University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATION – 2011/2012

PHYC 10160

Physics for Engineers II

Professor I. T. McGovern
Professor P. A. Dunne
Dr. I. Mercer *

Time Allowed: 2 Hours

Instructions for Candidates

Candidates should attempt all four questions. Clearly mark your attempted questions on the front cover of the answer booklets. All questions carry equal marks. The marks allocated to each part of a question are indicated in brackets.

Instructions for Invigilators

Non-programmable calculators are permitted.

1.

a) With the aid of a labeled diagram, describe the Bohr model of the hydrogen atom. (2 marks)

b) Derive the following relationship for a hydrogen atom according to the Bohr model:

$$r_n = a\, n^2$$

where r_n are the permitted radii of the electron orbit, n = 1, 2, 3…, and 'a' is a constant. Determine 'a' in terms of variables that you define.

Hint: equate Coulomb's law with the centripetal force acting on an electron, and then take angular momentum to be quantized according to Bohr. (4 marks)

c) Give a relationship for the quantum uncertainty principle, clearly defining variables. Reason why atoms don't collapse due to this principle. (2 marks)

d) A hydrogen atom makes a transition from the 5th to the 2nd quantum state. What is the wavelength of light emitted? Take the allowed energies, E of a hydrogen atom to be given by: $E_n = -(13.60\text{ eV})/n^2$ where n = 1, 2, 3… (2 marks)

2.

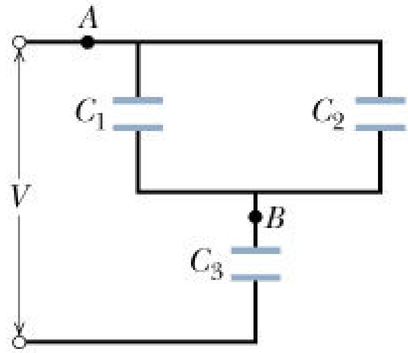
a) Describe Gauss's Law with the aid of a clearly labeled diagram. (2 marks)

b) Using Gauss's Law, derive the capacitance of two flat plates in terms of their area, A and their separation, d. Draw a clearly labeled diagram showing the capacitor, your Gaussian surface, the charge distribution and the electric field.

Hint: first determine the electric field using Gauss's Law, then determine the potential difference between the plates, then apply the equation for capacitance in terms of charge and this potential difference. (4 marks)

c) What is the modified form of this relationship, where a dielectric with a dielectric constant of κ, is inserted to fill the capacitor? (1 mark)

d) The following diagram shows three capacitors of capacitance C_1, C_2 and C_3 with a potential difference, V as shown. In terms of these variables, determine: (i) the capacitance between points A and B; (ii) the net capacitance across the input terminals and; (iii) the net charge, Q held by all three capacitors.



(3 marks)

3.

a) Describe Ampere's Law for a long straight wire carrying a current, and Faraday's Law of induction, and Lenz's Rule for a loop of wire in a magnetic field.

(5 marks)

b) A circular loop of area $0.10 m^2$, is perpendicular to a uniform magnetic field, B. The loop contains a resistor.

(i) What is the EMF across the resistor where the magnitude of the magnetic field varies with time according to $B = 0.10 - 0.04t$, with B in teslas and t in seconds? In a diagram, show the directions of the magnetic field and the resultant current in the loop. (3 marks)

(ii) What is the maximum emf across the resistor, where the magnetic field is instead held constant at B = 0.10 T, and the loop rotates about an axis perpendicular to the magnetic field at a steady 0.20 rotations per second?

(2 marks)

4.

a) Give an account of the nuclear processes that give rise to alpha and beta decay.

(3 marks)

b) Give an account of nuclear binding energy, accompanied by a labelled graph of binding energy per nucleon versus the number of nucleons that explains why some elements undergo fission whilst some undergo fusion. (3 marks)

d) Calculate the nuclear binding energy in MeV of the 92 protons and 146 neutrons in the nucleus of a ^{238}U atom. Note the following: the mass of ^{238}U atom = 238.05079 u; the mass of the Hydrogen atom = 1.00783 u; and the mass of the neutron = 1.00866 u, where u is the atomic mass unit. (4 marks)

Recommended Values of Physical Constants and Conversion Factors

(*Sources*: 2006 CODATA recommended values; http://physics.nist.gov/constants)

speed of light in vacuum, c = 299 792 458 (exact) m s^{-1}

electric (permittivity) constant, ε_0 = 8.854 187 817… × 10^{-12} (exact) F m^{-1}

magnetic (permeability) constant, μ_0 = 12.566 370 614… × 10^{-7} (exact) N A^{-2}

(unified) atomic mass unit, u = 1.660 538 782(83) × 10^{-27} kg

alpha particle mass (in u) = 4.001 506 179 127(62) u

atomic mass unit energy equivalent = 1.492 417 830(74) × 10^{-10} J

atomic mass unit energy equivalent (in MeV) = 931.494 028(23) MeV

Avogadro constant, N_A = 6.022 141 79(30) × 10^{23} mol^{-1}

Bohr radius, a_0 = 0.529 177 208 59(36) × 10^{-10} m

Bohr magneton, μ_B = 927.400 915(23) × 10^{-26} J T^{-1}

Boltzmann constant, k = 1.380 6504(24) × 10^{-23} J K^{-1}

classical electron radius, r_e = 2.817 940 2894(58) × 10^{-15} m

Compton wavelength of the electron, λ_C = 2.426 310 2175(33) × 10^{-12} m

deuteron mass (in u) = 2.013 553 212 724(78) u

electron mass, m_e = 9.109 382 15(45) x 10^{-31} kg

elementary charge, e = 1.602 176 487(40) × 10^{-19} C

molar mass of carbon-12 = 12 × 10^{-3} (exact) kg mol^{-1}

neutron mass, m_n = 1.674 927 211(84) x 10^{-27} kg

Newtonian constant of gravitation, G = 6.674 28(67) × 10^{-11} m^3 kg^{-1}

nuclear magneton, μ_N = 5.050 783 24(13) × 10^{-27} J T^{-1}

Planck constant, h = 6.626 068 96(33) × 10^{-34} J s

proton mass, m_p = 1.672 6216 37(83) x 10^{-27} kg

Rydberg constant, R = 10 973 731.568 527(73) m^{-1}

Stefan-Boltzmann constant, σ = 5.670 400(40) × 10^{-8} W m^{-2} K

triton mass (in u) = 3.015 500 7134(25) u

oOo