CMR INSTITUTE OF TECHNOLOGY

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Internal Assesment Test - I

Sub:	Material Science							Code:	15ME32A
Date:	18 / 09 / 2017	Duration:	90 mins	Max Marks:	50	Sem:	III	Branch:	Mechanical

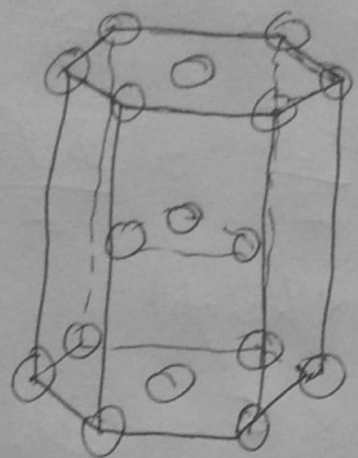
Answer ALL FIVE Questions

		Marks	OBE	
			CO	RBT
1.	Derive the atomic packing factor for a hexagonal close packed structure.	[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 $4X10^{-17} m^2/s$.	[10]	CO1	L3
3.	Define fatigue failure. With diagrams explain three types of fatigue loading.	[10]	CO2	L1
4.	a. With a figure show how you determine offset yield point on a stress-strain curve.	[6]	CO2	L1
	b. Define unit cell, space lattice, atomic packing factor and co-ordination number with respect to crystal structure.	[4]	CO1	L1
5.	Derive an expression to show that maximum shear stress is experienced by a slip plane at an angle of 45° with respect to the force applied.	[10]	CO2	L3

Material Science 15ME32A.

IAT-1 solution (2017-18).

Q.1 Hexagonal ~~closed~~ close packed structure :-



No of atoms per unit cell :-

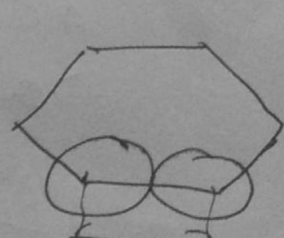
$$\frac{1}{6} \times 12 + \frac{1}{2} \times 2 + 3 = \underline{\underline{6}}.$$

A.P.F :-

$$APF = \frac{\text{volume of spheres}}{\text{Volume of unit cell}} = \frac{V_s}{V_u} \longrightarrow 1$$

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

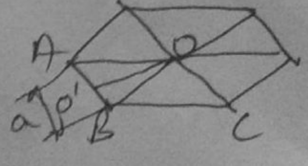
$$\Rightarrow \boxed{V_s = \pi a^3} \quad \text{—— } 2$$



To calculate V_u :-

Area of base = area of 6 equilateral Δ'es

Area = 6 × ΔABO.



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

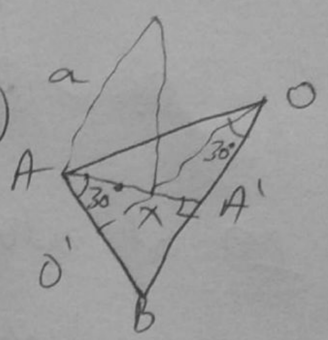
Now

$$\cos 30^\circ = \frac{OO'}{OB} = \frac{OO'}{a}$$
$$\Rightarrow OO' = a\cos 30^\circ \Rightarrow OO' = \frac{a\sqrt{3}}{2}$$

$$\Rightarrow \text{Area} = 6 \times \frac{1}{2} \times a \times \frac{a\sqrt{3}}{2} = \frac{3\sqrt{3}}{2} a^2.$$

But Volume = area × height.

$$\Rightarrow \text{Volume} = \frac{3\sqrt{3}}{2} a^2 \times c \quad \text{— (3)}$$



From $\Delta A'AB$, $\cos 30^\circ = \frac{AA'}{AB}$

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

$$AX = \frac{2}{3} AA' \Rightarrow AX = \frac{2}{3} \frac{\sqrt{3}}{2} a = \frac{a}{\sqrt{3}}$$

In ΔAXC

$$AC^2 = AX^2 + XC^2$$
$$\Rightarrow a^2 = \left(\frac{a}{\sqrt{3}}\right)^2 + \left(\frac{c}{2}\right)^2 \Rightarrow a^2 = \frac{a^2}{3} + \frac{c^2}{4}$$
$$\Rightarrow \frac{c^2}{4} = a^2 - \frac{a^2}{3} \Rightarrow \frac{c^2}{4} = a^2\left(1 - \frac{1}{3}\right) \Rightarrow \frac{c^2}{a^2} = \frac{8}{3}$$
$$\Rightarrow \frac{c}{a} = \sqrt{\frac{8}{3}} \Rightarrow \boxed{c = 1.633\,a}$$

From (3),

$$V_u = \frac{3\sqrt{3}}{2} a^2 \times 1.633\,a.$$

From 1, 2 & 3 we get

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

$$\Rightarrow \boxed{APF = 0.74} \text{ or } 74\%$$

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2 Given :-

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

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

$C_0 = 0$ atoms/m^3

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

$T = 1100°C = 1373 K.$

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

$t = ?$

$$\frac{C_x - C_0}{C_s - C_0} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

