CBCS Scheme

USN

15ME/MA32

# Third Semester B.E. Degree Examination, Dec.2017/Jan.2018

## Material Science

Time: 3 hrs. Max. Marks: 80

*Note: Answer any FIVE full questions, choosing one full question from each module.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

### Module-1

1 a. Define APF. Calculate the APF for an ideally packed HCP unit cell. (07 Marks)
b. Classify the crystal defects. Explain point defect with neat sketches. (07 Marks)
c. Calculate the rate of diffusion of iron at 700°C. Take $A = 4.9 \times 10^{-5}$ m$^2$/s, E = 153.2 kJ/mol. (02 Marks)

OR

2 a. List linear and non-linear elastic properties. Explain non-linear elastic properties. (06 Marks)
b. Draw S-N curve and typical creep curve. Explain them briefly. (10 Marks)

### Module-2

3 a. Explain the rules governs the formation of solid solution. (04 Marks)
b. What are the different cast metal structures? Explain with neat sketches. (04 Marks)
c. Draw Fe-$Fe_3C$ diagram. Explain the reactions in it. (08 Marks)



OR

4 a. Define homogeneous and heterogeneous nucleation. Obtain an expression for critical radius of nucleus. (06 Marks)
b. Explain the effect of alloying elements to the steel. (04 Marks)
c. Two metals A and B have their melting points at 600°C and 400°C respectively. These metals do not form any compound or intermetallic phase. The maximum solubility in each other is 4% which remains the same until 0°C. An eutectic reaction occurs at 300°C for 65% A.
i) Draw the phase diagram and label all the phases and fields.
ii) Find the temperature at which 20% A and 80% B starts and ends solidification.
iii) Find the temperature at which the same alloy contain 50% liquid and 50% solid. (06 Marks)

### Module-3

5 a. Define heat treatment. Give its classification. (05 Marks)
b. Distinguish between Austempering and Martempering. (05 Marks)
c. Draw TTT diagram. Explain briefly. (06 Marks)

OR

6 a. With neat sketch explain Jominy end quench test. (06 Marks)
b. Explain age hardening of Al-Cu alloys. (04 Marks)
c. Explain the properties, compositions and uses of gray cast iron and SG iron. (06 Marks)

## Module-4

7 a. Define ceramic. Explain briefly the types of ceramics. (05 Marks)
b. List the applications and mechanical properties of ceramics. (06 Marks)
c. Define smart material. Explain briefly the types of smart materials. (05 Marks)

OR

8 Write a note on:
a. Shape memory alloys
b. Piezo electric materials
c. Fibre optic materials
d. Use of non-destructive testing (16 Marks)



## Module-5

9 a. Define composite. How do you classify composites? (06 Marks)
b. Explain the role of matrix and reinforcement in composite material. (06 Marks)
c. With flow chart explain the production of carbon fibres. (04 Marks)

OR

10 a. With a neat sketch explain pultrusion process. (07 Marks)
b. List the advantages and applications of composites. (05 Marks)
c. Calculate the tensile modulus of elasticity of unidirectional carbon fibre reinforced composite material which contain 62% by volume of carbon fibres in iso-strain and iso-stress condition. Take Young's modulus of carbon fibre as $37.86 \times 10^4$ N/mm$^2$. Young's modulus of epoxy = $42 \times 10^2$ N/mm$^2$. (04 Marks)

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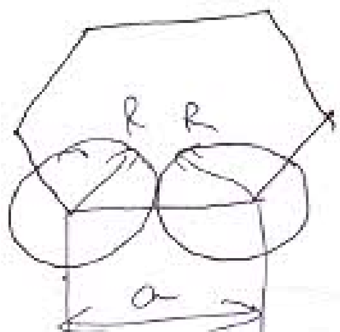
Solution to VTU question Paper dec-Jan 2018

① ⓐ Atomic Packing factor of a unit cell states the amount of space occupied by the atoms in the unit cell.

APF of HCP.




Each and every corner atom touches the neighbouring corner atom.

$\therefore$ $\boxed{D = a}$

No of atoms per unit cell:-

$\frac{1}{6} \times 12 + \frac{1}{2} \times 2 + 3 = 6.$

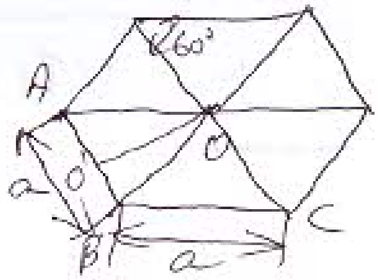
Co-ordination No = 12.

APF:-

Volume of spheres in unit cell $= V_s = \frac{4}{3}\pi R^3 \times 6$

$\Rightarrow V_s = \frac{4}{3}\pi\left(\frac{a}{2}\right)^3 \times 6 = \pi a^3.$

Volume of unit cell




Each hexagonal face consists of 6 equilateral triangles.

Area of base = area of 6 $\Delta^{le}$.

$= 6 \times ABO$

$= 6 \times \frac{1}{2} \times AB \times OO'$

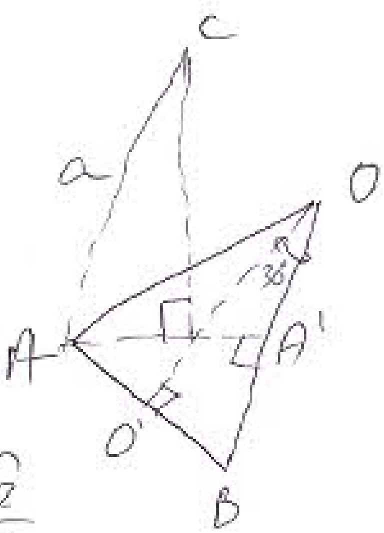
$= 6 \times \frac{1}{2} \times a \times OO'$ —— (1)

Now

$\cos 30° = \frac{OO'}{OB} = \frac{OO'}{a}$

$\Rightarrow OO' = a \cos 30°$

$= a \frac{\sqrt{3}}{2}$ —— (2)




Putting (2) in (1),

Area of base $= 6 \times \frac{1}{2} \times a \times a \frac{\sqrt{2}}{2}$

$= \frac{3\sqrt{3}}{2} a^2$.

