UNVERSITY OF SWAZILAND

MAIN EXAMINATION – SEMESTER I - NOV/DEC 2010

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF THE PAPER: ELECTROMAGNETIC FIELDS I

COURSE CODE: EE341

TIME ALLOWED: 3 HOURS

INSTRUCTIONS:

1. **THERE ARE SIX QUESTIONS IN THIS PAPER. ANWSER ANY FIVE OF THEM. EACH QUESTION CARRIES 20 MARKS**
2. **IF YOU THINK NOT ENOUGH DATA HAS BEEN GIVEN IN THE QUESTION YOU MAY ASSUME ANY REASONABLE VALUES.**
3. ***Useful constants***:
   1) Permittivity of free space, $\varepsilon_0 = 8.85\times10^{-12}$ F/m
   2) Permeability of free space, $\mu_0 = 4\pi\times10^{-7}$ H/m
   3) Electronic charge, $e = 1.602\times10^{-19}$ C
   4) Intrinsic impedance in free space, $\eta_0 = 120\pi\ \Omega$.
   5) Resistivity of copper = $1.7\times10^{-8}\ \Omega$-m

THIS PAPER SHOULD NOT BE OPEN UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

THIS PAPER CONTAINS SIX PAGES INCLUDING THIS PAGE.

Q 1

A) Define the dielectric constant and determine the permittivity of a material, when $\varepsilon_r = 4.5$ **2** Marks

B) An electric field E is 12 V/m at a point P which is a distance *r* from a point charge of Q = 100 nC. Assuming that $\varepsilon_r = 1$, find the distance *r*, electric potential at P, and work required to move a 50 nC charge from infinity to point P? **7** marks

C) With aid of a neat sketch, derive an equation for the superposition potential. **7** marks

D) Four point charges, **$Q_1 = 4$ nC, $Q_2 = 3$ nC, $Q_3 = 2$ nC and $Q_4 = 1$ nC** are placed around the surface of a sphere of radius 5 cm. Find the electric potential at the center of the sphere. **4 marks**

Q 2

A) A sphere of radius $r_1 = 50$ cm has a charge volume density variation with radius of $\rho_o \frac{r}{r_1}$ where $\rho_o = 200$ pC/m^3. Find the total charge of the sphere. **4** marks

B) Two point charges of 30 nC and -30 nC are situated at (1, 0, 0) and (0, 1, 0) in free space. Determine the electric field intensity and the resulting force at (0, 0, 1) **6** marks

C) Define Gauss's law of electrostatistics, and explain it. **2** marks

D) Using Gauss's law, derive the electric field strength E at any point P due to an isolated point charge Q. **4** marks

E) Use your result in (D) above to find an expression for the potential difference between two points due to a point charge Q at the origin. How can the absolute potential be determined from your answer? **4** marks

Q 3

A) An electron and a proton separated by a distance of 10^{-11} meters are symmetrically placed along the z-axis with z = 0 as its bisecting plane. Find the dipole moment, electric potential and electric field at point P (3, 4, 12).

4 marks

B) Charge is uniformly distributed within a spherical region of radius *a* (region I) as shown in Fig. 3B. An isolated conducting spherical shell with inner radius *b* and outer radius *c* is placed concentrically, thus forming regions II, III and IV. Determine expressions for the electric field intensity every where in each of the four regions I, II, III and IV respectively. ***7*** marks

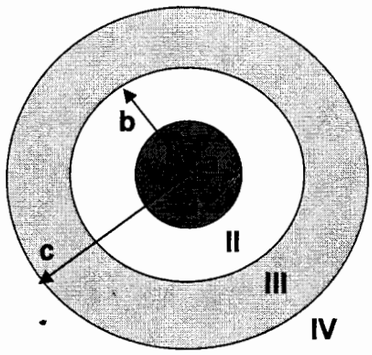

Figure 3 B A spherical charge distribution enclosed by a conducting cell

C) Two parallel conducting plates, each of area A, and holding opposite charges of magnitude Q, are separated by a dielectric of thickness d. Derive an expression for the capacitance of the system. Derive also an expression for the energy stored in the medium in terms capacitance of the system.