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

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

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

z	$erf(z)$
2.4	0.9993
z	0.9996
2.6	0.9998

By interpolation,

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

$$\Rightarrow z = 2.52.$$

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

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

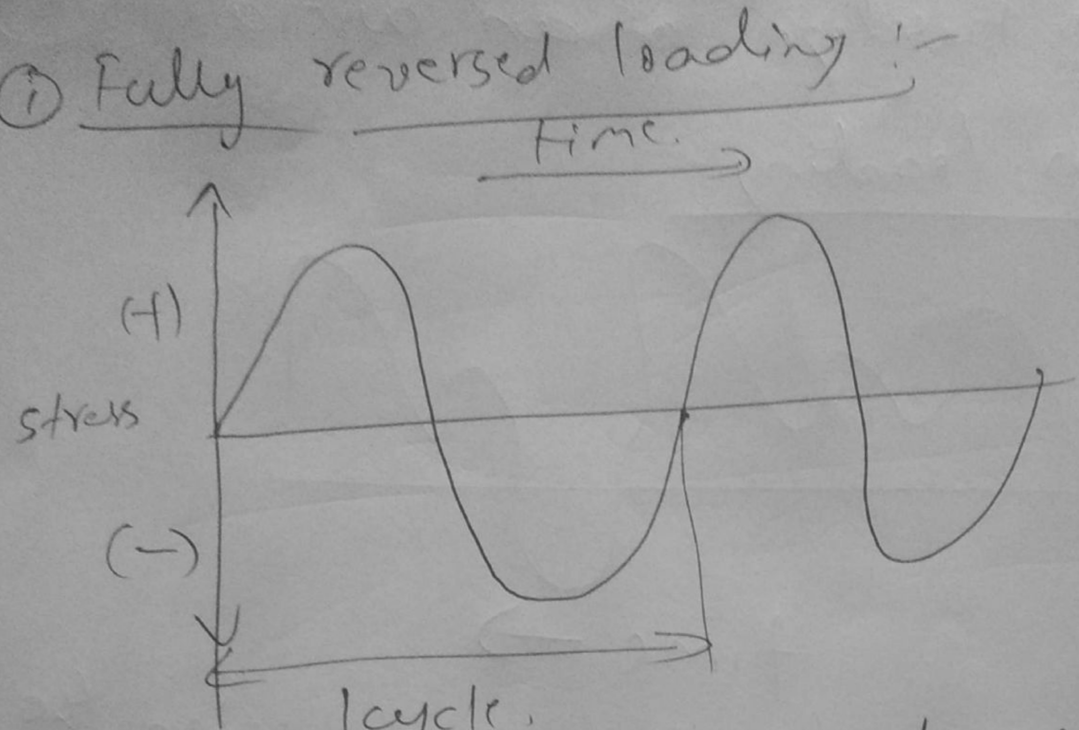
$$\Rightarrow \boxed{t = 6151.04 \text{ seconds}}$$

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.

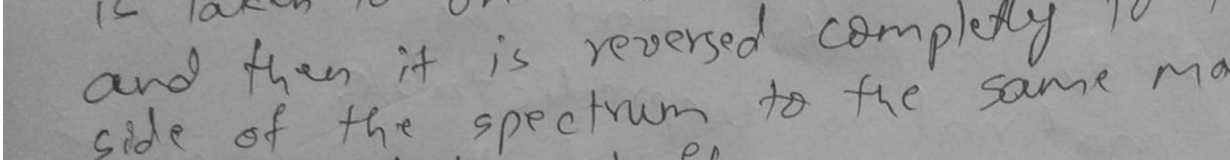
① Fully reversed loading :-



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

Eg:- Rotating shafts.

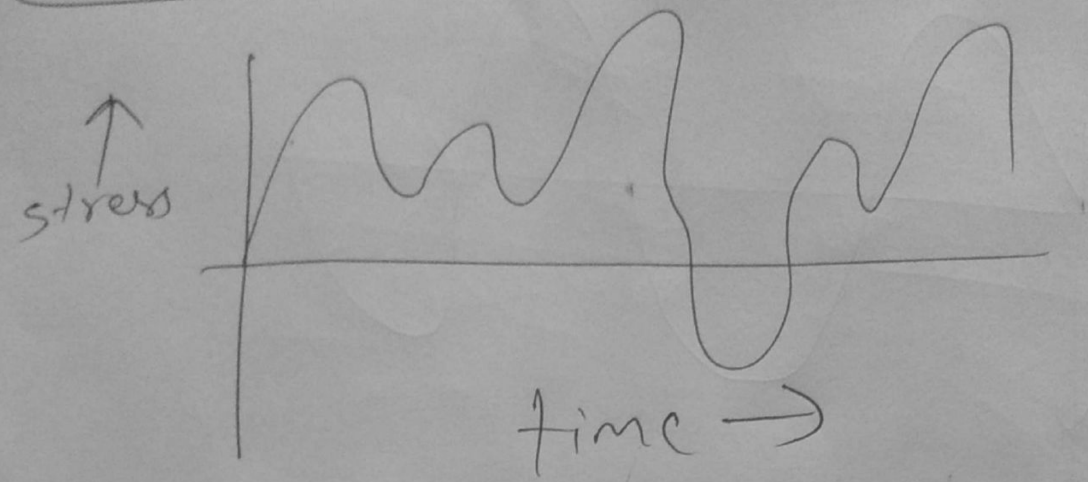
(ii) Repeated loading:-



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 element like wind, in nature. Here the loading on the material is unpredictable.

