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Web: www.madeeasy.in | E-mail: info@madeeasy.in | Ph: 011-45124612

MATERIAL SCIENCE

MECHANICAL ENGINEERING

Date of Test : 23/06/2026

ANSWER KEY >

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

DETAILED EXPLANATIONS

1. (c)

If 'a' is the lattice parameter then

$$\text{Atomic radius of BCC crystal, 'r'} = \frac{a\sqrt{3}}{4}$$

$$\text{atomic diameter} = 2r = \frac{a\sqrt{3}}{2} \text{ or } \frac{a}{2/\sqrt{3}}$$

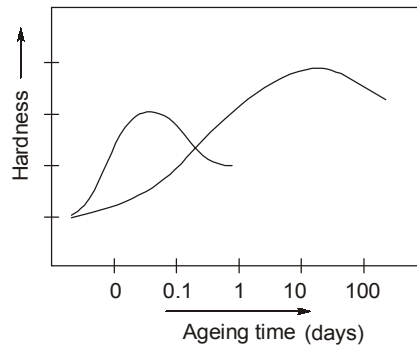
2. (c)

Grain boundaries restricts the motion of dislocation. It makes the material stronger.

3. (b)

Cooling curve of a binary alloy may look exactly similar to that of a pure metal if it is an eutectic alloy.

4. (d)

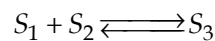


The increase in hardness in the initial stages of the ageing curves can be attributed to the precipitation process taking place progressively. After reaching the peak value, the hardness starts to decrease. This phenomena is called overageing.

5. (b)

6. (c)

When two solid phases combine together produces third solid phase upon cooling, the reaction is peritectoid.



7. (c)

Martensite is the hardest phase of iron which can be obtained after quenching of Austenitic Iron.

8. (d)

The dislocations have inherent tendency to keep smallest possible Burger's vector, which enhances the stability of crystal.

9. (d)

10. (a)

For a direction indices $[uvw]$ and a plane indices (hkl)

If $uh + vk + wl = 0$

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

11. (b)

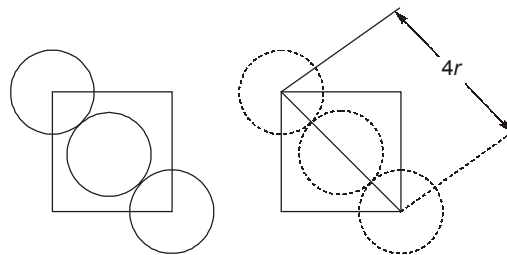
Pitting corrosion is a localized phenomenon confined to smaller areas. Formation of micropits can be very damaging. Pitting factor (ratio of deepest pit to average penetration) can be used to evaluate severity of pitting corrosion which usually occurs in passive metals and alloys.

12. (d)

In fiber reinforced composites last constituent to fail is matrix and first one is fiber.

13. (b)

14. (b)



$$4r = \sqrt{2}a$$

$$\text{Packing factor} = \frac{4 \times \frac{4}{3}\pi r^3}{a^3}$$

$$\text{P.F.} = \frac{16\pi}{3} \frac{r^3}{(2\sqrt{2}r)^3} = \frac{16\pi}{3 \times 16\sqrt{2}} = \frac{\pi}{3\sqrt{2}} = 0.74$$

15. (d)

According to lever rule, the fraction of solid phase is

$$x_s = \frac{C_L - C_0}{C_L - C_S} = \frac{72 - 48}{72 - 26} = 52\%$$

16. (a)

Lattice parameter of FCC structure be a

$$\text{Radius of an atom, } r = \frac{\sqrt{2}a}{4}$$

$$\text{Area of face} = a^2$$

$$\text{Area of 2 atoms} = 2\pi r^2$$

$$= 2\pi \times \left(\frac{\sqrt{2}a}{4}\right)^2$$

$$= 0.785 a^2$$

$$\text{Planar density} = \frac{0.785 a^2}{a^2}$$

$$= 78.5\%$$

17. (c)

