NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1105 – ELECTRICITY AND MAGNETISM

BSc HONOURS PART I: *DECEMBER 2005* *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF QUESTION **ONE** IN SECTION **A** AND ANY **THREE** QUESTIONS FROM SECTION **B**. SECTION **A** CARRIES 40 MARKS AND SECTION **B** CARRIES 60 MARKS.

Electronic charge	e	$= 1.60 \times 10^{-19}$ C
Mass of an electron	m_e	$= 9.11 \times 10^{-31}$ kg
Permittivity of free space	ε_0	$= 8.85 \times 10^{-12}$ F m^{-1}
Permeability constant	μ_0	$= 1.26 \times 10^{-6}$ H/m
Mass of a proton	m_p	$= 1.67 \times 10^{-27}$ kg^{-1}

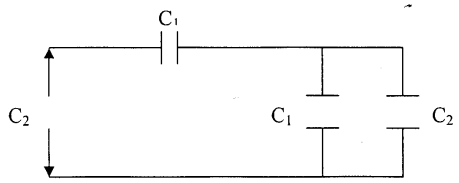
SECTION A

1. (a) Define *electric dipole* and the *electric dipole moment*. Write down an expression, in vector form, and show graphically the electric field intensity at point P on the normal to the axis of the dipole. [5]

(b) (i) Calculate the electric potential established by the nucleus of the hydrogen atom at the average distance of the circulating electron $r = 5.29 \times 10^{-11}$m. [2]

(ii) How much energy /in eV/ is required to ionize the hydrogen atom, e.g to remove the electron from the nucleus so that the separation is infinite? [3]

(c) Given the capacitor arrangement in the figure below find the relation between C_1 and C_2 in order that the capacity of the system is equal to C_2. [5]



(d) What is the effect on the capacitance of a parallel plate capacitor when a slab of material of dielectric constant **k** is inserted between the plates? Assume the thickness of the slab to be equal to the separation of the plates. [3]

(e) A maximum permissible current in the coil of an analogue ammeter is 2.5 A. Its resistance is 20Ω. What must be done to the instrument so that it may be inserted in an electric circuit carrying a current of 15 A and not destroy the coil? [5]

(f) Write brief notes on the Hall effect. Show on a diagram the polarity of the Hall voltage together with a given current and magnetic field direction, assuming the charge carriers to be conduction electrons. [4]

(g) A transformer has 600 turns on the primary and 12 turns on the secondary.

(i) Is this a set-up or a step-down transformer? [1]

(ii) If the primary is connected across a $120V_{rms}$, what is the open circuit voltage across the secondary? [2]

(iii) If the primary current is 0.1A, what is the current in the secondary, assuming negligible magnetizing current and no power loss? [2]

(h) What are *Eddy currents*? How can they be reduced in electrical machines? [4]

(i) Distinguish between *Reactance* and *Impedance* in an A.C circuit. Give relevant expressions for the two quantities using a simple AC circuit of your choice. [4]

SECTION B

2. (a) Define *Flux of the electric field.* Include a diagram in your answer. [4]

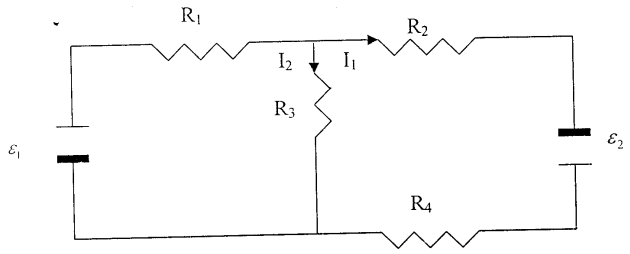
(b) Using Gauss's Law or otherwise, derive an expression for the electric field due to a uniformly charged hollow cylinder of inner radius ***a*** and outer radius ***b*** at a point:

(i) inside the hollow cylinder ($r < a$), [4]
(ii) within the cylinder wall ($b > r > a$), [3]
(iii) outside the cylinder ($r > b$). [2]

(c) In an ink-jet printer, - an ink drop of mass 1.3×10^{-10} kg and a negative charge $q = 1.5 \times 10^{-13}$ C/large/ enters the region between the deflecting plates, initially moving along the x – axis with speed $v_x = 18 m/s$. The length of the plates is L = 1.6 cm. The electric field between the plates is uniform pointing downward and a magnitude 1.4×10^6 N/C. What is the vertical deflection of the drop at the far end of the plates? [7]

3. (a) From the expression for Ohm's Law in its potential difference – current form, deduce the electric field intensity – current density of the law and comment briefly. [4]

(b) For the network in the figure below determine the currents I_1 and I_2.



$\varepsilon_1 = 18V$ $R_1 = 12\Omega$ $R_3 = 6\ \Omega$

$\varepsilon_2 = 12V$ $R_2 = 1\Omega$ $R_4 = 1\ \Omega$ [8]

(c) A 12 V battery is used to charge a 3μF capacitor in series with a 100 kΩ resistor. Calculate the potential difference across the capacitor and the circuit current after a time equal to twice the time constant, deriving the expressions you use. [8]

4. (a) Write brief notes on one practical application of the analysis of the motion of charged particles in a magnetic field. [5]

(b) (i) Using Ampere's Law or otherwise derive an expression for the magnetic field B of an infinitely long solenoid of N turns, each carrying current ***i.*** Draw a diagram to show the direction of the field. [4]

(ii) Show that the self-inductance of such a solenoid depends only on geometrical parameters and given by:

$$L = \mu_0 N^2 A / l$$ [4]

(c) A long wire lying along the x-axis carriers a current of 0.5A in the x – direction. A magnetic field $B = 3i + 8x^2j$ is present in the region. Where x is in meters and B is in mT. Calculate the force on the 2m segment of the wire that lies between x = 1.0 m and x = 3.0 m. [7]

5. (a) State Faraday's Law of induction. Comment on the statement that Lenz's Law is an expression of the principle of conservation of energy. [5]

(b) A coil having 150 turns is placed around a very long solenoid having 1000 turns per meter and a cross-section of $1.5 \times 10^{-3} m^2$. Determine:

(i) the mutual inductance of the system/derive the formula you use/, [6]

(ii) the e.m.f. in the coil if the initial current of 2.0A in the solenoid is reversed in 0.2 sec. [3]

(c) A circular coil of 300 turns and radius 5.0 cm is connected to galvanometer. The total resistance of the circuit is 20 Ω. The plane of the coil is originally aligned perpendicular to the Earth's magnetic field at some point. When the coil is rotated through 90°, the charge passing through the galvanometer is measured to be 9.4 μC. Calculate the magnitude of the Earth's magnetic field at that point. [6]

6. (a) Distinguish between ***average*** and ***r.m.s*** values of current, voltage and power in A.C. circuits, giving an expression for each. [5]

(b) A series LCR circuit with L = 2H, C = 2μF and R = 200 Ω is driven by a generator of maximum e.m.f. 120 V and variable frequency. Find:

(i) the resonance frequency of the circuit, [2]
(ii) the phase lag Φ and I_{max} when the generator angular frequency is ω = 400 rad/sec, [5]
(iii) the average power dissipated in each of the three circuit elements. [3]

(c) Show on a clearly labeled diagram the phase relations between the potential differences across the three circuit elements and the supplied e.m.f. [5]