NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1105 – ELECTRICITY AND MAGNETISM

BSc HOUNOURS PART I: DECEMBER 2001 *DURATION: 3 HOURS*

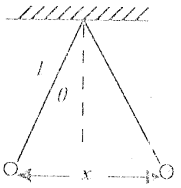
ANSWER ALL PARTS OF SECTION A AND ANY THREE IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

Electron volt	1eV	=	1.60×10^{-19} J
Mass of an electron		=	9.11×10^{-31} kg
Mass of a proton		=	1.67×10^{-27} kg
Permeability constant	μ_0	=	1.26×10^{-6} Hm^{-1}
Permitivity of free space	ε_0	=	8.85×10^{-12} Fm^{-1}
Radius of the Earth	R	=	6.37×10^{6} m

SECTION A

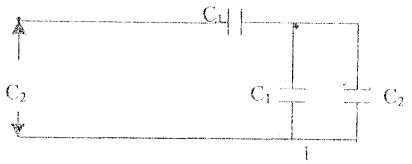
1 (a) Two tiny conducting balls of identical mass m and charge q hang from non-conducting threads of length l (see figure). Show that for equilibrium at small angle θ [5]

$$x = (q^2 l / 2\pi\varepsilon_0 mg)^{1/3}$$



(b) An electron starts from the cathode of a vacuum tube with negligible velocity. What are its kinetic energy and velocity at the anode if the potential difference between the electrodes is 100V. (Use Newtonian Mechanics). [4]

(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) A slab of material of dielectric constant k has the same area as the plates of a parallel plate capacitor but its thickness is $(¾)d$, where d is the separation between the plates. What is the effect on the capacitance when the slab is inserted between the plates? [5]

(e) The maximum permissible current in the coil of an analogue ammeter is 2.5A. Its resistance is 20 Ω. What must be done to the instrument so that it may be inserted in an electric circuit carrying a current of 15A and not destroy the coil? [4]

(f) A small permanent magnet is placed:

(i) in a uniform magnetic field, and
(ii) in a non-uniform magnetic field.

Is there any net force on the magnet? Explain. [4]

(g) Show that, in terms of the Hall electric field E and the current density J the charge carrier density n in a current carrying conductor is given by $n = JB/Ee$. [4]

(h) A transformer has 400 turns on the primary and 8 turns on the secondary.

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

(ii) If the primary is connected across a 120 V_{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]

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

SECTION B

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

(b) (i) State Gauss's Law and derive an expression for the electric field due to a spherical distribution of charges. [6]

(ii) Show that the electric field is zero at all points inside a hollow charged spherical conductor. [4]

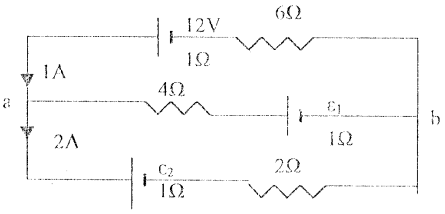
(c) (i) If the Earth had a net surface charge density of 1.0 electron per square meter (a very artificial assumption), what would its potential be? [Take V = 0 at infinity]. [3]

(ii) What would be the electric field due to the Earth just outside its surface? [3]

3 (a) From the expression for Ohm's Law in its potential difference –current form, deduce the electric field intensity-current density form of the law and comment briefly. [5]

(b) (i) Explain which of Kirchoff's rules is an expression of the principle of conservation of energy and why. [3]

(ii) Find the e.m.f's ε_1 and ε_2 in the circuit given below : [5]



(iii) What is the potential difference between points a and b. [2]

(c) In an RC circuit a capacitor is discharged through a resistor by closing a switch at time t = 0. The initial potential across the capacitor is 100V. If the potential difference has decreased to 10V after 10 seconds, find:

(i) the time constant RC; and [3]

(ii) the potential difference across the capacitor at time t = 18 seconds. [2]

4 (a) Write a short note on one of the practical applications of the analysis of the motion of charged particles in a magnetic field. [5]

(b) Using Ampere's law or otherwise derive an expression for the magnitude of the magnetic field set up by a long straight wire of radius a which carries a steady current I:

(i) at the surface of the wire; and [4]
(ii) at the points inside the wire, assuming a uniform current density. [3]

(c) Two circular co-axial coils of 150 turns each and radius r = 5.0 cm are separated a distance 5.0 cm apart and carry the same current I =10A in the same direction. This arrangement is known as *Helmholtz coils*.

(i) Calculate the magnitude B of magnetic field along the axis at positions x = 0; ± 2.5 cm, and ± 5.0 cm, taking x = 0 at the midpoint. [6]

(ii) Comment briefly on the variation of the field. [2]

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) (i) Define *self* and *mutual inductance*. [4]

(ii) Show that the mutual inductance M for length *l* of a combination of two co- axial solenoids is

$$M = \pi R_1^2 \mu_o l n_1 n_2$$

where R_1 is the radius of the inner solenoid, and n_1 and n_2 are the respective number of turns per unit length. [5]

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

(i) the mutual inductance of the system, [3]
(ii) the e.m.f. in the coil if the initial current of 2.0A in the solenoid is reversed in 0.2 seconds. [3]

6 (a) Derive an expression for the magnitude of the impedance of a circuit composed of an inductance and a resistor in series to which an alternating e.m.f. $\varepsilon = \varepsilon_o \sin \omega t$ is applied. [7]

(b) A circuit consisting of a 0.5 H inductor, a 150 Ω resistor and a capacitor in series resonates at a frequency of 900 Hz. Determine:

(i) the reactance of the inductor, [2]

(ii) the capacitance of the capacitor, [2]

(iii) the rms current in the circuit at resonance if the supply e.m.f. is 240 V_{rms}, and [2]

(iv) the average power dissipated in each of the three circuit elements. [3]

(c) Show on a clearly labelled diagram the phase relations between the potential differences across the three circuit elements and the supply e.m.f. [4]

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