Volume of unit cell = Area of base × height.

$= \frac{3\sqrt{3}}{2} a^2 \times c$ ⟶ (3)

To find relation b/w a & c,

In $\Delta A'AB$, $\cos 30° = \frac{AA'}{AB}$.

$AA' = AB\cos 30° = a\frac{\sqrt{3}}{2}$.

$AX = \frac{2}{3}AA' \Rightarrow AX = \frac{2}{3} \times \frac{\sqrt{3}}{2}a = \frac{a}{\sqrt{3}}$ ⟶ (4)

In $\triangle AXC$

$AC^2 = AX^2 + XC^2$

$\Rightarrow a^2 = \left(\frac{a}{\sqrt{3}}\right)^2 + \left(\frac{c}{2}\right)^2$

$\Rightarrow \frac{c}{a} = \sqrt{\frac{8}{3}}$

$\Rightarrow \boxed{\frac{c}{a} = 1.633}$

∴ Putting c/a ratio in eqn (3)

$V_c = \frac{3\sqrt{3}}{2}a^2 \times c = \frac{3\sqrt{3}}{2}a^3 \times 1.633$

$\therefore APF = \frac{\pi a^3}{\frac{3\sqrt{3}}{2}a^3 \times 1.633} = 0.74.$

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1(b) Classification of crystal defects:-

(i) Point defects
- → Vacancy defects
- → Interstitial defects
- → substitutional —"—

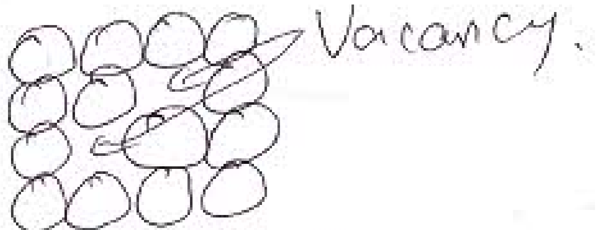
(ii) Line defects
- → Edge dislocation
- → Screw dislocation.

(iii) Surface defects

- → Grain boundary defect
- → Tilt boundary defect
- → Twin — " —

(iv) volume defects.

Vacancy defect is the simplest form of point defect, here one (or) more atoms are missing from the crystal lattice.

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(Q) (1) (c) Given.

Temperature = 700°C = 973 K.

$D_0 = A = 4.9 \times 10^{-5}\ m^2/s$

$Q = E = 153.2\ KJ/mol = 153.2\ J/mol$

$$D = D_0 e^{\left(\frac{-Q}{RT}\right)}$$

$$D = Ae^{\left(\frac{-E}{RT}\right)} = 4.9 \times 10^{-5}\ e^{\left(-\frac{153.2 \times 10^3}{8.314 \times 973}\right)}$$

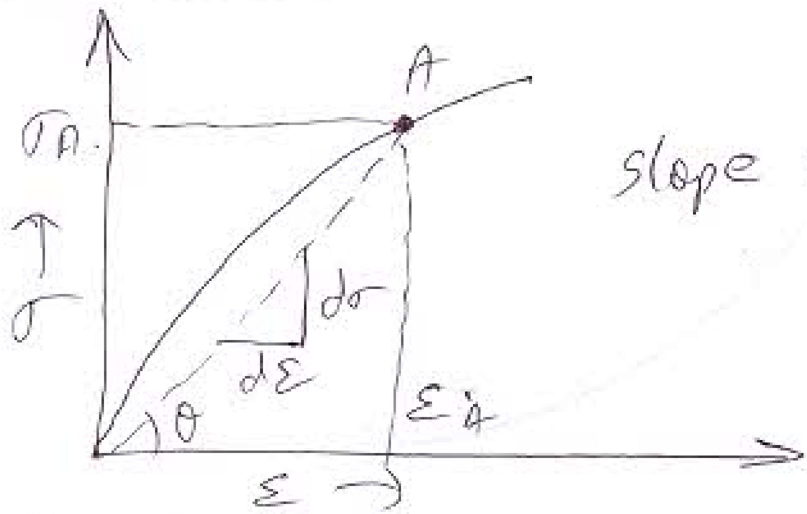
$$\Rightarrow \boxed{D = 2.92 \times 10^{-13}\ m^2/s.}$$

