Electric Dipole

Electric dipoles – i.e. two oppositely charged point charges at a fixed distance – can be found very often in nature, e.g. in polar molecules such as water. In this exercise you investigate the field of a dipole.

Prerequisites

- You can describe the field of a point charge.
- You have seen the field lines of an electric dipole.
- You know how to add field vectors.

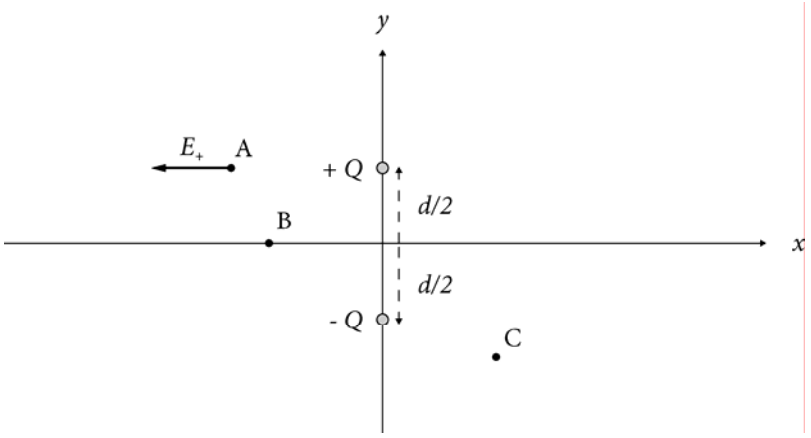
Goals

- You understand the field lines of a dipole as the superposition of the fields of two point charges.
- You can calculate the magnitude of the electric field in any point of the field.
- You know the behaviour of the dipole field far away from the charges.

Time: 30 minutes

Problem

Two point charges + *Q* and - *Q* are located at the points (0 | + d/2) and (0 | - d/2) in the coordinate plane.



Construct the field vectors in points A, B and C. Compare the results to the familiar field lines.

Find an expression for the magnitude *E(x)* of the electric field in an arbitrary point on the *x*-axis and discuss the asymptotic behaviour far away from the dipole.

Instructions

1. The magnitude E_+ of the electric field created by the positive charge in point A serves as a reference for the scale. Measure the distances from point A to both charges and calculate the magnitude E_- of the contribution from the negative charge. Draw the field vector $\vec{E}_-$ in point A. Add the two vectors in a graphically to get the resultant field vector.
2. Repeat step 1 for the field vectors in points B and C. Compare the directions of the field vectors to the familiar field lines of an electric dipole. Draw the field lines passing through points A, B and C.
3. For an arbitrary point on the *x*-axis, determine the vertical component of the field vector produced by the positive charge. Hint: Make use of similar triangles.
4. Include the effect of the negative charge. Check if the formula yields the expected result at the origin.
5. Neglecting "small" terms, determine an approximation for $x >> d$. How does the magnitude of the electric field far away from the dipole depend on the distance?

Additional problem:

6. Prove that the magnitude of the electric field decreases in the same way along the *y*-axis as along the *x*-axis.