General Physics: Electromagnetism, Problem Set 2

Exercise 1 :

In the Bohr theory of the hydrogen atom, an electron moves in a circular orbit about a proton, where the radius of the orbit is $a_0 = 5.29 \times 10^{-11}$ m. The proton has charge $e = 1.60 \times 10^{-19}$ C and the electron has charge $-e$ and mass $m_e = 9.11 \times 10^{-31}$ kg.

1. Find the magnitude of the electric force exerted on each particle.
2. If this force causes the centripetal acceleration of the electron, what is the speed of the electron?

Exercise 2 :

Charges q_1 and q_2 are located on the x axis at distances a and b respectively from the origin, as shown in the next figure.

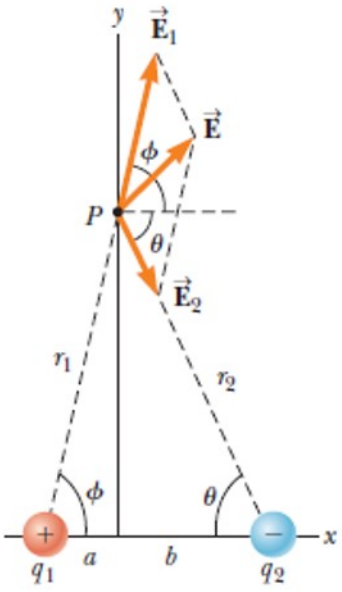

Figure 1: Positions of the charges q_1 and q_2 and of a field point P. The total electric field $\boldsymbol{E}$ at P equals the vector sum $\boldsymbol{E}_1 + \boldsymbol{E}_2$, where $\boldsymbol{E}_1$ is the field due to the positive charge q_1 and $\boldsymbol{E}_2$ is the field due to the negative charge q_2.

1. Find the components of the net electric field at the point P, which is at position $(0, y)$.

2. Evaluate the electric field at point P in the special case that $|q_1| = |q_2|$ and $a = b$.

3. Still for the special case of problem 2., find the electric field due to the electric dipole when point P is at distance $y \gg a$ from the origin.

Exercise 3 :

A ring of radius a carries a uniformly distributed positive total charge Q.

1. Calculate the electric field due to the ring at a point P lying at a distance x from its center along the central axis perpendicular to the plane of the ring (see next figure).

2. Suppose a negative charge is placed at the center of the ring and displaced slightly by a distance $x \ll a$ along the axis. When the charge is released, what type of motion does it exhibit?

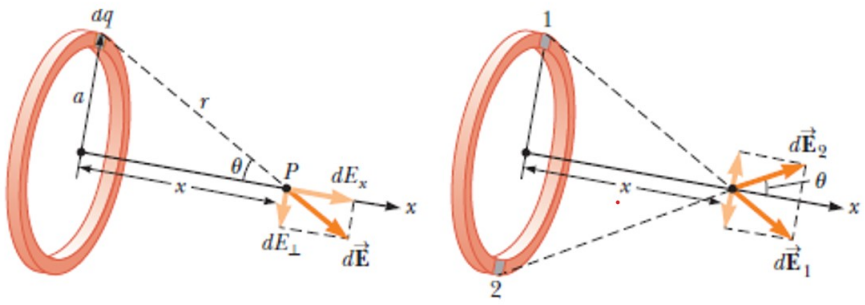

Figure 2: Ring with uniform positive charge Q and field point P at a distance x on the central axis of the ring. The infinitesimal electric field $d\boldsymbol{E}$ produced by an elementary charge dq on the ring in the point P can be divided in a component along the central axis dE_x and in a component lying on the ring's plane $dE_\perp$. The total electric field in the point P is given by the sum of the infinitesimal electric fields produced by all the elementary charges on the ring.

Exercise 4 :

A disk of radius R has a uniform surface charge density σ.

1. Calculate the electric field at a point P that lies at a distance x from the disk's center along the central axis perpendicular to the plane of the disk (see next figure).

2. What happens if we let the radius of the disk grow so that the disk becomes an infinite plane of charge?

3. Show that the electric field at distances x that are large compared with R approaches that of a particle with charge $Q = \sigma\pi R^2$.

   Hint: Use the fact that $x/(x^2 + R^2)^{1/2} = (1 + R^2/x^2)^{-1/2}$ and the approximation for the binomial expansion $(1 + \delta)^n \approx 1 + n\delta$ when $\delta \ll 1$.

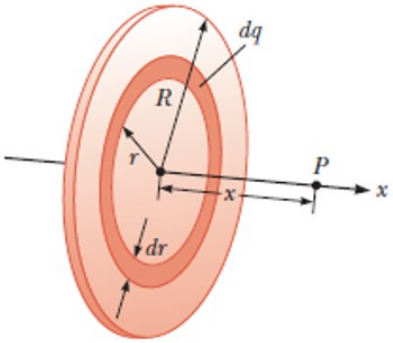

Figure 3: Disk of radius R with uniform surface density σ. The elementary charge dq is given by a circular crown of width dr located at distance r from the center. The field point is at distance x on the central axis of the ring.

Exercise 5 :

A proton of mass $m_{\mathrm{p}} = 1.67 \times 10^{-27}$ kg moves at 4.50×10^{5} m/s in horizontal direction. It enters a uniform vertical electric field with a magnitude of 9.60×10^{3} N/C. Ignoring any gravitational effects, find:

1. the time interval required for the proton to travel 5.00 cm horizontally,
2. its vertical displacement during the time interval in which it travels 5.00 cm horizontally,
3. the horizontal and vertical components of its velocity after it has traveled 5.00 cm horizontally.