CLASS TEST

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MATERIAL SCIENCE

MECHANICAL ENGINEERING

Date of Test : 10/10/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

Phases present at point 1 : $\alpha + L$

Phases present at point 2 : β

$$\alpha + L \rightleftharpoons \beta$$

$$S_1 + L \rightleftharpoons S_2 \qquad \text{(Peritectic reaction)}$$

2. (b)

Crystal System	Axial Ratio	Axial Angles
Cubic	a = b = c	$\alpha = \beta = \gamma = 90°$
Rhombohedral	a = b = c	$\alpha = \beta = \gamma \neq 90°$
Tetragonal	a = b ≠ c	$\alpha = \beta = \gamma = 90°$
Hexagonal	a = b ≠ c	$\alpha = \beta = 90°,\ \gamma = 120°$
Orthorhombic	a ≠ b ≠ c	$\alpha = \beta = \gamma = 90°$
Monoclinic	a ≠ b ≠ c	$\alpha = \gamma = 90° \neq \beta$
Triclinic	a ≠ b ≠ c	$\alpha \neq \beta \neq \gamma \neq 90°$

3. (c)

There is no mushy zone for the composition C3 so have the highest fluidity.

4. (d)

Elastic modulus of a material is the property of material and it does not changes with heat treatment. Heat treatment involves changes in the micro-structure and hence all the internal properties are effected i.e. strength, hardness, toughness, ductility, creep resistance and corrosion resistance.

5. (a)

$$\rho = \frac{N \times (\text{Atomic Weight})}{\text{Volume of unit cell} \times \text{Avagadro no.}}$$

$$19000 = \frac{N \times 0.183}{(0.4 \times 10^{-9})^3 \times 6.022 \times 10^{23}}$$

$$N = 4$$

6. (c)

Twin boundaries is a special type of grain boundary across which there is specific mirror lattice symmetry. Twin boundaries occurs in pairs such that the orientation change introduced by one boundary is restored by the other. The region between the pair of boundaries is called twinned region. Twinning occurs on a definite crystallographic plane and in a specific direction both of which depends on crystal structure.

7. (d)

- Ledeburite is formed at a temperature of 1150°C with carbon percentage of 4.3%.
- It has a plate like structure of austenite and Fe_3C.

$$\text{Liquid Iron} \xrightarrow[\text{On cooling}]{1150°\text{C},\ 4.3\%\text{C}} \gamma + Fe_3C$$

8. **(b)**

9. **(b)**

Annealing refers to a wide group of heat treatment process and is performed primarily for homogenisation, recrystallisation, or relief of residual stress in typical cold worked or welded components. During stress relief annealing process, workpiece is heated below its recrystallisation temperature, held for sometime and then cooled in air.

10. **(a)**

1. Eutectic reaction:

$$L \xrightleftharpoons[4.3\%\ C]{1150°C} \underbrace{\gamma - \text{iron} + Fe_3C}_{\text{Ledeburite}}$$

2. Eutectoid reaction:

$$\gamma - \text{iron} \xrightleftharpoons[0.8\%\ C]{725°C} \underbrace{\alpha - \text{iron} + Fe_3C}_{\text{Pearlite}}$$

Pealite is having plate like structure of α-iron and Fe_3C. It is phase mixture of α-iron and Fe_3C. It is mainly produced by diffusion.

3. Peritectic reaction:

$$\underbrace{\delta - \text{iron}}_{\substack{\downarrow \\ \text{Solid}}} + \underbrace{L}_{\substack{\downarrow \\ \text{Liquid}}} \xrightleftharpoons[0.18\%\ C]{1493°C} \underbrace{\gamma - \text{iron}}_{\text{solid}}$$

11. **(a)**

Crystal structure	Coordination Number	Packing factor
1. Diamond cubic	4	0.34
2. BCC	8	0.68
3. FCC	12	0.74

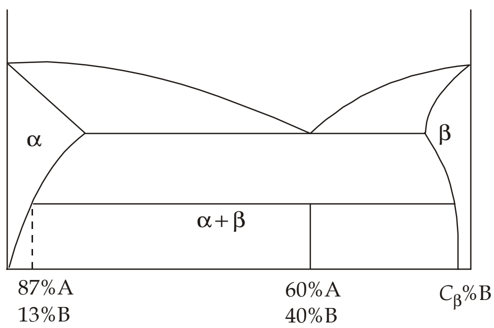
12. **(a)**

In some rare systems like Na-Zn, syntectic reaction occurs at constant temperature.

