip

Remember the "LEO says GER" or "OIL RIG" mnemonics for redox reactions. - Loss of Electrons is Oxidation (LEO) / Oxidation Is Loss (OIL) - Gain of Electrons is Reduction (GER) / Reduction Is Gain (RIG) The reducing agent gets oxidized while it causes the metal ions to be reduced.

56. Carnot engine consists of?

- (A) Two constant volume and two reversible adiabatic process
- (B) Two isothermal and two reversible adiabatic process
- (C) Two constant pressure and two reversible adiabatic process
- (D) One constant volume, one constant pressure and two reversible adiabatic process

Correct Answer: (B) Two isothermal and two reversible adiabatic process

Solution:

Step 1: Understanding the Question:

The question asks to identify the four processes that constitute the Carnot cycle, which is the theoretical thermodynamic cycle for the most efficient possible heat engine.

Step 2: Detailed Explanation:

The Carnot cycle consists of four fully reversible processes:

1. **Reversible Isothermal Expansion:** The working substance absorbs heat from a high-temperature reservoir (T_H) and expands, doing work on the surroundings. Temperature is constant.
2. **Reversible Adiabatic Expansion:** The working substance is thermally insulated and continues to expand, doing more work. Its temperature drops from T_H to T_L . No heat is exchanged.
3. **Reversible Isothermal Compression:** The working substance is compressed while in contact with a low-temperature reservoir (T_L), rejecting heat to it. Work is done on the substance. Temperature is constant.
4. **Reversible Adiabatic Compression:** The working substance is thermally insulated and further compressed, with its temperature rising from T_L back to T_H . No heat is exchanged.

Step 3: Final Answer:

The Carnot cycle is composed of two reversible isothermal processes and two reversible adiabatic (isentropic) processes.

💡 Quick Tip

Remember the Carnot cycle processes in order: Isothermal Expansion → Adiabatic Expansion → Isothermal Compression → Adiabatic Compression. This cycle forms a rectangle on a Temperature-Entropy (T-S) diagram.

57. A furnace uses preheated air at 300°C instead of ambient air at 30°C. If fuel consumption reduces by 20%, the impact is:

- (A) Higher stack temperature
- (B) Lower available heat
- (C) Increased efficiency
- (D) More fuel required

Correct Answer: (C) Increased efficiency

Solution:

Step 1: Understanding the Question:

The question describes a scenario where preheated air is used for combustion in a furnace, leading to a reduction in fuel consumption. We need to identify the overall impact of this change.

Step 2: Detailed Explanation:

Efficiency of a furnace is defined as the ratio of useful heat output to the total energy input (from fuel).

$$\eta = \frac{\text{Useful Heat Output}}{\text{Energy Input (Fuel)}}$$

The problem states that for the same heating task, fuel consumption is reduced by 20%. This means that less energy input is required to achieve the same useful heat output.

If the denominator (Energy Input) decreases while the numerator (Useful Heat Output) remains the same, the value of the fraction (efficiency, η) must increase.

Preheating the combustion air adds thermal energy to the system before the fuel is even burned. This means less fuel is needed to reach the desired flame temperature, and less heat is wasted heating up cold combustion air. This practice is a common method of waste heat recovery.

Step 3: Final Answer:

Using less fuel to perform the same amount of work is the very definition of increased efficiency.

💡 Quick Tip

In any combustion process, preheating the incoming air is a standard technique to improve thermal efficiency. It reduces the amount of fuel energy that is "wasted" on heating the air from ambient to combustion temperature.

58. Quantum dots are used in display technologies because they

- (A) Are very large in size
- (B) Emit fixed wavelengths regardless of size
- (C) Emit light with size-tunable wavelengths
- (D) Absorb only UV light

Correct Answer: (C) Emit light with size-tunable wavelengths

Solution:

Step 1: Understanding the Question:

The question asks for the key property of quantum dots that makes them useful in display technologies (like QLED TVs).

Step 2: Detailed Explanation:

Quantum dots are semiconductor nanocrystals. Their most important characteristic is the **quantum confinement effect**.

Because of this effect, the energy gap (bandgap) of a quantum dot is dependent on its physical size.

- **Smaller quantum dots** have a larger bandgap and emit higher-energy light, which corresponds to shorter wavelengths (e.g., blue).
- **Larger quantum dots** have a smaller bandgap and emit lower-energy light, which corresponds to longer wavelengths (e.g., red).

This means that by precisely controlling the size of the quantum dots during manufacturing, it is possible to make them emit very pure, specific colors of light across the entire visible spectrum. This **size-tunable emission wavelength** is what allows them to produce vibrant and accurate colors in displays.

Option (B) is incorrect because the wavelength is highly dependent on size. Option (A) is incorrect as they are nano-sized. Option (D) is incorrect as their absorption is also tunable.

Step 3: Final Answer:

The ability to emit light with highly specific and pure wavelengths that can be tuned by changing the particle size is the primary reason quantum dots are used in display technologies.

💡 Quick Tip

Remember the quantum dot size-color relationship: - Smallest dots → Blue light (shortest visible wavelength) - Largest dots → Red light (longest visible wavelength)
This tunability allows for a much wider and more precise color gamut compared to traditional display technologies.

59. Which of the following techniques is used to determine particle sizes in the sub-nanometer range?

- (A) Sedimentation
- (B) Dynamic light scattering
- (C) X-ray radiography
- (D) Sieving

Correct Answer: (B) Dynamic light scattering

Solution:

Step 1: Understanding the Question:

The question asks to identify a technique capable of measuring particle sizes below one nanometer.

Step 2: Detailed Explanation:

Let's evaluate the techniques:

- **Sieving and Sedimentation:** These are macroscopic techniques used for much larger particles, typically in the micrometer to millimeter range. They are completely unsuitable for the nanoscale.

- **X-ray Radiography:** This is an imaging technique based on X-ray absorption, used to see the internal structure of objects. It does not directly measure the size of individual nanoparticles.

- **Dynamic Light Scattering (DLS):** This is a widely used technique for measuring the size distribution of small particles and macromolecules in suspension. It works by illuminating the sample with a laser and analyzing the time-dependent fluctuations in the scattered light intensity. These fluctuations are caused by the Brownian motion of the particles. Smaller particles move faster, causing faster fluctuations. The Stokes-Einstein equation is then used to relate the speed of motion to the particle's hydrodynamic diameter. DLS is effective for particles from about 1 nanometer up to several micrometers, and with specialized instruments, it can probe into the sub-nanometer range.

Step 3: Final Answer:

Among the given options, Dynamic Light Scattering is the only technique suitable for measuring particle sizes in the nanometer and sub-nanometer range.

💡 Quick Tip

For particle sizing, remember the general ranges: - **Sieving/Sedimentation:** Large particles ($> 1 \mu\text{m}$) - **Dynamic Light Scattering (DLS):** Nanoparticles ($\sim 1 \text{ nm} - 10 \mu\text{m}$) - **Electron Microscopy (TEM/SEM):** Direct imaging of nanoparticles (can see sub-nm details)

60. Which of the information is true regarding scanning electron microscopy?

- (A) As working distance increases resolution increases
- (B) As working distance decreases resolution increases
- (C) As working distance decreases depth of field increases
- (D) As working distance changes depth of field remains unaltered

Correct Answer: (B) As working distance decreases resolution increases

Solution:

Step 1: Understanding the Question:

The question asks for the correct relationship between working distance, resolution, and depth of field in a Scanning Electron Microscope (SEM).

Step 2: Detailed Explanation:

- **Working Distance (WD):** This is the distance from the final objective lens of the SEM to the surface of the sample.

- **Resolution:** This is the ability to distinguish between two closely spaced points. Higher resolution means a smaller electron probe (spot size) on the sample.

- **Depth of Field (DOF):** This is the range of distances along the optical axis where the sample appears acceptably sharp. A large depth of field is a key advantage of SEMs.

The relationships are as follows:

1. **Working Distance and Resolution:** A shorter working distance allows the magnetic lenses to focus the electron beam to a smaller spot size on the sample. A smaller spot size results in higher resolution. Therefore, **as working distance decreases, resolution increases**. This makes option (B) correct and (A) incorrect.

2. **Working Distance and Depth of Field:** A longer working distance results in a more collimated beam (less convergence angle), which increases the depth of field. Conversely, a shorter working distance decreases the depth of field. Therefore, there is an inverse relationship between resolution and depth of field. Option (C) is incorrect.

Step 3: Final Answer:

To achieve the highest possible resolution in an SEM, one must use the shortest possible working distance.

💡 Quick Tip

Remember the trade-off in SEM: - **Short Working Distance** → High Resolution, Low Depth of Field. - **Long Working Distance** → Low Resolution, High Depth of Field. You choose the working distance based on whether your priority is to see the finest details (high resolution) or to have a large portion of a rough surface in focus (high depth of field).

61. Fugacity is a corrected pressure that:

- (A) Replaces pressure in ideal gas equations
- (B) Applies to solids only
- (C) Equals actual pressure
- (D) Increases with ideality

Correct Answer: (A) Replaces pressure in ideal gas equations

Solution:

Step 1: Understanding the Question:

The question asks for the definition and purpose of fugacity in thermodynamics.

Step 2: Detailed Explanation:

Thermodynamic equations for properties like Gibbs free energy are often simple when expressed in terms of pressure (P) for an **ideal gas**. For example, the change in molar Gibbs energy with pressure is $dG = VdP = RT\frac{dP}{P}$.

However, for a **real gas**, this simple relationship does not hold due to intermolecular forces. To retain the simple mathematical form of the ideal gas equations while applying them to real gases, G. N. Lewis introduced the concept of **fugacity** (f).

Fugacity is an "effective" or "corrected" pressure. It is defined in such a way that it **replaces pressure in the ideal gas equations to make them work for real gases**. The defining equation becomes $dG = RT\frac{df}{f}$.

The fugacity of a real gas approaches the actual pressure as the pressure approaches zero ($f \rightarrow P$ as $P \rightarrow 0$), where the gas behaves ideally. Thus, it does not always equal the actual pressure, and it doesn't "increase with ideality"; rather, the ratio f/P approaches 1 with ideality. The concept is primarily for gases and liquids, not just solids.

Step 3: Final Answer:

Fugacity is a thermodynamic property that serves as a corrected pressure, allowing the simple equations derived for ideal gases to be applied to real gases.

💡 Quick Tip

Think of fugacity as what pressure "feels like" to a real gas. Just as activity is the "effective concentration" for non-ideal solutions, fugacity is the "effective pressure" for non-ideal gases.

62. The throttling process is ----- process.

- (A) Reversible
- (B) Irreversible
- (C) Closed
- (D) Open

Correct Answer: (B) Irreversible

Solution:

Step 1: Understanding the Question:

The question asks to classify the throttling process based on its thermodynamic nature.

Step 2: Detailed Explanation:

A **throttling process** is a thermodynamic process in which a fluid is forced to flow through a restriction (like a valve, porous plug, or capillary tube) from a high-pressure region to a low-pressure region. Key characteristics are:

- It is an **isenthalpic** process (enthalpy remains constant, $\Delta h = 0$), assuming no heat transfer and negligible changes in kinetic/potential energy.
- It involves a significant pressure drop.
- The expansion is uncontrolled and involves fluid friction.

Any process that involves friction is inherently **irreversible**. In a throttling process, the fluid's initial state cannot be restored by simply reversing the pressure difference, as energy is dissipated as heat due to friction. This results in an increase in the entropy of the system and its surroundings, which is the hallmark of an irreversible process.

Step 3: Final Answer:

Due to the presence of fluid friction and uncontrolled expansion, the throttling process is fundamentally irreversible.

 Quick Tip

Remember that throttling is a constant-enthalpy (isenthalpic) process and is always irreversible. This is the principle behind refrigeration and air conditioning, known as the Joule-Thomson effect.

63. The fraction of heat which changes into work?

- (A) Helm - Holtz frequency
- (B) Gibbs's free energy
- (C) $H + G$
- (D) $F + G$

Correct Answer: (B) Gibbs's free energy

Solution:

Step 1: Understanding the Question:

The question asks for the thermodynamic potential that represents the maximum amount of non-expansion work that can be extracted from a system, which can be interpreted as the "fraction of heat" available to do useful work.

Step 2: Detailed Explanation:

The two key thermodynamic potentials related to "free energy" or "available work" are:

1. **Helmholtz Free Energy (A or F):** Defined as $A = U - TS$. The change in A (ΔA) represents the maximum amount of total work (expansion and non-expansion) that can be extracted from a system at a constant temperature.
2. **Gibbs Free Energy (G):** Defined as $G = H - TS = U + PV - TS$. The change in G (ΔG) represents the maximum amount of **non-expansion work** (e.g., electrical work in a battery) that can be extracted from a system at constant temperature and pressure.

In many practical chemical and biological processes that occur at constant pressure, the Gibbs free energy is the most relevant measure of the energy that is "free" to be converted into useful work. It accounts for the energy that is inherently "lost" as entropic heat (TS) and the energy used for expansion work ($P\Delta V$). The remaining portion, ΔG , is what can be harnessed.

Step 3: Final Answer:

The change in Gibbs's free energy (ΔG) represents the maximum useful (non-P-V) work obtainable from a process at constant temperature and pressure, which corresponds to the fraction of total energy change that can be converted into work.

Quick Tip

Remember the meanings of the free energies: - **Helmholtz (A):** Maximum total work at constant T V. - **Gibbs (G):** Maximum useful (non-P-V) work at constant T P. Since most lab/industrial processes are at constant pressure, Gibbs free energy is often the more practical measure.

64. Magnetic flux is expressed by?

- (A) Ampere
- (B) Volts
- (C) Weber
- (D) Weber/m²

Correct Answer: (C) Weber

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking for the SI unit of magnetic flux.

Step 2: Detailed Explanation:

Let's define the related quantities and their units:

- **Magnetic Flux (Φ_B):** This is a measure of the total number of magnetic field lines passing through a given area. Its SI unit is the **Weber (Wb)**.

- **Magnetic Flux Density (B):** Also known as the magnetic field strength, this is the amount of magnetic flux per unit area. Its SI unit is the **Tesla (T)**, which is equivalent to **Webers per square meter (Wb/m²)**. This corresponds to option (D).

- **Ampere (A):** The SI unit of electric current.

- **Volt (V):** The SI unit of electric potential difference.

Step 3: Final Answer:

The SI unit for magnetic flux is the Weber (Wb).

