Phys 13 2022

Lecture 4

Mon: HW by 5pm

Tuesday: Lecture

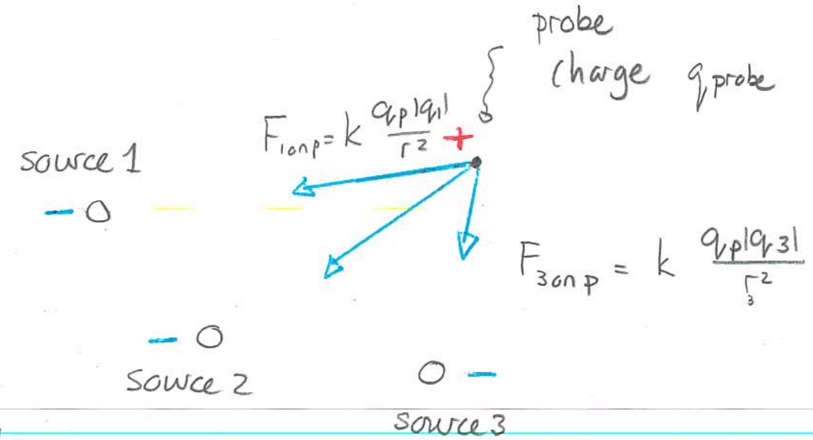
Wednesday: Discussion /quiz 18, 19, 20, 21, 22, 24

* Warm Up 2 (from last class)

Electric fields

Consider an electrostatic situation where multiple stationary point charges (sources) act on a single point charge (probe)

Every force exerted by the sources on the probe is proportional to



the charge of the probe. Thus the net electrostatic force is proportional to the probe charge. So the mathematics would suggest that $\vec{F}_{on\ probe} = q_{probe} \times \begin{pmatrix}\text{vector that}\\ \text{does not}\\ \text{depend on } q_{probe}\end{pmatrix}$

Mathematically.

> The net electrostatic force on any probe is
>
> $$\vec{F}_{elec} = q_{probe}\,\vec{E}$$
>
> where q_{probe} is the charge of the probe and $\vec{E}$ is the electric field produced by the stationary sources.

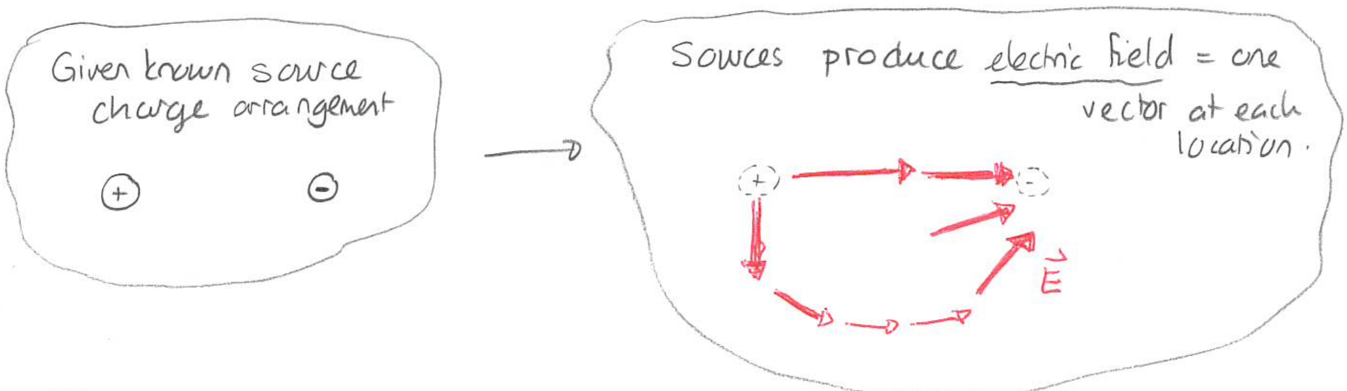
Some immediate consequences are:

