12 DC ELECTRICITY

DC ELECTRICITY–1

Which statement about a charge placed on a dielectric material is true?

(A) The charge diffuses across the material's surface.
(B) The charge diffuses through the interior of the material.
(C) The charge is confined to the region in which the charge was placed.
(D) The charge increases the conductivity of the material.

In a dielectric, all charges are attached to specific atoms or molecules.

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

DC ELECTRICITY–2

The coulomb force, F, acts on two charges a distance, r, apart. What is F proportional to?

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

The coulomb force is

$$F = \frac{q_1 q_2}{4\pi\epsilon r^2}$$

q_1 and q_2 are the charges, and ϵ is the permittivity of the surrounding medium. Hence, F is proportional to the inverse of r^2.

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

DC ELECTRICITY–3

The force between two electrons in a vacuum is 1×10^{-15} N. Approximately how far apart are the electrons?

(A) 1.4×10^{-12} m (B) 5.1×10^{-12} m (C) 4.8×10^{-7} m (D) 1.7×10^{-6} m

Coulomb's law is

$$F = \frac{q_1 q_2}{4\pi\epsilon_o r^2}$$

$\epsilon_o = 8.85 \times 10^{-12}$ C^2/N·m^2. Also, for an electron, $q = 1.6 \times 10^{-19}$ C. Solving for r,

$$\begin{aligned} r &= q\sqrt{\frac{1}{4\pi\epsilon_o F}} \\ &= (1.6 \times 10^{-19}\ \text{C})\sqrt{\frac{1}{4\pi\left(8.85 \times 10^{-12}\ \frac{\text{C}^2}{\text{N·m}^2}\right)(1 \times 10^{-15}\ \text{N})}} \\ &= 4.8 \times 10^{-7}\text{m} \end{aligned}$$

The answer is (C).

DC ELECTRICITY–4

Two solid spheres have charges of 1 C and −8 C, respectively. The permittivity, ϵ_o, is 8.85×10^{-12} C^2/N·m^2, and the distance between the sphere centers, r, is 0.3 m. Determine the force on the spheres.

(A) -1×10^{13} N (B) -8×10^{11} N (C) 0 N (D) 8×10^{11} N

Because of their symmetry, charged spheres may be treated as point charges. Use Coulomb's law.

$$\begin{aligned} F &= \frac{q_1 q_2}{4\pi\epsilon_o r^2} = \frac{(1\ \text{C})(-8\ \text{C})}{4\pi\left(8.85 \times 10^{-12}\ \frac{\text{C}^2}{\text{N·m}^2}\right)(0.3\ \text{m})^2} \\ &= -8 \times 10^{11}\ \text{N} \end{aligned}$$

The answer is (B).

DC ELECTRICITY–5

A parallel plate capacitor with plates of area A that are separated a distance d by air is initially charged with charge q_c. The energy stored in the capacitor initially is E. The plates are then separated by $2d$. What is the new energy stored in the capacitor?

(A) 0 (B) $0.5E$ (C) E (D) $2E$

The energy initially stored in the capacitor is

$$E = \frac{q_c^2}{2C}$$

C is the initial capacitance. After the increase in plate separation, the capacitance, C', is

$$C' = \frac{\varepsilon_0 A}{2d} = \tfrac{1}{2}C$$

Therefore the energy stored, E', after the plate distance is increased is

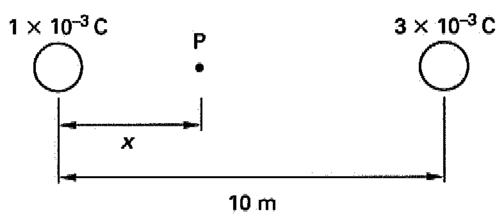
$$E' = \frac{q_c^2}{2C'} = \frac{q_c^2}{(2)\left(\frac{1}{2}C\right)} = 2E$$

The increased energy is added into the system when force is used to separate the plates against the electrostatic force between them.

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

DC ELECTRICITY–6

A 0.001 C charge is separated from a 0.003 C charge by 10 m. If P denotes the point of zero electric field between the charges, determine the distance, x, between the 0.001 C charge and point P.



(A) 2.2 m (B) 3.7 m (C) 6.3 m (D) 14 m

Electric field intensity E at point 2 due to a point charge, Q, at point 1 is

$$E = \frac{Q_1}{4\pi\epsilon r^2}$$

r is the distance between points 1 and 2.

At the point where E is zero, the electric field due to the 0.001 C charge equals the field due to the 0.003 C charge in magnitude.

$$\frac{0.001\ \text{C}}{4\pi\epsilon_o x^2} = \frac{0.003\ \text{C}}{4\pi\epsilon_o (10\ \text{m} - x)^2}$$
$$(10\ \text{m} - x)^2 = 3x^2$$
$$x^2 + 10x - 50 = 0$$

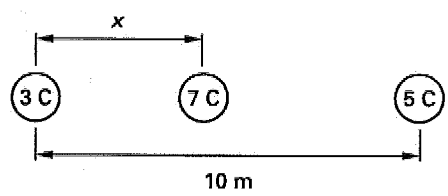
Solving for the positive x value,

$$\begin{aligned} x &= \frac{-b + \sqrt{b^2 - 4ac}}{2a} \\ &= \frac{-10\ \text{m} + \sqrt{(10\ \text{m})^2 - (4)(1\ \text{m})(-50\ \text{m})}}{2} \\ &= 3.66\ \text{m} \quad (3.7\ \text{m}) \end{aligned}$$

The answer is (B).

DC ELECTRICITY–7

A 3 C charge and a 5 C charge are 10 m apart. A 7 C charge is placed on a line connecting the two charges, x meters away from the 3 C charge. If the 7 C charge is in equilibrium, find the value of x.



(A) 3.9 m (B) 4.4 m (C) 5.0 m (D) 5.7 m

At equilibrium, $F_{37} = F_{75}$. Using Coulomb's law,

$$\frac{(3\ \text{C})(7\ \text{C})}{4\pi\epsilon_o x^2} = \frac{(7\ \text{C})(5\ \text{C})}{4\pi\epsilon_o(10\ \text{m} - x)^2}$$
$$(21\ \text{C}^2)(10\ \text{m} - x)^2 = 35x^2$$
$$x^2 + 30x - 150 = 0$$

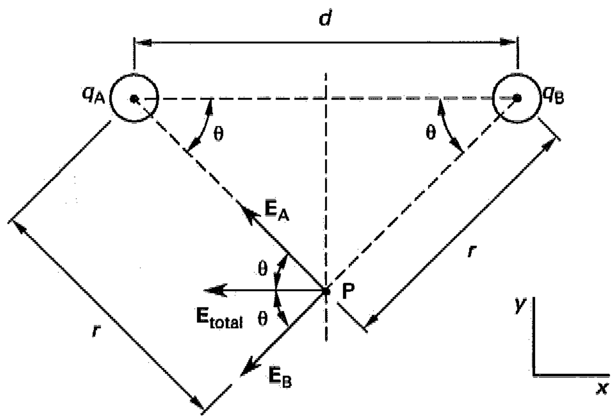
Solving for a positive value of x,

$$\begin{aligned} x &= \frac{-b + \sqrt{b^2 - 4ac}}{2a} \\ &= \frac{-30\ \text{m} + \sqrt{(30\ \text{m})^2 - (4)(1\ \text{m})(-150\ \text{m})}}{2} \\ &= 4.36\ \text{m} \quad (4.4\ \text{m}) \end{aligned}$$

The answer is (B).

