9 MATERIALS SCIENCE

MATERIALS SCIENCE–1

Which of the following affects most of the electrical and thermal properties of materials?

(A) the atomic weight expressed in grams per gram-atom
(B) the electrons, particularly the outermost ones
(C) the magnitude of electrical charge of the protons
(D) the weight of the atoms

The outermost electrons are responsible for determining most of the material's properties.

The answer is (B).

MATERIALS SCIENCE–2

The atomic weight of hydrogen is 1 g/mol. What is most nearly the mass of a hydrogen atom?

(A) 1.7×10^{-24} g/atom (B) 6.0×10^{-23} g/atom (C) 1.0×10^{-10} g/atom (D) 1.0 g/atom

By definition, the mass of an atom is its atomic weight divided by Avogadro's number.

$$W = \frac{1\ \frac{\text{g}}{\text{mol}}}{6.02 \times 10^{23}\ \frac{\text{atoms}}{\text{mol}}} = 1.66 \times 10^{-24}\ \text{g/atom} \quad (1.7 \times 10^{-24}\ \text{g/atom})$$

The answer is (A).

MATERIALS SCIENCE–3

What are valence electrons?

(A) the outer-shell electrons
(B) electrons with positive charge
(C) the electrons of complete quantum shells
(D) the K-quantum shell electrons

By definition, the outermost electrons are the valence electrons.

The answer is (A).

MATERIALS SCIENCE–4

What is the strong bond between hydrogen atoms called?

(A) the ionic bond
(B) the metallic bond
(C) ionic and metallic bonds
(D) the covalent bond

Covalent bonds provide the strongest attractive forces between atoms.

The answer is (D).

MATERIALS SCIENCE–5

What are van der Waals forces?

(A) weak secondary bonds between atoms
(B) primary bonds between atoms
(C) forces between electrons and protons
(D) forces not present in liquids

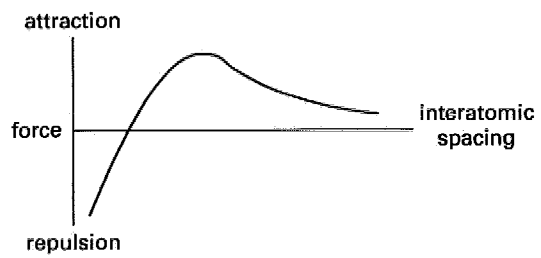
By definition, van der Waals forces are weak attractive forces between atoms or molecules.

$\boxed{\text{The answer is (A).}}$

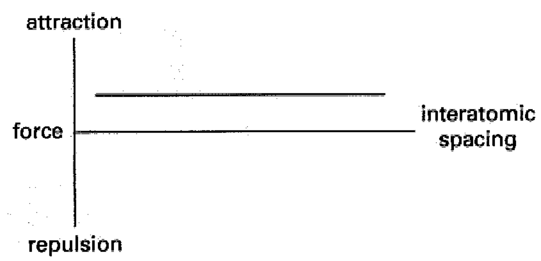
MATERIALS SCIENCE–6

Which of the following curves best illustrates the relationship between interatomic forces and interatomic spacing?

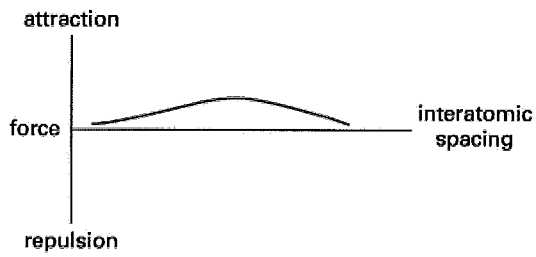
(A)



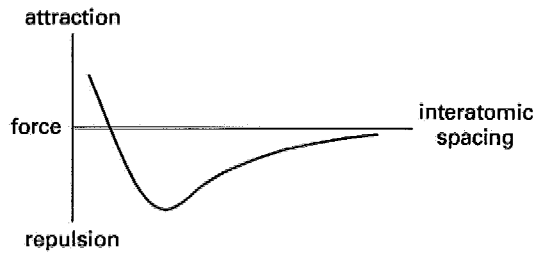
(B)



(C)



(D)



The interatomic force changes from repulsion to attraction as spacing between atoms increases.

The answer is (A).

MATERIALS SCIENCE–7

Compare the metallic iron atom Fe and the ferrous and ferric ions Fe^{2+} and Fe^{3+} at the same temperature. Which has the smallest atomic radius?

(A) Fe
(B) Fe^{2+}
(C) Fe^{3+}
(D) They have the same radii.

Ionizing removes valence electrons, causing the remaining electrons to be pulled in closer to the nucleus. Further reduction in spacing occurs with the removal of more electrons.

The answer is (C).

MATERIALS SCIENCE–8

Cesium (Cs) and sodium (Na) both have the same valence (+1), yet with chlorine (Cl), cesium has a coordination number of 8 in CsCl, while sodium has a coordination number of only 6 in NaCl. What is the main reason for this difference?

(A) The atomic weight of Cs is larger than the weight of Na.
(B) Cs forms covalent bonds in CsCl.
(C) Cs contains more electrons than Na.
(D) Cs is too large to be coordinated by only 6 chloride ions.

Since the Cl atoms are of constant size, the larger coordination number for Cs means that more Cl atoms are needed to fit around a Cs atom than around a Na atom. Therefore, the Cs atom is larger than the Na atom.

The answer is (D).

MATERIALS SCIENCE–9

Which of the following statements is FALSE?

(A) Ceramics are inorganic, nonmetallic solids that are processed or used at high temperatures.
(B) Metals are chemical elements that form substances that are opaque, lustrous, and good conductors of heat and electricity.
(C) Oxides, carbides, and nitrides are considered to be within the class of materials known as glasses.
(D) Most metals are strong, ductile, and malleable. In general, they are heavier than most other substances.

The classes of materials are ceramics, metals, and polymers. Oxides, carbides, nitrides, and glasses are all ceramics.

The answer is (C).

MATERIALS SCIENCE–10

Which of the following materials is NOT a viscoelastic material?

(A) plastic (B) metal (C) rubber (D) glass

A material that is viscoelastic exhibits time-dependent elastic strain. Of the choices, only metal does not fit this description. Metal is considered to be an elastoplastic material.

The answer is (B).

MATERIALS SCIENCE–11

In molecules of the same composition, what are variations of atomic arrangements known as?

(A) polymers
(B) noncrystalline structures
(C) monomers
(D) isomers

Isomers are molecules that have the same composition but different atomic arrangements.

The answer is (D).

MATERIALS SCIENCE–12

Which of the following accurately describes differences between crystalline polymers and simple crystals?

I. Crystalline polymers, unlike simple crystals, are made of folded chains of atoms.
II. Crystal size can be increased by raising the crystallization temperature only in polymers.
III. While a simple crystal may be totally crystallized, a polymer can reach only partial crystallization.

(A) I only (B) II only (C) III only (D) I and III

Only crystalline polymers are composed of folded chains and, at best, exhibit partial crystallization. The crystal size of both simple crystals and polymers can be increased by raising temperature.

The answer is (D).

MATERIALS SCIENCE–13

Polymers that favor crystallization are least likely to have which of the following?

(A) an atactic configuration of side groups
(B) small side groups
(C) only one repeating unit
(D) small chain lengths

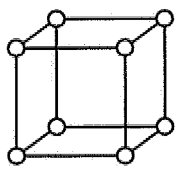
In order for crystallization to be favored, the molecules must be able to arrange themselves into an orderly structure. "Atactic" refers to a random configuration of side groups in the polymer; such a configuration would hinder crystallization.

The answer is (A).

MATERIALS SCIENCE–14

What is the atomic packing factor (APF) for a simple cubic crystal?

(A) 0.48 (B) 0.52 (C) 1.0 (D) 1.1



For a simple cubic crystal, there is one complete atom of radius r per cell. The cell has edges of length $2r$. By definition,

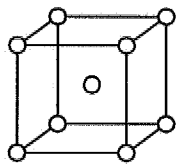
$$\begin{aligned} \text{APF} &= \frac{\text{volume of atoms}}{\text{volume of unit cell}} \\ &= \frac{\frac{4\pi r^3}{3}}{(2r)^3} \\ &= 0.52 \end{aligned}$$

The answer is (B).

MATERIALS SCIENCE–15

How many atoms are in the unit cell of a body-centered cubic structure?

(A) one (B) two (C) three (D) four



There is one atom at the center position and $^1/_8$ of an atom at each of the corners of the cube, since the atom present at each corner is shared by the adjoining unit cells. Therefore,

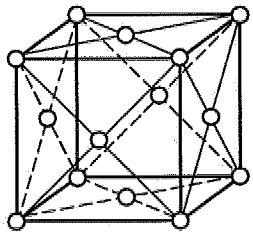
$$\begin{aligned} \text{total no. of atoms} &= \text{no. of atoms at center} \\ &\quad + (\text{no. of atoms at each corner})(\text{no. of corners}) \\ &= 1 + \left(\tfrac{1}{8}\right)(8) = 2 \end{aligned}$$

The answer is (B).