$$m_{\alpha} = \frac{(98 - 30)}{(98 - 10)} = \frac{68}{88}$$

$$m_{\beta} = 1 - \frac{68}{88} = \frac{20}{88}$$

Now, density of α and β ,

$$\frac{100}{\rho_{\alpha}} = \frac{10}{\rho_{Sn}} + \frac{90}{\rho_{Pb}} = \frac{10}{10} + \frac{90}{17} = \frac{107}{17}$$

$$\rho_{\alpha} = \frac{17 \times 100}{107} \text{ g/cc}$$

Now, for ρ_{β} ,

$$\frac{100}{\rho_{\beta}} = \frac{98}{\rho_{Sn}} + \frac{2}{\rho_{Pb}} = \frac{98}{10} + \frac{2}{17} = \frac{1686}{170}$$

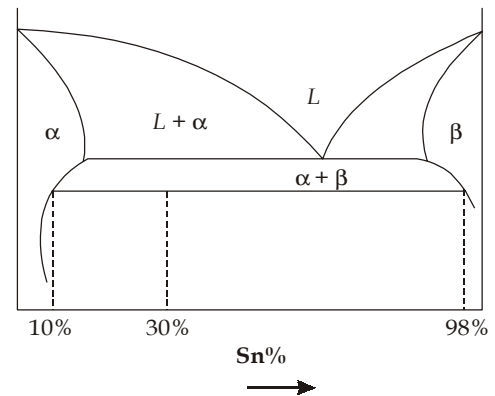
$$\rho_{\beta} = \frac{17000}{1686} \text{ g/cc}$$

$$V_{\alpha} = \frac{\frac{m_{\alpha}}{\rho_{\alpha}}}{\frac{m_{\alpha}}{\rho_{\alpha}} + \frac{m_{\beta}}{\rho_{\beta}}} = \frac{\frac{68}{88} \times \frac{107}{17 \times 100}}{\frac{68 \times 107}{88 \times 17 \times 100} + \frac{20 \times 1686}{88 \times 17000}} = \frac{1}{1 + \frac{20 \times 1686}{68 \times 1070}}$$

$$= 0.6833 = 68.33\%$$

And,

$$V_{\beta} = 1 - 0.6833 = 0.3167 = 31.67\%$$



18. (c)

Annealing is the heating of steel to austenite temperature and then cooling slowly in the furnace.

1. To reduce hardness
2. To improve machinability
3. To increase ductility
4. To relieve internal stresses
5. To reduce or eliminate structural inhomogeneity
6. To prepare steel for subsequent heat treatment

19. (b)

Crystal system	Axial relationship	Interaxial angles
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ, \gamma = 120^\circ$
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ \neq \beta$
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$

20. (c)

$$\text{Effective number of atoms in a diamond cubic unit cell} = \frac{1}{8} \times 8 + \frac{1}{2} \times 6 + 4 = 8$$

$$\text{Volume of each spherical atom} = \frac{4}{3} \pi r^3$$

Where r is the atomic radius of carbon atom.

$$\text{Radius of atom, } r = \frac{a\sqrt{3}}{8}, \text{ where } a \text{ is the lattice parameter.}$$

$$\begin{aligned} \text{Volume of atoms in unit cell} &= 8 \times \frac{4}{3} \pi r^3 = \frac{32}{3} \pi r^3 = \frac{32}{3} \times \pi \left(\frac{a\sqrt{3}}{8} \right)^3 \\ &= \frac{32}{3} \times \frac{\pi 3\sqrt{3}}{512} \times a^3 = \frac{\pi\sqrt{3}}{16} a^3 = 0.34a^3 \end{aligned}$$

$$\text{Now, Atomic packing factor} = \frac{\text{Volume of atoms in unit cell}}{\text{Volume of cubic in unit cell}} = \frac{0.34a^3}{a^3}$$

$$\text{APF} = 0.34$$

21. (a)

$$\lambda = 0.58 \text{ \AA}$$

$$\theta = 9.5^\circ \text{ for } n = 1, \text{ first order}$$

$$a = \text{Lattice parameter of unit cell}$$

$$\text{Inter planer distance, } d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$d_{200} = \text{Mean distance for } (2 \ 0 \ 0) \text{ planes}$$

