STRATHMORE UNIVERSITY

SCHOOL OF COMPUTING AND ENGINEERING SCIENCES

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

END OF TERM II EXAMINATION

PHY1201: PHYSICS 2

DATE: 13TH MARCH 2024 TIME: 15:30-18:30 HOURS

Instruction:

1. This paper consists of **FIVE** questions.
2. Answer question 1 (Compulsory) and **ANY** other **TWO** questions
3. Show all your working in a systematic manner, where necessary, use diagrams to illustrate your concepts.

Important constants

Charge of an electron or proton, q_{e^-} or $q_{e^+} = 1.6 \times 10^{-19} C$

Mass of an electron $m_e = 9.1095 \times 10^{-31}\ kg$

Mass of a proton, $m_p = 1.673 \times 10^{-27}\ kg$

Mass of deuterons, $m_d = 2m_p$

Avogadro's constant, $N_A = 6.02 \times 10^{23} mole^{-1}$

Mass density of copper $\rho = 8.96 \times 10^3 kg/m^3$

Molar mass of copper, $M = 63.54 \times 10^{-3}\ kg/mol$

Coulomb constant, $k_e = 8.99 \times 10^9\ N.m^2/C^2$

Permittivity of free space constant $\varepsilon_o = 8.85 \times 10^{-12}\ C^2/N.m^2$

Permeability constant $\mu_o = 1.26 \times 10^{-6}\ T.m/A$

Gravitational acceleration $g = 9.8\, m/s$

$1\ MeV = 1.60 \times 10^{-13} J$

QUESTION 1 (20 MARKS)

(i) State the characteristics of a conductor in electrostatics equilibrium (4 marks)

(ii) A current of $17.0\ mA$ is maintained in a single circular loop of 2.00 m circumference. A magnetic field of $800\ T$ is then directed parallel to plane of the loop. Calculate the magnetic moment of the loop (3 marks)

(iii) A charge $+q$ is at $x = a$ and the second charge $-q$ is at $x = -a$ as shown in Figure 1.

a. Find the electric field at an arbitrary point P a distance $x > a$. (3 marks)

b. Find the limiting form of electric field for $x >> a$. (2 marks)

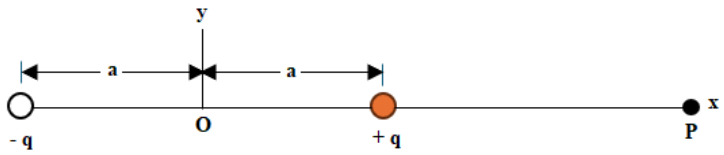

Figure 1

(iv) Figure 2 shows five charged lumps of plastic and an electrically neutral coin. The cross section of a Gaussian surface S is indicated. Calculate the net electric flux through this surface given that $q_1 = q_4 = +3.1\ nC,\ q_2 = q_5 = -5.9\ nC,$ and $q_3 = -3.1\ nC$ (3 marks)

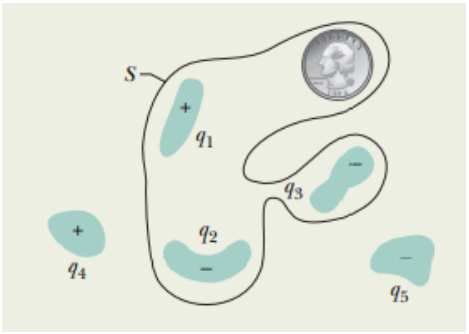

Figure 2

(v) An isolated conducting sphere whose radius is 6.85 cm has a charge of $q = 1.25\ nC$.

a. Show that the capacitance of the isolated sphere is given as $4\pi\varepsilon_0 R$ (3 marks)

b. The potential energy stored in the electric field of the charged sphere (3 marks)

c. The energy density of the surface of the sphere (3 marks)

