THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

ALL ENGINEERING – 01st YEAR DEGREE

FIRST SEMESTER EXAMINATIONS – 2023

EN113– ENGINEERING MATERIALS & PROPERTIES

FRIDAY, 02nd JUNE 2022 – 8.20 AM

TIME ALLOWED: **2 HOURS**

INSTRUCTIONS FOR CANDIDATES:

1. You have 10 minutes to read the paper. You **must not** begin writing during this time.
2. Answer **any five (5)** questions and you can do them in any order.
3. **Use only ink.** Do not use pencil for writing except for drawings and sketches.
4. Start each question on a new page and show all your calculations in the answer book provided. No other written material will be accepted.
5. Write your **NAME** and **NUMBER** clearly on the front page. **Do it now.**
6. Calculators are permitted in the examination room. Notes, textbooks or smart phones are not allowed.
7. All questions carry equal marks
8. Any candidate cheating the examinations will be disqualified

MARKING SCHEME:

Question Number 1	10 Marks
Question Number 2	10 Marks
Question Number 3	10 Marks
Question Number 4	10 Marks
Question Number 5	10 Marks
Question Number 6	10 Marks
Question Number 7	10 Marks

Question 1

a) Briefly describe the following terms
   i. Metallic bonding
   ii. Covalent bonding

b) Calculate the radius of an iridium atom, given that Ir has an FCC crystal structure, a density of 22.4 g/cm^3, and an atomic weight of 192.2 g/mol.

Question 2

a) i. Briefly explain the difference between self-diffusion and interdiffusion

   ii. What is the driving force for steady-state diffusion?

b) A sheet of steel 1.5 mm thick has nitrogen atmospheres on both sides at 1200°C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is 6×10^{-11} m^2 /s, and the diffusion flux is found to be 1.2×10^{-7} kg/m^2 -s. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 4 kg/m^3. How far into the sheet from this high-pressure side will the concentration be 2.0 kg/m^3? Assume a linear concentration profile.

Question 3

a) Briefly explain the following terms
   i. Hardness
   ii. Resilience

b) A cylindrical specimen of a titanium alloy having an elastic modulus of 10^7 GPa and an original diameter of 3.8 mm will experience only elastic deformation when a tensile load of 2000 N is applied. Compute the maximum length of the specimen before deformation if the maximum allowable elongation is 0.42 mm.

Question 4

a) State at least two measures that can be taken in order to extend fatigue life:

   i. ______________________

   ii. ______________________

b) An 8.0 mm diameter cylindrical rod fabricated from a red brass alloy (Figure 1) is subjected to reversed tension-compression load cycling along its axis. If the maximum tensile and compressive loads are +7500 N and -7500 N, respectively, determine its fatigue life. Assume that the stress plotted in Figure 1 is stress amplitude.

