NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1105 – ELECTRICITY AND MAGNETISM

SUPPLIMENTARY EXAMINATION

BSC HONOURS PART I: JULY 2005 *DURATION: 3 HOURS*

ANSWER ALL PARTS OF QUESTION 1-IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

Gravitational constant G	$= 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}
Permittivity of free space ε_0	$= 8.85 \times 10^{-12}$ Fm^{-1}
Permeability of free space μ_0	$= 1.26 \times 10^{-6}$ Hm^{-1}
Electron mass m_e	$= 9.11 \times 10^{-31}$ kg
Proton mass m_p	$= 1.66 \times 10^{-27}$ kg
Charge on an electron e	$= 1.60 \times 10^{-19}$ C

SECTION A

1. (a) Equal electric charges of 3 μC each are placed at the vertices of an equilateral triangle whose sides are 2.5 cm in length Calculate the electric field at each vertex of the triangle. [4]

(b) A dielectric material is placed between the plates of a charged capacitor. Explain the effect on

(i) electric field between the plates

(ii) capacitance [4]

(c) Two point charges $q_1 = 2.5$ μC and $q_2 = -2.5$ μC are separated by 5 mm. What is the dipole moment of these two charges? Sketch the pair and indicate the direction of the dipole moment. [6]

(d) A galvanometer of internal resistance 20 Ω reads full scale deflection when 45 mA passes through it. Design an ammeter to read up to 2.0 A [4]

(e) (i) What is a solenoid? [2]

(ii) Find the magnetic flux at the centre of a long, tightly wound solenoid of length 50 cm and radius 5 cm carrying a current of 300 mA. The number of turns is 300. [4]

(f) Derive the balance condition of a Wheatstone Bridge. Explain how it can be used to calculate an unknown resistance. [4]

(g) Explain briefly how static electricity can be used in Xerography. [4]

(h) Find the magnetic field induction at the centre of a square current loop of side 2m carrying a current of 2 A as shown in Figure 1 below. [4]

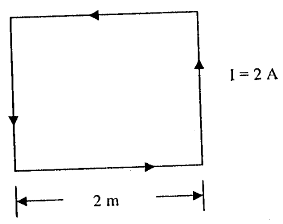

Figure 1

(i) A long wire parallel to the x-axis carries a current of 8 A in the direction of increasing x. There is a uniform magnetic field of magnitude 1.8 T in the positive y- direction. Find the force per unit length on the wire. [4]

SECTION B

2. (a) Distinguish between reactance and impedance. Illustrate your answer with relevant expressions. [5]

(b) In a certain LCR circuit $X_c = 16\ \Omega$, $X_L = 4\ \Omega$ at some frequency ω. The resonance frequency $\omega_o = 10^4$ rad/s. [4]

(i) Find L and C.

If $R = 5\Omega$ and $\varepsilon_{max} = 26$ V, find

(ii) the Q value, [3]

(iii) the maximum current. [3]

(c) Compute by direct integration the area under the curve $\sin^2\omega t$ from t = 0 to t = T = $2\pi/\omega$ and show that it is equal to $\frac{1}{2}T$. [5]

3. (a) Define

(i) the ampere and

(ii) the coulomb. [4]

(b) Describe the motion of a positive charge if it is:

(i) released into a uniform magnetic field of intensity B at an angle θ to the field.

(ii) released into the same field with a velocity directly perpendicular to the field. [4]

(c) A current-carrying wire induces a magnetic field into the surrounding space, given by Biot – Savart Law: .

$$d\vec{B} = \frac{\mu_o}{\pi}\frac{Idl\times\hat{r}}{r^2}$$

Explain all terms in the above equation [6]

(d) Use this law to derive the magnitude of the magnetic field due a thin wire of infinite length carrying a current I [6]

4. (a) State Kirchhoff's laws. [2]

(b) In Figure 2 below, find

(i) the current in each resistor [3]

(ii) the potential difference between a and b [3]

(iii) the power dissipated in each resistor. [3]

Take $E_1 = 6.0$ V, $E_2 = 5.0$ V, $E_3 = 4.0$ V, $R_1 = 100\ \Omega$ and $R_2 = 50\ \Omega$

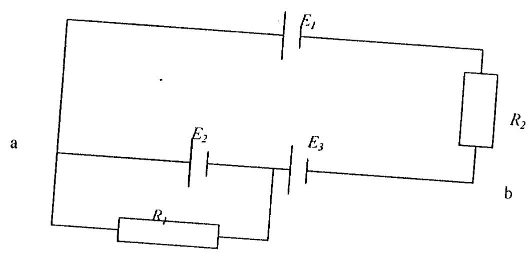

Figure 2

(c) A 1.0μf capacitor with an initial stored energy of 0.50J is discharged through a 1.0MΩ resistor.

(i) What is the initial charge on the capacitor. [3]

(ii) What is the current through the resistor when the discharge starts. [3]

(iii) Determine V_c, the voltage across the capacitor and V_R, the voltage across the resistor as a function of time. [3]

5. (a) (i) State Gauss's law and explain the physical meaning of all quantities involved. [4]

(ii) Use this law to derive an expression for the electric field due to a spherical distribution of charges. [4]

(b) Figure 3 shows a charge +q arranged as a uniform non-conducting sphere of radius a and placed at the centre of a spherical conducting shell of wider radius b and outer radius c. The outer shell carries a charge of –q.

Find $E(r)$

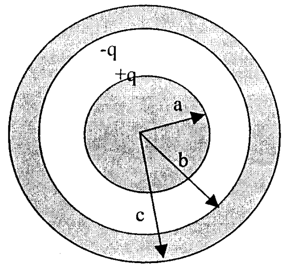

Figure 3

(i) within the sphere ($r < a$) [4]

(ii) between the sphere and the shell ($a < r < b$) [2]

(iii) inside the shell ($b < r < c$) [2]

(iv) outside the shell ($r > c$) [2]

(v) what charges appear on the inner and outer surfaces of the shell. [2]

6. (a) Distinguish between potential and potential difference. [4]

(b) What is an equi-potential surface? [4]

(c) Three positive 2 μC point charges are at the corners of a square of side 3m.

(i) What is the potential V at the fourth unoccupied corner of the square. [3]

(ii) How much work is needed to bring up a fourth positive charge of 2μC and place it at the fourth corner of the square? [3]

(d) Find the potential on the axis of a disk of uniform surface charge density σ. [6]

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