Electricity and Magnetism

- Physics 259 – L02
- Lecture 9

Chapter 22.1-3

Last time

- Chapter 21
- Van De Graaff Generator Experiment 
- Electric Ping Pong Experiment 

This time

- Chapter 22
- Electric Field

Action-at-a-Distance Forces

A exerts a force on **B** through empty space.

- No contact.
- No apparent **mechanism**.

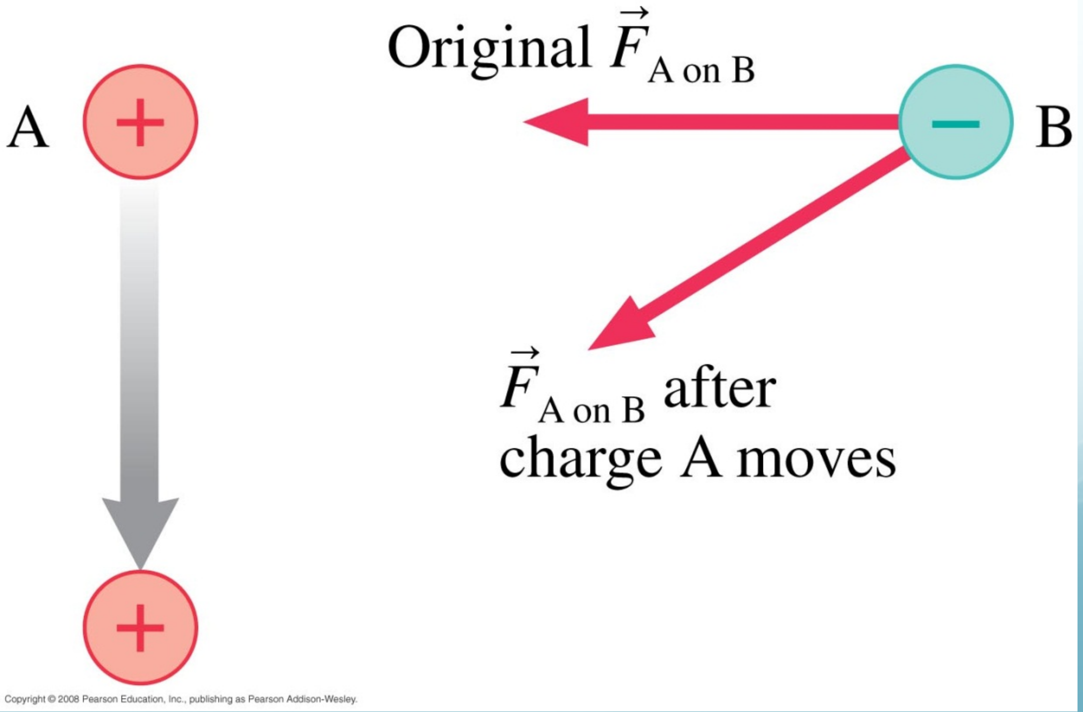
- Let’s try it with gravity (weight force)

Action-at-a-Distance Forces

A exerts a force on B through empty space.

- No contact.
- No apparent **mechanism**.

If A suddenly moves to a new position, the force on B varies to match. **How?**



What if B wasn’t there?

If we have only one charge→ charge still “does something” to the **surrounding space**. We can quantify this by using the concept of an **electric field**.

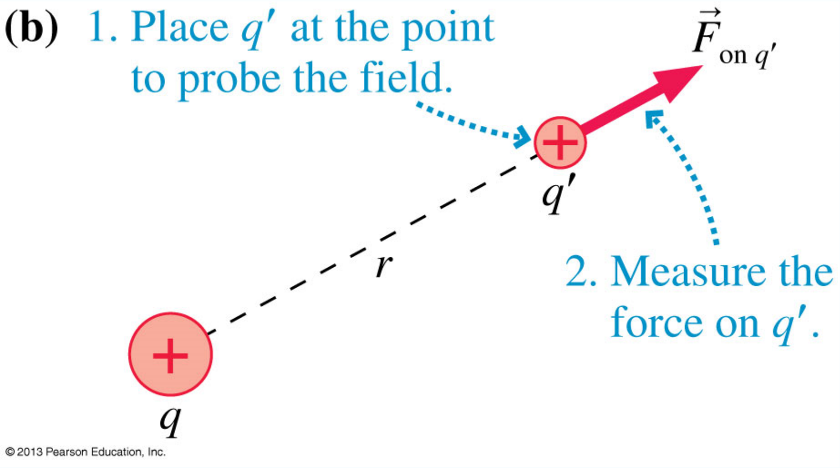
- Charges create fields & then Fields push charges
- A field is the ability to exert an electric force if a charge were present

Electric fields

$$\vec{E}(x,y,z)=\frac{\vec{F}_{\text{on q}}\ \text{at}\ (x,y,z)}{q}$$

This is a general statement, we can always find the field this way, regardless of what the configuration of charge is.

