CLASS TEST

S.No. : 01 JP_ME_250622

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MECHANICAL ENGINEERING

Material Science

Duration : 1:00 hr. **Maximum Marks : 50**

Read the following instructions carefully

1. This question paper contains **30** objective questions. **Q.1-10** carry one mark each and **Q.11-30** carry two marks each.
2. Answer all the questions.
3. Questions must be answered on Objective Response Sheet (**ORS**) by darkening the appropriate bubble (marked **A**, **B**, **C**, **D**) using HB pencil against the question number. Each question has only one correct answer. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
4. There will be **NEGATIVE** marking. For each wrong answer **1/3rd** of the full marks of the question will be deducted. More than one answer marked against a question will be deemed as an incorrect response and will be negatively marked.
5. Write your name & Roll No. at the specified locations on the right half of the **ORS**.
6. No charts or tables will be provided in the examination hall.
7. Choose the **Closest** numerical answer among the choices given.
8. If a candidate gives more than one answer, it will be treated as a **wrong answer** even if one of the given answers happens to be correct and there will be same penalty as above to that questions.
9. If a question is left blank, i.e., no answer is given by the candidate, there will be **no penalty** for that question.

DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

Q. No. 1 to Q. No. 10 carry 1 mark each

Q.1 Which of the following is correct regarding properties of ceramics?

(a) Extremely brittle, high thermal stability and low chemical stability.

(b) Low brittleness, low thermal stability and low chemical stability.

(c) Low hardness, high thermal stability and high chemical stability.

(d) High hardness, high thermal stability and high chemical stability.

Q.2 Match **List-I** (Types of cast iron) with **List-II** (Carbon%) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Gray iron	**1.** 2.8 - 3.3%
B. White iron	**2.** 1.8 - 3.6%
C. High strength gray iron	**3.** 3.0 - 4.0%
D. Nodular iron	**4.** 2.5 - 4.0%

Codes:

	A	**B**	**C**	**D**
(a)	3	1	2	4
(b)	4	1	2	3
(c)	3	4	1	2
(d)	4	2	1	3

Q.3 Which one of the following reaction shows the peritectoid reaction?

(a) $L + S_1 \xrightarrow{\text{Cooling}} S_2$

(b) $S_1 \xrightarrow{\text{Heating}} S_2 + S_3$

(c) $S_1 + S_2 \xrightarrow{\text{Heating}} S_3$

(d) $S_1 \xrightarrow{\text{Cooling}} S_2 + S_3$

Q.4 Which of the following statement(s) is/are incorrect regarding fluidity of material phases?

1. Fluidity of the material is maximum for pure material and for eutectoids.
2. Fluidity of the material is independent of the extent of mushy zone.

(a) Only statement 1 (b) Only statement 2

(c) Both 1 and 2 (d) Neither 1 nor 2

Q.5 Consider the following statements regarding phase diagrams:

1. Hardness or strength of pure material is very poor and the maximum strength will be at a point of maximum solid solubility of one material into another because alloys are always stronger than the pure metal.
2. As the weight% of Ni increases in Cu, tensile strength of an Ni-Cu alloy first increases and then decreases.

Select the correct statements:

(a) Only statement 1 is correct

(b) Only statement 2 is correct

(c) Both statements are correct

(d) Neither 1 nor 2 correct

Q.6 A quantum dot is

(a) the sharpest possible tip of the Atomic force microscope

(b) a nanoparticle with electrons confined in all directions

(c) a term used in science fiction

(d) unexplained spot of less than 1 nm seen in electron microscope images

Q.7 Which one of the following phase of iron is the hardest phase of iron?

(a) Austenite (b) Cementite

(c) Martensite (d) δ-Ferrite

Q.8 Pearlite phase of an iron is transform into spheroidite form of an iron, by:

(a) Heating the eutectoid steel at a temperature below eutectoid point for sufficiently long period.

(b) Heating the eutectic steel at a temperature above eutectic point for sufficiently long period.

(c) Heating the eutectoid steel at a temperature below eutectoid point for small period.

(d) Moderately cooling the eutectoid steel.

