VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

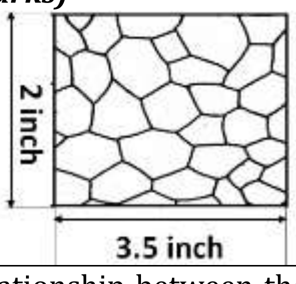
SCHOOL OF MECHANICAL ENGINEERING
CONTINUOUS ASSESSMENT TEST I
FALL SEMESTER 2023-2024

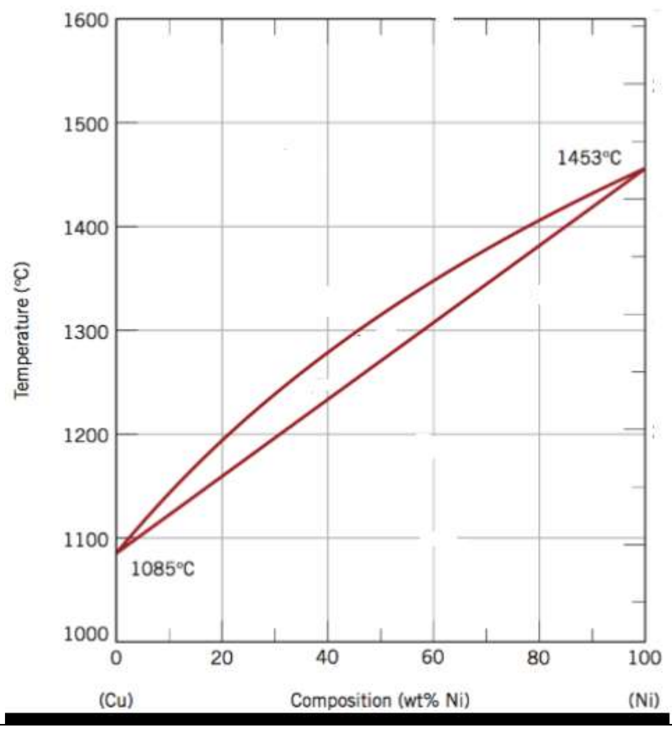
SLOT: B2+TB2

Programme Name & Branch	:	B.Tech. Mechanical Engineering
Course Code	:	BMEE209L
Course Name	:	Materials Science and Engineering
Faculty Name(s)	:	Dr. Ariful Rahaman, Dr. Padmanabhan K, Dr. Sreekanth M.S., Dr. Sitaram Das, Dr. Arivazhaghan N.
Class Number(s)	:	VL2023240101870, VL2023240101663, VL2023240101665, VL2023240101869, VL2023240101661

Exam Duration: 90 minutes **Maximum Marks: 50**

General instruction(s): Answer **all**

Q. No.	**Question**	Marks	Course Outcome (CO)	Bloom Taxonomy (BL)
1.	(a) A ceramic is suspected to have magnesium cations (Mg^{2+}) at locations (½, 0, 0), (0, ½, 0), (0, 0, ½), (½, ½, ½) and oxygen anions (O^{2-}) at all (0,0,0), (½, ½, 0), (½, 0, ½), (0, ½, ½) positions. Draw and label the contents of a unit cell of this material. What is the chemical formula? ***(05 Marks)***	10	CO1	BL3
	(b) On each of three separate drawings of one face of an FCC unit cell, indicate one of each of the following: (i) Substitutional impurity; (ii) vacancy; (iii) interstitial impurity with example. ***(05 Marks)***			
2.	(a) Draw $(1\bar{1}0)$ and $(1\bar{1}1)$ planes in a unit cubic cell. Find the Miller indices of the directions which are common to both the planes. ***(05 Marks)***	10	CO1	BL3
	(b) A cubic metal (r = 0.05 nm) exhibits plastic deformation by slip along <111> directions. Determine its planar density (atoms/m^2) for its densest family of planes. ***(05 Marks)***			
3.	(a) There is a dislocation lying along $[10\bar{1}]$ in a FCC crystal. Its Burgers vector is $[01\bar{1}]$. What type of dislocation is it? Determine its slip plane. ***(05 Marks)***	10	CO1	BL4
	(b) Determine the ASTM grain size number and calculate the grain size (mm) of the single phase metal shown in **Figure** (200X magnification). [Assume all grains are same size] ***(05 marks)*** 			
4.	(i) Derive the relationship between the applied tensile stress and the shear stress acting on the slip plane in the	10	CO3	BL4

	slip direction during the plastic deformation of single crystal material. ***(06 Marks)***			
	(ii) Polycrystalline aluminum (Al) has a higher tensile strength than single crystal Al. Support your answer with an appropriate sketch. ***(04 marks)***			
5.	(a) For the solidification of iron, calculate the critical radius r*, if nucleation is homogeneous. Values for the latent heat of fusion and surface free energy are -1.85×10^{9} J/m^3 and 0.204 J/m^2, respectively. Use the super-cooling value of 295^{o}C (or 295K) and melting temperature of Fe (1538^{o}C). ***(04 Marks)***	10	CO2	BL5
	(b) Answer the following questions by referring to the Cu-Ni phase diagram: (i) Regardless of temperature what is the maximum amount of Cu that can be dissolved in Ni and what is the maximum amount of Ni that can be dissolved in Cu? (ii) Cite the phases that are present and the composition of each phase: 50 wt% Cu-50 wt% Ni at 1300^{o}C 90 wt% Cu-10 wt% Ni at 1000^{o}C 90 wt% Cu-10 wt% Ni at 1300^{o}C (iii) Calculate the amount of each phase present in 10 gm of a 50 wt% Cu-50 wt% Ni alloy at 1300^{o}C. ***(06 Marks)***  			