For a point charge



$$\vec{F}_{on\,q'}(x,y,z) = \left(\frac{1}{4\pi\varepsilon_o}\frac{qq'}{r^2}, away \text{ from q'}\right)$$

$$\vec{E}(x,y,z) = \frac{\vec{F}_{on\,\mathrm{q'}}}{q'} = \left(\frac{1}{4\pi\varepsilon_o}\frac{qq'}{q'}\frac{1}{r^2}, away\ \ from\ q'\right)$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

Add up the fields like vectors: superposition principle

- We can add up all of the forces on a charge, and divide out the charge

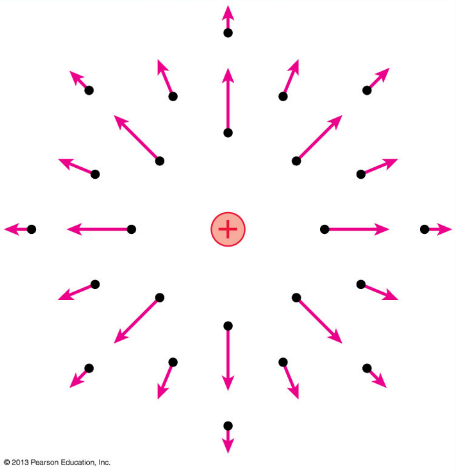
$$\vec{E}(x,y,z)=\frac{\vec{F}_{\text{total on q}}}{q}=\frac{\vec{F}_{\text{1 on q}}}{q}+\frac{\vec{F}_{\text{2 on q}}}{q}+\frac{\vec{F}_{\text{3 on q}}}{q}+\cdots$$

$$=\vec{E}_1+\vec{E}_2+\vec{E}_3+\cdots=\sum\vec{E}_i$$

Field lines

- Field lines show the density of a field.
- They' re lines with arrows showing the direction of the field.
- The density of field lines gives an idea of how strong the field is.
- Field lines never cross

