University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours
Level 2 (Semester I) Examination, June 2026
Academic year 2024/2025

Course Unit: ENT 2152- Properties of Material and Their Applications(R)
ENT 2152- Properties of Material and Applications **Duration: 2 hours**

Instructions to Candidates

- This paper contains **four (04)** questions on **three (03)** pages.
- Answer all questions, every question carries equal marks and the maximum mark attainable for the sub parts of each question is indicated in the bracket.
- This examination accounts for 50% of the module assessment.
- This is a close book examination.
- All the figures are attached to a separate document with two (02) pages.
- Electronic communication devices are not permitted, only allowed is the calculator approved by the Faculty of Technology, University of Ruhuna.

Question 01

a) Consider the phase diagram for lead-tin in Figure 01 (refer to the attachment). Answer the following questions.

(i) What phases are present for a 80 wt% Sn, 20 wt% Pb alloy at 200 °C? (01 mark)

(ii) What phases are present for a 10 wt% Sn, 90 wt% Pb alloy at 200 °C? (01 mark)

(iii) What are the compositions of phases for a 40 wt% Sn, 60 wt% Pb alloy at 150 °C? (02 marks)

(iv) Calculate the relative amount of each phases present in terms of Mass fraction for part (iii) condition. (06 marks)

b) Steel is made by mixing iron (Fe) with carbon (C). This mixing produces an interstitial solid solution as the carbon atom is much smaller than the Fe atom.

(i) Describe the crystal structures of α-Ferrite, γ- Austenite and δ-Ferrite phases. (03 marks)

(ii) What is the maximum solubility of carbon in α-Ferrite and γ-Austenite phases? (02 marks)

(iii) Explain why carbon has higher solubility in γ-Austenite compared to α-Ferrite. (02 marks)

(iv) Briefly describe Eutectic and Eutectoid reactions in iron-carbon phase diagram. (03 marks)

(v) Heat treatment processes are controlled heating (annealing) and cooling operations used to bring about a desired change in the physical properties of a metal. Briefly describe the annealing method. (05 marks)

Question 02

a) Sketch the unit cell arrangements for the following crystal structures.
   (i) Simple Cubic (SC)
   (ii) Face Centered Cubic (FCC)
   (iii) Body Centered Cubic (BCC) (03 marks)

b) (i) Calculate the Atomic Packing Factor (APF) for FCC crystal structure. Consider the unit cell edge length and the atomic radius are a and r, respectively. (06 marks)

   (ii) Briefly explain the terms elastic deformation and plastic deformation. (02 marks)

c) The tensile stress–strain behavior for the brass specimen is shown in Figure 02 (refer to the attachment)
   (i) Determine the modulus of elasticity. (03 marks)
   (ii) Calculate the yield strength. (02 marks)
   (iii) Find the maximum load that can be sustained by a cylindrical specimen having an original diameter of 10 mm. (02 marks)
   (iv) Find the change in length (Δl) of a specimen originally 80 mm long that is subjected to a tensile stress of 380 MPa. (03 marks)
   (v) A brass specimen experiences two different loading conditions.
   Condition A: The material returns to its original shape after unloading.
   Condition B: Permanent deformation remains after unloading.
   Analyze the deformation behavior in both conditions and identify the type of deformation. (04 marks)

Question 03

Fiber-reinforced composites (FRC) loaded in tension are usually incorporated with unidirectional aligned continuous fibers.

a) Derive equations for the tensile elastic modulus of FRC with unidirectional aligned continuous fibers in the following directions.
   (i) Parallel to the fiber axis. (04 marks)
   (ii) Perpendicular to the fiber axis. (04 marks)

b) Using the derived equations in part (a) above, find the E_c (Composite elastic modulus) parallel to the axis of the fiber (E_1) and perpendicular to the fiber axis (E_2). If $E_f = 300\ GPa$, $E_m = 70\ GPa$, *and* $V_m = 40\ \%$. (04 marks)

c) Explain why fiber-reinforced composites exhibit maximum strength parallel to the fiber direction. (02 marks)

d) The toughness of a composite can be calculated using the following equation. The γ_F values of the matrix and fiber materials are given by $(\gamma_F)_m$ and $(\gamma_F)_f$, respectively.

$$(\gamma_F)_c = (\gamma_F)_f \times V_f + (\gamma_F)_m \times (1 - V_f)$$

   Estimate the toughness of C/Epoxy composite with 30% volume fraction of matrix. γ_F values of carbon and epoxy are 90 J/m^2 and 350 J/m^2, respectively. (02 marks)

e) Tensile stress (σ_c) is applied along the fiber axis of FRC (discontinuous fibers composite) as shown in Figure 03 (refer to the attachment).

(i) Draw the stress distribution graph on fiber. (03 marks)

(ii) Draw the shear stress distribution graph in the region BC of the fiber produces shear stresses at the fiber – matrix interface. (03 marks)

f) A lightweight material is required for aircraft body panels. Evaluate whether fiber-reinforced polymer composites are more suitable than steel for this application. (03 marks)

Question 04

a) Briefly explain the conductivity of conductors, insulators and semi-conductors using band structure theory. (04 marks)

b) Derive an equation for the current flow through a conductor ($\boldsymbol{I}$) and label the names of all the parameters, if the drift velocity of electrons ($\boldsymbol{V_d}$) through the conductor is $\mu_e E$. Where, μ_e is the electron mobility and E is the value of electric felid. (05 marks)

c) Electrical conductivity ($\boldsymbol{\sigma}$) is proportional to the number of free electrons and electron mobility. It can be expressed as below.

