EGERTON UNIVERSITY

UNIVERSITY EXAMINATIONS

NJORO CAMPUS

REGULAR PROGRAM

FIRST SEMESTER 2020/2021 ACADEMIC YEAR

SECOND YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDUCATION (SCIENCE)

PHYS 212: ELECTRICITY AND MAGNETISM I

STREAM: B. Sc., B. ED., & B. Sc. (COMPUTER). **TIME: 2 HOURS**

EXAMINATION SESSION: APRIL **YEAR: 2021**

INSTRUCTIONS

- **Read the question paper carefully**
- **Answer question ONE and any other THREE questions**
- **Show all the workings clearly**
- **Use the constants provided below whenever necessary**

Newton's gravitational constant (G).	$G = 6.67 \times 10^{-11}\ N.m^2.kg^{-2}$
Permittivity of free space (ϵ_o).	$\epsilon_o = 8.85 \times 10^{-12}\ C^2.N^{-1}.m^{-2}$
Coulomb's constant (k_e).	$k_e = 8.99 \times 10^9\ N.m^2.C^{-2}$
Electron's charge (q_e).	$q_e = -1.602 \times 10^{-19}\ C$
Proton's charge (q_p).	$q_p = +1.602 \times 10^{-19}\ C$
Gravitational acceleration (g).	$g = 9.81\ m.s^{-2}$

QUESTION ONE (40 MARKS)

a) Newton's law of gravitation says that the magnitude of the force between any two objects is proportional to the masses of the objects and decreases with the square of the distance between them:

$$F_g = \frac{Gm_1m_2}{r^2}$$

How is Newton's law of gravitation similar to Coulombs law? How is it different? **(5 mks)**

b) In a simple model of the hydrogen atom, an electron orbits the nucleus at a mean distance of $5.29 \times 10^{-11}\ m$. The nucleus (a proton) has a mass of $1.67 \times 10^{-27}\ kg$ and the electron has a mass of $9.11 \times 10^{-31}\ kg$. What is the ratio of the gravitational force to the electrostatic force acting on the electron due to the nucleus? **(3 mks)**

c) When atoms bind ionically at least one electron is transferred from one atom to the other. This is how sodium and chlorine bind to form sodium chloride (salt). In a salt crystal the sodium is Na^{+} and the chlorine is Cl^{-1}, each with a charge of $\pm 1e$. They are separated in a salt crystal by $0.28\ nm$. Considering only a single pair of ions, $Na^{+}Cl^{-1}$, what is the electric field at a point halfway between the two ions? **(3 mks)**

d) Consider a Gaussian surface that encloses part of the distribution of positive charges shown in **figure 1**.

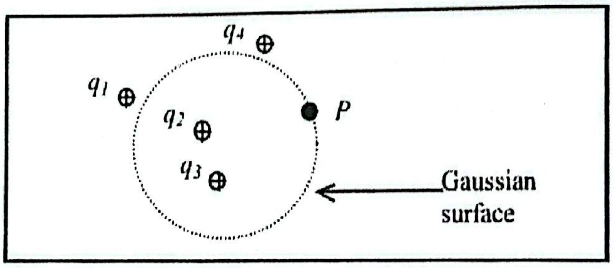

Figure 1

i. Write an expression for the flux through the Gaussian surface shown. **(2 mks)**
ii. Which of the charges contribute to the electric field at point P and why? **(2 mks)**

e) A neutral, spherical, thin metal shell has a point charge +q at its center.
  i. Draw a diagram showing the field lines and distribution of charges. **(2 mks)**
  ii. Use Gauss' law to derive expressions for the electric field between the charge and the shell, and the field outside the shell. **(4 mks)**

f) A capacitor consists of two parallel plates with area A which are separated by a distance d. What will be the effect on the capacitance if?
  i. Pushing the plates toward each other so d is halved? **(1 mk)**
  ii. Doubling the area, A, of both plates? **(1 mk)**
  iii. Doubling the area of one plate only? **(1 mk)**
  iv. Sliding one of the plates relative to the other so the overlap is halved? **(1 mk)**
  v. Doubling the potential difference between the plates? **(1 mk)**

g) Electric shock can injure and harm. But it can also be used to revive people using a cardiac defibrillator which sends an electrical impulse to the heart to re-start it. A certain cardiac defibrillator consists of a capacitor charged up to $1.0 \times 10^4\ V$ with a total stored energy of $450\ J$.