Field lines: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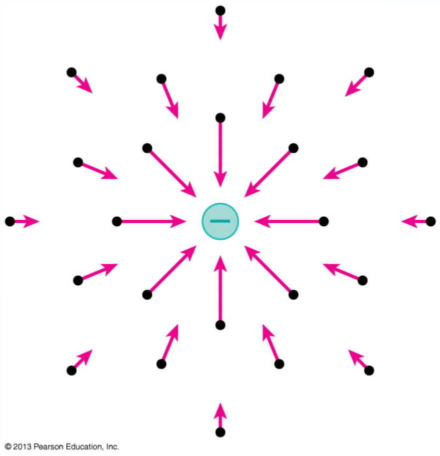
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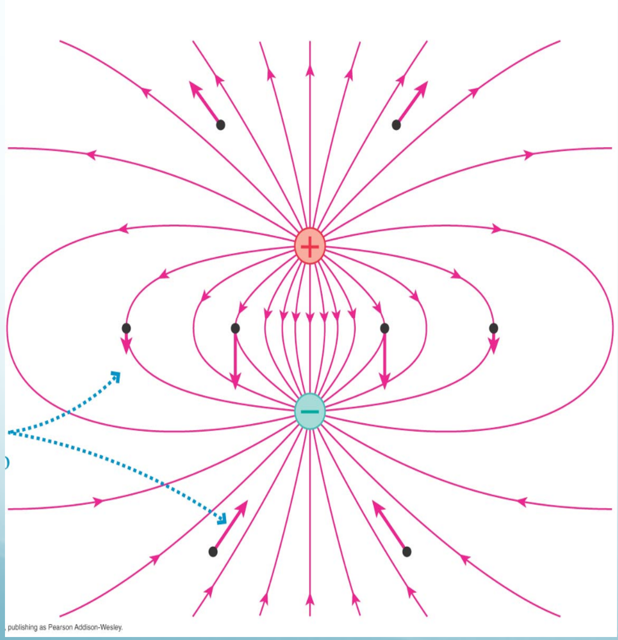
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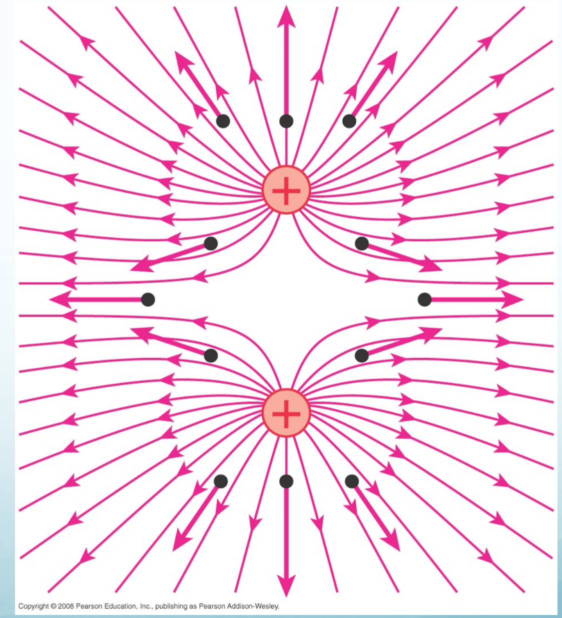