2 (a) Linear elastic properties :-

(i) Elastic strength
(ii) Stiffness.
(iii) Resilience

Non-Linear elastic properties:-

(i) Secant Modulus

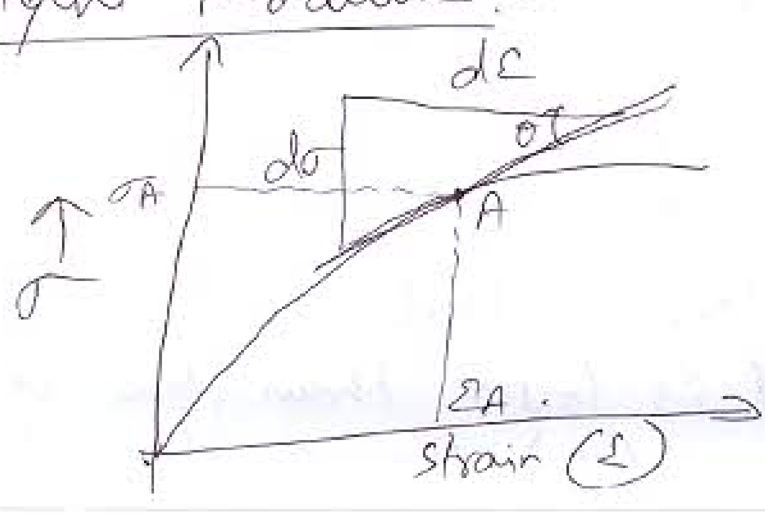



slope $= \frac{d\sigma}{d\varepsilon}$ = secant modulus

Secant modulus is the measure of average stiffness at any given stress value.

$$E_{sec} = \left[\frac{\sigma}{\varepsilon}\right]_{\sigma=\sigma_A} = \tan\theta$$

(ii) Tangent Modulus:-



When the non-linearity of the curve is too high, tangent modulus is used.

$$E_{tan} = \left\{\frac{\sigma}{\varepsilon}\right\}_{\sigma=\sigma_A} = \tan\theta.$$

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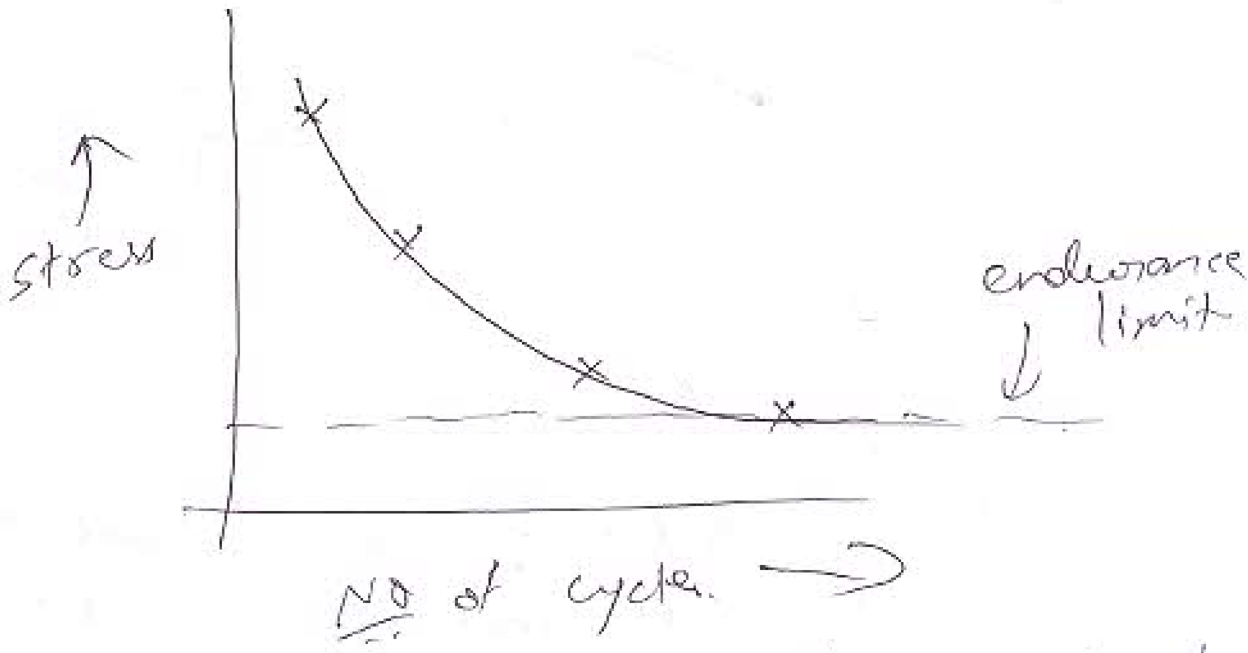
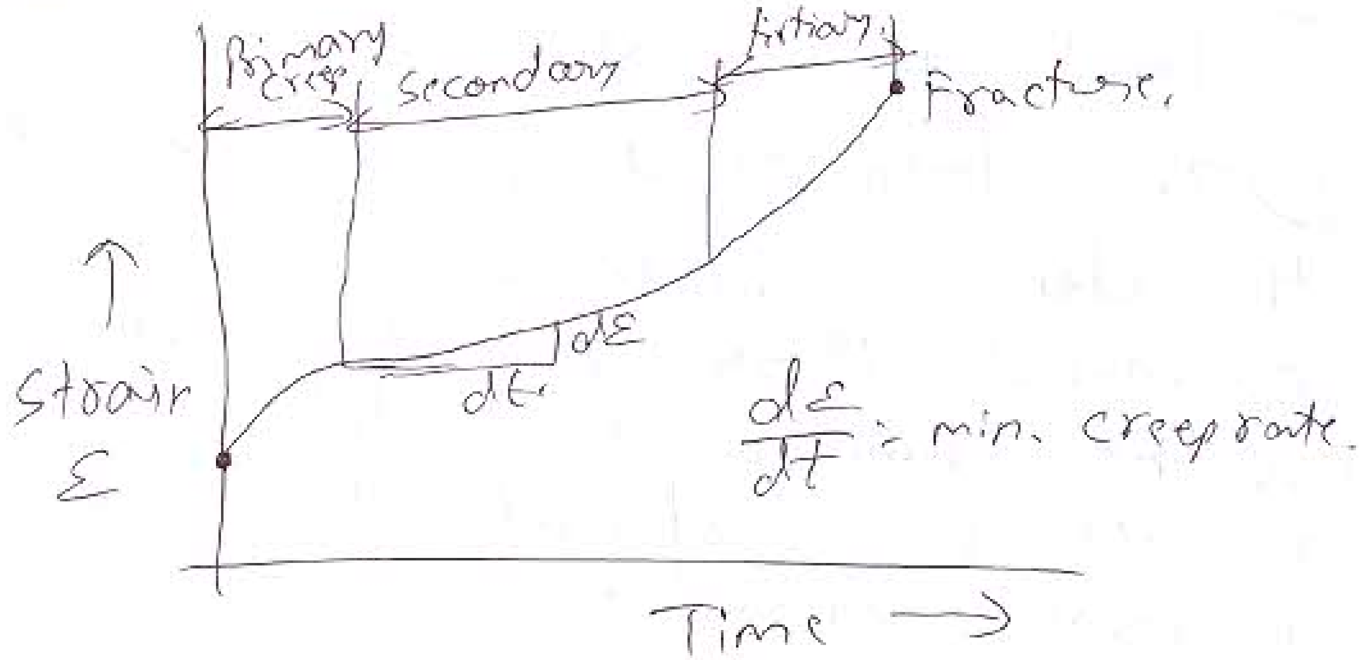
(2) (b) S-N curve




