University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATION – 2012/2013

PHYC 10160

Physics in Engineering II

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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 with an equation and defined variables, and with the aid of a clearly labeled diagram. (2 marks)

(b) A spherical ball of charged particles has a uniform charge density. From Gauss's Law, derive equations for the electric field magnitude as a function of radius, inside, and outside, of the ball. Sketch and label a graph to illustrate this variation. (4 marks)

(c) A Geiger counter is used to detect ionizing radiation. For this device, a positively charged central wire is surrounded by a concentric, conducting cylindrical shell with an equal negative charge, creating a strong radial electric field. The shell contains a low-pressure inert gas, which when ionized by the radiation, leads to a detectable electric current between the wire and shell.

What is the surface charge density on the central wire, where the radius of the central wire is 20 μm, the radius of the inner shell is 1.4 cm, the length of the shell is 16 cm, and the magnitude of the electric field at the shell's inner wall is 2.9×10^4 N/C? Define variables used, give a clear labeled diagram, and discuss the role of symmetry and any assumptions required. (4 marks)

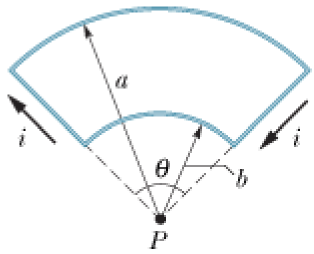
3.

(a) Describe with the aid of equations and defined variables with diagrams, Ampere's Law for a long straight wire carrying a current, and Faraday's Law of induction for a loop of wire in a magnetic field. Describe how Lenz's Rule is incorporated into Faraday's Law, and discuss the physical significance of Lenz's Rule.

(4 marks)

(b) Three hundred turns of insulated copper wire are wrapped around a plastic cylindrical core of cross-sectional area 2.30×10^{-3} m^2. The two ends of the wire are connected to a resistor, and the total resistance in the circuit is 9.0 Ω. If an externally applied uniform magnetic field in the core changes from 0.70 T to 0.10 T whilst maintaining direction longitudinally along the core, what is the total charge that flows through a point in the circuit? (3 marks)

(c) In the following figure, a wire loop consisting of two circular arcs of radii, a = 7.5 cm and b = 3.5 cm, subtending an angle θ = 74.0° centred at the same point, P. The wire carries a current, i = 1.2 A. What is the magnitude and direction (into or out of the page) of the net magnetic field at P?



(3 marks)

4.

(a) A radioactive source contains two phosphorus radionuclides, ^{32}P with $T_{1/2}$ = 14.3 days, and ^{33}P with $T_{1/2}$ = 25.3 days. Initially, 10.0% of the decays are coming from ^{33}P. How long must one wait until 90.0% to come from ^{33}P?

(5 marks)

(b) Calculate the energy released from one atom undergoing the fission reaction: ^{235}U + n $\longrightarrow$ ^{141}Cs + ^{93}Rb + 2n. For this, use the following atomic and particle masses: ^{235}U 235.04392 u; ^{141}Cs 140.91963 u; ^{93}Rb 92.92157 u; n 1.00866 u.

(2 marks)

(c) The power output from a ^{235}U fission reactor is maintained at 350 MW. The reactor consumes half of its initially pure ^{235}U fuel in 4.50 years. How much ^{235}U fuel did it contain initially? Assume that the power station is 50% efficient in converting the fission energy of ^{235}U to useful power output, and assume that this nuclide is consumed only by the fission process given in part (b).

(3 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, $\varepsilon_0 = 8.854\ 187\ 817\ldots \times 10^{-12}$ (exact) F m^{-1}

magnetic (permeability) constant, $\mu_0 = 12.566\ 370\ 614\ldots \times 10^{-7}$ (exact) N A^{-2}

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

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

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

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

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

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

Bohr magneton, $\mu_B = 927.400\ 915(23) \times 10^{-26}$ J T^{-1}

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

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

Compton wavelength of the electron, $\lambda_C = 2.426\ 310\ 2175(33) \times 10^{-12}$ m

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

electron mass (in u), $m_e = 5.485\ 799\ 0943(23) \times 10^{-4}$ u

elementary charge, $e = 1.602\ 176\ 487(40) \times 10^{-19}$ 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, $G = 6.674\ 28(67) \times 10^{-11}$ m^3 kg^{-1}

nuclear magneton, $\mu_N = 5.050\ 783\ 24(13) \times 10^{-27}$ J T^{-1}

Planck constant, $h = 6.626\ 068\ 96(33) \times 10^{-34}$ 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, $\sigma = 5.670\ 400(40) \times 10^{-8}$ W m^{-2} K

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

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