MATERIALS SCIENCE–16

How many atoms are there per unit cell for a face-centered cubic structure?

(A) one (B) two (C) three (D) four



Like a body-centered cubic structure, there is $^1/_8$ of an atom at each corner of the cube. There is also $^1/_2$ of an atom at the center of each of the six faces, since each atom here is shared by the neighboring unit cell.

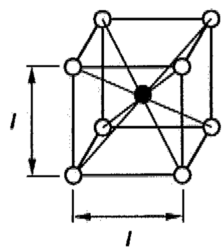
$$\begin{aligned}\text{total no. of atoms} &= (\text{no. of atoms at each corner})(\text{no. of corners}) \\ &\quad + (\text{no. of atoms at center of each face})(\text{no. of faces}) \\ &= \left(\frac{1}{8}\right)(8) + \left(\frac{1}{2}\right)(6) = 4\end{aligned}$$

The answer is (D).

MATERIALS SCIENCE–17

What is the first coordination number of a body-centered cubic structure?

(A) 4 (B) 6 (C) 8 (D) 10



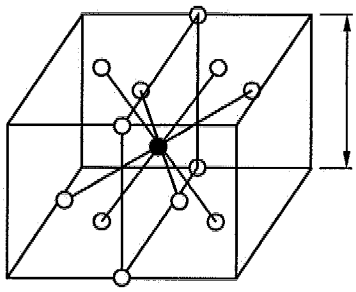
The first coordination number is the number of nearest neighbor atoms. In a body-centered cubic cell of edge length l, the minimum distance between atoms is $(\sqrt{3}/2)l$. By inspection of the figure, there are eight neighboring atoms at this distance.

The answer is (C).

MATERIALS SCIENCE–18

What is the first coordination number of a face-centered cubic structure?

(A) 2 (B) 4 (C) 8 (D) 12



The closest atoms in a face-centered cubic cell of edge length l are $l/\sqrt{2}$ apart. Each atom in the center of a face has 12 such neighboring atoms. The atoms are: $(\pm(1/2)l, \pm(1/2)l, 0)$, $(\pm(1/2)l, 0, \pm(1/2)l)$, and $(0, \pm(1/2)l, \pm(1/2)l)$.

The answer is (D).

MATERIALS SCIENCE–19

Which of the following statements is FALSE?

(A) Both copper and aluminum have a face-centered cubic crystal structure.

(B) Both magnesium and zinc have a hexagonal close-packed crystal structure.

(C) Iron can have either a face-centered or a body-centered cubic crystal structure.

(D) Both lead and cadmium have a hexagonal close-packed crystal structure.

Lead does not have a hexagonal close-packed structure. Its structure is face-centered cubic.

The answer is (D).

MATERIALS SCIENCE–20

Which of the following statements is FALSE?

(A) The coordinates of the unique lattice points for a body-centered cubic unit cell are: (0 0 0) and ($\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$).

(B) The coordinates of the unique lattice points for a face-centered cubic unit cell are: (0 0 0); ($\frac{1}{2}$ $\frac{1}{2}$ 0); ($\frac{1}{2}$ 0 $\frac{1}{2}$); and (0 $\frac{1}{2}$ $\frac{1}{2}$).

(C) The coordinates of the unique lattice points for a simple cubic unit cell are: (0 0 0).

(D) The coordinates of the unique lattice points for a rhombohedral unit cell are: ($\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$).

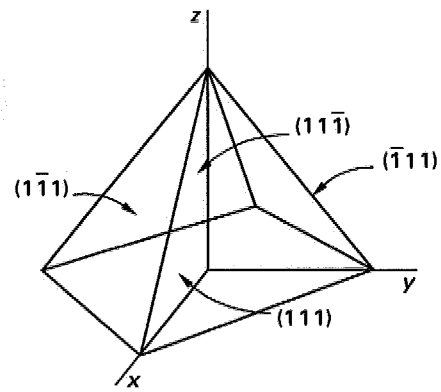
The rhombohedral Bravais lattice is a primitive cell and has only the point (0 0 0).

The answer is (D).

MATERIALS SCIENCE–21

How are the close-packed planes in a face-centered cubic metal designated?

(A) (1 0 0) (B) (2 0 0) (C) (1 1 0) (D) (1 1 1)



The close-packed planes are as shown.

The answer is (D).

MATERIALS SCIENCE–22

Which crystal structure possesses the highest number of close-packed planes and close-packed directions?

(A) simple cubic
(B) body-centered cubic
(C) face-centered cubic
(D) close-packed hexagonal

The face-centered cubic structure has four close-packed planes: $(1\ 1\ 1)$, $(\bar{1}\ 1\ 1)$, $(1\ \bar{1}\ 1)$, and $(1\ 1\ \bar{1})$. Each plane has three close-packed directions.

The answer is (C).

MATERIALS SCIENCE–23

What are the most common slip planes for face-centered cubic and body-centered cubic structures, respectively?

(A) face-centered: (1 1 1); body-centered: (1 1 0)
(B) face-centered: (1 0 0); body-centered: (1 1 0)
(C) face-centered: (1 1 0); body-centered: (1 1 1)
(D) face-centered: (1 1 1); body-centered: (1 0 0)

Slip planes are usually the most closely packed planes, since they have the largest spacing. The close-packed planes are (1 1 1) and (1 1 0) for the respective crystal structures.

The answer is (A).

MATERIALS SCIENCE–24

Comparing the face-centered cubic lattice with the hexagonal close-packed lattice, which of the following features describes the hexagonal close-packed structure only?

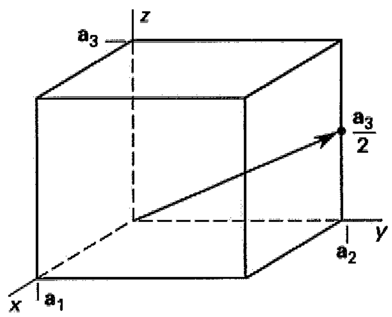
(A) It has the closest packed lattice structure.
(B) Its coordination number is 12.
(C) Its deformation properties are more directional.
(D) Its stacking order is ABCABC.

Options (A) and (B) are true for both face-centered cubic and hexagonal close-packed structures, while option (D) is true for the face-centered cubic lattice. Option (C) applies to the hexagonal close-packed lattice only.

The answer is (C).

MATERIALS SCIENCE–25

In the following unit cell, what direction is indicated by the arrow?



(A) (0 1 2) (B) (0 1 $\frac{1}{2}$) (C) (2 1 0) (D) (0 $\frac{1}{2}$ 1)

Direction is given by the intercepts, as ratios of the lattice dimension.

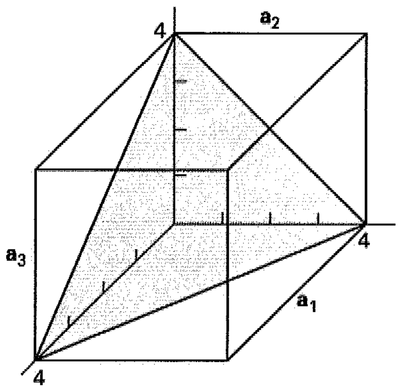
$$\left(\frac{x}{a_1}\ \frac{y}{a_2}\ \frac{z}{a_3}\right)$$

$$\left(\frac{0}{a_1}\ \frac{a_2}{a_2}\ \frac{\frac{a_3}{2}}{a_3}\right) = \left(0\ 1\ \tfrac{1}{2}\right)$$

The answer is (B).

MATERIALS SCIENCE–26

What are the Miller indices of the given plane?



(A) (4 4 4) (B) (1 1 1) (C) $\left(\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\right)$ (D) (2 2 2)

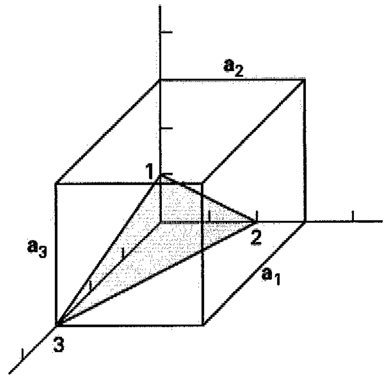
The x, y, and z intercepts are a_1, a_2, and a_3, respectively, since $a_1 = a_2 = a_3 = 4$. The Miller indices are

$$\left(\left(\frac{x}{a_1}\right)^{-1} \left(\frac{y}{a_2}\right)^{-1} \left(\frac{z}{a_3}\right)^{-1}\right) = \left(\left(\frac{4}{a_1}\right)^{-1} \left(\frac{4}{a_2}\right)^{-1} \left(\frac{4}{a_3}\right)^{-1}\right) = (1\ 1\ 1)$$

The answer is (B).

MATERIALS SCIENCE–27

What are the Miller indices of the given plane?