Q.9 Which one of the following statement is incorrect regarding dislocations ?

(a) Mixed dislocations generally emerge at the curved boundaries on which the directional continuity gets changed, such as holes, notched and cuts in the material.

(b) The distortion 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.
(c) The edge dislocations in a crystal are much more in number than the screw dislocation in any crystalline material.
(d) The dislocations have inherent tendency to keep largest possible burger's vector, which enhances the stability of crystals.

Q.10 Which one of the following metal can be used as anode to reduce corrosion when brass is acting as cathode?
(a) Cu (b) Ni
(c) Bronze (d) Pb

Q. No. 11 to Q. No. 30 carry 2 marks each

Q.11 What will be the volume fraction of phases present in an alloy at Pb-Sn with 30% Sn at 100°C. At this temperature 10% Sn can be dissolved in Pb and 2% Pb can be dissolved in Sn. The densities of Pb and Sn at this temperature are 17 g/cc and 10 g/cc respectively.
(a) 10.14%, 89.86% (b) 4.53%, 95.47%
(c) 31.67%, 68.33% (d) 64%, 36%

Q.12 What is the mass fraction of α-ferrite phase present in pearlite?
(a) 51.1% (b) 88.3%
(c) 64% (d) 44.14%

Q.13 Which the following is not the purpose of annealing?
1. To increase hardness.
2. To refine grain size.
3. To prepare steel for subsequent heat treatment.
4. To increase ductility.

Select the correct answer using codes given below:
(a) 1, 2 and 3 only
(b) 2 and 3 only
(c) 1 only
(d) 1, 2, 3 and 4

Q.14 Which of the following statements is/are correct regarding annealing?
(a) Diffusion annealing or homogenizing is applied to alloy steel ingots and heavy complex casting for eliminating the chemical inhomogeneity within the separate crystals by diffusion.
(b) Process annealing is usually carried out to remove the effects of cold working and to soften it make it suitable for further plastic deformation as in the case of sheet and wire industries.
(c) Spheroidise annealing is applied to high carbon steels which are difficult to machine.
(d) All of the above.

Q.15 Consider the following statements regarding the tempering process:
1. In medium temperature tempering, martensite is heated and then cooled slowly in furnace. Submicroscopic cementite will combine together and produces a coarse structure. This microstructure is called troosite.
2. In high temperature tempering since the temperature is high so diffusion will also be high. So the cementite will appear at a finer level as compare to troosite. This microstructure is called sorbite.

Select the correct statement using codes given below:
(a) Only statement 1
(b) Only statement 2
(c) Both statements 1 and 2
(d) Neither 1 nor 2

Q.16 Match **List-I** (Crystal system) with **List-II** (Interaxial angles) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Rhombohedral	**1.** $\alpha=\beta=90°, \gamma = 120°$
B. Monoclinic	**2.** $\alpha \neq \beta \neq \gamma \neq 90°$
C. Hexagonal	**3.** $\alpha = \beta = \gamma \neq 90°$
D. Triclinic	**4.** $\alpha = \gamma = 90° \neq \beta$

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	3	4	1	2
(c)	1	2	3	4
(d)	2	1	4	3

Q.17 What will be the linear density and planer density along a diagonal of any face of face centered cubic crystal structure and on any face of face centered cubic structure? (Assume R is the radius of atom.)

(a) $\frac{1}{2R}, \frac{1}{2R^2\sqrt{2}}$ (b) $\frac{1}{R}, \frac{1}{4R^2}$

(c) $\frac{1}{2R}, \frac{1}{4R^2}$ (d) $\frac{1}{R}, \frac{1}{4R^2\sqrt{2}}$

Q.18 What will be the atomic packing factor of silicon? (Take radius of atom, $r = \frac{a\sqrt{3}}{8}$, where a is the side of cubic unit cell).

