THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING – 3rd YEAR DEGREE

FIRST SEMESTER EXAMINATIONS – 2022

ME 113– ENGINEERING MATERIALS & PROPERTIES

MONDAY, 6TH JUNE 2022 – 12.50 PM

TIME ALLOWED: 3 HOURS

INSTRUCTIONS FOR CANDIDATES

1. You have 10 minutes to read the paper. You **must not** begin writing during this time.
2. Answer **any four (4)** 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.

MARKING SCHEME:

Question Number 1	15 Marks
Question Number 2	15 Marks
Question Number 3	15 Marks
Question Number 4	15 Marks
Question Number 5	15 Marks

Question 1

a) Briefly describe the following types of bonding:

(i) Ionic Bonding *(2.5 Marks)*

(i). Metallic bonding *(2.5 Marks)*

b) The force of attraction between a divalent cation and a divalent anion is 1.67×10^{-8} N. If the ionic radius of the cation is 0.080 nm, what is the anion radius?

Question 2

a) What is the difference between atomic structure and crystal structure? *(2.5 Marks)*

b) Define atomic packing factor (APF) *(2.5 Marks)*

c) Titanium (Ti) has an HCP crystal structure and a density of 4.51 g/cm^3. (a) What is the volume of its unit cell in cubic meters? (b) If the c/a ratio is 1.58, compute the values of *c* and *a*.

(10 Marks)

Question 3

a) Describe the following terms;

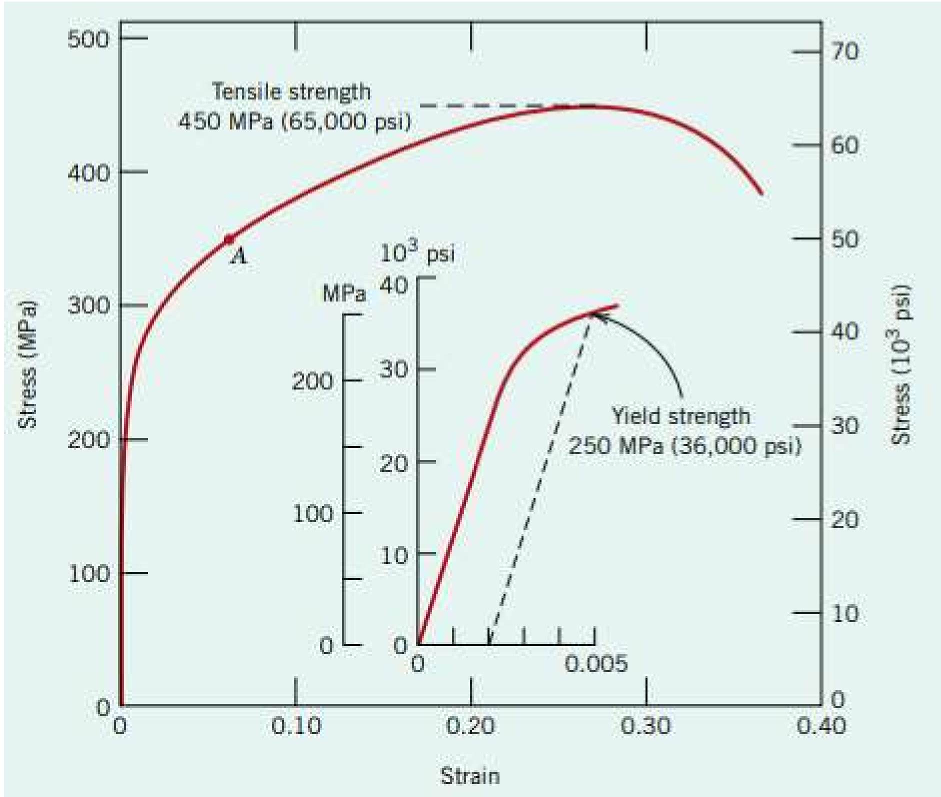
(i) Tensile strength *(2.5 Marks)*

(ii) Hardness *(2.5 Marks)*

b) Consider the brass alloy for which the stress– strain behavior is shown below. A cylindrical specimen of this material 10.0 mm in diameter and 101.6 mm long is pulled in tension with a force of 10,000 N (2250 lbf). If it is known that this alloy has a value for Poisson's ratio of 0.35, compute

(i) the specimen elongation *(5 Marks)*

(ii) the reduction in specimen diameter *(2.5 Marks)*



Question 4

a) Briefly describe the following terms;

(i) Brittle fracture *(2.5 Marks)*

(ii) Ductile fracture *(2.5 Marks)*

b) The fatigue data for a steel alloy are given as follows:

(i) Make an S–N plot (stress amplitude versus logarithm of cycles to failure) using these data.

