PHYS102 - Forces and Fields

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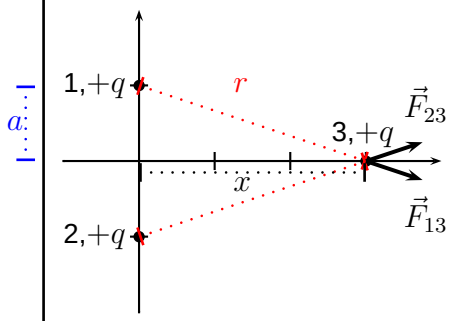
0.1 Worked Problem

Worked Problem #2

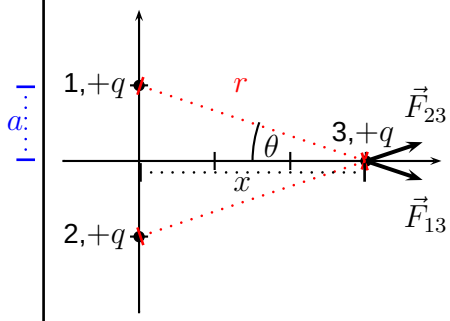


The force on the charge (3) at a distance x from the origin of the coordinate system is given by the vector sum of the forces due to the separate charges.

At a distance x along the x-axis:

$|F_{23}| = \frac{1}{4\,\pi\,\varepsilon_0}\,\frac{q^2}{(x^2+a^2)}$

Worked Problem #2 - p.2



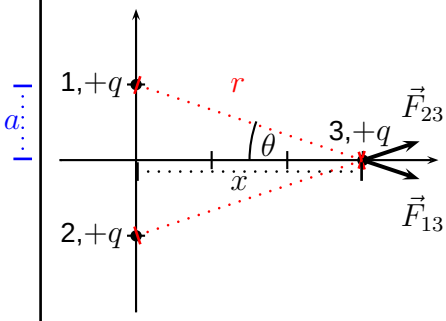
The transverse components of $\vec{F}_{23}$ and $\vec{F}_{13}$ are equal but opposite, thus their resultant force is directed along the x-axis and has a magnitude:

$F = 2\,F_{23}\,\cos\theta$

$\cos\theta = \frac{x}{\sqrt{(x^2+a^2)}}$

$F = 2\,\frac{1}{4\,\pi\,\varepsilon_0}\,\frac{q^2}{(x^2+a^2)}\,\frac{x}{\sqrt{(x^2+a^2)}}$

Worked Problem #2 - p.3



The resultant force experienced by particle 3 is :

$$F = \frac{1}{2\,\pi\,\varepsilon_0}\,\frac{q^2\,x}{(x^2+a^2)^{\frac{3}{2}}}$$

Where is the force a maximum?

Answer: $x = \frac{a}{\sqrt{2}}$

Graphing

Let's move to the board to graph the force we just found.

Fields slide 7

The Electric Field

If we place two charged bodies near each other, we know that each will experience a force (Coulomb force).

This force acts even though the bodies are not in physical contact, very much like gravitational forces.

We do not understand 'why' this happens, it is just an observed fact that charged bodies exert forces on each other.

By using Coulomb's law, we are considering the direct interaction of the charged objects:

$$\vec{F}_{12} = \frac{1}{4\,\pi\,\varepsilon_0}\,\frac{q_1\,q_2}{r^2}\,\hat{r}_{12}$$

View interaction as one of charge 1 directly with charge 2.

Electric Field II

- Remove q_1 from the above discussion
  - charge q_2 experiences no Coulombic force
  - presence of q_1 must influence the space at the location of charge q_2.
- The influence on the space around q_1 is termed the electric field established by q_1.
- The electric field plays an 'intermediate' role in the interaction between charged objects.

Concept of a Field

- Does the idea of a force field seem odd to you?
  - IF it seems odd, then you haven't seen Star Wars!
  - Actually, if the concept of a field seems odd, think about the gravitational field you live in.
    - Weight (a force) varies with position away from the earth's center – it is not uniform.
      - Don't forget all the techniques involved with ***non***-constant forces.

Defining the Electric Field

- In discussing the interaction between charged particles we must:

  (a) Calculate the electric field set up by the charge(s).

  (b) Calculate the force exerted by this electric field on any charged particle(s) placed in it.

THE ELECTRIC FIELD: define the strength of the electric field in terms of the force $\vec{F}$ that a positive test charge q' experiences.

- Problem: The force experienced by the test charge is dependent on q'.
- Solution: define the electric field in terms of the force per unit charge.

Defining the Electric Field II

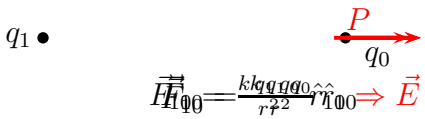
- If a test charge has charge $q^{'}$ and experiences a force $\vec{F}$ then we have:

$$\vec{E} = \frac{\vec{F}}{q^{'}} \tag{1}$$

- Units of $\vec{E}$:
  - $[\vec{E}] = \frac{N}{C}$
- The electric field, $\vec{E}$, is a vector field (magnitude and direction at every point in space).

Electric Field of a Point Charge

- Using our knowledge of Coulomb's Law and the definition of the electric field
  - $\vec{F} = \frac{1}{4\,\pi\,\varepsilon_0}\,\frac{q_1\,q_2}{r^2}\,\hat{r}$
  - $\vec{E} \equiv \frac{\vec{F}}{q}$
- we can quantitatively find the electric field generated by a point particle of positive charge q_1 at any point in space by placing a positive test charge (q_0) at the point (labeled P)in question.



$$\vec{F}_{10} = \frac{k\,q_1\,q_0}{r^2}\,\hat{r}_{10} \Rightarrow \vec{E} = \frac{k\,q_1}{r^2}\,\hat{r}_{1P}$$

Properties of the Electric Field

$$\vec{E} = \frac{k\,q}{r^2}\,\hat{r}_{1P}$$

- This is the *electric field* generated by a *point charge* (q) at a position P a distance r away from the charge.