(a) 0.68 (b) 0.52

(c) 0.34 (d) 0.74

Q.19 What will be the planer density (in nm^{-2}) of the plane located on FCC structure and it has miller indices [0, 1, 1]? [Assume lattice parameter, a = 0.5 nm]

(a) $2\sqrt{2}$ (b) $8\sqrt{2}$

(c) $\frac{4}{\sqrt{3}}$ (d) $4\sqrt{2}$

Q.20 X-rays with a wavelength of 0.58Å are used for calculating d_{200} in nickel. The reflection angle is 9.5°. What is the lattice parameter a? (Given sin95° = 0.165)

(a) 3.515Å (b) 1.215Å

(c) 0.585Å (d) 2.110Å

Q.21 Consider the following statements regarding screw dislocation:

1. There is a half plane of atoms in screw dislocation and it is formed when a part of crystal displaces angularly over the remaining part, as if a shear stress has produced this dislocation.
2. The atomic bonds in the vicinity of dislocation line undergo through shear deformation. This gives rise to the development of shear stress and shear strain field.

Select the correct statement(s) using codes given below:

(a) Only statement 1 is correct
(b) Only statement 2 is correct
(c) Both statements are correct
(d) Neither 1 nor 2 correct

Q.22 A round specimen of wrought iron of diameter 10 mm and gauge length of 100 mm was tested in tension upto fracture. Following observations were made:
Yield strength = 210 MPa, Diameter at neck = 7 mm
If load at the time of fracture is 10% higher than the load at yield point then what will be the actual breaking stress (in MPa)?

(a) 471.43
(b) 456.27
(c) 480.11
(d) 466.42

Q.23 A 10 mm diameter Brinell ball produced an indentation of diameter $\sqrt{1.99}$ mm in a steel alloy when a load of 4.9 kN is used. What will be the Brinell hardness number?

(a) 315.17 (b) 325.25

(c) 310.95 (d) 318.18

Q.24 Consider the following statements regarding hydrogen embrittlement:

1. BCC and FCC crystals are most susceptible to hydrogen embrittlement, but HCP metals are generally not susceptible.
2. Hydrogen embrittlement increases by slow strain rates.

Which of the above statement(s) is/are correct?

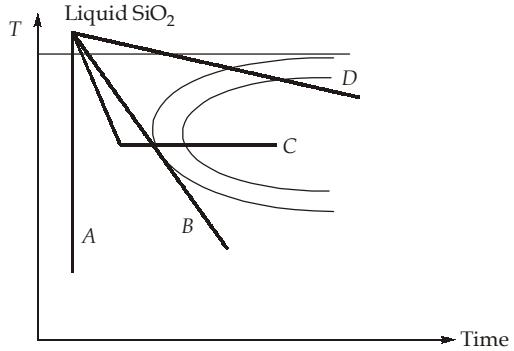
(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Q.25 **Statement (I):** Every solid and liquid matter in the nature have some impurity of sulphur. Sulphur after reacting with iron produces iron sulphite (FeS) has high melting point.
Statement (II): If the presence of Mn is 12% in steel then strength of material appear very high called hadfield steel.
(a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are true but Statement (II) is not a correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

Q.26 Consider an organic polymer with the combined form of crystalline and amorphous part. If ρ_c is the density of crystalline part and ρ_a is the density of amorphous part then the density of polymer sample (ρ) is:
Where, f_c - Ratio of volume of crystalline to volume of amorphous part.

(a) $\frac{\rho_a + \rho_c f_c}{1 - f_c}$ (b) $\frac{\rho_a - \rho_c f_c}{1 + f_c}$
(c) $\frac{\rho_a + \rho_c f_c}{1 + f_c}$ (d) $\frac{\rho_a - \rho_c f_c}{1 - f_c}$

Q.27 Consider the following processes on T-T-T diagram. Which one of the following process has highest probability of getting metallic glass used in transformer cores to minimize the eddy current loss, on cooling of liquid metal(liquid SiO_2)?



(a) Process (d) (b) Process (c)
(c) Process (b) (d) Process (a)

Q.28 Which of the following is correct statement regarding plastics?
1. Polyethylene and polystyrene are thermoplastics whereas epoxy and bakelite are thermosetting plastic.
2. Polyethylene and poly tetra fluoro ethylene are thermoplastics whereas phenol formaldehyde is thermosetting plastic.
(a) 1 only
(b) 2 only
(c) both (1) and (2)
(b) Neither (1) nor (2) correct.

