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Scheme and solution of Internal Assesment Test - II

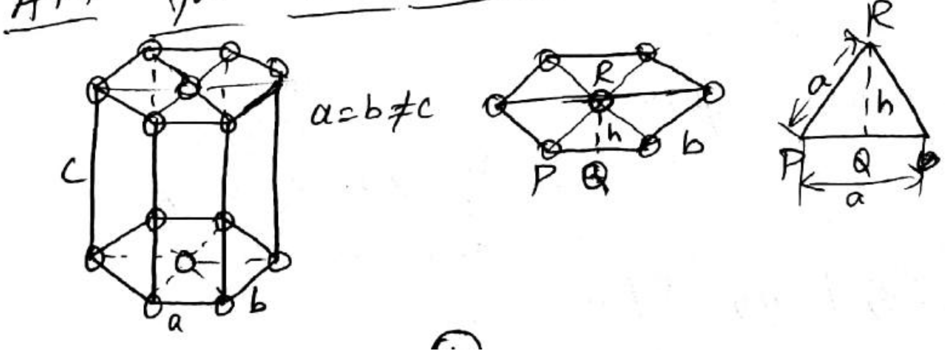
Sub:	Material Science							Code:	18ME34
Date:	12 / 10 / 2019	Duration:	90 mins	Max Marks:	50	Sem:	III	Branch:	Mechanical

Answer ALL FIVE Questions

		Marks	OBE	
			CO	RBT
1.	Derive the atomic packing factor for a hexagonal close packed structure. **Derivation with diagram – 10Marks**	[10]	CO1	L3
2.	To produce a p-type semiconductor, boron is doped in pure silicon. Doping is done by B_2O_2 vapour. The atmosphere is equivalent to a surface concentration of $3X10^{26}$ boron atoms per cubic meter. Calculate the time required to get a boron content of 10^{23} atoms per cubic meter at a depth of 2.5µm. The doping temperature is 1100˚C and D at this temperature is $4X10^{-17} m^2/s$. **Given data – 2 Marks** **Equation – 2 Marks** **Steps and solution – 6 Marks**	[10]	CO2	L3
3.	Define fatigue failure. With diagrams explain three types of fatigue loading. **Definition – 2 marks** **Types of fatigue with graphs – 8 marks**	[10]	CO2	L1
4.	a.Why is the surface of a metal considered to be a defect. What are grain boundaries and why are they said to be defects? **Surface defect explanation – 4 marks** **Grain boundary explanation – 6 marks**	[6]	CO1	L1
	b. Define unit cell, space lattice, atomic packing factor and co-ordination number with respect to crystal structure. **4 definitions – 1Mark each**	[4]	CO1	L1
5.	The surface of a steel gear made of 1020 (0.2% carbon) is to be carburized at 927ºC. Calculate the time required to increase the carbon content to 0.4% at 1mm below the surface if the carbon potential at the surface is 1.2%. Diffusion co-efficient at 927ºC is $1.28 \times 10^{-11} m^2/sec$ and erf (0.9) = 0.8 **Given data – 2 Marks** **Equation – 2 Marks** **Steps and solution – 6 Marks**	[10]	CO2	L3

1.

APF for HCP structure



Atomic packing factor APF = $\dfrac{\text{Volume of atoms per unit cell}}{\text{volume of unit cell}}$

$= \dfrac{\text{Volume of each atom} \times \text{number of atoms per unit cell}}{\text{Volume of unit cell}}$ → (1)

Volume of each atom (sphere) $= \frac{4}{3}\pi r^3$ → (2)

To find number of atoms per unit cell

In an HCP structure there are totally 12 atoms at the corners of each face of HCP. However only $\frac{1}{6}$ th of each corner atom is actually inside the unit cell.

Also ½ of the volume of each atom at the center of both top & bottom faces. In addition 3 atoms completely inside the unit cell

∴ Total number of atoms $= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 2+1+3 = 6$ atoms → (3)

Volume of an HCP ~~each~~ unit ~~unit~~ cell

Volume of an HCP = Cross sectional area of hexagon × height of hexagon (c)

Cross sectional area of HCP

Let the hexagonal plane be divided into 6 triangular parts

Let 'h' be the height of the triangle

Area of hexagonal face = area of each triangle × Number of triangles

$= \frac{1}{2} b \times h \times 6$

$= \frac{1}{2} a \times h \times 6$

Area of hexagonal face $= 3ah$ → (4)