 Quick Tip

Remember the relationship: - Magnetic Flux = Magnetic Flux Density $\times$ Area - $\Phi_B = B \cdot A$ - Units: Weber (Wb) = Tesla (T) $\times$ square meter (m²) This helps distinguish between flux (total amount) and flux density (amount per area).

65. Which of the following technique is used to measure the chemical composition of the nanomaterials?

- (A) Raman spectroscopy
- (B) X-ray diffraction

- (C) Energy Dispersive Spectroscopy
- (D) UV - VIS spectroscopy

Correct Answer: (C) Energy Dispersive Spectroscopy

Solution:

Step 1: Understanding the Question:

The question asks for a technique used to determine the elemental or chemical composition of nanomaterials.

Step 2: Detailed Explanation:

Let's evaluate the techniques:

- **Energy Dispersive Spectroscopy (EDS or EDX):** This is an analytical technique used for the elemental analysis or chemical characterization of a sample. It is almost always coupled with an electron microscope (SEM or TEM). The high-energy electron beam excites electrons in the sample, causing them to emit characteristic X-rays. The energy of these X-rays is specific to each element, allowing for qualitative and quantitative determination of the chemical composition.
- **Raman Spectroscopy:** Provides information about vibrational modes in a molecule or crystal lattice. It is excellent for identifying chemical bonds, phases, and crystallinity, but not for direct elemental composition.
- **X-ray Diffraction (XRD):** Provides information about the crystal structure, phase, and lattice parameters of a material, not its elemental composition.
- **UV-Vis Spectroscopy:** Measures the absorption of ultraviolet and visible light. It is used to study electronic transitions and is useful for determining the concentration of a substance in solution or characterizing optical properties, but not for direct elemental analysis of a solid.

Step 3: Final Answer:

Energy Dispersive Spectroscopy (EDS) is the standard technique among the options for measuring the chemical/elemental composition of nanomaterials.

 Quick Tip

Associate characterization techniques with their primary output: - **XRD:** Crystal Structure - **EDS/XPS:** Elemental Composition - **Raman/FTIR:** Chemical Bonds / Vibrational Modes - **SEM/TEM:** Imaging (Morphology, Size, Shape)

66. In simple harmonic motion, the velocity is zero when:

- (A) Displacement is zero
- (B) Only displacement is maximum
- (C) Only acceleration is maximum
- (D) Both displacement and acceleration is maximum

Correct Answer: (D) Both displacement and acceleration is maximum

Solution:

Step 1: Understanding the Question:

The question asks to identify the point in a simple harmonic motion (SHM) cycle where the velocity of the object is zero.

Step 2: Detailed Explanation:

Consider a mass oscillating on a spring, a classic example of SHM.

- **Equilibrium Position:** This is the center point where the net force is zero. Here, **displacement is zero** ($x = 0$) and acceleration is zero ($a = 0$). The object is moving fastest at this point, so **velocity is maximum**.

- **Extreme Positions (Amplitudes):** These are the two points of maximum displacement from the equilibrium ($x = \pm A$). At these points, the object momentarily stops to change direction. Therefore, at the extreme positions, the **velocity is zero**.

Now let's consider acceleration. The restoring force in SHM is given by $F = -kx$, and since $F = ma$, the acceleration is $a = -\frac{k}{m}x$. This shows that acceleration is directly proportional to the negative of the displacement.

Therefore, when the **displacement is maximum** ($x = \pm A$), the magnitude of the **acceleration is also maximum** ($a = \mp \frac{k}{m}A$).

Combining these facts, the velocity is zero at the extreme positions, which is precisely where both the displacement and the magnitude of the acceleration are at their maximum values.

Step 3: Final Answer:

In simple harmonic motion, the velocity is zero at the points of maximum displacement, which are also the points of maximum acceleration.

 Quick Tip

For SHM, remember these relationships: - **Center (Equilibrium)**: Max Velocity, Zero Displacement, Zero Acceleration. - **Ends (Amplitudes)**: Zero Velocity, Max Displacement, Max Acceleration. Velocity is maximum when acceleration is zero, and vice-versa.

67. Miller indices for a plane cutting $x = a$, $y = \infty$, $z = c$ is:

- (A) (1 0 1)
- (B) (1 0 0)
- (C) (1 1 1)
- (D) (0 1 1)

Correct Answer: (A) (1 0 1)

Solution:

Step 1: Understanding the Question:

The question asks to determine the Miller indices for a crystallographic plane given its intercepts with the crystal axes.

Step 2: Key Formula or Approach:

The procedure to find Miller indices (h k l) for a plane is:

1. Find the intercepts of the plane with the x, y, and z axes in terms of the lattice parameters (a, b, c).
2. Take the reciprocals of these intercepts.
3. Clear any fractions by multiplying by the least common multiple to get the smallest set of integers.
4. Enclose the integers in parentheses (h k l).

Step 3: Detailed Explanation:

1. Find Intercepts:

The intercepts are given as:

$$\text{x-intercept} = 1a$$

$$\text{y-intercept} = \infty \text{ (meaning the plane is parallel to the y-axis)}$$

$$\text{z-intercept} = 1c$$

In terms of lattice parameters, the intercepts are (1, ∞ , 1).

2. Take Reciprocals:

$$\text{Reciprocal of } 1 \text{ is } \frac{1}{1} = 1.$$

$$\text{Reciprocal of } \infty \text{ is } \frac{1}{\infty} = 0.$$

Reciprocal of 1 is $\frac{1}{1} = 1$.

The reciprocals are (1, 0, 1).

3. Clear Fractions:

There are no fractions to clear. The integers are 1, 0, and 1.

4. Enclose in Parentheses:

The Miller indices are (1 0 1).

Step 4: Final Answer:

The Miller indices for the plane are (1 0 1).

 Quick Tip

Remember that an intercept of infinity (∞) always corresponds to a Miller index of zero (0). This signifies that the plane is parallel to that axis.

68. For a certain gas, $C_p = 29 \text{ J/mol} \cdot \text{K}$ and $C_v = 21 \text{ J/mol} \cdot \text{K}$. What is the gas constant R ?

- (A) $8 \text{ J/mol} \cdot \text{K}$
- (B) $6 \text{ J/mol} \cdot \text{K}$
- (C) $10 \text{ J/mol} \cdot \text{K}$
- (D) $12 \text{ J/mol} \cdot \text{K}$

Correct Answer: (A) $8 \text{ J/mol} \cdot \text{K}$

Solution:

Step 1: Understanding the Question:

The question provides the molar specific heat at constant pressure (C_p) and constant volume (C_v) for a gas and asks to calculate the molar gas constant (R).

Step 2: Key Formula or Approach:

The relationship between C_p , C_v , and R for an ideal gas (or a gas behaving ideally) is given by Mayer's relation:

$$C_p - C_v = R$$

Step 3: Detailed Explanation:

We are given:

- $C_p = 29 \text{ J/mol} \cdot \text{K}$
- $C_v = 21 \text{ J/mol} \cdot \text{K}$

Substitute these values into Mayer's relation:

$$R = C_p - C_v$$

$$R = 29 \text{ J/mol} \cdot \text{K} - 21 \text{ J/mol} \cdot \text{K}$$

$$R = 8 \text{ J/mol} \cdot \text{K}$$

Step 4: Final Answer:

The value of the gas constant R for this gas is $8 \text{ J/mol} \cdot \text{K}$. (Note: This is close to the universal gas constant, which is approximately $8.314 \text{ J/mol} \cdot \text{K}$).

Quick Tip

Mayer's relation, $C_p - C_v = R$, is a fundamental equation in thermodynamics. Remember that C_p is always greater than C_v because at constant pressure, some of the heat supplied must do work of expansion, in addition to raising the internal energy.

69. The total area under stress - strain curve represents?

- (A) Malleability
- (B) Toughness
- (C) Resilience
- (D) Fracture strength

Correct Answer: (B) Toughness

Solution:

Step 1: Understanding the Question:

The question asks for the mechanical property represented by the total area under the engineering stress-strain curve up to the point of fracture.

Step 2: Detailed Explanation:

The area under the stress-strain curve represents the work done per unit volume, or the energy absorbed per unit volume, to deform the material.

- **Toughness:** This is defined as the total amount of energy a material can absorb per unit volume before it fractures. This corresponds to the **total area under the stress-strain curve**. A material with high toughness can withstand both high stresses and high strains.
- **Resilience (or Modulus of Resilience):** This is the amount of energy a material can absorb per unit volume without undergoing permanent (plastic) deformation. It is represented by the area under the elastic portion of the stress-strain curve only.
- **Malleability:** The ability of a material to undergo large plastic deformation under compressive stress. It is not directly quantified by the area under the tensile stress-strain curve.
- **Fracture Strength:** The stress at which the material fractures. This is a single point on the curve, not an area.

Step 3: Final Answer:

The total area under the stress-strain curve up to the point of fracture represents the material's toughness.

💡 Quick Tip

Remember the areas on the stress-strain curve: - **Area under elastic region** = Modulus of Resilience (energy absorbed elastically) - **Total area under the entire curve** = Toughness (total energy absorbed before fracture)

70. The free energy of a nano-sized system compared to its bulk counterpart?

- (A) Is no longer intensive
- (B) Continues to be intensive
- (C) Is no longer extensive
- (D) Continuous to be extensive

Correct Answer: (A) Is no longer intensive

Solution:

Step 1: Understanding the Question:

The question asks how the nature of free energy (as an intensive or extensive property) changes when moving from a bulk system to a nano-sized system.

Step 2: Detailed Explanation:

In classical thermodynamics (bulk systems), Gibbs free energy (G) is an **extensive property** (depends on the amount of substance), while molar Gibbs free energy ($G_m = G/n$) is an **intensive property** (independent of the amount of substance).

However, for nano-sized systems, the surface-area-to-volume ratio is extremely high. A significant fraction of the atoms are on the surface, and these surface atoms have a higher energy than the bulk atoms. This extra energy is called surface energy.

The total free energy of a nanoparticle is the sum of the bulk free energy and the surface free energy:

$$G_{total} = G_{bulk} + G_{surface}$$

$$G_{total} = nG_m + \gamma A$$

where γ is the surface tension and A is the surface area.

If we now consider the molar free energy of the nanoparticle:

$$G_{m,nano} = \frac{G_{total}}{n} = G_m + \frac{\gamma A}{n}$$

The term $\frac{\gamma A}{n}$ depends on the size and shape of the nanoparticle (since area A and moles n are related to the particle's radius). Because this term depends on the size of the system, the molar free energy of a nano-sized system is **no longer an intensive property**. It becomes size-dependent.

Step 3: Final Answer:

Due to the significant contribution of surface energy, the molar free energy of a nano-sized system depends on its size, and therefore, it is no longer an intensive property.

💡 Quick Tip

The key takeaway for nanomaterials is that surface effects become dominant. Properties that are independent of size in the bulk world (intensive properties like melting point, molar free energy) often become size-dependent at the nanoscale.

71. Total internal reflection in optical fibers occurs when:

- (A) Light goes from low to high refractive index
- (B) Angle of incidence < critical angle
- (C) Light is absorbed by the cladding
- (D) Angle of incidence > critical angle and $n_1 > n_2$

Correct Answer: (D) Angle of incidence $>$ critical angle and $n_1 > n_2$

Solution:

Step 1: Understanding the Question:

The question asks for the necessary conditions for total internal reflection (TIR) to occur, specifically in the context of an optical fiber.

Step 2: Detailed Explanation:

Total internal reflection is the phenomenon that allows light to be guided within the core of an optical fiber. For TIR to occur, two specific conditions must be met simultaneously:

1. **Refractive Index Condition:** Light must be traveling from a medium with a higher refractive index to a medium with a lower refractive index. In an optical fiber, this means light travels from the core (n_1) to the cladding (n_2), so it must be that $n_1 > n_2$. Option (A) is incorrect.

2. **Angle of Incidence Condition:** The angle at which the light ray strikes the interface between the two media (the angle of incidence, θ_i) must be **greater than the critical angle** (θ_c). The critical angle is a specific angle determined by the refractive indices of the two media ($\sin \theta_c = n_2/n_1$). If the angle is less than the critical angle, refraction will occur instead of reflection. Option (B) is incorrect.

Option (D) correctly combines both of these necessary conditions.

Step 3: Final Answer:

Total internal reflection occurs when the angle of incidence is greater than the critical angle AND the light is traveling from a higher refractive index medium (core) to a lower refractive

index medium (cladding).

💡 Quick Tip

Remember the two key ingredients for TIR:

1. **Direction:** High-n to Low-n medium.
 2. **Angle:** Greater than critical.
- Both must be true.

72. Burgers vector is used to describe:

- (A) Twinning
- (B) Dislocation
- (C) Plastic flow
- (D) Vacancy migration

Correct Answer: (B) Dislocation

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking what crystal defect is characterized by a Burgers vector.

Step 2: Detailed Explanation:

A **dislocation** is a line defect in a crystal lattice. The **Burgers vector** ($\vec{b}$) is a vector that represents the magnitude and direction of the lattice distortion resulting from the dislocation.

It is a fundamental characteristic that defines the dislocation:

- For an **edge dislocation**, the Burgers vector is perpendicular to the dislocation line.
- For a **screw dislocation**, the Burgers vector is parallel to the dislocation line.
- For a **mixed dislocation**, it has both edge and screw components.

The movement of dislocations, characterized by their Burgers vectors, is the primary mechanism of plastic flow in crystalline materials. Twinning and vacancy migration are other types of defects/mechanisms, but they are not described by a Burgers vector.

Step 3: Final Answer:

The Burgers vector is a unique and defining characteristic used to describe the geometry of a dislocation.

💡 Quick Tip

To visualize the Burgers vector, imagine making a closed loop, atom by atom, around a dislocation line in a perfect crystal. The vector needed to close the loop is the Burgers vector. It quantifies the "mistake" in the lattice.

73. One of the optical properties of nanomaterials that changes with size is:

- (A) Luster
- (B) Absorption spectrum
- (C) Transparency
- (D) Density

Correct Answer: (B) Absorption spectrum

Solution:

Step 1: Understanding the Question:

The question asks to identify an optical property of nanomaterials that is size-dependent.

Step 2: Detailed Explanation:

Many properties of materials that are constant in the bulk become size-dependent at the nanoscale due to quantum confinement and surface effects.