Q.29 Match **List-I** (Iron phases) with **List-II** (Maximum temperature) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. γ-Austenite	**1.** 910°C
B. δ-Ferrite	**2.** 768°C
C. α-Ferrite	**3.** 1535°C
	4. 1410°C
	5. 1590°C
	6. 1452°C

Codes:

	A	B	C
(a)	5	6	1
(b)	4	6	2
(c)	6	4	2
(d)	4	3	1

Q.30 **Statement (I):** Jominy distance in Jominy end quench test indicates the hardenability of the material and it will be maximum for eutectic composition.
Statement (II): If we deviates from 0.8% carbon composition in iron-carbon diagram then we do not get 100% martensite structure after quenching.
(a) Both Statement (I) and Statement (II) are true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are true but Statement (II) is not a correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

■■■■

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MATERIAL SCIENCE

MECHANICAL ENGINEERING

Date of Test : 25/06/2022

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

1. (d)

The properties of ceramics are:

1. Extremely brittle 2. High thermal stability
3. High chemical stability 4. High hardness

3. (c)

There is a invariant reaction, which does not appear on Fe-C diagram is called peritectoid reaction. When two solid phases combine together produces third solid phase upon cooling.

$$S_1 + S_2 \underset{\text{Heating}}{\overset{\text{Cooling}}{\rightleftharpoons}} S_3$$

4. (c)

Fluidity is maximum for pure materials and eutectics. It is directly affected by the extent of mushy zone. Larger is the mushy zone lower will be the fluidity. Eutectic composition has higher fluidity. In any alloy system there will be at a particular composition there will be eutectic composition where there is no mushy zone. So, that particular composition has the highest/higher fluidity.

Fluidity has no relation with eutectoids.

5. (c)

Generally density is lower for low melting point material.

6. (b)

A quantum dot is a zero dimensional nanoparticle with electrons confined in all the directions.

7. (c)

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

9. (d)

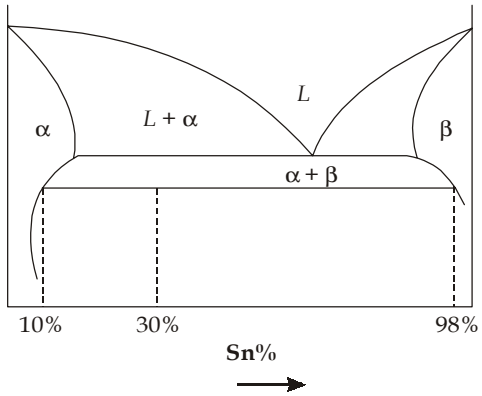
The dislocations have inherent tendency to keep smallest possible burger's vector, which enhances the stability of crystal.

10. (d)

Galvanic seres order of given materials:

$$\underset{\text{Anode}}{\overset{\text{Cathode}}{\text{Ni} \rightarrow \text{Bronze} \rightarrow \text{Cu} \rightarrow \text{Brass} \rightarrow \text{Pb}}}$$

11. (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,

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

$$\rho_\alpha = \frac{17 \times 100}{107}$$

Now, for ρ_β,

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

$$\rho_\beta = \frac{17000}{1686}$$

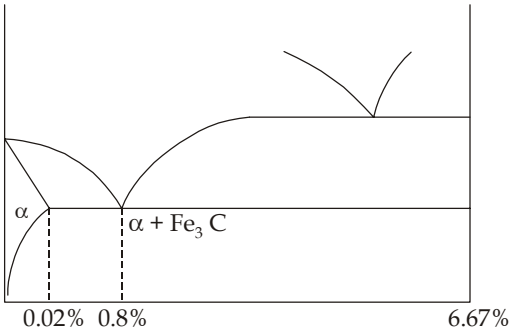
$$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}} = \frac{\frac{68}{88} \times \frac{107}{17 \times 100}}{\frac{68 \times 107}{88 \times 17 \times 100} + \frac{20 \times 1686}{88 \times 17000}} = \frac{1}{1 + \frac{20 \times 1686}{68 \times 1070}}$$

$$= 0.6833 = 68.33\%$$

And, $V_\beta = 1 - 0.6833 = 0.3167 = 31.67\%$

12. (b)

$$m_\alpha = \frac{6.67 - 0.8}{6.67 - 0.02} = 88.3\%$$



13. (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

15. (d)

