Homework No. 02 (Spring 2023)

PHYS 205B: UNIVERSITY PHYSICS

School of Physics and Applied Physics, Southern Illinois University–Carbondale

Due date: Thursday, 2023 Feb 2, 9:30 AM, on D2L

Instructions

- You are encouraged to use any of the resources to complete this homework. However, the extent to which you depend on resources while doing homework is usually a measure of how much extra work you need to put in to master the associated concepts. Solutions should be the last resource.
- Describe your thought process in detail and organize it clearly. Make sure your answer has units and the right number of significant digits.
- After completion, scan the pages as a single PDF file, and submit the file on D2L (under Assessments → Assignments).

Problems

1. (**10 points.**) Consider a configuration of two charges q_1 and q_2 positioned at $(+a, 0)$ and $(-a, 0)$, respectively. Let $x = 2a$ and $y = 2a$. Given $q_1 = +1.0\,\text{nC}$, $q_2 = -1.0\,\text{nC}$, and $a = 1.0\,\text{cm}$.

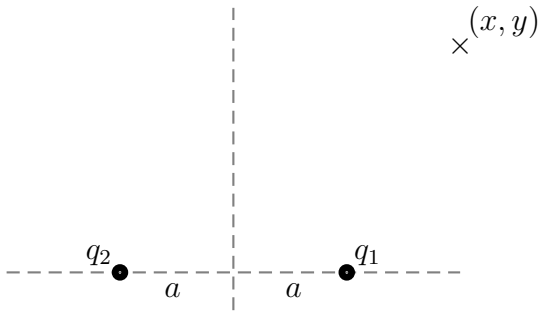

Figure 1: Problem 1

   (a) Determine the magnitude and direction of the electric field at the point marked × at (x, y).

(b) Determine the total electric force a charge $q_3 = 3.0\,\text{nC}$ would experience if it were placed at the point (x, y).

Solution

2. (**10 points.**) The electric dipole moment of a configuration consisting of two equal and opposite point charges, separated by a distance d, is defined to be

$$\vec{\mathbf{p}} = q\vec{\mathbf{d}}, \tag{1}$$

where $\vec{\mathbf{d}}$ points from the negative to the positive charge and $d = |\vec{\mathbf{d}}|$. Let $d = 2a$. Given $q = 1.0\,\mu\text{C}$, $d = 2.00\,\text{cm}$, and $y = 5.00\,\text{cm}$.

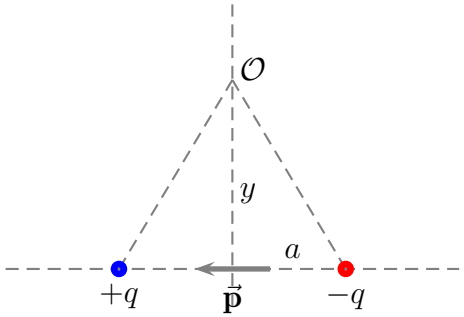

Figure 2: Problem 2

(a) Determine the magnitude and direction of the electric dipole.

(b) Determine magnitude and direction of the total electric field at $\mathcal{O}$ along a bisector of the electric dipole, a distance y away from the center of the dipole.

(c) Calculate the magnitude and direction of the force on a charge $Q = +7.0\,\mu\text{C}$ when placed at $\mathcal{O}$.

Solution

3. (**10 points.**) Consider a thin conducting spherical shell of radius $a = 1.0\,\text{cm}$ with a total charge of $Q = 3.0\,\text{nC}$ (distributed uniformly) on its surface. The electric field due to such a spherical charge distribution is given by

$$\mathbf{E} = \begin{cases} 0, & \text{if} \quad r < a \quad \text{(inside)}, \\ \hat{\mathbf{r}}\dfrac{kQ}{r^2}, & \text{if} \quad a < r \quad \text{(outside)}. \end{cases} \tag{2}$$

(a) Find the electric field 0.5 cm from the center of the charge distribution.

(b) Find the electric field 2.0 cm from the center of the charge distribution.

Solution

4. (**10 points.**) Consider a configuration consisting of two charged concentric spherical shells of radius a and b with charges Q_a and Q_b, respectively. Let us have $a < b$. Given $a = 1.0\,\text{cm}$, $b = 3a$, $Q_a = +1.0\,\text{nC}$, and $Q_b = -3.0\,\text{nC}$.

   (a) Determine the expression for the electric field in region $r < a$. Determine the magnitude and direction of the electric field at $r = 0.25\,\text{cm}$.

   (b) Determine the expression for the electric field in region $a < r < b$. Determine the magnitude and direction of the electric field at $r = 2.0\,\text{cm}$.

   (c) Determine the expression for the electric field in region $b < r$. Determine the magnitude and direction of the electric field at $r = 4.0\,\text{cm}$.

Solution

5. (**10 points.**) Consider a region of uniform electric field

$$\vec{\mathbf{E}} = (1.0\,\hat{\mathbf{i}} + 2.0\,\hat{\mathbf{j}}) \times 10^3\,\frac{\text{N}}{\text{C}}. \tag{3}$$

   Calculate the electric flux through a rectangular plane 0.40 m wide and 0.20 m long if the plane is parallel to the yz plane.

Solution

6. (**10 points.**) A charge of $105\,\mu\text{C}$ is at the center of a (hypothetical) cube of edge 75.0 cm. No other charges are nearby.

   (a) Find the flux through each face of the cube.

   (b) Find the flux through the whole surface of the cube.

   (c) Would your answers to parts (a) or (b) change if the charge were not at the center?

Solution

7. (**10 points.**) Charges are placed on the $z = 0$ plane such that it forms a square lattice of length a that extends to infinity in the plane. Refer Figure 3. The charge on each lattice point has a magnitude of $17.7 \times 10^{-12}\,\text{C}$. Determine the electric flux through the surface G of a sphere of radius $R = 1.7\,a$ shown in Figure 3.

Solution

8. (**10 points.**) A large, flat, horizontal sheet of dielectric material has a charge per unit area of $8.85\,\mu\text{C/m}^2$. Using Gauss's law dind the electric field just above and below the middle of the sheet.

Solution

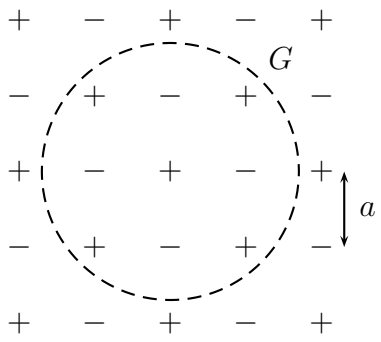

Figure 3: Problem 7

9. (**10 points.**) A large, flat, horizontal sheet of conducting material has a charge per unit area of $8.85\,\mu\text{C/m}^2$. Using Gauss's law dind the electric field just above and below the middle of the sheet.

   Solution