(A) (3 2 1) (B) $(\frac{1}{3}\ \frac{1}{2}\ 1)$ (C) $(\frac{2}{6}\ \frac{3}{6}\ \frac{6}{6})$ (D) (2 3 6)

The intercepts for this plane are a_1, $2a_2/3$, and $a_3/3$. The Miller indices are

$$\left(\left(\frac{a_1}{a_1}\right)^{-1}\left(\frac{\frac{2a_2}{3}}{a_2}\right)^{-1}\left(\frac{\frac{a_3}{3}}{a_3}\right)^{-1}\right) = (1\ \tfrac{3}{2}\ 3) = (2\ 3\ 6)$$

The answer is (D).

MATERIALS SCIENCE–28

A plane intercepts the coordinate axis at $x = 1$, $y = 3$, and $z = 2$. What are the Miller indices of the plane?

(A) (1 3 2) (B) (1 2 3) (C) (6 2 3) (D) (3 2 6)

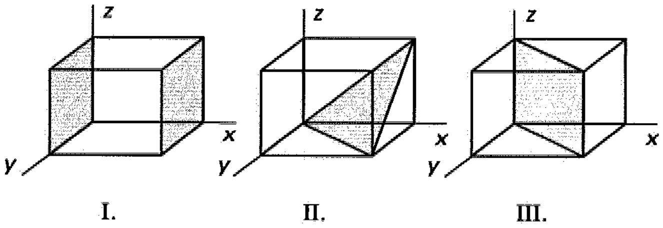
The Miller indices are computed by taking the reciprocal of each intercept and converting to whole numbers of the same ratio.

$$(1\ \tfrac{1}{3}\ \tfrac{1}{2}) = (6\ 2\ 3)$$

The answer is (C).

MATERIALS SCIENCE–29

Which of the following gives the correct designations for the planes shown?



(A) I: (1 1 1), II: (2 0 0), III: (1 1 0)
(B) I: (1 0 0), II: (1 1 0), III: (1 1 1)
(C) I: (1 0 0), II: (1 1 1), III: (1 0 2)
(D) I: (1 0 0), II: (1 1 1), III: (1 1 0)

I. Since the plane passes through the origin, move the plane to $x = 1$, $y = \infty$, $z = \infty$. Take reciprocals of the intercepts.

$$\frac{1}{x} = 1,\ \frac{1}{y} = 0,\ \frac{1}{z} = 0 \quad (1\ 0\ 0)$$

II. Since the plane passes through the origin, move the plane to $x = -1$, $y = 1$, $z = 1$. Take reciprocals of the intercepts.

$$\frac{1}{x} = -1,\ \frac{1}{y} = 1,\ \frac{1}{z} = 1 \quad (-1\ 1\ 1)$$

$(-1\ 1\ 1)$, but $(-1\ 1\ 1)$ is identical to $(1\ 1\ 1)$.

III. Since the plane passes through the origin, move the plane to $x = -1$, $y = 1$, $z = \infty$. Take reciprocals of the intercepts.

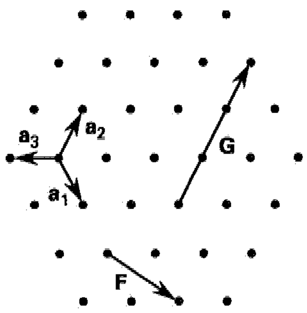
$$\frac{1}{x} = -1,\ \frac{1}{y} = 1,\ \frac{1}{z} = 0 \quad (-1\ 1\ 0)$$

$(-1\ 1\ 0)$ is identical to $(1\ 1\ 0)$.

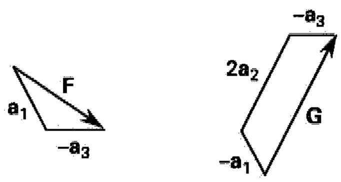
The answer is (D).

MATERIALS SCIENCE–30

Using the four-index scheme for a hexagonal crystal system, how would the directions **F** and **G** shown be defined?



(A) $\mathbf{F} = [\bar{1}\ 0\ 1\ 0]$, $\mathbf{G} = [1\ \bar{2}\ 1\ 0]$
(B) $\mathbf{F} = [0\ 1\ 1\ 0]$, $\mathbf{G} = [0\ 3\ 0\ 0]$
(C) $\mathbf{F} = [0\ \bar{1}\ 1\ 0]$, $\mathbf{G} = [\bar{1}\ 3\ \bar{2}\ 0]$
(D) $\mathbf{F} = [1\ 0\ \bar{1}\ 0]$, $\mathbf{G} = [\bar{1}\ 2\ \bar{1}\ 0]$



The **F** vector is the sum of one unit in the positive $\mathbf{a}_1$ direction and one unit in the negative $\mathbf{a}_3$ direction. The **G** vector is the sum of one unit in the negative $\mathbf{a}_1$ direction, two units in the positive $\mathbf{a}_2$ direction, and one unit in the negative $\mathbf{a}_3$ direction.

The answer is (D).

MATERIALS SCIENCE–31

Given that **a** is a lattice constant and that h, k, and l are the Miller indices, which of the following equations describes the interplanar distance d in a cubic crystal?

(A) $d = \dfrac{2\mathbf{a}}{\sqrt{\left(\frac{1}{h}\right)^2 + \left(\frac{1}{k}\right)^2 + \left(\frac{1}{l}\right)^2}}$

(B) $d = \mathbf{a}\left(\frac{1}{h} + \frac{1}{k} + \frac{1}{l}\right)$

(C) $d = \left(\frac{\mathbf{a}}{2}\right)\sqrt{h^2 + k^2 + l^2}$

(D) $d = \dfrac{\mathbf{a}}{\sqrt{h^2 + k^2 + l^2}}$

Geometrically, $1/d^2 = (h^2 + k^2 + l^2)/\mathbf{a}^2$. Therefore,

$$d = \frac{\mathbf{a}}{\sqrt{h^2 + k^2 + l^2}}$$

The answer is (D).

MATERIALS SCIENCE–32

The atomic weight of copper is 63.5 g/mol. Calculate the theoretical density of copper given that the unit cell is face-centered cubic and the lattice parameter is 3.61 Å.

(A) 4.5 g/cm^3 (B) 7.9 g/cm^3 (C) 8.8 g/cm^3 (D) 9.0 g/cm^3

There are four atoms per unit cell for a face-centered cubic structure. By definition,

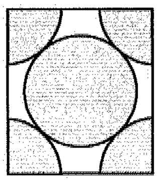
$$\begin{aligned}\rho &= \frac{m}{V} \\ &= \frac{\left(4\ \frac{\text{atoms}}{\text{unit cell}}\right)\left(63.5\ \frac{\text{g}}{\text{mol}}\right)\left(\frac{1\ \text{mol}}{6.02\times 10^{23}\ \text{atoms}}\right)}{\left((3.61\ \text{Å})\left(\frac{1\times 10^{-8}\ \text{cm}}{\text{Å}}\right)\right)^3} \\ &= 8.97\ \text{g/cm}^3 \quad (9.0\ \text{g/cm}^3)\end{aligned}$$

The answer is (D).

MATERIALS SCIENCE–33

Determine the planar density of copper atoms in a (1 0 0) plane given that the unit cell is face-centered cubic and the lattice parameter is 3.61 Å.

(A) 7.68×10^{18} atoms/m^2
(B) 1.53×10^{19} atoms/m^2
(C) 2.30×10^{19} atoms/m^2
(D) 3.84×10^{19} atoms/m^2



There are two atoms total in the (1 0 0) plane. The planar density is, therefore,

$$\text{planar density} = \frac{\text{no. atoms per face}}{\text{area of face}}$$

$$= \frac{2 \text{ atoms}}{(3.61 \times 10^{-10} \text{ m})^2} = 1.53 \times 10^{19} \text{ atoms/m}^2$$

The answer is (B).

MATERIALS SCIENCE–34

Which of the following statements is FALSE regarding X-ray diffraction?

(A) The geometrical structure factor F(hkl) is the ratio of the amplitude of the X-ray reflected from a plane in a crystal to the amplitude of the X-ray scattered from a single electron.

(B) X-ray diffraction is only useful for studying simpler crystals such as the body-centered cubic structure, rather than more complex crystals like the hexagonal close-packed structure.

(C) X-ray diffraction can be used to determine the grain size of a specimen.

(D) Bragg's law states that $n\lambda/2d = \sin\theta$ (n is an integer, λ is the wavelength of the X-ray, d is the interplanar spacing, and θ is the scattering angle).

X-ray diffraction is used to study all types of crystals. It is not limited to simple crystals.

The answer is (B).

MATERIALS SCIENCE–35

A sample of face-centered cubic nickel (Ni) was placed in an X-ray beam of wavelength $\lambda = 0.154$ nm. If the lattice parameter for Ni is $a_0 = 0.352$ nm, what is the first-order angle of diffraction most nearly?

(A) 5.7° (B) 7.0° (C) 13° (D) 19°

Using Bragg's law, with $n = 1$, $\lambda = 0.154$ nm, and $d = 0.352$ nm,

$$\begin{aligned}\lambda &= 2d\sin\theta \\ \theta &= \sin^{-1}\frac{\lambda}{2d} = \sin^{-1}\frac{0.154\ \text{nm}}{(2)(0.352\ \text{nm})} \\ &= 12.6^\circ\end{aligned}$$

The answer is (C).

