University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION (RESIT) – 2013/2014

PHYC 10160

Physics for Engineers II

Professor P.A. Dunne
Dr. Ian Mercer*

Time Allowed: 2 Hours

Instructions for Candidates

Candidates should attempt all questions. 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) Describe the photoelectric effect with the aid of a clearly labeled diagram showing an apparatus. (2 marks)

b) Derive an equation from conservation of energy for the stopping potential in terms of the frequency of the incident light and the work function for the material. Define variables used. (3 marks)

c) Describe an observation for the photoelectric effect that can't be explained using classical physics. (1 mark)

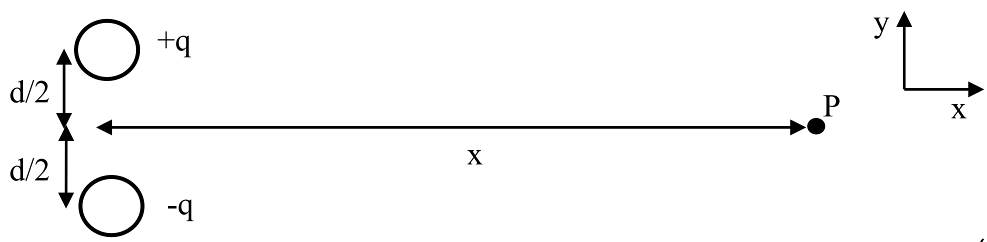
d) The work function for a certain metal is 1.8 eV. What is the stopping potential for ejected electrons when light of wavelength 400 nm shines on the metal? (2 marks)

e) An orbiting satellite can become charged by sunlight via the photoelectric effect. This can affect sensitive electronics, and to minimize this a satellite is coated with platinum, which has a large work function, $\Phi = 5.32$ eV. What is the longest wavelength of incident sunlight that can charge the satellite? (2 marks)

2.

a) Describe Gauss's Law, and use it to derive Coulomb's Law for a single point change in a vacuum. Also, show that the field from a single point charge is equivalent to that from a hollow sphere with a uniform charge distribution, where one is measuring the field outside of the sphere. (3 marks)

b) Using Coulomb's Law, derive an expression for the electric field at the position, P due to two hollow spheres charged to +q and –q, with centers separated by d, and with P separated from the dipole centre by a distance, x as shown in the following diagram, where x>>d:



(4 marks)

c) What is the field strength at P, taking the electric dipole moment to be 10^{-9} C.m, d = 1 mm and x = 1 m? (1 mark)

d) Determine the electric potential at point P by considering an integration along the x-axis from infinity to the point, P. (2 marks)

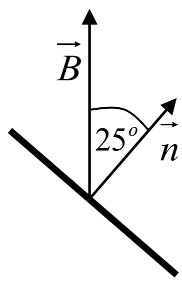
3.

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.

(4 marks)

b) A long cylindrical solenoid consists of 150 turns of wire per cm. A wire loop of area 10 mm^2 is placed inside the solenoid, and a sinusoidally varying current of maximum amplitude 1.1A and frequency 300 rad/s is passed through the solenoid. The central axis of the loop and solenoid coincide. From Ampere's Law, derive an expression for the magnetic field within the solenoid, and from Faraday's Law determine the maximum EMF induced in the loop. (4 marks)

c) A circular wire of 5 cm diameter (shown edge on), is placed with its normal, $\vec{n}$ at an angle, $\theta = 25^o$ to the direction of a uniform magnetic field, $\vec{B}$ of magnitude 0.3 T.



The loop is rotated such that $\vec{n}$ rotates in a cone about $\vec{B}$ at a rate of 50 revolutions per minute, with θ remaining unchanged. Determine the EMF induced in the loop. (2 marks)

4.

a) Derive the exponential expression that describes the radioactive decay in the number of nuclei, N, over a time, t. Give an example of another physical phenomenon which is described by an exponential relationship such as this.

(3 marks)

b) A radioactive nuclide has a half-life of 20.0 years. What fraction of an initially pure sample of this nuclide will remain at the end of (i) 50.0 years, and (ii) 100.0 years. (2 marks)

c) 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 reactions whilst some undergo fusion reactions.

(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. (2 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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