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MATERIAL SCIENCE

MECHANICAL ENGINEERING

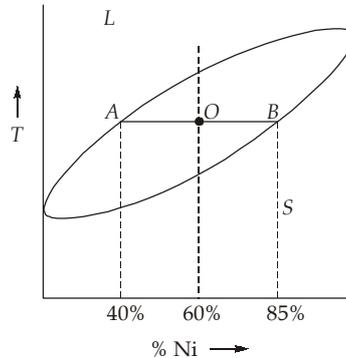
Date of Test : 25/03/2026

ANSWER KEY >

- | | | | | |
|--------|---------|---------|---------|---------|
| 1. (c) | 7. (a) | 13. (d) | 19. (b) | 25. (d) |
| 2. (b) | 8. (c) | 14. (a) | 20. (d) | 26. (c) |
| 3. (a) | 9. (c) | 15. (b) | 21. (b) | 27. (c) |
| 4. (b) | 10. (c) | 16. (d) | 22. (c) | 28. (a) |
| 5. (d) | 11. (d) | 17. (a) | 23. (b) | 29. (d) |
| 6. (c) | 12. (a) | 18. (c) | 24. (d) | 30. (c) |

DETAILED EXPLANATIONS

6. (c)



$$m_s = \frac{OA}{AB} = \frac{60 - 40}{85 - 40} = \frac{20}{45} = 0.444$$

$$m_s = 44.4\%$$

7. (a)

From Gibb's phase rule, $F + P = C + 1$

$$F + 2 = 2 + 1$$

$$F = 1$$

8. (c)

The resulting microstructure will be a mixture of cementite and austenite which is known as Ledeburite.

10. (c)

Jominy end quench test is used to determine hardenability of steel. Hardenability is the ability of a steel to partially or completely transform from austenite to some fraction of martensite at a given depth below the surface, when cooled under a given condition.

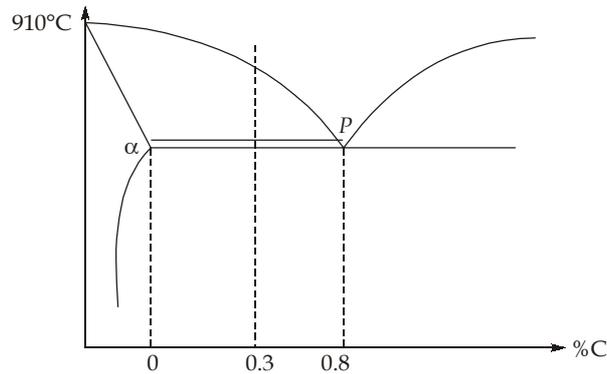
12. (a)

Given: $a = 10\text{\AA}$

$$\text{Linear density, BCC} \rightarrow [1\ 1\ 1] \text{ is } \frac{2}{a\sqrt{3}}$$

$$= \frac{2}{10\sqrt{3}} = 0.115/\text{\AA}$$

13. (d)



$$m_p = \frac{0.3 - 0.02}{0.8 - 0.02}$$

$$m_p = 0.3589 \approx 35.9\%$$

15. (b)

Toughness is given by the area under stress-strain curve,

$$\begin{aligned} \therefore \text{Modulus of toughness} &= \int_0^1 400(\epsilon + 0.2)^{0.5} d\epsilon \\ &= \left[\frac{400}{1+0.5} (\epsilon + 0.2)^{1+0.5} \right]_0^1 \\ &= \frac{400}{1.5} (1.2)^{1.5} - (0.2)^{1.5} = 326.70 \text{ N/mm}^2 \end{aligned}$$

16. (d)

Invariant reactions found in iron-carbon system are:

- Eutectic : $L \xrightleftharpoons[4.3\%C]{1150^\circ C} \gamma + \text{Fe}_3\text{C}$
- Eutectoid : $\gamma \xrightleftharpoons[0.8\%C]{725^\circ C} \alpha + \text{Fe}_3\text{C}$
- Peritectic : $L + \delta \xrightleftharpoons[0.18\%C]{1493^\circ C} \gamma$
- Monotectic : $L \xrightleftharpoons[0.51\%C]{1493^\circ C} L + \gamma$

17. (a)

Two planes $(h_1 \ k_1 \ l_1)$ & $(h_2 \ k_2 \ l_2)$ are said to be perpendicular if

$$h_1 h_2 + k_1 k_2 + l_1 l_2 = 0$$

Here, $h_1 = -2; k_1 = 5, l_1 = -1$

and, $h_2 = 2; k_2 = x, l_2 = 1$

$$\therefore h_1 h_2 + k_1 k_2 + l_1 l_2 = 0$$

$$(-2)(2) + 5x + (-1)(1) = 0$$

$$-4 + 5x - 1 = 0$$

$$5x = 5$$

$$x = 1$$

18. (c)

The number of nearest neighbour lattice points in HCP crystal structure is given by its co-ordination number which is 12.