MATERIALS SCIENCE–36

In a crystal structure, what is an interstitial atom?

(A) an extra atom sitting at a nonlattice point
(B) an atom missing at a lattice point
(C) a different element at a lattice point
(D) a line defect

An interstitial atom is an extra atom lodged within the crystal structure; it is a point defect.

The answer is (A).

MATERIALS SCIENCE–37

Which of the following is a line defect in a lattice crystal structure?

(A) tilt boundary
(B) screw dislocation
(C) vacancy
(D) Schottky imperfection

The most common type of line defect is a dislocation.

The answer is (B).

MATERIALS SCIENCE–38

It is often desired to know the number of atoms, n, in a crystal structure that possess more than a specified amount of energy, E. Which of the following equations gives n, given that N is the total number of atoms present, M is a constant, k is the Boltzmann constant, and T is the temperature of the specimen?

(A) $n = \frac{M}{N}e^{-kE/T}$ (B) $n = \frac{EM}{N}e^{-kT}$
(C) $n = MNe^{-E/kT}$ (D) $n = MNe^{-kT/E}$

The equation in option (C) is the correct relationship for thermal energy distribution within a specimen.

The answer is (C).

MATERIALS SCIENCE–39

Which of the following statements regarding diffusion in a crystal structure is true?

(A) Solid interstitial atoms cannot diffuse through structures that lack vacancies.
(B) It occurs only in alloys, never in pure crystals.
(C) It often uses an exchange or vacancy mechanism.
(D) It occurs primarily as a result of mechanical work.

Diffusion is the movement of a defect from one point to another.

The answer is (C).

MATERIALS SCIENCE–40

What is Fick's first law for one-dimensional, steady-state diffusion? C is the volume concentration of atoms, x is the distance along which diffusion occurs, D is the diffusion coefficient, and J is the flux or current density.

(A) $J = -D\frac{\partial C}{\partial x}$ (B) $J = C\frac{\partial D}{\partial x}$

(C) $J = \left(-\frac{1}{D}\right)\frac{\partial C}{\partial x}$ (D) $J = 2D\frac{\partial C}{\partial x}$

The flux is proportional to the diffusion constant and the concentration gradient $\partial C/\partial x$.

The answer is (A).

MATERIALS SCIENCE–41

Which of the following are true about Fick's first law for diffusion?

I. It is only applicable to gases and liquids, not solids.
II. The law states that the flux moves from high to low concentration.
III. J, the flux, may be in units of $\text{cm}^3/\text{cm}^2\cdot\text{s}$.

(A) I only (B) II only (C) III only (D) II and III

Fick's law says that the flux of diffusion is proportional to the negative volume concentration gradient; the negative sign indicates that the flux is in the down-gradient direction. It applies to diffusion in a crystal. Flux, by definition, is the amount of volume moving across a unit surface area in unit time.

The answer is (D).

MATERIALS SCIENCE–42

What is the Arrhenius equation for the rate of a thermally activated process? A is the reaction constant, T is the absolute temperature, R is the gas constant, and Q is the activation energy.

(A) $\text{rate} = Ae^{-Q/RT}$ (B) $\text{rate} = Ae^{-QRT}$

(C) $\text{rate} = Ae^{Q/RT}$ (D) $\text{rate} = Ae^{QRT}$

The rate increases as the thermal energy increases.

The answer is (A).

MATERIALS SCIENCE–43

Which of the following statements is FALSE?

(A) The surface energy of a liquid tends toward a minimum.

(B) The surface energy is the work required to create a unit area of additional space.

(C) The energy of an interior atom is greater than the energy of an atom on the surface of a liquid.

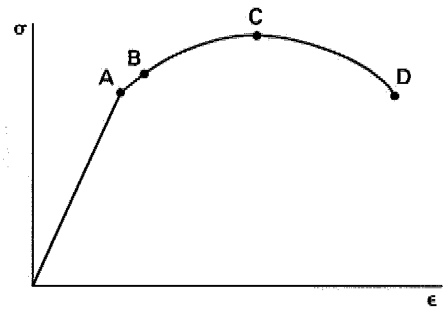
(D) Total surface energy is directly proportional to the surface area.

In a liquid, the energy of a surface atom is greater than the surface energy of an interior atom. Note: Although surface energy and surface tension have the same numerical value, they have different units.

The answer is (C).

MATERIALS SCIENCE–44

Which point on the stress-strain curve shown gives the ultimate stress?



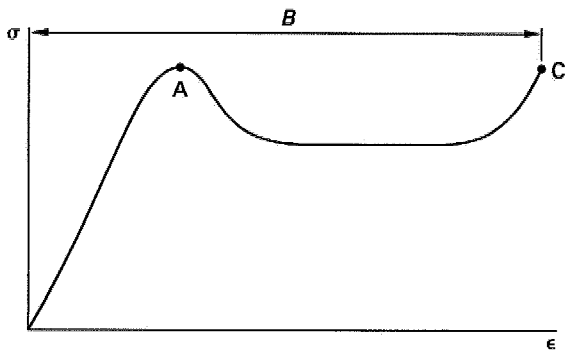
(A) A (B) B (C) C (D) D

The ultimate stress corresponds to the point of maximum load, beyond which further strain is accompanied by a reduction in load.

The answer is (C).

MATERIALS SCIENCE–45

A stress-strain diagram for a polymer is shown. Identify items A, B, and C.



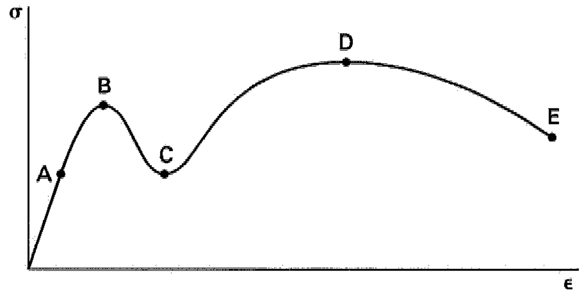
(A) A = lower yield point; B = plastic deformation; C = upper yield point
(B) A = lower yield point; B = proportional limit; C = upper yield point
(C) A = yield point; B = elastic deformation; C = elastic limit
(D) A = yield point; B = elongation at fracture; C = fracture point

Beginning at the yield point, considerable elongation occurs with no noticeable increase in tensile stress. Eventually, fracture occurs. The total strain at fracture is known as the elongation.

The answer is (D).

MATERIALS SCIENCE–46

Which statement is true for the stress-strain relationship for the metal shown?



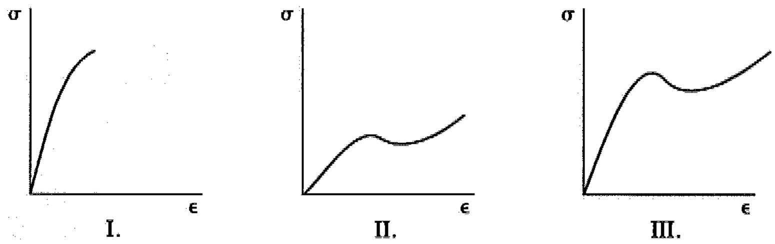
(A) Point A is the lower yield point.
(B) Point D is the fracture stress point.
(C) Point B is the upper yield point.
(D) The range from point C to point D is known as the elastic range.

Point A is the elastic limit, and point D is the ultimate stress point. The region between points C and D is not the elastic region but the plastic region. Only option (C) is true.

$\boxed{\text{The answer is (C).}}$

MATERIALS SCIENCE–47

Identify the properties of the materials whose stress-strain diagrams are shown.



(A) I: soft and weak; II: soft and tough; III: hard and brittle
(B) I: hard and brittle; II: soft and weak; III: hard and tough
(C) I: soft and tough; II: hard and brittle; III: hard and strong
(D) I: hard and strong; II: soft and brittle; III: soft and tough

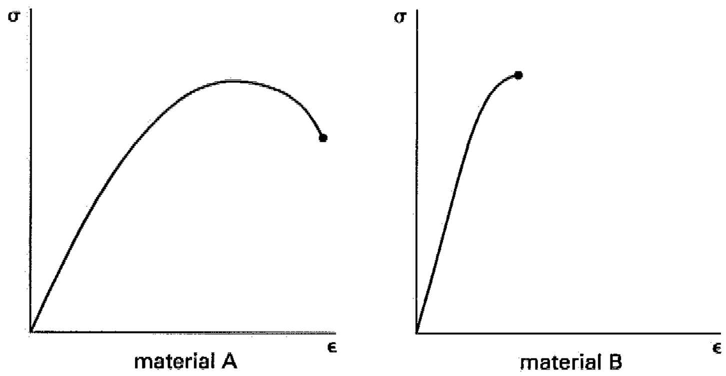
The properties and their relationships to the stress-strain diagrams are given in the following table.

	elastic modulus	yield point	elongation at fracture	ultimate strength
hard and brittle	high	undefined	low	moderate to high
soft and weak	low	low	moderate	low
hard and tough	high	high	high	high

The answer is (B).