(vi) A uniform magnetic field $\vec{B}$, with magnitude of 1.2 mT, is directed vertically upward throughout the volume of a laboratory chamber. A proton with kinetic energy 5.3 MeV enters the chamber, moving horizontally from south to north.

a. Find the deflecting force experienced by the proton as it enters the chamber (4 marks)

b. The magnitude of the proton's acceleration due to this deflecting force (2 marks)

QUESTION 2 (15 MARKS)

(i) In a certain particle accelerator, pulses of electrons at a rate of 250 pulses per second emerge with an energy of 40 MeV. The time interval between the pulses is 4.00 m/s and each of the pulse has a duration of 200 ns as shown in Figure 3.

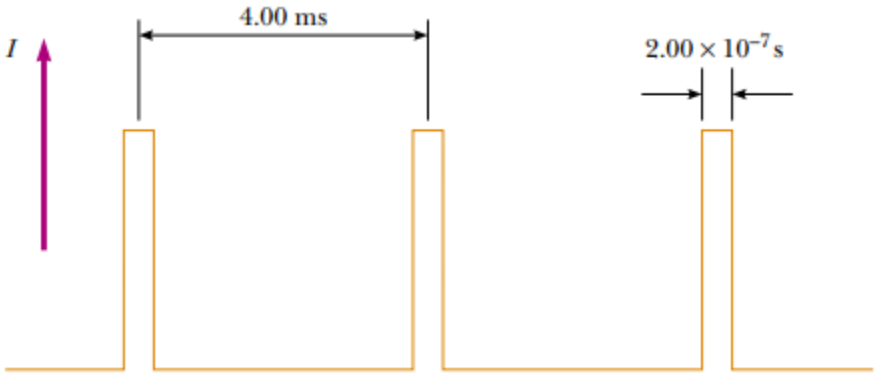

Figure 3

If an electron in a pulse has a current of 250 mA and the current is zero between the pulses. Calculate

a. The number of electrons delivered by the accelerator per pulse (3 marks)

b. The average current per pulse delivered by the accelerator (2 marks)

c. The peak power delivered by the electron beam (2 marks)

d. The average power delivered by the electron beam (2 marks)

(ii) Two long parallel wires 5.0 cm apart carry current $i_1 = 15\ A$ and $i_2 = 32\ A$ in opposite directions as shown in Figure 4. Determine the magnitude and direction of the net magnetic field at point P shown in the figure. (6 marks)

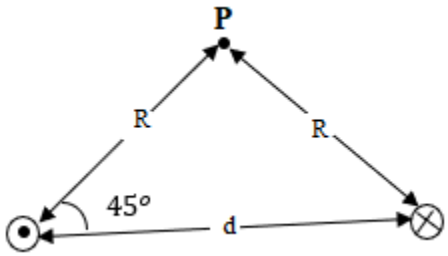

Figure 4

QUESTION 3 (15 MARKS)

(i) A proton is released from rest in a uniform electric field that has a magnitude of $8.0 \times 10^4\ V/m$, as shown in Figure 5. The proton undergoes a displacement of 0.50 m in the direction of the electric field $\vec{\boldsymbol{E}}$.

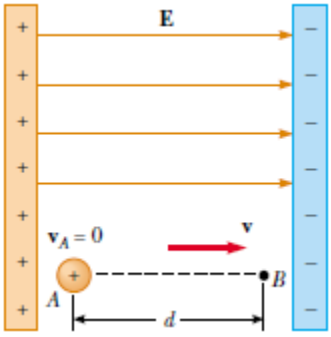

Figure 5

a. Find the change in electric potential between points A and B, (2 marks)

b. Find the speed of the proton after completing the 0.50m in displacement in the electric field (3 marks)

(ii) Three light waves combine at a certain point where the electric components are,

$$E_1 = E_o \sin \omega t$$

$$E_2 = E_o \sin(\omega t + 60^o)$$

$$E_3 = E_o \sin(\omega t - 30^o)$$

Find the resultant component $E(t)$ at that point (6 marks)