DC ELECTRICITY-8

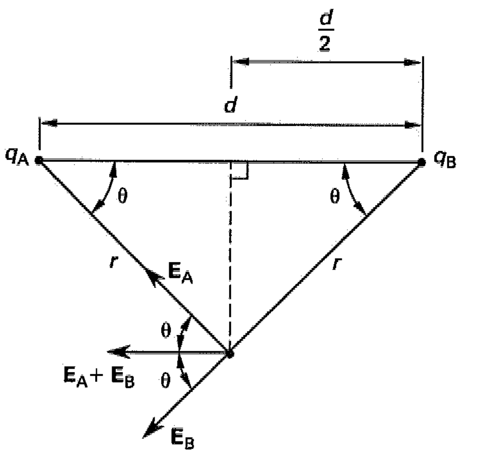
Two charges, A and B, of equal and opposite value are separated by a distance, d. r is the distance from a charge to any point, P, lying on the normal plane that bisects the length d. What is the electric field at point P if K is a constant equal to $1/4\pi\epsilon$?



(A) $\dfrac{Kqd}{r^3}$ (B) $\dfrac{Kq^2d}{r^3}$ (C) $\dfrac{Kq}{r^2}$ (D) $\dfrac{2Kq}{r^2}$

The total electric field will be in the x direction only, since the y components of the charges cancel each other out. By definition, with $\mathbf{a_r}$ denoting the unit radial vector,

$$\mathbf{E}_{\text{total}} = \left(\frac{Kq}{r^2}\right)\mathbf{a_r}$$



Therefore,

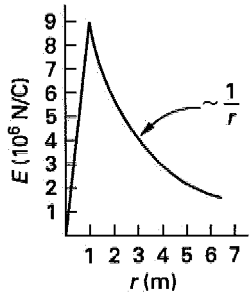
$$\begin{aligned} E_{\text{total}} &= E_A + E_B = \left(\frac{Kq_A}{r^2}\right)\cos\theta + \left(\frac{Kq_B}{r^2}\right)\cos\theta \\ &= \left(\frac{2Kq}{r^2}\right)\left(\frac{\frac{1}{2}d}{r}\right) \\ &= \frac{Kqd}{r^3} \end{aligned}$$

The answer is (A).

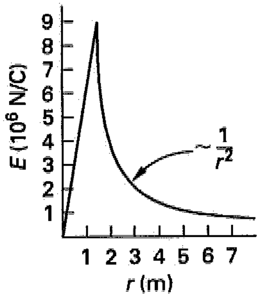
DC ELECTRICITY–9

A hollow metallic spherical shell has a charge of 0.001 C. The shell is 2 m in diameter. Which of the following correctly shows the variation of electric field with respect to the distance, r, from the center of the sphere?

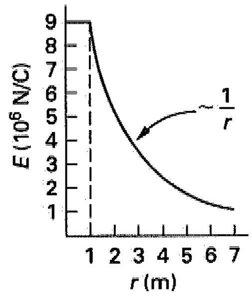
(A)



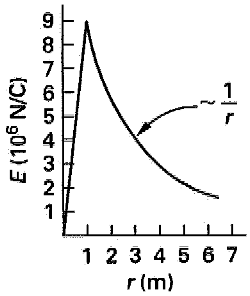
(B)



(C)



(D)



Outside the sphere, Coulomb's law can be used to find the electric field. Thus, the electric field varies as $1/r^2$ for $r > 1$ m. On the surface of the sphere, $r = 1$ m.

$$E = \frac{q}{4\pi\epsilon_o r^2} = \frac{0.001\ \text{C}}{4\pi\left(8.85\times10^{-12}\ \dfrac{\text{C}^2}{\text{N}{\cdot}\text{m}^2}\right)(1\ \text{m})^2} = 9\times10^6\ \text{N/C}$$

Gauss' law states that the electric flux passing through a given closed surface is proportional to the charge enclosed by the surface. There is no charge within the sphere. Therefore, the electric field is zero for $r < 1$ m. Only (D) is correct.

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

DC ELECTRICITY–10

Approximately how far away must an isolated positive point charge of 1×10^{-8} C be in order for it to produce an electric potential of 100 V? The charge is in free space with $\epsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2/N{\cdot}m^2}$.

(A) 0.90 m (B) 1.2 m (C) 5.3 m (D) 8.6 m

At a distance, r, from a point charge, q,

$$V = -\int E\,dr\,\frac{q}{4\pi\epsilon r}$$

$$r = \frac{q}{4\pi\epsilon V}$$

$$= \frac{1 \times 10^{-8}\ \mathrm{C}}{4\pi\left(8.85 \times 10^{-12}\ \frac{\mathrm{C^2}}{\mathrm{N{\cdot}m^2}}\right)(100\ \mathrm{V})}$$

$$= 0.90\ \mathrm{m}$$

The answer is (A).

DC ELECTRICITY–11

A point charge, q, in a vacuum creates a potential, V, at a distance, r. A reference voltage of zero is arbitrarily selected when $r = a$. If $K = 1/4\pi\epsilon_o$, which of the following is the correct expression for V?

(A) $Kq\left(\frac{1}{r^2} - \frac{1}{a^2}\right)$ (B) $Kq\frac{1-a}{r^2}$

(C) $Kq\left(\frac{1}{r} - \frac{1}{a}\right)$ (D) $Kq\left(\frac{1}{r^3} - \frac{1}{a^3}\right)$

From Coulomb's law for a point charge,

$$E = \frac{Kq}{r^2}$$

The total voltage is measured between the reference voltage, a, and r.

$$V = -\int E\,dr = -\int_a^r \frac{Kq}{r^2}dr$$

$$= Kq\left(\frac{1}{r} - \frac{1}{a}\right)$$

The answer is (C).

DC ELECTRICITY–12

What accelerating voltage is required to accelerate an electron to a kinetic energy of 5×10^{-15} J? The charge of an electron is 1.6×10^{-19} C.

(A) 8 kV (B) 13 kV (C) 19 kV (D) 31 kV

For an electron, after the potential energy has been converted to kinetic energy, kinetic energy is

$$\begin{aligned} E_k &= qV \\ V &= \frac{E_k}{q} = \frac{5 \times 10^{-15}\ \text{J}}{1.6 \times 10^{-19}\ \text{C}} \\ &= 31\,250\ \text{V} \quad (31\ \text{kV}) \end{aligned}$$

The answer is (D).

DC ELECTRICITY–13

A certain potential variation in the xy plane is given by the expression

$$\nabla V = \left(\frac{1}{\sqrt{x^2 + 4y^2}}\right)(\mathbf{i} + \mathbf{j})$$

Which of the following gives the magnitude and direction (angle made with the x-axis) of the electric field intensity at the point (2,1)?

