

Question 1. (10%) LA

A plate of iron is exposed to a carburizing (carbon rich) atmosphere on one side and a decarburizing (carbon-deficient) atmosphere on the other side at 700 °C. If steady state is achieved, calculate the diffusion flux of carbon through the plate, if the concentrations of carbon at position 5 and 10 mm beneath the carburizing surface are 1.2 and 0.8 kg/m³ respectively. Assume a diffusion coefficient of 3×10^{-11} m²/s at this temperature.

$$J = -D \frac{dC}{dx}$$

$$J = -(3.0 \times 10^{-11} \text{ m}^2/\text{s}) \left(\frac{1.2 \text{ kg/m}^3 - 0.8 \text{ kg/m}^3}{0.01 \text{ m} - 0.005 \text{ m}} \right)$$

$$= +2.4 \times 10^{-9} \frac{\text{Kg}}{\text{m}^2 \cdot \text{s}}$$

~~Handwritten scribble~~ ✓

Flux: rate of transfer/unit area per unit time

flux: rate of transfer/unit area per unit time

Question 2 (8%)

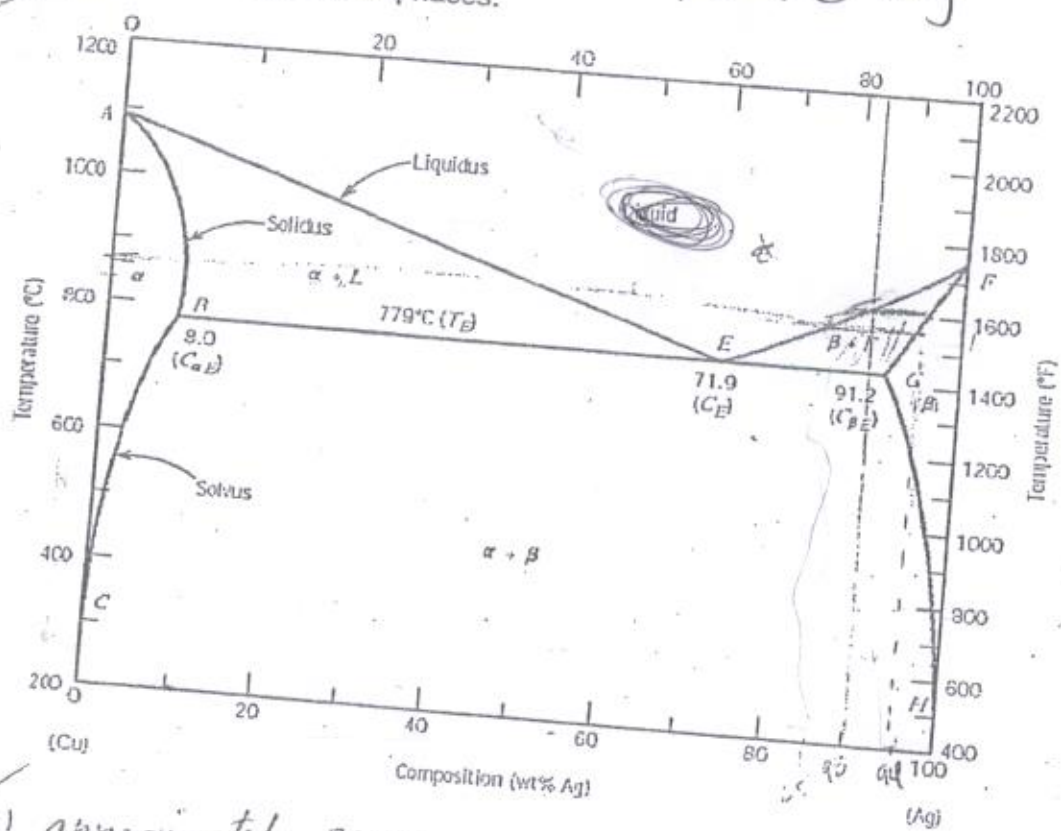
1. Surfactants are compounds that consist of a hydrophobic part and a hydrophilic part. ✓
2. Surfactants are used to reduce surface tension. ✓
3. Capillary effect is due to surface attraction between a liquid and a solid where wetting occurs. ✓
Van der Waals
4. Name four types of colloids: a) emulsions emulsions
b) aerosols, c) gels and d) foams foams.

Question 3. (15%)

A 90 wt% Ag-10 wt% Cu alloy is heated to a temperature within the β + liquid phase region. If the composition of the liquid phase is 85 wt% Ag, determine:

- (a) the temperature of the alloy,
- (b) the composition of the β phase, and
- (c) the mass fractions of both phases.