MATERIALS SCIENCE–48

Which statement is most accurate regarding the two materials represented in the given stress-strain diagrams?



(A) Material B is more ductile and has a lower modulus of elasticity than material A.

(B) Material B would require more total energy to fracture than material A.

(C) Material A will withstand more stress before plastically deforming than material B.

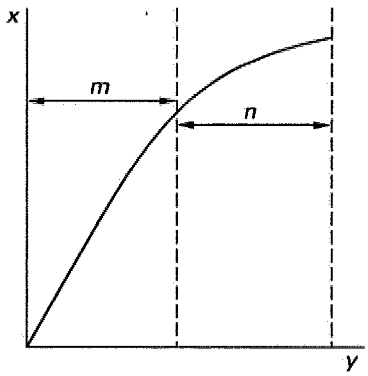
(D) Material B will withstand a higher load than material A but is more likely to fracture suddenly.

From the graphs, the modulus of elasticity of material B is greater than that of material A. This means that material A is more ductile, that is, it can undergo more strain before fracturing. However, material B can withstand higher loads than material A. Only option (D) is correct.

The answer is (D).

MATERIALS SCIENCE—49

If the diagram below represents deformation of rigid bodies, what do x, y, m, and n refer to?



(A) x = stress, y = strain, m = plastic deformation, n = elastic deformation
(B) x = strain, y = stress, m = plastic deformation, n = elastic deformation
(C) x = stress, y = strain, m = elastic deformation, n = plastic deformation
(D) x = strain, y = stress, m = elastic deformation, n = plastic deformation

Option (C) is the only choice that fits the graph.

The answer is (C).

MATERIALS SCIENCE–50

Which of the following best describes the 0.2% offset yield stress?

(A) It is the elastic limit after which a measurable plastic strain has occurred.
(B) It is the stress at which the material plastically strains 0.2%.
(C) It is the stress at which the material elastically strains 0.2%.
(D) It is 0.2% below the fracture point of the material.

By definition, the offset yield stress is where the material undergoes a 0.2% plastic strain.

The answer is (B).

MATERIALS SCIENCE–51

Which of the following is true regarding the ductile-to-brittle transition temperature?

I. It is important for structures used in cold environments.
II. It is the point at which the size of the shear lip or tearing rim goes to zero.
III. It is the temperature at which 20 J of energy causes failure in a Charpy v-notch specimen of standard dimensions.

(A) I only (B) I and II (C) I and III (D) II and III

II is the only choice that is false. A test piece broken at 20 J of energy usually has a small shear lip.

The answer is (C).

MATERIALS SCIENCE–52

Which of the following are true regarding creep?

I. It is caused by the diffusion of vacancies to edge dislocations, permitting dislocation climb.
II. It involves the plastic deformation of materials at loads below the yield stress.
III. It may involve whole grain sliding.

(A) I only (B) II only (C) I and III (D) I, II, and III

All are true.

The answer is (D).

MATERIALS SCIENCE–53

Under conditions of very slow deformation and high temperature, it is possible to have plastic flow in a crystal at shear stresses lower than the critical shear stress. What is this phenomenon called?

(A) slip (B) twinning (C) creep (D) bending

Creep involves the flow of material.

The answer is (C).

MATERIALS SCIENCE–54

What does the Charpy impact test measure?

I. the energy required to break a test sample
II. the strength of a test sample
III. the ductile to brittle transition temperature of metals

(A) I only (B) II only (C) III only (D) I and III

The Charpy test measures toughness, the energy required to break a sample. By conducting the test at different temperatures, the brittle transition temperature can be determined.

The answer is (D).

MATERIALS SCIENCE–55

A shaft made of good quality steel breaks in half due to fatigue. What would the surface of the fracture site look like?

(A) like a cup and cone

(B) quite smooth to the unaided eye, with ripples apparent under low-power magnification

(C) smooth over most of the surface, with tearing at the location of fracture

(D) very jagged and rough

Typically, the surface is mostly smooth. Where final fracture took place however, the surface is torn.

The answer is (C).

MATERIALS SCIENCE–56

To which of the following can the large discrepancy between the actual and theoretical strengths of metals mainly be attributed?

(A) heat (B) dislocations (C) low density (D) stress direction

Although point defects do contribute to the discrepancy in strengths, the major reason for the difference is the presence of dislocations.

The answer is (B).

MATERIALS SCIENCE–57

The ease with which dislocations are able to move through a crystal under stress accounts for which of the following?

I. ductility
II. lower yield strength
III. hardness

(A) I only (B) II only (C) III only (D) I and II

The ease with which dislocations move through a crystal accounts for its ductility and lower yield strength.

The answer is (D).

MATERIALS SCIENCE–58

As the amount of slip increases, additional deformation becomes more difficult and decreases until the plastic flow finally stops. Slip may begin again only if a larger stress is applied. What is this phenomenon known as?

(A) cooling (B) crowding (C) strain hardening (D) twinning

This is known as strain hardening.

The answer is (C).

MATERIALS SCIENCE–59

Which word combination best completes the following sentence?

"Plastic deformation of a single crystal occurs either by ______ or by ______, but ______ is the more common method."

(A) bending; compression; bending
(B) shearing; compression; compression
(C) slip; twinning; slip
(D) twinning; slip; twinning

Bending, compression, and shear are elastic phenomena. Slip is a more common method of plastic deformation than twinning.

The answer is (C).

MATERIALS SCIENCE–60

Which one of these statements is true for twinning?

(A) It occurs at lower shear stresses than slip.
(B) It is the most significant form of plastic deformation.
(C) It cannot be caused by impact or thermal treatment.
(D) It frequently occurs in hexagonal close-packed structures.

Options (A), (B), and (C) are false. Twinning requires a relatively high shear stress, is much less common than slip, and can be caused by impact or thermal treatment. It occurs in hexagonal close-packed crystal structures.

The answer is (D).

MATERIALS SCIENCE–61

Which of the following does NOT produce vacancies, interstitial defects, or impurity defects in a material?

(A) plastic deformation
(B) slow equilibrium cooling
(C) quenching
(D) increasing the temperature (which increases atomic energy)

Slow equilibrium cooling is used to reduce variations in the material.

The answer is (B).

MATERIALS SCIENCE–62

Which of the following are true statements about the modulus of elasticity, E?

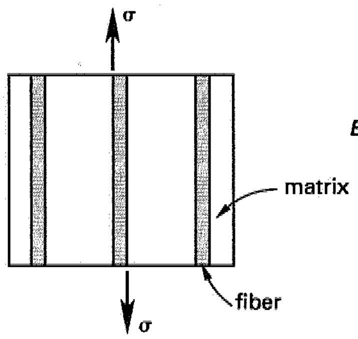
(A) It is the same as the rupture modulus.
(B) It is the slope of the stress-strain diagram in the linearly elastic region.
(C) It is the ratio of stress to volumetric strain.
(D) Its value depends only on the temperature of the material.

The modulus of elasticity is equal to the ratio of stress to strain for a particular material. It is the slope of the stress-strain diagram in the linearly elastic region.

The answer is (B).

MATERIALS SCIENCE–63

What is the modulus of elasticity, E, for a composite material in which the fibers take up 20% of the total volume and the load is applied parallel to the fibers as shown?



$E_{\text{fiber}} = 1.38 \times 10^{11}$ Pa
$E_{\text{matrix}} = 3.45 \times 10^{6}$ Pa

(A) 2.76×10^{10} Pa (B) 2.95×10^{10} Pa (C) 1.38×10^{11} Pa (D) 3.45×10^{11} Pa

The matrix and fibers experience the same strain, ϵ. The total stress, σ, is the sum of the stresses carried by the fibers and the matrix.

$$\sigma = E_f \epsilon V_f + E_m \epsilon (1 - V_f)$$

V_f is the fraction of the total volume taken up by the fibers. Thus,

$$\begin{aligned} E &= \frac{\sigma}{\epsilon} = E_f V_f + E_m(1 - V_f) \\ &= (1.38 \times 10^{11}\ \text{Pa})(0.2) + (3.45 \times 10^{6}\ \text{Pa})(1 - 0.2) \\ &= 2.76 \times 10^{10}\ \text{Pa} \end{aligned}$$

The answer is (A).

MATERIALS SCIENCE–64

What is the proper relationship between the modulus of elasticity, E, the Poisson ratio, ν, and the bulk modulus of elasticity, K?