(A) $-\sqrt{2}/4,\ \pi$ (B) $1/2,\ -\pi/4$ (C) $\sqrt{2}/2,\ \pi/4$ (D) $1/2,\ \pi/4$

$$\begin{aligned} V &= \int E\, dr \\ \mathbf{E} = \nabla V &= \frac{\partial V}{\partial x}\mathbf{i} + \frac{\partial V}{\partial y}\mathbf{j} \end{aligned}$$

Since this is equivalent to the expression given,

$$\begin{aligned} E = \sqrt{E_x^2 + E_y^2} &= \sqrt{\left(\frac{\partial V}{\partial x}\right)^2 + \left(\frac{\partial V}{\partial y}\right)^2} \\ &= \sqrt{\left(\frac{1}{\sqrt{x^2 + 4y^2}}\right)^2 + \left(\frac{1}{\sqrt{x^2 + 4y^2}}\right)^2} \\ &= \sqrt{\frac{2}{x^2 + 4y^2}} \end{aligned}$$

Evaluating at the point (2,1),

$$E = \sqrt{\frac{2}{(2)^2 + (4)(1)^2}}$$
$$= 1/2$$

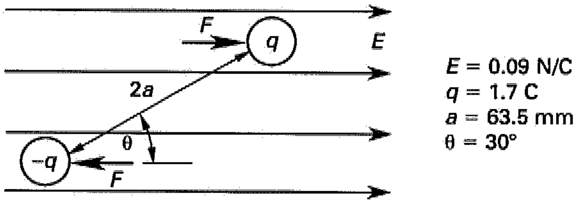
The angle from horizontal that the **E** field is directed is

$$\tan\theta = \frac{E_x}{E_y}$$
$$= \frac{\dfrac{1}{\sqrt{x^2+4y^2}}}{\dfrac{1}{\sqrt{x^2+4y^2}}} = 1$$
$$\theta = \pi/4$$

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

DC ELECTRICITY–14

An electric dipole is placed in a uniform electric field of intensity, E. Given the information in the figure, what is most nearly the torque acting on the dipole?



(A) 1.7×10^{-3} N·m (B) 3.3×10^{-3} N·m (C) 4.8×10^{-3} N·m (D) 9.5×10^{-2} N·m

The torque is

$$T = F(2a)\sin\theta$$

F is the force from the electric field.

$$F = Eq = 0.09\ \frac{\text{N}}{\text{C}} \times 1.7\ \text{C}$$
$$= 0.15\ \text{N}$$

Solving for torque,

$$\begin{aligned} T &= (0.15 \text{ N})(2)\left(\frac{63.5 \text{ mm}}{1000 \frac{\text{mm}}{\text{m}}}\right)\sin 30^\circ \\ &= 9.5 \times 10^{-2} \text{ N·m} \end{aligned}$$

The answer is (D).

DC ELECTRICITY-15

Current i is applied to a long N-turn solenoid with cross-section area A and length d. The magnetic field intensity inside the solenoid is $H = Ni/d$ when d is very large. What is the inductance of this long solenoid in air?

(A) $\frac{\mu_0 NA}{d}$ (B) $\frac{\mu_0 N^2 A}{d}$ (C) $\frac{\mu_0 NA}{i}$ (D) $\frac{\mu_0 NA}{id}$

The magnetic flux passing through one turn of the solenoid is

$$\Phi_1 = \int \mathbf{B} \cdot d\mathbf{S} = \mu_0 HA$$

The total flux enclosed by the N turns is obtained by summing the contribution of all the turns.

$$\Phi = \sum_{\text{turns}} \Phi_1 = \mu_0 NHA$$

The inductance is

$$L = \frac{\Phi}{i} = \frac{\mu_0 NHA}{i} = \frac{\mu_0 N\left(\frac{Ni}{d}\right)A}{i} = \frac{\mu_0 N^2 A}{d}$$

The answer is (B).

DC ELECTRICITY–16

Which of the following is NOT a property of magnetic field lines?

(A) The field is stronger where the lines are closer together.
(B) The lines intersect surfaces of equal intensity at right angles.
(C) Magnetic field lines have no beginnings and no ends.
(D) The lines cross themselves only at right angles.

Magnetic field lines do not cross. Their direction at any given point is unique.

The answer is (D).

DC ELECTRICITY–17

The tesla is a unit of

(A) permittivity
(B) capacitance
(C) inductance
(D) magnetic flux density

The tesla is a unit of magnetic flux density.

The answer is (D).

DC ELECTRICITY–18

The south poles of two bar magnets are 7.5 cm apart in air. The magnets are of equal strength and repel each other with a force of 4.9×10^{-4} N. What is most nearly the strength of each magnet?

(A) 6.6×10^{-6} Wb (B) 0.86 Wb (C) 11 Wb (D) 53 Wb

The force between two magnets of strength M_1 and M_2 is

$$F = \frac{M_1 M_2}{4\pi\mu r^2}$$

$M_1 = M_2$. Therefore,

$$\begin{aligned} M &= \sqrt{4\pi\mu r^2 F} \\ &= \sqrt{4\pi\left(4\pi \times 10^{-7}\ \frac{\text{H}}{\text{m}}\right)(0.075\ \text{m})^2(4.9 \times 10^{-4}\ \text{N})} \\ &= 6.60 \times 10^{-6}\ \text{Wb} \quad \text{[unit poles]} \end{aligned}$$

The answer is (A).

DC ELECTRICITY–19

A conductor has length of 1 m, electrical resistivity of 0.1 Ω·m, and area of 0.01 m^2. A uniform direct current having a density of 100 A/m^2 flows through this conductor. What is the power loss in the conductor?

(A) 0 W (B) 1 W (C) 10 W (D) 100 W

The resistance of the conductor is

$$R = \frac{\rho L}{A} = \frac{(0.1\ \Omega\cdot\text{m})(1\ \text{m})}{0.01\ \text{m}^2} = 10\ \Omega$$

The current flows through the conductor is

$$I = JA = \left(100\ \frac{\text{A}}{\text{m}^2}\right)(0.01\ \text{m}^2) = 1\ \text{A}$$

Therefore, the power consumed in the conductor is

$$P = I^2R = (1\ \text{A})^2(10\ \Omega) = 10\ \text{W}$$

The answer is (C).

DC ELECTRICITY–20

For a field given by $B = \mu H$ (Wb/m^2), what is the energy storage per unit volume?

(A) $U = \dfrac{B^2}{2\mu}$ (B) $U = \dfrac{H^2}{2}$ (C) $U = \dfrac{H^2}{2\mu}$ (D) $U = \dfrac{H^2}{2\mu^2}$

The energy stored in a magnetic field H per unit volume is $U = {}^1\!/\!_2 BH$. Since $B = \mu H$, $H = B/\mu$. Therefore,

$$U = \tfrac{1}{2}B\frac{B}{\mu} = \frac{B^2}{2\mu}$$

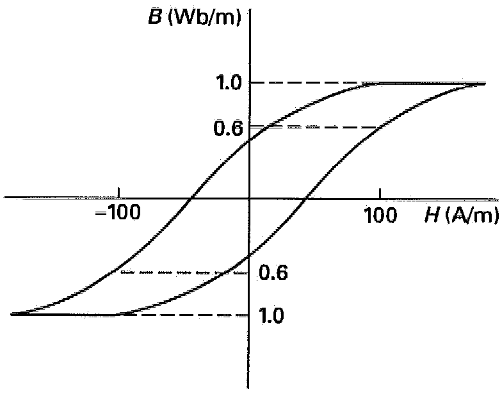
The answer is (A).

