UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2007/2008

TITLE OF PAPER	**:**	**ELECTRICITY & MAGNETISM**
COURSE NUMBER	**:**	**P221**
TIME ALLOWED	**:**	**THREE HOURS**
INSTRUCTIONS		**ANSWER ANY FOUR QUESTIONS - EACH QUESTION CARRIES 25 MARKS – MARKS FOR EACH SECTION OF EACH QUESTION ARE SHOWN IN THE RIGHT-HAND COLUMN**

THIS PAPER HAS 8 PAGES INCLUDING THIS PAGE AND THE DATA SHEET

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Question 1

A charged, isolated parallel plate capacitor is placed in a vacuum. The capacitor remains electrically isolated, but the separation of the plates is halved. How does this affect the following quantities

a the capacitance [2]

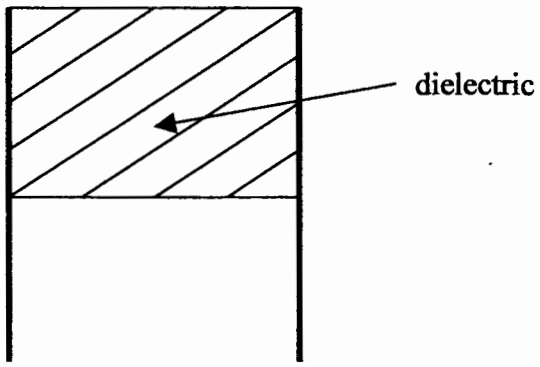
b the potential difference between the plates [2]

c the electric field between the plates [2]

d the energy stored in the capacitor [2]

A parallel plate capacitor has a capacitance of 10 μF. A dielectric with a relative permittivity of 4 is inserted between the plates; it fills the top-half of the space between the plates. See the diagram. Determine the new capacitance. [10]

If it were required to create an energy density of 10^{10} J.m^{-3} between the plates of a capacitor, with separation of the plates equal to 0.2 m, and each plate having an area of 0.5 m^2, how big a potential difference would be needed between the plates? [7]



Question 2

A charged particle moves, in free space, so that its trajectory makes an angle with a magnetic field $\boldsymbol{H}$, which is parallel to the x-axis (Cartesian co-ordinates are being used). The particle initially moves in the xz-plane and starts at the origin of the co-ordinate system at $t = 0$. Evaluate the following quantities

a $m\ddot{x}$ [3]

b $m\ddot{y}$ [3]

c $m\ddot{z}$ [3]

d and hence determine the time dependence of z [8]

$\hat{\mathbf{x}} = \hat{\mathbf{y}} \times \hat{\mathbf{z}}$ $\quad$ $\hat{\mathbf{y}} = \hat{\mathbf{z}} \times \hat{\mathbf{x}}$ $\quad$ $\hat{\mathbf{z}} = \hat{\mathbf{x}} \times \hat{\mathbf{y}}$

[hint: to determine $z(t)$ you need to perform an integral and then make a substitution]

e a proton is moving in a circular orbit of radius 0.1 m in a uniform magnetic field of 0.2 *Tesla*, which has a direction perpendicular to the velocity of the proton. What is the orbital speed of the proton? [5]

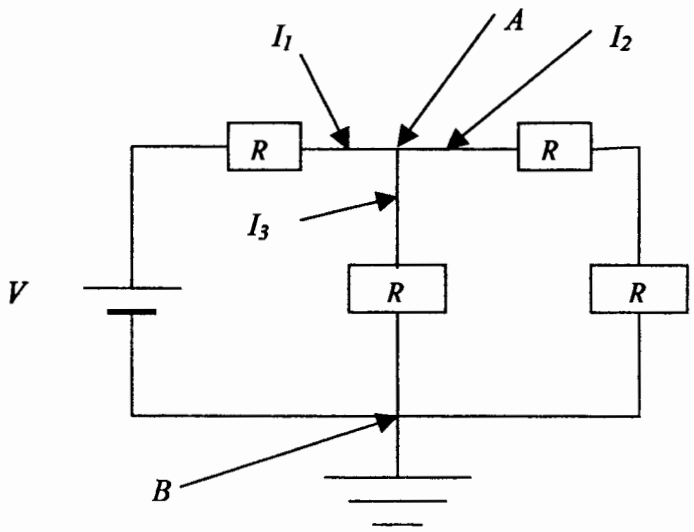
f if the proton were replaced by an electron moving at the same speed, what would be the radius of its orbit? [3]

Question 3

Write down expressions for Kirchhoff's current and voltage laws and explain the meaning of both. [8]

In the circuit drawn below, what is the potential at point A? Point B is earthed and can be taken to have zero potential. The conventional currents I_1, I_2 and I_3 are the currents flowing in the three arms of the circuit that meet at point A. I_1 flows from left-to-right into junction A; both I_2 and I_3 flow away from junction A: I_2 flows from left-to-right in the diagram, while I_3 flows vertically downwards away from point A. [5]

Calculate the power, in terms of V and R, dissipated in each resistor shown in the circuit below. Each resistor has the same value. [12]



Question 4

What is meant by an equipotential surface? What shape are the equipotential surfaces that surround a point charge? [4]

In electrostatics, a conductor is defined as a material within which $\mathbf{E} = 0$ at every point. In which direction is **E**, if it exists, close to the surface of any conductor? Explain. [4]

Consider a hollow conductor which contains no charges within it.

a what is the magnitude of the electric field inside the conductor? [6]

b what is the spatial variation of the electrostatic potential within the space inside the conductor? [3]

c how would you screen a delicate electronic instrument from electrical noise? Explain. [8]

Question 5

You are provided with an alternating current source which has a peak value in voltage of $50V$. You wish to attempt an experiment which requires a peak voltage of $200V$. How might you be able to use the supply you have been provided with? Describe the component you would need to perform this task. [10]

How is the current in the $200V$ supply related to the current in the $50V$ supply? [Assume the device used to change the voltage is 100% efficient]. [7]

List and describe any forms of loss that might occur in changing the magnitude of the peak voltage. [8]
[hint: you should name four sources of loss that may occur in changing the magnitude of the peak value of voltage – each will be awarded 2 marks]

Question 6

To perform a particular experiment, you require a constant current. You only have an alternating current source. You have access to any component you might require to produce a smoothly varying current supply (i.e. one that is almost independent of time).

Draw a diagram of a circuit that would give full rectification of the alternating current, but not a smooth output with time. Name the component required. [6]

Draw a diagram of the time-dependence of the potential difference across the load. [4]

Your experiment requires a very small variation in the magnitude of the potential difference across the load. Describe how you would "smooth" the voltage by

a using a single capacitor [3]

b using capacitors and an inductor. [3]

c what effect does the inductor have on the output voltage? [4]

Draw a circuit which employs capacitors and an inductor which should produce a very smooth output voltage. [5]