



# UNIVERSITY OF RUHUNA

## Faculty of Engineering

End-Semester 4 Examination in Engineering: January 2022

Module Number: ME 4212

Module Name: Nanotechnology

[Three Hours]

[Answer all questions, each question carries 12 marks]

Q1. a) Bohr radius of an electron orbiting around the nucleus of an atom can be expressed as,

$$a_0 = \frac{4\pi\epsilon_0\hbar^2}{mq^2}, \text{ all terms in the equation have their usual meaning.}$$

i) Deriving the above equation for Bohr radius ( $a_0$ ) of an electron and express it for an exciton.

[4.0 Marks]

ii) If  $m_e$ ,  $m_h$  and  $\epsilon$  for InAs exciton are  $0.02m_0$ ,  $0.4m_0$  and 14.5, respectively. Calculate the physical size of a InAs nanoparticle. You may take the mass of the electron  $m_0$  as  $9.11 \times 10^{-31}$ .

[3.0 Marks]

b)  $\psi = B \sin\left(\frac{n\pi x}{l}\right)$  is the wave function of a two-dimensional nanoparticle in the quantum confinement region of size  $l$ , while  $\psi$  outside of this region is zero.

i) Show that the value of the constant B is proportional to  $l^{-\frac{1}{2}}$ .

[2.0 Marks]

ii) What is the expression for the energy of the  $n^{\text{th}}$  energy state and hence draw the first four energy states.

[2.0 Marks]

iii) Draw the wave function  $\psi$  and  $|\psi|^2$  for the first three energy states.

[1.0 Mark]

Q2. a) Nanomaterials and nano devices have been extensively used in a vast range of applications.

i) Discuss briefly the differences between "Nanoscience" and "Nanotechnology".

[2.0 Marks]

ii) Nanoparticles shows high surface area with compared to the bulk of the same material. Prove mathematically that "the surface-to-volume ratio of nanoparticles is much higher than that of a bulk particle of same volume of the identical material". Use a neat sketch also in answering.

[3.0 Marks]

iii) Explain why the melting point of metallic materials decreases when the sizes of the particles of materials decrease.

[2.0 Marks]

b) Nanomaterials can be classified into two categories as "Natural nanomaterials" and "Engineered nanomaterials". Briefly explain each of the categories and give examples for each.

[2.0 Marks]

c) Define the followings according to the 2011 European Union (EU) recommendations.

i) Particle

ii) Aggregates

iii) Agglomerates

[3.0 Marks]

Q3. a) Materials that belong to the natural world (animal and mineral), which are in existence without human modification or processing have remarkable properties because of their inherent nanostructure.

i) Briefly explain the terms "Lotus effect" and "Gecko effect" and give two potential applications of each.

[4.0 Marks]

ii) Write down Young's equation in terms of surface tensions with a neat sketch. Define all the parameters you use here.

[2.0 Marks]

iii) Discuss the differences between a hydrophilic surface and a hydrophobic surface.

[2.0 Marks]

b) Nantoxicity is a key subject of concern in nanoscience and nanotechnology because of the increasing toxic effects of nanomaterials on the living organisms.

i) Briefly explain the reasons for nanoparticles having greater toxicity risks than larger particles of the same material.

[2.0 Marks]

ii) Discuss the disadvantages of nanotechnology other than the nanotoxicity.

[2.0 Marks]

Q4. a) X-ray diffraction (XRD) is an analytical technique based on the diffraction of X-rays by matter, especially in case of crystalline materials.

i) Derive the Bragg's equation ( $n\lambda = 2d\sin\theta$ ) for diffraction of x-rays by crystalline materials. Use a neat sketch and define all terms used in the equation.

[4.0 Marks]



- ii) List the types of information that can be obtained by using X-ray diffraction (XRD) spectroscopy on a given material.

[2.0 Marks]

- b) The electron interactions on a specimen is the fundamental of the Electron Microscopy, where the energetic electrons in the microscope strike the specimen and various reactions can occur as given in Figure Q4 (b). Using a neat sketch, discuss the **formation** and **utilisation** of following electrons.

- i) Secondary electrons.  
ii) Backscattered electrons.

[3.0 Marks]

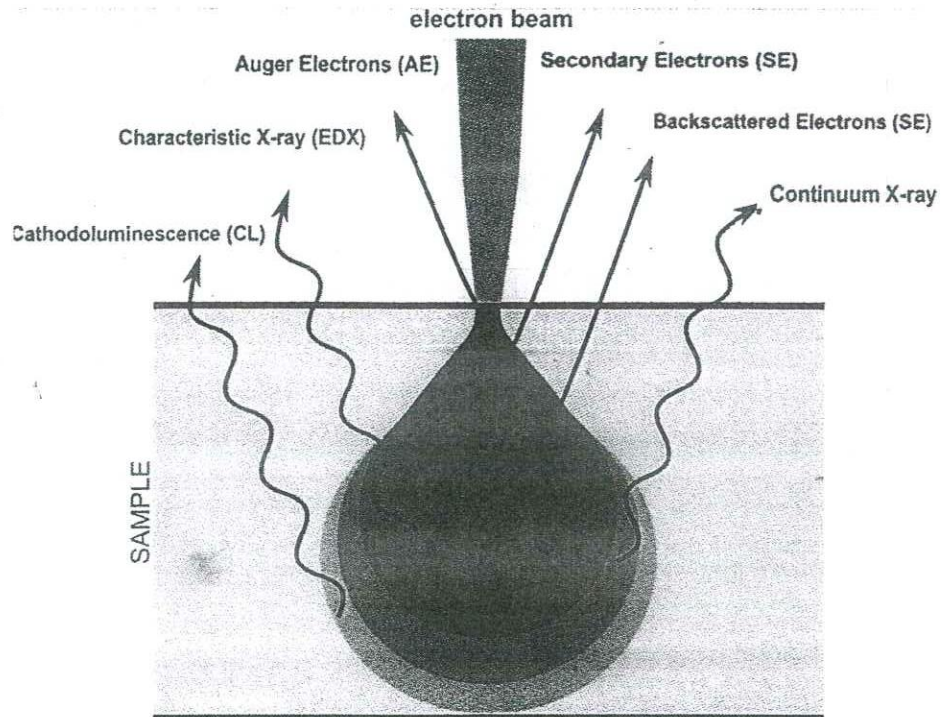


Figure Q4 (b)

- c) Compare the differences between the Scanning electron microscope (SEM) and the Atomic Force Microscope (AFM).

[3.0 Marks]

- Q5. a) Nanoparticle synthesis based on microemulsion technique refers to nucleation and growth of nanoparticles in liquid under controlled conditions.

- i) Name the factors influencing the formation of a microemulsion.

[1.0 Mark]

- ii) Explain the arrangement of surfactant molecules during the formation of the "Micelle" and "Reverse-micelle" in a microemulsion.

[2.0 Marks]

- iii) By using appropriate sketches, describe the steps used for the synthesis of nanoparticles if the reverse-micelle technique is followed.

[3.0 Marks]

b) Write short notes on the following.

- i) Properties and applications of Buckminsterfullerene.
- ii) Dip-pen nanolithography (DPN).
- iii) Synthesis of nanoparticle by the "coprecipitation" technique.

[6.0 Marks]