5 marks

D) A spherical capacitor is formed by two concentric metallic spheres of radii *a* and *b* as shown in Figure 3 D.

(i) Determine an expression for the capacitance of the system.

(ii) Use your result in (i) to find the capacitance of the earth when considered to be an isolated sphere of radius 6.5×10^6 m,

(iii) What would be the approximate expression for two large concentric spheres with the separation between them much smaller than their individual radii?

4 marks

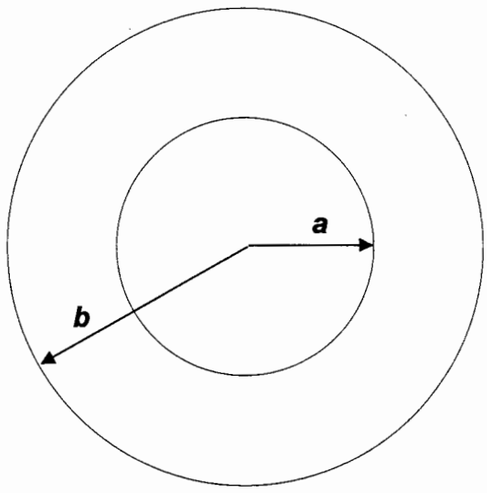

Figure 3 D. A spherical capacitor

Q 4

A) Define Biot-Savart law and with a suitable sketch, derive it. ***6*** marks

B) An infinitely long straight conductor with a circular cross section of radius *b* carries a steady current *I*. Determine the magnetic flux density both inside and out side of the conductor. ***4*** marks

C) State and derive Ampere's force law between two conductors. ***5*** marks

D) Figure 4C shows a current carrying conductor of finite length L placed at a distance b from another carrying conductor of infinite length. Determine the magnetic force per unit length acting on the finite conductor. **5** marks

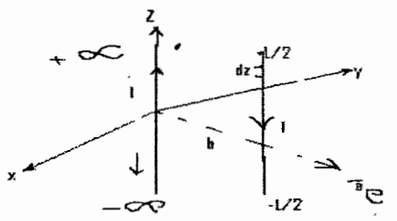

Figure 4C

Q 5

A) Define Faraday's and Lenz's law of induction. ***3*** marks

B) A circular conducting loop of radius 40 cm lies in the xy plane and has a resistance of 30 Ω. If the magnetic flux density in the region is given as $B = 0.2\cos 500t\, a_x + 0.75\sin 400t\, a_y + 1.2\cos 314t\, a_z$, Tesla, determine the effective value of the induced current in the loop. ***5*** marks

C) A coaxial cable has an inner conductor of outer radius ***a*** and an outer conductor of inner radius **b.** The outer conductor has negligible thickness, and the current is uniformly distributed inside the inner conductor. Derive an expression for self-inductance per unit length the coaxial cable. ***8*** marks

D) A toroidal coil of 3000 turns is wound over a magnetic ring with inner radius 10 mm, outer radius of 15 mm, height of 10 mm, and relative permeability of 500. A very long straight conductor passing through the centre of the toroid carries a time varying current. Determine the mutual inductance between the toroid and the straight conductor. ***4*** marks

Q 6

A) State Kirchhoff current law and Kirchhoff voltage law. ***2*** marks

B) A potential difference of V_0 is maintained across the two ends of a copper wire of length L. If A is the cross-sectional area of the wire, derive an expression for the resistance of the wire. What is the resistance of the wire if L = 250 km, and A = 40 mm^{2} ? ***5*** marks

C) A parallel-plate capacitor whose plates are 10 cm square and 0.2 cm apart contains a medium with $\varepsilon_r = 2$ and $\sigma = 4x10^{5}$ S/m. To maintain a steady current through the medium, a potential difference of 120 V is applied between the plates. Determine the electric field intensity, the volume current density, the power density, power dissipation, the current, and the resistance of the medium. ***10*** marks

D) Write down the Maxwell's equations relating to Gauss's, Faraday's, and Ampere's law. ***3*** marks