The above diagram represents a typical S-N curve. This curve is ploted to represent the experimental data obtained from fatigue testing. As the stress level is higher, the sample fractures at a lower no of cycles but as the stress level on the sample reduces, the No of cycles to failure increases. Once the stress level is lower than the endurance limit (for ferrous metals), the sample will not fracture even after an infinite $n^o$ of cycles?

Creep curve:—




During the primary creep stage the rate of strain is higher and then during the second stage the strain rate is reduced because of the strain hardening effect. This is the stage on the creep cycle that the material endures all the stress during its usable life. Here the strain rate is very low. Then comes the third stage of creep where the strain rate increases again due to lowered c/s over the secondary stage and increased stress. At the end of this stage the specimen fractures without any warning.

(8)

③ ⓐ Hume-Ruthery rules

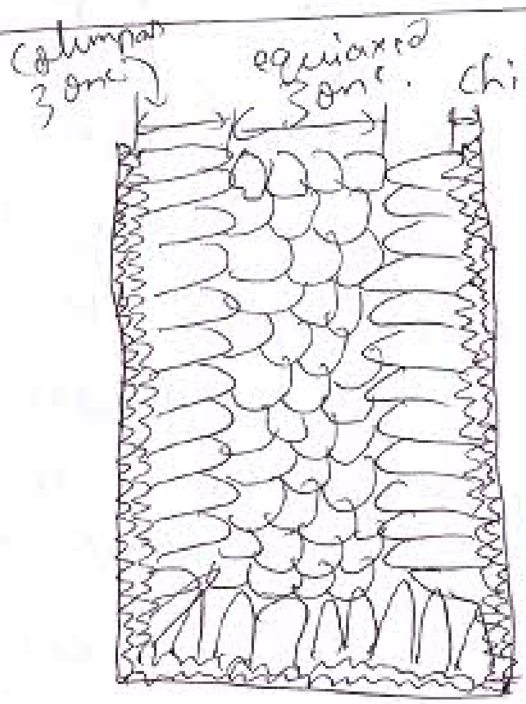
(i) Size difference b/w the solute & solvent atoms must be less than 15%.

(ii) The electro negativity difference b/w the elements should be small. (min chemical affinity to each other)

(iii) The solubility of metal with high valence in a solvent of lower valence is more compared to the inverse.

(iv) For complete solubility over the entire range of compositions, the crystal structure ~~str~~ of the solute & solvent ~~ha~~ must be the same.

③ ⓑ



Chill zone

This is formed close to the walls of the mould as heat is extracted at a higher rate.

Columnar zone:-

~~Oncer~~ Once the grains are formed by ~~chil~~ chilling effect, the moltenmetal gets a stable platform on which long grains grow.

Equiaxed zone

In this zone the metal solidifies due to constitutional cooling.

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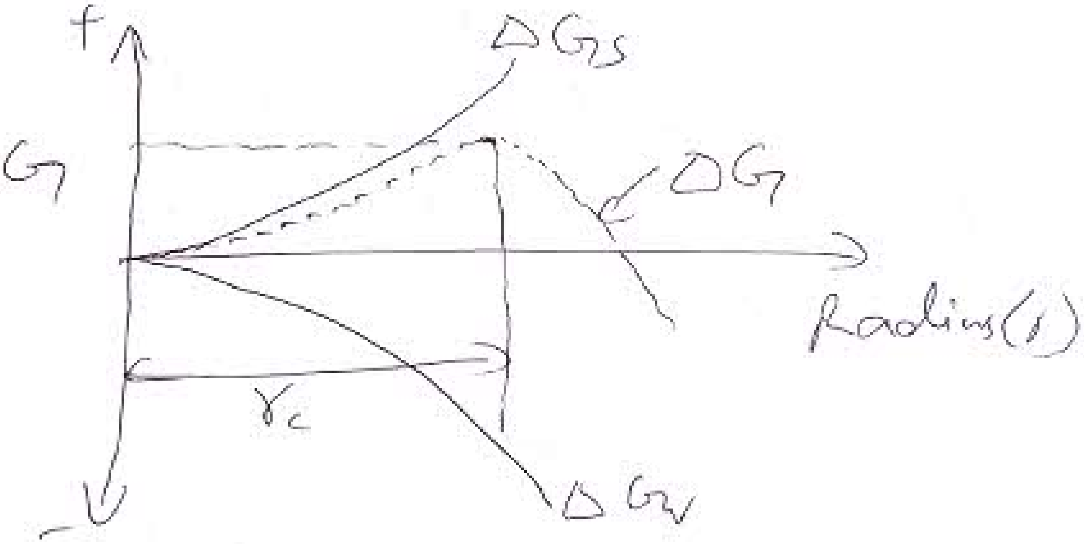
(4) (a) Homogeneous Nucleation occurs in the liquid metal with the help of any impurities.

