RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Third Year - Semester II Examination – July 2020

PHY 3210 – PROPERTIES OF MATERIALS

Time: Two (02) hour

Answer All Questions.

Symbols have their usual meaning.
Use of a non programmable calculator is allowed.

Planck's constant $h = 6.626 \times 10^{-34}$ J s
Velocity of light $c = 3.0 \times 10^{8}$ m s^{-1}
Mass of an electron = 9.1×10^{-31} kg
Charge of an electron = 1.6×10^{-19} C

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1. Luminescence is the generic name for light emission by spontaneous emission in solids and can occur by a number of mechanisms.

   a) Discuss briefly two different mechanisms of luminescence. (06 marks)

   b) Using schematic diagrams explain what is meant by direct gap materials and indirect gap materials. (06 marks)

   c) Explain why it is difficult to make light emitting devices out of indirect gap materials. (06 marks)

   d) When a direct gap semiconductor is excited by absorption of photons with energy greater than the band gap, it is generally found that the luminescence spectrum is independent of the excitation frequency. Explain this phenomenon. (07 marks)

2. Details of the Fermi surface in metals could be obtained by the study of electron motion under the influence of a uniform magnetic field. The total electron energy in the presence of a magnetic field applied along the z-direction is written as

$$E_n(k_z) = \frac{\hbar^2 k_z^2}{2m} + \left(n + \frac{1}{2}\right)\hbar\omega_c$$

a) i. Show that an electron of mass m and charge e performs circular orbits around a magnetic field with an angular frequency (cyclotron frequency) $\omega_c = \frac{eB}{m}$, where B is the field strength. (08 marks)

ii. Explain what is meant by cyclotron resonance. (06 marks)

b) i. An electron in sodium at the Fermi level moves initially in the xy-plane. Calculate the radius of its cyclotron orbit when a magnetic field of 1 T is applied along the z-direction. (06 marks)

ii. What is the ratio of the orbital area in real space to that in k-space? (05 marks)

3. The electrical properties of ceramics are often overlooked in favour of their ability to withstand abrasion, corrosion, and extreme heat conditions. However, electrical properties of ceramics are of prime significance in some devices such as Solid Oxide Fuel Cells (SOFCs).

a) By way of a clear diagram, discuss the working principle of the SOFC. (10 marks)

b) Explain the mechanism by which the electrolyte of the SOFC (yttria stabilized ZrO_2) is made O^{2-} ionic conducting by stabilizing ZrO_2 with Y_2O_3 (yttria).

Hint: Valencies of Zr and Y are +4 and +3 respectively.

(10 marks)

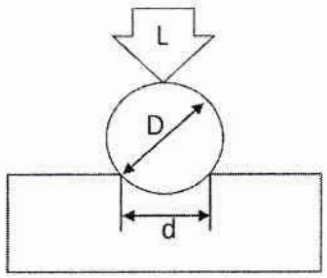
c) What are the other applications of yttria stabilized zirconia? (05 marks)

4. Hardness of a material is defined as its resistance to permanent deformation such as indentation, wear, abrasion or scratch.

a) Discuss the importance of hardness testing in engineering design, analysis of structures, and materials development. (02 marks)

b) Distinguish between macrohardness testing and microhardness testing. (05 marks)

c) The Brinell hardness test method consists of indenting the test material with a hardened steel ball of diameter D (mm) subjected to a load of L (N) as follows.



If the diameter of the indentation made on the surface of the test material is d (mm), show that the Brinell Hardness Number (*BHN*) of the material is given by;

$$BHN = \frac{L}{\frac{\pi}{2} D\left(D - \sqrt{D^2 - d^2}\right)}$$

(15 marks)

d) Briefly discuss the disadvantages of Brinell hardness test method. (03 marks)

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