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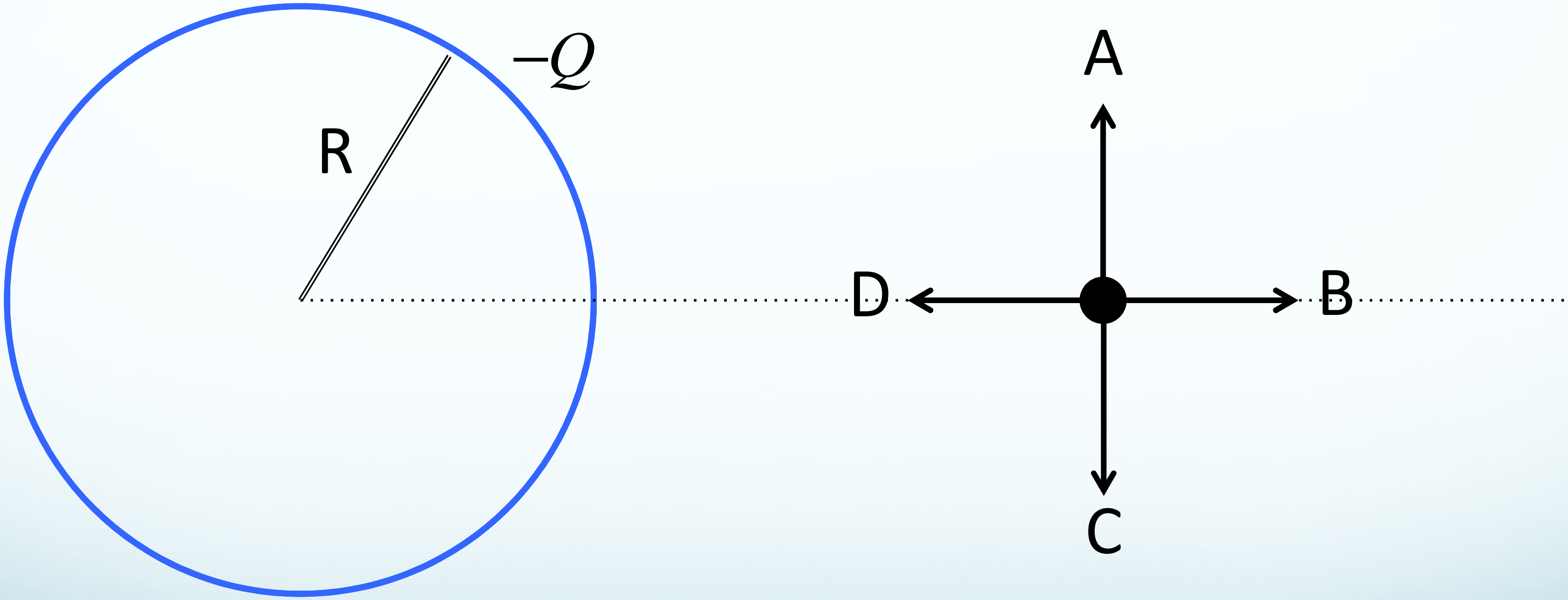
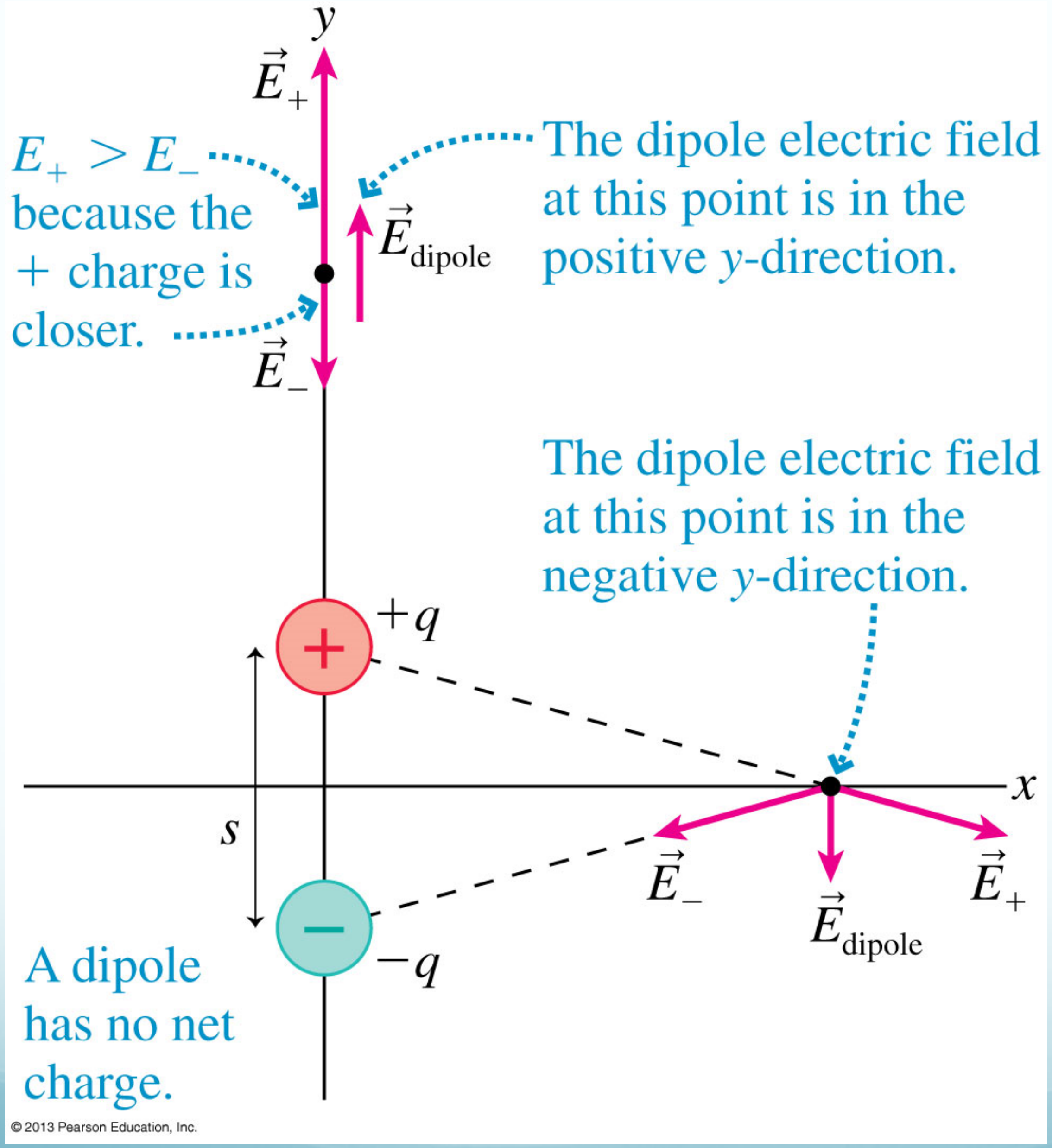
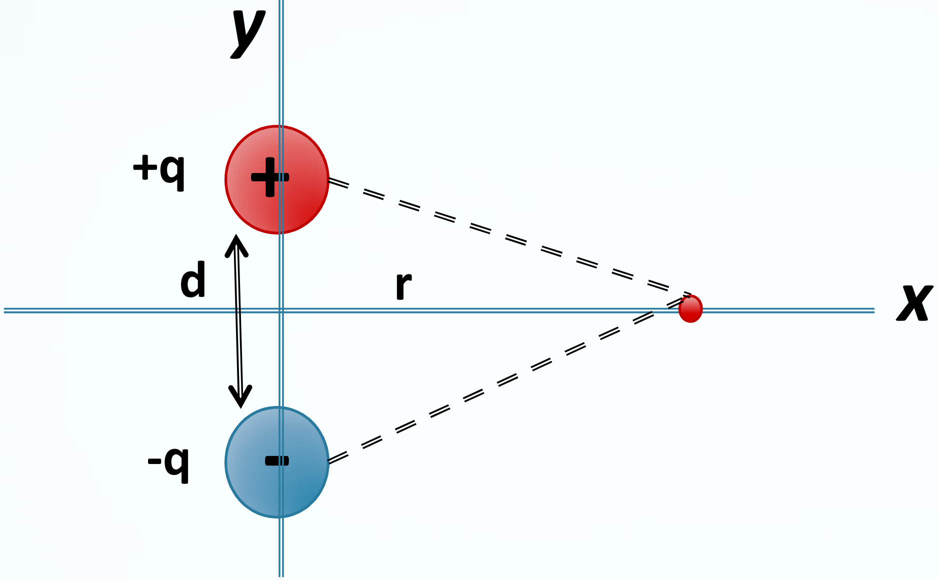
What is the direction of the electric field at the point indicated?