(A) $E = K(1 - 2\nu)$ (B) $E = K(1 - \nu)$

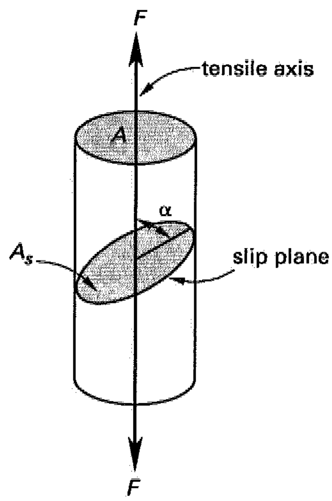
(C) $E = \dfrac{3K}{1 - 2\nu}$ (D) $E = 3K(1 - 2\nu)$

For an element in triaxial stress, the unit volume change can be obtained from Hooke's law. The resultant equation is given by option (D).

The answer is (D).

MATERIALS SCIENCE–65

A crystal is subjected to a tensile load acting along its axis. α is the angle between the tensile axis and the slip plane as shown. At what value of α will the shear stress in the slip plane be a maximum?



(A) 0° (B) 30° (C) 45° (D) 60°

The component of force along the shear surface is equal to $F\cos\alpha$. The area of the shear surface, A_s, is related to the cross-sectional area, A, by $A_s = A/\sin\alpha$.

$$\tau = \frac{F\cos\alpha}{\frac{A}{\sin\alpha}} = \left(\frac{F}{A}\right)\sin\alpha\cos\alpha$$

Taking the first derivative and setting it equal to zero,

$$\frac{\partial \tau}{\partial \alpha} = \left(\frac{F}{A}\right)\left(\cos^2\alpha - \sin^2\alpha\right) = 0$$

$$\cos^2\alpha - \sin^2\alpha = 0$$

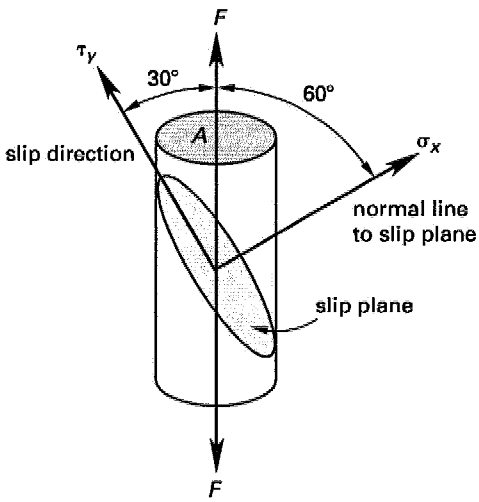
$$\cos\alpha = \sin\alpha$$

$$\alpha = 45^\circ$$

The answer is (C).

MATERIALS SCIENCE–66

An axial stress $\sigma_x = F/A$ is applied as shown. Calculate the resolved shear stress, τ_y, along the slip plane.



(A) $\tau_y = \frac{1}{4}\sigma_x$ (B) $\tau_y = \frac{1}{2}\sigma_x$ (C) $\tau_y = \frac{\sqrt{2}}{3}\sigma_x$ (D) $\tau_y = \frac{3}{4}\sigma_x$

$$\tau_y = \left(\frac{F}{A}\right)\sin 60^\circ \cos 30^\circ$$

$$= \sigma_x\left(\frac{\sqrt{3}}{2}\right)\left(\frac{\sqrt{3}}{2}\right)$$

$$= \tfrac{3}{4}\sigma_x$$

The answer is (D).

MATERIALS SCIENCE–67

If G is the shear modulus, b is the magnitude of the Burgers vector, and r is half the distance between particles, what is the local stress, τ, required to bend dislocations around a particle?

(A) $\frac{Gb}{r}$ (B) Gbr (C) $\frac{br}{G}$ (D) $\frac{Gr}{b}$

Line tension is given by $\tau = 2T/bl$. $T = Gb^2$ and $l = 2r$. Therefore, $\tau = Gb/r$.

$\boxed{\text{The answer is (A).}}$

MATERIALS SCIENCE–68

Given that d is the distance between dislocations and b is the magnitude of the Burgers vector, what is the expression for the misorientation angle θ of a tilt boundary?

(A) $\sin\theta = \frac{d}{b}$ (B) $\tan\theta = \frac{b}{d}$ (C) $\theta = \frac{b}{d}$ (D) $\theta = \frac{d}{b}$

By definition, $\tan\theta = b/d$.

$\boxed{\text{The answer is (B).}}$

MATERIALS SCIENCE–69

In general, what are the effects of cold working a metal?

(A) increased strength and ductility
(B) increased strength, decreased ductility
(C) decreased strength and ductility
(D) decreased strength, increased ductility

The strength of the metal will increase at the expense of a loss in ductility.

$\boxed{\text{The answer is (B).}}$

MATERIALS SCIENCE–70

Which of the following does cold working a metal cause?

(A) elongation of grains in the flow direction, an increase in dislocation density, and an overall increase in energy of the metal

(B) elongation of grains in the flow direction, a decrease in dislocation density, and an overall decrease in energy of the metal

(C) elongation of grains in the flow direction, a decrease in dislocation density, and an overall increase in energy of the metal

(D) shortening of grains in the flow direction, a decrease in dislocation density, and an overall decrease in the energy of the metal

Cold working a metal produces elongations of grains coupled with increases in both dislocation density and energy.

The answer is (A).

MATERIALS SCIENCE–71

Which of the following statements is FALSE?

(A) The amount or percentage of cold work cannot be obtained from information about change in the area or thickness of a metal.

(B) The process of applying force to a metal at temperatures below the temperature of crystallization in order to plastically deform the metal is called cold working.

(C) Annealing eliminates most of the defects caused by the cold working of a metal.

(D) Annealing reduces the hardness of the metal.

The percentage of cold work can be calculated directly from the reduction in thickness or area of the metal.

The answer is (A).

MATERIALS SCIENCE–72

Which of the following statements is FALSE?

(A) There is a considerable increase in the hardness and the strength of a cold-worked metal.

(B) Cold working a metal significantly reduces its ductility.

(C) Cold working causes a slight decrease in the density and electrical conductivity of a metal.

(D) Cold work decreases the yield point of metal.

Cold working increases the yield point as well as the strength and hardness of metal.

The answer is (D).

MATERIALS SCIENCE–73

Which of the following statements is FALSE?

(A) Hot working can be regarded as the simultaneous combination of cold working and annealing.

(B) Hot working increases the density of the metal.

(C) One of the primary goals of hot working is to produce a fine-grained product.

(D) Hot working causes much strain hardening of the metal.

In hot working, the high temperature immediately releases any strain hardening that could occur in the deformation of the metal.

The answer is (D).

MATERIALS SCIENCE–74

Which of the following is FALSE?

(A) Grain size is of minor importance in considering the properties of polycrystalline materials.

(B) Fine-grained materials usually exhibit greater yield stresses than coarse-grained materials at low temperatures.

(C) At high temperatures, grain boundaries become weak, and sliding occurs.

(D) Grain boundary sliding is the relative movement of two grains by a shear movement parallel to the grain boundary between them.

Grain size is an important factor to consider in understanding the properties of polycrystalline materials because it affects the area and length of the grain boundaries.

The answer is (A).

MATERIALS SCIENCE–75

Which of the following correctly describes atoms located at grain boundaries?

(A) They are subjected to the same type of interatomic forces that are present in the interior atoms of the crystal.

(B) They are located primarily in highly strained and distorted positions.

(C) They have a higher free energy than atoms in the undisturbed part of the crystal lattice.

(D) All of the above are correct.

All are correct statements regarding atoms at the grain boundary.

The answer is (D).

MATERIALS SCIENCE–76

What causes the vinyl interiors of automobiles to crack when subjected to prolonged direct sunlight?

(A) the volatilization (evaporation) of plasticizers
(B) repetitive expansion and contraction of the plastic
(C) oxidation of the plastic by sunlight and oxygen
(D) all of the above

All of the statements are true.

The answer is (D).

MATERIALS SCIENCE–77

Low-density polyethylene undergoes extensive (over 100%) elongation prior to rupture, while polystyrene undergoes only 1–2% elongation. What is the main reason for this difference?

(A) The polyethylene is less dense.
(B) The large styrene groups in the polystyrene prevent slippage.
(C) More cross-linking occurs in the polystyrene.
(D) Polyethylene is less crystalline.

Polystyrene has large styrene groups on the side of its carbon chain. These prevent slippage, making the polystyrene brittle.

The answer is (B).

MATERIALS SCIENCE–78

Which of the following describe(s) the modulus of elasticity of an elastomer?

I. It is directly proportional to the number of cross links in the elastomer.
II. Its value increases with temperature.
III. It is directly proportional to the number of double bonds in the chemical structure.

(A) I only (B) II only (C) III only (D) I and II

Choice III is false, since a double bond prevents rotation along the bond, inhibiting elasticity.

The answer is (D).

MATERIALS SCIENCE–79

Which statement(s) describe(s) the glass transition temperature?

I. It is the temperature at which the rate of volume contraction decreases abruptly.
II. It is the temperature at which residual stresses in the glass can be relieved.
III. It is the point where the material behaves more like a solid than a viscous liquid.