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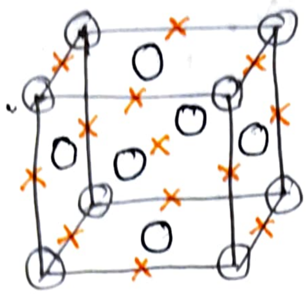
Fall 2023-24

CAT-I (Answer keys)

(BMEE 209L)

1. (a)



O – O^{2-}

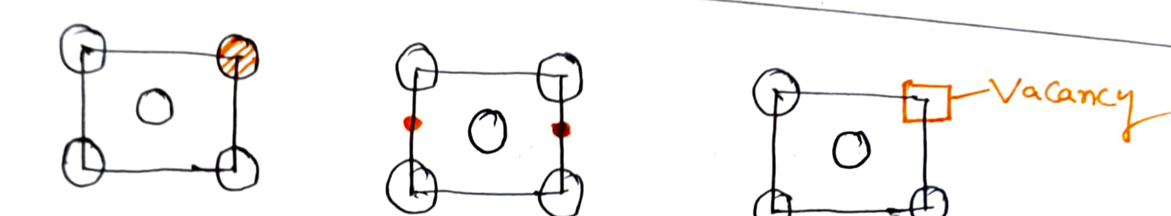
X – Mg^{2+}

$$n_{Mg^{2+}} = 12\times\frac{1}{4} + 1 = 4\,Mg^{2+}$$

$$n_{O^{2-}} = 8\times\frac{1}{8} + 6\times\frac{1}{2} = 4\,O^{2-}$$

$\boxed{\text{Chemical formula} = MgO}$

1 (b)



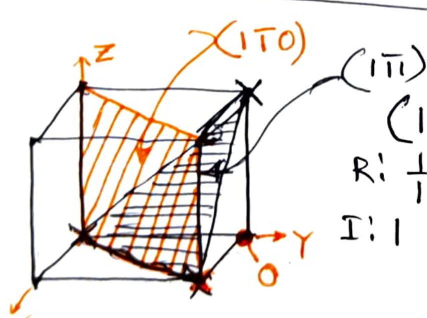
O → Cu

● → Ni

O → Fe

• → C

2 (a)



	$(1\bar{1}0)$	$(1\bar{1}1)$
R:	$\frac{1}{1}\ \frac{1}{-1}\ \frac{1}{0}$	$\frac{1}{1}\ \frac{1}{-1}\ \frac{1}{1}$
I:	$1\ -1\ \infty$	$1\ -1\ 1$

MI of directions ⇒ $[110]$ or $[\bar{1}\bar{1}0]$

(b) $r = 0.05$ nm → BCC structure ⇒

Slip plane $\{110\}$

$$P.D_{(110)} = \frac{2}{\sqrt{2}a^2} = \frac{2}{\sqrt{2}\times(0.115\times10^{-9})^2}\ \text{atom/m}^2$$

$$4r = \sqrt{3}a$$

$$a = \frac{4\times0.05}{\sqrt{3}}$$

3. (a) Angle betn $[10\bar{1}]$ & $[01\bar{1}]$

$$\cos\theta = \frac{1\times0+0\times1+(-1)\cdot(-1)}{\sqrt{1^2+0^2+(-1)^2}\cdot\sqrt{0^2+1^2+(-1)^2}}$$

$$\cos\theta = \frac{1}{2}$$

$\theta = 60^\circ \longrightarrow$ Mixed dislocation.

slip plane is (111).

3(b)

$$N_M\left(\frac{M}{100}\right)^2 = 2^{n-1}$$

$$N_M = \frac{35}{7} = 5 \text{ grains/inch}^2 = \frac{5}{(25.4)^2} \text{ grains/mm}^2$$

$$5\left(\frac{200}{100}\right)^2 = 2^{n-1}$$

$$20 = 2^{n-1}$$

$$2^n = 40 \Rightarrow n =$$

$$\boxed{d = \frac{1}{\sqrt{N_M}} = \frac{1}{\sqrt{\frac{5}{(25.4)^2}}} \text{ mm}}$$

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4. (i) Derivation

(ii)

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5. (a) $R^* = \dfrac{2\gamma \cdot T_M}{\Delta H \cdot \Delta T}$ $T_M = 1538 + 273 = 1811$ K

$$\boxed{R^* = \frac{2\times0.024\times1811}{1.85\times10^9\times295} \text{ m}}$$

(b) (i) 100%.

(ii) • $C_0 = 50\%$ Ni @ 1300°C, $P=2$ (α/L)

$C_\alpha \approx 58\%$ Ni / $C_L \approx 45\%$ Ni

• $C_0 = 10\%$ Ni @ 1000°C, $P=1$ (α)

$C_\alpha = 10\%$ Ni

• $C_0 = 10\%$ Ni @ 1300°C, $P=1$ (L)

$C_L = 10\%$ Ni.

(iii)

$$W_L = \frac{58-50}{58-45} \approx 0.61$$

$$W_\alpha \simeq 0.39$$