PHYS102 - Electric Fields
Dipole Moments
Field Lines

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0.1 Superposition of Fields

Superposition Principle

We have shown in the previous lecture that the electric field generated by a point particle of charge q at a position P in space.

$$\vec{\mathbf{E}}_{iP} = \frac{k\,q}{r_{iP}^2}\hat{r}_{iP}$$

Since the electric field is defined in terms of *force* and we know forces obey the superposition principle, electric fields also obey the superposition principle.

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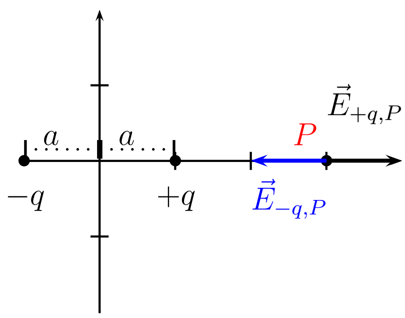
0.2 Field along the x-axis

Example Problem #1



Find the electric field along the x-axis due to the configuration of point charges on the left for $x > a$.

At a distance $x > a$ along the x-axis:

$$\vec{E}_{+q,P} = \frac{k\,q}{(x-a)^2}\,\hat{\imath}$$
$$\vec{E}_{-q,P} = \frac{-k\,q}{(x+a)^2}\,\hat{\imath}$$

$$\vec{E}_P = k\,q\left(\frac{1}{(x-a)^2} - \frac{1}{(x+a)^2}\right)\hat{\imath}$$

$$E_{x,P} = k\,q\left(\frac{4\,x\,a}{(x^2-a^2)^2}\right)$$

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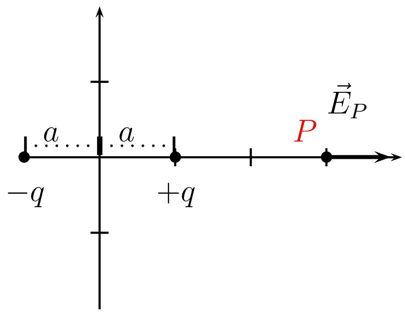
Example Problem #1 - p.2



$$E_{x,P} = k\,q\left(\frac{4\,x\,a}{(x^2-a^2)^2}\right)$$

This is the electric field along the x-axis for $x > a$.

For $x \gg a$, the electric field is approximately:

$$E_{x,P} \approx \frac{4\,k\,q\,a}{x^3}$$

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Dipoles

slide 6

Permanent Dipole Moments

- This type of charge distribution (equal but oppositely charged particles separated a distance L) is termed an electric dipole configuration.
- Polar molecules such as: water, acetone, methanol, and rocket-fuel have permanent dipole moments.
- Definition: Electric dipole $\equiv$ system of two equal and opposite charges, q, separated a distance L. Mathematically,
  - $\vec{p} = q\,\vec{L}$
    where $\vec{L}$ is the separation vector pointing from the negative charge to the positive charge.

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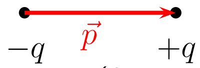
Dipoles - Clarification



This would be the dipole moment (for the example covered in lecture).

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0.3 Continuous Charge Distributions

Macroscopic Objects

- If we consider the simple act of charging a glass rod, we could ask the following question:
  - How would you find the electric field generated by a long continuous glass rod?
  - You could sum up the electric field generated by each charge on the rod, but this may take a very long time since there could be $\sim 10^{23}$ charged particles on the rod.
  - You may be able to simplify your life:
    - Treat collection of charged particles as a "spread" of continuous charge.

Charge Density

- Charged distributions extended throughout a:
  - Volume: described by a volume charge density ($\rho = \frac{\Delta Q}{\Delta V}$).
  - Area: described by a surface charge density ($\sigma = \frac{\Delta Q}{\Delta A}$).
  - Line: described by a linear charge density ($\lambda = \frac{\Delta Q}{\Delta L}$).
- Units:
  - $[\rho] = \frac{C}{m^3}$.
  - $[\sigma] = \frac{C}{m^2}$.
  - $[\lambda] = \frac{C}{m}$.

Board Time

Let's move to the board for an example.

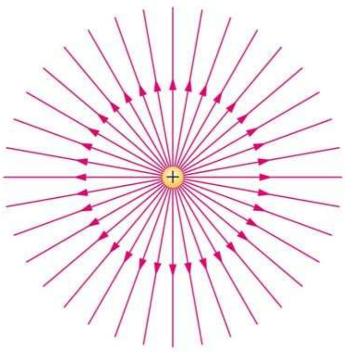
Electric Field Lines

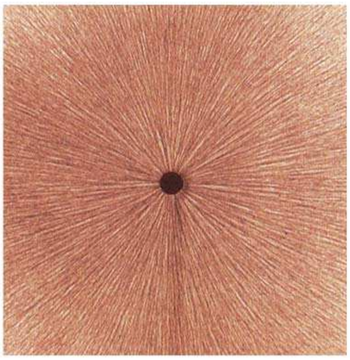
In discussing electric fields, it is sometimes better to visualize the electric field.
Since the electric field is everywhere surrounding a charged particle, so we use a set of standard rules when drawing electric fields.

- Electric field lines begin on positive (or at infinity) and end on negative charges (or at infinity).
- Lines are drawn uniformly spaced entering or leaving an isolated point charge.
- Number of lines proportional to the magnitude of the charge.
- The density of lines is proportional to the magnitude of the electric field at that point.
- Electric field lines do not cross.

Field Line Example +

Field line representation of a positive charge.





Field Line Example -/+

Field line representation of a negative and positive charge.