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

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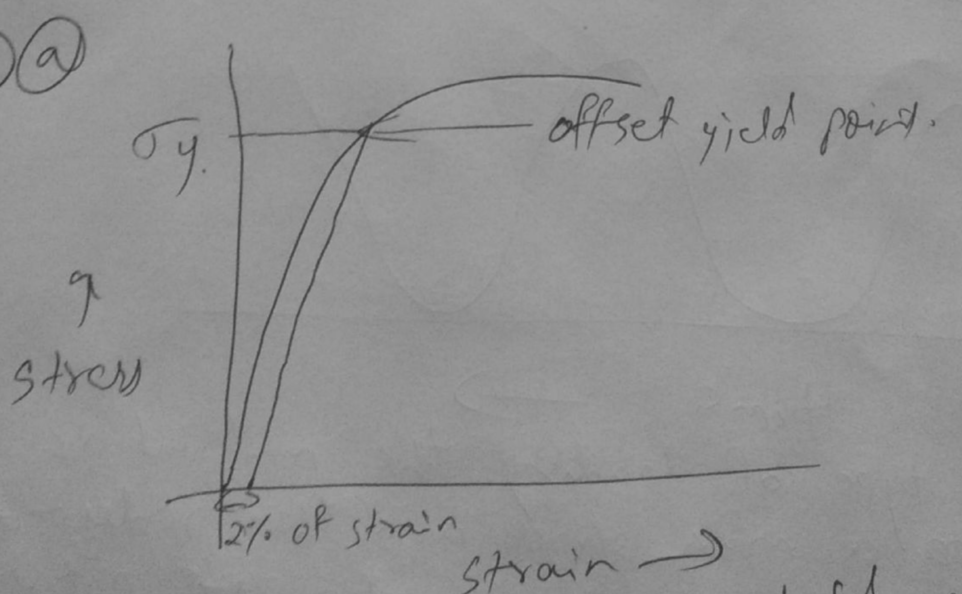
(4) (a)



To determine the offset yield point one must draw a line parallel to the linear portion

(7)

of the curve at an offseting distance of 2% of the entire strain value. Where ever the line meets the curve will be the offset yield point.

(b) (i) Unit cell:- It is the smallest repeatable 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.

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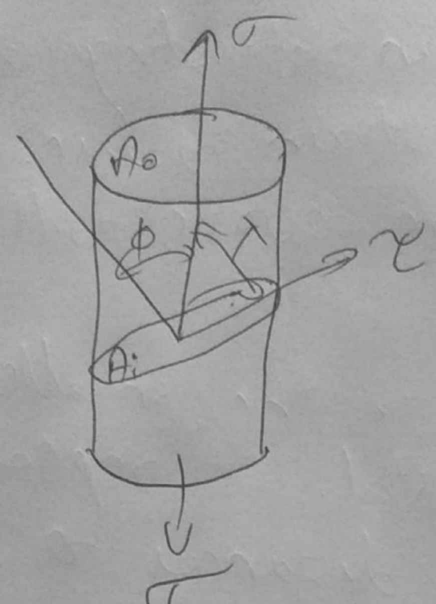
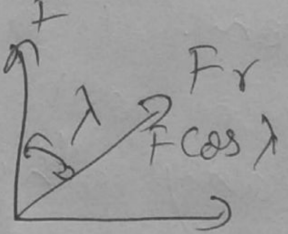
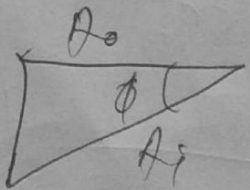


Consider the above cylindrical unit cell where a tensile load is applied w.r.t A_0, but A_i a slip plane at an angle ϕ to A_0 will experience a shear force for the same load



$$\boxed{F_r = F\cos\lambda}$$



and $\frac{A_0}{A_i} = \cos\phi$

$$\Rightarrow A_0 = A_i\cos\phi \Rightarrow \boxed{A_i = \frac{A_0}{\cos\phi}}$$

$$\therefore \tau = \frac{F_r}{A_i} = \frac{F\cos\lambda}{A_0/\cos\phi} \Rightarrow \tau = \frac{F}{A_0}\cos\lambda\cos\phi$$

$$\Rightarrow \boxed{\tau = \sigma\cos\lambda\cos\phi}$$

at $\lambda = 45$ $\phi = 45^\circ$

$$\Rightarrow \tau = \sigma\frac{1}{\sqrt{2}}\cdot\frac{1}{\sqrt{2}} \Rightarrow \boxed{\tau = \frac{\sigma}{2}} = \text{max.}$$