19. (b)

Since, Atomic packing factor = $\frac{\text{Volume occupied by atoms}}{\text{Volume of unit cell}}$

Thus, volume occupied by atoms is 0.82 times the volume of unit cell or 82% of unit cell. The remaining volume will be void and hence 18% volume is void.

20. (d)

Some important microstructures with their crystal structure are listed below:

1. α - Fe : BCC
2. γ - Fe : FCC
3. δ - Fe : BCC
4. Cementite : Orthorhombic
5. Martensite : Body centred tetragonal

21. (b)

Ausforming may be defined as deforming metastable steel while in austenite phase. Since presence of alloying elements delay the beginning of phase transformation, it is possible to combine heat treating and strain hardening advantageously.

This principle is utilized in ausforming. An alloy steel containing about 0.45% carbon is heated to form austenite and is then quenched to the bay between the pearlite and bainite noses of the transformation curve (i.e. to about 500°C).

At this stage, the component is worked by rolling or forging to produce large deformations of the order of 80-90% reduction of area.

Then the steel is quenched to form martensite. The resulting micro-structure consists of fine martensitic plates, the size and dispersion of which is governed by prior austenite grain size and the magnitude of plastic deformation.

22. (c)

There are several features of the solute and solvent atoms that determine the degree to which the former dissolves in the latter, as follows:

1. **Atomic size factor**, appreciable quantities of a solute may be accommodated in this type of solid solution only when the difference in atomic radii between the two atom types is less than about $\pm 15\%$. Otherwise, the solute atoms will create substantial lattice distortions and a new phase will form.
2. **Crystal structure**, for appreciable solid solubility the crystal structures for metals of both atom types must be the same.
3. **Electronegativity**, the more electropositive one element and the more electronegative the other, the greater is the likelihood that they will form an intermetallic compound instead of a substitutional solid solution.
4. **Valences**, other factors being equal, a metal will have more of a tendency to dissolve another metal of higher valency than one of a lower valency:

Hence, option (c) is incorrect as Cu and Ni have similar electronegativities (1.9 and 1.8 respectively)

23. (b) Rockwell has cone shaped pyramid while vicker has squared shape pyramid.

24. (d) It is known that copper has FCC structure.

∴ Volume of a unit cell of copper is

$$V_C = 16\sqrt{2}r^3$$

where, r is atomic radius of copper

$$\therefore V_C = 16\sqrt{2} \times (1.28 \times 10^{-8})^3 = 4.7 \times 10^{-23} \text{ cm}^3$$

$$\therefore \alpha = 4.7$$

25. (d) Using lever rule, fraction of α phase in an alloy is given by

$$f_\alpha = \frac{C_o - C_L}{C_\alpha - C_L}$$

Where,

C_o : Composition of the alloy

C_α = Composition of α phase

C_L = Composition of liquid phase

Here,

$$C_o = 23.7\% \text{ B}$$

$$C_\alpha = 5.2\% \text{ B}$$

$$C_L = 34.5\%$$

$$\therefore f_\alpha = \frac{34.5 - 23.7}{34.5 - 5.2} = 0.3686$$

Thus, Percentage of alpha = $0.3686 \times 100 = 36.86\%$

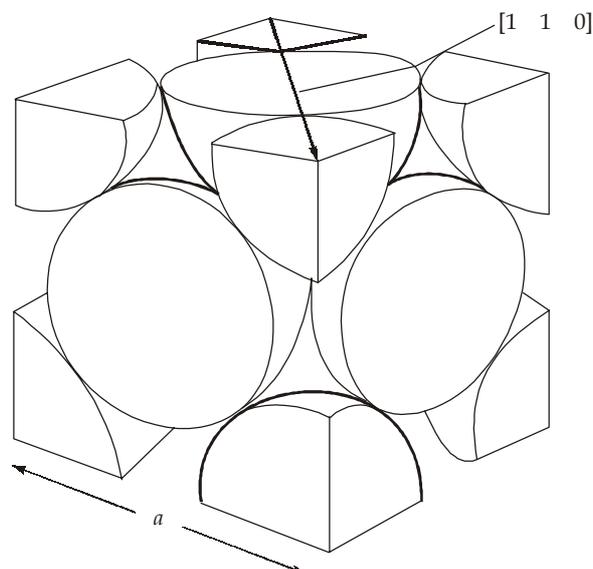
Since alpha phase and liquid make up 100% of the composition of the alloy,

$$\therefore \text{Percentage of liquid} = 100 - 36.86 = 63.14\% \simeq 63.1\%$$

26. (c)

$$\text{Linear density} = \frac{\text{No. of atoms along } [1 \ 1 \ 0]}{\text{Length of the direction}}$$