DC ELECTRICITY–21

The magnetic flux density, B, and the magnetic field intensity, H, have the following relationship.

$$B = \mu_o(H + M)$$

μ_o is the permeability of free space (in H/m), and M is the magnetic polarization of the material (in A/m). If B is increasing, which of the following may be true about the state of metal X at a value of $H = 100$ A/m? The B-H curve of the metal is as shown.



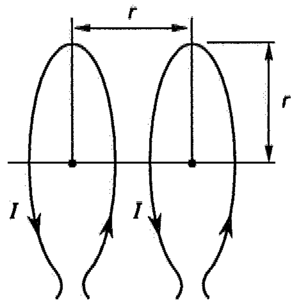
(A) $B = 0.6$ Wb/m; metal X is nonferrous
(B) $B = 0.6$ Wb/m; metal X is ferrous
(C) $B = 1.0$ Wb/m; metal X is nonferrous
(D) $B = 1.0$ Wb/m; metal X is ferrous

Nonferrous metals do not exhibit hysteresis; hence, metal X is ferrous. The hysteresis curve follows a counterclockwise path. Therefore, for B to be increasing at an H value of 100 A/m, $B = 0.6$ Wb/m.

The answer is (B).

DC ELECTRICITY–22

Two identical coils of radius r are placed at a distance r apart as shown. Such a configuration is called a Helmholtz coil. Which of the following describes the magnetic field created by passing a uniform current through the assembly?



(A) The magnetic field is negligible regardless of the magnitude of I.
(B) The magnetic field is zero midway between the two coils.
(C) The magnetic field is fairly uniform between the two coils.
(D) The magnetic field is zero at the centers of the coils.

The magnetic field between the two coils is the superposition of the field created by each coil. Since the currents in both coils are in the same direction, the direction of each individual magnetic field is also the same, using the right-hand rule. Therefore, the fields will not cancel each other.

Since the two coils are circular with their centers aligned, the field between them will be fairly uniform.

The answer is (C).

DC ELECTRICITY–23

Which statement is true?

(A) Magnetic flux lines have sources only.
(B) Magnetic flux lines have sinks only.
(C) Magnetic flux lines have both sources and sinks.
(D) Magnetic flux lines do not have sources or sinks.

Magnetic flux lines are closed loops with no sources or sinks. No known particle produces lines of magnetism.

The answer is (D).

DC ELECTRICITY–24

A charge of 0.75 C passes through a wire every 15 s. What is most nearly the current in the wire?

(A) 5.0 mA (B) 9.4 mA (C) 20 mA (D) 50 mA

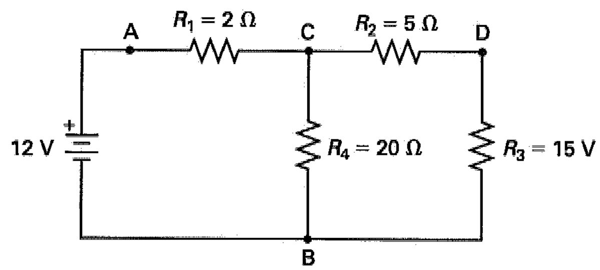
Current is the charge per unit time passing through the wire.

$$I = \frac{q}{t} = \frac{(0.75\ \text{C})\left(1000\ \frac{\text{mA}}{\text{A}}\right)}{15\ \text{s}}$$
$$= 50\ \text{mA}$$

The answer is (D).

DC ELECTRICITY–25

What is most nearly the total resistance between points A and B?



(A) 0 Ω (B) 12 Ω (C) 16 Ω (D) 22 Ω

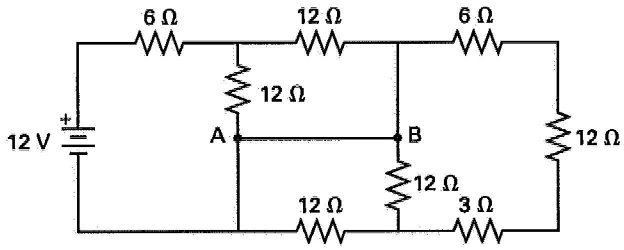
The total resistance is the sum of the resistance between points A and C, plus the equivalent resistance of the resistors in parallel between points C and B.

$$R_{\text{total}} = R_1 + R_4 \parallel (R_2 + R_3)$$
$$= R_1 + \frac{1}{\frac{1}{R_4} + \frac{1}{R_2 + R_3}}$$
$$= 2\ \Omega + \frac{1}{\frac{1}{20\ \Omega} + \frac{1}{5\ \Omega + 15\ \Omega}}$$
$$= 2\ \Omega + 10\ \Omega$$
$$= 12\ \Omega$$

The answer is (B).

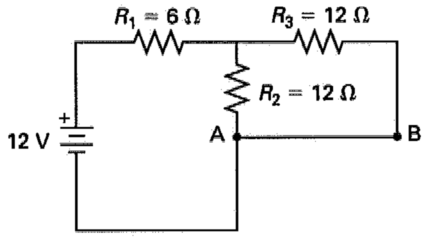
DC ELECTRICITY–26

What is the total resistance (as seen by the battery) of the following network?



(A) 6.0 Ω (B) 12 Ω (C) 15 Ω (D) 24 Ω

AB is a short circuit. Therefore, the rest of the circuit does not contribute to the resistance. The effective circuit is

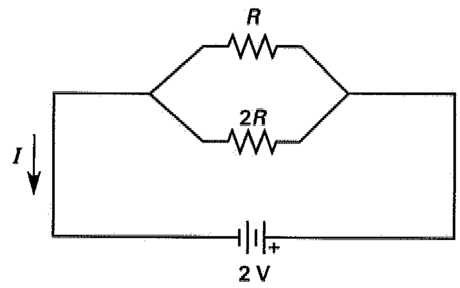


$$\begin{aligned} R_{\text{total}} &= R_1 + R_2 \parallel R_3 \\ &= R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}} \\ &= 6\ \Omega + \frac{1}{\frac{1}{12\ \Omega} + \frac{1}{12\ \Omega}} \\ &= 6\ \Omega + 6\ \Omega \\ &= 12\ \Omega \end{aligned}$$

The answer is (B).

DC ELECTRICITY–27

In the circuit shown, $R = 10\ \Omega$, and the electromagnetic force, V, is 2 V. What is most nearly the current, I?



