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UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

EXAMINATION: 2010/2011

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 8 PAGES, INCLUDING THIS PAGE.

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Question 1

(a) The electric field inside a hollow, uniformly charged sphere is zero. Does this imply that the potential is zero inside the sphere? Explain.

[4 marks]

(b) Suppose the electric potential due to a certain charge distribution can be written in cartesian coordinates.

$$V(x, y, z) = Ax^2 + Bxyz$$

where A and B are constants.

(i) What is the associated electric field?

[3 marks]

(ii) Given that x and y are measured in meters, what are the units of A and B?

[4 marks]

(c) An uncharged spherical conductor centered at the origin has a cavity of some weird shape carved out of it. Somewhere within the cavity is a charge $q > 0$. What is the field outside the sphere?

[4 marks]

(d) A point charge $q_1 = q$ where $q > 0$ is located at the origin.

(i) What is the potential difference between between $r = a$ and $r = 2a$.

[3 marks]

(ii) Suppose a second charge $q_2 = -3q$ is placed at a distance $r = a$ from $+q$ and is then moved to the position $r = 2a$. What is the work done by external agent to relocate q_2 to $r = 2a$ from $r = a$.

[2 marks]

(e) How much energy is released when a system of the two protons at a distance $r = 2fm$ apart, is dismantled. *Useful constants:* $k_e = 1/(4\pi\epsilon_0) = 8.99\times10^9 N\cdot m^2/C^2$, $fm = 1 \times 10^{-15}m, e = 1.602 \times 10^{-19}C$.

[5 marks]

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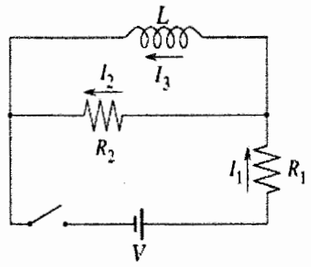

FIG. 1:

Question 2

(a) What analogies can you draw between an ideal solenoid and a parallel plate capacitor?

[4 marks]

(b) LC oscillators have been used in circuits connected to load speakers to create some sound of " electronic music". What inductance must be used with a $1.1\mu F$ capacitance to produce a frequency of 10 kHz, near the upper end of the audible range of frequencies.

[5 marks]

(c) The switch in Fig. 1 has been open for a long time. Determine the currents I_1,I_2, and I_3 in the resistors and in the self-inductor at the moment

(i) the switch is closed,

[4 marks]

(ii) a long time after the switch is closed.

[4 marks]

The internal resistance of the battery is negligible. Express your answer only in terms of V, R_1,R_2, and L.

(d) Replace the inductor in the above circuit with a capacitor C. Determine the I_1, I_2, and I_3 in terms of V, R_1, R_2, and C under the same conditions as in (c).

[8 marks]

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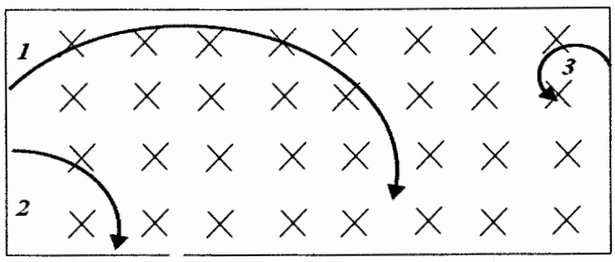

FIG. 2:

Question 3

(a) (i) Write down the expression for the external force felt by a charge Q moving with speed **v**in a uniform field **B**.

[2 marks]

(ii) Show that magnetic force do no work.

[4 marks]

(b) Figure 2 shows the trajectories of three charged particles moving in a uniform magnetic field **B**, that points into the plane of the paper. The direction in which each particle is moving is shown by the arrows.

(i) For each particle, find if the charge is positive or negative.

[6 marks]

(ii) Assume all particles have the same momentum. Which particle has the greatest magnitude of charge? Explain.

[4 marks]

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

[4 marks]

(d) A straight, copper rod of length L is parallel to the x axis and a has mass m. It is exposed to a uniform magnetic field **B**, anti-parallel to the z axis. What is the magnitude and the direction of the current that is needed to exactly balance the gravitational force downward$(-\hat{y})$.

