Section 4: Electromagnetism I

1. Coulomb's Law (2D)

Four point charges of +1.0 C each are placed at the corners of a square with sides of 1.0 m. Calculate the magnitude and direction of the electric force on a charge of -2.0 C placed at the center of the square.

2. Electric Potential

Point charges of +1C, -2C, +3C, and -4C are placed at the corners of a square with sides of 1.0 m (in order). Calculate the electric potential at the center of the square.

3. Magnetic Field of Charge

An electron is moving in a circular path with a radius of $r = 10$ cm at a constant speed of $v = 10^6$ m/s. Calculate the magnitude of the magnetic field it produces at the center of the circle.

4. Mass Spectrometry

A proton (charge $+e$, mass m_p) and an alpha particle (charge $+2e$, mass $\approx 4m_p$) enter a uniform magnetic field with the same velocity, perpendicular to the field lines. What is the ratio of the radii of their circular paths, r_p/r_α?

5. Force Comparison

Calculate the magnitude of the electric force and the gravitational force between an electron and a proton in a hydrogen atom (average distance $r \approx 5.3 \times 10^{-11}$ m). What is the ratio F_e/F_g?

6. Cyclotron Motion

An electron is accelerated from rest through a potential difference of 5000 V. It then enters a region of uniform magnetic field B = 0.1 T, perpendicular to its velocity. What is the radius of the circular path it will follow?

7. Lorentz Force on Wire

A straight wire 2.0 m long carries a current of 10 A. It is placed in a uniform magnetic field of B = 0.5 T. Calculate the magnetic force on the wire if the angle between the wire and the magnetic field is:

a) 90°
b) 45°
c) 0°

8. Electrostatic Equilibrium

Find the equilibrium position for a charge $q_3 = +1$C placed on the line between a charge $q_1 = +4$C and a charge $q_2 = +9$C which are separated by a distance of 2 m.

9. Vector Lorentz Force

A proton moves with a velocity $\vec{v} = (2\hat{i} - 4\hat{j} + \hat{k})$ m/s in a region where the magnetic field is $\vec{B} = (\hat{i} + 2\hat{j} - \hat{k})$ T. What is the magnitude of the magnetic force this charge experiences?

10. Field Levitation

What electric field strength is required to make a proton levitate against Earth's gravity at the level of the Earth's surface? (Mass of proton $m_p \approx 1.67 \times 10^{-27}$ kg, charge of proton $e \approx 1.6 \times 10^{-19}$ C, gravitational acceleration $g \approx 9.8$ m/s^2).