University of Fort Hare
Together in Excellence

DEPARTMENT OF PHYSICS

ELECTROMAGNETISM

PHY212

DEGREE EXAMINATION

MAY/JUNE 2023

Time :3 hours

Marks : 100

INTERNAL EXAMINER

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MODERATOR

Mr. P. Kwinana

INSTRUCTION

Answer any five (5) questions

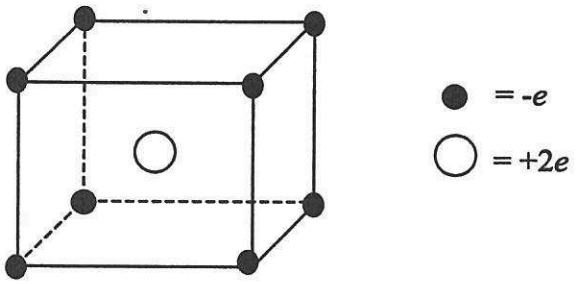
Question 1

(a) Consider a charge q and a test charge q_0 separated by a distance r.

(i) Write an expression for the force between the two charges. (4)

(ii) Derive an expression for the work done in moving the test charge from a distance r to a point at infinity. (9)

(b) Calculate the potential energy of an arrangement of eight negative charges on the corners of a cube of side length b, with a positive charge in the center of the cube as shown below. Given that each negative charge is an electron with charge $-e$, while the central particle carries a positive charge of $+2e$. (12)



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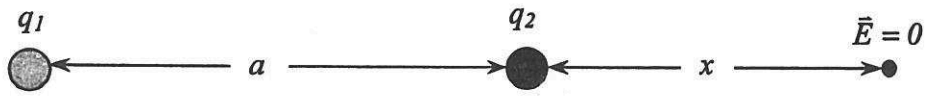
Question 2

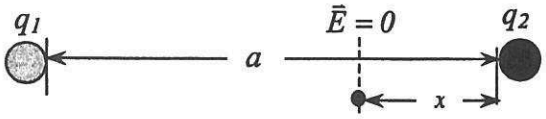
(a) The figure below shows two point charges q_1 and q_2 separated by a distance a. At some point x-units to the right of q_2, the electric field $\vec{E} = 0$.



(i) Write an expression for the ratio $\frac{q_1}{q_2}$ at the point where $\vec{E} = 0$. (4)

(ii) Compare the signs of q_1 and q_2 at that point. (2)

(b) Suppose now the electric field $\vec{E} = 0$ is now x-units to the left of q_2 as shown below.



(i) Determine the ratio $\frac{q_1}{q_2}$ at the point where $\vec{E} = 0$. (4)

(ii) Compare the signs of q_1 and q_2 at that point. (2)

(c) Use Gauss's law to calculate the electric field $\vec{E}$ of a solid spherical charge distribution with charge density ρ at the following points:

(i) $r > a$; (3)

(ii) $r = a$; (3)

(iii) $r < a$, where a is the radius of the sphere. The volume of the sphere is $\frac{4}{3}\pi r^3$. (3)

(d) Draw a graph of $\vec{E}$ against r. (4)

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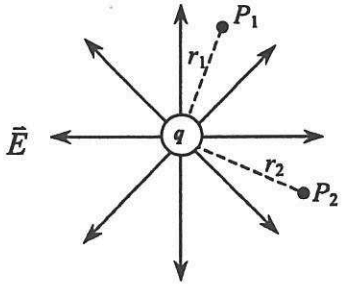
Question 3

(a) Determine the potential difference $\varphi_1 - \varphi_2$ between P_1 and P_2 as shown in the figure below, where q is a point charge whose electric field $\vec{E} = \frac{kq}{r^2}$. [***Hint***: one of the paths can be an equipotential line]. (13)



(b) Given $\varphi = f(r)$ where $r^2 = x^2 + y^2 + z^2$. Calculate the gradient $\nabla\varphi$. (12)

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Question 4

(a) Write an expression for the divergence of a vector function $\vec{E}$ in terms of flux. (5)

(b) Write an expression for the divergence of $\vec{E}$ in coordinate form. (5)

(c) Show that the divergence of $\vec{E}$ depends only on the charge distribution by deriving the following expression: (15)

$$\nabla \cdot \vec{E} = 4\pi\rho$$

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Question 5

(a) Define capacitance and give at least three applications of a capacitor. (5)