Consider the right angle triangle

$\Delta^{le}\ PQR \ni PR^2 = QR^2 + PQ^2$

$$a^2 = h^2 + \left(\frac{a}{2}\right)^2$$

$$h^2 = a^2 - \frac{a^2}{4} = \frac{3a^2}{4}$$

$$h = \frac{a\sqrt{3}}{2} \rightarrow (5)$$

Area of hexagonal face $= 3 \times a \times \frac{a(\sqrt{3})}{2} = \frac{3a^2\sqrt{3}}{2}$

Volume of hexagonal unit cell $= \frac{3a^2\sqrt{3}}{2} \times C \rightarrow (6)$

In General the ratio of height of the hexagonal prism (c) to the Side of the hexagonal face (a) is expressed as $\frac{C}{a} = 1.633$

$C = 1.633\, a$

Volume of hexagonal unit cell $= \frac{3a^2\sqrt{3}}{2} \times (1.633\, a)$

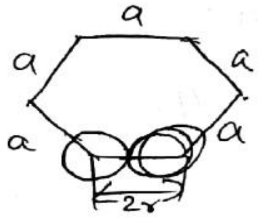
$= 4.242\, a^3 \rightarrow (7)$

Substituting (2), (3) & (7) in equation (1)

$$APF = \frac{\frac{4}{3}\pi r^3 \times 6}{4.242\, a^3} = \frac{8\pi r^3}{4.242\, a^3}$$

To express 'a' in terms of 'r' = ?

$\therefore a = 2r$



$$APF = \frac{8\pi r^3}{4.242(2r)^3} = \frac{8\pi r^3}{4.242 \times 8 r^3} = 0.74$$

$APF = 0.74$ or 74%.

So HCP is packed with atoms around 74% & 26% is empty space.

(2) Given:-

$C_s = 3 \times 10^{26}$ atoms/m^3

$C_x = 10^{23}$ atoms/m^3

$C_o = 0$ atoms/m^3

$x = 2.5\ \mu m = 2.5 \times 10^{-6}$ m

$T = 1100^\circ C = 1373 K.$

$D = 4 \times 10^{-17}\ m^2/s$

$t = ?$

$$\frac{C_x - C_o}{C_s - C_o} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\frac{10^{23} - 0}{3 \times 10^{26} - 0} = 1 - \text{erf}\left(\frac{2.5 \times 10^{-6}}{2\sqrt{4 \times 10^{-17} \times t}}\right)$$

$$3.333 \times 10^{-4} = 1 - \text{erf}\left(\frac{197.64}{\sqrt{t}}\right)$$

$$\Rightarrow \text{erf}\left(\frac{197.64}{\sqrt{t}}\right) = 0.9996$$

z	$\operatorname{erf}(z)$
2.4	0.9993
z	0.9996
2.6	0.9998

By interpolation,

$$\frac{z-2.4}{2.6-2.4}=\frac{0.9996-0.9993}{0.9998-0.9993}$$

$$\Rightarrow z=2.52.$$

$$\Rightarrow \frac{197.64}{\sqrt{t}}=2.52.$$

$$\Rightarrow \sqrt{t}=\frac{197.64}{2.52}$$

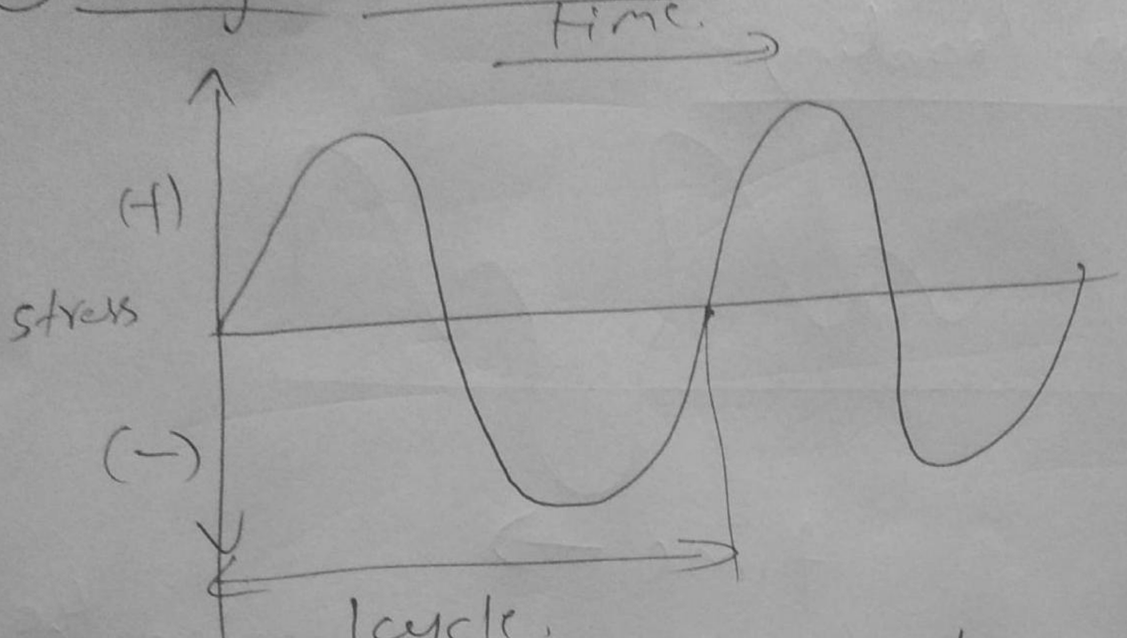
$$\Rightarrow \boxed{t=6151.04 \text{ seconds}}$$