High temperature tempering: Martensite is heated to approximately 500 to 650°C and then cooled slowly in the furnace. Submicroscopic cementite will combine together and produces a coarse structure this microstructure is called sorbite.

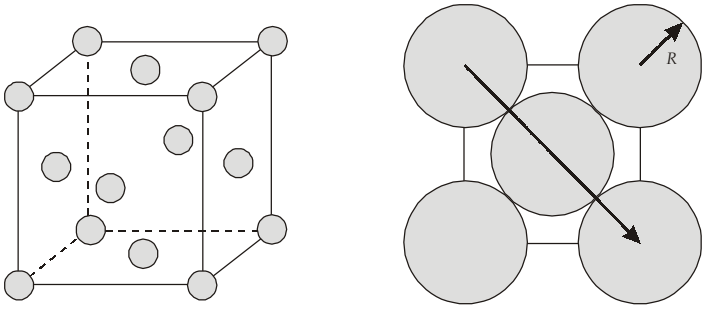
Medium temperature tempering: In this tempering process since the temperature is low so diffusion will also be low. So the cementite will appear at a finer level as compared to sorbite. This microstructure is called troosite. It is used for manufacturing of spring.

Sorbite structure is coarse as compared to troostie and troosite structure is finer structure.

16. (b)

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

17. (c)



(a) (b)

(i)Linear density along X-Z = $\dfrac{\text{No. of atoms centered on direction vector}}{\text{Length of direction vector}}$

$= \dfrac{2 \text{ atoms}}{4R} = \dfrac{1}{2R}$

(ii) Planer density = $\dfrac{\text{No. of atoms centered a plane}}{\text{Area of plane}}$

$= \dfrac{2 \text{ atoms}}{8R^2} = \dfrac{1}{4R^2}$

18. (c)

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

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

Where r is the atomic radius of carbon atom.

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

$$\text{Volume of atoms in unit cell} = 8\times\frac{4}{3}\pi r^3 = \frac{32}{3}\pi r^3 = \frac{32}{3}\times\pi\left(\frac{a\sqrt{3}}{8}\right)^3$$

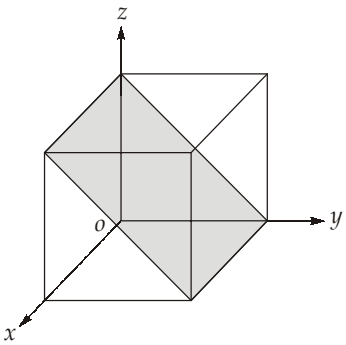
$$= \frac{32}{3}\times\frac{\pi 3\sqrt{3}}{512}\times a^3 = \frac{\pi\sqrt{3}}{16}a^3 = 0.34a^3$$

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

$$\text{APF} = 0.34$$

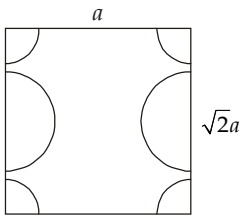
19. (d)

$$\text{Planer density} = \frac{\text{No. of atoms centered a plane}}{\text{Area a plane}}$$



$$\text{Number of atoms} = 2$$

$$\text{Now, Area of plane} = \sqrt{2}a\times a = \sqrt{2}a^2$$



$$\text{Planer density} = \frac{2}{\sqrt{2}a^2} = \frac{2}{\sqrt{2}a^2}\,\text{m}^{-2} = \frac{2}{\sqrt{2}\times 0.5^2\times 10^{-9\times 2}}$$

$$= 4\sqrt{2}\ \text{nm}^{-2}$$

20. (a)

$\lambda = 0.58\text{Å}$

$\theta = 9.5°$ for n = 1, first order

a = Lattice parameter of unit cell

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

d_{200} = Mean distance for (200 plane),

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, $2d\sin\theta = n\lambda$

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

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

$$a = 3.515\text{Å}$$

21. (b)

There is no extra half plane of atoms (as in the case of edge dislocation), but a screw dislocation (atoms distorted along an helix of a screw) is formed when a part of the crystal displaces angularly over the remaining part, as if a shear stress has produced this dislocation.