$$L_1 + L_2 \xrightarrow[\text{Syntectic temperature}]{\text{Cooling}} \alpha$$

13. **(c)**

14. **(c)**



Given: C_o = 66% α-phase + 34% β-phase

We know that,

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

$$0.66 = \frac{C_\beta - 0.40}{C_\beta - C_\alpha} \quad ...(i)$$

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

$$0.34 = \frac{0.40 - 0.13}{C_\beta - C_\alpha} \quad ...(ii)$$

Now eq. (i) ÷ (ii):

$$\frac{0.66}{0.34} = \frac{C_\beta - 0.40}{0.27}$$

Composition of B is, C_β = (0.92411) = 92.411 wt%B

Composition of A in β-phase = 100 – 92.411

Composition of β-phase = 7.589 ≃ 7.59 wt% A

15. (d)

In 100 atoms of Cu-Ni alloy, there are 64 atoms of Cu and 36 atoms of Ni.

$$\text{Weight of 64 copper atoms} = \frac{64 \times 63.55}{6.023 \times 10^{23}}\text{gram} = 6.75278 \times 10^{-21} \text{ gram}$$

$$\text{Weight of 36 nickel atoms} = \frac{36 \times 58.69}{6.023 \times 10^{23}}\text{gram} = 3.507953 \times 10^{-21} \text{ gram}$$

$$\text{Weight fraction of copper} = \frac{W_{Cu}}{W_{Cu} + W_{Ni}} = \frac{6.75278 \times 10^{-21}}{6.75278 \times 10^{-21} + 3.507953 \times 10^{-21}}$$

$$= 0.65812$$

Weight fraction of copper = 65.81%

16. (d)

- Impurity of sulphur in iron is very dangerous because it produces FeS after reacting with iron which is having very low melting point.
- For removing ill effect of sulphur small amount of manganese is added in iron. Mn capture sulphur and produces MnS, which is having very high melting point and low shear strength. Because of low shear strength it increases machinability.
- Silicon is added for removing trapped oxygen. Si after reacting with O_2 produces SiO_2 and this SiO_2 is sludge, so it can be removed easily.

17. (b)

BHN number = 450

Load, P = 500 kg

Indenter diameter, D = 10 mm

Indentation diameter, d = ?

$$\text{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

$$450 = \frac{2\times500}{(10\pi)\left[10-\sqrt{(10^2-d^2)}\right]}$$

$$10-\sqrt{(100-d^2)} = \frac{1000}{450\times10\pi}$$

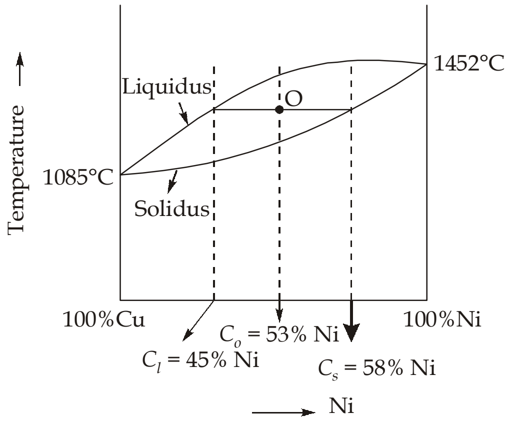
$$9.92926447 = \sqrt{100-d^2}$$

$$98.5803 = 100 - d^2$$

$$d^2 = 1.4097$$

$$d = 1.187 \text{ mm} \simeq 1.19 \text{ mm}$$

18. (b)



$$42\%\text{Cu} = (100 - 42)\%\text{ Ni} = 58\%\text{ Ni}$$

$$55\%\text{Cu} = (100 - 55)\%\text{ Ni} = 45\%\text{ Ni}$$

$$\%\text{liquid} = \left(\frac{C_s-C_o}{C_s-C_l}\right)\times100$$

$$= \left(\frac{58-53}{58-45}\right)\times100\% = 38.46\%$$

19. (d)

Sample size = 100 gram

Mass of iron atoms = 99.99 gram

Mass of carbon atoms = 0.01 gram

Molecular weight of iron = 56 g/mol

Molecular weight of carbon = 12 g/mol

Avogadro's number, N_A = 6.023×10^{23} atoms/mol

$$\text{Number of iron atoms} = \frac{99.99}{56}\times6.023\times10^{23} = 10.7542816\times10^{23}\text{ atoms}$$

$$\text{Number of carbon atoms} = \left(\frac{0.01}{12}\right)\times6.023\times10^{23} = 5.0191667\times10^{20}\text{ atoms}$$