90% Ag



- ✓ a) approximately 560°C
- b) composition of β phase

$$\frac{90 - 85}{94 - 85} \times 100\%$$

$$= \frac{5}{9}$$

$$= 55.55\%$$

$$= 56\% \beta \text{ phase}$$

mass fractions

a) ~~mass fractions~~

$$\frac{85 - 80}{94 - 85} = 0.5 = 50\%$$

$$\frac{90 - 85}{95 - 85} = \frac{5}{10} = 50\%$$

95% Ag
5% Cu

Liquid

$$\frac{95 - 91.2}{95 - 85} = 0.5 = 50\%$$

$$\frac{90 - 85}{95 - 85} = 50\%$$

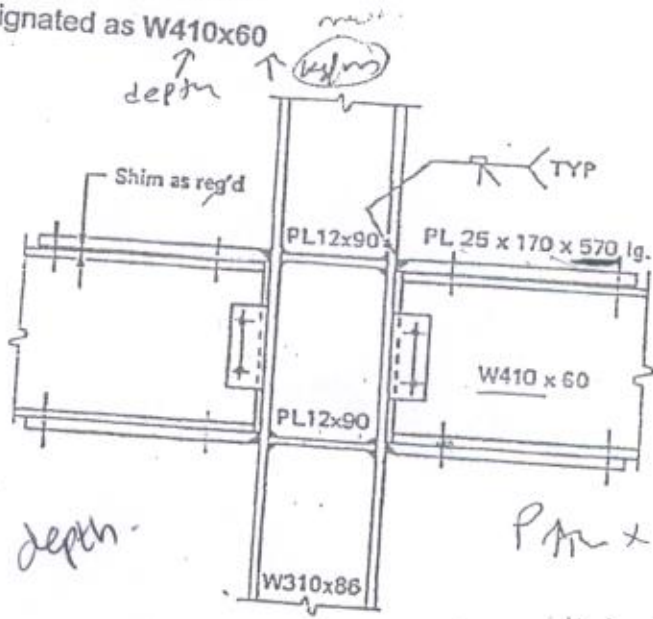
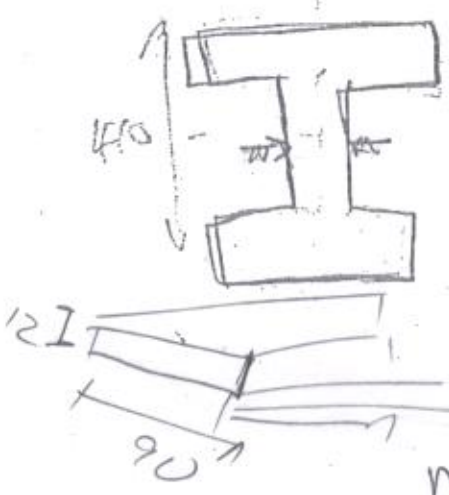
13.8
14.1

Question 4 (6%)

Given below is a typical structural drawing for a steel structure.

W320
x mass (kg/m)

a) Sketch the shape of the section designated as W410x60



- b) What do the numbers 410 and 60 represent? the first number of W410 x 60 is W410 means numerical depth and 60 refers to the mass in kg/m.
- c) What does PL12x90 designate? It is a standard designation for steel products. Plates PL12x90 means thickness x width in mm.

Question 5 (10%)

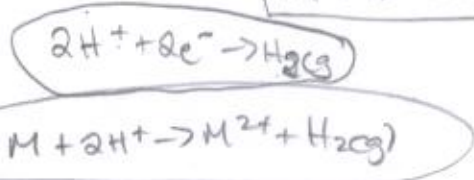
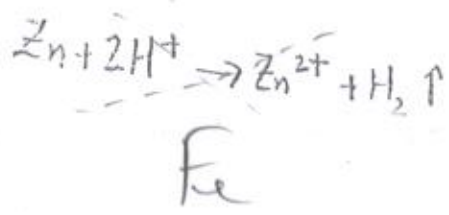
- 5.1 The electrochemical cell has the following four components: a) anode, b) cathode, c) connection between anode and cathode, and d) a liquid electrolyte in contact with both anode and cathode.

2) Write the anode, cathode and overall reactions in an oxygen free liquid, such as hydrochloric acid. (6)

anode reaction: (undergoes oxidation reaction by which metals atoms are ionized)
metal ion enter the electrolyte solution and electrons leave metal through electrical connection. $M \rightarrow M^{n+} + n e^-$

cathode reaction: (hydrogen gas produced at the cathode). $2H^+ + 2e^- \rightarrow H_2 \uparrow$

overall reaction: $M + 2H^+ \rightarrow M^{2+} + H_2 \uparrow$



c) Sieve analysis of a 1000-g sample of fine aggregate resulted in the following data. Find the fineness modulus. (5)

Sieve size	4	8	16	30	50	100
Weight retained	26	130	240	252	210	138

2.6 13 24 25.2 21 13.8
 2.6 15.6 39.6 64.8 85.8 99.6

Fineness Modulus = $\frac{26 + 130 + 240 + 252 + 210 + 138}{100}$

$= \frac{308}{100} = 3.08$

1000 g total
 pan = 4g

% retained

$\frac{26}{1000} \times 100 =$

2.6 13.0 24.0 25.2 21.0 13.8
 2.6 15.6 39.6 64.8 85.8 99.6

$\frac{308}{100} = 3.08$

Question 7 (8%)

a) Describe the five CSA types of Portland Cement (5)

Type 10 → normal portland cement

Type 20 → moderate heat of hydration and sulphate resistance

Type 30 → high early strength

Type 40 → low heat of hydration portland cement

Type 50 → high sulphate resistance.

