NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION

DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

ELECTRICITY AND MAGNETISM (PST 1172)

Main Examination Paper

NOVEMBER 2024

This Examination Paper consists of 4 printed pages

Time Allowed:	3 hours
Total Marks:	100
Special Requirements:	None Internal
Examiner:	Mrs. N. Moyo
External Examiner:	Dr N. Zezekwa

INSTRUCTION

1. This paper consists of **5** questions.
2. Answer **all** questions from **section A** and any **three** from **section B**
3. Begin each full question on a new page.
4. Show all your working steps clearly in any calculation.

MARK ALLOCATION

QUESTION	**MARKS**
First question	40
Second question	20
Third question	20
Fourth question	20
TOTAL	100

CONSTANTS

Electric charge	e	=	106 x 10^{-19} C
Mass of an electron	m_e	=	9.11 x 10^{-31} Kg
Permittivity of free space	ε_0	=	8.85 x $10^{-12}Fm^{-1}$
Permeability of free space	μ_0	=	1.26 x 10^{-6}Hm
Mass of proton	m_p	=	1.67 x 10^{-27} Kg
Coulomb constant	k	=	8.99 × 10 9 N · m 2 /C

SECTION A

1. (a) (i) Write down Coulombs law and define all the parameters. [4]

(b) (i) Define the electron volt. [1]

(ii) The charge on the electron is 1.6x 10^{-19}C in magnitude. With an electric field of 5 x 10^5 V/m between the plates of the Milikan's oil drop experiment. The oil drop is observed to be essentially balanced.

(I) What forces are at equilibrium? [2]

(II) What is the total charge on the oil drop? [3]

(III) Find the number of electrons in the oil drop. [3]

(c) Suppose the mass of the oil drop is 1.8 x 10^{-12}g and the oil drop is held at rest between two horizontal charged plates 1.8 cm apart. What voltage must be there between the two charged plates. [3]

(d) Define the following terms

(i) Capacitance

(ii) Capacitative reactance

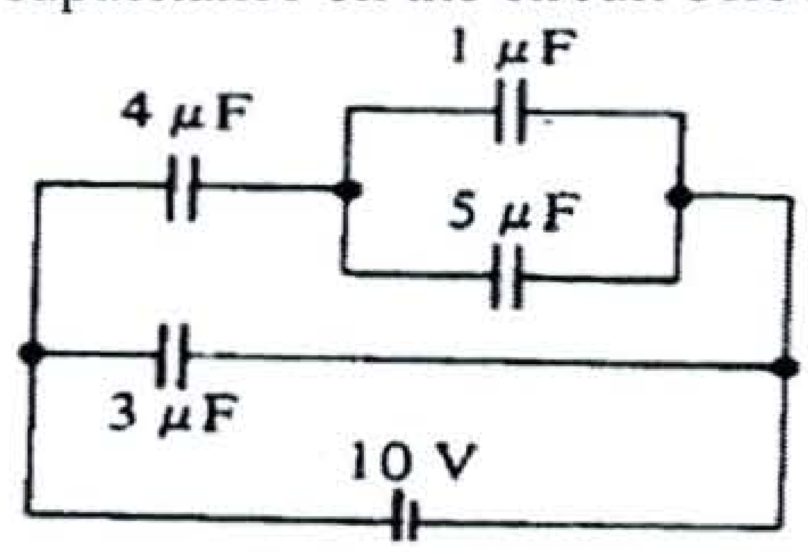
(iii) Impedance [3]

(e) (i) What is the difference in energy storage in an inductor and a capacitor. State one application of inductors. [3]

(ii) What is the self-inductance of a coil if the induced *emf* is 0.1V and the current decreases at a rate of – 0.01A. s^{-1}. [2]

(iii) Suppose wo capacitors 16 μF and 48 μF are connected in series to a D.C supply of 4V Comment on the charge stored and the potential difference across each capacitor. [2]

(iv) Find the equivalent capacitance on the circuit below, Fig 1.1



[4]

Fig 1,1

(f) (i) Write down the expression for the Lorentz force. [1]

(ii) In certain region of space we have an electric field $\overline{\boldsymbol{E}}$ and a magnetic field $\overline{\boldsymbol{B}}$ given by

$\overline{\boldsymbol{E}} = [7i + 4j + 6k]$ and $\overline{\boldsymbol{E}} = [-3i - 4j + 10k]$

If an electron is moving in this region with velocity $v = [2i + 3j]$m/s. What is the instantaneous force (full vector form by components) that acts on eth electron? [4]

(g) What is the relationship between resistance and resistivity of a material? [3]

(h) A copper wire of 3.0 mm^2 cross-sectional area carries a current of 5.0A. Find the magnitude of the velocity for the electrons in the wire. [2]

SECTION B

2. You wind 1000m of copper wire (resistivity of $\rho = 1.7 \times 10^{-8}\ \Omega$m, where the diameter $d = 0.9$ mm) into a solenoid of length $l = 2.0$m and diameter $D = 0.1$ m.

