PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINERING

EXAMINATION QUESTION PAPERS

EN 113
ENGINEERING MATERIALS & PROPERTIES

SEMESTER ONE – 2024

BY GK

THE PAPUA NEW GUINEA NIVERSITY OF TECHNOLOGY

EXAMINATIONS

SEMESTER I-2024

EN122 ENGINEEING MATERIALS & PROPERTIES

MONDAY, 27 MAY 2024 [12:50NOON-3:50PM]

TIME ALLOWED: **3 HOURS**

INSTRUCTIONS:

1. You have 10 minutes to read the paper. You must not begin writing this time.
2. **Answer any four (5) questions 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 will be accepted.
5. Write down your full name and student number clearly on the front page. **Do it now.**
6. Calculator is 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.**

Question No.	**Topic**	**Marks**
1	Structure of solids	/20
2	Mechanical Properties of Metals & Failure	/20
3	Imperfections in Solids & Diffusion	/20
4	Phase Diagrams	/20
5	Introduction to Physical Properties of Materials	/20
6	Corrosion & Degradation of Materials	/20
7	Materials Selection	/20
	Total	______**/100**

Question 1

a) Explain the difference between covalent and ionic bonding, including examples of each.

b) Explain how defects in interatomic bonding, such as vacancies or dislocations, can affect the mechanical properties of materials and how these defects can be controlled or engineered for specific applications.

c) Calculate the force of attraction between a K^+ and an O^{2-} ion the centers of which are separated by 1.5 nm.

d) Zinc has an HCP crystal structure, a c/a ratio of 1.856, and a density of 7.13 g/cm^3. Compute the atomic radius for Zn.

Question 2

a) What is the significance of the yield point in a stress-strain curve?

b) In designing a bicycle frame, why is it important to consider the tensile strength and fatigue resistance of the chosen material?

c) A cylindrical specimen of a titanium alloy having an elastic modulus of 107 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.

d) The fatigue data for a ductile cast iron are given as follows:

Stress Amplitude (MPa)	Cycles to Failure (N)
248	1×10^5
236	3×10^5
224	1×10^6
213	3×10^6
201	1×10^7
193	3×10^7
193	1×10^8
193	3×10^8

Question 3

a) Describe the mechanisms by which atoms or molecules diffuse through a solid material. How do vacancy diffusion and interstitial diffusion differ?

b) How can the diffusion of carbon atoms into the surface of steel be utilized to create a hardened surface layer through processes like carburizing in automotive component manufacturing?

c) Calculate the number of vacancies per cubic meter in iron at 850°C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm^3 and 55.85 g/mol, respectively.

d) The activation energy for the diffusion of carbon in chromium is 111,000 J/mol. Calculate the diffusion coefficient at 1100 K (827°C), given that D at 1400 K (1127°C) is 6.25 × 10-11 m^2/s.

Question 4

a) What is a phase diagram, and what does it represent for a given material system?

b) Can you explain the significance of the solidus and liquidus lines in a phase diagram, and how they relate to the melting and freezing temperatures of a material?

c) How would you use a phase diagram to determine the appropriate heat treatment process for a steel alloy to achieve a desired combination of hardness and toughness?

d) 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:

-The temperature of the alloy

-The composition of the β phase

-The mass fractions of both phases

Question 5

a) Define cathodic protection

b) Describe selective leaching and erosion corrosion

c) What are the key differences between uniform corrosion and localized corrosion in metals, and how do environmental factors contribute to their occurrence?

d) 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?

Question 6

a) How does the coefficient of thermal expansion (CTE) affect the dimensional stability of materials with changes in temperature?

b) Can you explain how the coefficient of thermal expansion (CTE) affects the dimensional changes of materials with temperature variations? Give examples of materials with high and low CTE values.

c) How would you analyze the effectiveness of thermal insulation materials in reducing heat transfer through conduction, convection, and radiation?

d) An aluminum wire 10 m long is cooled from 38 to -1°C. How much change in length will it experience?

Question 7

a) What factors are typically considered in materials selection for engineering applications?

b) How do engineers typically approach the process of materials selection for a given application?

c) How would you select materials for the construction of a bridge spanning a coastal area prone to corrosion from saltwater exposure?

d) How would you analyze the trade-offs between different material properties, such as strength, stiffness, and ductility, when selecting materials for a structural component?

Equation Summary

Equation Number	*Equation*	*Solving For*	*Page Number*
2.5a	$E = \int F dr$	Potential energy between two atoms	31
2.5b	$F = \frac{dE}{dr}$	Force between two atoms	31
2.9	$E_A = -\frac{A}{r}$	Attractive energy between two atoms	32
2.11	$E_R = \frac{B}{r^n}$	Repulsive energy between two atoms	33
2.13	$F_A = \frac{1}{4\pi\epsilon_0 r^2}(\lvert Z_1\rvert e)(\lvert Z_2\rvert e)$	Force of attraction between two isolated ions	35
2.16	$\%IC = \{1 - \exp[-(0.25)(X_A - X_B)^2]\} \times 100$	Percent ionic character	43

4.1	$N_v = N \exp\left(-\frac{Q_v}{kT}\right)$	Number of vacancies per unit volume	107
4.2	$N = \frac{N_A \rho}{A}$	Number of atomic sites per unit volume	108