(A) 0.10 A (B) 0.30 A (C) 0.67 A (D) 3.3 A

$$
\begin{aligned}
R_{\text{total}} = R \parallel 2R &= \frac{1}{\frac{1}{R} + \frac{1}{2R}} \\
&= \frac{2R}{3} \\
&= \frac{(2)(10\ \Omega)}{3} \\
&= 6.67\ \Omega
\end{aligned}
$$

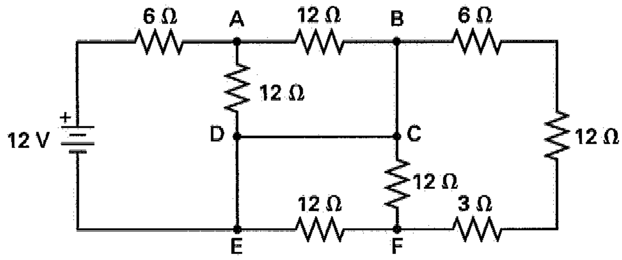
Use Ohm's law. Current is calculated as voltage divided by total resistance.

$$
\begin{aligned}
I &= \frac{V}{R_{\text{total}}} \\
&= \frac{2\ \text{V}}{6.67\ \Omega} \\
&= 0.30\ \text{A}
\end{aligned}
$$

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

DC ELECTRICITY–28

Find the current passing through the 3 Ω resistor.



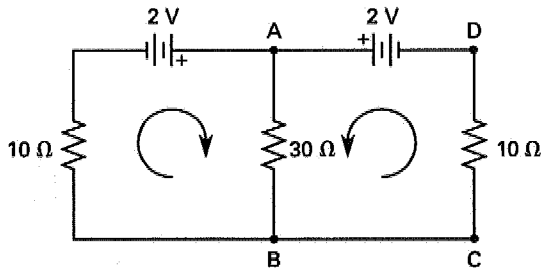
(A) 0 A (B) 0.3 A (C) 1 A (D) 4 A

Current from a battery will always follow a path of zero resistance in a circuit. Instead of flowing through the 3 Ω resistor and its neighboring resistors, the current will follow the path BCDE, a short circuit. There will be no current in the resistor.

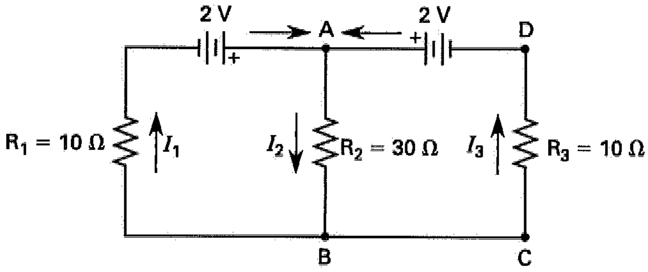
The answer is (A).

DC ELECTRICITY–29

What is most nearly the current passing through the 30 Ω resistor?



(A) 0.0 A (B) 29 mA (C) 50 mA (D) 57 mA



The circuit is symmetrical. Therefore, a current, I_1, flows through the resistors, R_1, and R_3. Another current, I_2, flows through resistor R_2. From Kirchhoff's current law at point A,

$$\sum I = 0$$
$$I_2 = 2I_1$$

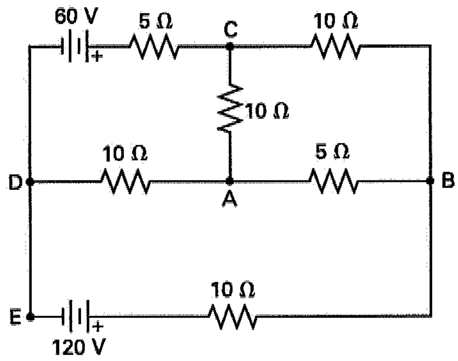
Using Kirchhoff's voltage law around the loop ABCDA.

$$\begin{aligned}
V &= R_2 I_2 + R_3 I_1 \\
2V &= (30\ \Omega)I_2 + (10\ \Omega)I_1 \\
2V &= (30\ \Omega)(2I_1) + (10\ \Omega)I_1 \\
2V &= (70\ \Omega)I_1 \\
I_1 &= 0.0286\ \text{A} \\
I_2 &= 2I_1 = (2)(0.0286\ \text{A})\left(1000\ \frac{\text{mA}}{\text{A}}\right) \\
&= 57\ \text{mA}
\end{aligned}$$

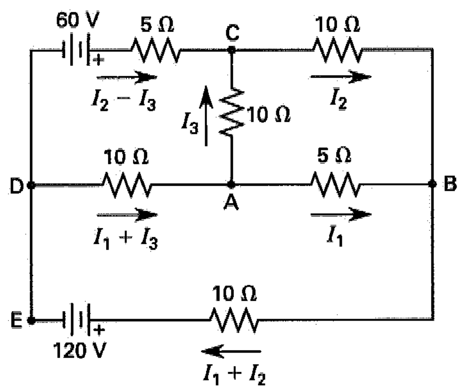
The answer is (D).

DC ELECTRICITY–30

What is most nearly the current through AB?



(A) 0.5 A (B) 1 A (C) 3 A (D) 4 A



By redrawing the circuit and designating the currents as shown in loop ACBA, the currents through the remaining loops can be expressed in terms of I_1, I_2, and I_3. Since voltage equals resistance multiplied by current, for loop CDAC,

$$60 \text{ V} = (5\ \Omega)(I_2 - I_3) - (10\ \Omega)(I_1 + I_3) - (10\ \Omega)I_3$$

$$2I_1 - I_2 + 5I_3 = -12 \text{ A} \quad \text{[I]}$$

For loop BEDAB,

$$120 \text{ V} = (10\ \Omega)(I_1 + I_2) + (10\ \Omega)(I_1 + I_3) + (5\ \Omega)I_1$$

$$0 = 25I_1 + 10I_2 + 10I_3 - 120$$

$$5I_1 + 2I_2 + 2I_3 = 24 \text{ A} \quad \text{[II]}$$

Around loop ACBA,

$$0\ \text{V} = -(5\ \Omega)I_1 + (10\ \Omega)I_2 + (10\ \Omega)I_3$$
$$I_1 - 2I_2 - 2I_3 = 0\ \text{A} \quad \text{[III]}$$

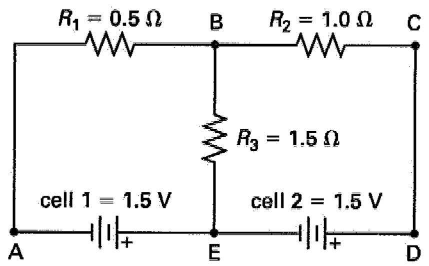
Observe that adding Eqs. II and III can directly solve I_1.

$$6I_1 = 24\ \text{A}$$
$$I_1 = 4\ \text{A}$$

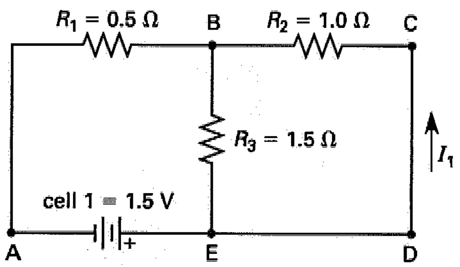
The answer is (D).

