Lecture 4

Thes: Discussion / quiz

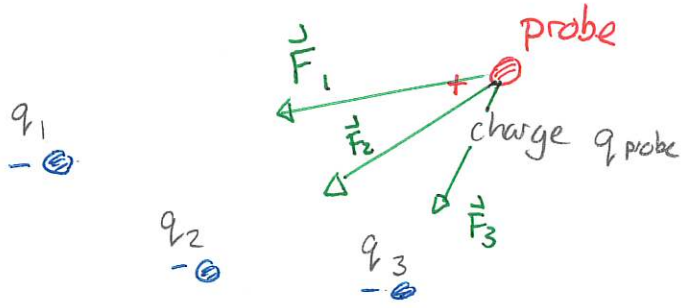
Ex 9, 11, 13, 15, 16, 20

Weds / Thurs - Labs Group Exercise

Electric fields

Suppose that multiple fixed charge particles (source) exert electric forces on a single charge of interest (probe).
Then the force exerted by source j on the probe has magnitude

$$F_j = k \frac{q_{probe}\,|q_j|}{r_j^2}$$



where r_j is the separation between the source j and probe. Then

$$F_j = \underbrace{q_{probe}}_{\text{only refers to probe}} \underbrace{k \frac{|q_j|}{r_j^2}}$$

can be calculated at any likely probe location only using information about the sources.

So the magnitude of the force is proportional to q_{probe}. One can build the vector direction in and this gives, the force exerted by any source is proportional to the probe charge. Adding over all sources gives

The electric force on any probe charge is

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

where q_{probe} is the charge of the probe
$\vec{E}$ is the electric field produced by the sources (at the probe location)

This introduces the idea of an electric field, $\vec{E}$.

The electric field $\vec{E}$ is a collection of vectors, one at each location, produced by source charges. The electric field can be used to determine the force (exerted by the sources) on any conceivable probe charge at any location

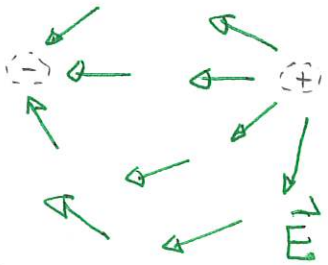
DEMO: PhET Charges and Fields

* situate several fixed source
* show field arrows
* place probe at various locations

The scheme is

Given known source charge arrangement

→ Sources produce electric field
* one vector at each location
* units N/C.

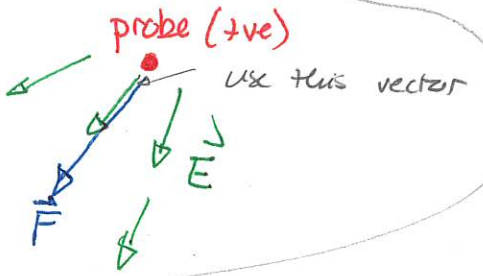


← Place a probe (distinct from sources) somewhere. Then the net electric force on the probe is

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

where q_{probe} = charge of probe

$\vec{E}$ = electric field vector at probe location



Warm Up 1

Quiz 1 80

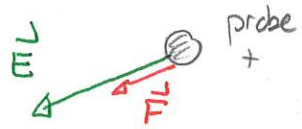
Note that the force and field are not necessarily in the same direction

Positive probe

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

q_{probe}: +

$\Rightarrow \vec{F}$ and $\vec{E}$ are in same direction

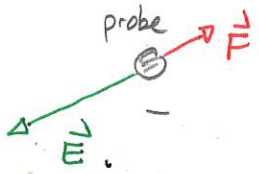


Negative probe

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

q_{probe}: −

$\Rightarrow \vec{F}$ and $\vec{E}$ are in opposite directions



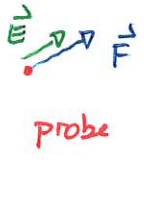
~~Quiz1~~ Quiz2 70% - 95%

Quiz3 80% - 95%

Electric field produced by a point charge

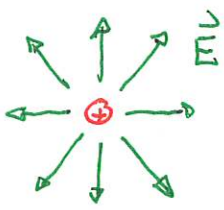
The simplest source for an electric field is a point (source) charge. To determine the field we need:

* the magnitude
* the direction



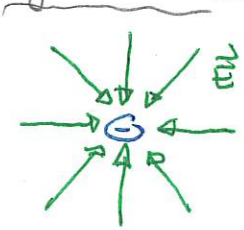
One can determine the direction by considering a positive probe charge. The Coulombs law predicts that the force exerted by the source points directly away. For a positive probe, the field and force are in the same direction. Thus

Positive source



Field is radially away

Negative source



Field is radially towards

The magnitude of the field can be determined by considering the force on a positive probe. The magnitude of this force is

$$F = k \frac{q_{probe}\,|q_{source}|}{r^2} = q_{probe}\left\{ k \frac{|q_{source}|}{r^2} \right\}.$$

But

$$F = q_{probe}\, E \quad \Rightarrow \quad E = k \frac{|q_{source}|}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{|q_{source}|}{r^2}$$

Thus

Consider a point source charge with charge q. The electric field produce by the source:

1) has magnitude

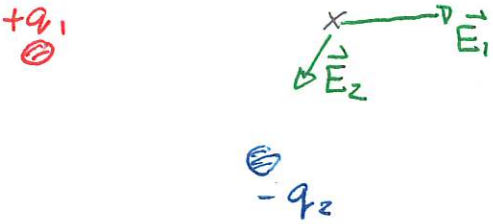
$$E = \frac{1}{4\pi\epsilon_0} \frac{|q|}{r^2}$$

where r is the distance from the source to the point where the field is calculated

2) has direction
   * radially away from source for a positive source
   * radially towards the source for a negative source

Multiple sources

Now consider multiple point source charges. Then the net field produced by all of these at any location is



$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \dots$$

where $\vec{E}_i$ is the field produced by the point source i at that location.

Warm Up 2

End

Quiz 4

Quiz 5