MACHAKOS UNIVERSITY

University Examinations 2016/2017

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR DEGREE IN BACHELOR OF EDUCATION (SCIENCE)

SPH 401: ELETRODYNAMICS

DATE: 30/5/2017 **TIME: 2:00 – 4:00 PM**

INSTRUCTION:

Answer Question **ONE** in **section A** and Any Other **TWO** Questions in **section B.**

Important constants:

Take Permittivity of free space, $\varepsilon_0 = 8.085\times10^{-12} C^2 N^{-1} m^{-2}$

Permeability of free space, $\mu_0 = 4\pi\times10^{-7} WbA^{-1}m^{-1}$

Electronic charge, $e = 1.6\times10^{-19} C$

Electronic mass, $m_e = 9.1\times10^{-31} kg$

Protonic mass, $m_p = 1.67\times10^{-27} kg$

Mean distance that an electron in a hydrogen atom orbits the nucleus, $r = 5.29\times10^{-11} m$

1 amu = 1.67×10^{-27} kg

SECTION A (COMPULSORY)

QUESTION ONE (30 MARKS)

a) i. State Coulomb's and Gauss's Laws? (2 marks)

ii. Determine the electric force on the electron of a hydrogen atom exerted by the single proton that is in its nucleus, when the electron orbits the proton at its average distance of 5.3×10^{-11} m. (2 marks)

iii. Two point charges q_1=5 μC and q_2=3 μC are fixed 4 cm apart. Calculate the distance in between them at which the resultant field is zero. (3 marks)

b) State Faraday's laws of electrolysis. (2 marks)

c) (i) Define a magnetic dipole moment (1 mark)

(ii) A coil of 20 turns with an area of 800mm^2 carries a current of 0.5A. Determine the torque on the coil when placed parallel to a field of 0.3 T. (3 marks)

d) Define the ampere and verify its value using the flux density due to two parallel conductors that are placed a unit distance from each other. (3 marks)

e) Show that the electrostatic force is stronger in magnitude than the gravitational force between the electron and proton in a hydrogen atom. (3 marks)

f) A helicopter is hovering with its 5.0 m long blades rotating at 200 rpm. The local magnetic field is directed upwards at approximately 60^0 to the horizontal and has a magnitude of 50 mT. What is the induced *emf* between the hub (where the blades join to the helicopter) and the tips of the blades? (Hint – the *emf* induced across a short length, Δl, of conductor is the rate at which it cuts through magnetic flux.) (4 marks)

g) A photocopier works by putting positive charge onto the paper at the places where the image will appear. The toner particles are given a negative charge so that they will be attracted to these points. A wire, called the corona wire, is used to put the positive charge onto the paper. This wire typically has a radius of around 50 μm and charged to a potential of around +7 kV, giving the wire a linear charge density of 40 nC.m^{-1}:

(i) Assuming the corona wire is uniformly charged, draw a diagram showing the wire and the field it produces. (2 marks)

(ii) How does the field strength vary with the distance from the wire? How does this compare to the way field varies with distance from a point charge? What about a sheet of charge? (2 marks)

(iii) Write down an expression for the field at some distance *r* from the wire. (1 mark)

(iv) What is the electric field at a distance of 0.1 mm from the wire, approximately the distance from the wire to the paper? (2 marks)

QUESTION TWO (20 MARKS)

a) Electrodynamics is the study of the entire electromagnetic field summarized by the Maxwell's equations. State the inhomogeneous Maxwell's wave equations in free space expressed in terms of electric **E** and magnetic **B** fields. . (12 marks)

b) i. Three charges are situated at the corners of the square (side a). How much work does it take to bring another charge +q, from far away and bring it in the fourth corner (6 marks)

ii. How much work does it take to assemble the whole configuration of four charges? (2 marks)

QUESTION THREE (20 MARKS)

a) A moving electric charge enters a uniform magnetic field perpendicular to its path. Write down the force acting on the charge, explaining any symbols used, and show the path of the charge in the field (4 marks)

b) In an evacuated tube electron are accelerated from rest through a potential difference of 3600V and then travel in a narrow beam through a field-free space before entering a uniform magnetic the flux lines of which are perpendicular to the beam. In the magnetic field the electrons describe a circular arc of radius 0.10 m. Calculate:

(i) The speed of the electrons on entering the magnetic field (4 marks)

(ii) The magnitude of the magnetic flux density (4 marks)

c) An electric dipole consisting of two opposite charges of magnitude $2\mu C$ and separated by 10cm is placed in an external field of 2.0×10^5 N/C. Calculate :-

(i) The maximum torque on the dipole (4 marks)

(ii) The work to turn the dipole by a half a turn, starting from 0^o (4 marks)

QUESTION FOUR (20 MAKRS)

a) i. State Lenz's law and Faraday's laws of Electromagnetic induction (3 marks)

ii. State the four factors that determine the force on a conducting carrying current in a magnetic field. (2 marks)

iii. An electric trolley car cable carries a direct current of 380 A in a region where the vertical component of the earth's magnetic field is 5.0×10^{-6} T. What is the horizontal force on a 12.0 m section of the wire due to magnetic effect? (3 marks)

b) Find the magnetic force exerted on an electron moving vertically upward at speed of 2×10^{7} m/s by a horizontal magnetic field of 0.5 T directed north. (3mks)

c) State the Fleming's Right Hand rule of electromagnetism. (1 mark)

d) A wire 5 g in weight and 2 m length is carrying a current of 10 A, is placed perpendicular in a field of flux density 0.5 T. What is the force on the wire, and hence acceleration. (4 mkars)

e) Find the instantaneous acceleration of an electron that is moving at 1.0×10^{7} m/s in the x-y plane, at an angle of 30^{0} with the y-axis. A uniform magnetic field of magnitude 10 T is in the positive y direction. (4 marks)

QUESTION FIVE (20 MARKS)

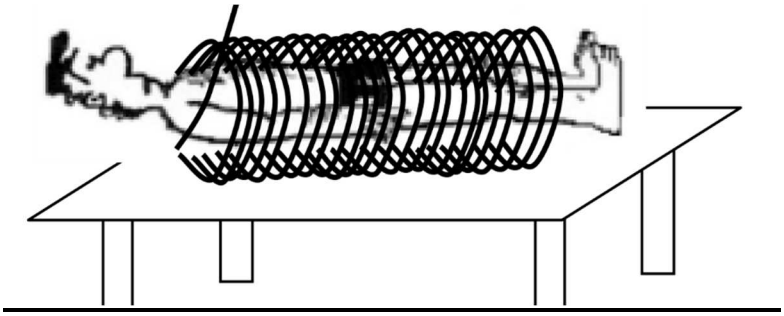
a) The Earth's magnetic field is important because it protects us from charged particles radiated by the sun.

i. Sketch the magnetic field lines for the Earth's magnetic field. (2 marks)

ii. Sketch the path of a charged particle which has become trapped in the Earth's magnetic field. (2 marks)

iii. Would the aurora australis (southern lights) or the aurora borealis (northern lights) be possible if the earth had no magnetic field? Explain your answer. (2 marks)

b) Magnetic field therapy is used to treat all sorts of ailments in humans and in horses and even dogs and cats, in particular soft tissue and bone damage. A magnetic field generator which consists of a coil of wire is placed around the person to be treated as shown below. The generator can produce a field inside the coil of 100 G = 0.015 T when a current of 1.5 A runs through the coil. The coil has a diameter of 510 mm and has a total length of 230 mm. If the coil is a simple solenoid, what length of wire is used to make the coil? (6 marks)



c) The heart produces an electric field due to the movement of charges required to trigger the heart muscles to contract. Measuring the changes in potential is a common way of investigating heart function and is called an electrocardiogram or ECG measurement. The heart also produces a magnetic field of around 5.5 × 10-11 T, and measuring changes in this magnetic field, called a magnetocardiogram (MCG), can also give valuable information about the condition of the heart. Consider a carbonate ion, HCO_3^-, moving in the blood at 0.52 $m.s^{-1}$.

i. What will be the maximum possible acceleration of this ion as it moves past the heart? (4 marks)

ii. What will be the minimum acceleration of this ion as it moves past the heart? Assume HCO_3 has a mass of 61 amu. (2 marks)