- **Absorption Spectrum:** This is a prime example of a size-dependent optical property. Due to quantum confinement, the energy bandgap of semiconductor nanomaterials (quantum dots) changes with size. A smaller size leads to a larger bandgap. Since the absorption of light corresponds to exciting an electron across this bandgap, a change in the bandgap directly changes the wavelengths of light the material can absorb. This results in a size-tunable **absorption spectrum**. Similarly, for metallic nanoparticles like gold, the surface plasmon resonance peak in the absorption spectrum shifts with particle size.

- Luster, transparency, and density are generally considered bulk properties that do not exhibit such dramatic and direct size-dependent changes in the same way the absorption spectrum does. Density, in particular, is a bulk property (mass/volume) that is largely independent of size.

Step 3: Final Answer:

The absorption spectrum is a key optical property of nanomaterials that is highly dependent on their size and shape.

 Quick Tip

When you see "nanomaterials" and "optical properties" in the same question, immediately think about size-dependent phenomena like quantum confinement (for semiconductors) and surface plasmon resonance (for metals). Both of these directly affect the absorption and emission of light.

74. Vant Hoff's isotherm is used to relate:

- (A) Enthalpy and entropy
- (B) Heat of reaction and pressure
- (C) Equilibrium constant and temperature
- (D) Fugacity and activity

Correct Answer: (C) Equilibrium constant and temperature

Solution:

Step 1: Understanding the Question:

The question asks for the relationship described by the Van't Hoff equation. Note: There is some confusion in terminology. The Van't Hoff isotherm relates ΔG to the reaction quotient, while the Van't Hoff equation relates the equilibrium constant to temperature. Given the options, the question is referring to the Van't Hoff equation.

Step 2: Key Formula or Approach:

The Van't Hoff equation describes how the equilibrium constant (K) of a chemical reaction changes with a change in temperature (T). The differential form is:

$$\frac{d(\ln K)}{dT} = \frac{\Delta H^\circ}{RT^2}$$

where ΔH° is the standard enthalpy of reaction and R is the gas constant. The integrated form, which is often used to compare the equilibrium constant at two different temperatures, is:

$$\ln \left(\frac{K_2}{K_1} \right) = -\frac{\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Step 3: Detailed Explanation:

Both forms of the equation clearly establish a relationship between the **equilibrium constant** (K) and **temperature** (T). It allows one to calculate the equilibrium constant at a new temperature if its value at an initial temperature and the enthalpy of reaction are known.

Step 4: Final Answer:

The Van't Hoff equation is used to relate the equilibrium constant of a reaction to the temperature.

💡 Quick Tip

The Van't Hoff equation is the quantitative version of Le Chatelier's principle for temperature changes. For an exothermic reaction ($\Delta H < 0$), increasing T decreases K. For an endothermic reaction ($\Delta H > 0$), increasing T increases K.

75. Carbon nanotubes are the typical example of?

- (A) Zero-dimensional materials
- (B) Two-dimensional materials
- (C) Three-dimensional materials
- (D) One-dimensional materials

Correct Answer: (D) One-dimensional materials

Solution:

Step 1: Understanding the Question:

The question asks to classify carbon nanotubes based on their dimensionality in the context of nanomaterials.

Step 2: Detailed Explanation:

Nanomaterials are classified based on the number of dimensions that are confined to the nanoscale (typically ≤ 100 nm).

- **Zero-dimensional (0D):** All three dimensions are at the nanoscale. These are particles, like quantum dots or nanoparticles.

- **One-dimensional (1D):** Two dimensions are at the nanoscale, while one dimension is extended. This results in a nano-object with a length that is significantly larger than its width or diameter. Examples include nanowires, nanorods, and **carbon nanotubes**. A carbon nanotube has a diameter on the order of nanometers, but its length can be many micrometers or even centimeters.

- **Two-dimensional (2D):** One dimension is at the nanoscale, while two dimensions are extended. This results in a sheet-like material. Graphene is the classic example.

- **Three-dimensional (3D):** None of the dimensions are confined to the nanoscale. These are bulk materials that may have a nanostructured feature, like a nanocomposite or a material with nano-sized grains.

Step 3: Final Answer:

Since carbon nanotubes are confined in two dimensions (their diameter) but extended in the third (their length), they are classified as one-dimensional (1D) nanomaterials.

💡 Quick Tip

Think about how many "large" dimensions the nanomaterial has. - 0 large dimensions = 0D (dots) - 1 large dimension = 1D (wires, tubes) - 2 large dimensions = 2D (sheets) - 3 large dimensions = 3D (bulk)

76. For an ideal gas, enthalpy is a function of:

- (A) Pressure
- (B) Temperature only
- (C) Volume
- (D) Entropy

Correct Answer: (B) Temperature only

Solution:

Step 1: Understanding the Question:

The question asks for the variable upon which the enthalpy of an ideal gas depends.

Step 2: Detailed Explanation:

For any simple compressible system, enthalpy (H) can be expressed as a function of temperature (T) and pressure (P), $H = H(T, P)$. The total differential is $dH = (\frac{\partial H}{\partial T})_P dT + (\frac{\partial H}{\partial P})_T dP$.

The first term is the specific heat at constant pressure, $C_p = (\frac{\partial H}{\partial T})_P$.

For an **ideal gas**, a key defining characteristic is that its internal energy (U) is a function of temperature only, $U = U(T)$.

The enthalpy of an ideal gas is defined as $H = U + PV$. Using the ideal gas law, $PV = nRT$, we get:

$$H = U(T) + nRT$$

Since U is only a function of T , and n and R are constants, the entire expression for enthalpy (H) depends only on **temperature**.

This means that for an ideal gas, $(\frac{\partial H}{\partial P})_T = 0$. The enthalpy does not change with pressure at a constant temperature.

Step 3: Final Answer:

For an ideal gas, both internal energy and enthalpy are functions of temperature only.

💡 Quick Tip

Remember this crucial rule for ideal gases: - Internal Energy: $U = f(T)$ only - Enthalpy: $H = f(T)$ only This is a fundamental assumption that simplifies many thermodynamic calculations.

77. The critical resolved shear stress (CRSS) determines:

- (A) When slip initiates
- (B) Dislocation density
- (C) Fracture toughness
- (D) Twinning behavior

Correct Answer: (A) When slip initiates

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking for the physical significance of the critical resolved shear stress (CRSS).

Step 2: Detailed Explanation:

Plastic deformation in crystalline materials occurs by the process of **slip**, which is the movement of dislocations on specific crystallographic planes (slip planes) and in specific directions (slip directions).

For a dislocation to move, a shear stress must act on the slip plane in the slip direction. This component of the applied stress is called the **resolved shear stress** (τ_R).

The **Critical Resolved Shear Stress (CRSS)** is the minimum value of resolved shear stress that is required to initiate dislocation motion and cause slip. It is a fundamental material

property that represents the intrinsic resistance of the crystal lattice to dislocation movement.

When the resolved shear stress on a particular slip system reaches the CRSS, that slip system becomes active, and plastic deformation begins. This is described by Schmid's Law: $\tau_R = \sigma \cos \phi \cos \lambda$, where slip occurs when $\tau_R \geq \text{CRSS}$.

Step 3: Final Answer:

The critical resolved shear stress is the threshold stress required to initiate slip in a crystal.

💡 Quick Tip

Think of CRSS as the "yield strength" for a single crystal on a specific slip system. It's the point where the material starts to deform plastically by dislocation motion.

78. Which of the following property makes carbon nanotubes an excellent material for nanoelectronics?

- (A) High aspect ratio
- (B) High melting point
- (C) High specific heat capacity
- (D) Ballistic electron transport

Correct Answer: (D) Ballistic electron transport

Solution:

Step 1: Understanding the Question:

The question asks for the specific property of carbon nanotubes (CNTs) that makes them particularly promising for use in nanoelectronics (e.g., as interconnects or in transistors).

Step 2: Detailed Explanation:

- **High Aspect Ratio, High Melting Point, High Specific Heat:** While CNTs possess these impressive mechanical and thermal properties, these are not the primary reasons for their application in *electronics*.

- **Ballistic Electron Transport:** This is the key electronic property. In an ideal (defect-free) metallic carbon nanotube over short distances, electrons can travel without being scattered by the atoms of the lattice. This scattering is the primary cause of electrical resistance in conventional conductors. In the ballistic regime, electrons move like bullets down a smooth barrel, experiencing virtually no resistance. This property allows CNTs to carry extremely high current densities without significant heating, making them ideal candidates for tiny, highly efficient

wires (interconnects) and channels in future electronic devices.

Step 3: Final Answer:

The phenomenon of ballistic electron transport, which leads to extremely low electrical resistance and high current-carrying capacity, is the property that makes carbon nanotubes an excellent material for nanoelectronics.

💡 Quick Tip

For carbon nanotubes, associate their properties with applications: - **Mechanical Strength/Aspect Ratio** → Composites, Reinforcements - **Thermal Conductivity** → Heat Sinks, Thermal Interface Materials - **Ballistic Transport** → Nanoelectronics, Interconnects

79. Which is not a feature of cold working?

- (A) Increase in dislocation density
- (B) Grain refinement
- (C) High ductility
- (D) Strain hardening

Correct Answer: (C) High ductility

Solution:

Step 1: Understanding the Question:

The question asks to identify which of the listed options is NOT a characteristic result of cold working a metal.

Step 2: Detailed Explanation:

Cold working (or strain hardening) is the process of plastically deforming a metal below its recrystallization temperature. This has several effects on the microstructure and properties:

- **Increase in dislocation density (A):** Plastic deformation occurs by the movement and multiplication of dislocations. As deformation proceeds, dislocations become entangled and their density increases significantly. This is a primary feature.
- **Strain hardening (D):** The increased dislocation density and their entanglement make it progressively harder for dislocations to move. This means a higher stress is required to cause further deformation, leading to an increase in hardness and strength. This is also a primary

feature.

- **Grain Refinement (B):** While not refinement in the sense of forming new small grains (that's recrystallization), the original grains become elongated and distorted in the direction of working. This change in grain shape and internal structure is a feature.

- **High ductility (C):** Ductility is the ability of a material to deform plastically before fracture. Cold working consumes ductility. As the material becomes stronger and harder due to strain hardening, it becomes more brittle, and its capacity for further plastic deformation (its ductility) is significantly **reduced**. Therefore, high ductility is NOT a feature of a cold-worked material.

Step 3: Final Answer:

Cold working increases strength and hardness at the expense of ductility. Therefore, high ductility is not a feature of a cold-worked metal; rather, ductility is decreased.

💡 Quick Tip

Remember the trade-off in cold working: - Properties that **increase**: Yield Strength, Tensile Strength, Hardness, Dislocation Density. - Properties that **decrease**: Ductility, Toughness.

80. X-rays are?

- (A) Stream of electrons
- (B) Stream of positively charged particles
- (C) Electromagnetic radiations of high frequency
- (D) Stream of uncharged particles

Correct Answer: (C) Electromagnetic radiations of high frequency

Solution:

Step 1: Understanding the Question:

This is a fundamental physics question asking for the definition of X-rays.

Step 2: Detailed Explanation:

X-rays are a form of **electromagnetic radiation**, just like visible light, radio waves, and gamma rays. They are composed of photons and travel at the speed of light.

The electromagnetic spectrum is ordered by frequency (or wavelength). X-rays are characterized by their very **high frequency** and correspondingly short wavelength, placing them between ultraviolet (UV) light and gamma rays in the spectrum.

- A stream of electrons is a beta particle or an electron beam.
- A stream of positively charged particles could be alpha particles (helium nuclei) or protons.
- A stream of uncharged particles could be neutrons.

Step 3: Final Answer:

X-rays are high-frequency (and therefore high-energy) electromagnetic radiations.

💡 Quick Tip

Memorize the order of the electromagnetic spectrum: Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays, Gamma rays. Frequency and energy increase from left to right, while wavelength decreases.

81. When temperature increases, the energy bandgap of a semiconductor?

- (A) Decreases
- (B) Does not change
- (C) Increases
- (D) Almost zero

Correct Answer: (A) Decreases

Solution:

Step 1: Understanding the Question:

The question asks about the effect of increasing temperature on the energy bandgap (E_g) of a semiconductor.

Step 2: Detailed Explanation:

The energy bandgap of a semiconductor is the energy difference between the top of the valence band and the bottom of the conduction band.

When the temperature of a semiconductor increases, the atoms in the crystal lattice vibrate with greater amplitude. This increased thermal vibration causes the interatomic spacing to expand slightly (thermal expansion).

The interaction between the lattice potential and the electrons is affected by this change. The increased vibration and expansion effectively reduce the potential seen by the electrons, which causes the energy levels in the valence and conduction bands to shift. The net effect is that the top of the valence band moves up in energy and the bottom of the conduction band moves down in energy, leading to a **decrease** in the energy bandgap.

This effect is generally small but significant and is described by empirical formulas like the Varshni equation.

Step 3: Final Answer:

As the temperature of a semiconductor increases, its energy bandgap decreases.

💡 Quick Tip

Remember this inverse relationship for semiconductors: Temperature $\uparrow \implies$ Bandgap $\downarrow$. This is one of the reasons why the performance of semiconductor devices can degrade at high operating temperatures.

82. Hall-Petch equation relates yield strength (σ_y) to:

- (A) Strain rate
- (B) Grain size
- (C) Stacking fault energy
- (D) Poisson's ratio

Correct Answer: (B) Grain size

Solution:

Step 1: Understanding the Question:

The question asks to identify the microstructural parameter that the Hall-Petch equation relates to the yield strength of a material.

Step 2: Key Formula or Approach:

The Hall-Petch equation is an empirical relationship that describes how the yield strength (σ_y) of a polycrystalline material depends on its average grain diameter (d). The equation is:

$$\sigma_y = \sigma_0 + k_y d^{-1/2}$$

where:

- σ_y is the yield strength.
- σ_0 is a materials constant for the starting stress for dislocation movement (or the friction stress).
- k_y is the strengthening coefficient (a constant specific to each material).
- d is the average **grain size**.

Step 3: Detailed Explanation:

The equation shows that the yield strength increases as the grain size decreases (proportional to $1/\sqrt{d}$). This phenomenon is known as grain boundary strengthening. Grain boundaries act as barriers to dislocation motion. A material with smaller grains has a larger total grain boundary area, which provides more barriers, making the material stronger.

Step 4: Final Answer:

The Hall-Petch equation relates the yield strength of a material to its grain size.

💡 Quick Tip

The key message of the Hall-Petch relationship is: Smaller grains = Stronger material. This is one of the most fundamental strengthening mechanisms in metallurgy.

