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GENERAL STUDIES AND ENGINEERING APTITUDE

SUBJECT: BASICS OF MATERIAL SCIENCE AND ENGINEERING

SOLUTIONS

01. Ans: (a)

Sol: Face centered cubic structure metals are more ductile because of closely packed arrangement of atoms and due to that dislocation moment is easy.

02. Ans: (b)

Sol: Body centered cubic ((BCC) Structure.

n = 2

$4R = \sqrt{3}a$

$$V_{VC} = \left(\frac{4R}{\sqrt{3}}\right)^3 = \frac{64R^3}{3\sqrt{3}}$$

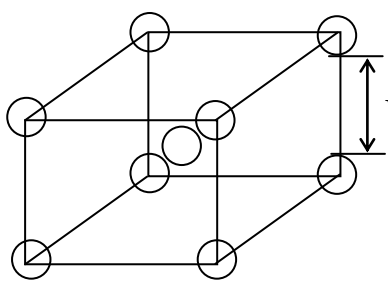
$$\text{Density} = \frac{n \times AW}{AN \times V_{VC}} = \frac{2 \times A}{N \times \frac{64R^3}{3\sqrt{3}}} = \frac{3\sqrt{3}A}{32R^3N}$$

03. Ans: (a)

Sol: Body centered cubic structure ($4R = \sqrt{3}\,a$)

$D = a - 2R$

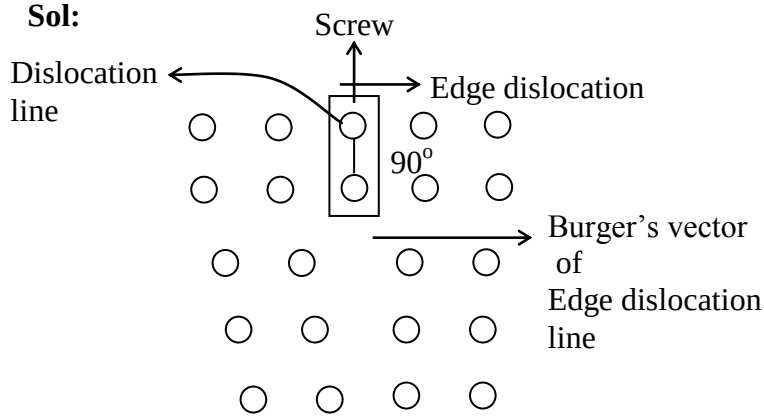
$$= a - \frac{\sqrt{3}a}{2} = a\left(1 - \frac{\sqrt{3}}{2}\right)$$



Void space = a – 2R

04. Ans: (a)

Sol:



In Edge dislocation Burger's vector is perpendicular to the dislocation line.

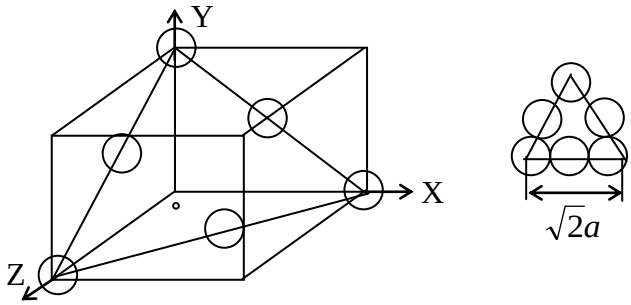
05. Ans: (a)

Sol:

Crystal Structure	Examples
1. SC	Po
2. BCC	∝-Fe, W, Na, Cr
3. FCC	Ni, Al, Cu, Au, Ag
4. DCS	Diamond, Si, Ge
5. HCP	Zn, Co, Cd, Be, Zr

06. Ans: (c)

Sol: FCC $(4R = \sqrt{2}a)$



$$Planar\ Density = \frac{No.of\ atoms\ in\ a\ plane}{Area\ of\ plane}$$

$$Planar Density = \frac{\frac{1}{6}\times 3 + \frac{1}{2}\times 3}{\frac{\sqrt{3}}{4}\left(\sqrt{2}a\right)^2} = \frac{2}{\frac{\sqrt{3}}{4}\times 2a^2} = \frac{4}{\sqrt{3}a^2}$$

07. Ans: (b)

08. Ans: (a)

Sol: Ionic solids:

Ex: Nacl, LiF, $MgCl_2$, Kcl^+, Al_2D_3

1. Ionic solids formed by complete transfer of electron.
2. Ionic solids are soluble in polar solvents like water and liquid ammonia and are insoluble in non-polar solvents like benzene.
3. Pure and dry ionic solids are good insulators because all the electrons are tightly bound.
4. Ionic solids are hard and brittle. Ionic solids have high melting point and boiling point.

