NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1105 ELECTRICITY AND MAGNETISM

SUPPLEMENTARY EXAMINATION

BSC HONOURS PART I : JULY 2001 DURATION : 3 HOURS

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

Section A

Gravitational constant G = 6.67 x 10-11N-m^{2}kg^{-2} Permeability constant μ_0 = 1.26 x 10^{-6} Hm^{-1}

Electron mass m_e = 9.11 x 10^{-31} kg Permittivity constant ε_0 = 8.85 x 10^{-12} Fm^{-1}

Elementary charge e = 1.6 x 10^{-19}C

1. a) Comment in just one or two sentences, on what you understand by the statement: "Charge is quantized". [3]

   b) i) Two protons in a nucleus of an iron atom are separated by 4.0 x 10^{-15} m distance. Treating the protons as positively charged particles, calculate the force between the two protons. [3]

   ii) Calculate the gravitational force between the two particles and compare your result with the result obtained in (i) above. [3]

   c) Three charges are arranged as shown in the adjacent figure. Each of the charges is placed at a distance r from the origin at point P. Calculate the net electric field at point P at the origin. [6]

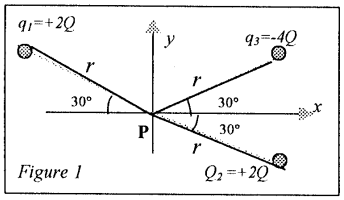

Figure 1

   d) Four charges are located in the x-y plane as shown in the Figure 2. Given that d = 2 m; q_1 = +10 nC; q_2 = -25 nC; q_3 = +21 nC and q_4 = +15 nC, determine the electric potential at point **P** located at the centre of the square whose vertices are formed by the four charges. [5]

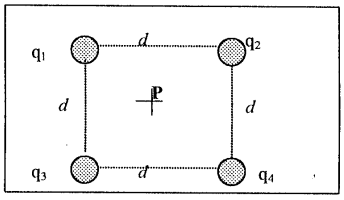

Figure 2

   e) i) In just one sentence, write down what you understand of Gauss' Law as related to charge and electric fields. [3]

   ii) A storage capacitor on a chip in a computer has a capacitance of 60 x 10^{-16}F. The capacitor is charged to 5.8V. Calculate the excess electrons on its negative plate. [4]

f) A solenoid of length L = 1.30 m and inner diameter d = 3.50 cm carries a current i = 5.0 A. If it consists of five closely packed layers of 800 turns each, along the length L, find $\vec{B}$ at its centre. [5]

g) A neutral molecule of water has 10 protons and 10 electrons. When in a gaseous state, it has an electric dipole moment of magnitude 8.0 x 10^{-30} C.m.
i) How far apart are the molecule's centres of positive and negative charges? [3]

If the molecule is placed in an electric field of 2 x 10^3 N/C,
ii) what is the maximum torque the field exerts on the molecule? [2]
iii) Calculate the total work an external agent must do to turn the molecule end for end while in this field, starting from its fully aligned position. [3]

Section B

Answer at least three questions in this section

2. a) An electron moving in a uniform magnetic field $\vec{B} = 5.2\text{x}10^{-4}$ T has a kinetic energy of 25 eV. The angle between the direction of $\vec{B}$ and the electron velocity $\vec{v}$ is 55.5°. Calculate the pitch of the helical path taken by the electron. [10]

b) A Gaussian tube is placed in a uniform electric field $\vec{E} = \hat{x}5.0x + \hat{y}4.0$. Calculate the electric flux that passes through
i) the top face [5]
ii) the right side face [5]
of the Gaussian surface.

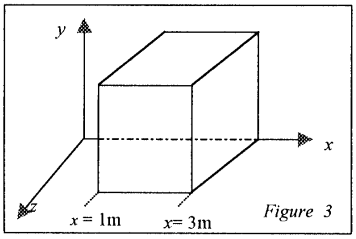

Figure 3

3. a) A rod is being pulled to the left with a velocity $\vec{v}$, in sliding contact with conducting rails [*See Figure 4*]. Derive the relationship for the induced e.m.f. in the system. Does the rod have to move in order to induce a current?

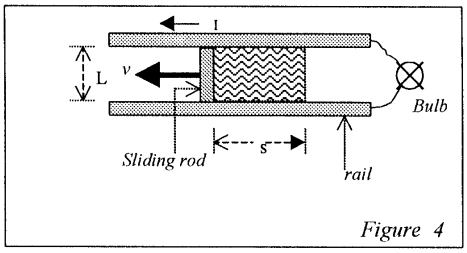

Figure 4

[14]

b) Using the three rules of the electric flux concept and the expression for $\vec{E}$, construct the electric flux plot for an infinite line of uniform charge $+\rho_\ell$ (Cm^{-1}). [6]

4. a) A circular coil of 300 turns and area 2.0 x $10^{-4}m^2$ carries a current of 100 x 10^{-6}A. The

coil is known to be at rest in a uniform magnetic field $\vec{B}$ = 0.80 T with its magnetic dipole moment $\vec{\mu}$ initially aligned with $\vec{B}$.

i) what is the direction of the current in the coil?

ii) How much work would the torque applied by an external agent have to do on the coil to rotate it 90° from its initial orientation so that $\vec{\mu}$ is perpendicular to $\vec{B}$ and the coil is again at rest? [3]

b) Find the electric field due to a sphere of radius R that carries a charge Q of density $\rho = kr$ proportional to the distance from the sphere's centre. [7]

5. a) Determine the expression for the $\vec{B}$ field inside a wire of radius R, carrying a current of density λ (Am^{-2}). Make a sketch of the variation of magnetic field strength inside and outside the wire. [Assume the current is uniformly distributed through the wire]. [10]

b) Two conductors are connected as shown in Figure 6 with a sliding conducting wire between them. As the rod is pulled to the left, electrons move along the rod with a drift velocity v_d (i.e. a current flows in the rod). What is the effect of this action on the rod if the magnetic field is directed into the paper perpendicular to the current carrying conductor [10]

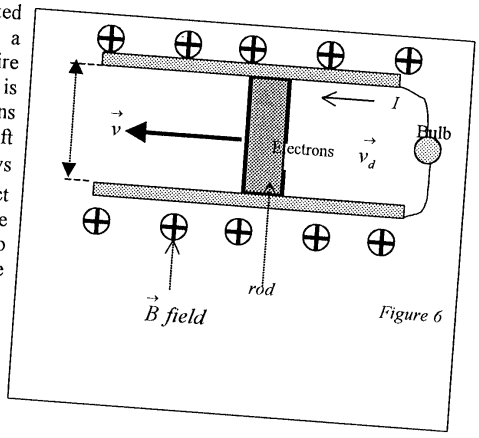

Figure 6

i) using the Lorentz force law [5]

ii) starting with the expression for force element on a wire carrying a current in an external magnetic field as $\vec{dF} = I\,\vec{dl} \times \vec{B}$ [5]

END OF EXAMINATION