Heterogenious nucleation ~~the~~ takes place in the presence of impurities / air bubbles.




Volume free energy $G_v = -\frac{4}{3}\pi r^3 \Delta G_v$

Surface energy = $G_s = 4\pi r^2 \gamma$

$\Delta G = G_v + G_s$

$\Delta G = -\frac{4}{3}\pi r^3 \Delta G_v + 4\pi r^2 \gamma$

$\frac{d}{dr}(\Delta G) = \frac{d}{dr}\left(-\frac{4}{3}\pi r^3 \Delta G_v + 4\pi r^2 \gamma\right) = 0$

$= 4\pi r^2 \Delta G_v + 8\pi r \gamma = 0$

$$r = r_c = \frac{2\gamma}{\Delta G_v}$$

(4) (b) As we know steel is an alloy of Iron, Carbon and various othe elements present in miniscule amounts. But all of these minor elements have some-thing to ~~give to~~ contribute to the property of the steel.

For example ~~is~~ if carbon is added, hardness increases.

If Chromium is aded it forms a chromium oxide passive layer to prevent carrosion. Molybdenum increases hardness and toughness, Phosphorus increases yield strength, Lead increases machinability.

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(5) (a) Heat treatment is defined as controlled heating and cooling of a metal inorder to alter its physical and mechanical propertis without changing its shape

Classification of heat treatment:-

(i) Annealing.

(ii) Normalizing.

(iii) Hardening.

(iv) Tempering.

(v) Austempering.
(vi) Martempering.
(vii) Surface hardening.

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(5) (b) Austempering is a process where steel is completely austenized and the quenched to a lower temp at around 400°C. Then maintained at the same temp until the formation of Bainite.

Where as Martempering is a process in which the steel is austenized the quenched to just above Martensitic temp and then maintained there till the entire cross section reaches that temp then cooled in air to form martensite.

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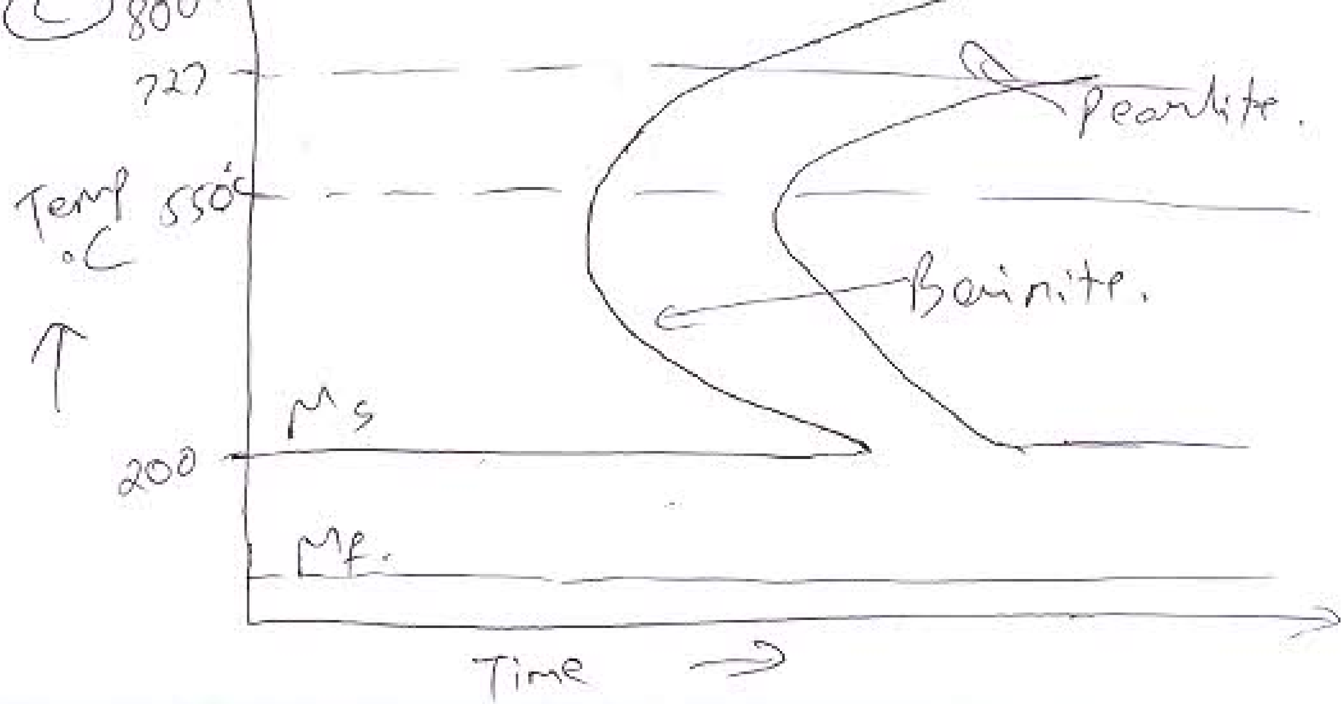
(5) (c)



TTT diagram explains how the different phases in steel can be formed by just ~~varying~~ controlling the temp of cooling.