The electric field of a dipole





$$(E_{net})_x = (E_+)_x + (E_-)_x = 0$$

$$(E_{net})_y = (E_+)_y + (E_-)_y$$

$$(E_+)_y = (E_-)_y = \frac{1}{4\pi\varepsilon_o}\frac{-q}{(d/2)^2 + r^2}\cos(\theta), \cos(\theta) = \frac{d/2}{((d/2)^2 + r^2)^{1/2}}$$

$$(E_{dipole})_y = -\frac{q}{4\pi\varepsilon_o}\frac{2(d/2)}{((d/2)^2 + r^2)^{3/2}} \Rightarrow \vec{E}_{dipole} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{((d/2)^2 + r^2)^{3/2}}$$

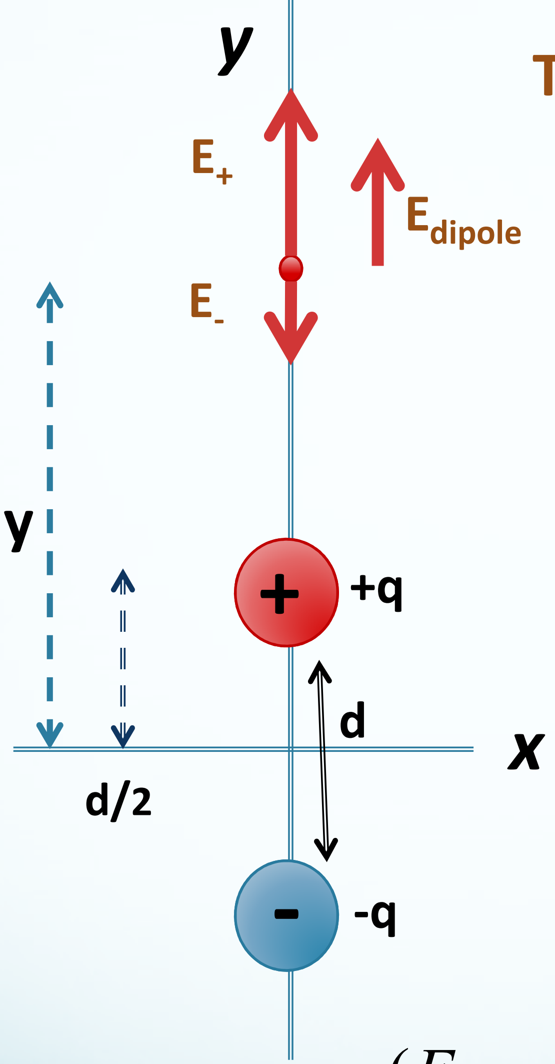
On the bisecting plane of the electric dipole:

$$\vec{E}_{dipole} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{((d/2)^2 + r^2)^{3/2}}$$

Limiting case:

$$r >> s \rightarrow \vec{E}_{dipole} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{r^3}$$

The field along the axis of the dipole



$$(E_{net})x = (E_+)x + (E_-)x = 0$$

$$(E_{net})y = (E_+)y + (E_-)y$$

$$(E_{dipole})_y = \frac{1}{4\pi\varepsilon_o}\frac{q}{(y-(d/2))^2} + \frac{1}{4\pi\varepsilon_o}\frac{-q}{(y+(d/2))^2}$$

$$(E_{dipole})_y = \frac{q}{4\pi\varepsilon_o}\frac{2yd}{(y-(d/2))^2(y+(d/2))^2}$$

On the axis of electric dipole:

$$(E_{dipole})_y = \frac{q}{4\pi\varepsilon_o} \frac{2yd}{(y-(d/2))^2(y+(d/2))^2}$$

Limiting case:

$$y >> s \rightarrow \vec{E}_{dipole} = \frac{1}{4\pi\varepsilon_o} \frac{2\vec{p}}{r^3}$$

Y is the distance from the center of dipole → r

This section we talked about:

Chapter 22.1-3

See you on Wednesday