DC ELECTRICITY–31

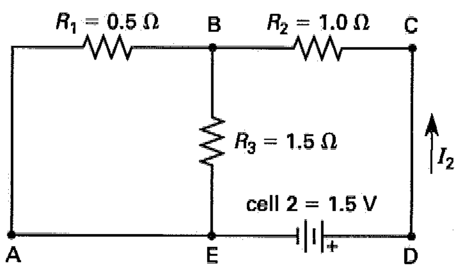
In the circuit shown, what is the current through CD?



(A) 0.20 A (B) 0.60 A (C) 1.0 A (D) 1.9 A



(a)



(b)

The method of superposition is used to find the current, I. Let I_1 be the current from cell 1, and let I_2 be the current from cell 2. Then, $I = I_1 + I_2$. Short circuiting cell 2 to find I_1 as shown in illustration (a), the equivalent total resistance is

$$\begin{aligned}
R_{\text{total},1} &= R_1 + R_2 \parallel R_3 \\
&= R_1 + \frac{R_2 R_3}{R_2 + R_3} \\
&= 0.5\ \Omega + \frac{(1.5\ \Omega)(1\ \Omega)}{2.5\ \Omega} \\
&= 1.1\ \Omega \\
I_1 &= \left(\frac{1.5\ \Omega}{2.5\ \Omega}\right)\left(\frac{1.5\ \text{V}}{1.1\ \Omega}\right) \\
&= 0.82\ \text{A}
\end{aligned}$$

Short circuiting cell 1 to find I_2, as shown in illustration (b), the equivalent total resistance is

$$\begin{aligned}
R_{\text{total},2} &= R_1 \parallel R_3 + R_2 \\
&= \frac{R_1 R_3}{R_1 + R_3} + R_2 \\
&= 1\ \Omega + \frac{(0.5\ \Omega)(1.5\ \Omega)}{2\ \Omega} \\
&= 1.375\ \Omega \\
I_2 &= \frac{1.5\ \text{V}}{1.375\ \Omega} \\
&= 1.1\ \text{A}
\end{aligned}$$

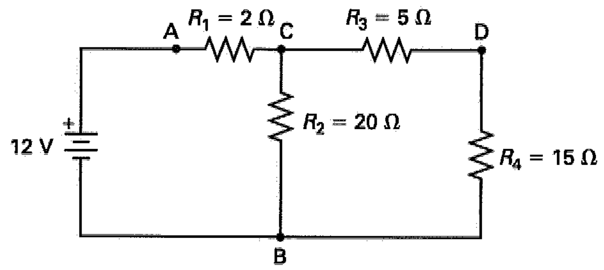
The total current is

$$\begin{aligned}
I &= I_1 + I_2 = 0.82\ \text{A} + 1.1\ \text{A} \\
&= 1.92\ \text{A} \quad (1.9\ \text{A})
\end{aligned}$$

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

DC ELECTRICITY–32

For the network shown, find the voltage drop from C to D.



(A) 2.0 V (B) 2.5 V (C) 3.0 V (D) 8.0 V

The total resistance is

$$\begin{aligned} R_{\text{total}} &= R_1 + R_2 \parallel (R_3 + R_4) \\ &= R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3 + R_4}} \\ &= 2\ \Omega + \frac{1}{\frac{1}{20\ \Omega} + \frac{1}{15\ \Omega + 5\ \Omega}} \\ &= 12\ \Omega \\ I_{\text{total}} &= \frac{V}{R_{\text{total}}} = \frac{12\ \text{V}}{12\ \Omega} = 1\ \text{A} \end{aligned}$$

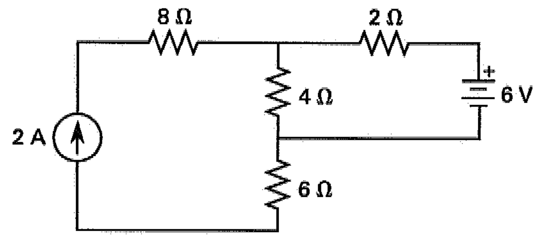
Use a current divider to find the current in section CDB.

$$\begin{aligned} I_{\text{CDB}} &= I_{\text{total}}\left(\frac{R_2}{R_2 + R_3 + R_4}\right) \\ &= (1\ \text{A})\left(\frac{20\ \Omega}{40\ \Omega}\right) \\ &= 0.5\ \text{A} \\ V_{\text{CD}} &= I_{\text{CDB}} R_3 \\ &= (0.5\ \text{A})(5\ \Omega) \\ &= 2.5\ \text{V} \end{aligned}$$

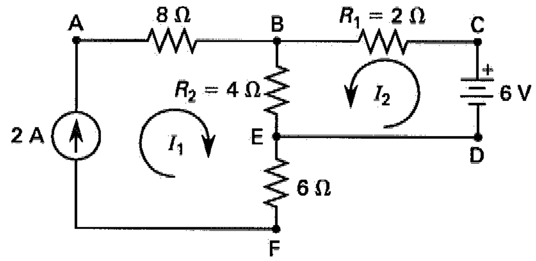
The answer is (B).

DC ELECTRICITY–33

Determine the voltage drop across the 4 Ω resistor in the network shown.



(A) 4.3 V (B) 6.7 V (C) 12 V (D) 24 V



The network is redrawn with the currents and circuit points labeled as shown. The current through BE is equal to the sum of currents from AB and CB.

$$I_{\text{BE}} = I_1 + I_2 = 2\text{ A} + I_2$$

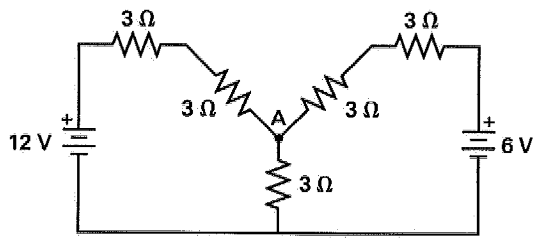
Kirchhoff's voltage law around loop DCBE gives

$$V_{\text{CD}} = R_1 I_2 + R_2 I_{\text{BC}}$$
$$6V = (2\ \Omega)I_2 + (4\ \Omega)I_{\text{BE}} = (2\ \Omega)I_2 + (4\ \Omega)(2\text{ A} + I_2)$$
$$I_2 = -0.333\text{ A} \quad \text{[opposite to the direction that it was defined]}$$
$$I_{\text{BE}} = 2\text{ A} - 0.333\text{ A} = 1.67\text{ A}$$
$$V_{\text{BE}} = (1.67\text{ A})(4\ \Omega)$$
$$= 6.68\text{ V} \quad (6.7\text{ V})$$

The answer is (B).

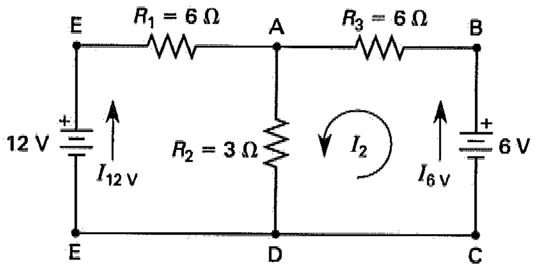
DC ELECTRICITY–34

The voltage at point A in the network shown is most nearly



(A) 1.0 V (B) 2.3 V (C) 3.0 V (D) 4.5 V

The circuit is redrawn.