75 1/2
150

b) Two concrete mixes were tested for their slump. Mix 1 had a slump of 75 mm and Mix 2 a slump of 150 mm. (3)

- a) Which mix has a higher water/cement ratio? mix 2
- b) Which mix is easy to place and work with? mix 1
- c) Which mix is expected to be stronger? mix 1 high strength

Question 8 (5%)

1. Name the three types of bitumen a) tars b) asphalts and c) pitch

2. A cutback asphalt is obtained from diluents → asphalt cements that are liquefied by blend with petroleum solvents

3. What is the difference between the ingredients of a rapid curing and slow curing cutback asphalt?
rapid curing is for hot weather and slow curing is for cold weather.

4. What is the effect of oxidation on asphalt?
harder and loss of ductility and adhesion resources it from asphalt thus makes it

5. Name the three types of asphalt grading systems. a) viscosity and c) performance based (penetration / traditional) } this is for asphalt

6. What are emulsified asphalts? asphalt suspended in water.

Question 9 (7%)

1. Wood obtained from conifers is called soft woods
2. Name three hardwoods a) maples b) walnut and c) oaks
3. Name three softwoods a) spruces b) firs and c) pinus
4. The critical moisture content below which wood would shrink is called fibre-saturation point
5. Name three wood defects a) cracks b) knots and c) slope of grain
6. When lumber shrinks, the highest shrinkage occurs in the tangential direction, while the least shrinkage occurs in the longitudinal direction.
7. Controlled removal of moisture from wood is called paper piling

Question 10 (10%)

A wood sample taken from a roof truss and identified as Black Spruce measures 38 mm x 89 mm x 25 mm and weights 51.3 g. After being in the oven for 24 hours at 99 °C it weights 45.8 g.

- a) Determine its Moisture Content, MC ✓
- b) Find the % change in all radial, tangential and longitudinal directions, when the moisture content changes from 30% to 9%.

$W_i = 51.3g$
 $W_f = 45.8g$

$\frac{51.3g - 45.8g}{45.8g}$

$M.C. =$

$\frac{30-9}{30}$

Use the following properties for Black Spruce

Shrinkage (from green to oven dry)	
Radial	4.1%
Tangential	6.8%
Longitudinal	0.2%
Volumetric	11.3%

$S_{M_2-M_1} = \frac{M_2 - M_1}{30} S_{G-D}$

Please turn toward page

measures 38 mm x 89 mm x 25 mm

weights 51.3g. It is oven for 24 hrs @ 95°C, weighs 45.8g.

a) moisture content (MC)

$$MC = \frac{W_{199} - W_{10}}{W_{10}} \times 100$$

$$= \frac{51.3g - 45.8g}{45.8g} \times 100$$

$$\approx 12\%$$

b) % change in all radial, tangential and longitudinal directions.

$$S_{M_2 - M_1} = \frac{M_2 - M_1}{30} \quad \text{SG is:}$$

$$(S_{M_2 - M_1})_{\text{radial}} = \frac{21}{30} (4.1\%) = 2.87\%$$

$$(S_{M_2 - M_1})_{\text{tangential}} = \frac{21}{30} (6.8\%) = 4.76\%$$

$$(S_{M_2 - M_1})_{\text{longitudinal}} = \frac{21}{30} (0.2\%) = 0.14\%$$

Question 11 (10%)

11.1 For a polymer-matrix fiber-reinforced composite:

- a) List three functions of the matrix phase (3),
- binds the fibers together
 - protects fibers from surface damage.
 - acts as medium through which loads are transferred to the fibers.

- b) Compare the desired mechanical characteristics of the matrix and the fibers. (2)
- mechanical properties are dependent on stress-strain behavior of fiber and matrix phase, phase volume fractions and the direction in which stress is applied.
 - Fibre is brittle
 - matrix is ductile

not all fibers fracture @ the same time.

$$E_m > E_f$$

11.2 In an aligned and continuous glass fiber-reinforced nylon 6,6 composite, the fibers are to carry 94% of a load applied in the longitudinal direction. Using the data provided, determine the volume fraction of fibers that will be required. (5)

	Elastic Modulus, [Gpa]	Tensile Strength, [MPa]
Glass fiber	72.0	3,400.0
Nylon 6,6	3.0	76.00

$$\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m} = \frac{E_f V_f}{E_m (1 - V_f)}$$

$$\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m}$$

$$\frac{0.94}{0.06} = \frac{72 \times 10^9 \text{ Pa } V_f}{3.0 \times 10^9 \text{ Pa } V_m}$$

$$15.667 = 24 \frac{V_f}{V_m}$$

$$0.65 = 0.29 \dots$$