(2.5 Marks)

(ii) What is the fatigue limit for this alloy? *(2.5 Marks)*

(iii) Determine fatigue lifetimes at stress amplitudes of 415 MPa and 275 MPa. *(2.5 Marks)*

(iv) Estimate fatigue strengths at 2 x 10^4 and 6 x 10^5 cycles. *(2.5 Marks)*

Question 5

a) Briefly describe the following terms;

(i) Fatigue (endurance) limit *(2.5 Marks)*

(ii) Fatigue strength *(2.5 Marks)*

b) A fatigue test was conducted in which the mean stress was 70 MPa, and the stress amplitude was 210 MPa.

(i) Compute the maximum and minimum stress levels. *(3.5 Marks)*

(ii) Compute the stress ratio. *(3.5 Marks)*

(iii) Compute the magnitude of the stress range. *(3 Marks)*

$$F_A = \frac{dE_A}{dr} = \frac{d\left(-\frac{A}{r}\right)}{dr} = -\left(\frac{-A}{r^2}\right) = \frac{A}{r^2} \tag{2.12}$$

$$F_A = \frac{1}{4\pi\epsilon_0 r^2}(|Z_1|e)(|Z_2|e) \tag{2.13}$$

$$F_A = \frac{1}{4\pi(8.85 \times 10^{-12}\text{ F/m})(r^2)}[|Z_1|(1.602 \times 10^{-19}\text{C})][|Z_2|(1.602 \times 10^{-19}\text{C})]$$
$$= \frac{(2.31 \times 10^{-28}\text{ N}\cdot\text{m}^2)(|Z_1|)(|Z_2|)}{r^2} \tag{2.14}$$

$$r_0 = r_{K^+} + r_{Br^-} \tag{2.15}$$

3.4	$a = \frac{4R}{\sqrt{3}}$	Unit cell edge length, BCC	56
3.8	$\rho = \frac{nA}{V_C N_A}$	Theoretical density of a metal	60

Equation Summary

Equation Number	***Equation***	***Solving For***	***Page Number***
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

Equation Summary

Equation Number	*Equation*	*Solving For*	*Page Number*
8.1	$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2}$	Maximum stress at tip of elliptically shaped crack	258
8.4	$K_c = Y\sigma_c\sqrt{\pi a}$	Fracture toughness	260
8.5	$K_{Ic} = Y\sigma\sqrt{\pi a}$	Plane-strain fracture toughness	261
8.6	$\sigma_c = \frac{K_{Ic}}{Y\sqrt{\pi a}}$	Design (or critical) stress	262
8.7	$a_c = \frac{1}{\pi}\left(\frac{K_{Ic}}{\sigma Y}\right)^2$	Maximum allowable flaw size	263
8.14	$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$	Mean stress (fatigue tests)	270
8.15	$\sigma_r = \sigma_{max} - \sigma_{min}$	Range of stress (fatigue tests)	270
8.16	$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$	Stress amplitude (fatigue tests)	270
8.17	$R = \frac{\sigma_{min}}{\sigma_{max}}$	Stress ratio (fatigue tests)	270
8.23	$\sigma = \alpha_l E \Delta T$	Thermal stress	281
8.24	$\dot{\epsilon}_s = K_1\sigma^n$	Steady-state creep rate (constant temperature)	283
8.25	$\dot{\epsilon}_s = K_2\sigma^n \exp\left(-\frac{Q_c}{RT}\right)$	Steady-state creep rate	284
8.27	$m = T(C + \log t_r)$	Larson–Miller parameter	285