University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER 1 EXAMINATION (RESIT) – 2011/2012

PHYC 10160

Physics for Engineers II

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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) Describe the photoelectric effect with the aid of a clearly labelled diagram showing a typical apparatus. (3 marks)

(b) Derive an equation that relates the stopping voltage, the frequency of the incident light, and the work function for the material. Sketch and clearly label an accompanying graph. Clearly state any laws used and define all variables. (4 marks)

(c) What new physical understanding is derived from the observation of the photoelectric effect? (1 mark)

(d) In a measurement, the stopping voltage is measured to be 0.20 V for incident light of 500 nm wavelength. Determine the work function for the material. (2 marks)

2.

(a) Describe Gauss's Law with a clearly labelled sketch, and give an associated equation with clearly defined variables. (2 marks)

(b) Use Gauss's law to derive the capacitance of a parallel plate capacitor in terms of the stored charge and the potential difference, also showing an accompanying clearly labelled diagram. (3 marks)

(c) A parallel plate capacitor consists of two strips of metal each of area 0.2 m^2, and separated from each other by a dielectric of thickness 10^{-4} m, that has a dielectric constant of 4.0. A potential difference of 20 V is applied across the capacitor at time t=0. For this:

i) calculate the capacitance of the capacitor. (2 marks)

ii) calculate the final charge on the capacitor. (1 mark)

iii) draw a labelled graph of how charge on the capacitor varies in time, where a resistance, R is included in series with the capacitor. (2 marks)

3.

(a) How many 2.0 μF capacitors must be connected in parallel to store a charge of 0.01 C, with a potential of 170 V across the capacitors? (2 marks)

(b) Two parallel plate capacitors of 3.0 μF each, are connected in series to a 10 V battery. One of the capacitors is then squeezed such that its plate separation is 50% of its initial value. Because of this squeezing, what is the increase of the total energy stored in the capacitors, given in Joules? (5 marks)

(c) A dielectric material of dielectric constant, $\kappa = 4.6$ is inserted to fill the volume between the plates of both capacitors. Describe how this material effects the electric field between the plates and the energy stored by the capacitor. By how much does the answer to part b change, for the energy stored in the combined capacitors? (3 marks)

4.

(a) Derive the exponential expression that describes the radioactive decay in the number of nuclides, 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^{-1}

(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

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