i. Calculate the charge on the capacitor in this defibrillator. **(2 mks)**

ii. If the internal resistance of the defibrillator is small, and the resistance across the skin of the patient's chest is $1.0\ k\Omega$, how long will it take the defibrillator to discharge 90% of its stored charged into the patient's chest? **(5 mks)**

h) What resistance must be placed in parallel with $12\ \Omega$ to obtain a combined resistance of $4\ \Omega$? **(2 mks)**

i) Name any four modern technological devices that rely on magnetism and magnetic properties of material. **(2 mks)**

j) An electric power line carries a current of $1.2 \times 10^6\ mA$ in a location where the earth's magnetic field is $5.0 \times 10^{-3}\ T$. The line makes an angle of 60^o with respect to the field. Determine the magnitude of the magnetic force on a $1.5 \times 10^4\ cm$ length of line. **(3 mks)**

QUESTION TWO (10 MARKS)

A charge of $+75\ \mu C$ and mass 0.015 kg has a velocity of $2.5 \times 10^4\ m/s$ in the direction shown in **figure 2**. It is travelling in a region near the surface of the earth where the magnetic field is uniform and has a magnitude of $1.45 \times 10^{-1}\ T$. There is also an electric field $\boldsymbol{E} = 3.0 \times 10^3\ N/C$. The velocity of the charge is perpendicular to the magnetic field but makes an angle of 45^o with the electric field.

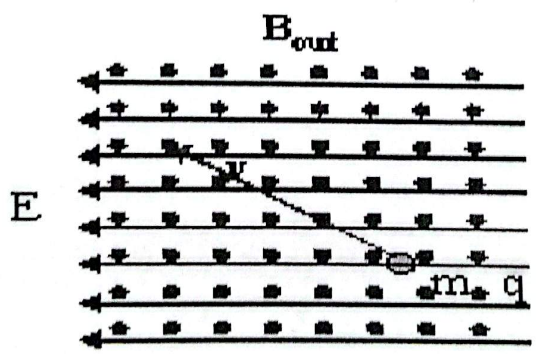

Figure 2

Determine the magnitude of:

i. The coulombic force. **(2 mks)**
ii. The magnetic force. **(2 mks)**
iii. Gravitational force. **(2 mks)**
iv. The acceleration of the charge. **(4 mks)**

QUESTION THREE (10 MARKS)

Apply Kirchhoff's rules to solve for current I_1, I_2 and I_3 and the potential difference (p.d) between **a** and **b** in circuit shown in **figure 3**, given that $R = 5\,\Omega$ and $\varepsilon = 20\,V$. Assume the voltmeter and the ammeter to be ideal. **(10 mks)**

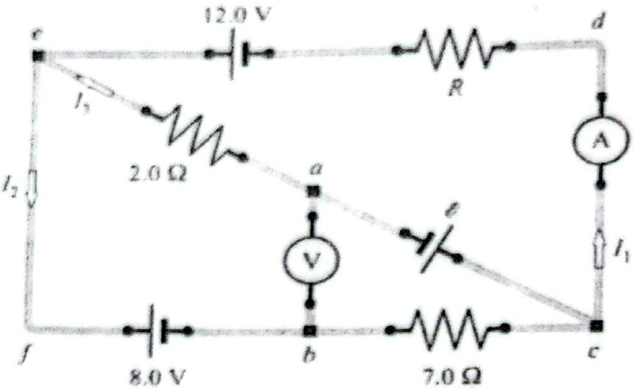

Figure 3

QUESTION FOUR (10 MARKS)

i. Express electric field in equation form. **(1 mk)**

ii. Hence show that the electric field, **E**, at point **p**, a distance of $x\ units$ away and perpendicular to the mid-point of a uniform line of charge of length $L\ units$ as shown in **figure 4**, is given by

$$E = \frac{1}{4\pi\epsilon_o} \cdot \frac{\lambda L}{x\sqrt{x^2+\left(\frac{L}{2}\right)^2}},$$ where λ is the linear charge density. **(9 mks)**