[5 marks]

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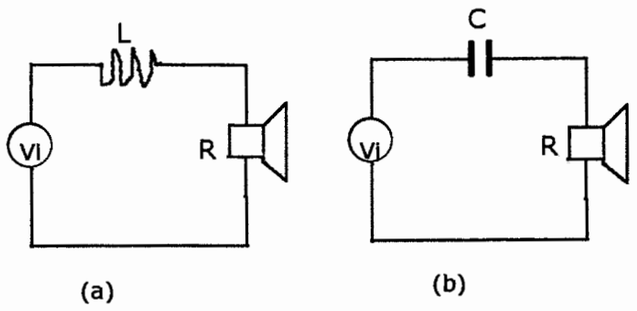

FIG. 3:

Question 4

(a) A RLC circuit consists of a 360Ω resistor, a $22\mu F$ capacitor and a $500mH$ inductor, connected in series with a $240V$, $60Hz$ power supply.

(i) What is the impedance of the circuit?

[5 marks]

(ii) What is the amplitude of the alternating current (peak current)?

[3 marks]

(iii) Calculate the phase angle between the current and the applied voltage. Does the current or the voltage reach its peak earlier?

[5 marks]

(b) In a woofer only low frequencies of the input signal of are audible (low pass filter). In a tweeter only high frequencies of the input signal are audible (high pass filter). Which speaker corresponds to a "woofer" and to a "tweeter", in Fig. 3? Show your analysis. *Tip: You may replace each speaker with a resistor, with a resistance R, and compare the voltage drop V_o across that resistor to the input voltage V_i at different frequencies of the input signal.*

[12 marks]

Question 5

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(a) A hollow sphere has an inner radius a and an outer radius b and it carries a charge density

$$\rho(r) = \frac{k}{r^2}$$

in the region $a \leq r \leq b$.

(i) Find the total charge enclosed by a concentric spherical surfaces with radius r when $r < a$, $a < r < b$, and $r > b$.

[8 marks]

(ii) Find the electric field in the regions r when $r < a$, $a < r < b$, and $r > b$.

[8 marks]

(b) A steady current I flows down a long cylindrical wire of radius a. Find the magnetic field both inside and outside the wire if the current is uniformly distributed over the outside surface of the wire.

[9 marks]

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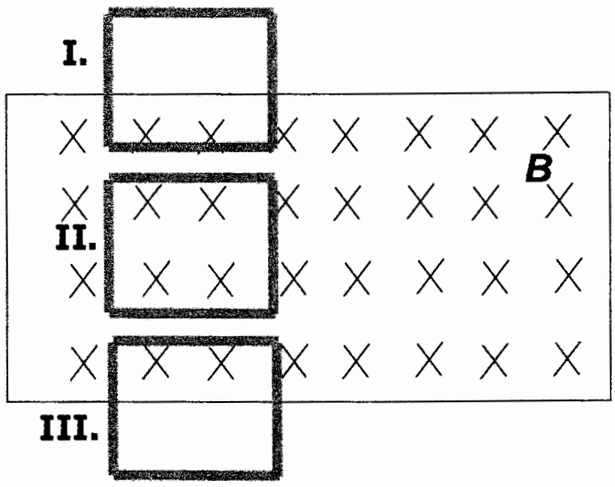

FIG. 4:

Question 6

(a) State Faraday's laws, describe every term in the expression.

[3 marks]

(b) State Lenz's law.

[2 marks]

(c) Discuss three different ways that can be used to change magnetic flux.

[6 marks]

(d) Figure 4 is a schematic diagram of a conducting loop falling through a uniform magnetic field. The field points into the page. The loop is located in the plane of the paper and is moving downwards under the influence of gravity. The diagram shows three positions of the loop: (I) While it is entering the magnetic field, (II) while it is moving inside the magnetic field, and (III) while it is exiting the magnetic field.

(i) For each step of the loop state whether the magnitude of the magnetic flux through the loop Φ_B is increasing, constant or decreasing.

[3 marks]

(Continued next page)

(ii) For each step of the loop indicate whether the induced current is clockwise, counter-clockwise or zero.

[6 marks]

(iii) How does the velocity of the loop change, while it is completely inside the magnetic field. Consider the forces acting on the loop in this case.

[5 marks]