$$\sigma = n|e|\mu_e$$

i) Compare and discuss the differences in the electrical conductivity of metals and semiconductors using the above equation. (02 marks)

ii) Write down the five types of scattering events in the materials that are affected for the conductivity of materials. (05 marks)

iii) The Matthiessen Rule states the total resistance measured as a contribution of all the resistive scattering processes. Write down the equation for total resistivity ($\boldsymbol{\rho_{total}}$) and label the parameters in the equation. (03 marks)

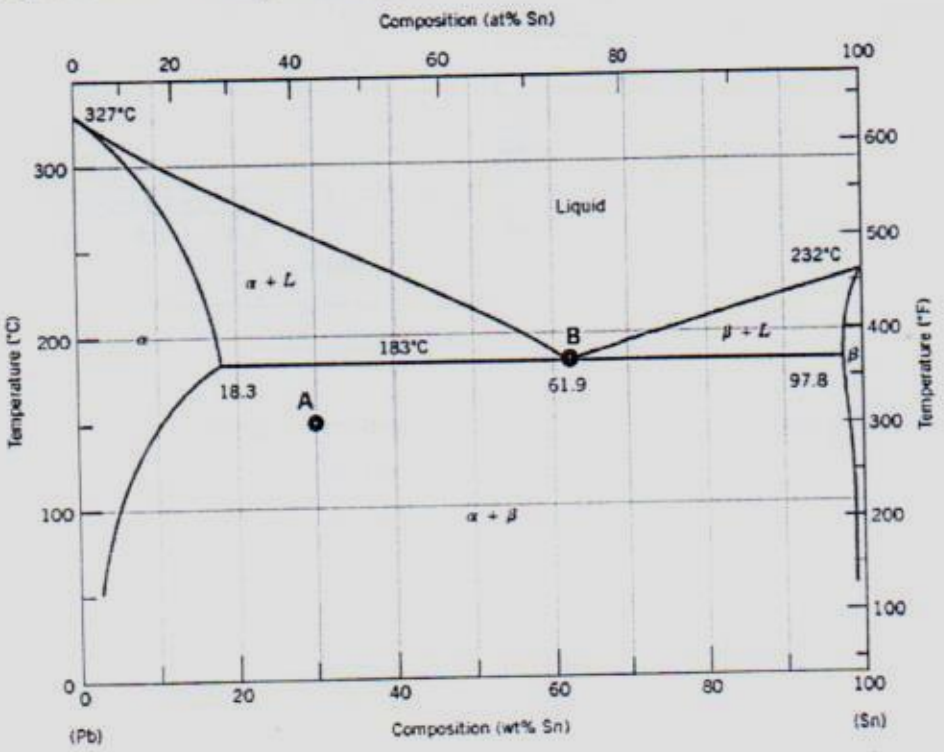
d) The equation for the intrinsic conductivity ($\boldsymbol{\sigma_i}$) for an intrinsic semiconductor can be derived from $\boldsymbol{\sigma = n|e|\mu_e + p|e|\mu_h}$. Gallium arsenide is an intrinsic semiconductor and its electrical conductivity is $1.602 \times 10^{-9}(\Omega.\mathrm{m})^{-1}$, the electron and hole mobility are 0.95 and 0.05 $\mathrm{m^2/V.s}$, respectively. Compute the intrinsic carrier concentration ($\boldsymbol{n_i}$) at room temperature. (06 marks)

***** End of the paper*****

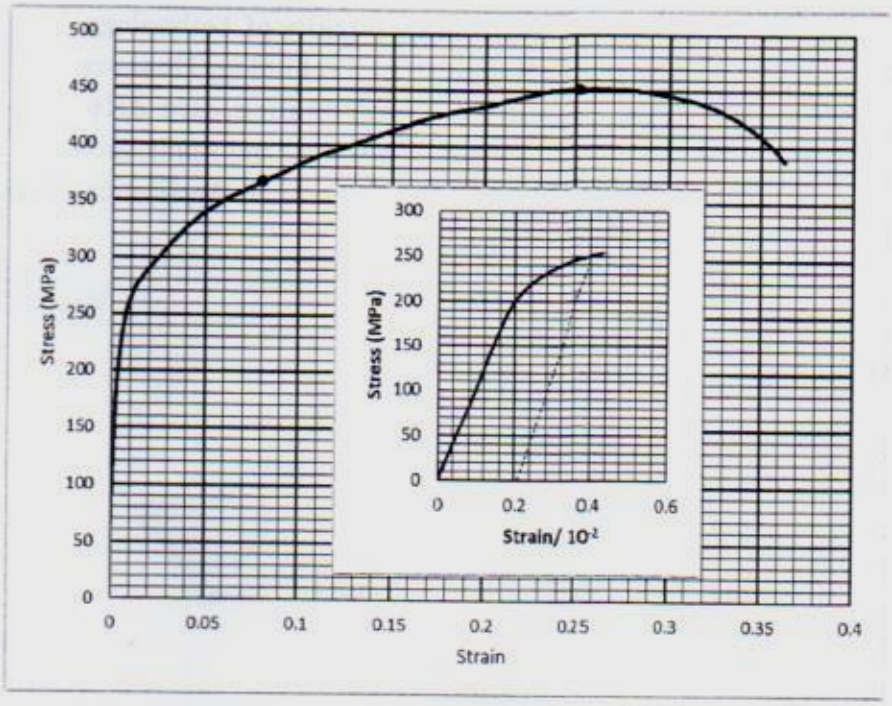
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ENT 2152- Properties of Material and Their Applications(Rpeat)

Attachment I- Figures

Question 1- Figure No 01: Pb-Sn phase diagram



Question 2 - Figure No 02: Stress vs Strain curve



Question 3- Figure No 03: Tensile stress (σ_c) is applied along the fiber axis of FRC (discontinuous fibers composite)

