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MATERIAL SCIENCE

MECHANICAL ENGINEERING

Date of Test : 24/05/2023

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (a)

Tempering is the process of annealing martensite at low temperatures. Although martensite is strong and wear resistant, it is brittle. Its toughness is low, primarily because of residual stresses introduced by the transformation. When tempering is carried out at a temperature below 200°C, stress relief occurs. The martensite grains retain their strength, but improve their toughness and do not change shape on storage.

2. (b)

TiC and TiN are the coating materials for coated carbide tools and chemical vapor deposition is the technique used for coating.

4. (c)

Vulcanization of rubber is done to improve its strength and elasticity by heating it in presence of sulphur, which results in three dimensional cross-linking of the chain of rubber molecules bonded to each other by sulphur atoms.

5. (d)

Nickel, Cobalt, Copper and maganese are austenitic stabilizers.

6. (c)

In martemperting, steel is heated below the lower critical temperature at about 600°C.

7. (c)

The ability of a material to plastically deform depends on the ability of dislocations to move. Since hardness and strength are related to the ease with which plastic deformation can be made to occur, by reducing the mobility of dislocations, the mechanical strength may be enhanced. Because of this greater mechanical forces will be required to initiate plastic deformation. In contrast, more the unconstrained dislocation motion, the greater is the facility with which a metal may deform, and softer and weaker it becomes. Virtually all strengthening techniques rely on this simple principle: "restricting or hindering dislocation motion renders a material harder and stronger".

9. (b)

Following three invariant reactions take place on Fe - Fe_3C diagram.

1. Eutectic reaction:
$$\text{Liquid} \underset{4.3\%C}{\overset{1150^\circ C,\ \text{on cooling}}{\rightleftharpoons}} \underbrace{\gamma - \text{Iron} + Fe_3C}_{\text{Ledeburite}}$$

2. Eutectoid reaction:
$$\gamma - \text{Iron} \underset{0.8\%C}{\overset{725^\circ C,\ \text{on cooling}}{\rightleftharpoons}} \underbrace{\alpha - \text{Iron} + Fe_3C}_{\text{Pearlite}}$$

3. Peritectic reaction:
$$\delta - \text{Iron} + \text{Liquid} \underset{0.18\%C}{\overset{1493^\circ C,\ \text{on cooling}}{\rightleftharpoons}} \gamma - \text{Iron}$$

10. (b)

Rhombohedral crystal structure is also known as trigonal crystal structure.
For rhombohedral crystal structure, $a = b = c$, $\alpha = \beta = \gamma \neq 90^\circ$

11. (d)

- Pure iron has less than 0.008 wt% C in α-ferrite at room temperature.
- α-ferrite is stable form of iron at room temperature. The maximum solubility of carbon in α-ferrite is 0.022 wt% C.

12. (d)

For a ternary system, at constant pressure i.e. N= 1

Gibbs phase rule gives

$$P + F = C + N$$

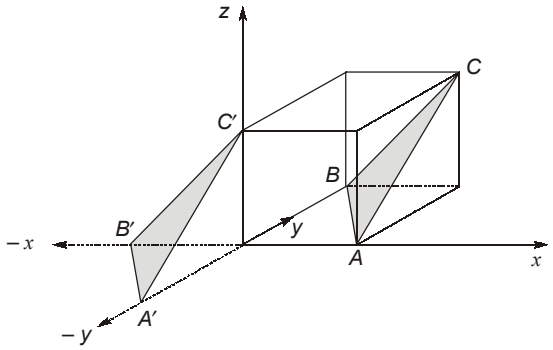
$$P + F = 3 + 1 \qquad \text{(As ternary system, } C = 3\text{)}$$

$$\Rightarrow \quad P = 4 - F$$

If $F = 0$ then number of phases will be maximum.

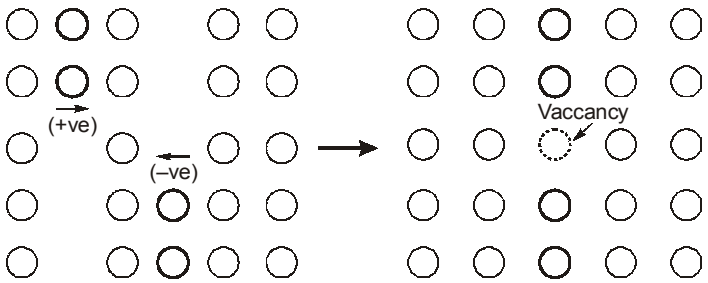
Maximum no. of phases, $P = 4$

13. (d)



Planes *ABC* and *A′ B′ C′* are same and plane *A′ B′ C′* is obtained by shifting *ABC* plane to (–1, – 1,1) co-ordinate which gives miller indices $(\bar{1}\,\bar{1}\,1)$.

15. (d)



16. (a)

At high temperatures, grains are stronger than grain boundaries that's why creep fracture is an intergranular fracture.

18. (b)

- In Izod impact test, hammer strikes on the face having notch.
- In Charpy impact test, hammer strikes on the opposite face of the notch.

20. (b)

$$\sigma_T = \sigma_0(1 + e)$$

$$= 300(1.35) = 405 \text{ MPa}$$

21. (a)

With increase in planar density satisfied atomic bonds increases which increases the stability of crystal structure and decreases the surface energy.