1) the electric field is a vector
2) the electric field has units N/c

To illustrate the concepts behind the electric field consider the demonstration

Demo: PhET Charges + Fields
- fix sources (no field)
- show field arrows
- place sensor at various locations

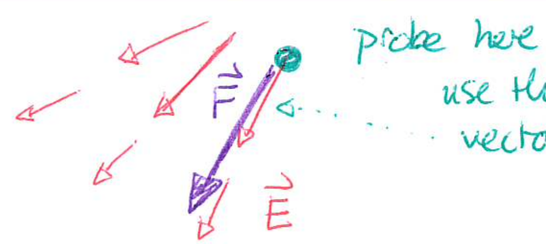
Generally the force exerted on a probe will depend on the probe location. Thus the electric field must depend on the probe location. Schematically



Place probe charge (distinct from sources) in electric field. Then the 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



Quiz 1 100%

Quiz 2 80%

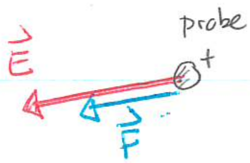
There is a close relationship between the direction of an electric field vector and the force exerted on a probe

Positive Probe

$$\vec{F} = q_P \vec{E}$$

positive

$\Rightarrow$ force is in same direction as field

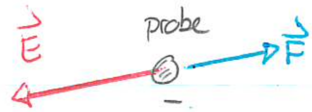


Negative Probe

$$\vec{F} = q_P \vec{E}$$

negative

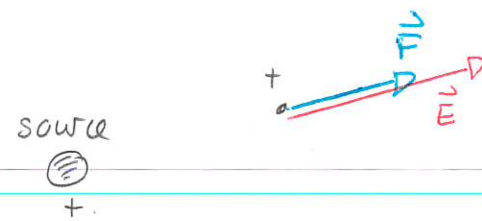
$\Rightarrow$ force is in opposite direction to the field



Electric field due to a point charge

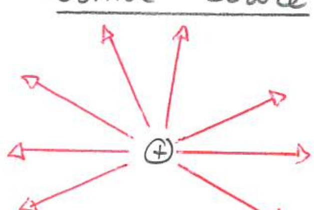
The basic method for computing the electric field for a charge arrangement starts with the electric field produced by a point source charge. There are two pieces

- the magnitude
- the direction.



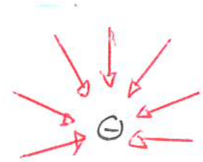
We can establish the direction by placing a positive probe at some location and relating the force to the field. These will be in the same direction for a positive probe. Thus gives:

Positive source



Field is radially out

Negative source



Field is radially in

We can determine the rule for the magnitude by considering a point probe at distance r from the source. Then the magnitude of the force exerted by the source on the probe is:

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

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

But $F = |q_{probe}|\, E$ then gives

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

So we get:

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

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.

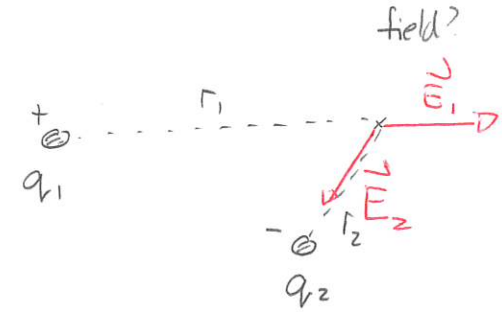
2) direction:

radially away from a positive source

" in toward a negative source.

Multiple sources

Suppose that there are multiple point source charges. Then the field produced by all at any location is:



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

where $\vec{E}_i$ is the field produced by charge i at the location. So

$$E_i = \frac{1}{4\pi\epsilon_0} \frac{|q_i|}{r_i^2}$$

The individual fields are each vectors and so vector addition is required to determine the net field.

Quiz 3 90%

Quiz 4 30% - 90%