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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS WITH APPROPRIATE TECHNOLOGY AND BACHERLOR OF EDUCATION

COURSE CODE: SPH 114

COURSE TITLE: INTRODUCTION TO ELECTRICITY & MAGNETISM

DATE: THURSDAY 21ST APRIL, 2022 **TIME:** 12:00 PM - 02:00 PM

INSTRUCTIONS TO CANDIDATES

TIME: 2 Hours

Answer question ONE and any TWO of the remaining.

Symbols used bear the usual meaning.

MMUST observes ZERO tolerance to examination cheating

Useful constants

Speed of light in free space, $c = 3 \times 10^{8} ms^{-1}$
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$
Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} (Fm^{-1})$
Elementary charge, $e = 1.60 \times 10^{-19} C$
Planck constant , $h = 6.63 \times 10^{-34} Js$
Rest mass of electron, $m_e = 9.11 \times 10^{-31} Kg$
Rest mass of proton, $m_p = 1.67 \times 10^{-27} Kg$
Rest mass of neutron, $m_n = 1.675 \times 10^{-27} Kg$
Rest mass of α-particle, $m_\alpha = 6.646 \times 10^{-27} Kg$
Molar gas constant, $R = 8.31 JK^{-1} mol^{-1}$
Avogadro constant, $N_A = 6.02 \times 10^{23} mol^{-1}$
Boltzmann constant, $k = 1.38 \times 10^{-23} JK^{-1}$
Gravitational constant, $G = 6.63 \times 10^{-11} Nm^2 Kg^{-2}$
Acceleration of free fall, $g = 9.81 ms^{-2}$

QUESTION ONE (30 marks)

a) Distinguish between electrostatics and magnetostatics. (2 marks)

b) A current through a horizontal power line flows in east to west direction. What is the direction of magnetic field at a point directly below it and at a point directly above it? (2 marks)

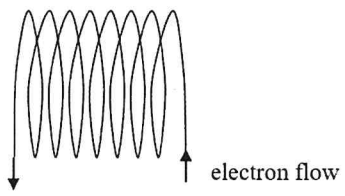
c) Define resistivity. A silver wire has a length of 5m and a cross sectional radius of 0.002m. Silver has a resistivity of 1.59 × 10-8□m. It is connected to a potential difference of 0.006V

d) Calculate the resistance of the wire and the current through the wire. (3 marks)

e) A proton in a particle accelerator has a speed of 5.0 x 10^6 m/s. The proton encounters a magnetic field whose magnitude is 0.40 T and whose direction makes an angle of 30.0^0 with respect to the proton's velocity. Find the magnitude of the magnetic force on the proton. (3 marks)

(i) State the relationship for the electric field strength, E: at a distance r from a point charge Q
(ii) between two parallel plates, a distance d apart, when a potential difference (p.d.) V is applied across the plates. (3 marks)

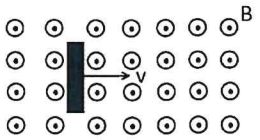
(f) Sketch the magnetic field pattern around the following electromagnet. (2 marks)



(g) What is the voltage $5.0cm$ away from the center of a $1.0cm$ diameter solid metal sphere that has a $-3.0nC$ static charge? (2 marks)

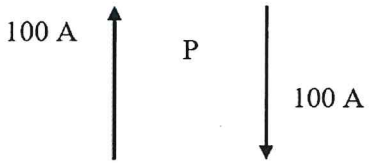
(h) A current of 10A flows through a conductor for two minutes. Calculate the amount of charge passed through any area of cross section of the conductor. (If the charge of an electron is $1.6 \times 10^{-19} C$, then calculate the total number of electrons flowing. (3 marks)

(i) A conductive rod is moving through a region of magnetic field, directed out of the page as diagrammed below. As a result of its motion, the mobile charge in the rod separates, creating an electric potential across the length of the rod. The length of the rod is 0.12m and the magnitude of the magnetic field is 0.022T. If the rod is moving with velocity $v = 17ms^{-1}$, what is the magnitude and direction of the potential from one end of the rod to the other? (4 marks)



(j) A p.d. of $3{\cdot}0 \times 10^4\ V$ is applied between two parallel conducting plates. The electric field strength between the plates is $5{\cdot}0 \times 10^5\ NC^{-1}$. (i) Determine the separation of the parallel plates. (ii) The separation of the plates is reduced to half the value found in (a).What happens to the magnitude of the electric field strength between the plates? (4 marks)

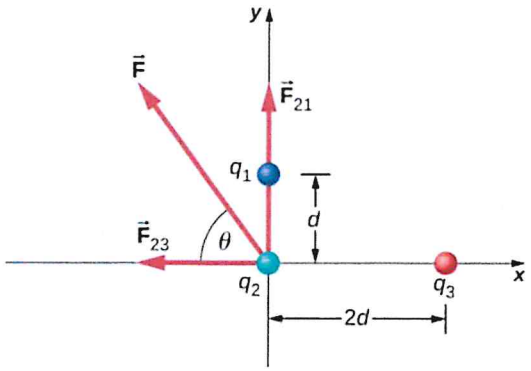
(k) Two long straight parallel wires are 0·10 m apart. The current in each wire is 100 A but the currents in the wires are in opposite directions as shown below.