Q3. Fatigue failure is said to occur in a material when it is subjected to cyclic loading and the load applied is less than its fracture load.

Types of fatigue loading:-

(i) Fully reversed loading.
(ii) Repeated loading.
(iii) Irregular loading.

(i) Fully reversed loading:-

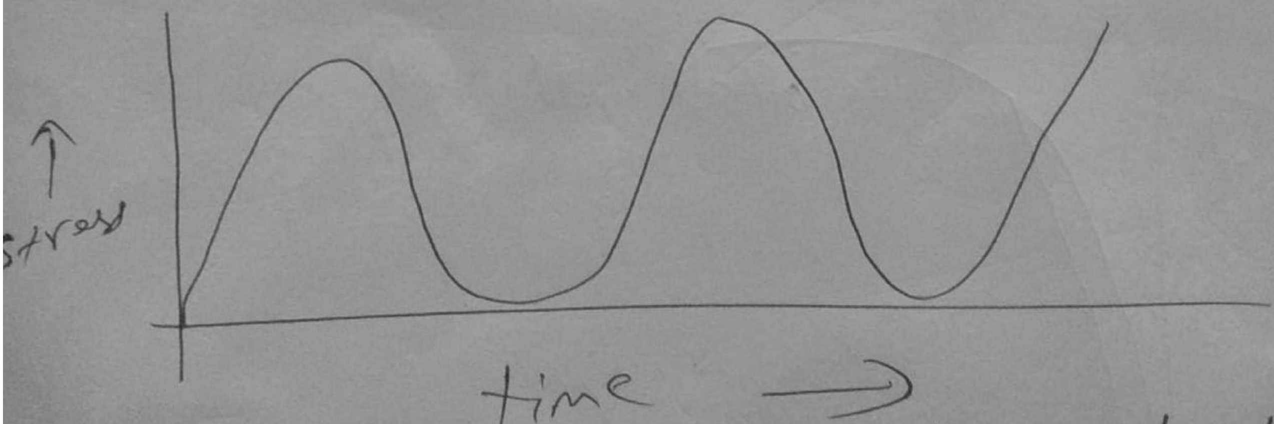


stress level

In this type of loading the stress
is taken to one extreme end of the spectru
and then it is reversed completly to the oth
side of the spectrum to the same magnitude

Eg:- Rotating shafts.