09. Ans: (b)

Sol: Hall voltage coefficient $(R_H) = \frac{1}{ne} = 5 \times 10^3$

$$n = \frac{1}{R_H e} = \frac{1}{5\times 10^3 \times 1.6\times 10^{-19}}$$

$$= 1.25 \times 10^{15}/cm^3$$

10. Ans: (a)

Sol: Ferromagnetic materials:

Ex: Fe, Co, Ni, Al

M_{Fe} = 2.2 Bohr magneton

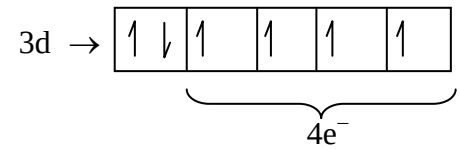
M_{Co} = 1.1 Bohr magneton

M_{Ni} = 0.8 Bohr magneton

Note: Aluminium is a paramagnetic material.

11. Ans: (d)

Sol:



M_{Fe} = 4 Bohr magneton

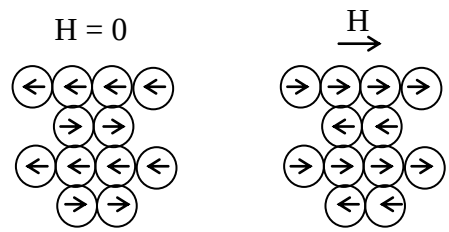
Note: Bohr magneton = It is the total magnetic dipole moment generated by one election.

$1\ \mu_B = 9.27 \times 10^{-24}$ A-m^2

12. Ans: (c)

Sol: Ferrimagnetic material:

1. Magnetic susceptibility χ = +ve
2. Anti-parallel and unequal magnitudes of dipoles.
3. Follow $\chi = \frac{C}{T \pm \theta}$.



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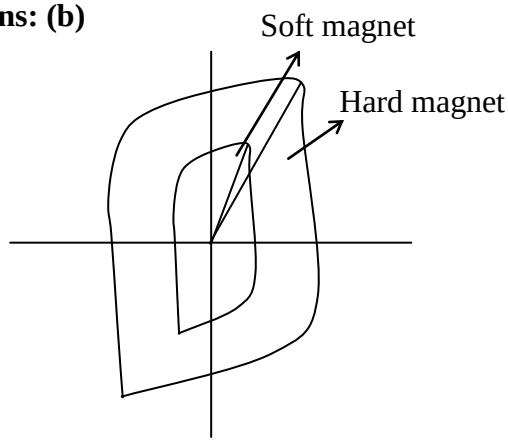
13. Ans: (b)

Sol:



Soft magnetic materials are produced by annealing process and it is used in transformer core.

14. Ans: (b)

Sol: The magnetic susceptibility of paramagnetic material is positive and small.

15. Ans: (a)

Sol: (1) Ferrite → Hysteresis losses
(2) Super conductor → Meisner Effect
(3) Quartz → Piezoelectric material
(4) Iron → Faraday effect

16. Ans: (c)

Sol: 1. The magnetic susceptibility of super conductor is –1.
2. Based on meisner effect, magnetic flux density of super conductor is zero.
3. It is a perfect diamagnetic material.
4. Isotopic effect.