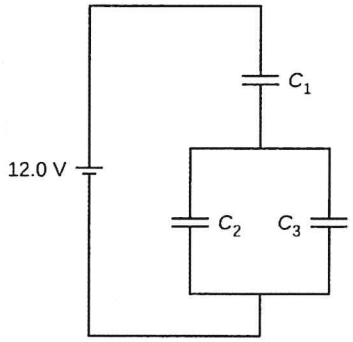
(i) Sketch the magnetic field lines around each of the wires. Use your sketch to determine whether the force between the wires is attractive or repulsive. (2 marks)

QUESTION TWO (20 marks)

(a) Three different, small charged objects are placed as shown in Figure below. The charges q_1 and $q_3$are fixed in place; $q_2$is free to move. Given that $q_1 = 2e$, $q_2 = -3e$ and $q_3 = -5e$ and that $d = 2 \times 10^{-7} m$ what is the net force on the middle charge q_2? (8 marks)



(b) Determine the net capacitance of the capacitor combination shown in Figure below when the capacitances are $C_1 = 12.0\mu F$, $C_2 = 2.0\mu F$, $C_3 = 4.0\mu F$. When a 12-V potential difference is maintained across the combination, find the charge and the voltage across each capacitor. (8 marks)



(ii) Calculate the energy stored in the capacitor network in 4(b) above when the capacitors are fully charged. (4 marks)

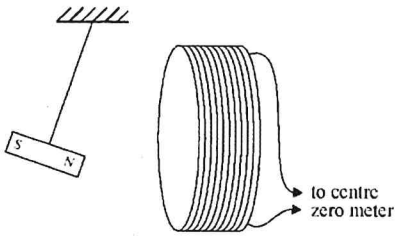
QUESTION THREE (20 marks)

a) Find the forces per unit length on two long, straight, parallel conductors if they carry currents A_1 and A_2 in the same direction and the separation distance is x. (6 marks)

b) Calculate (a) the electric field, and (b) the electric potential at a distance of 15 cm from an isolated point charge of 5 μC. (6 marks)

c) Two metal plates are separated by a distance d. The potential difference between the plates is V. A positive charge Q is pulled at a constant speed with a constant force F from the negative plate all the way to the positive plate. Using the definition for electric field strength and the concept of work done, show that the magnitude of the electric field strength E is given by the equation: $E = \frac{V}{d}$ (5 marks)

d) The magnet in the sketch below is mounted like a pendulum. It is allowed to swing to and fro into and out of a coil which has N turns. (3 marks)

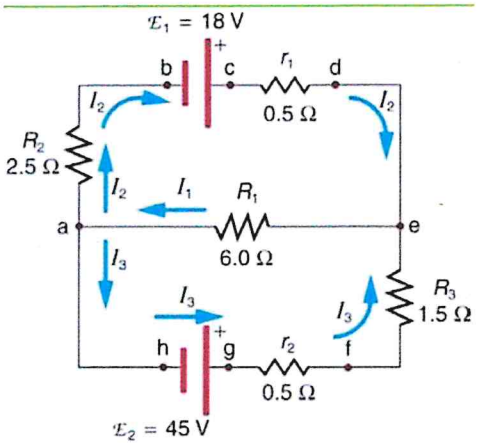


(i) What is the induced e.m.f. when the magnet momentarily stops?
(ii) State what happens to the induced e.m.f. as the magnet reverses its direction of movement.
(iii) What happens to the induced e.m.f. at the positions where the magnet moves fastest?

QUESTION FOUR (20 marks)

a) Draw a block diagram to show the construction and operations of the various parts of a cathode-ray oscilloscope. (8 marks)

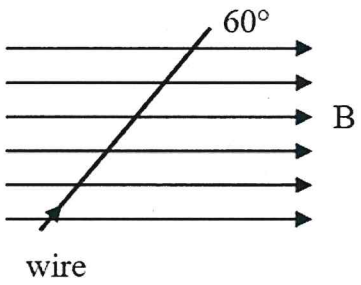
b) State the Kirchhoff's voltage law and use it to find the currents I_1, I_2 *and* I_3 flowing in the circuit. (12 marks)



QUESTION FIVE (20 marks)

a) A transformer on a KPLC pole steps the rms voltage down from $12kV$ to $240V$. (a) What is the ratio of the number of secondary turns to the number of primary turns? (b) If the input current to the transformer is $2.0A$, what is the output current? (c) Determine the power loss in the transmission line if the total resistance of the transmission line is 200Ω. (d) What would the power loss have been if the transmission $240V$ the entire length of the line, rather than providing voltage at$12kV$. What does this say about transmission lines? (8 marks)

b) A straight wire, 0·05 m long, is placed in a uniform magnetic field of magnetic induction 0·04 T. The wire carries a current of 7·5 A, and makes an angle of 60° with the direction of the magnetic field. (6 marks)



The arrow on the wire shows the direction of the electron current in the wire.

i. Calculate the magnitude of the force exerted on the wire.
ii. Draw a sketch of the wire in the magnetic field and show the direction of the force
iii. Describe the conditions for this force to be a maximum. (6 marks)