where, $h = 2, k = 0, l = 0,$

$$d_{200} = \frac{a}{\sqrt{2^2 + 0^2 + 0^2}} = \frac{a}{2} = 0.5a$$

As per Bragg's law, $2d \sin \theta = n\lambda$

$$2 \times d \times \sin 9.5 = 1 \times \lambda$$

$$2 \times \frac{a}{2} \times 0.165 = 0.58$$

$$a = 3.515 \text{ \AA}$$

22. (a)

$$\text{Yield strength} = \frac{(P)_{YP}}{A} = \frac{(P)_{YP}}{\frac{\pi}{4} d^2}$$

$$210 = \frac{4 \times (P)_{YP}}{\pi \times 10^2}$$

$$(P)_{YP} = 210 \times \frac{22}{7} \times \frac{10^2}{4} = 16500 \text{ N}$$

$$(P)_{YP} = 16.5 \text{ kN}$$

$$\text{Now, Actual breaking stress, } \sigma_f = \frac{(P)_{\text{Fracture}}}{(A)_{\text{neck}}} = \frac{(P)_{\text{Fracture}}}{\frac{\pi}{4} \times d_{\text{neck}}^2}$$

$$\sigma_f = \frac{4 \times 1.1 \times 16.5 \times 10^3}{\frac{22}{7} \times 7^2} = 471.43 \text{ MPa}$$

23. (d)

$$\begin{aligned} \text{BHN} &= \frac{P \text{ (in kg)}}{\frac{\pi D}{2} [D - \sqrt{D^2 - d^2}]} = \frac{\left(\frac{4900}{9.8}\right)}{\frac{\pi \times 10}{2} [10 - \sqrt{10^2 - (\sqrt{1.99})^2}]} \\ &= \frac{7 \times 50 \times 2}{22 \times 10 [10 - \sqrt{100 - 1.99}]} = \frac{700}{22 [10 - \sqrt{98.01}]} \\ &= \frac{700}{22 [10 - 9.9]} = \frac{700}{22 \times 0.1} = 318.182 \end{aligned}$$

24. (c)

$$\begin{aligned} (m)_{\text{polymer sample}} &= m_a + m_c \\ \rho V &= \rho_a V_a + \rho_c V_c \end{aligned}$$

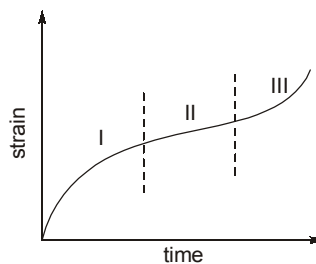
$$\rho \left(\frac{V_c}{V_a} + 1 \right) = \rho_a + \rho_c \frac{V_c}{V_a}$$

$$\rho = \frac{\rho_a + \rho_c f_c}{1 + f_c}$$

25. (b)

26. (d)

Creep curve shows the increase in plastic strain as a function of time.

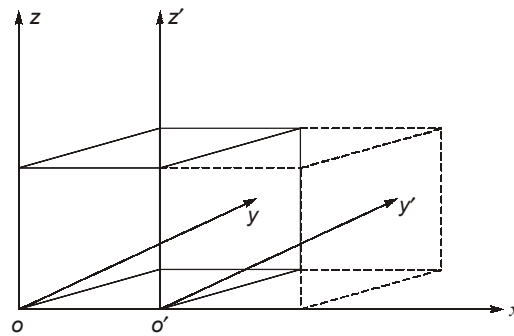


It consists of 3 stages:

- In stage I, creep rate decreases with time.
- In stage II, creep rate is minimum and constant with time.
- In stage III, creep rate increases with time until fracture occurs.

27. (d)

Since the plane passes through origin O , a new origin must be chosen at the corner of an adjacent unit cell, taken as o' and shown in diagram.



This plane is parallel to the z axis, and the intercept may be taken as ∞ . The x and y axes intersections, referenced to the new origin o' , are -1 and 1 respectively. The reciprocals of these numbers are -1 , 1 and 0 . So, miller indices of shown plane is $(\bar{1} 1 0)$.

28. (c)

According to Hume-Rothery rules, it is not necessary condition that elements of the system should form compounds with each other.

29. (b)

30. (a)