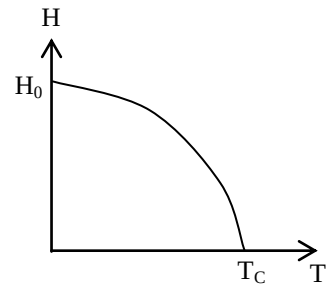
$$T_t \propto \frac{1}{\sqrt{M_{isotope}}}$$

T_t = Transition temperature
$M_{isotope}$ = Mass of isotope

17. Ans: (d)

Sol: Critical magnetic field of a superconductor (H_C)

$$H_C = H_O\left[1-\left(\frac{T}{T_t}\right)^2\right]$$



18. Ans: (a)

Sol: Ruchelle's salt is a Ferroelectric material with high dielectric constant.
Piezo electric materials are used in electric oscillator circuits and all ferroelectric electric materials show Piezo electric behaviour, so Rochelle salt also used in oscillators.
Ferro electric material follows Curie's law, and above Curie temperature, it convert into para electric material.

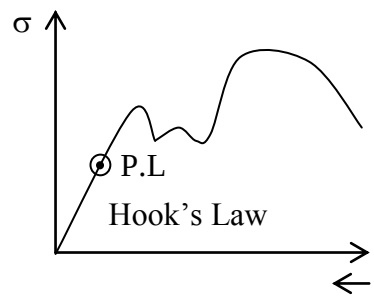
19. Ans: (a)

Sol: Ductility = % ε longation = $\frac{l_F - l_o}{l_o} \times 100$

$$= \frac{11.5-10}{10} = \frac{1.5}{10} \times 100 = 15\%.$$

20. Ans: (d)

Sol: **Linear elastic materials:**
The linear elastic materials follows hook's law.
$\sigma \propto \varepsilon$
$\sigma = E\varepsilon$ upto proportionality limits
Ex: Steels



Note: Polymers are non-linear elastic materials.

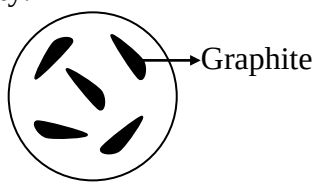
21. Ans: (b)

Sol: Super alloys have high corrosion resistance.

22. Ans: (c)

Sol: Gray castiron:

In gray castiron, graphite is present in flakes from, due to that, gray castiron possess high damping capacity.



Gray castiron

The fracture surface of gray cast iron is gray

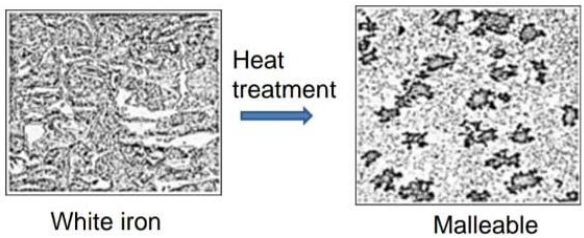
Applications: Lathe machine beds

Engine blocks

23. Ans: (c)

Sol:

- Malleable castiron – Carbon 2.3 – 2.7 wt%, Si : 1.0 – 1.75%
- Obtained by heat treating white iron for a prolonged period that causes decomposition of cementite into graphite.
- **Heat treatment:** Two stages- Isothermal holding at 950 ^{o}C and then holding at 720 ^{o}C
- Graphite forms in the form of rosettes in a ferrite or pearlite matrix.
- Reasonable strength and improved ductility (malleable)



24. Ans: (d)

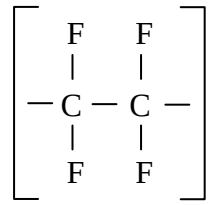
Sol: By adding alloying elements to host material, properties are changed.

25. Ans: (a)

Sol:
1. Transformer core is made up of silicon steel, silicon is added to steel to reduce eddy current losses.
2. Gas turbine blades are made up of inconel and monel metal alloy. These are Ni based alloys with high temperature strength, corrosion resistance.
3. Bearings are produced by Babbit alloys and gun metals. Gun metal is an alloy 80% Cu, 10% Sn and 2% Zn.

26. Ans: (b)

Sol: Teflon is a polytetrafluoroethene. It is thermo-plastic polymer.



27. Ans: (d)

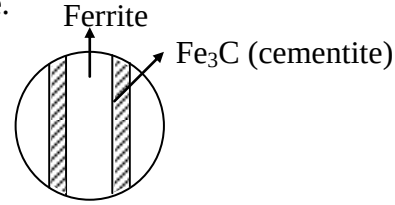
Sol: Glass Fiber Reinforced Polymer (GFRP):

Ex: Optical fiber, Transportation vehicle glasses

Carbon Fiber Reinforced Polymer (CFRP):

Ex: Kalam sat, Sports goods, Aeroplane body parts

Pearlite: It is an eutectoid mixture of ferrite and cementite.