22. (d)

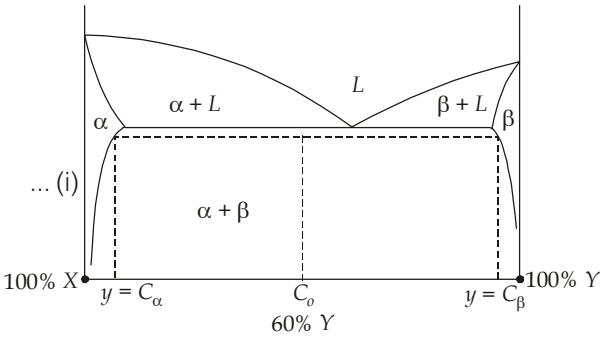
By Lever rule,

$$W_\alpha = \frac{C_\beta - C_o}{C_\beta - C_\alpha}$$

$$0.5 = \frac{C_\beta - 60}{C_\beta - C_\alpha}$$

$$C_\beta - C_\alpha = 2C_\beta - 120$$

$$C_\beta + C_\alpha = 120 \quad \text{... (i)}$$



$$W_\beta = \frac{C_o - C_\alpha}{C_\beta - C_\alpha}$$

$$0.5 = \frac{60 - C_\alpha}{C_\beta - C_\alpha}$$

$$C_\beta - C_\alpha = 120 - 2C_\alpha$$

$$C_\beta + C_\alpha = 120 \quad \text{... (ii)}$$

Both equation (i) and (ii) are same. So there are infinite possible solutions, choosing the option which satisfy the above condition is option (d).

23. (b)

Given: A = 188 g/mol, APF = 0.70, r = 0.136 nm = 0.136 × 10^{-7} cm, N_A = 6.023 × 10^{23} atoms/mol

We know that,

$$\text{APF} = \frac{n \times \frac{4}{3}\pi r^3}{a^3}$$

$$\frac{APF}{\frac{4}{3}\pi r^3} = \frac{n}{a^3} \quad \text{... (i)}$$

$$\text{Density, } \rho = \frac{n \times A}{a^3 \times N_A}$$

From equation (i),

$$\rho = \left(\frac{APF}{\frac{4}{3}\pi r^3}\right) \times \left(\frac{A}{N_A}\right) = \frac{0.7 \times 188}{\frac{4}{3}\pi \times \left(0.136 \times 10^{-7}\right)^3 \times 6.023 \times 10^{23}}$$

$$= 20.7366 \text{ g/cm}^3$$

24. (c)

At point P there will be 100% fine pearlite and at point Q there will be 100% martensite. As we move from point A to B, percentage of pearlite decreases and percentage of martensite increases.

25. (c)

Two main features must be displayed by the phase diagrams of alloy systems for precipitation hardening.

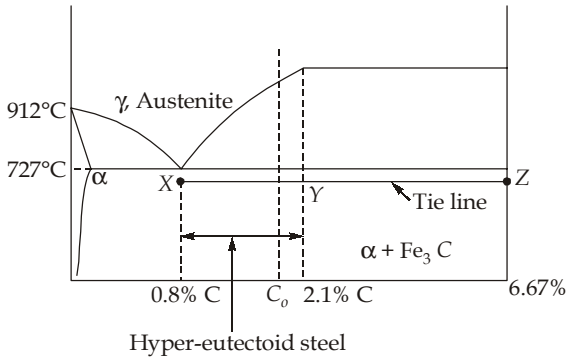
1. An appreciable maximum solubility of one component in the other, on the order of several percent.
2. A solubility limit that decreases rapidly in concentration of the major component with temperature reduction.

26. (d)

1. Boron can significantly increase the hardenability of steel without loss of ductility. Its effectiveness is most noticeable at lower carbon levels. The addition of boron is usually in very small amount ranging from 0.0005 to 0.003 percent.
2. Silicon is used as a deoxidizer in the manufacturing of steel. It slightly increases the strength of ferrite, and when used in conjunction with other alloys, it can help in increasing the toughness and hardness of steel.
3. Tungsten when used in small amounts combines with the free carbides in steel during heat treatment, to produce high wear resistance with little or no loss of toughness. High amounts combined with chromium gives steel a property known as red hardness. This means that the steel will not lose its working hardness at high temperature.

27. (c)

For hyper eutectoid alloy, $0.8 \le \text{wt\% } C \le 2.1$



The mass fraction of pro-eutectoid cementite,

$$W_C = \left(\frac{XY}{XZ}\right) = \frac{C_o - 0.8}{6.67 - 0.8}$$

where value of C_o varies from, $0.8 \le C_0 \le 2.1$.

For maximum value of W_C, C_o must be maximum.

Maximum value of pro-eutectoid cementite, $W_C = \dfrac{2.1 - 0.8}{6.67 - 0.8} = 0.22146$ or 22.1%

28. (d)

Angle between two intersecting directions $(h_1\ k_1\ l_1)$ and $(h_2\ k_2\ l_2)$ is given by,

$$\cos\theta = \frac{h_1h_2 + k_1k_2 + l_1l_2}{\sqrt{h_1^2 + k_1^2 + l_1^2} \times \sqrt{h_2^2 + k_2^2 + l_2^2}}$$

So for directions [1 1 1] and [1 $\bar{2}$ 1]

$$\cos\theta = \frac{1\times1 + 1\times(-2) + 1\times1}{\left(\sqrt{1^2 + 1^2 + 1^2}\right)\left(\sqrt{1^2 + (-2)^2 + 1^2}\right)}$$

$$\cos\theta = 0$$

$$\theta = 90°$$

30. (a)

For a direction indices [$u\ v\ w$] and a plane indices (h k l)

If $uh + vk + wl = 0$

Then both direction and plane are parallel to each other or direction lies in the given plane.

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