   (a) What is a solenoid? How many turns does this solenoid has? [3]

   (b) How much current flows through the solenoid? [4]

   (c) What is then the magnetic field inside the solenoid. [3]

   (d) What is the total energy inside the solenoid under these conditions? [5]

   (e) Draw the magnetic field of a solenoid. State **two** uses of a solenoid. [5]

3. A wire loop in the shape of a an equilateral triangle (each of side 0.20m long) travelling at a constant speed v = 5.0m/s moves point end first, into a region where a uniform magnetic field B = 0.40T points into the paper as shown below.

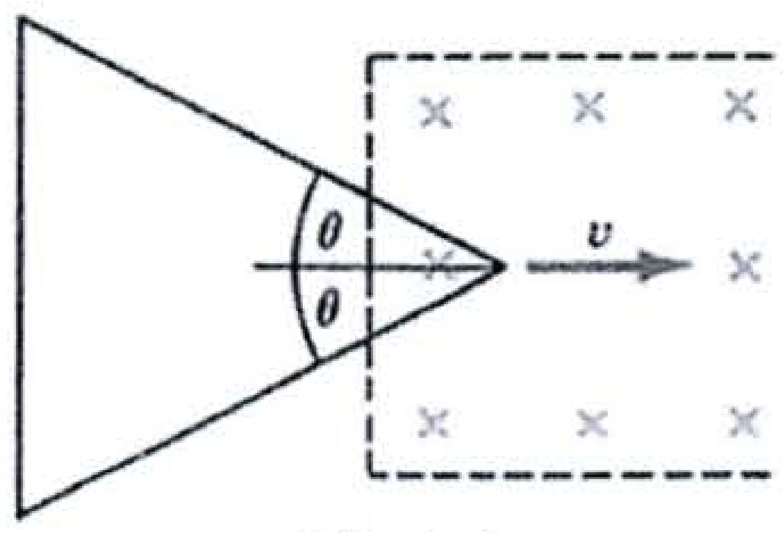
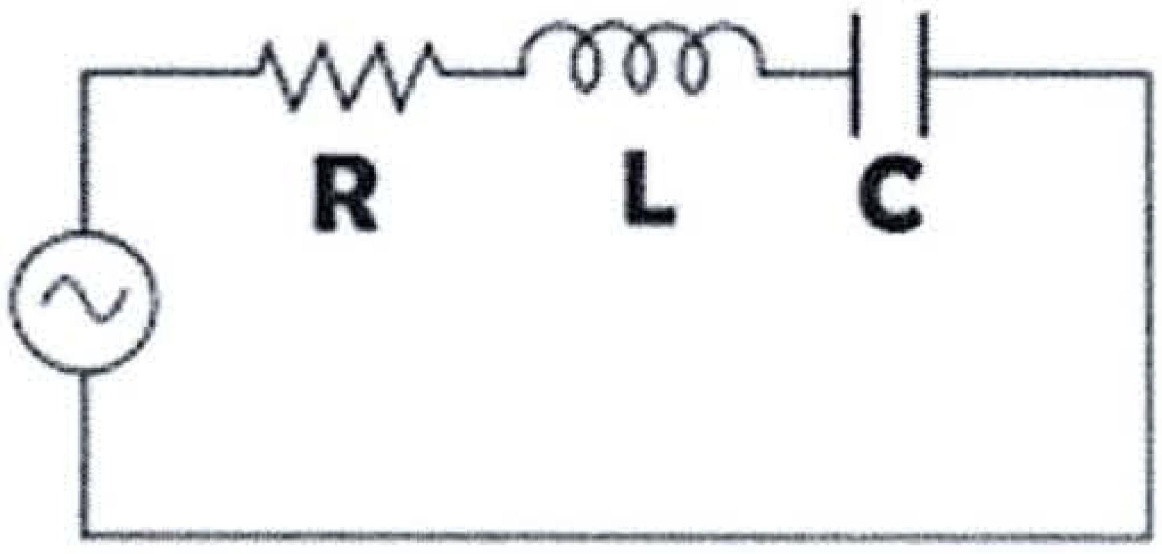