Number of iron atoms per unit cell of BCC structure = 2

Number of iron atoms in 10000 unit lattices = 20000 atoms

$$\text{Number of carbon atom} = 20000\times\left(\frac{5.0191667\times10^{20}}{10.7542816\times10^{23}}\right) = 9.33426 \simeq 10$$

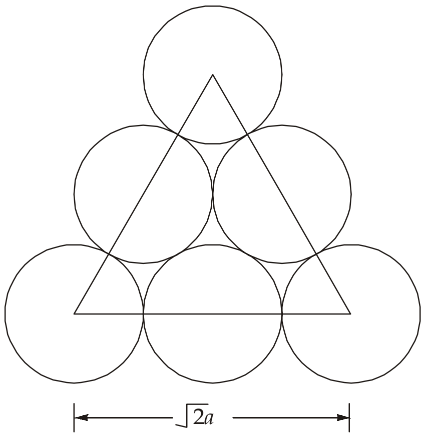
20. (a)

$$\text{Planar density}_{(1\,1\,0)} = \frac{2}{a^2\sqrt{2}} = \frac{\sqrt{2}}{a^2}$$

$$\text{Planar density}_{(1\,1\,1)} = \frac{2}{\left(\frac{\sqrt{3}}{4}\right)\times\left(\sqrt{2}a\right)^2} = \frac{4}{\left(\sqrt{3}\right)a^2}$$

$$\text{Planar density}_{(1\,0\,0)} = \frac{2}{a^2}$$

In FCC crystal{1 1 1} plane is most densely packed plane.



{1 1 1}plane

21. (b)

If grains are coarse, creep strength is improved.

22. (b)

Let, the true stress and true relationship is,

$$\sigma_T = k\varepsilon_T^n$$

where, σ_T is true stress and ε_T is true strain.

$$250 = k \times (0.175)^n \quad \text{...(1)}$$

$$300 = k \times (0.225)^n \quad \text{...(2)}$$

$$\frac{250}{300} = \left(\frac{0.175}{0.225}\right)^n$$

$$\ln\left(\frac{5}{6}\right) = n\ln\left(\frac{7}{9}\right)$$

$$n = 0.72547$$

Now, putting value of 'n' in equation (1).

$$250 = k \times (0.175)^{0.72547}$$

$$k = 885.30 \text{ MPa}$$

True stress for true strain of 0.205.

$$\sigma_T = k\varepsilon_T^n = 885.30 \times (0.205)^{0.72547}$$

$$\sigma_T = 280.40 \text{ MPa}$$

We know that, $\varepsilon_T = \ln(1 + \varepsilon)$

$$0.205 = \ln(1 + \varepsilon)$$
$$\varepsilon = 0.2275$$

Let, ε is engineering strain and σ_e is engineering stress.

$$\sigma = \sigma_e(1 + \varepsilon)$$
$$\sigma_e = \frac{280.40}{1.2275} = 228.43 \text{ MPa}$$

23. **(d)**

1. In full annealing process specimen is cooled slowly in the furnace, so resulting microstructure is coarse pearlite.
2. In normalizing process specimen is cooled in air, so resulting microstructure is fine pearlite.
3. Quenching is primarily done for obtaining the martensite microstructure.
4. After hardening resulting microstructure is extremly hard and brittle. Tempering is performed for reducing hardness and brittleness and to increase ductility or toughness.
   (i) High temperature tempering - Sorbite microstructure
   (ii) Medium temperature tempering - Troosite microstructure
   (iii) Low temperature tempering is used for relieving thermal stresses. There is no change in microstructure.

24. **(a)**

Intercepts of plane abc in x, y and z are 0.5, 1 and 0.5 respectively.

$$\text{Miller indices} = \left(\frac{1}{0.5}, \frac{1}{1}, \frac{1}{0.5}\right) = (2\ 1\ 2)$$

So, $p^2 + qr - 2q = 4 + 1 \times 2 - 2 \times 1 = 4$

25. **(c)**

Stacking fault is a example of surface defect.

26. **(b)**

Quenching of steel from a recrystallization temperature produces a needle bike structure called martensite. It is extremely hard and brittle. The strength of martensite is derived from the fact that the movement of dislocations is effectively blocked by the distorted lattice. The distorted lattice structure is a body-central tetragonal and formed when steel is cooled rapidly at a high rate which is of the order of 200°C/second.

27. **(d)**

Nitriding produces hardest case over the specimen. As nitride case will be too brittle, it is always tempered before use.

28. **(c)**

There is no peritectoid point in Fe-Fe_3C phase diagram.

29. **(d)**

- Upper and lower yield points are found in mild steel, not in aluminium alloys.
- Yield point indicates heterogeneous deformation.

30. **(c)**

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

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