~~If~~ First the steel is completely austenized then if it is cooled slowly it forms pearlite, if it is quenched to around 400°C then cooled at that temp it formes Bainite. ~~If~~ If its quenched directly below 200°C ~~to~~ it forms martensite directly from austenite.

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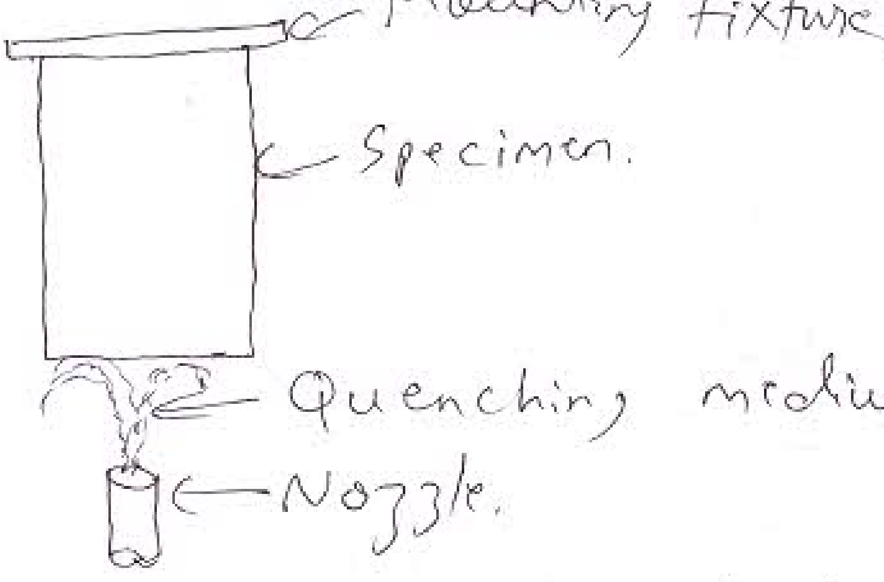
(b) (a)




The sample is first austenized then placed in the fixture, then its subjected to ~~a~~ spray ~~@~~ of uniform flow rate. Now the specimen cools at different rates the the sections of the specimen is taken then tested with rockwell hardness test.

(6)(b) When there is an alloy of Al with any other element, its starts to age harden. Age hardening is the hardening of the alloy by precepitation of the solute elements. This occurs naturaly ~~oth~~ over a long time, but this process can be fastened by heat treatment process. In this process the alloy is heated to a certain temp where it is held for a few hours depending on the cross section and amount of precipitation required then its quenched to retain that precipitation and hence the required hardness.

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(6)(c) Gray Cast iron:-

Composition:-

C − 2.5 − 3.8 %

Si − 1.1 − 2.8 %

Mn − 0.4 − 1 %

P − 0.15 %

S − 0.1 %

Fe − Remainder.

Properties:-

→ MP − 1127°C to 1206°C.

→ Brinell hardness no = 260
→ Density – 7.2 g/cm³

Uses:-
→ Gas & water pipes
→ Manhole covers
→ sanitary Wares
→ Piston rings.

S.G. Iron

Composition:-
C – 3.2 – 4.2%
Si – 1.1 – 3.5%
Mn – 0.3 – 0.8%
Ph – 0.08%
S – 0.2%
Fe – Remainder

Properties
→ M.P. – 1149°C
→ Density – 6.66 g/cm³
→ Brinell hardness Number is 170.

Uses:-
→ Valves & fittings
→ Pumps & compressor.
→ Farm implements

7 (a) Ceramics are inorganic solid materials, containing compounds of metallic & non-metallic nature.

Types of ceramics

→ Traditional ceramics :-

Silica, Feldspar, Dolomite, Calcite.

→ Advanced ceramics:-

Aluminium Oxide, Zirconium oxide.

→ Glass ceramics :-

CaO, $Na_2O$.

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7 (b) Mechanical Properties

→ Low tensile & high compressive strength.

→ Low fracture toughness

→ High hardness

→ Higher wear resistance.

Applications:-

→ Pottery.

→ disc brakes

→ Pyrometers

→ Burner tips.

... (or) more properties that ... designed materi-
... significantly changed in a
controlled fassion. by means of external
stimuli.

Types of Smart Materials

-> Piezo electric Materials
-> Shape memory alloy.
-> Electro-rheostatic alloys.
Quantum Tunneling Composity.

② Shape memory alloy :-
* They exhibit shape memory effect based
change in temp and pseudo- elasticity
... on change in internal stresses.
... the alloy is at room temp, it can
...formed but when its heated it will
... its original shape.

...zo electric materials :-
... electric material emits an electric
... on mechanical deformation and can be
...ally deformed by supplying ~~is~~ ~~are~~ a
... across it. Usually quartz is used to
... these material.

(8)(c) Fiber optic matrial :—

Fiber optic matrial is used to make cables which carry electric signals in the form of light with very minimum loss. Its made of a glass tube in which the signals in form of laser light is made to travel by undergoing total internal reflection in the fiber. Its faster & has less no of losses.

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(8)(b) Use of non-destructive testing :—

Non-destructive testing is done on a component which is not intended to be broken. These tests help us identify if there are any internal or external defects without breaking the component.