(iii) Calculate the drift speed of the conduction electrons in a copper wire of radius $r = 900\ \mu m$ when a uniform current of $i = 17\ mA$ passes through it. (assume that each copper atom

contributes one electron conduction to the current and the current density J is uniform across the wire's cross section). (4 marks)

QUESTION 4 (15 MARKS)

(i) Two identical small-charged spheres q_1 and q_2, each having a mass of $3.0 \times 10^{-2} kg$, hang in equilibrium as shown in Figure 6. The length of each string is 0.15 m and the angle θ is 5.0^o. Find the magnitude of the charge on each sphere. (6 marks)

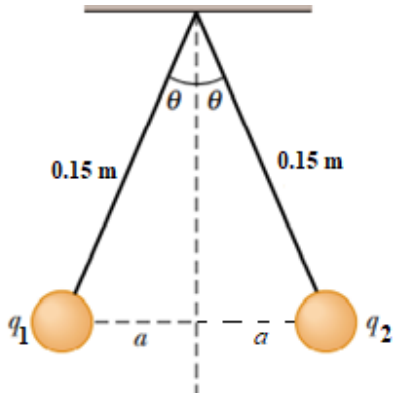

Figure 6

(ii) Two uncharged spherical conductors of radius $R_1 = 6.0\ cm$ and $R_2 = 2.0\ cm$ as shown in Figure 7 and separated by a distance much greater than 6.0 cm are connected by a long, very thin connecting wire. A total charge of $Q = +80\ nC$ is placed on one of the spheres and the system is allowed to reach electrostatic equilibrium.

Figure 7

a. Calculate the charge total charge distributed on each sphere when the system attains electrostatic equilibrium, (3 marks)

b. Find the electric field strength at the surface of each sphere (3 marks)

(iii) A cross section of three infinitely large nonconducting sheets on which charge is uniformly spread is shown in Figure 8. The surface charge densities on the conducting sheets are $\sigma_1 = 2.0\ \mu C/m^2$, $\sigma_2 = +4.0\ \mu C/m^2$, $\sigma_3 = -5.0\ \mu C/m^2$, and the distance $L = 1.50\ cm$. In unit vector notation, find the net electric field at point P. (3 marks)

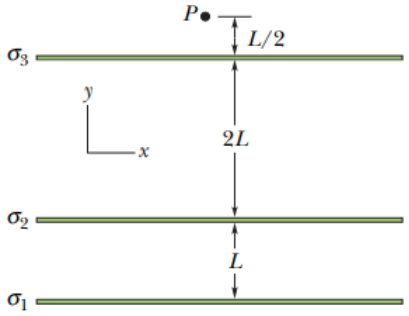

Figure 8

QUESTION 5 (15 MARKS)

(i) State the properties of an electric charge (3 marks)

(ii) A dead battery is charged by connecting it to a live battery of another car with jumper wires as shown in Figure 9.

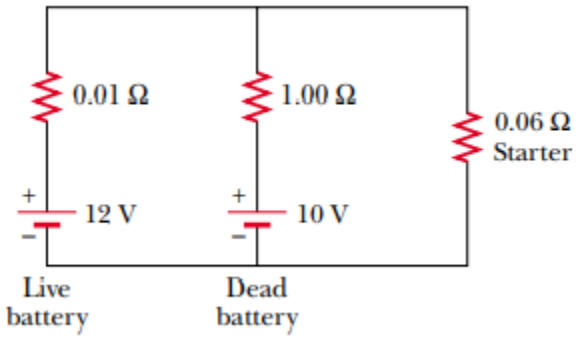

Figure 9

a. Redraw the circuit indicating the direction of the current, (2 mark)

b. Determine the current needed by the starter. (7 marks)

(iii) Using how magnetic permeability of materials compare to permeability of free space, classify magnetic substances (3 marks)