UNIVERSITY of York

Department of Electronic Engineering

Assessments 2019/20

ELE00023H

Nanoelectronics

This assessment (**Tutorial Questions 1**) contributes **13%** of the assessment for this module.

Clearly indicate your **Exam Number** on every separate piece of work submitted.

Unless the assessment specifies a group submission, you should assume all submissions are individual and therefore should be your own work.

All assessment submissions are subject to the Department's policy on plagiarism and, wherever possible, will be checked by the Department using Turnitin software.

Submission is via **the VLE** and is due by **12:00** on **30 January 2020 (Spring Term, Thursday, Week 4)**. Please try and submit early as any late submissions will be penalised.

Please remember that if this is your first year of study, you need to complete the mandatory Academic Integrity Tutorial http://www.york.ac.uk/integrity/

19/20 Nanoelectronics: Tutorial Questions 1

Question 1.

In order to describe quantum mechanical behaviour, de Broglie wave can be used, of which wavelength is defined as $\lambda = \frac{h}{p} = \frac{h}{mv}$ (Planck constant: $h = 6.625 \times 10^{-34}$ $[J \cdot s]$). Calculate the de Broglie wavelength for the following cases:

(1) A human with the mass of 60 kg is walking at the speed of 0.8 m/s.

(2) A bullet of mass 9 g is flying at the speed of 10^3 m/s.

(3) A free electron with the mass of 9.10938×10^{-31} $[kg]$ is travelling at the speed 10^6 m/s.

Question 2.

(1) In order to observe a crystal, of which atomic separation is 1 Å, estimate energy of the following waves in the unit of eV; (a) X-ray, (b) electron-beam and (c) neutron-beam. Calculate the energy required for imaging using $E = \frac{hc}{\lambda}$ for X-ray and the relationship between the wavelength and kinetic energy for electron- and neutron-beam.

(2) In order to investigate atomic core structures of 10^{-15} m, estimate energy of the following waves in the unit of eV; (a) X-ray, (b) electron-beam and (c) neutron-beam. Calculate the energy required for imaging using $E = \frac{hc}{\lambda}$ for X-ray and the relationship between the wavelength and kinetic energy for electron- and neutron-beam.

Note you do not need to consider the theory of relativity for the above calculations.

Question 3.

In a Rutherford Hydrogen model, derive quantum energy levels by assuming angular momentum of an electron is quantised as integer multiples of the Planck constant ($\hbar n$; $n = 1, 2, 3, \cdots$). Calculate the Bohr radius for $n = 1$.