83. Which of the following polymers are widely used in organic light emitting diodes (OLEDs)?

- (A) Polypropylene
- (B) Electroluminescent polymers
- (C) Polyaniline
- (D) Kevlar

Correct Answer: (B) Electroluminescent polymers

Solution:

Step 1: Understanding the Question:

The question asks to identify the class of polymers commonly used in the fabrication of OLEDs.

Step 2: Detailed Explanation:

- **Electroluminescent polymers (B):** Electroluminescence is the phenomenon where a material emits light in response to the passage of an electric current. This is the fundamental operating principle of an OLED. Therefore, the polymers used must be electroluminescent.

This is a broad functional class that includes specific conjugated polymers like PPV and PFO. This is the most accurate description among the choices.

- **Polypropylene (A):** This is a common insulating plastic and is not electroluminescent.

- **Polyaniline (C):** This is a well-known conducting polymer, but it is generally not used as the primary light-emitting layer in commercial OLEDs because its electroluminescence efficiency is poor compared to other materials. It's more often studied for applications like sensors or antistatic coatings.

- **Kevlar (D):** This is a high-strength aramid fiber known for its excellent mechanical properties (used in bulletproof vests). It is an insulator and not used in OLEDs.

Step 3: Final Answer:

By definition, the active materials in an OLED must be capable of electroluminescence. Therefore, "electroluminescent polymers" is the correct classification for polymers used in OLEDs.

Quick Tip

For a polymer to be used in electronics like OLEDs or organic solar cells, it must be a "conjugated polymer." This means it has a backbone of alternating single and double carbon-carbon bonds, which is the key to its semiconducting behavior. Standard plastics like polypropylene, polyethylene, and PVC are insulators.

84. The Gibbs-Helmholtz equation relates:

- (A) Enthalpy and entropy
- (B) Gibbs free energy and enthalpy
- (C) Internal energy and volume
- (D) Work and entropy

Correct Answer: (B) Gibbs free energy and enthalpy

Solution:

Step 1: Understanding the Question:

The question asks to identify the thermodynamic properties related by the Gibbs-Helmholtz equation.

Step 2: Key Formula or Approach:

The Gibbs-Helmholtz equation describes how the Gibbs free energy (G) of a system changes with temperature (T). One of its most common forms is:

$$\left(\frac{\partial(G/T)}{\partial T} \right)_P = -\frac{H}{T^2}$$

where H is the enthalpy of the system and the subscript P indicates that the pressure is held constant.

Step 3: Detailed Explanation:

This equation provides a direct mathematical link between the change in **Gibbs free energy** with temperature and the system's **enthalpy**. It is very useful for calculating the change in Gibbs free energy for a reaction at one temperature if it is known at another temperature, provided the enthalpy is known.

The relationship clearly connects Gibbs free energy and enthalpy, making option (B) the correct choice.

Step 4: Final Answer:

The Gibbs-Helmholtz equation relates the Gibbs free energy, enthalpy, and temperature of a system.

💡 Quick Tip

Remember the Gibbs-Helmholtz equation as the link between the two major thermodynamic potentials, G and H , via temperature. It's a powerful tool for studying the temperature dependence of chemical equilibria.

85. In an impurity semiconductor, donor impurity atoms?

- (A) Add holes to the valence band
- (B) Remove electrons from the valence band
- (C) Add electrons to the conduction band
- (D) Add electrons to the valence band

Correct Answer: (C) Add electrons to the conduction band

Solution:

Step 1: Understanding the Question:

The question asks about the function of donor impurity atoms when they are added to a semiconductor (a process called doping).

Step 2: Detailed Explanation:

- **Semiconductors** like Silicon (Si) or Germanium (Ge) are in Group IV of the periodic table, having 4 valence electrons.
- **Donor Impurities** are elements from Group V, such as Phosphorus (P) or Arsenic (As), which have 5 valence electrons.

When a donor atom (e.g., P) replaces a Si atom in the crystal lattice, four of its valence electrons form covalent bonds with the neighboring Si atoms. The fifth valence electron is loosely bound to the phosphorus atom.

Only a small amount of thermal energy is needed to break this fifth electron free. Once freed, this electron can move into the **conduction band** of the semiconductor, becoming a free charge carrier and increasing the material's conductivity.

Because these impurities "donate" a free electron to the conduction band, they are called donors. This process creates an n-type semiconductor, where electrons are the majority charge carriers.

- Adding holes is done by acceptor impurities (Group III), which creates a p-type semiconductor.

Step 3: Final Answer:

Donor impurity atoms introduce an extra, loosely bound electron that is easily excited into the conduction band, thereby adding free electrons to the conduction band.

💡 Quick Tip

Remember the doping types:

- **n-type**: Doping with Group **V** elements (donors) → adds electrons to the conduction band. (Think 'n' for negative charge).
- **p-type**: Doping with Group **III** elements (acceptors) → creates holes (absences of electrons) in the valence band. (Think 'p' for positive charge of the hole).

86. In the sol - gel process, the transition from sol to gel is mainly due to?

- (A) High temperature annealing
- (B) Hydrolysis and poly-condensation reactions
- (C) Application of external magnetic field
- (D) Application of an electric field

Correct Answer: (B) Hydrolysis and poly-condensation reactions

Solution:

Step 1: Understanding the Question:

The question asks for the primary chemical mechanism responsible for the transformation of a sol into a gel in the sol-gel process.

Step 2: Detailed Explanation:

The sol-gel process is a chemical synthesis method used to create solid materials from small molecules. It proceeds in several stages:

1. **Sol Formation:** A precursor, typically a metal alkoxide (e.g., tetraethoxysilane, TEOS), is dissolved in a solvent (usually water/alcohol). This liquid solution, containing colloidal particles, is the "sol".
2. **Gelation (Sol to Gel Transition):** This is the crucial step. The precursor molecules undergo chemical reactions.
 - First, **hydrolysis:** The alkoxide groups (-OR) are replaced by hydroxyl groups (-OH).
 - Then, **poly-condensation:** The hydroxyl groups on different molecules react with each other to form bridges (e.g., M-O-M) and release a small molecule like water or alcohol. As these condensation reactions continue, the small colloidal particles link together to form a continuous, three-dimensional solid network that spans the entire volume of the liquid. This interconnected solid network with the liquid trapped inside its pores is the "gel".
3. **Aging and Drying:** The gel is further processed to strengthen it and then the liquid is removed to obtain a solid material (aerogel or xerogel).
4. **Densification:** High-temperature annealing may be used as a final step to densify the dried gel into a ceramic, but it is not the cause of the sol-to-gel transition itself.

Step 3: Final Answer:

The transition from a liquid sol to a solid gel is driven by the chemical reactions of hydrolysis and subsequent poly-condensation, which build the solid network.

💡 Quick Tip

Remember the sequence in the sol-gel process: **Sol** (colloidal solution) $\xrightarrow{\text{Hydrolysis + Condensation}}$ **Gel** (solid network in liquid) $\xrightarrow{\text{Drying}}$ **Solid** (e.g., Xerogel). The key transformation is the chemical linking of particles.

87. Which material typically shows no yield point in its stress-strain diagram?

- (A) Mild steel
- (B) Cast iron

- (C) Annealed copper
- (D) High carbon steel

Correct Answer: (B) Cast iron

Solution:

Step 1: Understanding the Question:

The question asks to identify a material that does not exhibit a distinct yield point phenomenon in its stress-strain curve.

Step 2: Detailed Explanation:

- **Yield Point Phenomenon:** A distinct yield point is characterized by a sharp drop in stress (upper and lower yield points) after the elastic limit is reached. This behavior is typical of low-carbon (mild) steels and is caused by the interaction of carbon atoms with dislocations (Cottrell atmospheres).
- **Mild steel (A) and High carbon steel (D):** Both typically show a yield point, although it is much more pronounced in mild steel.
- **Annealed copper (C):** As a face-centered cubic (FCC) metal, annealed copper does not have a sharp yield point. Instead, it shows a smooth, gradual transition from elastic to plastic behavior. However, the most distinct answer is cast iron.
- **Cast iron (B):** Cast iron is a brittle material. It has very little to no plastic deformation. Its stress-strain curve is nearly linear up to the point of fracture. It does not yield in the ductile sense, and therefore, it shows **no yield point**. It simply breaks when the stress reaches its ultimate tensile strength.

Comparing the options, while many non-ferrous metals lack a sharp yield point, brittle materials like cast iron are the classic example of materials that fail without any significant yielding at all.

Step 3: Final Answer:

Cast iron, being a brittle material, typically fractures before undergoing any significant plastic deformation and thus does not show a yield point on its stress-strain diagram.

💡 Quick Tip

Remember the general shapes of stress-strain curves: - **Mild Steel**: Shows a distinct upper and lower yield point. - **Most other ductile metals (Al, Cu)**: Smooth, continuous curve after the elastic region (no sharp yield point). - **Brittle Materials (Cast Iron, Ceramics)**: Almost entirely linear curve that ends abruptly in fracture, with no yielding.

88. When hydrogen peroxide is added to an acidified solution of KI, iodine (I₂) is liberated. In this case, hydrogen peroxide acts as?

- (A) A weak acid
- (B) A strong acid
- (C) Oxidizing agent
- (D) Reducing agent

Correct Answer: (C) Oxidizing agent

Solution:

Step 1: Understanding the Question:

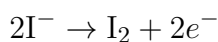
The question describes a chemical reaction and asks to identify the role of hydrogen peroxide (H₂O₂).

Step 2: Detailed Explanation:

The reaction involves potassium iodide (KI) and hydrogen peroxide (H₂O₂). In KI, iodine exists as the iodide ion (I⁻) with an oxidation state of -1.

The reaction liberates iodine (I₂), where the oxidation state of each iodine atom is 0.

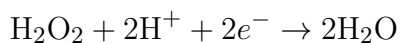
The half-reaction for iodine is:



The iodide ion has lost electrons, so it has been **oxidized**.

For a redox reaction to occur, if one species is oxidized, another must be reduced. Therefore, hydrogen peroxide must be the species that is causing the oxidation. The agent that causes oxidation is called the **oxidizing agent**.

The hydrogen peroxide itself gets reduced. The half-reaction for hydrogen peroxide in an acidic solution is:



Here, the oxidation state of oxygen goes from -1 in H_2O_2 to -2 in H_2O . It has gained electrons, so it is reduced.

Step 3: Final Answer:

Since hydrogen peroxide causes the iodide ion (I^-) to be oxidized to iodine (I_2), it acts as an oxidizing agent.

💡 Quick Tip

Remember "OIL RIG": Oxidation Is Loss (of electrons), Reduction Is Gain (of electrons). - The species that is oxidized is the reducing agent. - The species that is reduced is the oxidizing agent. In this case, I^- is oxidized, so it's the reducing agent. H_2O_2 is reduced, so it's the oxidizing agent.

89. The laws of thermodynamic apply only to

- (A) Matter in bulk
- (B) Individual atom
- (C) Individual molecule
- (D) Individual proton

Correct Answer: (A) Matter in bulk

Solution:

Step 1: Understanding the Question:

The question asks about the scope or domain of applicability of the laws of thermodynamics.

Step 2: Detailed Explanation:

Thermodynamics is a macroscopic science. Its laws and the properties it defines (like temperature, pressure, entropy) are statistical in nature and are only meaningful for systems containing a very large number of particles (atoms, molecules).

These properties represent the average behavior of the vast collection of particles. For example, temperature is related to the average kinetic energy of the particles, and pressure is the result of countless collisions of particles with the container walls.

The concepts of temperature, pressure, or entropy cannot be applied to an **individual atom, molecule, or proton**. The motion and energy of a single particle are described by mechanics (classical or quantum), not thermodynamics.

Therefore, the laws of thermodynamics apply to macroscopic systems, which is best described as **matter in bulk**.

Step 3: Final Answer:

The laws of thermodynamics are statistical laws that describe the behavior of large ensembles of particles, i.e., matter in bulk.

💡 Quick Tip

Remember the distinction:

- **Mechanics (Classical/Quantum)**: Describes the behavior of individual or few particles.
- **Thermodynamics/Statistical Mechanics**: Describes the average behavior of a huge number of particles (bulk matter).

90. A furnace uses 1000 kJ of fuel energy. Useful heat output = 700 kJ. What is the furnace efficiency?

- (A) 50%
- (B) 70%
- (C) 80%
- (D) 30%

Correct Answer: (B) 70%

Solution:

Step 1: Understanding the Question:

The question provides the energy input and useful heat output for a furnace and asks to calculate its efficiency.

Step 2: Key Formula or Approach:

The efficiency (η) of a furnace (or any energy conversion device) is defined as the ratio of the useful energy output to the total energy input, usually expressed as a percentage.

$$\eta = \frac{\text{Useful Output}}{\text{Total Input}} \times 100\%$$

Step 3: Detailed Explanation:

We are given:

- Total Input (fuel energy) = 1000 kJ
- Useful Output (useful heat) = 700 kJ

Substitute these values into the efficiency formula:

$$\eta = \frac{700 \text{ kJ}}{1000 \text{ kJ}} \times 100\%$$

$$\eta = 0.7 \times 100\%$$

$$\eta = 70\%$$

Step 4: Final Answer:

The efficiency of the furnace is 70%.

Quick Tip

Efficiency calculation is always about (Useful Output) / (Total Input). In this case, 300 kJ of energy was lost to the surroundings (e.g., through the flue gas and furnace walls).

91. The ΔH for a reaction is independent of?

- (A) The path followed
- (B) ΔV
- (C) The initial and final states
- (D) T

Correct Answer: (A) The path followed

Solution:

Step 1: Understanding the Question:

The question asks what factor the change in enthalpy (ΔH) for a reaction does NOT depend on.

Step 2: Detailed Explanation:

Enthalpy (H) is a **state function**. A state function is a property of a system that depends only on its current state, as determined by variables like temperature, pressure, and composition. It does not depend on how the system arrived at that state.

Consequently, the change in a state function (ΔH) during a process depends only on the **initial and final states** of the system, not on the specific **path followed** between those states. This is the essence of Hess's Law.

- ΔH is dependent on the initial and final states (C is incorrect). - ΔH is dependent on temperature, T (D is incorrect), as described by Kirchhoff's law. - ΔH is related to the change in internal energy ΔU and the $P\Delta V$ work, so it is related to ΔV (B is incorrect).

The only thing ΔH is independent of is the pathway taken to get from the reactants to the products.