(b) Given the system illustrated below, where C_1 = 100 μF, C_2 = 200 μF, C_3 = 300 μF and V = 12 V, find: (15)

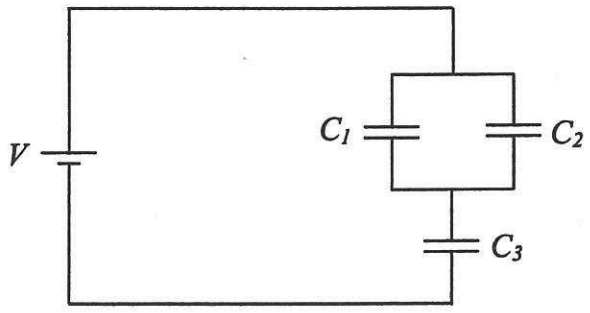
(i) The equivalent capacitance C_{eq};

(ii) The charge q on each capacitor;

(iii) The voltage across each capacitor;

(iv) The energy stored in each capacitor;

(v) The energy stored in C_{eq}.



(c) Show that the energy stored in a capacitor is given by $U = \frac{q^2}{2C}$. (5)

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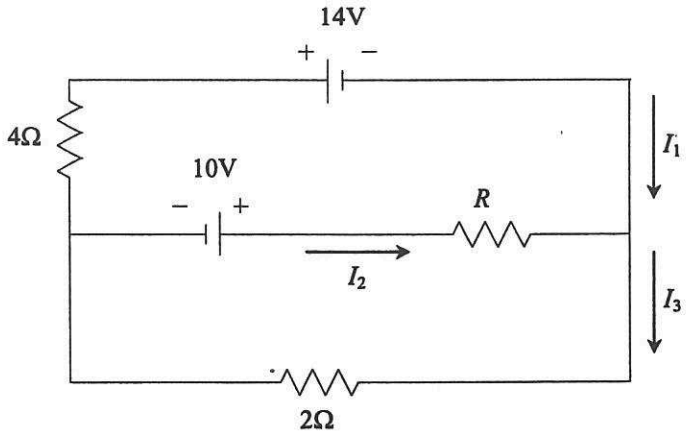
Question 6

(a) State *Kirchhoff's* loop and junction rules. (8)

(b) Use *Kirchhoff's* rules to find the currents I_1, I_2 *and* I_3 in the circuit shown below. (17)



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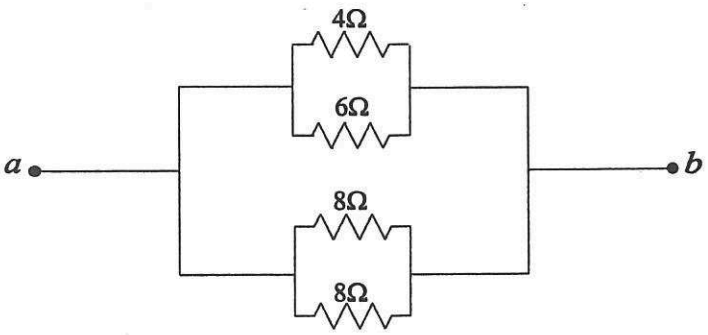
Question 7

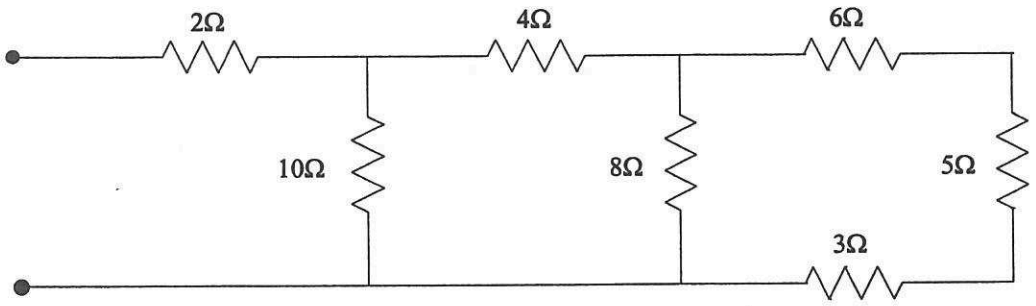
(a) Consider the combination of resistors shown below.

(i) Find the equivalent resistance between points *a* and *b* in the diagram below. (3)

(ii) If the potential between *a* and *b* is 12 V, find the current in each resistor. (16)



(b) What is the equivalent resistance of the network shown below? (6)



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