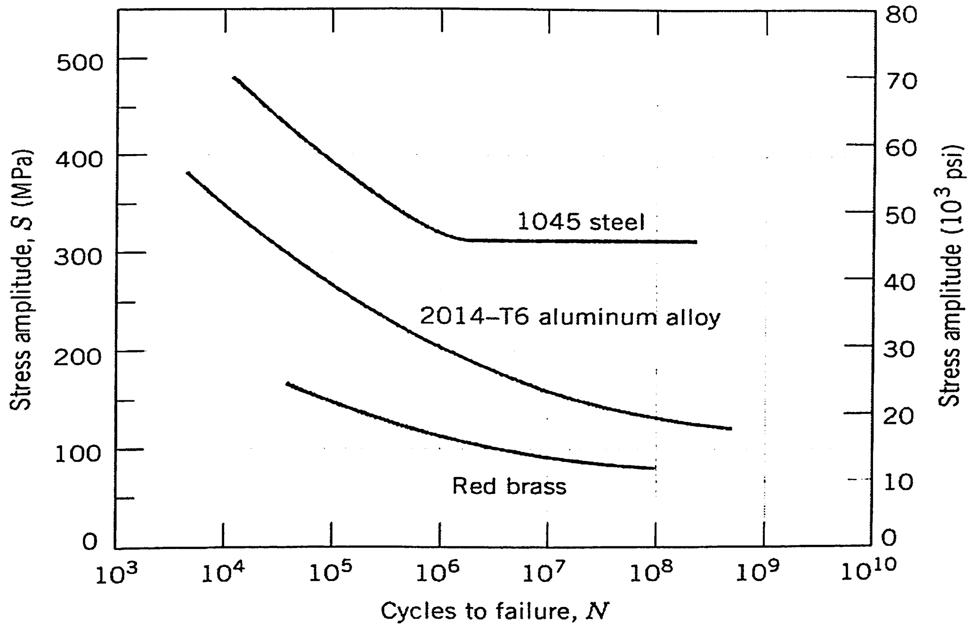

Figure 1. Stress magnitude S versus the logarithm of the number N of cycles to fatigue failure for red brass, an aluminum alloy, and a plain carbon steel

Question 5

a) What is the magnitude of the maximum stress that exists at the tip of an internal crack having a radius of curvature of 2.5×10^{-4} mm and a crack length of 2.5×10^{-2} mm when a tensile stress of 170 MPa is applied?

b) Following is tabulated data that were gathered from a series of Charpy impact tests on a ductile cast iron.

Temperature (°C)	Impact Energy (J)
-25	*124*
-50	*123*
-75	*115*
-85	*100*
-100	*73*
-110	*52*
-125	*26*
-150	*9*
-175	*6*

i. Plot the data as impact energy versus temperature.

ii. Determine a ductile-to-brittle transition temperature as that temperature corresponding to the average of the maximum and minimum impact energies

Question 6

a) Cite three variables that determine the microstructure of an alloy

i._______________

ii._______________

iii._______________

b) A copper-nickel alloy of composition 70 wt% Ni-30 wt% Cu is slowly heated from a temperature of 1300°C as show in Figure 2.

i. At what temperature does the first liquid phase form?

ii. What is the composition of this liquid phase?

iii. At what temperature does complete melting of the alloy occur?

iv. What is the composition of the last solid remaining prior to complete melting?

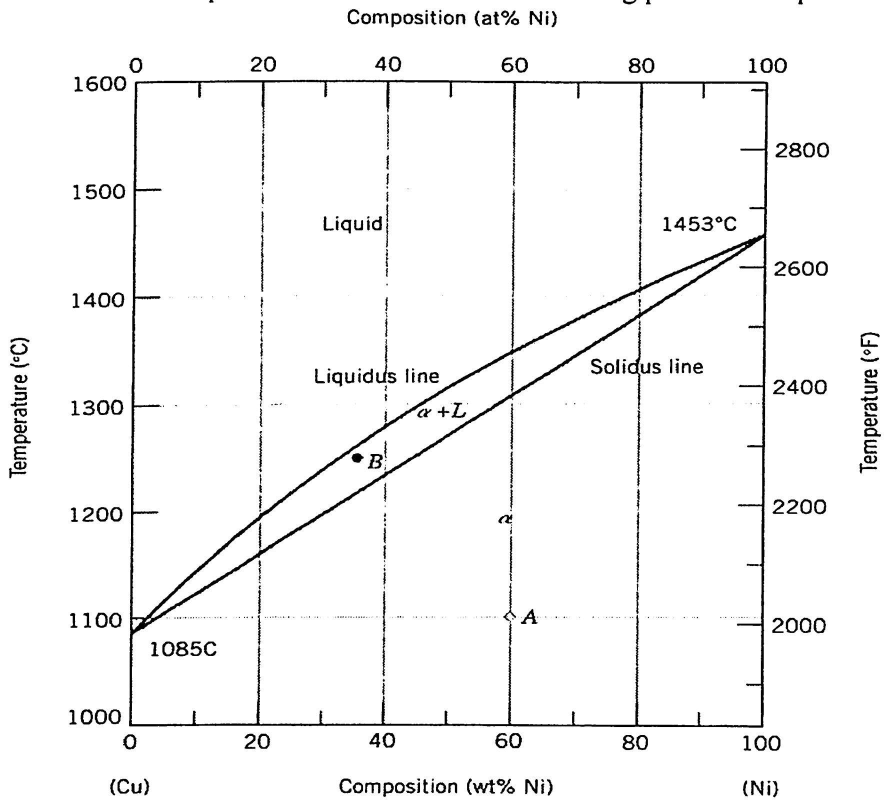

Figure 2 (a) The copper–nickel phase diagram

Question 7

a) i. Briefly explain the use of multilayer insulation (MLI) on satellites

ii. Briefly explain the difference between oxidation and reduction electrochemical reactions, and which reaction occurs at the anode and which at the cathode?