28. Ans: (b)

Sol: Processing steps in powder metallurgy process

1. Making powders
2. Adding additives and blending
3. Compaction (or) pressing
4. Sintering

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29. Ans: (c)

Sol: In addition to wear resistance abrasive should have high toughness and high refractoriness to withstand for impact load and high temperature.

30. Ans: (a)

Sol:

Radius Ratio	Coordinate number	Type of void	Example
< 0.155	2	Linear	
0.155 - 0.225	3	Triangular planar	B_2O_3
0.225 - 0.414	4	Tetrahedral	ZnS, CuCl
0.414 - 0.732	6	Octahedral	NaCl, Mgo
0.732 - 1.000	8	Cubic	CsCl, NH_4Br
1	12	Close packing (ccp and hcp)	Metals

31. Ans: (b)

Sol: $E_{Glass} = 72$ GPa $V_{Glass} = 0.6$

$E_{epoxy} = 3$ GPa $V_{epoxy} = 0.4$

$(E_{composits})$iso-strain

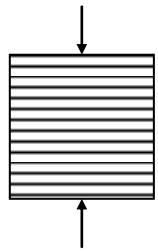
$= E_{glass} \times V_{glass} + E_{epoxy} \times V_{epoxy}$

$= 72 \times 0.6 + 3 \times 0.4 = 44.4$ GPa

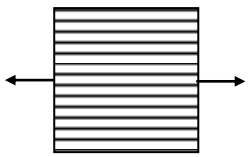
Note:

(i) Iso-stress condition: (Load applied perpendicular to the reinforcement phase)

$$\frac{1}{E_C} = \frac{E_{RP}}{V_{RP}} + \frac{E_{MP}}{V_{MP}}$$



(ii) Iso-strain condition: (Load applied parallel to the reinforcement phase)



$E_c = E_{RP} V_{RP} + E_{MP} V_{MP}$

32. Ans: (c)

Sol: Mechanical properties of ceramics:

1. High compressive strength, but low tensile strength due to porocity.
2. Ceramics are more harder than metals & polymers
3. Ceramics are anticorrosive materials
4. Ceramics are brittle materials

33. Ans: (a)

Sol: Silver and copper materials are good electrical conductors

$\sigma_{Ag} = 7 \times 10^7$ $(\Omega\text{-m})^{-1}$,

$\sigma_{cu} = 6.7 \times 10^7$ $(\Omega\text{ -m})^{-1}$

Doped germanium is a semiconductor

Pure silica is an insulator

34. Ans: (c)

Sol: Creep curve:

Primary creep:

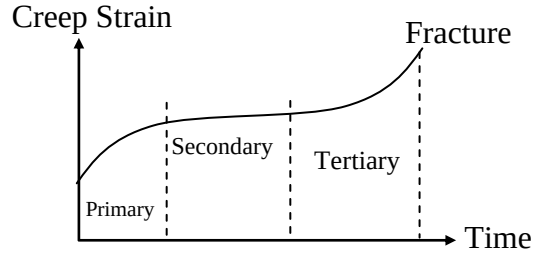
Starts at a rapid elongation rate and slow down with time

Secondary creep:

Relatively uniform rate

Tertiary creep:

An accelerated creep rate and terminate when the material breaks to ruptures.



35. Ans: (b)

Sol: (i) Hypoeutectectoid alloy

% C = 0.008% to 0.8%

(ii) Hypereutectoid alloy

% C = 0.8% to 2.1%

(iii) Hypoeutectic alloy

%C = 2.1% to 4.2%

(iv) Hypereutectic alloy

%C = 4.2% to 6.67%

36. Ans: (c)

Sol: Eutectoid reaction

$$\text{Solid 1} \underset{\text{Heating}}{\overset{\text{cooling}}{\rightleftharpoons}} \text{solid 2 + solid 3}$$

In Fe-C alloy at 0.8% C, 723^{o}C Eutectoid reaction

$$\text{Austenite} \underset{723^{o}\text{C}}{\overset{0.8\%\text{C}}{\rightleftharpoons}} \alpha\text{–Ferrite + Cementite}$$

37. Ans: (c)

Sol: Quantum well: It is a one dimensional nano-material, formed by reduction of size of bulk material in only one direction.