Superposition is used to find I_2.

$$I_2 = I_{6\,\mathrm{V}} - I_{12\,\mathrm{V}}$$

$I_{6\,\mathrm{V}}$ is the current through BA from the 6 V source, and $I_{12\,\mathrm{V}}$ is the current through BA from the 12 V source. The equivalent resistances are calculated by short circuit for each voltage source.

$$\begin{aligned} R_{6\,\mathrm{V}} &= R_3 + R_1 \parallel R_2 \\ &= R_3 + \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \\ &= 6\ \Omega + \frac{1}{\frac{1}{6\Omega} + \frac{1}{3\Omega}} \\ &= 8\ \Omega \end{aligned}$$

$$I_{6\,\mathrm{V}} = \frac{V_{6\,\mathrm{V}}}{R_{6\,\mathrm{V}}} = \frac{6\ \mathrm{V}}{8\ \Omega} = 0.75\ \mathrm{A}$$

$$\begin{aligned} R_{12\,\mathrm{V}} &= R_1 + R_2 \parallel R_3 \\ &= R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}} \\ &= 6\ \Omega + \frac{1}{\frac{1}{6\Omega} + \frac{1}{3\Omega}} \\ &= 8\ \Omega \end{aligned}$$

$$I_{12\,\mathrm{V}} = \left(\frac{V_{12\,\mathrm{V}}}{R_{12\,\mathrm{V}}}\right)\left(\frac{R_2}{R_2 + R_3}\right) = \left(\frac{3\ \Omega}{9\ \Omega}\right)\left(\frac{12\ \mathrm{V}}{8\ \Omega}\right) = 0.5\ \mathrm{A}$$

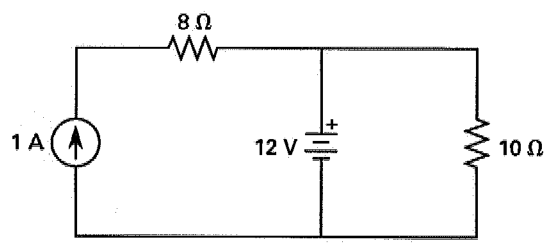
$$\begin{aligned} I_2 &= I_{6\,\mathrm{V}} - I_{12\,\mathrm{V}} \\ &= 0.75\ \mathrm{A} - 0.5\ \mathrm{A} \\ &= 0.25\ \mathrm{A} \end{aligned}$$

$$\begin{aligned} V_\mathrm{A} &= V_{6\,\mathrm{V}} - I_2 R_3 \\ &= 6\ \mathrm{V} - (0.25\ \mathrm{A})(6\ \Omega) \\ &= 4.5\ \mathrm{V} \end{aligned}$$

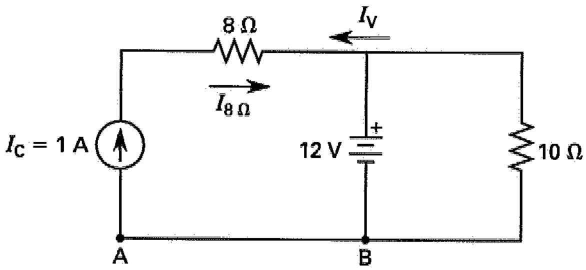
The answer is (D).

DC ELECTRICITY–35

What is the voltage drop across the 8 Ω resistor in the following circuit?



(A) 8 V (B) 12 V (C) 20 V (D) 22 V



Redrawing the circuit as shown, with I_C equal to the component of the current through the 8 Ω resistor due to the current source, and I_V equal to the component of the current through the resistor due to the voltage source,

$$I_{8\,\Omega} = I_C - I_V$$

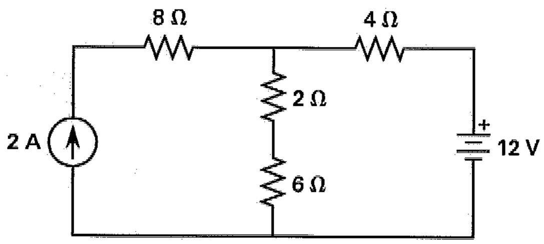
But, $I_C = 1$ A, and $I_V = 0$ A. Therefore,

$$\begin{aligned} I_{8\,\Omega} &= 1 \text{ A} \\ V_{8\,\Omega} &= IR = (1 \text{ A})(8\ \Omega) \\ &= 8 \text{ V} \end{aligned}$$

The answer is (A).

DC ELECTRICITY–36

Determine the voltage drop across the 6 Ω resistor.



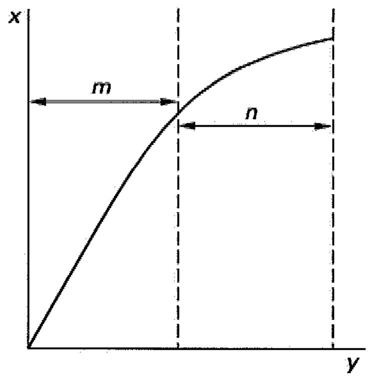
(A) 6.0 V (B) 9.0 V (C) 10 V (D) 18 V

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?

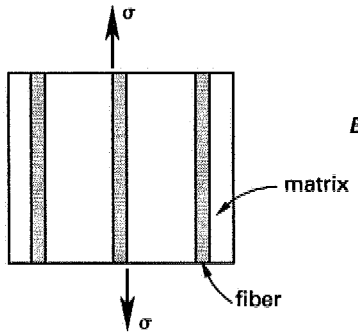
(A) It is the same as the rupture modulus.
(B) It is the slope of the stress-strain diagram in the linearly elastic region.
(C) It is the ratio of stress to volumetric strain.
(D) Its value depends only on the temperature of the material.

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?



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

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

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

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) $E = K(1 - \nu)$

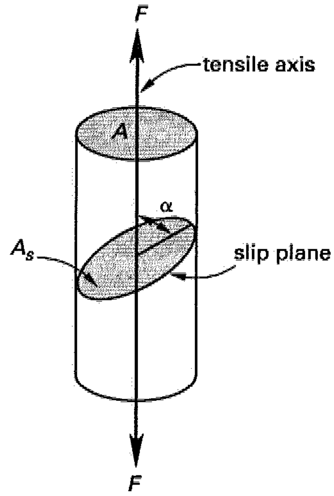
(C) $E = \dfrac{3K}{1 - 2\nu}$ (D) $E = 3K(1 - 2\nu)$

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,

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

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

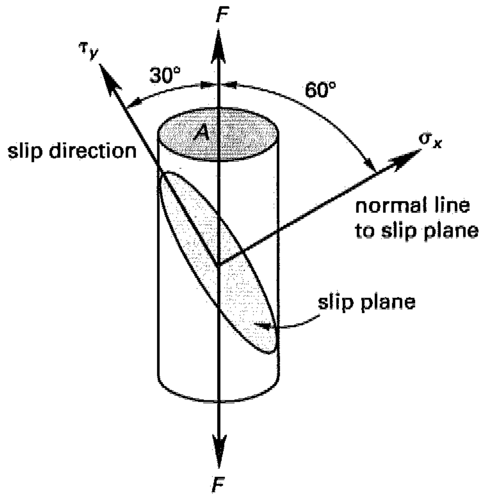
$$\cos\alpha = \sin\alpha$$

$$\alpha = 45°$$

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) $\tau_y = \frac{3}{4}\sigma_x$

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

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

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

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, $\tau = Gb/r$.