b) A thick steel sheet of area 400 cm^2 is exposed to air near the ocean. After a one-year period it was found to experience a weight loss of 375 g due to corrosion. To what rate of corrosion, in both mpy and mm/yr, does this correspond?

Equation Summary

Equation Number	Equation	Solving for
3.1	$a = 2R\sqrt{2}$	Unit cell edge length, FCC
3.2	$\text{APF} = \dfrac{\text{volume of atoms in a unit cell}}{\text{total unit cell volume}} = \dfrac{V_S}{V_C}$	Atomic packing factor
3.3	$a = \dfrac{4R}{\sqrt{3}}$	Unit cell edge length, BCC
3.5	$\rho = \dfrac{nA}{V_C N_A}$	Theoretical density of a metal

5.1a	$J = \dfrac{M}{At}$	Diffusion flux
5.3	$J = -D\dfrac{dC}{dx}$	Fick's first law—diffusion flux for steady-state diffusion
5.4b	$\dfrac{\partial C}{\partial t} = D\dfrac{\partial^2 C}{\partial x^2}$	Fick's second law—for nonsteady-state diffusion
5.5	$\dfrac{C_x - C_0}{C_s - C_0} = 1-\text{erf}\left(\dfrac{x}{2\sqrt{Dt}}\right)$	Solution to Fick's second law—for constant surface composition
5.8	$D = D_0 \exp\left(-\dfrac{Q_d}{RT}\right)$	Temperature dependence of diffusion coefficient

6.1	$\sigma = \dfrac{F}{A_0}$	Engineering stress
6.2	$\epsilon = \dfrac{l_i - l_0}{l_0} = \dfrac{\Delta l}{l_0}$	Engineering strain
6.5	$\sigma = E\epsilon$	Modulus of elasticity (Hooke's law)

8.6	$\sigma_c = \dfrac{K_{Ic}}{Y\sqrt{\pi a}}$	Design (or critical) stress
8.7	$a_c = \dfrac{1}{\pi}\left(\dfrac{K_{Ic}}{\sigma Y}\right)^2$	Maximum allowable flaw size
8.14	$\sigma_m = \dfrac{\sigma_{max} + \sigma_{min}}{2}$	Mean stress (fatigue tests)
8.15	$\sigma_r = \sigma_{max} - \sigma_{min}$	Range of stress (fatigue tests)
8.16	$\sigma_a = \dfrac{\sigma_{max} - \sigma_{min}}{2}$	Stress amplitude (fatigue tests)
8.17	$R = \dfrac{\sigma_{min}}{\sigma_{max}}$	Stress ratio (fatigue tests)
8.18	$\sigma = \alpha_l E \Delta T$	Thermal stress

17.18	$\Delta V^0 = V_2^0 - V_1^0$	Electrochemical cell potential for two standard half-cells	
17.19	$\Delta V = (V_2^0 - V_1^0) - \dfrac{RT}{n\mathcal{F}}\ln\dfrac{[M_1^{n+}]}{[M_2^{n+}]}$	Electrochemical cell potential for two nonstandard half-cells	
17.20	$\Delta V = (V_2^0 - V_1^0) - \dfrac{0.0592}{n}\log\dfrac{[M_1^{n+}]}{[M_2^{n+}]}$	Electrochemical cell potential for two nonstandard half-cells, at room temperature	
17.23	$\text{CPR} = \dfrac{KW}{\rho A t}$	Corrosion penetration rate	K= 87.6 (mm/yr) K=354(mil/yr)
17.24	$r = \dfrac{i}{n\mathcal{F}}$	Corrosion rate	
17.25	$\eta_a = \pm\beta \log \dfrac{i}{i_0}$	Overvoltage for activation polarization	