UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2018

Module Number: ME 6211 **Module Name: Nanotechnology**

[Three Hours]

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

Q1 a) Fundamental concepts of nanoscience are important to develop new materials with different characteristics. Answer the following questions based on fundamentals of nanoscience.

i) Distinguish between compact materials and dispersed nanomaterials.

[1.0 Mark]

ii) Classify the metal nanoparticles according to their shapes.

[1.5 Marks]

iii) Reclassify the metal nanoparticles in Q1 part (ii) again according to the quantum definition.

[1.5 Marks]

iv) Sketch the density of states of a quantum dot.

[1.0 Mark]

b) Bohr radius of an electron that orbit around the nucleus is given by $a_0 = \frac{4\pi\epsilon_0\hbar^2}{mq^2}$. All terms in the equation have their general meaning.

i) Derive the above equation for Bohr radius (a_0) of an electron.

[3.0 Marks]

ii) Give the expression for the Bohr radius of an exciton.

[1.0 Mark]

iii) Calculate the physical size of the CdS nanoparticle if m_e, m_h and ε for CdS exciton are $0.2m_o$, $0.7m_0$ and 8.6 respectively.

[3.0 Marks]

Q2. a) In the treatment of interactions between the particles within a nanoparticle, dipole-ion interaction is considered as one of contributions to the interaction energy.

i) Define the dipole moment (u) of a pair of charges $+q$ and $-q$ separated by distance l.

[0.5 Mark]

ii) Calculate the dipole moment (u) of two electronic charges separated by 0.1 nm distance.

[0.5 Mark]

b) An ion of charge Q and a molecule of a pair of two electronic charges $+q$ and $-q$, separated by distance l are placed in such a way that horizontal distance between the ion and the center of the molecule is r. The angle of the molecule to the horizontal line is θ.

i) What is the electric field of charge E(r), acting on the dipole?

[4.0 Marks]

ii) Show that the energy of the interaction is given by

$$w(r,\theta) = -\vec{u} \cdot \vec{E}$$

[5.0 Marks]

iii) Calculate the interaction energy of the dipole with respect to the permittivity of the medium if the charge of the ion (z) is 2+, r = 0.3 nm, l = 0.1 nm and the angle Q = 60°.
[Charge of a electron (e) is 1.602×10^{-19} C and Q = ze]

[2.0 Marks]

Q3. a) Nanotechnology can be used across all the fields of science, such as chemistry, biology, physics, materials science, and engineering.

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

[2.0 Marks]

ii) State four challenges that are faced by researchers in the field of nanotechnology.

[2.0 Marks]

iii) By using a neat sketch, mathematically show that "the surface-to-volume ratio of nanoparticles is much higher than that of the bulk particle of the identical material".

[3.0 Marks]

iv) Explain briefly, the variation of the melting point of a material when decreasing the size of a metallic particles.

[2.0 Marks]

v) Discuss the advantages of nanotechnology in energy and medial sectors.

[3.0 Marks]

Q4. a) Scanning electron microscopy (SEM) and atomic force microscopy (AFM) are extensively used in characterization of nanomaterials.

i) Write down any two types of electrons detected in scanning electron microscopy.

[1.0 Mark]

ii) Explain briefly, the working principle of atomic force microcopy.
Use neat sketches where necessary.

[3.0 Marks]

iii) Compare the differences of scanning electron microscopy(SEM) and atomic force microscopy(AFM).

[2.0 Marks]

b) Nanoparticles used in bio-medical applications have been widely synthesized using the microemulsion technique.

i) Explain the formation of "Micelle" and "Reverse-micelle" in microemulsion.

[2.0 Marks]

ii) By using appropriate sketches, describe the synthesis steps of nanoparticles through the reverse-micelle technique.

[4.0 Marks]

Q5. a) According to the Wenzel 's model, wetting of liquid on a textured solid surface (rough solid surface) at micro and nano levels can be expressed as follows.

$$Cos\ \theta^* = r\ cos\ \theta$$

i) Define the parameters θ^*, r *and* θ.

[2.0 Marks]

ii) When $r = 1.2$, discuss the deviation of the quality of the solid surface for the two conditions: $\theta < 90^\circ$ and $\theta > 90^\circ$.

Use appropriate values for the θ in both cases to justify your answer.

[4.0 Marks]

b) Write short notes on the following terms.

i) Solid phase synthesis of nanoparticles and their limitations.

[3.0 Marks]

ii) Carbon nanotubes.

[3.0 Marks]