University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION (RESIT) – 2012/2013

PHYC 10160

Physics for Engineers II

Dr P. J. M. van der Burgt
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 Heisenberg's 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 eV)/n^2 where n = 1, 2, 3… [2 marks]

2.

a) State Coulomb's Law and Gauss's Law for electric and magnetic fields. Illustrate with one diagram each how Gauss's Law applies to the field of an electric dipole and the field of a magnetic dipole. [5 marks]

b) Two point charges q_1= − 5.5 x10^{-9} C and q_2= + 5.5 x 10^{-9} C are fixed in a vacuum at apexes A and B of an equilateral triangle ABC of side 0.1 m. For this:
   i) Describe the electric field in the neighbourhood of the two charges by drawing field lines. [2 marks]
   ii) Calculate the value and direction of the electric field at C. [2 marks]
   iii) Calculate the electric potential at C. [1 mark]

3.

a) State Faraday's Law and Lenz's Rule in relation to electromagnetic induction. [4 marks]

b) Describe the principle of an alternating current generator, deriving an equation for the EMF generated as a loop rotates at a constant rate. You should assume that the loop is rectangular with sides *a* and *b*. [4 marks]

c) What are the values of the peak and root-mean-square EMF generated by a coil of area 0.1 m^2 and 1,0000 turns, rotating at 50 Hz perpendicular to a uniform magnetic field of 10^{-1} T? [2 marks]

4.

a) Briefly explain what is meant by the nuclear processes alpha and beta decay, and give an example of each process. [3 marks]

b) Explain the concept 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]

c) 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 (in u), m_e = 5.485 799 0943(23) × 10^{-4} u

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 (in u), m_n = 1.008 664 915 97(43) u

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 (in u), m_p = 1.007 276 466 77(10) u

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

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