Lecture 4

Mon: Warm Up 2 (D2L)
GROUP EXERCISE

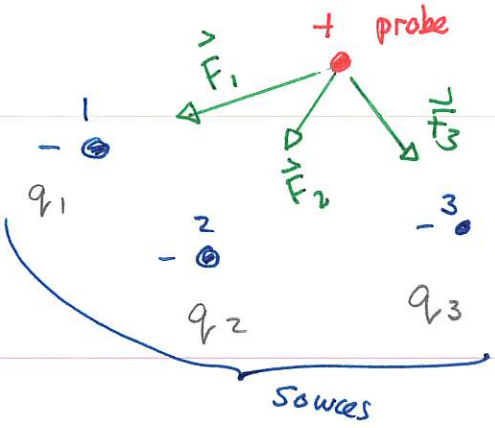
Tues: Discussion / quiz

Ex

* Bring solutions to class - no turn in, discuss in groups
* 10 min quiz at end of class

Electric fields

Consider a situation where multiple fixed charged particles (the sources) interact with one other charged particle (the source). Then let $\vec{F}_j$ be the force exerted by source j ($=1,2,3,\ldots$) on the probe. The magnitude of this force is



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

can be calculated at any possible probe location

where r_j is the distance from j to the probe. In a more complete formulation, one can include the direction of the force in the formula. The force will still be proportional to the probe charge. Adding over all sources gives

The force on the probe can be determined from an auxiliary quantity, established by the sources and called the electric field $\vec{E}$. This satisfies

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

where $\vec{E}$ is the electric field produced by the sources at the probe location.

DEMO: PhET Charges + Fields

* situated several fixed sources
  - no field
  - show force
* now show field

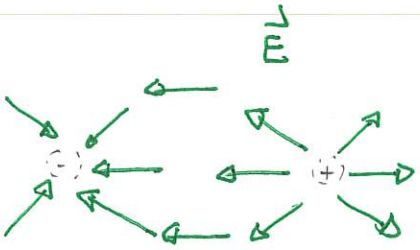
In this scheme

Known source charges in fixed arrangement

→

Source charges produce an electric field $\vec{E}$. This

* is one vector at each location in space
* has units N/C

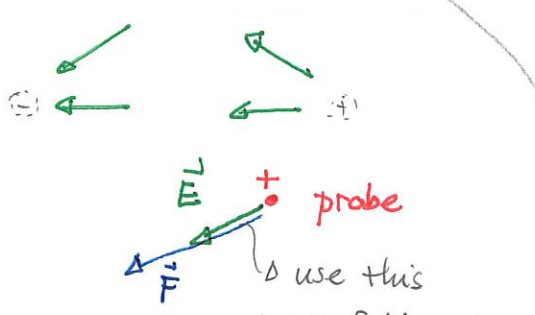


Place a probe charge (not counted in the sources) at a location. Then the net electric force on the probe is

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

where q_{probe} = charge of probe

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



Quiz 1

Quiz 2

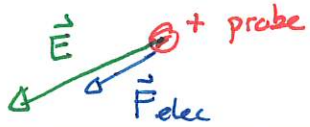
The directions of the force relative to the field follows from vector algebra

Positive probe

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

q_{probe} ↑ positive

$\Rightarrow \vec{F}_{elec}, \vec{E}$ in same direction

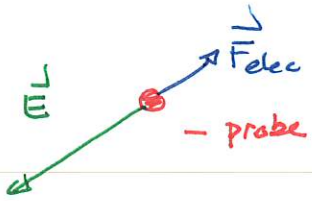


Negative probe

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

q_{probe} ↑ negative

$\Rightarrow \vec{F}_{elec}$ and $\vec{E}$ opposite



Quiz3

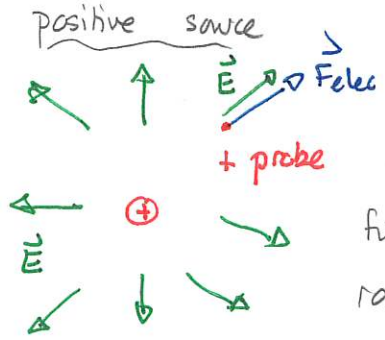
Electric field produced by a point charge source.

We need a rule for the electric field produced by a point source. This requires:

* a magnitude
* a direction

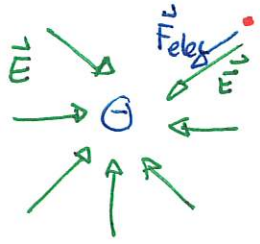
The way to do this is via the force that the source exerts on a positive probe. So for the direction of the electric field:

positive source



Electric field points radially out

negative source



Electric field is radially in

The magnitude can be determined from Coulomb's Law. For a positive probe

$$F_{elec} = k \frac{|q_{probe}||q_{source}|}{r^2} = q_{probe}\, k \frac{|q_{source}|}{r^2}$$

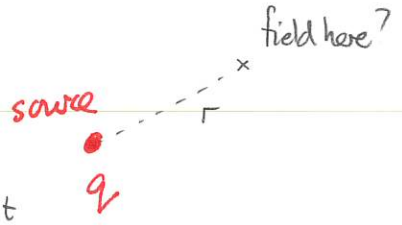
$$F_{elec} = q_{probe} E \quad \text{give} \quad E = k \frac{|q_{source}|}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{|q_{source}|}{r^2}$$

Thus

The electric field produced by a point source with charge q

1) has magnitude

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



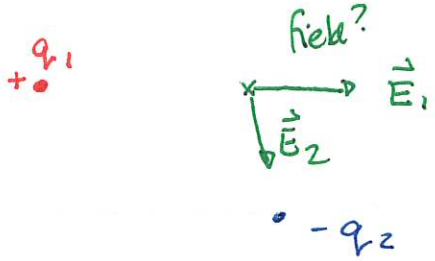
where r is the distance from the source to the point where the field is calculated

2) has direction

* radially inward for a negative point source
* " outward " " positive " "

Multiple point sources

The electric field produced by multiple sources is the vector sum of the fields produced by individual sources



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

where $\vec{E}_j$ is the field produced by source j at the location of interest.

Quiz 4