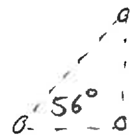
Lecture 4

Tues: Discussion / quiz

Supp 7, 8, 9, 10ab

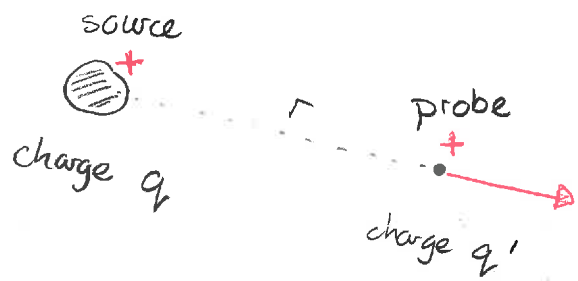
Ch 20 Prob 17, 59



Weds, Thurs Labs

Electric fields

We now develop an alternative framework for electrostatics which has the same predictive power as Coulomb's law but involves the idea of a field. This will be essential for more general treatments of electric + magnetic forces. To illustrate the idea consider two point charges. The charge in whose motion we are interested will be called the "probe" and the other which affects it the "source." Then the magnitude of the force exerted by the source on the probe is



$$F_{\text{on probe}} = k\frac{q'q}{r^2}$$

$$= q' \, k\frac{q}{r^2}$$

q': only depends on probe

$k\frac{q}{r^2}$: depends on source and location of the probe — magnitude of electric field, E

We can separate the contributions of the probe and the source by defining a new quantity, called the electric field produce by the source

In terms of magnitudes we can see that

$$F_{\text{on probe}} = q' E$$

q' → probe charge

E → electric field produced by source charge (here $E = k\frac{q}{r^2}$)

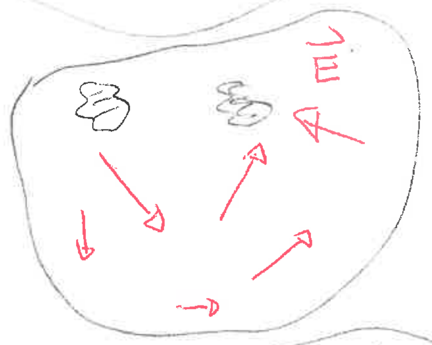
We can rework this to include information about directions and convert this into a vector equation. We can also extend this to situations where multiple source charges are present. The scheme will be:

DEMO: PhET Charges + Fields

There is a collection of fixed source charges and we eventually want to know what force they will exert on a probe

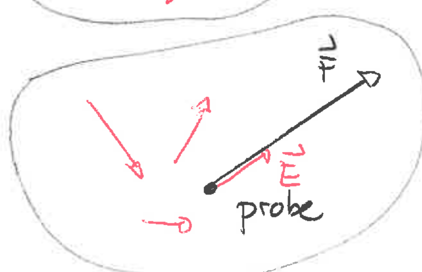
- no fields visible
- show force on sensor

Source charges (NOT probe) produce an electric field = one vector at each location



- show fields

Field produces a force on the probe



- show force

The key rule is:

> The force exerted by an electric field $\vec{E}$ on a probe charge is
>
> $$\vec{F} = q_{\text{probe}} \vec{E}$$
>
> q_{probe}: charge of probe
>
> $\vec{E}$: electric field vector at probe location

Notes:

1) the units of electric field are N/C

2) this equation involves vectors - both field and force are vectors.

3) the electric field only depends on the arrangement of the sources.

Quiz 1 - 95%

Warm Up 1

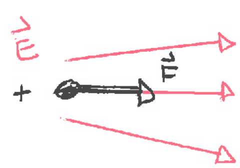
Warm Up 2

In this framework, the probe has no effect on the electric field produced by the sources. But the force on the probe is determined partly by the probe's charge.

Electric field direction and force

Consider an electric field produced by some (hidden) source charges. We can consider the effects of the field on various probes.

Positive probe

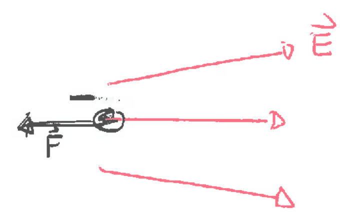


$$\vec{F} = q_{probe}\,\vec{E}$$

↑ positive scalar

means $\vec{F}, \vec{E}$ have same direction

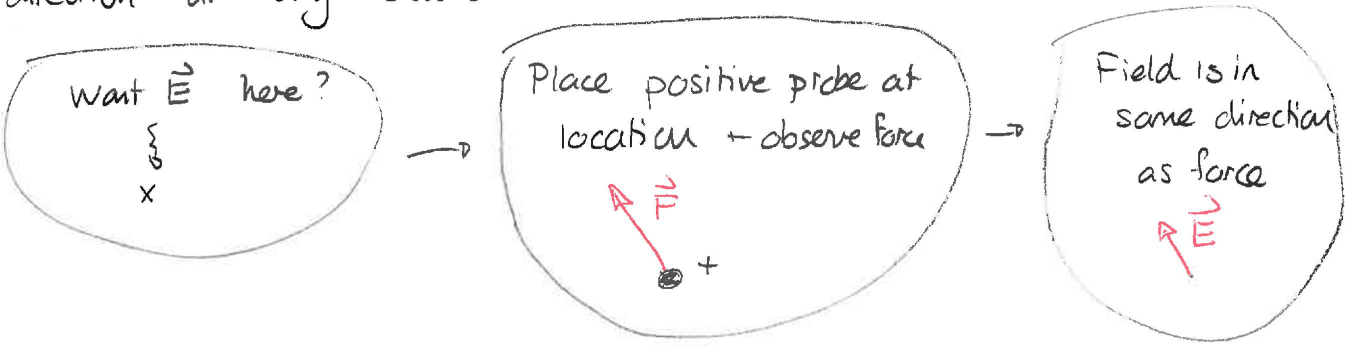
Negative probe



$$\vec{F} = q_{probe}\,\vec{E}$$

↑ negative scalar $\Rightarrow$ $\vec{F}, \vec{E}$ are opposite.

We can use this as a guidline for determining the field direction at any location:



Quiz 2

Quiz 3 → 0% – 90%

Example: The electric field needed to cause a spark in air is about 5.0×10^{6} N/C. Consider such an electric field. A small ball has a excess of 3.0×10^{10} electrons

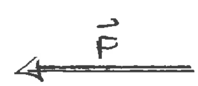
Determine the force exerted by the field on the ball.

Answer: $\vec{F} = q_{probe} \vec{E}$ Vectors

Here q_{probe} = number of excess electrons × charge one electron

$= 3.0 \times 10^{10} \times (-1.6 \times 10^{-19} C) = -4.8 \times 10^{-9} C$

This is negative, so $\vec{F}$ is opposite to $\vec{E}$



The force has magnitude

$$F = |q_{probe}| E \Rightarrow F = 4.8 \times 10^{-9} C \times 5.0 \times 10^{6} N/C$$

$$\Rightarrow F = 0.024 N$$

$$\Rightarrow \vec{F} = 0.024 N \text{ to left}$$