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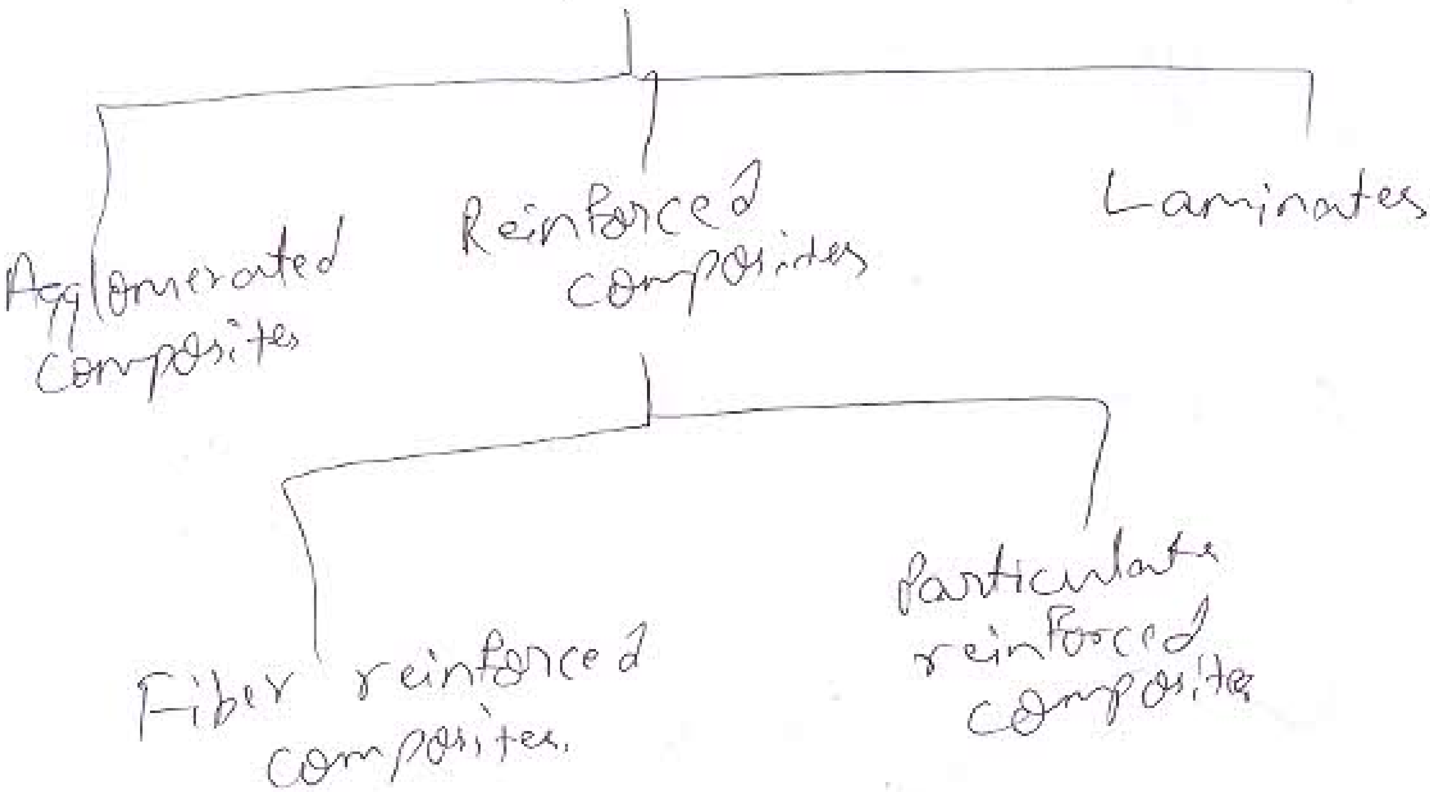
(9)(a) Composites can be defined as the combination of two or more materials with different physical & chemical properties, which is synthetically manufactures

P.T.O.

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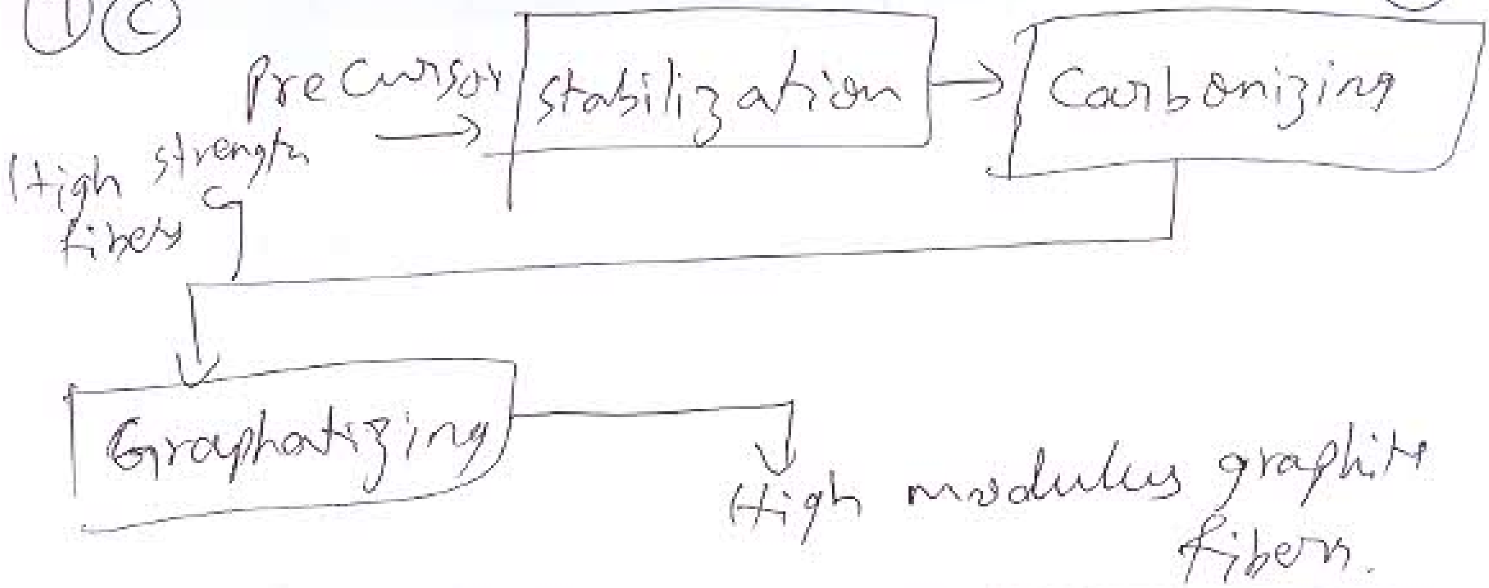
9(b) Role of matrix:-

