THE COPPERBELT UNIVERSITY

IN ASSOCIATION WITH

THE TECHNICAL AND VOCATIONAL TEACHERS' COLLEGE

BACHELOR OF SCIENCE IN MATHEMATICS AND SCIENCE WITH EDUCATION

SECOND YEAR - ODL

ELECTRICITY AND MAGNETISM (PHY 250)

DECEMBER 2022 PROMOTIONAL EXAMINATION

TOTAL MARKS – 100%

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS AND INFORMATION TO CANDIDATES

1. All questions carry equal marks.
2. The marks are shown in brackets.
3. This paper contains seven questions. Answer **any five** questions of your choice.
4. Show clearly all the necessary calculations.
5. Marks will be awarded for neat and well-drawn diagrams.
6. Clearly indicate on the answer booklet cover page the questions you have attempted.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO

WHEREVER NECESSARY USE:

$g = 9.81 m/s^2$

$P_A = 1.01 \times 10^5 Pa$

$1cal = 4.184 J$

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

$1Ci = 3.7 \times 10^{10} Bq$

$\mu_0 = 4\pi \times 10^{-7} Tm/A$

$\varepsilon_0 = 8.85 \times 10^{-12} F/m$

$m_e = 9.11 \times 10^{-31} kg$

$k_e = 8.99 \times 10^9 Nm^2/C^2$

$e = 1.60 \times 10^{-19} C$

$\hbar = 1.05 \times 10^{-34} Js$

$R_H = 1.097 \times 10^7 m^{-1}$

$\sigma = 5.669 \times 10^{-8} W/m^2 K^4$

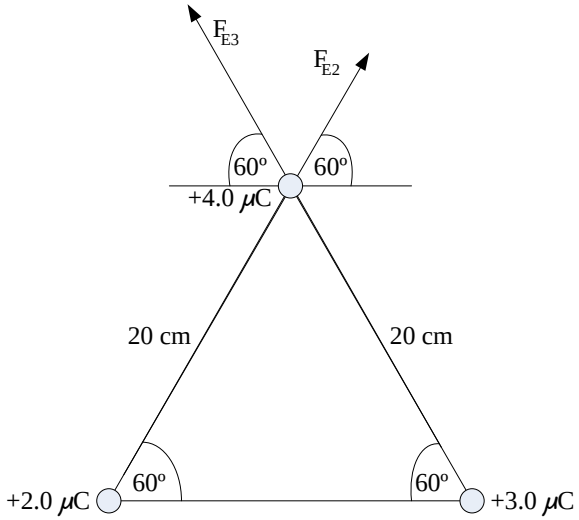
$h = 6.626 \times 10^{-34} Js$

Question One

a. Define electric charge. [2 marks]

b. State any 3 rules for drawing electric field lines for any charge distribution. [3 marks]

c. The charges shown in the figure below are stationary. Find the force on the 4.0 μC charge due to the other two.



[11 marks]

d. With the aid of well-drawn diagrams, show some representative electric field lines for:

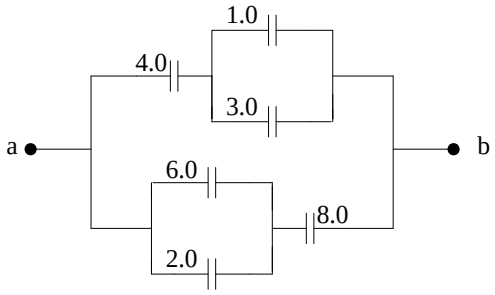
i. Two equal and opposite point charges. [2 marks]

ii. Two positive point charges. [2 marks]

Question Two

a. Define the capacitance of a capacitor. [2 marks]

b. The figure below shows a combination of series and parallel capacitors. The capacitors are in microfarads (μF).



i. Calculate the equivalent capacitance between a and b for the combination of capacitors shown. [7 marks]

ii. If a 12 V battery is connected across the system between points a and b, find the charge on the 4.0 μF capacitor and the voltage drop across it. [5 marks]

c. Derive the expression for the equivalent capacitance for two capacitors connected in series. [6 marks]

Question Three

a. State three (3) factors that affect the capacitance of a capacitor. [3 marks]

b. The plates of a parallel-plate capacitor in vacuum are 5.00 mm apart and 2.00 m^2 in area. A potential difference of 10.0 kV is applied across the capacitor. Compute:

i. The capacitance [3 marks]

ii. The charge on each plate [2 marks]

iii. The magnitude of the electric field in the space between them. [3 marks]

c. A resistor with resistance 10 MΩ is connected in series with a capacitor with capacitance 1.0 μF and a battery with e.m.f 12.0 V. Before the switch is closed at time t = 0, the capacitor is uncharged.

i. Calculate the time constant? [2 marks]

ii. What fraction of the final charge is on the plates at time t = 46 s? [4 marks]

iii. What fraction of the current remains at t = 46 s? [3 marks]

Question Four

a. State the units of electric charge and current. [2 marks]

b. Describe the factors that affect the magnitude and direction of induced e.m.f. [3 marks]

c. Three resistors having resistances of 1.60 Ω, 2.40 Ω, and 4.80 Ω are connected in parallel to a 28.0 V battery that has negligible internal resistance. With the aid of a well-drawn diagram, find:

i. The equivalent resistance of the combination. [2 marks]

ii. The current in each resistor. [3 marks]

iii. The voltage across each resistor. [3 marks]

iv. The power dissipated in each resistor. [3 marks]

d. The potential difference across resistors in parallel is the same because each resistor is connected directly across the battery terminals. The currents are however, generally not the same.

