UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

MAIN EXAMINATION: 2009/2010

TITLE OF THE PAPER: ELECTRICITY AND MAGNETISM

COURSE NUMBER: P221

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:
Answer any four Questions.
Each Question carries 25 Marks.
Marks for different sections of each Question are shown in the right hand margin.

THE PAPER HAS 7 PAGES, INCLUDING THIS PAGE.

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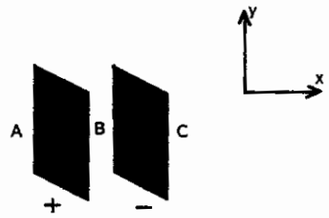

FIG. 1:

Question 1

(a) Write down an expression for Gauss' law, and explain carefully the meaning of each term in the expression.

[4 marks]

(b) An electric field in a region of space with no electric charge is given by $\mathbf{E}=3\hat{i}+4\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the unit vectors along the x-axis and y-axis, respectively. What is the total electric flux through a gaussian surface placed in this region of space?

[3 marks]

(c) Using Gauss' law one find's that the electric field due to a infinite plane of charges with a surface charge density σ has the magnitude $E = \frac{\sigma}{2\epsilon_0}$, where the constant ϵ_0 is the permittivity of free space. Using this information, determine the electric field in each of the three regions of two very large plates:(**A**) to the left of both, (**B**) between them, and (**C**) to the right of both. The two plates carry equal but opposite uniform densities $\pm\sigma$ as shown in Fig. 1.

[7 marks]

(d) Draw the field lines of the net electric field due to the two plates in Fig. 1.

[2 marks]

(e) Find the capacitance of a parallel-plate capacitor consisting of two metal plates surface of area A held a distance d apart.

[9 marks]

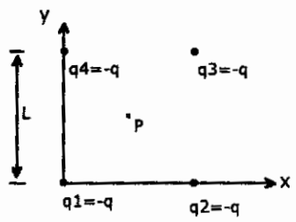

FIG. 2:

Question 2

(a) Four equal charges, $q1 = q2 = q3 = q4 = -q$, are situated at the four corners of a square of an edge length L, as shown in Fig. 2.

(i) Calculate the electric field at the center of the square, point P. Show the details of your calculations.

[6 marks]

(ii) Suppose the charge at the third corner is removed, what is the net electric field at point P?

[3 marks]

(iii) How much work is done (by a external agent) to bring back the charge $-q$ to the third corner from infinity?

[5 marks]

(iv) How much work is done to assemble the four charges in the configuration given by Fig. 2?

[4 marks]

(b) The electric potential in a certain region is given by $V(x, y) = a(x^2 + y^2) + bx + c$, where $a = 1V/m^2$, $b = -2V/m$ and $c = 5V$.

(i) Find electric field at a point where $x = 1m$ and $y = 3m$.

[4 marks]

(ii) Determine the position where the electric field is zero.

[3 marks]

Question 3

(a) A current carrying conductor experiences no magnetic force when placed in a certain manner in a magnetic field. Explain.

[3 marks]

(b) Consider two charges, first of the same sign and then of opposite signs, that are moving along separate parallel paths with the same velocity. Compare the direction of the mutual electric and magnetic forces in each case.

[4 marks]

(c) A steady current I flows down a long cylindrical wire of radius a. Find the magnetic field both inside and outside the wire if

(i) the current is uniformly distributed over the outside surface of the wire,

[8 marks]

(ii) the current is uniformly distributed within the the surface of the wire.

[10 marks]

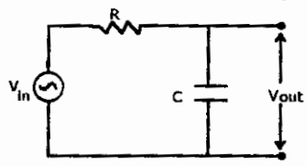

FIG. 3:

Question 4

(a) (i) If the frequency is doubled in a series circuit, what happens to the resistance, inductive reactance and capacitance reactance?

[6 marks]

(ii) What is the impedance of an RLC circuit at the resonance frequency?

[2 marks]

(b) The RC low-pass filter shown in Fig. 3 has a resistance $R = 90\Omega$ and capacitance $C = 8\mu F$. Calculate the gain V_{out}/V_{in} and the phase angle for an input frequency.

(i) $f = 600Hz$

[5 marks]

(ii) $f = 600kHz$

[5 marks]

(iii) Comment on the two results above

[2 marks]

(c) A RLC circuit consists of a 150Ω resistor, a $21\mu F$ capacitor and a $460mH$ inductor, connected in series with a $120V$, $60Hz$ power supply. Calculate the phase angle between the current and the applied voltage. Does the current or the voltage reach its peak earlier?

[5 marks]

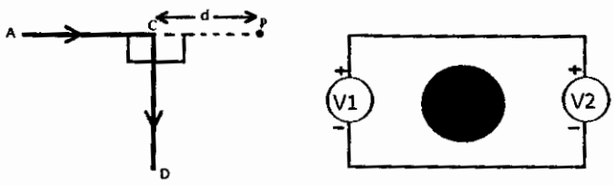

FIG. 4: From left to right are the schematic diagrams for question 5(a) and 5(b) respectively.

Question 5

(a) A current of I Amperes runs through a very long wire of which a portion (ACD) is shown by the arrows in Fig. 4. The angle $A\hat{C}D = 90°$. CA is straight, and it continues beyond A to the far left. CD is also straight and continues far beyond D. P is at the distance d meters from C. What is the magnitude of the magnetic field at P in Tesla?

[10 marks]

(b) Two voltmeters $V1$ and $V2$, each with internal resistance of $10^6\Omega$ are connected through wires of negligible resistance as shown in Fig. 4. A changing magnetic field is present in the shaded area. At a particular moment in time $V2$ reads -0.1 Volts.

(i) At that moment, what is the induced emf in Volts in the circuit?

[4 marks]

(ii) At that moment, what is the reading of $V1$?

[3 marks]

(c) A battery of emf $\mathcal{E}$ and internal r is hooked up to a variable"load" resistor, R. If you want to deliver the maximum possible power to the load, what resistance R should you choose? (You can't change $\mathcal{E}$ and r, of course.)

[8 marks]

Question 6

(a) (i) Suppose an electron is chasing a proton, up along this page when suddenly a magnetic field directed into the page is introduced. What will happen to the particles?

[3 marks]

(ii) How can the motion of a moving charged particle be used to distinguish between a magnetic field and an electric field. Give a specific example to justify your answer.

[4 marks]

(b) An electron in a TV tube is moving at $7.2 \times 10^6 m/s$ in a magnetic field.

(i) Without knowing anything about the field direction, find the greatest and the least magnitude of the force the electron could feel due to the field?

[6 marks]

(ii) At one point the acceleration of the electron is $4.90 \times 10^{14} m/s^2$. What is the angle between the electron's velocity and the magnetic field? Take the magnitude of the field to be B to be $83.0mT$

[5 marks]

(c) A straight, horizontal copper wire of length L carries a current $i = 28A$, moving from left to right. What is the magnitude and the direction of the magnetic field $\vec{B}$ needed to 'float', that is, to balance its weight. It has a linear density of $\lambda = 46.4g/m$.

[7 marks]