RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree
Third Year – Semester II Examination – October/ November 2014

PHY 3309- STRUCTURE AND PROPERTIES OF MATERIALS

Answer **question one** and any **other five** questions Time: Three hours

Planck constant, h	$= 6.624 \times 10^{-34}$ J s
Mass of electron, m_e	$= 9.1 \times 10^{-31}$ kg
Speed of light in free space, c	$= 3.0 \times 10^{8}$ m s^{-1}
1 eV	$= 1.6 \times 10^{-19}$ J

Use of a non-programmable calculator is permitted.

1. a) Briefly explain the disordered state and ordered state of solids.
   b) What do you mean by translational symmetry?
   c) Define space lattice.
   d) Distinguish between primitive cell and unit cell.
   e) What are fundamental translation vectors?
   f) Draw the unit cell and primitive cell for b.c.c. and compare.
   g) Distinguish between ionic and covalent bonds.
   h) Find the ionic character of MgO. [Electronegativities of Mg and Oxygen are 1.2 and 3.5 respectively.]
   i) Sketch the following planes in a cubic unit cell.
   (2 2 1) $(1\bar{1}2)$ (1 1 0) (200)
   j) Sketch the following directions in a cubic unit cell.
   [2 2 1] [110] $[1\bar{1}2]$ [200]

[10 x10 marks]

2. (a) X-rays are widely used in diffraction methods in order to determine crystal structures. What are the advantages and disadvantages in using x-ray comparing to other radiations? [20 marks]

(b) How are the crystal structures of solids usually determined? [25 marks]

(c) For crystal diffraction experiments, wavelengths of the order of 0.1 nm are often appropriate. Find the energy, in electron volts, for a particle with this wavelength if the particle is

i. a photon and
ii. an electron. [20 marks]

(d) Explain the Rotating Crystal Method with suitable figures. [35 marks]

3. (a) A long chain molecules is composed of identical atoms evenly spaced. The potential energy of interaction (between nearest neighbours only) is given by

$$V_{(X)} = -\frac{A}{X^6} + \frac{B}{X^{12}}$$

Determine,

i. the equilibrium spacing x_0 of the atoms and
ii. the modulus of elasticity of the chain in terms of A and B [25 marks]

(b) Explain how the shape of the Condon-Morse curves of a solid related to its properties using examples. [30 marks]

(c) List the different types of defects present in a material and explain briefly. [20 marks]

(d) Show the energy per unit length of an screw dislocation is $\frac{E}{l} = Gb^2$.
Where, E- Energy, l- length, G- Shear modulus and b- Burgers' vector. [25 marks]

4. (a) Discuss the importance of knowing the mechanical properties of a material with suitable examples [at least three]. [15 marks]

(b) Draw the typical stress-strain curve for a metal and explain the significances of the curve. [15 marks]

(c) Draw the engineering stress vs engineering strain curves for the following materials.
(i) brittle, lower toughness material.
(ii) ductile, higher toughness material
(iii) high ductility, lower strength and lower toughness material. [15 marks]

(d) What is creep? How it is tested? Draw the characteristic creep curve for a material giving the significances of the curve. [25 marks]

(e) Creep tests on a stainless steel at 550°C produced a strain of 0.12 after 300 hours when subjected to a stress of 350 MN/m^2 and a strain of 0.08 after 1200 hours when stressed to 245 MN/m^2. Assuming steady state creep, calculate the time to produce 0.1 % strain in a link bar of the same material when stressed to 75 MN/m^2 at 550°C. [30 marks]

5. (a) Why the actual strength of a solid very much lower than the theoretical value? [20 marks]

(b) Show that the theoretical cohesive strength of the solid is $\sigma_C = \sqrt{\frac{\epsilon \gamma_s}{a_0}}$.

Where, σ_C - cohesive strength of the solid, ϵ - Young's modulus, γ_s - surface energy, a_0- equilibrium distance between atomic centers. [30 marks]

(c) What do you mean by critical stress intensity factor or fracture toughness? [20 marks]

(d) A metal has fracture toughness, K_{IC} = 40 N m$^{-3/2}$ and yield strength of 1000 N m^{-2}. Usually edge cracks perpendicular to the applied tensile stress are present when wide sheets of the metal are used in service. Calculate the length of the crack which will reduce the residual static strength to 90 % of the yield strength. [30 marks]

6. (a) Write down the assumptions made in Drude model. [20 marks]

(b) Define relaxation time, mean free path and drift velocity of an electron inside a Metal. [30 marks]

(c) Explain and derive the Ohm's law by using Drude model. [30 marks]

(d) What are the failures of Drude model? [20 marks]

7. (a) "Sommerfeld modified the classical free electron model by treating the problem quantum mechanically" Explain briefly. [30 marks]

(e) What is Density of States in energy space [$D_{(E)}$]? [15 marks]

(c) Find the number of energy levels in a small energy range dE for a particle in a very large potential box. [40 marks]

(f) Plot the variation of Density of States with energy for a free electron gas in three dimensions. [15 marks]