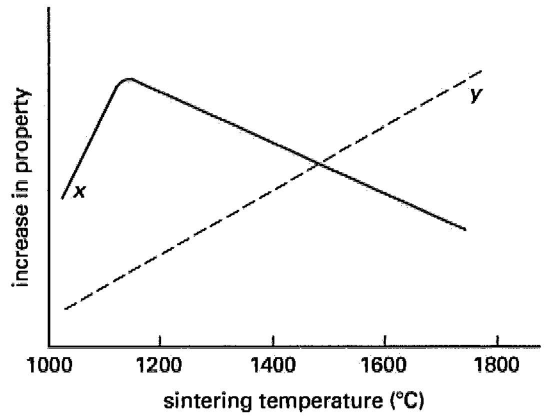
(A) I only (B) I and II (C) I and III (D) II and III

The glass transition temperature is the point at which the free movement of the glass molecules past each other becomes difficult. The glass begins to act like a solid, increasing in specific volume.

The answer is (C).

MATERIALS SCIENCE-80

If the following diagram represents the sintering of the ceramic MgO, what could the curves x and y refer to?



(A) x = grain size; y = porosity
(B) x = grain size; y = strength
(C) x = porosity; y = grain size
(D) x = strength; y = grain size

As the sintering temperature increases, the strength of a ceramic will increase first and then drop abruptly. The grain size will increase linearly with rising temperature.

The answer is (D).

MATERIALS SCIENCE–81

Of the following inorganic glasses, which have tetrahedral lattice structures?

$$SiO_2,\ B_2O_3,\ BeF_2,\ GeO_2$$

(A) SiO_2 and B_2O_3
(B) SiO_2 and BeF_2
(C) SiO_2, B_2O_3, and BeF_2
(D) SiO_2, BeF_2, and GeO_2

SiO_2, BeF_2, and GeO_2 have tetrahedral structures. B_2O_3 has an almost triangular structure.

The answer is (D).

MATERIALS SCIENCE–82

Which of the following is NOT an important criterion for forming a complete binary solid solution?

(A) The difference in radii should be less than 15%.
(B) The constituent elements must have the same crystal structure.
(C) The atoms should be close to one another in the periodic table.
(D) The difference in atomic numbers should be small.

All choices except option (D) are criteria for a binary solid solution.

The answer is (D).

MATERIALS SCIENCE–83

How can an ordered solid solution be distinguished from a compound?

(A) In an ordered solid solution, the solute atoms occupy interstitial positions within the lattice.
(B) The solute atoms in an ordered solid solution substitute for atoms in the parent lattice.
(C) The atoms in an ordered solid solution form layers in the lattice structure.
(D) When heated, an ordered solid solution becomes disordered before melting.

Unlike a compound, an ordered solid solution becomes disordered when heated.

The answer is (D).

MATERIALS SCIENCE–84

What is transformed in a eutectoid reaction?

(A) One liquid is transformed into two solids of different composition.
(B) A solid becomes a liquid at the eutectic temperature.
(C) A liquid becomes a solid at the solidus temperature.
(D) A solid becomes a liquid at the liquidus temperature.

In a eutectoid reaction, one liquid is transformed into two different solids.

The answer is (A).

MATERIALS SCIENCE–85

Which of the following is the correct representation of a eutectic cooling reaction? (The subscripts denote different compositions.)

(A) $(\text{liquid}) \longrightarrow (\text{solid})_1 + (\text{solid})_2$
(B) $(\text{solid})_1 + (\text{liquid}) \longrightarrow (\text{solid})_2$
(C) $(\text{solid})_1 \longrightarrow (\text{solid})_2 + (\text{solid})_3$
(D) $(\text{solid})_1 + (\text{solid})_2 \longrightarrow (\text{solid})_3$

A eutectic reaction is the transformation from one liquid phase to two solid phases.

The answer is (A).

MATERIALS SCIENCE–86

Two pieces of copper are brazed together using a eutectic alloy of copper and silver. The braze material melts at 780°C. If a second braze is attempted in order to attach another piece of copper, which of the following is true?

(A) The first braze will melt if the braze temperature is again 780°C.
(B) The braze temperature must be lowered below 780°C.
(C) The first braze will partially melt, causing the parts to slide.
(D) The first braze will not melt at 780°C, but the second braze will.

All compositions of copper and silver other than the eutectic will have a melting point higher than the eutectic temperature. The alloy of the first braze will dissolve somewhat into the copper pieces, changing its composition. It will not melt again at the second braze temperature of 780°C.

The answer is (D).

MATERIALS SCIENCE–87

On an alloy phase diagram, what is the solidus temperature?

(A) The point at which all solids completely reach the liquid stage.

(B) The temperature of the liquid phase at which the first solid forms for a given overall composition.

(C) The temperature of the solid phase at which the first liquid forms for a given overall composition.

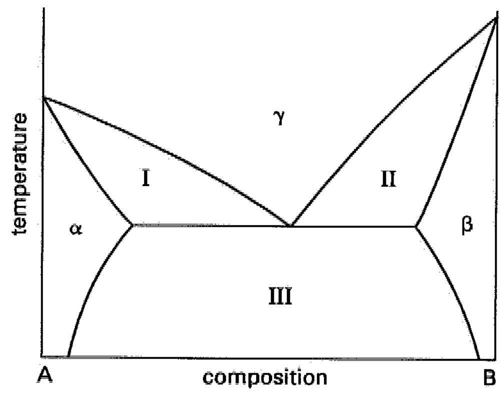
(D) The temperature at which the solid is at equilibrium.

The solidus temperature is the temperature at which liquid first forms.

$\boxed{\text{The answer is (C).}}$

MATERIALS SCIENCE–88

In this phase diagram, what can be said about the phases present in regions I, II, and III?



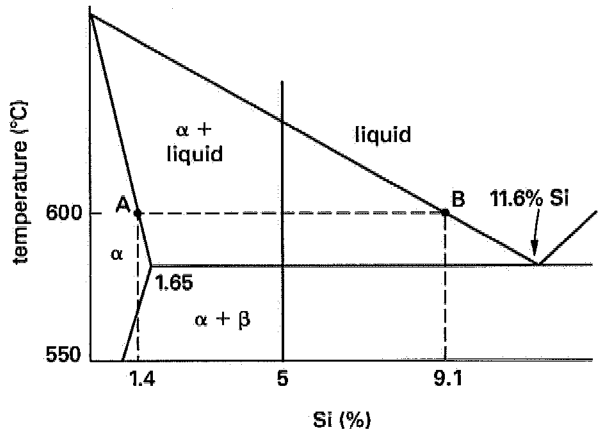
(A) α, β, and γ are present in region I.
(B) β and γ are present in region II.
(C) α, β, and γ are present in region III.
(D) α and γ are present in region III.

β and γ are present in region II. γ is not present in region III, nor is β present in region I.

$\boxed{\text{The answer is (B).}}$

MATERIALS SCIENCE–89

Given the following phase diagram, determine the percentage of liquid remaining at 600°C that results from the equilibrium cooling of an alloy containing 5% silicon and 95% aluminum.



(A) 0.0% (B) 47% (C) 53% (D) 67%

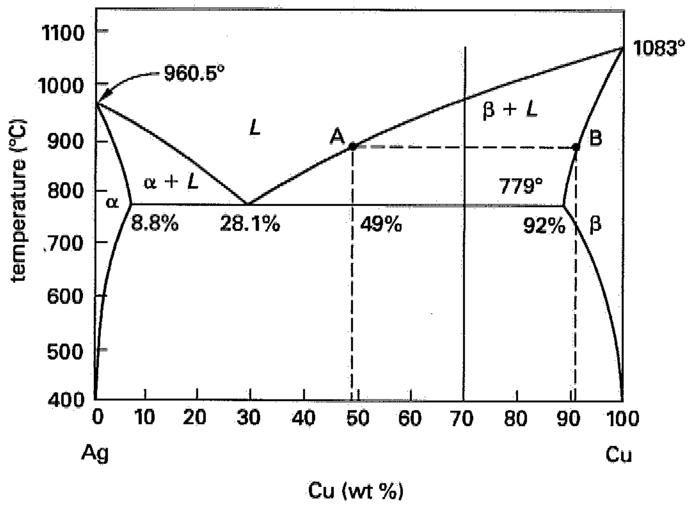
Use the lever rule. At point A there is 1.4% Si and no liquid, while at point B there is 9.1% Si and all liquid. Therefore,

$$\text{percent liquid} = \frac{5\% - 1.4\%}{9.1\% - 1.4\%} \times 100\% = 47\%$$

The answer is (B).

MATERIALS SCIENCE–90

Consider the Ag-Cu phase diagram given. Calculate the equilibrium amount of β in an alloy of 30% Ag, 70% Cu at 850°C.



(A) 0.0% (B) 22% (C) 49% (D) 52%

At 70% Cu, A = 49% Cu and B = 92% Cu.