Step 3: Final Answer:

Because enthalpy is a state function, the change in enthalpy (ΔH) for a reaction is independent of the path followed.

💡 Quick Tip

Remember the key state functions in thermodynamics: Pressure (P), Temperature (T), Volume (V), Internal Energy (U), Enthalpy (H), Entropy (S), and Gibbs Free Energy (G). Changes in these quantities (ΔP , ΔT , etc.) only depend on the start and end points. In contrast, work (W) and heat (Q) are path functions.

92. A metal specimen elongates 0.2 mm under a tensile load. Original gauge length = 50 mm. Find engineering strain.

- (A) 0.004
- (B) 0.02
- (C) 0.002
- (D) 0.04

Correct Answer: (A) 0.004

Solution:

Step 1: Understanding the Question:

The question asks to calculate the engineering strain given the original length of a specimen and its elongation under load.

Step 2: Key Formula or Approach:

Engineering strain (ϵ) is defined as the change in length (ΔL) divided by the original length (L_0).

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

Step 3: Detailed Explanation:

We are given:

- Change in length (elongation), $\Delta L = 0.2$ mm
- Original gauge length, $L_0 = 50$ mm

Substitute these values into the strain formula:

$$\epsilon = \frac{0.2 \text{ mm}}{50 \text{ mm}}$$

$$\epsilon = \frac{2}{500} = \frac{1}{250}$$

$$\epsilon = 0.004$$

Strain is a dimensionless quantity as the units of length cancel out.

Step 4: Final Answer:

The engineering strain is 0.004.

💡 Quick Tip

Be careful to distinguish between engineering strain and true strain. Engineering strain is always based on the original length, while true strain is based on the instantaneous length and is calculated as $\ln(L/L_0)$. For small deformations, the two values are nearly identical.

93. Which is a bottom-up approach in nanotechnology?

- (A) Ball milling
- (B) Lithography
- (C) Chemical vapour deposition
- (D) Cutting bulk materials

Correct Answer: (C) Chemical vapour deposition

Solution:

Step 1: Understanding the Question:

The question asks to identify which of the listed fabrication techniques is a "bottom-up" approach in nanotechnology.

Step 2: Detailed Explanation:

Nanofabrication approaches are categorized into two main types:

- **Top-Down Approaches:** These methods start with a larger, bulk material and carve, etch, or mill it down to the desired nanoscale structure. Examples include:
 - **Lithography (B):** Using a pattern to selectively remove material.
 - **Ball Milling (A):** Grinding bulk powders down to nano-sized particles.
 - **Cutting bulk materials (D):** A macroscopic example of a top-down process.
- **Bottom-Up Approaches:** These methods start with atoms or molecules as building blocks and assemble them into the desired nanostructure. Examples include:
 - **Chemical Vapor Deposition (CVD):** Precursor gas molecules are decomposed, and the resulting atoms are deposited onto a substrate, building a thin film or nanostructures (like carbon nanotubes) atom by atom.
 - Sol-gel synthesis
 - Self-assembly

Step 3: Final Answer:

Chemical vapor deposition is a bottom-up approach because it constructs nanomaterials from atomic or molecular precursors. The other options are top-down methods that break down larger materials.

💡 Quick Tip

Remember the analogy: - **Top-Down** is like a sculptor carving a statue from a block of marble. - **Bottom-Up** is like building a structure with individual Lego bricks.

94. A cantilever beam carrying a point load at free end, BM at fixed end is:

- (A) Zero
- (B) PL
- (C) PL/2
- (D) Maximum at mid-span

Correct Answer: (B) PL

Solution:

Step 1: Understanding the Question:

The question asks for the magnitude of the bending moment (BM) at the fixed end of a cantilever beam of length L , which is subjected to a point load P at its free end.

Step 2: Key Formula or Approach:

A cantilever beam is fixed at one end and free at the other. The bending moment at any section of a beam is the algebraic sum of the moments of the forces to one side of the section. We will consider the moments about the fixed end.

Step 3: Detailed Explanation:

Let the beam have length L . The point load P is at the free end. We want to find the bending moment at the fixed end.

The moment caused by the force P about the fixed end is given by:

Moment = Force $\times$ Perpendicular distance

$$BM_{fixed} = P \times L$$

This moment at the fixed support is a reaction moment that counteracts the tendency of the load P to rotate the beam. It is the maximum bending moment experienced by the beam. The bending moment at the free end is zero and it increases linearly to a maximum value of PL at the fixed end.

Step 4: Final Answer:

The bending moment at the fixed end of the cantilever beam is PL .

💡 Quick Tip

For a cantilever beam with a point load P at the free end: - Maximum Shear Force = P (constant along the beam) - Maximum Bending Moment = PL (at the fixed end)
These are standard results worth memorizing for structural mechanics problems.

95. Which of the following material deposition techniques involves plasma for the deposition of the material?

- (A) Co-precipitation
- (B) Thermal evaporation
- (C) Sputtering
- (D) Sol - gel

Correct Answer: (C) Sputtering

Solution:

Step 1: Understanding the Question:

The question asks to identify a material deposition technique that utilizes plasma.

Step 2: Detailed Explanation:

Let's examine the techniques:

- **Co-precipitation and Sol-gel (A, D):** These are wet chemical synthesis methods that occur in a liquid solution. They do not involve plasma.

- **Thermal Evaporation (B):** This is a physical vapor deposition (PVD) technique where a source material is heated in a vacuum until it evaporates. The vapor then travels and condenses on a substrate, forming a thin film. While it occurs in a vacuum, it does not typically involve plasma.

- **Sputtering (C):** This is another PVD technique. In sputtering, a target made of the material to be deposited is bombarded by high-energy ions from a **plasma**. This bombardment physically ejects or "sputters" atoms from the target. These ejected atoms then travel and deposit onto a substrate. The plasma, usually of an inert gas like Argon, is essential to the sputtering process as it is the source of the energetic ions.

Step 3: Final Answer:

Sputtering is a deposition technique that fundamentally relies on the use of plasma to bombard a target and eject material for deposition.

💡 Quick Tip

Remember the two main types of Physical Vapor Deposition (PVD): 1. **Evaporation**: Uses heat to "boil" off atoms. 2. **Sputtering**: Uses a plasma to "knock off" atoms. Plasma is the key ingredient that distinguishes sputtering.

96. A stacking fault is an example of:

- (A) Volume defect
- (B) Line defect
- (C) Point defect
- (D) Planar defect

Correct Answer: (D) Planar defect

Solution:

Step 1: Understanding the Question:

The question asks to classify a stacking fault within the hierarchy of crystal defects.

Step 2: Detailed Explanation:

Crystal defects are classified by their dimensionality:

- **0D (Point Defects)**: Defects localized to a single atomic site (e.g., vacancies, interstitials).
- **1D (Line Defects)**: Defects that extend along a line (e.g., dislocations).
- **2D (Planar or Surface Defects)**: Defects that extend across a two-dimensional plane.

Examples include:

- **Stacking Faults**: An error in the stacking sequence of crystallographic planes. For example, in an FCC crystal, the normal stacking is ABCABC... A stacking fault would be an interruption like ABCABABC...
- **Grain Boundaries**: The interface between two grains of different crystallographic orientation.
- **Twin Boundaries**: A special type of grain boundary where the lattice on one side is a mirror image of the other.
- **3D (Volume Defects)**: Extended defects like pores, cracks, or inclusions (precipitates of a second phase).

Step 3: Final Answer:

A stacking fault is an error in the stacking of atomic planes, making it a two-dimensional or planar defect.

💡 Quick Tip

Remember the dimensions of defects: - 0D: Point (vacancy) - 1D: Line (dislocation) - 2D: Plane (grain boundary, stacking fault) - 3D: Volume (pore, crack)

97. In a nanomaterial, quantum confinement occurs when the particle size becomes comparable to the?

- (A) Thermal wavelength of electrons
- (B) Gravitational wavelength of electrons
- (C) De Broglie wavelength of electrons
- (D) Electron magnetic moment

Correct Answer: (C) De Broglie wavelength of electrons

Solution:

Step 1: Understanding the Question:

The question asks for the characteristic length scale of electrons that the particle size must be comparable to for quantum confinement effects to become significant.

Step 2: Detailed Explanation:

Quantum confinement is the phenomenon where the motion of charge carriers (electrons and holes) in a material is restricted in one or more dimensions due to the material's small size. This restriction leads to the quantization of energy levels, fundamentally altering the material's electronic and optical properties.

This effect becomes prominent when the physical dimensions of the material are comparable to or smaller than the natural length scale associated with the wave-like behavior of the electrons. This length scale is the **De Broglie wavelength** ($\lambda = h/p$).

When the size of the box (the nanoparticle) is similar to the wavelength of the particle inside it (the electron), the wave "feels" the boundaries, and its energy states become discrete, like the standing waves on a guitar string. For semiconductors, a more relevant length scale is the exciton Bohr radius, which is also fundamentally related to the electron's wave nature.

Step 3: Final Answer:

Quantum confinement occurs when the particle size is comparable to the De Broglie wavelength of the electrons (or more precisely, the exciton Bohr radius).

💡 Quick Tip

Quantum effects become important when the size of the "container" is comparable to the De Broglie wavelength of the particle being contained. This is the fundamental principle behind quantum dots, quantum wells, and quantum wires.

98. During a constant pressure process, the heat added equals:

- (A) Change in internal energy
- (B) Work done
- (C) Change in enthalpy
- (D) Zero

Correct Answer: (C) Change in enthalpy

Solution:

Step 1: Understanding the Question:

The question asks what thermodynamic quantity is equal to the heat transferred during a process that occurs at constant pressure.

Step 2: Key Formula or Approach:

The First Law of Thermodynamics states:

$$\Delta U = Q - W$$

where ΔU is the change in internal energy, Q is the heat added, and W is the work done. For a process at constant pressure involving expansion or compression, the work done is $W = P\Delta V$.

The definition of enthalpy (H) is $H = U + PV$. Therefore, the change in enthalpy is:

$$\Delta H = \Delta U + \Delta(PV)$$

Step 3: Detailed Explanation:

Let's substitute the expressions into the first law.

$$\Delta U = Q - P\Delta V$$

Rearranging for heat, Q :

$$Q = \Delta U + P\Delta V$$

Since the pressure P is constant, the term $P\Delta V$ is equal to $\Delta(PV)$. So we can write:

$$Q = \Delta U + \Delta(PV)$$

From the definition of enthalpy change, we know that $\Delta H = \Delta U + \Delta(PV)$.

By comparing the two equations, we see that for a constant pressure process:

$$Q = \Delta H$$

Step 4: Final Answer:

The heat added to a system during a constant pressure process is equal to the change in enthalpy of the system.

💡 Quick Tip

Remember the specific conditions for heat transfer: - At constant **volume**, heat added = change in **internal energy** ($Q = \Delta U$). - At constant **pressure**, heat added = change in **enthalpy** ($Q = \Delta H$). This is why specific heat is defined at constant volume (C_v) and constant pressure (C_p).

99. The Carnot cycle is:

- (A) Reversible and ideal
- (B) Irreversible
- (C) Isobaric
- (D) Isochoric

Correct Answer: (A) Reversible and ideal

Solution:**Step 1: Understanding the Question:**

The question asks for the fundamental nature of the Carnot cycle.

Step 2: Detailed Explanation:

The Carnot cycle is a theoretical thermodynamic cycle proposed by Sadi Carnot. It is not a practical, real-world engine cycle but rather a theoretical construct that establishes the maximum possible efficiency for a heat engine operating between two given temperatures.

The key characteristics of the Carnot cycle are:

- It is composed of four processes (two isothermal, two adiabatic) that are all assumed to be perfectly **reversible**. A reversible process is one that can be reversed without leaving any change in either the system or the surroundings. This implies no friction, no turbulence, and infinitely slow processes.
- Because it is composed of entirely reversible processes, the entire cycle is reversible.
- It is an **ideal** cycle, meaning it represents a theoretical upper limit that real engines can only approach but never achieve, due to inherent irreversibilities in any real process.

Isobaric (constant pressure) and isochoric (constant volume) processes are parts of other cycles (e.g., Otto, Diesel), but not the Carnot cycle.

Step 3: Final Answer:

The Carnot cycle is a theoretical, ideal cycle composed entirely of reversible processes.

💡 Quick Tip

Any cycle described as "Carnot" in a thermodynamics problem is, by definition, the most efficient possible cycle operating between two temperatures. This efficiency is given by $\eta_{Carnot} = 1 - T_L/T_H$, and it is always reversible and ideal.

100. Which of the following is the correct relationship between fugacity (f) and chemical potential (μ)?

- (A) $\mu = \mu_0 + RT \ln(f)$
- (B) $f = \mu_0 + RT \ln(\mu)$
- (C) $\mu_0 = f + RT \ln(\mu)$
- (D) $f = \mu + RT \ln(\mu_0)$

Correct Answer: (A) $\mu = \mu_0 + RT \ln(f)$

Solution:

Step 1: Understanding the Question:

The question asks for the defining relationship between chemical potential (μ) and fugacity (f).

Step 2: Key Formula or Approach:

The concept of fugacity was introduced to extend the simple thermodynamic relations for ideal gases to real gases.

For an ideal gas, the chemical potential is related to its partial pressure (P_i) by:

$$\mu_i = \mu_i^\circ + RT \ln(P_i)$$

where μ_i° is the standard state chemical potential.

Step 3: Detailed Explanation:

For a real gas, this simple relationship does not hold. Fugacity (f) is defined as an "effective" pressure that allows the same mathematical form to be used. The pressure term P_i is simply replaced by the fugacity f .

Therefore, the relationship for a real gas (or any substance in general) is:

$$\mu = \mu_0 + RT \ln(f)$$

where μ_0 represents the chemical potential in the standard state (where $f = 1$ bar).

This equation is the fundamental definition that connects fugacity to chemical potential. The

other options are dimensionally and conceptually incorrect rearrangements.

Step 4: Final Answer:

The correct relationship defining fugacity in terms of chemical potential is $\mu = \mu_0 + RT \ln(f)$.

💡 Quick Tip

Remember that fugacity is a stand-in for pressure in real systems. Just as the chemical potential of an ideal gas depends on the logarithm of its pressure, the chemical potential of a real substance depends on the logarithm of its fugacity.