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

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.

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.

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

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.

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

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.

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

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.

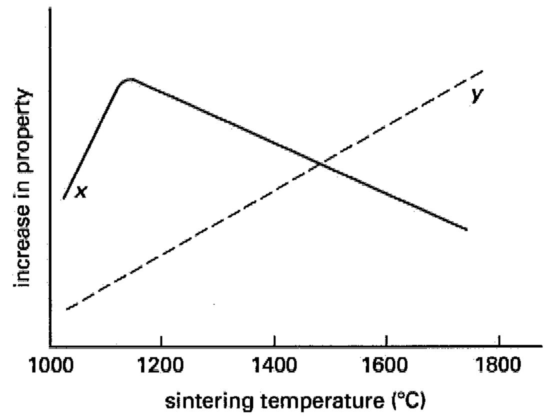
(A) I only (B) I and II (C) I and III (D) II and III

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.

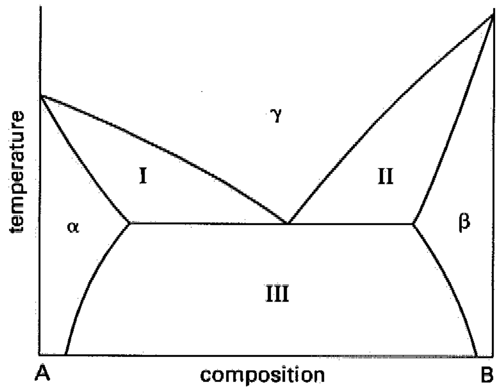
(D) The temperature at which the solid is at equilibrium.

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

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.

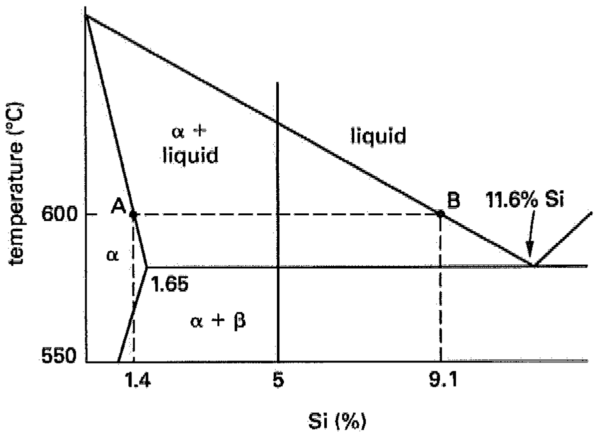
(D) α and γ are present in region III.

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

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%

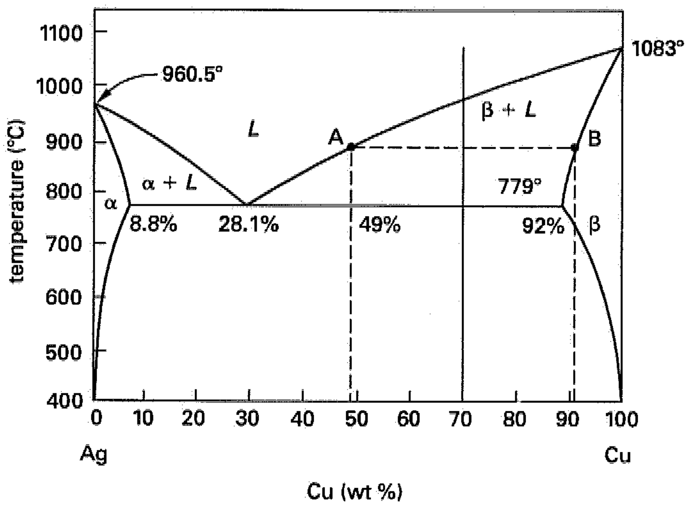
Use the lever rule. At point A there is 1.4% Si and no liquid, while at point B there is 9.1% Si and all liquid. Therefore,

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

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.

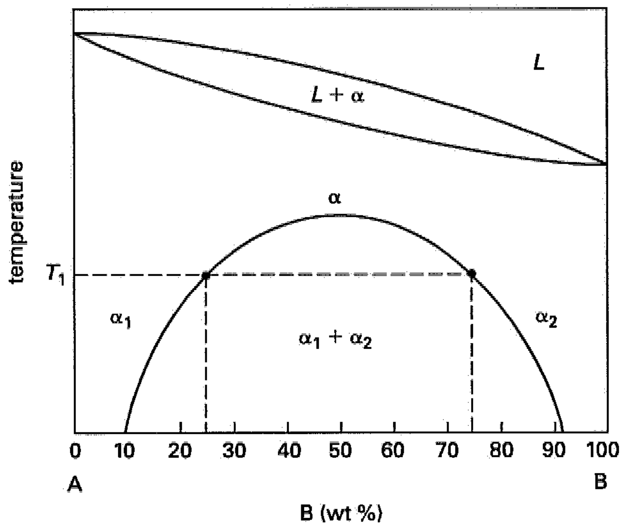
$$\text{percent } \beta = \frac{\%\ \text{Cu in alloy} - \%\ \text{Cu at point A}}{\%\ \text{Cu at point B} - \%\ \text{Cu at point A}} \times 100\%$$

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

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,

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

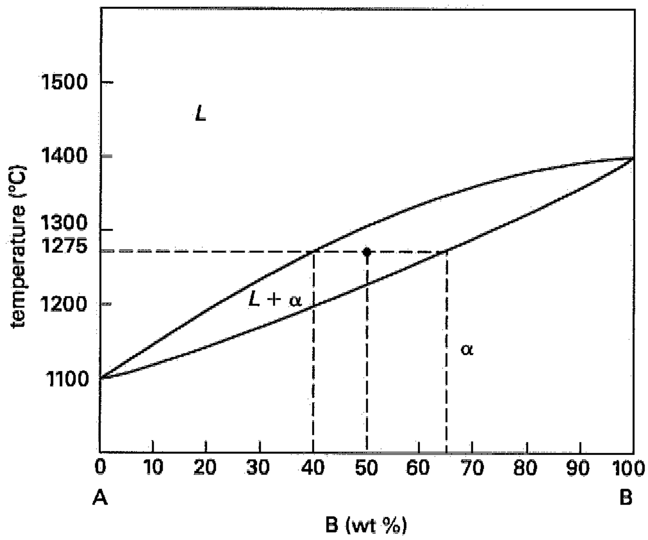
Solving the two equations using $C_0 = 70\%$,

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

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

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).