Fig 1.1

   (a) Indicate on the diagram, the direction of the current flow in the triangular loop as it enters the field. [3]
   (b) What is the maximum induces *emf* round the loop as it enters the field? [5]
   (c) Sketch the graph of induced *emf* round the loop as a function of time from the time it begins to enter the field until it is entirely in the field. [5]
   (d) A velocity selector in another magnetic field $\overline{\boldsymbol{B}}$ is perpendiclular to an electric field of 20.000V/m. We find that the charged particles with velocity V = 4.0 x 10^4 move through the device un-deflected. What is the strength of $\overline{\boldsymbol{B}}$. [4]
   (e) List three applications velocity selectors in present day technologies. [3]

4. (a) The circuit shown below is driven by an AC power supply generating, $V(t) = V_0\, Sin\omega t$, where V_0 = 150 Volts and $\omega = 2\pi$ x 60Hz. This voltage is applied to the resistance, R, a capacitor, C and an inductor, L, connected in series.



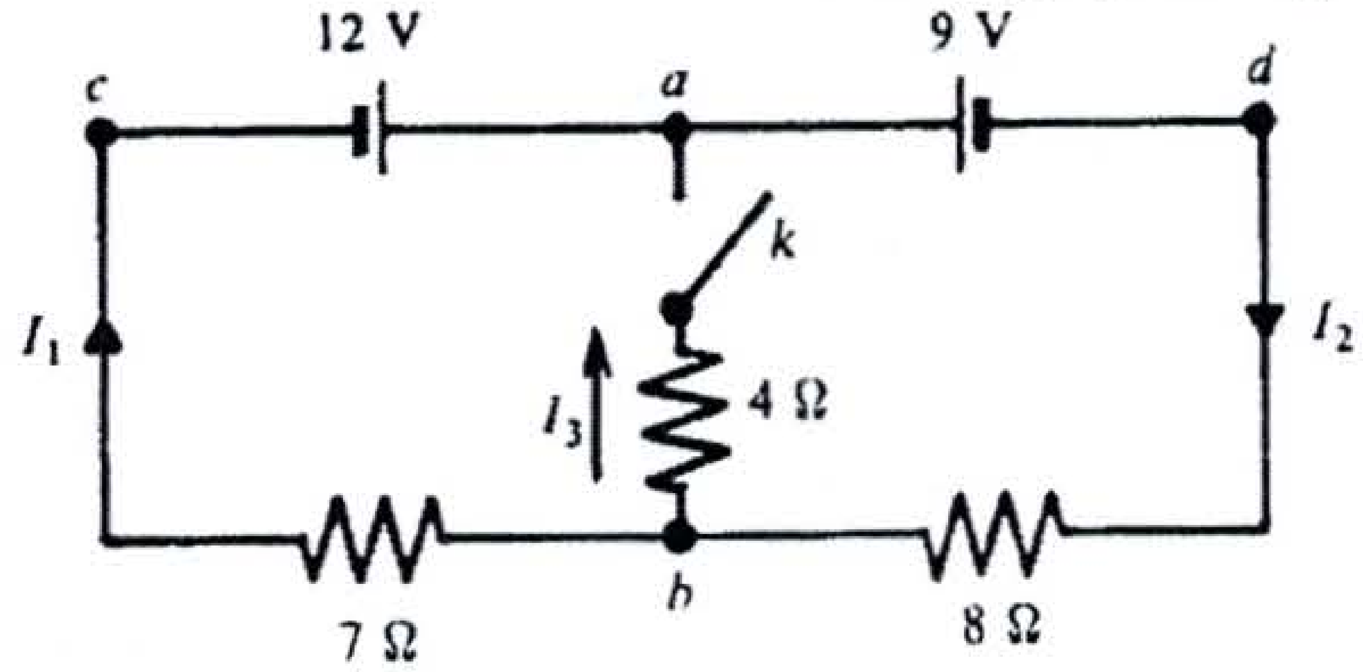
(i) If L = 0, C= 0 and R= 10.00Ω. What are the values of maximum current, i_m and the average current i in the circuit? [4]

(ii) If R = 10.00 Ω and C = 6.00μF, what is the value of the inductance L in the largest possible amplitude of current oscillations in the circuit? [4]

(iii) With the values of R, C, and L, given or calculated in the preceding parts, what is the average power dissipated in the circuit? [4]

(b) (i) State the Kirchoff laws. What is their physical implication? [2]

(ii) In the diagram below Find the values of current i_1, i_2 and i_3 [4]



5. (a) List the four properties of electric charge. [4]

(b) Equal electric charges of 1μ C each are placed at the vertices of an equilateral triangle whose sides are 0.1m each. Calculate

(I) The force on each charge as a result of the other two. [6]

(ii) The net and the direction of the force on any one the charge chosen to be the reference point. [5]

(c) What are equipotential surfaces. [1]

(d) Use Gauss law to derive Coulomb's law. [4]

END OF PAPER