UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

Module Number: ME4212   **Module Name: Nanotechnology**

[Three Hours]
[Answer **all questions**, each question carries **12** marks]

Q1. Synthesis of nanomaterials and nanostructures is an important aspect of nanoscience and nanotechnology. Physical properties and applications of nanomaterials are only possible when nanostructured materials are prepared with desired size, shape, morphology, crystal structure and chemical composition.

   i) Define the terms: "nanomaterials" and "nanotechnology".

[2.0 Marks]

   ii) Briefly explain the ways of forming nanomaterials naturally.
Is it possible to use these nanomaterials for any industrial applications? Explain your answer.

[3.0 Marks]

   iii) Describe the **two** prominent approaches: "top-down" and "bottom-up" in synthesis of nanoparticles and write down any **two** examples in each approach.

[3.0 Marks]

   iv) State and briefly explain the key challenges in nanoparticles synthesis.

[2.0 Marks]

   v) Discuss the processing parameters that can be controlled to achieve the desired properties such as size and shape in nanoparticle synthesis.

[2.0 Marks]

Q2. a) Nanomaterials/nanostructures are found in living systems of nature and nanoscientists are examining the properties and potential uses of these natural nanostructures, particularly in an area of research called biomimicry. Discuss the following categories of objects and their functions that can be served as inspirations for various nanotechnological developments towards day-to-day appliances.

   i) Lizard and spider.
   ii) Shark and seashell.
   iii) Kingfisher and peacock

[6.0 Marks]

b) Sri Lanka is enriched with high-purity mineral ores. Name **one** of the minerals that can be converted into valuable nanomaterials, which can be used in the energy sector. You should explain your answer by considering the properties of the respective nanomaterial.

[2.0 Marks]

c) Despite the wide use of nanotechnology and numerous benefits it has delivered, there are still lots of concerns and uncertainties on the use of nanoparticles. There are many potential risks to living organisms and the environment.

i) What are the potential ways of nanomaterials entering into the human body?

[2.0 Marks]

ii) Discuss key precautions that can be taken to minimize the risk to human lives and the environment during the production or fabrication of nanoparticles or nanostructures.

[2.0 Marks]

Q3. a) X-Ray diffraction analysis (XRD) is a nondestructive technique that provides detailed information about the crystallographic structure, chemical composition, and physical properties of a material.

i) Briefly discuss the constructive interference and destructive interference of **two** electromagnetic waves.

[2.0 Marks]

ii) 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]

b) Chemical vapor deposition (CVD) processes are being used to prepare high-performance thin films and nanoparticles.

i) State and explain the basic requirements of precursor use in the CVD process.

[1.0 Mark]

ii) Briefly explain the **three** basic types of chemical reactions that occur in the CVD process. Give examples for each.

[3.0 Marks]

iii) Discuss the advantages and disadvantages of the CVD process.

[2.0 Marks]

Q4. a) Microscopy techniques represent a class of multifunctional techniques often used for in-depth analysis and understanding of materials in nano or micro scales.

    i) Explain, why optical microscopic technique cannot be used for observing nano-structured materials.

[1.0 Mark]

    ii) Compare the differences between the Electron microscope and the optical microscope.

[3.0 Marks]

    iii) Name **two** main types of scanning-probe microscopic techniques used in observing nanostructured materials and differentiate the working principles of those.

[2.0 Marks]

b) When the electron beam interacts with the sample in scanning electron microscopy, different kinds of electrons and X-rays emit as shown in Figure Q4(b). Using neat sketches, discuss the formation and utilization of the following.

    i) Characteristic x-rays
    ii) Auger electrons
    iii) Secondary electrons
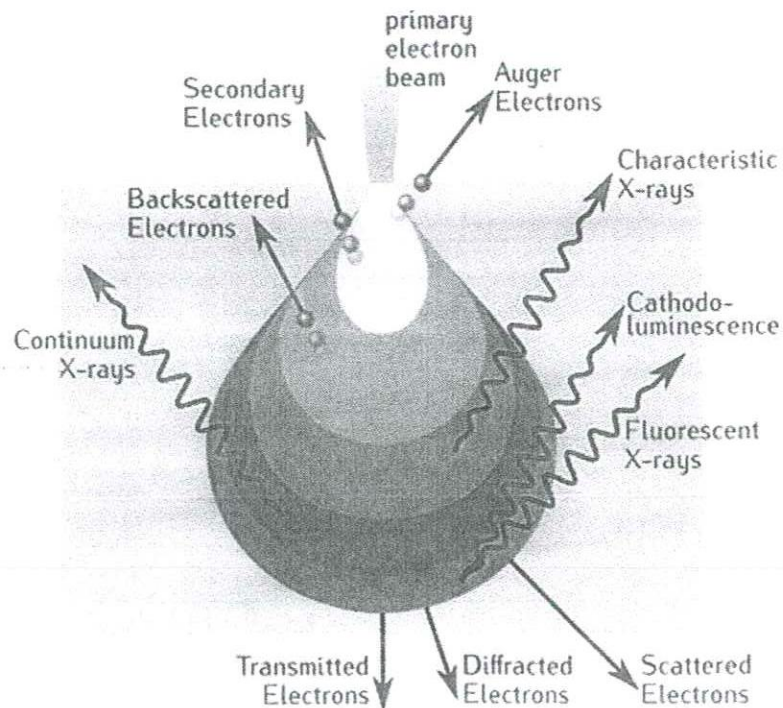   iv) Backscattered electrons

[6.0 Marks]

Figure Q4 (b)

Q5. a)   The interaction of nanoparticles in a certain system can be explained by the Lennard-Jones potential equation as given below.

$$V(r) = 4\epsilon \left[\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} \right]$$

   i)   Define the notations V(r), σ and ε in the equation and identify the attractive term and the repulsive term.

[1.5 Marks]

   ii)   Prove that the optimum bond distance is $r_{opt} = 2^{1/6}\sigma$.

[2.0 Marks]

b)   Recently, it has been identified that potassium iodide nanoparticles have the capability to enhance the effectiveness of radiotherapy treatments.

   i)   Calculate the Coulombic attractive force between a pair of K^+ and I^- ions, which are just touching each other. Consider the ionic radius of K^+ and I^- are 0.138 nm and 0.22 nm, respectively.

[3.0 Marks]

   ii)   Further determine the **net potential energy** of the pair according to the formula $E_N = E_A + \dfrac{b}{r^9}$, where E_N is net potential energy, E_A is attractive energy, r is bond distance and b is a constant, respectively.

   Consider that the permittivity of the free space is 8.85 x 10⁻¹² C²/Nm²

[4.0 Marks]

c)   According to the DLVO (Derjaguin–Landau–Verwey–Overbeek) theory, what are the reasons for sudden attraction of particles in each of the following cases.

   i)   Two positive ions are too close.

   ii)   Two positive ions are interfered by an electrolyte.

[1.5 Marks]

End of the paper.