22. (a)

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

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

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

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

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

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

23. (d)

$$\text{BHN} = \frac{P\,(\text{in kg})}{\frac{\pi D}{2}\left[D-\sqrt{D^2-d^2}\right]} = \frac{\left(\frac{4900}{9.8}\right)}{\frac{\pi\times 10}{2}\left[10-\sqrt{10^2-\left(\sqrt{1.99}\right)^2}\right]}$$

$$= \frac{7\times 50\times 2}{22\times 10\left[10-\sqrt{100-1.99}\right]} = \frac{700}{22\left[10-\sqrt{98.01}\right]}$$

$$= \frac{700}{22[10-9.9]} = \frac{700}{22\times 0.1} = 318.182$$

24. (b)

BCC and HCP crystals are most susceptible to hydrogen embrittlement but FCC metals are generally not susceptible.

25. (d)

Every solid and liquid mater in the nature will have some impurity of sulphur. Sulphur after reacting with iron produces iron sulphite (FeS). FeS gets accumulated on the grain boundaries and is having lower melting point. Upon hot working the material FeS melts out producing number of cracks on the grain boundaries. As a result of that material will fail as brittle fracture. This phenomenon is called 'Hot shortness'. To avoid this phenomenon Mn is added into the material. 'Mn' captures sulphur before it can react with iron. Also a larger number of 'MnS' pockets will be present in the materials. Which improves the machinability because MnS is having low shear strength. If 'Mn' is around 12% the strength of material appears to be very high called 'Hadfield steel', which is used to make bull-dozer rolls.

26. (c)

$$(m)_{\text{polymer sample}} = m_a + m_c$$

$$\rho V = \rho_a V_a + \rho_c V_c$$

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

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

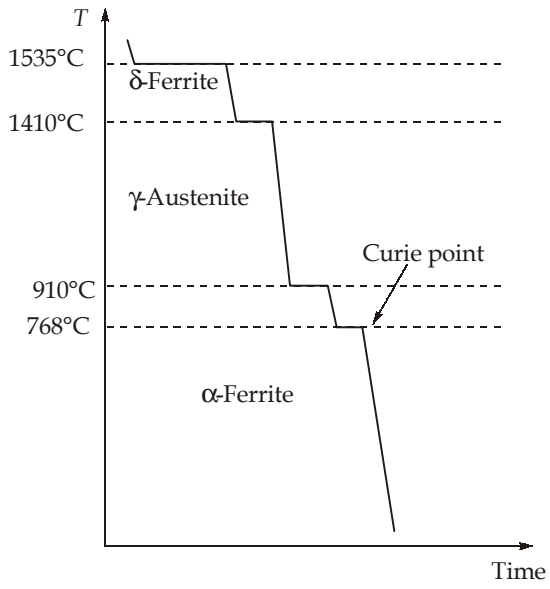
27. (d)

Upon quenching liquid metals at a very fast rate (10^6 °C/sec) the metal will also convert into glass called metallic glass and is used in transformer cores to minimize the eddy current losses.

28. (c)

Polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE) and polystyrene (PS) are thermoplastics, known as B1G-4. Other well known thermoplastics are poly tetra fluoro ethylene, acrylic etc. The commonly used thermosetting plastics are epoxy, polyster and phenol formaldehyde (Bakelite) etc. Most of these thermosetting plastics are used as matrix in composite materials.

29. (d)



30. (d)

Jominy distance in Jominy end quench test indicates the hardenability of the material and it will be maximum for eutectoid composition. If we deviate from 0.8% carbon composition i.e. eutectoid point we do not get martensite structure which is harder.

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