From the figure given below,



$$\text{Number of atoms along } [1 \ 1 \ 0] = \frac{1}{2} + 1 + \frac{1}{2} = 2$$

$$\text{Length of the direction} = \sqrt{2}a$$

where, a : Lattice parameter = 0.405 nm

$$\therefore \text{Linear density} = \frac{2}{\sqrt{2}a} = \frac{\sqrt{2}}{a} = \frac{\sqrt{2}}{0.405} \approx 3.5 \text{ nm}^{-1}$$

27. (c)

A piece of steel when kept at just above lower critical temperature will have ferrite and austenite. Assuming 0.8% carbon in austenite and negligible in ferrite,

$$\% \text{ Ferrite} = \frac{(0.8 - 0.2) \times 100}{0.8} = 75\%$$

And % Austenite = 25%

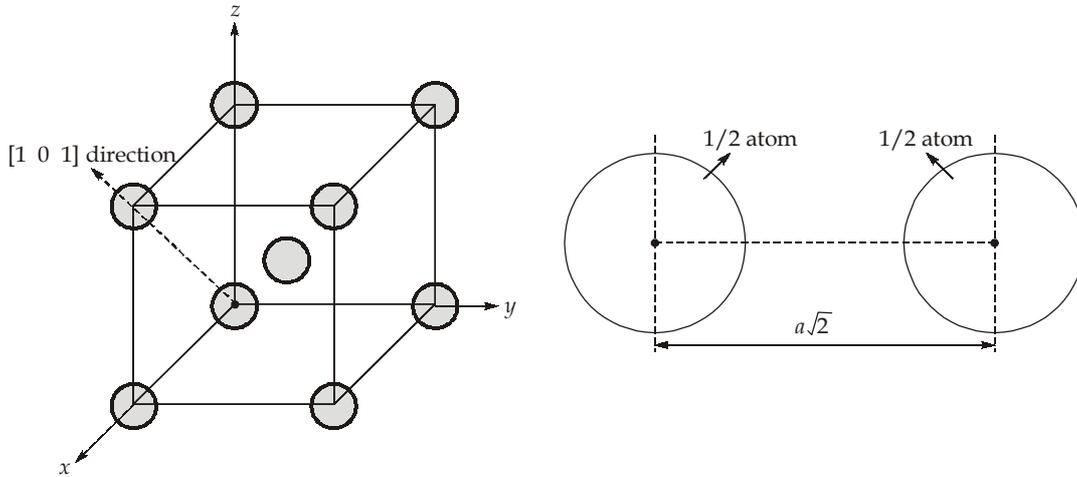
If quenched 25% austenite present at soaking temperature will convert to martensite. The structure at room temperature will consist of 75% ferrite and 25% martensite.

28. (a)

The properties and behaviour of dislocations are characterized by certain geometries which are as follows:

1. A crystal normally consists of a large number of dislocations. Hence, there exist numerous Burger's vectors. The sum of these vectors meeting at a point called nodal inside the crystal remains zero.
2. A dislocation does not abruptly end within the crystal. It vanishes either at the nodal point or on the surface of the crystal.
3. A dislocation under the influence field may close on as a loop. The profile of the loop may be circle or edge.
4. The distortional energy associated with dislocations may be the source of crystal's instability. The distortional energy is produced due to tensile and compressive stresses/strains field around the edge dislocation and due to shear stress-shear strain field in the case of screw dislocations.
5. The dislocations have inherent tendency to keep smallest possible Burger's vector, which enhances the stability of the crystal.
6. The edge dislocations travels much faster (about 50 times) than the screw dislocations.
7. Due to plastic deformation of the crystal, the dislocations get multiplied.
8. The edge dislocations in a crystal are much more in number than the screw dislocations in any crystalline material.

29. (d)
[1 0 1] direction for BCC crystal structure.



For BCC crystal, $4R = a\sqrt{3}$

$$\begin{aligned} \text{Linear density} &= \frac{\text{No. of atoms on the line}}{\text{Length of the line}} = \frac{\left(\frac{1}{2} + \frac{1}{2}\right)}{a\sqrt{2}} \\ &= \frac{1}{\left(\frac{4R}{\sqrt{3}}\right)\sqrt{2}} = \left(\frac{\sqrt{3}}{2\sqrt{2}}\right)\left(\frac{1}{2R}\right) \end{aligned} \quad \dots (i)$$

Comparing (i) with $\frac{x}{2R}$, $x = \frac{\sqrt{3}}{2\sqrt{2}} = 0.61237 \simeq 0.6124$

30. (c)
Two main features must be displayed by the phase diagrams of alloy systems for precipitation hardening.
1. An appreciable maximum solubility of one component in the other, on the order of several percent.
 2. A solubility limit that decreases rapidly in concentration of the major component with temperature reduction.