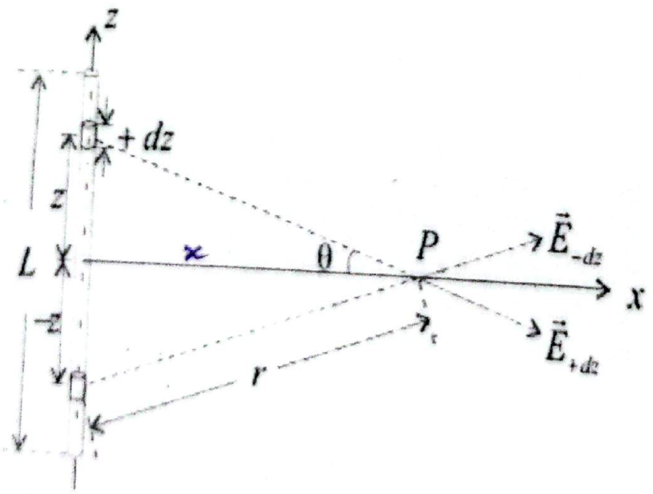

Figure 4

QUESTION FIVE (10 MARKS)

Electrocardiograms (ECGs) record electric potential differences between points on the chest due to the electrical activity of the heart. The heart behaves at some moments like a **charge dipole** as shown in **figure 5**. The charges are 6 cm apart, point **P** is at an electrode 6.0 cm from charge **A** and point **Q** is at an electrode 9.0 cm from a point half way between the charges also as shown in the same figure. The charge at point **A** is $+2.0 \times 10^{-14}\ C$, and that at point **B** is $-1.5 \times 10^{-14}\ C$.

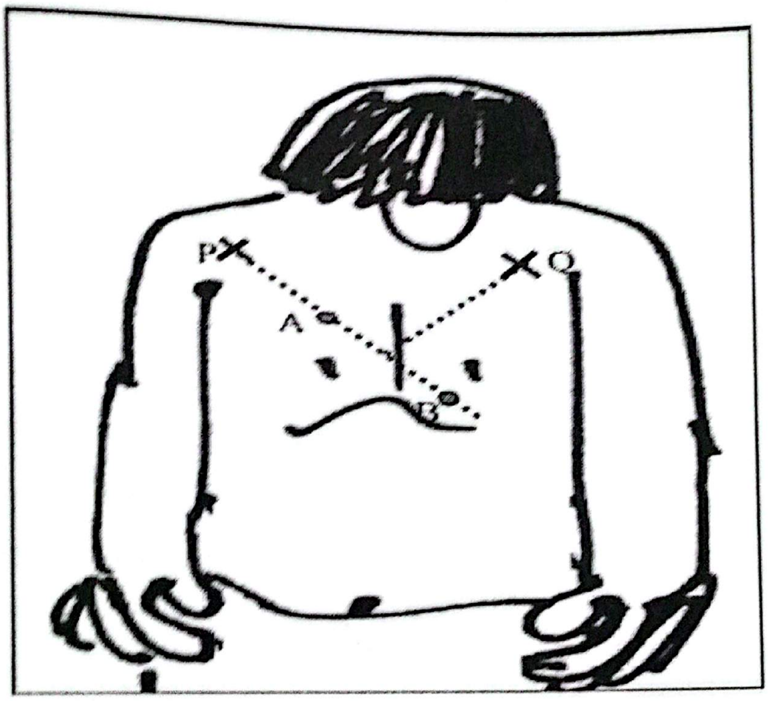

Figure 5

i. What is the potential at point P due to charge A? **(2 mks)**

ii. What is the potential at point P due to charge B? **(2 mks)**

iii. What is the potential at point P? **(1 mk)**

iv. What is the potential difference between points P and Q? **(5 mks)**

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