Ex: Graphene
Nano painting
Nano coasting
Thinfilms

38. Ans: (d)

Sol: Hune Ruthory Rule

There rules are conditions to form substitutional solid solutions

(1) Atomic size factor: $R_{H.A} - R_{F.A} \leq 14\%$

(2) Crystal structure: Crystal structures of solvent and solute must be same.

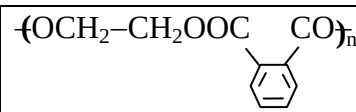
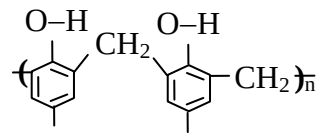
(3) Electro negativity: Difference in electro negativity of solvent and solute must be low.

(4) Valence: Valence difference between solvent and solute is low.

39. Ans: (b)

Sol:

Name of Polymer	Monomer	Structure	Uses
Polypropene	Propene	$\left(CH_2.\underset{\displaystyle CH_2}{\underset{\vert}{CH}}\right)_n$	Manufacture of ropes, toys, pipes, fibers. Etc
Polystyrene	Styrene	$\left(CH_2.\underset{\displaystyle C_2H_3}{\underset{\vert}{CH}}\right)_n$	As insulator, wrapping material, manufacture of toys, radio and television cabinets
Polyvinyl chloride(PVC)	Vinyl chloride	$\left(CH_2.\underset{\displaystyle CI}{\underset{\vert}{CH}}\right)_n$	Manufacture of rain coats, hand bags, vinyl flooring, water pipes.
Urea-formaldehyle Resin	(a) Urea (b) Formaldehyde	$\left(NH–CO–NH–CH_2\right)_n$	For making unbreakable cups and laminated sheets.

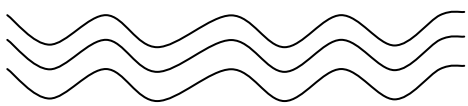
Glyptal	(a) Ethylene glycol (b) Phthalic acid		Manufacture of paints and lacquers
Bakelite	(a) Phenol (b) Formaldehyde		For making combs, electrical switches, handles of utensils and computer discs.

40. Ans: (b)

Sol: There are three different types based on the structure of the polymers.

1. Linear polymers

These polymers consist of long and straight chains. The examples are high density polyvinyl chloride, etc. These are represented as:

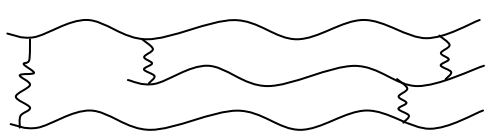


2. Branched chin polymers

These polymers contain linear chains having some branches, e.g., low density polythene. These are depicted as follows:

3. Cross linked or Network polymers

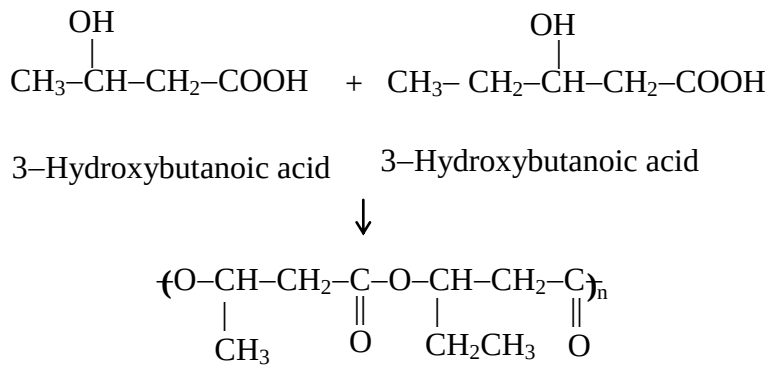
These are usually formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains, e.g. bakelite, melamine, etc. These polymers are depicted as follows:



41. Ans: (c)

Sol: Aliphatic polyesters are one of the important classes of biodegradable polymers. Some important examples are given below:

1. Poly β-hydroxybutyrate–co-β-hydroxy valerate (PHBV): It is obtained by the copolymerisation of 3-hydroybutanoic acid and 3 – hydroxypentanoic acid. PHBV is used in speciality packaging, orthopaedic devices and in controlled release of drugs. PHBV undergoes bacterial degradation in the environment.