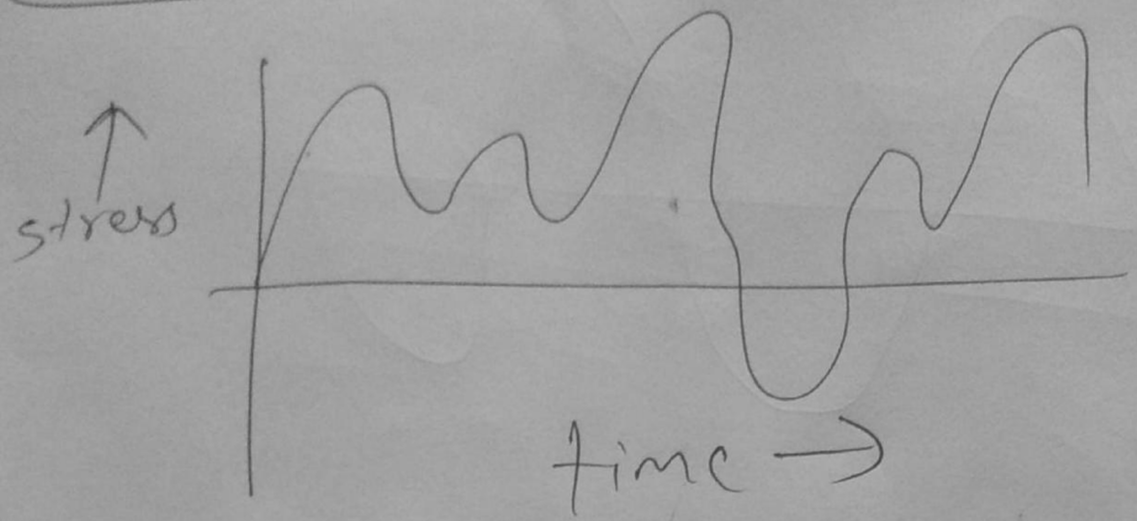
(ii) Repeated loading:-



In this type of loading the material is subjected to a max stress and then reduced to a minimum stress but of the same nature. This can be either tensile (or) compressive in nature. The loads operate within this envelop.

Eg. Fuselage of an aircraft

(iii) Irregular loading:-



This type of loading occurs when the material is usually left to face the elem[ents] like wind, in nature. Here the loading on the material is unpredictable.

Eg:- Blades of windmill (or) wings of an aircraft.

4.

(b) (i) Unit cell:- It is the smallest ... block of the crystal. It repeats itself over large atomic distances to produce the crystal structure.

(ii) Space lattice:- It is the 3-D array of points, each point representing an atom. Every atom in a particular space latice will have the same surroundings as any other point in the same space latice

(iii) APF:- It is the space occupied by atoms in a unit cell. It is given by.

$$APF = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

(iv) Co-ordination number:-

It is the number of ~~nearest~~ adjacent atoms to any given atom. It remains same for every atom in that particular space lattice.

Problem 8 A 1020 steel is to be gas carburized at 927°C. The carbon content of the surface of the gear is 0.90% and the steel has a nominal carbon content of 0.20%. Calculate the carbon content at 0.5 *mm* beneath the surface of the gear after 5 *hours* carburizing time. $D_{927°C} = 1.28 \times 10^{-11}\ m^2/sec$. Take error function values erf(0.5) = 0.5205 and erf(0.55) = 0.5633.

Solution : Temperature = $927°C = 927 + 273 = 1200\ K$

$$\text{Carbon content of the gear} = C_o = 0.2\%$$

$$\text{Carbon content at the surface} = C_S = 0.9\%$$

$$\text{Depth of Carburization} = x = 0.5\ mm = 0.5 \times 10^{-3} m$$

$$\text{Time of Carburization} = t = 5\ hours = 5 \times 60 \times 60 = 18000\ seconds.$$

To find Carbon content (C_x) needed at a distance of $x = 0.5\ mm$ from the surface

$$\text{w.k.t.}\quad \frac{C_s - C_x}{C_s - C_o} = erf\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\frac{0.9 - C_x}{0.9 - 0.2} = erf\left(\frac{0.5 \times 10^{-3}}{2\sqrt{(1.28 \times 10^{-11})18000}}\right)$$

$$\frac{0.9 - C_x}{0.7} = erf(0.5208) \qquad \text{-----}(1)$$

$$\text{Let}\quad y = \frac{0.9 - C_x}{0.7} \qquad \text{-----}(2)$$

$$\therefore \text{ equation (1) reduces to, } y = erf(0.5208) \qquad \text{-----}(3)$$

It is clear that, erf(0.5208) = y lies between the 2 values given in the table below.

i.e.,

z	*erf (z)*
0.50	0.5205
0.5208	$y = ?$
0.55	0.5633

$$\text{By interpolation,}\quad \frac{0.5208 - 0.50}{0.55 - 0.50} = \frac{y - 0.5205}{0.5633 - 0.5205}$$

$$\therefore\ y = 0.538 \qquad \text{-----}(4)$$

$$\text{Comparing equation (2) and (3) we have, } y = \frac{0.9 - C_x}{0.7} = 0.538$$

$$0.9 - C_x = 0.3766 \qquad \mathbf{C_x = 0.523\%}$$