101. Adiabatic flame temperature is highest when:

- (A) Air-fuel ratio is lean
- (B) Combustion is complete and adiabatic
- (C) Heat loss occurs
- (D) Fuel is incomplete

Correct Answer: (B) Combustion is complete and adiabatic

Solution:

Step 1: Understanding the Question:

The question asks for the conditions that lead to the maximum possible adiabatic flame temperature.

Step 2: Detailed Explanation:

The **adiabatic flame temperature** is the theoretical maximum temperature that can be achieved by the products of combustion, assuming all the chemical energy released by the reaction is used to heat up the product gases.

For this temperature to be at its absolute maximum, several ideal conditions must be met:

1. **Adiabatic Process:** The combustion must be perfectly insulated so that there is absolutely no heat loss to the surroundings. If any heat is lost (Option C), the final temperature will be lower.
2. **Complete Combustion:** The fuel must react completely with the oxidizer to release the maximum possible amount of chemical energy. If combustion is incomplete (Option D), some chemical energy remains unreleased, lowering the final temperature.
3. **Stoichiometric Mixture:** The fuel and oxidizer (e.g., air) should be supplied in the exact chemically correct (stoichiometric) ratio. - If the mixture is **lean** (excess air, Option A), some of the energy released must be used to heat up the extra, non-reacting nitrogen and oxygen, which lowers the final temperature. - If the mixture is **rich** (excess fuel), combustion will be incomplete, and the unburned fuel will absorb heat, lowering the temperature.

Combining these, the highest temperature is achieved when combustion is complete and the process is adiabatic, which occurs at the stoichiometric ratio. Option (B) is the best description of these ideal conditions.

Step 3: Final Answer:

The adiabatic flame temperature is highest under the ideal conditions of complete combustion with no heat loss to the surroundings.

 Quick Tip

The maximum adiabatic flame temperature requires three things: a stoichiometric mixture, complete combustion, and no heat loss. Any deviation from these (lean/rich mixture, incomplete combustion, or heat loss) will result in a lower flame temperature.

102. The Zeroth Law of Thermodynamics is used to define:

- (A) Entropy
- (B) Enthalpy
- (C) Temperature
- (D) Internal energy

Correct Answer: (C) Temperature

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental concept that is defined by the Zeroth Law of Thermodynamics.

Step 2: Detailed Explanation:

The Zeroth Law of Thermodynamics states:

If two thermodynamic systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

This law, while seemingly obvious, is the fundamental principle that makes the concept of **temperature** a valid and measurable property. It establishes that "thermal equilibrium" is an equivalence relation.

It allows us to define a scale for a property (temperature) such that two systems have the same temperature if and only if they are in thermal equilibrium. A thermometer acts as the "third system" to compare the thermal state of two other systems.

- The First Law defines internal energy and its relation to heat and work. - The Second Law defines entropy and the direction of spontaneous processes.

Step 3: Final Answer:

The Zeroth Law of Thermodynamics provides the formal basis for the definition and measurement of temperature.

💡 Quick Tip

Associate each law with its key concept: - **Zeroth Law** → Temperature and thermal equilibrium. - **First Law** → Internal Energy and conservation of energy. - **Second Law** → Entropy and the direction of time/spontaneity. - **Third Law** → Absolute zero of entropy.

103. Glass transition temperature (T_g) in polymers marks:

- (A) Melting point
- (B) Onset of cross-linking
- (C) Transition from brittle to rubbery state
- (D) Start of crystallization

Correct Answer: (C) Transition from brittle to rubbery state

Solution:

Step 1: Understanding the Question:

The question asks to define the physical meaning of the glass transition temperature (T_g) in polymers.

Step 2: Detailed Explanation:

The glass transition is a phenomenon specific to the amorphous (non-crystalline) regions of a polymer. It is not a true phase transition like melting.

- **Below T_g :** The polymer is in a "glassy" state. The polymer chains are frozen in place and can only vibrate. The material is hard, stiff, and often brittle.
- **Above T_g :** The polymer is in a "rubbery" state. The polymer chains have enough thermal energy to move past one another (segmental motion). The material becomes soft, flexible, and rubbery.

Therefore, the glass transition temperature (T_g) marks the reversible **transition from a hard, brittle (glassy) state to a soft, rubbery state** upon heating.

- Melting point (T_m) is the temperature at which crystalline regions of a polymer melt, which is a different and distinct transition that occurs at a higher temperature than T_g .

- Cross-linking and crystallization are different processes altogether.

Step 3: Final Answer:

The glass transition temperature (T_g) is the temperature at which an amorphous polymer transitions from a brittle, glassy state to a flexible, rubbery state.

💡 Quick Tip

For polymers, remember the two key transition temperatures: - T_g (Glass Transition): Amorphous regions go from solid-like to liquid-like. - T_m (Melting Temperature): Crystalline regions melt. For a semi-crystalline polymer, T_m is always greater than T_g . Fully amorphous polymers only have a T_g .

104. According to free electron theory, electrical conductivity increases with:

- (A) Increasing temperature
- (B) Decreasing temperature
- (C) Increasing atomic number
- (D) Decreasing electron mobility

Correct Answer: (B) Decreasing temperature

Solution:

Step 1: Understanding the Question:

The question asks how electrical conductivity changes according to the free electron theory, which is used to model metals.

Step 2: Key Formula or Approach:

The electrical conductivity (σ) in the free electron model is given by:

$$\sigma = \frac{ne^2\tau}{m}$$

where n is the number density of free electrons, e is the electron charge, m is the electron mass, and τ is the mean free time between collisions.

Conductivity is directly proportional to the mean free time, τ .

Step 3: Detailed Explanation:

The free electron theory describes electrical resistance in metals as arising from the scattering of moving electrons. The primary scattering mechanism at room temperature and above is collision with vibrating lattice atoms (phonons).

- As **temperature increases**, the lattice atoms vibrate with greater amplitude. This increases the probability of an electron colliding with an atom.

- An increased collision probability means the average time between collisions (τ) **decreases**.
- Since conductivity is directly proportional to τ ($\sigma \propto \tau$), a decrease in τ leads to a **decrease in conductivity** (or an increase in resistivity).

Conversely, as **temperature decreases**, lattice vibrations are reduced, the mean free time (τ) between collisions increases, and thus the **electrical conductivity increases**.

Step 4: Final Answer:

According to the free electron theory for metals, electrical conductivity increases with decreasing temperature.

💡 Quick Tip

Remember the difference between metals and semiconductors: - ****Metals:**** Temperature $\uparrow \implies$ Resistivity $\uparrow$ (Conductivity $\downarrow$). More lattice vibration = more scattering. - ****Semiconductors:**** Temperature $\uparrow \implies$ Resistivity $\downarrow$ (Conductivity $\uparrow$). More thermal energy = more free carriers.

105. A quantum dot is a nanomaterial of dimension?

- (A) One
- (B) Four
- (C) Two
- (D) Zero

Correct Answer: (D) Zero

Solution:

Step 1: Understanding the Question:

The question asks for the dimensionality of a quantum dot in the context of nanomaterials classification.

Step 2: Detailed Explanation:

Nanomaterials are classified based on the number of dimensions that are NOT confined to the nanoscale (i.e., the number of "large" or "extended" dimensions). An equivalent way is to count the number of dimensions that ARE confined to the nanoscale.

- A **quantum dot** is a nanocrystal that is confined in **all three** spatial dimensions (x, y, and z) to the nanoscale.

Since it has no extended dimensions, it is classified as a **zero-dimensional (0D)** nanomaterial. It is a "point" in the context of dimensionality, although it has a physical volume.

- **One-dimensional (1D)** nanomaterials are confined in two dimensions (e.g., carbon nanotubes, nanowires). - **Two-dimensional (2D)** nanomaterials are confined in one dimension (e.g., graphene, nanosheets).

Step 3: Final Answer:

A quantum dot is confined in all three dimensions, making it a zero-dimensional (0D) nanomaterial.

💡 Quick Tip

Think about how many "large" dimensions the nanomaterial has. - 0 large dimensions = 0D (dots) - 1 large dimension = 1D (wires, tubes) - 2 large dimensions = 2D (sheets) - 3 large dimensions = 3D (bulk)

106. A ductile material exhibits:

- (A) Brittle fracture without warning
- (B) Large plastic deformation before breaking
- (C) High thermal conductivity
- (D) High hardness

Correct Answer: (B) Large plastic deformation before breaking

Solution:

Step 1: Understanding the Question:

This is a definition-based question asking for the defining characteristic of a ductile material.

Step 2: Detailed Explanation:

Ductility is a mechanical property that describes the extent to which a material can undergo plastic (permanent) deformation under tensile stress before it fractures.

- A ductile material, like copper or mild steel, can be stretched into a wire. On a stress-strain diagram, it shows a long plastic region after the yield point. Therefore, it exhibits **large plastic deformation before breaking**.
- The opposite of ductility is brittleness. A brittle material, like glass or cast iron, exhibits little or no plastic deformation and fractures suddenly without warning (Option A).
- High thermal conductivity and high hardness (Options C and D) are different material properties and are not synonyms for ductility. For example, ceramics can have high hardness but are very brittle (low ductility).

Step 3: Final Answer:

The defining characteristic of a ductile material is its ability to undergo significant plastic de-

formation before it fractures.

 Quick Tip

Remember the distinction: - **Ductile:** Stretches a lot before it breaks (e.g., chewing gum). - **Brittle:** Breaks suddenly with little stretching (e.g., a dry twig).

107. The work done during isothermal expansion of an ideal gas is:

- (A) Zero
- (B) $P\Delta V$
- (C) $nRT \ln(V_2/V_1)$
- (D) $nC_v\Delta T$

Correct Answer: (C) $nRT \ln(V_2/V_1)$

Solution:

Step 1: Understanding the Question:

The question asks for the formula for the work done by an ideal gas during a reversible isothermal expansion.

Step 2: Key Formula or Approach:

The work done (W) by a gas during an expansion from state 1 to state 2 is given by the integral:

$$W = \int_{V_1}^{V_2} P dV$$

Step 3: Detailed Explanation:

For an **ideal gas**, the pressure P is given by the ideal gas law: $P = \frac{nRT}{V}$.

For an **isothermal** process, the temperature T is constant.

Substitute the expression for P into the work integral:

$$W = \int_{V_1}^{V_2} \frac{nRT}{V} dV$$

Since n , R , and T are all constants during this process, we can take them out of the integral:

$$W = nRT \int_{V_1}^{V_2} \frac{1}{V} dV$$

The integral of $1/V$ is $\ln(V)$. Evaluating the definite integral gives:

$$W = nRT [\ln(V)]_{V_1}^{V_2} = nRT (\ln(V_2) - \ln(V_1))$$

Using the properties of logarithms, this simplifies to:

$$W = nRT \ln \left(\frac{V_2}{V_1} \right)$$

Step 4: Final Answer:

The work done during the reversible isothermal expansion of an ideal gas is given by $nRT \ln(V_2/V_1)$.

💡 Quick Tip

Remember the work formulas for different ideal gas processes: - **Isobaric (constant P):** $W = P\Delta V$ - **Isochoric (constant V):** $W = 0$ - **Isothermal (constant T):** $W = nRT \ln(V_2/V_1)$ - **Adiabatic (Q=0):** $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = -nC_v\Delta T$

108. What is the primary reason for the unique properties of nanomaterials?

- (A) High density
- (B) Large grain size
- (C) High surface area to volume ratio
- (D) High porosity

Correct Answer: (C) High surface area to volume ratio

Solution:

Step 1: Understanding the Question:

The question asks for the most fundamental reason why materials at the nanoscale exhibit properties different from their bulk counterparts.

Step 2: Detailed Explanation:

The two main reasons for the unique properties of nanomaterials are:

1. **Quantum Effects:** When materials become small enough to be comparable to the de Broglie wavelength of their electrons (quantum confinement), their electronic and optical properties change dramatically.
2. **Surface Effects:** As a particle's size decreases, its surface-area-to-volume ratio increases dramatically. For a sphere of radius r , the ratio is $A/V = (4\pi r^2)/(\frac{4}{3}\pi r^3) = 3/r$. As r becomes very small, this ratio becomes enormous.

This **high surface area to volume ratio** means that a large fraction of the atoms in a nanoparticle are on the surface. Surface atoms have fewer neighbors and are in a different

bonding environment than atoms in the bulk, making them more chemically reactive and altering properties like melting point, catalytic activity, and mechanical behavior.

Of the given options, the high surface area to volume ratio is the most encompassing and primary reason for the unique behavior of nanomaterials. Large grain size is the opposite of the nano regime. High density and porosity are not universal features.

Step 3: Final Answer:

The primary reason for the unique properties of nanomaterials is their extremely high surface area to volume ratio, which makes surface effects dominant.

 Quick Tip

When asked for the reason behind nanomaterials' unique properties, the two key answers are always "quantum confinement" and "high surface-area-to-volume ratio". The latter is the more general and universally applicable reason.

109. In semiconductors, light is emitted when:

- (A) Holes move from valence to conduction band
- (B) Electrons recombine with holes
- (C) Photons collide with atoms
- (D) Energy band gap increases

Correct Answer: (B) Electrons recombine with holes

Solution:

Step 1: Understanding the Question:

The question asks for the physical process responsible for light emission in a semiconductor (the principle behind LEDs and laser diodes).

Step 2: Detailed Explanation:

Light emission in a semiconductor is the result of a process called **radiative recombination**.

- An electron exists in a high-energy state in the **conduction band**.
- A hole (an absence of an electron) exists in a lower-energy state in the **valence band**.

When an electron from the conduction band "falls down" to fill a hole in the valence band, it transitions from a high-energy state to a low-energy state. This process is called **recombination**.

To conserve energy, the excess energy of the electron must be released. In a direct bandgap semiconductor, this energy is released in the form of a **photon**, which is a particle of light.

The energy of the emitted photon is approximately equal to the bandgap energy (E_g) of the semiconductor.

$$E_{\text{photon}} = hf \approx E_g$$

- Option (A) describes absorption of energy, not emission. - Option (C) describes scattering, not the primary emission mechanism. - Option (D) is a change in a material property, not a dynamic process of emission.

Step 3: Final Answer:

Light is emitted in a semiconductor when an electron in the conduction band recombines with a hole in the valence band, releasing its excess energy as a photon.

 Quick Tip

Remember the two fundamental light-matter interactions in semiconductors: - **Absorption:** A photon is absorbed, creating an electron-hole pair (electron moves from valence to conduction band). - **Emission:** An electron and hole recombine, destroying the pair and creating a photon.