→ It binds & holds the reinforcements in place.
→ It helps protect the reinforcement.
→ It transfers the load uniformely.

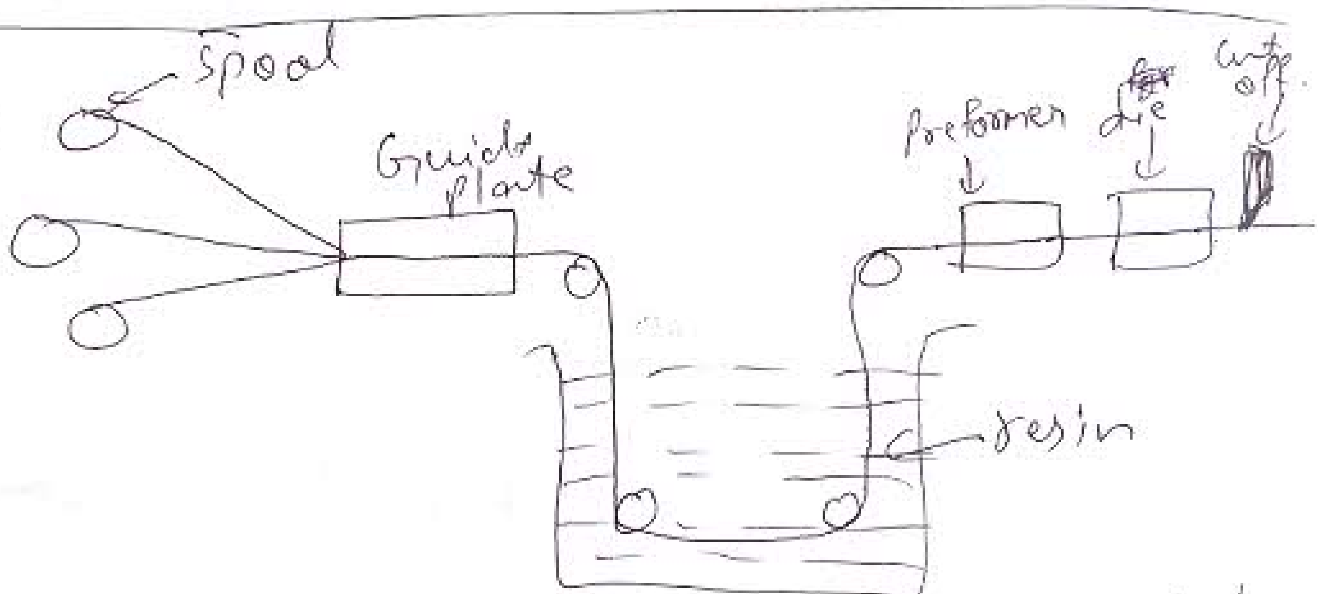
Role of reinforcements:-

→ It carries the bulk of the load
→ It provides stiffness to the composite.
→ It should ~~not be cha~~ be chemically stable.

(9) (c)




(10) (a)




Fibers from different spools are guided into the resin bath and then preformed by heating it then its pulled through a die with the help of rollers and then cut off at required lengths.

(10) (b) Advantages of composites

→ Higher strength to weight ratio.
→ Non-corrosive.
→ Chemically inhert.

(iv) higher load carrying capacity.
(v) Easy to process.

Applications :-

(i) Used in skin of aircrafts.
(ii) Used in brake discs.
(iii) Used in tyres.
(iv) Used in golf clubs.
(v) Used in bicycle frame.

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(10) (c) $E_{epoxy} = 42\times10^2\ N/mm^2 = E_m$

$E_{carbon\ fiber} = 37.86\times10^4\ N/mm^2 = E_f$.

Volume fraction of fiber $= V_f = 62\% = 0.62$

$V_f + V_m = 1 \Rightarrow V_m = 1 - V_f$

$\Rightarrow V_m = 1 - 0.62$

$V_m = 0.38$.

Iso-stress condition (Transverse modulus)

$$(E_c)_2 = \frac{E_f \cdot E_m}{E_f \cdot V_m + E_m V_f} = \frac{(37.86\times10^4)(42\times10^2)}{\left[(37.86\times10^4)(0.38)+(42\times10^2)(0.62)\right]}$$

$$\Rightarrow (E_c)_2 = 0.1085\times10^5\ N/mm^2.$$

Iso - strain condition (Longitudinal modulus)

$(E_c)_1 = E_f V_f + E_m V_m$

$= [(37.86 \times 10^4)(0.62) + (42 \times 10^2)(0.38)]$

$(E_c)_1 = 2.36 \times 10^5 \ N/mm^2$