6.1	$\sigma = \frac{F}{A_0}$	Engineering stress	172
6.2	$\epsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta l}{l_0}$	Engineering strain	172
6.5	$\sigma = E\epsilon$	Modulus of elasticity (Hooke's law)	174
6.8	$\nu = -\frac{\epsilon_x}{\epsilon_z} = -\frac{\epsilon_y}{\epsilon_z}$	Poisson's ratio	177
6.11	$\%EL = \left(\frac{l_f - l_0}{l_0}\right) \times 100$	Ductility, percent elongation	184
6.12	$\%RA = \left(\frac{A_0 - A_f}{A_0}\right) \times 100$	Ductility, percent reduction in area	184

$$W_L = \frac{S}{R + S} \tag{9.1a}$$

or, by subtracting compositions,

Lever rule expression for computation of liquid mass fraction (per Figure 9.3*b*)

$$W_L = \frac{C_\alpha - C_0}{C_\alpha - C_L} \tag{9.1b}$$

Similarly, for the α phase,

Lever rule expression for computation of α-phase mass fraction (per Figure 9.3*b*)

$$W_\alpha = \frac{R}{R + S} \tag{9.2a}$$

$$= \frac{C_0 - C_L}{C_\alpha - C_L} \tag{9.2b}$$

Equation Summary

Equation Number	Equation	Solving For	Page Number
17.18	$\Delta V^0 = V_2^0 - V_1^0$	Electrochemical cell potential for two standard half-cells	687
17.19	$\Delta V = (V_2^0 - V_1^0) - \frac{RT}{n\mathcal{F}} \ln \frac{[M_1^{n+}]}{[M_2^{n+}]}$	Electrochemical cell potential for two nonstandard half-cells	688
17.20	$\Delta V = (V_2^0 - V_1^0) - \frac{0.0592}{n} \log \frac{[M_1^{n+}]}{[M_2^{n+}]}$	Electrochemical cell potential for two nonstandard half-cells, at room temperature	688
17.23	$\text{CPR} = \frac{KW}{\rho A t}$	Corrosion penetration rate	690

19.1	$C = \frac{dQ}{dT}$	Definition of heat capacity	786
19.3a	$\frac{l_f - l_0}{l_0} = \alpha_l (T_f - T_0)$	Definition of linear coefficient of thermal expansion	790
19.3b	$\frac{\Delta l}{l_0} = \alpha_l \Delta T$		
19.4	$\frac{\Delta V}{V_0} = \alpha_v \Delta T$	Definition of volume coefficient of thermal expansion	790

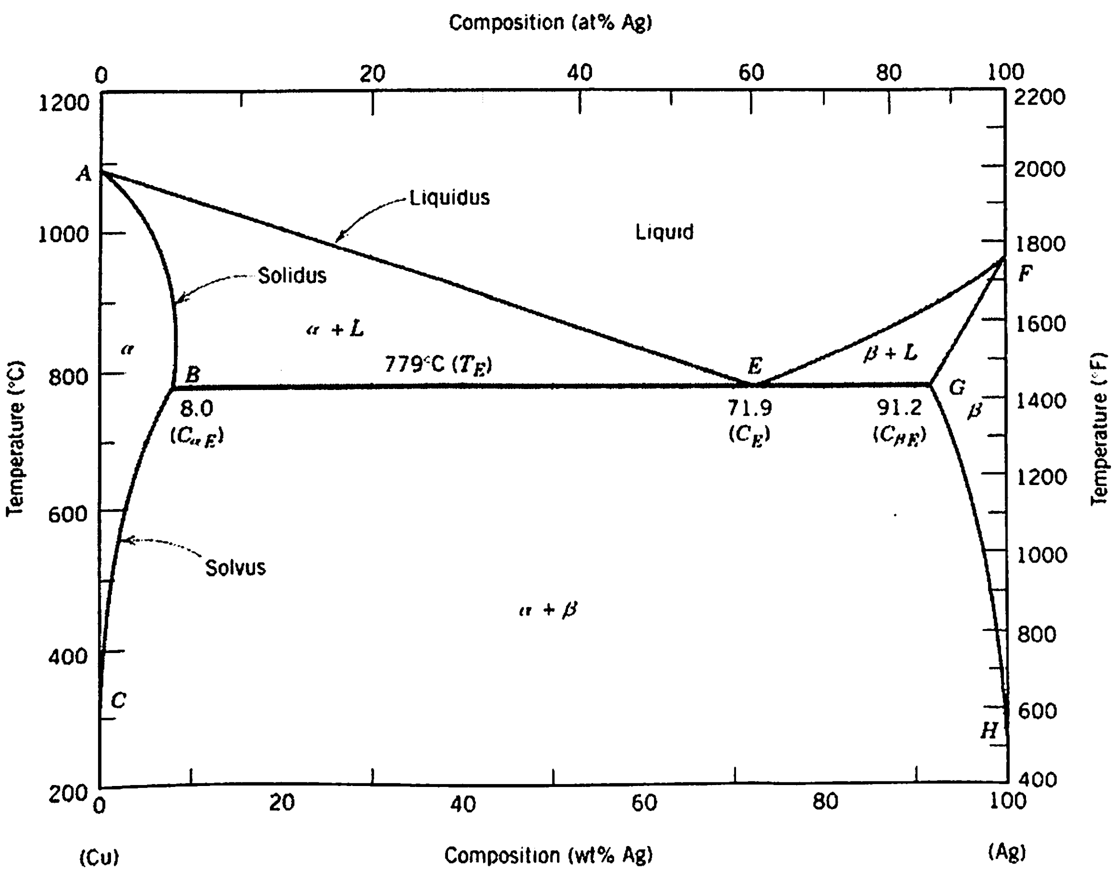

Figure 9.7 The copper–silver phase diagram.