110. The monomer of poly vinyl chloride (PVC) is?

- (A) Ethylene dichloride
- (B) Ethylene chloride
- (C) Chloroform
- (D) Chloro ethene

Correct Answer: (D) Chloro ethene

Solution:

Step 1: Understanding the Question:

The question asks to identify the monomer unit that polymerizes to form the polymer known as poly(vinyl chloride) or PVC.

Step 2: Detailed Explanation:

The name of a polymer often gives a clue to its monomer.

- The prefix "**poly-**" means "many".
- The part that follows is the name of the monomer.

Therefore, the monomer for **poly(vinyl chloride)** is **vinyl chloride**.

Now we need to find the systematic IUPAC name for vinyl chloride. The "vinyl" group refers to an ethene molecule ($\text{CH}_2 = \text{CH}_2$) that is missing one hydrogen atom ($\text{CH}_2 = \text{CH}-$). When a chlorine atom is attached to this group, the molecule is vinyl chloride ($\text{CH}_2 = \text{CHCl}$).

The IUPAC name for this molecule is **Chloroethene**.

- "Ethene" indicates the two-carbon chain with a double bond.
- "Chloro" indicates the chlorine substituent.

The other options are incorrect: - Ethylene dichloride ($\text{CH}_2\text{Cl} - \text{CH}_2\text{Cl}$) is 1,2-dichloroethane. - Ethylene chloride is an ambiguous, non-standard name. - Chloroform is trichloromethane (CHCl_3).

Step 3: Final Answer:

The monomer of poly(vinyl chloride) is vinyl chloride, whose systematic name is chloroethene.

💡 Quick Tip

For many common polymers, the monomer's name is right there in the polymer's name: - Poly(ethylene) → Monomer: Ethylene - Poly(styrene) → Monomer: Styrene
- Poly(vinyl chloride) → Monomer: Vinyl chloride (Chloroethene)

111. If A is a 3×3 matrix with eigenvalues 1, 2 and 3, what is the trace of $A^2 - 3A + I$?

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

Correct Answer: (D) -1

Solution:

Step 1: Understanding the Question:

We are given the eigenvalues of a matrix A and asked to find the trace of a polynomial of that matrix, $B = A^2 - 3A + I$.

Step 2: Key Formula or Approach:

We will use two key properties of eigenvalues:

1. If a matrix A has eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_n$, then a polynomial of the matrix, $P(A)$, has eigenvalues $P(\lambda_1), P(\lambda_2), \dots, P(\lambda_n)$.
2. The trace of a matrix is the sum of its eigenvalues.

Step 3: Detailed Explanation:

Let the given eigenvalues of A be $\lambda_1 = 1$, $\lambda_2 = 2$, and $\lambda_3 = 3$.

Let the new matrix be $B = A^2 - 3A + I$.

According to property 1, the eigenvalues of B will be:

$$\begin{aligned} - \mu_1 &= \lambda_1^2 - 3\lambda_1 + 1 = (1)^2 - 3(1) + 1 = 1 - 3 + 1 = -1 \\ - \mu_2 &= \lambda_2^2 - 3\lambda_2 + 1 = (2)^2 - 3(2) + 1 = 4 - 6 + 1 = -1 \\ - \mu_3 &= \lambda_3^2 - 3\lambda_3 + 1 = (3)^2 - 3(3) + 1 = 9 - 9 + 1 = 1 \end{aligned}$$

So, the eigenvalues of the matrix $B = A^2 - 3A + I$ are -1, -1, and 1.

According to property 2, the trace of B is the sum of its eigenvalues:

$$\text{trace}(B) = \mu_1 + \mu_2 + \mu_3$$

$$\text{trace}(B) = (-1) + (-1) + 1 = -1$$

Step 4: Final Answer:

The trace of the matrix $A^2 - 3A + I$ is -1.

💡 Quick Tip

This problem is a classic application of eigenvalue properties. Remember that eigenvalues behave very predictably under matrix operations. If $P(A) = c_k A^k + \cdots + c_1 A + c_0 I$, then the eigenvalues of $P(A)$ are simply $P(\lambda_i) = c_k \lambda_i^k + \cdots + c_1 \lambda_i + c_0$.

112. Consider the system of equations:

$$x + 2y - z = 3$$

$$2x + 4y - 2z = 7$$

$$3x + 6y - 3z = 9$$

Which of the following statements is true about the system?

- (A) The system has a unique solution.
- (B) The system has infinitely many solutions
- (C) The system has no solution
- (D) The system has finitely many solutions but not unique.

Correct Answer: (C) The system has no solution

Solution:

Step 1: Understanding the Question:

We need to determine the nature of the solution for the given system of linear equations.

Step 2: Key Formula or Approach:

We can analyze the system by comparing the equations or by using matrix methods (calculating the rank of the coefficient matrix and the augmented matrix). Let's use direct comparison.

Step 3: Detailed Explanation:

Let the three equations be:

$$(1) \ x + 2y - z = 3$$

$$(2) \ 2x + 4y - 2z = 7$$

$$(3) \ 3x + 6y - 3z = 9$$

Let's examine the relationship between these equations.

- Multiply Equation (1) by 2:

$$2(x + 2y - z) = 2(3)$$

$$2x + 4y - 2z = 6$$

Now compare this with Equation (2), which is $2x + 4y - 2z = 7$.

We have a contradiction: the same expression $2x + 4y - 2z$ cannot be equal to both 6 and 7 simultaneously. This means the system is inconsistent.

- Similarly, let's multiply Equation (1) by 3:

$$3(x + 2y - z) = 3(3)$$

$$3x + 6y - 3z = 9$$

This is identical to Equation (3). This means Equation (3) is redundant and provides no new information. However, the contradiction between (1) and (2) is sufficient to determine the nature of the solution.

Geometrically, the first two equations represent two parallel planes that never intersect. Since there is no point (x, y, z) that can satisfy both equations, the system has no solution.

Step 4: Final Answer:

Because the system of equations is inconsistent, it has no solution.

💡 Quick Tip

When analyzing a system of linear equations, first look for simple relationships. If you can show that one equation is a multiple of another but with a different constant term (e.g., $L_1 = k$ and $c \cdot L_1 = m$, where $m \neq c \cdot k$), you've immediately proven the system is inconsistent and has no solution.

113. A direction in which the function $f(x) = 2x + y$ remain constant at the point (1,1) is -----

(A) $\frac{\hat{i}}{\sqrt{5}} - \frac{2\hat{j}}{\sqrt{5}}$

(B) $-\frac{2\hat{i}}{\sqrt{5}} + \frac{\hat{j}}{\sqrt{5}}$

- (C) $-\frac{\hat{i}}{\sqrt{5}} - \frac{\hat{j}}{\sqrt{5}}$
 (D) $\frac{\hat{i}}{\sqrt{5}} + \frac{2\hat{j}}{\sqrt{5}}$

Correct Answer: (A) $\frac{\hat{i}}{\sqrt{5}} - \frac{2\hat{j}}{\sqrt{5}}$

Solution:

Step 1: Understanding the Question:

We are looking for a direction (a unit vector) along which the directional derivative of the function $f(x, y) = 2x + y$ is zero. The function remaining constant means its rate of change in that direction is zero.

Step 2: Key Formula or Approach:

The rate of change of a function f in the direction of a unit vector $\vec{u}$ is given by the directional derivative, $D_{\vec{u}}f = \nabla f \cdot \vec{u}$.

For the function to remain constant, this derivative must be zero: $\nabla f \cdot \vec{u} = 0$.

This means the direction vector $\vec{u}$ must be orthogonal (perpendicular) to the gradient vector ∇f .

Step 3: Detailed Explanation:

First, find the gradient of the function $f(x, y) = 2x + y$.

$$\nabla f = \frac{\partial f}{\partial x}\hat{i} + \frac{\partial f}{\partial y}\hat{j}$$

$$\nabla f = 2\hat{i} + 1\hat{j}$$

The gradient vector is constant, so it is $(2, 1)$ at all points, including $(1, 1)$.

Now we need to find a unit vector $\vec{u} = u_1\hat{i} + u_2\hat{j}$ such that $\nabla f \cdot \vec{u} = 0$.

$$(2\hat{i} + \hat{j}) \cdot (u_1\hat{i} + u_2\hat{j}) = 0$$

$$2u_1 + u_2 = 0$$

This implies $u_2 = -2u_1$. So, any vector in the direction $(u_1, -2u_1)$ is orthogonal to the gradient. A simple choice is the vector $\vec{v} = (1, -2)$ or $\vec{v} = \hat{i} - 2\hat{j}$.

Finally, we need to normalize this vector to make it a unit vector.

Magnitude of $\vec{v}$ is $\|\vec{v}\| = \sqrt{1^2 + (-2)^2} = \sqrt{1 + 4} = \sqrt{5}$.

The unit vector is $\vec{u} = \frac{\vec{v}}{\|\vec{v}\|} = \frac{\hat{i} - 2\hat{j}}{\sqrt{5}} = \frac{\hat{i}}{\sqrt{5}} - \frac{2\hat{j}}{\sqrt{5}}$.

Let's check the options. Option (A) matches our result.

Step 4: Final Answer:

The direction in which the function remains constant is given by the unit vector $\frac{\hat{i}}{\sqrt{5}} - \frac{2\hat{j}}{\sqrt{5}}$.

💡 Quick Tip

The gradient vector ∇f points in the direction of the function's fastest increase. The function remains constant (level curve) in directions perpendicular to the gradient. To find a perpendicular vector to (a, b) in 2D, you can use $(-b, a)$ or $(b, -a)$. Then, just normalize it.

114. The surface integral $\iint_S x^2 dS$ over the upper hemisphere $z = \sqrt{1 - x^2 - y^2}$ with radius 1 is -----

- (A) $\frac{\pi}{4}$
- (B) $\frac{\pi}{3}$
- (C) π
- (D) $\frac{2\pi}{3}$

Correct Answer: (D) $\frac{2\pi}{3}$ (There seems to be a mismatch between the provided solution checkmark (A) and the mathematical result. The correct calculation leads to $2\pi/3$, which corresponds to option (D) if we assume OCR error on checkmark placement)

Solution:**Step 1: Understanding the Question:**

We need to evaluate a surface integral of the function $f(x, y, z) = x^2$ over the surface of the upper hemisphere of a sphere with radius 1, centered at the origin.

Step 2: Key Formula or Approach:

We will use spherical coordinates to parameterize the hemisphere and evaluate the integral.

The parameterization for a sphere of radius $\rho = 1$ is:

$$x = \rho \sin \phi \cos \theta = \sin \phi \cos \theta$$

$$y = \rho \sin \phi \sin \theta = \sin \phi \sin \theta$$

$$z = \rho \cos \phi = \cos \phi$$

For the upper hemisphere, the ranges are $0 \leq \phi \leq \pi/2$ and $0 \leq \theta \leq 2\pi$.

The surface element in spherical coordinates is $dS = \rho^2 \sin \phi d\phi d\theta = \sin \phi d\phi d\theta$.

Step 3: Detailed Explanation:

Substitute the parameterization into the integral:

$$\begin{aligned}
\iint_S x^2 dS &= \int_0^{2\pi} \int_0^{\pi/2} (\sin \phi \cos \theta)^2 (\sin \phi d\phi d\theta) \\
&= \int_0^{2\pi} \int_0^{\pi/2} \sin^2 \phi \cos^2 \theta \sin \phi d\phi d\theta \\
&= \int_0^{2\pi} \int_0^{\pi/2} \sin^3 \phi \cos^2 \theta d\phi d\theta
\end{aligned}$$

We can separate the integrals with respect to ϕ and θ :

$$= \left(\int_0^{2\pi} \cos^2 \theta d\theta \right) \left(\int_0^{\pi/2} \sin^3 \phi d\phi \right)$$

Evaluate the θ integral:

Using the identity $\cos^2 \theta = \frac{1+\cos(2\theta)}{2}$:

$$\int_0^{2\pi} \frac{1+\cos(2\theta)}{2} d\theta = \frac{1}{2} \left[\theta + \frac{\sin(2\theta)}{2} \right]_0^{2\pi} = \frac{1}{2} [(2\pi + 0) - (0 + 0)] = \pi$$

Evaluate the ϕ integral:

Using $\sin^3 \phi = \sin \phi (1 - \cos^2 \phi)$:

$$\begin{aligned}
\int_0^{\pi/2} (\sin \phi - \sin \phi \cos^2 \phi) d\phi &= \left[-\cos \phi + \frac{\cos^3 \phi}{3} \right]_0^{\pi/2} \\
&= \left(-\cos(\pi/2) + \frac{\cos^3(\pi/2)}{3} \right) - \left(-\cos(0) + \frac{\cos^3(0)}{3} \right) \\
&= (0 + 0) - \left(-1 + \frac{1}{3} \right) = -\left(-\frac{2}{3} \right) = \frac{2}{3}
\end{aligned}$$

Combine the results:

$$\text{Integral} = (\pi) \times \left(\frac{2}{3} \right) = \frac{2\pi}{3}$$

Step 4: Final Answer:

The value of the surface integral is $\frac{2\pi}{3}$.

 Quick Tip

For surface integrals over spheres or hemispheres, spherical coordinates are almost always the best approach. Remember the surface element $dS = \rho^2 \sin \phi d\phi d\theta$. Also, by symmetry, $\iint_S x^2 dS = \iint_S y^2 dS = \iint_S z^2 dS$. Since $x^2 + y^2 + z^2 = R^2 = 1$, we have $3 \iint_S x^2 dS = \iint_S (x^2 + y^2 + z^2) dS = \iint_S 1 dS = \text{Area} = 2\pi(1)^2 = 2\pi$. Therefore, $\iint_S x^2 dS = \frac{2\pi}{3}$.

115. The set of all critical points of the function $f(x) = |x^2 - 1|$ on $[-2, 2]$ is -----

- (A) $\{-1, 1\}$
- (B) $\{-1, 0, 1\}$
- (C) $\{1, 0\}$
- (D) $\{0\}$

Correct Answer: (B) $\{-1, 0, 1\}$

Solution:

Step 1: Understanding the Question:

We need to find all the critical points of the function $f(x) = |x^2 - 1|$ within the closed interval $[-2, 2]$.

Step 2: Key Formula or Approach:

Critical points of a function $f(x)$ occur where the derivative $f'(x)$ is either equal to zero or is undefined.