Derive an expression for the equivalent resistance for two resistors connected in parallel. [4 marks]

Question Five

a. Define magnetic field. [2 marks]

b. A wire carries a current of 22.0 A from west to east. Assume that at this location the magnetic field of Earth is horizontal and directed from south to north and it has a magnitude of 0.500×10^{-4} T.

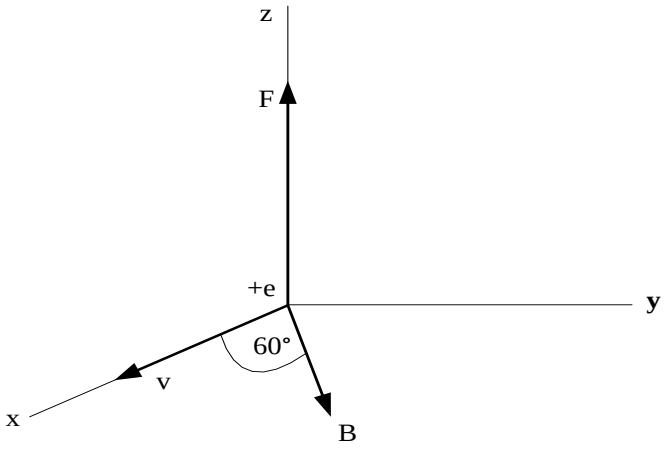
i. Find the magnitude and direction of the magnitude force on a 36.0 m length of wire. [3 marks]

ii. Calculate the gravitational force on the same length of wire if it's made of copper and has a cross-sectional area of 2.50×10^{-6} m^2. $\rho_{cu} = 8.92 \times 10^3$ kg/m^3. [4 marks]

c. Show that the magnetic force F_1 on a wire (wire 1) in the presence of magnetic field B_2 produced by another wire (wire 2) is given by;

$$F_1 = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$ [4 marks]

d. A proton moves at 8.00×10^6 m/s along the x-axis. It enters a region in which there is a magnetic field of magnitude 2.50 T, directed at an angle of 60.0° with the x-axis and lying in the xy-plane as shown in the below.



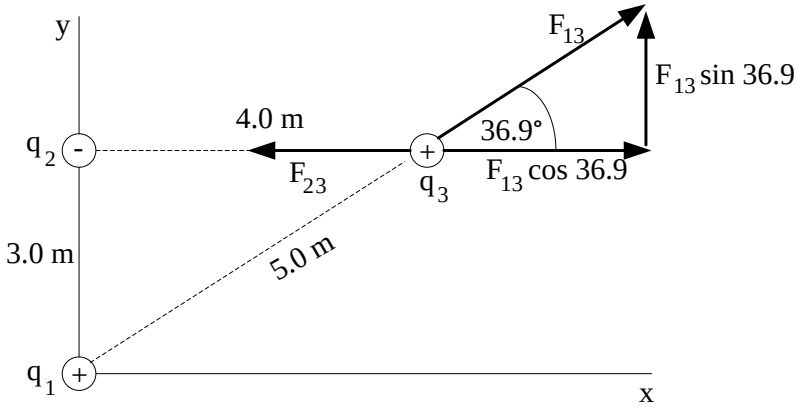
i. Find the magnitude and direction of the magnetic force on the proton. [4 marks]

ii. Calculate the proton's initial acceleration. [3 marks]

Question Six

a. State Ohm's law. [2 marks]

b. Consider three point charges at the corners of a triangle as shown in the figure below, where $q_1 = 6.0 \times 10^{-9}$ C, $q_2 = -2.0 \times 10^{-9}$ C and $q_3 = 5.0 \times 10^{-9}$ C.



i. Find the components of the force F_{23} exerted by q_2 and q_3. [3 marks]

ii. Find the components of the force F_{13} exerted by q_1 and q_3. [3 marks]

iii. Find the resultant force on q_3, in terms of components and also in terms of magnitude and direction. [8 marks]

c. Explain the following:

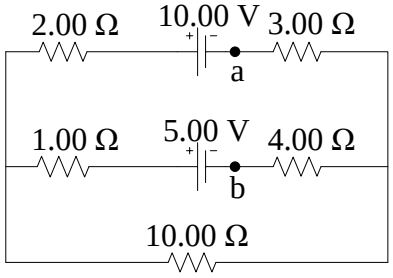
i. Ferromagnetism [2 marks]

ii. Paramagnetism [2 marks]

Question Seven

a. Define electromotive force (e.m.f) of a battery. [2 marks]

b. In the circuit shown in the figure below,

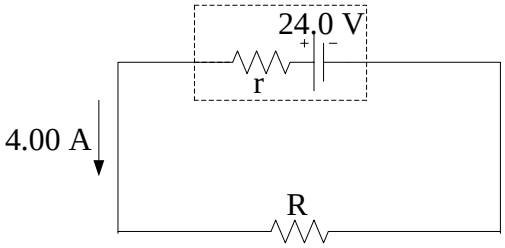


Find:

i. the current in each branch and [9 marks]

ii. the potential difference V_{ab} of point a relative to point b. [3 marks]

c. Consider the circuit shown in the figure below. The terminal voltage of the 24.0 V battery is 21.2 V.



Evaluate:

i. the internal resistance r of the battery? [3 marks]

ii. the resistance R of the circuit? [3 marks]

END OF EXAMINATION