2. Nylon 2-nylon 6:

It is an alternating polyamide copolymer of glycine ($H_2N–CH_2–COOH$) and amino caproic acid [$H_2N(CH_2)_5COOH$] and is biodegradable.

42. Ans: (a)

Sol: Babbitt metal in a soft alloy of tin, antimony and copper. Babbitts are relatively hard crystal embedded in a softer mainly used in bearings.

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43. Ans: (a)

Sol: Refractory Materials:

- Refractory- retains its strength at high temperatures > 500°C.
- Must be chemically and physically stable at high temperatures. Need to be resistant to thermal shock, should be chemically inert, and have specific ranges of thermal conductivity and thermal expansion.
- Are used in linings for furnaces, kilns, incinerators, crucibles and reactors.
- Aluminium oxide (alumina), silicon oxide (silica), calcium oxide (lime) magnesium oxide (magnesia) and fireclays are used to manufacture refractory materials.
- Zirconia-extremely high temperatures.
- SiC and Carbon-also used in some very severe temperature conditions, but cannot be used in oxygen environment, as they will oxidize and burn.

44. Ans: (b)

Sol: Shape memory alloys: Shape memory alloys are ability to go back to it's original shape by applying heat treatment.

Ex: Nitinal (Ni-Ti alloy)

Applications:

1. Teeth braces 2. Collapsable antenas
3. Foldable spectacles

45. Ans: (b)

Sol: Composites are combination of two or more chemically unlike materials to improve properties and to reduce cost based on availability.

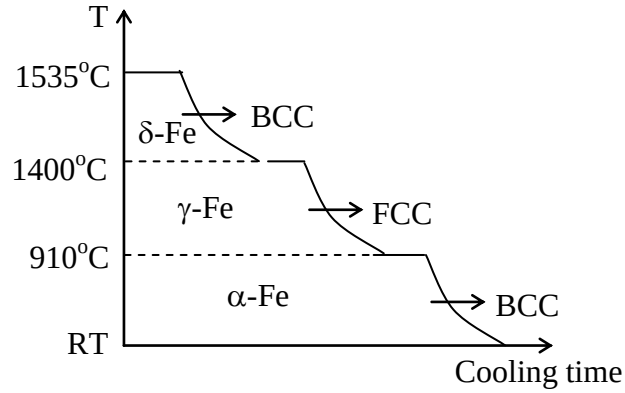
Ex: Reinforce cement concrete

Optical fibre

Properties of composites are different from their individual material properties.

46. Ans: (b)

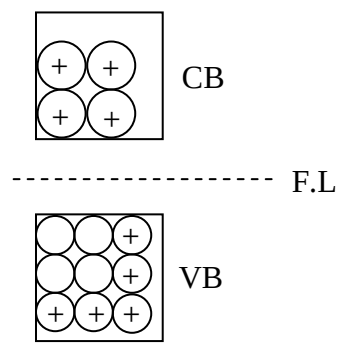
Sol: The Iron is an allotropic material, that exhibits different crystal structures with temperatures.



47. Ans: (b)

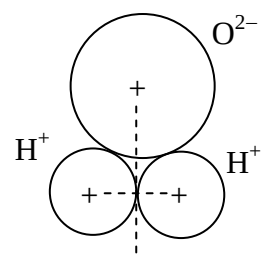
48. Ans: (d)

Sol: Statement (I) is incorrect. In intrinsic semiconductor Fermi level lie exactly of middle of energy band gap.



49. Ans: (c)

Sol: Statement **(**I) is correct and statement **(**II) is incorrect. Water molecule posses permanent dipoles become of non-centro symmetric arrangement of atoms.



50. Ans: (c)

Sol: Statement (II) is incorrect, cold working increases the number of dislocation per unit volume of the materials.