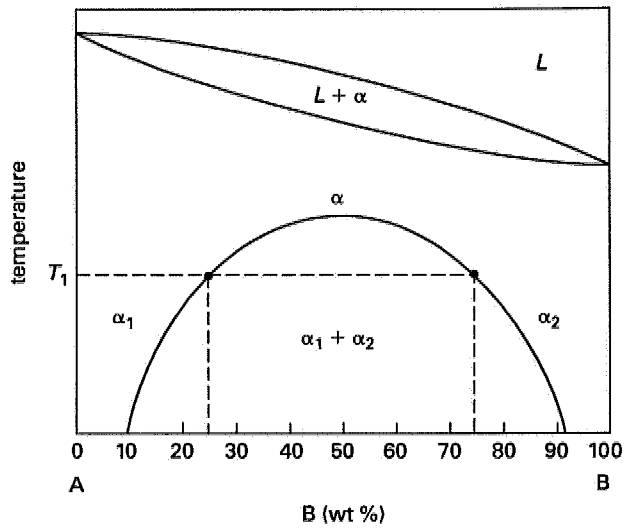
$$\text{percent } \beta = \frac{\%\text{ Cu in alloy} - \%\text{ Cu at point A}}{\%\text{ Cu at point B} - \%\text{ Cu at point A}} \times 100\%$$

$$= \frac{70\% - 49\%}{92\% - 49\%} \times 100\% = 49\%$$

The answer is (C).

MATERIALS SCIENCE–91

Using the given phase diagram, what are the relative weights of phases α_1 and α_2 for an alloy of 70% B at temperature T_1?



(A) 10% α_1, 90% α_2
(B) 30% α_1, 70% α_2
(C) 50% α_1, 50% α_2
(D) 70% α_1, 30% α_2

Let W_{α_1} denote the weight fraction of α_1 and W_{α_2} denote the weight fraction of α_2. From the diagram, $C_{\alpha_1} = 25\%$ and $C_{\alpha_2} = 75\%$. Then,

$$W_{\alpha_1} + W_{\alpha_2} = 1$$
$$W_{\alpha_1}C_{\alpha_1} + W_{\alpha_2}C_{\alpha_2} = C_0$$

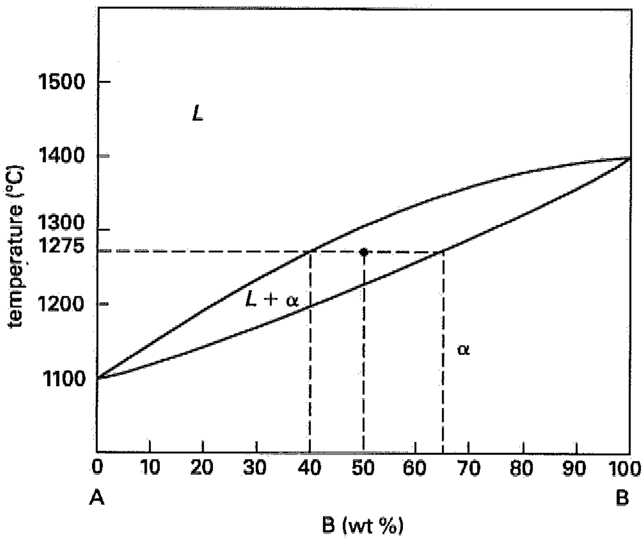
Solving the two equations using $C_0 = 70\%$,

$$W_{\alpha_1} = \frac{C_{\alpha_2} - C_0}{C_{\alpha_2} - C_{\alpha_1}} = \frac{75\% - 70\%}{75\% - 25\%} = 10\%$$

$\boxed{\text{The answer is (A).}}$

MATERIALS SCIENCE–92

For 50% B at 1275°C as shown, what is the relative amount of each phase present?



(A) 40% liquid, 60% solid
(B) 45% liquid, 55% solid
(C) 50% liquid, 50% solid
(D) 60% liquid, 40% solid

From the phase diagram, $C_\alpha = 65\%$ and $C_L = 40\%$. With C_0 given as 50%, and denoting the weight fraction of liquid and solid by W_L and W_α, respectively,

$$W_L + W_\alpha = 1$$
$$W_L C_L + W_\alpha C_\alpha = C_0$$

$$W_L = \frac{C_\alpha - C_0}{C_\alpha - C_L} = \frac{65\% - 50\%}{65\% - 40\%} = 60\%$$

The answer is (D).

MATERIALS SCIENCE–93

Which of the following is NOT a structural class of steels?

(A) carbon
(B) high-strength, low-alloy
(C) low-alloy
(D) tool and die

"Tool and die" steel is an application class, not a structural class.

The answer is (D).

MATERIALS SCIENCE–94

Which of the following phases of steel has a face-centered cubic structure?

(A) ferrite (B) cementite (C) pearlite (D) austenite

Only austenite has a face-centered cubic structure.

The answer is (D).

MATERIALS SCIENCE–95

Low-carbon steels are generally used in the "as rolled" or "as fabricated" state. What is the reason for this?

(A) They come in many different shapes and thicknesses.
(B) Their strength generally cannot be increased by heat treatment.
(C) They degrade severely under heat treatment.
(D) Their chromium content is so low.

Since their strength cannot be increased by heat treatment, low-carbon steels are used as fabricated.

The answer is (B).

MATERIALS SCIENCE–96

The equilibrium cooling of a steel containing 0.8% carbon results in a product with little use because it is extremely brittle. Which of the following is the primary reason for this poor characteristic?

(A) The material has not been cold worked.
(B) The austenite grains are too small, and the carbide grains are too large.
(C) Thick layers of iron carbide surround the coarse ferrite grains.
(D) The carbide forms thin plates that are brittle.

When hypereutectoid steels are slow cooled, brittle carbide plates are formed.

The answer is (D).

MATERIALS SCIENCE–97

Ductile cast iron and gray cast iron both contain 4% carbon. Ductile cast iron, however, has a higher tensile strength and is considerably more ductile. Which of the following is the major difference that accounts for the superior properties of the ductile iron?

(A) The gray cast iron contains iron carbide, whereas the ductile iron contains graphite.
(B) The gray cast iron contains flakes of graphite, whereas the ductile iron contains spheroids of graphite.
(C) The ductile iron is tempered to give better properties.
(D) The ferrite grains in the gray cast iron are excessively large.

Gray cast iron contains flakes of graphite while ductile cast iron contains spheroids. The difference in the shape of the graphite gives the ductile cast iron approximately twice the tensile strength and 20 times the ductility of the gray cast iron.

The answer is (B).

MATERIALS SCIENCE–98

In preparing a metallographic iron specimen, the grain boundaries are made most visible by which of the following steps?

(A) grinding the sample with silicon carbide abrasive
(B) polishing the sample with Al_2O_3
(C) mounting the sample in an epoxy resin mold
(D) etching the sample in a 2% solution of nitric acid in alcohol

Etching the specimen with nitric acid in alcohol dissolves metal from the surface and preferentially attacks the grain boundaries. It is the last step in the sample preparation process.

The answer is (D).

MATERIALS SCIENCE–99

Which of the following statements is FALSE?

(A) Low-alloy steels are a minor group and are rarely used.
(B) Low-alloy steels are used in the heat-treated condition.
(C) Low-alloy steels contain small amounts of nickel and chromium.
(D) The addition of small amounts of molybdenum to low-alloy steels makes it possible to harden and strengthen thick pieces of the metal by heat treatment.

Low-alloy steels are one of the most commonly used classes of structural steels.

The answer is (A).

MATERIALS SCIENCE–100

Which of the following statements is FALSE?

(A) High-strength, low-alloy steels are not as strong as nonalloy, low-carbon steels.
(B) Small amounts of copper increase the tensile strength of steels.
(C) Small amounts of silicon in steels have little influence on toughness or fabricability.
(D) Addition of small amounts of silicon to steel can cause a marked decrease in yield strength of the steel.

Addition of small amounts of silicon to steel increases both the yield strength and the tensile strength.

The answer is (D).

MATERIALS SCIENCE–101

Which of the following statements is FALSE?

(A) Stainless steels contain large amounts of chromium.

(B) There are three basic types of stainless steels: martensitic, austenitic, and ferritic.

(C) The nonmagnetic stainless steels contain large amounts of nickel.

(D) Stabilization of the face-centered cubic crystal structure of stainless steels imparts a nonmagnetic characteristic to the alloy.

There are only two basic types of stainless steels: magnetic (martensitic or ferritic) and nonmagnetic (austenitic).

The answer is (B).

MATERIALS SCIENCE–102

For a completely corrosion-resistant stainless steel, what minimum percentage of chromium in the alloy is required?

(A) 1.1% (B) 3.2% (C) 8.3% (D) 11%

For complete corrosion resistance, the chromium content must be at least 11%.

The answer is (D).

MATERIALS SCIENCE–103

Which of the following would most likely require a steel containing 0.6% carbon that has been spheroidized, cold-drawn, and slightly tempered?

(A) a bridge beam
(B) a water pipe
(C) a cutting tool
(D) a ball bearing

A hypoeutectoid steel that has been worked using the above process has good strength and excellent toughness. A cutting tool undergoes tremendous stress loads due to the relatively small contact area. It requires a stronger material than do the other objects.

The answer is (C).