The function is $f(x) = |x^2 - 1|$. We can write this as a piecewise function:

$$f(x) = \begin{cases} x^2 - 1 & \text{if } x^2 - 1 \geq 0 \implies x \leq -1 \text{ or } x \geq 1 \\ -(x^2 - 1) = 1 - x^2 & \text{if } x^2 - 1 < 0 \implies -1 < x < 1 \end{cases}$$

Step 3: Detailed Explanation:

We need to check two types of critical points:

1. Points where $f'(x)$ is undefined:

The absolute value function can have sharp corners where its argument is zero. The argument here is $x^2 - 1$.

$$x^2 - 1 = 0 \implies x^2 = 1 \implies x = 1 \text{ and } x = -1.$$

At these points, the derivative is undefined because the function has sharp "cusps". Let's check the derivatives from the left and right:

- At $x = 1$, the derivative from the left is $-2x = -2$, and from the right is $2x = 2$. They don't match.

- At $x = -1$, the derivative from the left is $2x = -2$, and from the right is $-2x = 2$. They

don't match.

So, $x = -1$ and $x = 1$ are critical points.

2. Points where $f'(x) = 0$:

We take the derivative in the different pieces of the function:

- For $x < -1$ or $x > 1$, $f'(x) = (x^2 - 1)' = 2x$. Setting $2x = 0$ gives $x = 0$, but this is not in the domain $x < -1$ or $x > 1$.

- For $-1 < x < 1$, $f'(x) = (1 - x^2)' = -2x$. Setting $-2x = 0$ gives $x = 0$. This point is within the domain $-1 < x < 1$.

So, $x = 0$ is also a critical point.

Combining both types, the critical points are $\{-1, 0, 1\}$. All of these lie within the given interval $[-2, 2]$.

Step 4: Final Answer:

The set of all critical points of the function on the given interval is $\{-1, 0, 1\}$.

💡 Quick Tip

When dealing with absolute value functions, always remember that critical points can occur where the derivative is undefined. This happens at the "sharp corners" or "cusps," which are the points where the argument of the absolute value is zero.

116. Suppose $\sum_{n=1}^{\infty} a_n(x-2)^n$ is convergent at $x = -5$, then it need not be convergent on which interval?

- (A) $|x - 2| \leq 5$
- (B) $|x - 2| < 5$
- (C) $|x - 2| \leq 7$
- (D) $|x - 2| < 7$

Correct Answer: (C) $|x - 2| \leq 7$

Solution:

Step 1: Understanding the Question:

We have a power series centered at $c = 2$. We are told it converges at $x = -5$. We need to find an interval where the series is not guaranteed to converge.

Step 2: Key Formula or Approach:

For a power series $\sum a_n(x - c)^n$, there is a radius of convergence, R . The series is guaranteed to converge absolutely for $|x - c| < R$ and diverge for $|x - c| > R$. The convergence at the endpoints $|x - c| = R$ must be checked separately.

Step 3: Detailed Explanation:

The series is centered at $c = 2$. We are given that it converges at $x = -5$.

The distance from the center to this point of convergence is:

$$|x - c| = |-5 - 2| = |-7| = 7.$$

This tells us that the radius of convergence, R , must be at least 7. So, $R \geq 7$.

Based on this, we know the series must converge for all x such that $|x - 2| < 7$.

The interval of guaranteed convergence is at least $(-5, 9)$.

Let's analyze the options:

- (B) $|x - 2| < 5$: This interval is entirely within our guaranteed convergence interval of $|x - 2| < 7$. So, the series must converge here.
- (A) $|x - 2| \leq 5$: This interval is also within the guaranteed convergence interval. So, the series must converge here.
- (D) $|x - 2| < 7$: This is the interval of guaranteed absolute convergence based on our finding that $R \geq 7$. So, the series must converge here.
- (C) $|x - 2| \leq 7$: This interval is $|x - 2| < 7$ plus the endpoints $x = -5$ and $x = 9$. We know the series converges at $x = -5$ (given). However, the convergence theorem for power series does not guarantee convergence at the other endpoint, $x = 9$. The series might converge or diverge at $x = 9$. For example, the series $\sum \frac{(-1)^n}{n7^n}(x - 2)^n$ converges at $x = -5$ but diverges at $x = 9$. Therefore, the series **need not be convergent** on the entire interval $|x - 2| \leq 7$.

Step 4: Final Answer:

Since convergence at one endpoint ($x = -5$) does not guarantee convergence at the other endpoint ($x = 9$), the series need not be convergent on the entire closed interval $|x - 2| \leq 7$.

💡 Quick Tip

Information about convergence at a single point x_0 for a power series centered at c establishes a minimum radius of convergence $R \geq |x_0 - c|$. The series is then guaranteed to converge for $|x - c| < R$ but not necessarily anywhere outside or at the other endpoint of this interval.

117. The general solution of the ordinary differential equation $\frac{dy}{dx} = \log(x \frac{dy}{dx} - y)$ is

- (A) $y = cx + e^c$, where c is an arbitrary constant
- (B) $y = cx^2 + e^c$, where c is an arbitrary constant
- (C) $y = cx - e^c$, where c is an arbitrary constant
- (D) $y = cx^2 - e^c$, where c is an arbitrary constant

Correct Answer: (C) $y = cx - e^c$

Solution:

Step 1: Understanding the Question:

We need to find the general solution to the given first-order ordinary differential equation.

Step 2: Key Formula or Approach:

The given equation is of the form $f(x, y, y') = 0$. Let's try to rearrange it into a standard form. The structure suggests it might be a Clairaut's equation. A Clairaut's equation has the form $y = xp + f(p)$, where $p = \frac{dy}{dx}$.

Step 3: Detailed Explanation:

Let $p = \frac{dy}{dx}$. The equation becomes:

$$p = \log(xp - y)$$

To isolate the term in the logarithm, we can exponentiate both sides:

$$e^p = xp - y$$

Now, rearrange the equation to solve for y :

$$y = xp - e^p$$

This is exactly the form of a Clairaut's equation, $y = xp + f(p)$, where $f(p) = -e^p$.

The general solution of a Clairaut's equation is found by simply replacing the parameter p with an arbitrary constant c .

So, the general solution is:

$$y = cx - e^c$$

where c is an arbitrary constant.

Step 4: Final Answer:

The general solution of the differential equation is $y = cx - e^c$.

💡 Quick Tip

Recognizing the form of a Clairaut's equation, $y = x(\frac{dy}{dx}) + f(\frac{dy}{dx})$, can save a lot of time. Its general solution is always found by replacing $\frac{dy}{dx}$ with a constant c , giving $y = cx + f(c)$.

118. If X is a normal distribution with mean μ and variation σ^2 , then the standard deviation and the mean of $Z = \frac{X-\mu}{2\sigma}$ are ----- respectively.

- (A) σ, μ
- (B) $1, 0$
- (C) $0, \frac{1}{2}$
- (D) $\frac{1}{2}, 0$

Correct Answer: (D) $\frac{1}{2}, 0$

Solution:

Step 1: Understanding the Question:

We are given a normally distributed random variable X and a new variable Z which is a linear transformation of X . We need to find the mean and standard deviation of Z .

Step 2: Key Formula or Approach:

We use the properties of expectation (mean) and variance:

1. $E[aX + b] = aE[X] + b$
2. $Var(aX + b) = a^2Var(X)$

The standard deviation is the square root of the variance: $SD(Y) = \sqrt{Var(Y)}$.

Step 3: Detailed Explanation:

We are given:

- $E[X] = \mu$
- $Var(X) = \sigma^2$

The transformation is $Z = \frac{X-\mu}{2\sigma} = \frac{1}{2\sigma}X - \frac{\mu}{2\sigma}$. This is a linear transformation of the form $aX + b$ with $a = \frac{1}{2\sigma}$ and $b = -\frac{\mu}{2\sigma}$.

Calculate the mean of Z:

$$\begin{aligned} E[Z] &= E\left[\frac{1}{2\sigma}X - \frac{\mu}{2\sigma}\right] \\ &= \frac{1}{2\sigma}E[X] - \frac{\mu}{2\sigma} \\ &= \frac{1}{2\sigma}(\mu) - \frac{\mu}{2\sigma} = 0 \end{aligned}$$

So, the mean of Z is 0.

Calculate the variance of Z:

$$\begin{aligned} Var(Z) &= Var\left(\frac{1}{2\sigma}X - \frac{\mu}{2\sigma}\right) \\ &= \left(\frac{1}{2\sigma}\right)^2 Var(X) \end{aligned}$$

$$= \frac{1}{4\sigma^2}(\sigma^2) = \frac{1}{4}$$

Calculate the standard deviation of Z:

$$SD(Z) = \sqrt{Var(Z)} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

The question asks for the standard deviation and the mean, respectively. The values are $\frac{1}{2}$ and 0.

Step 4: Final Answer:

The standard deviation of Z is $\frac{1}{2}$ and the mean of Z is 0.

 Quick Tip

Remember the standard normal variable $Z_{std} = \frac{X-\mu}{\sigma}$ has a mean of 0 and a standard deviation of 1. In this problem, the variable is $Z = \frac{1}{2} \left(\frac{X-\mu}{\sigma} \right) = \frac{1}{2} Z_{std}$. The mean is $E[\frac{1}{2} Z_{std}] = \frac{1}{2} E[Z_{std}] = 0$. The standard deviation is $SD[\frac{1}{2} Z_{std}] = \frac{1}{2} SD[Z_{std}] = \frac{1}{2}(1) = \frac{1}{2}$.

119. In a binomial distribution $B(n = 10, p)$ the probability of getting exactly 4 successes equals the probability of getting exactly 6 successes. What is the mean of the distribution?

- (A) 0.5
- (B) 3.5
- (C) 2.5
- (D) 5

Correct Answer: (D) 5

Solution:

Step 1: Understanding the Question:

We are given a binomial distribution with $n = 10$. We are told that the probability of 4 successes, $P(X = 4)$, is equal to the probability of 6 successes, $P(X = 6)$. We need to find the mean of this distribution.

Step 2: Key Formula or Approach:

The probability mass function for a binomial distribution is:

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$$

The mean of a binomial distribution is given by $\mu = np$.

Step 3: Detailed Explanation:

We are given $P(X = 4) = P(X = 6)$ with $n = 10$.

$$\binom{10}{4} p^4 (1 - p)^{10-4} = \binom{10}{6} p^6 (1 - p)^{10-6}$$

$$\frac{10!}{4!6!} p^4 (1 - p)^6 = \frac{10!}{6!4!} p^6 (1 - p)^4$$

The combinatorial coefficients $\binom{10}{4}$ and $\binom{10}{6}$ are equal, so they cancel out.

$$p^4 (1 - p)^6 = p^6 (1 - p)^4$$

Since p cannot be 0 or 1 for a non-trivial distribution, we can divide both sides by p^4 and $(1-p)^4$:

$$(1 - p)^2 = p^2$$

Taking the square root of both sides:

$$1 - p = p$$

(We take the positive root since p must be positive).

$$1 = 2p$$

$$p = \frac{1}{2} = 0.5$$

Now, calculate the mean of the distribution:

$$\mu = np = 10 \times 0.5 = 5$$

Step 4: Final Answer:

The mean of the distribution is 5.

 Quick Tip

For a binomial distribution, the probability mass function is symmetric about the mean when $p = 0.5$. The condition $P(X = k) = P(X = n - k)$ is a general property of symmetric binomial distributions. Here, $k = 4$ and $n - k = 10 - 4 = 6$. So the condition $P(X = 4) = P(X = 6)$ immediately implies that the distribution is symmetric, and therefore p must be 0.5.

120. Given $x_0 \neq 0$, the iteration $x_{n+1} = \frac{1}{2} \left(\frac{9}{x_n} + x_n \right)$, $n \geq 0$ is a

- (A) Newton's method for $f(x) = -9 + x^2$
- (B) Fixed point iteration for $f(x) = \frac{9+x^2}{2x}$
- (C) Newton's method for $f(x) = 9 + x^2$
- (D) Fixed point iteration for $f(x) = 9 + x^2$

Correct Answer: (A) Newton's method for $f(x) = -9 + x^2$

Solution:

Step 1: Understanding the Question:

We are given an iterative formula and need to determine if it represents Newton's method or a fixed-point iteration for one of the given functions.

Step 2: Key Formula or Approach:

Newton's method for finding a root of $f(x) = 0$ is given by the iterative formula:

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

A fixed-point iteration for finding a root of $x = g(x)$ is given by $x_{n+1} = g(x_n)$.

Step 3: Detailed Explanation:

Let's test the options for Newton's method first.

Option (A): $f(x) = -9 + x^2$.

The root is found by solving $x^2 - 9 = 0$, which gives $x = \pm 3$.

The derivative is $f'(x) = 2x$.

Let's construct the Newton's method formula for this function:

$$\begin{aligned} x_{n+1} &= x_n - \frac{-9 + x_n^2}{2x_n} \\ &= x_n - \left(\frac{-9}{2x_n} + \frac{x_n^2}{2x_n} \right) \end{aligned}$$

$$\begin{aligned}
&= x_n + \frac{9}{2x_n} - \frac{x_n}{2} \\
&= \left(1 - \frac{1}{2}\right)x_n + \frac{9}{2x_n} \\
&= \frac{1}{2}x_n + \frac{9}{2x_n} \\
&= \frac{1}{2} \left(x_n + \frac{9}{x_n}\right)
\end{aligned}$$

This formula exactly matches the given iteration. Therefore, the iteration is Newton's method for $f(x) = x^2 - 9 = 0$. This corresponds to option (A).

Let's check Option (C): $f(x) = 9 + x^2$. This function has no real roots, so Newton's method would not be used to find a real root.

Let's check Option (B): The given iteration is of the form $x_{n+1} = g(x_n)$ with $g(x) = \frac{1}{2}(\frac{9}{x} + x) = \frac{9+x^2}{2x}$. So it is a fixed point iteration for $f(x) = \frac{9+x^2}{2x}$ if we interpret $f(x)$ as the function $g(x)$ in $x = g(x)$. While technically true, the method is more famously known as Newton's method for finding the square root of 9. Option (A) provides the underlying function $f(x)$ whose root is being sought.

Step 4: Final Answer:

The given iterative formula is the application of Newton's method to find the roots of the function $f(x) = x^2 - 9$.

💡 Quick Tip

The iterative scheme $x_{n+1} = \frac{1}{2} \left(x_n + \frac{A}{x_n}\right)$ is a famous and very efficient algorithm for finding the square root of a number A . It is derived from applying Newton's method to the function $f(x) = x^2 - A$.