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

Read the textbook please

Action-at-a-Distance Forces

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

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

there is no contact between charges

How B applies force on A ?

lets compare =>

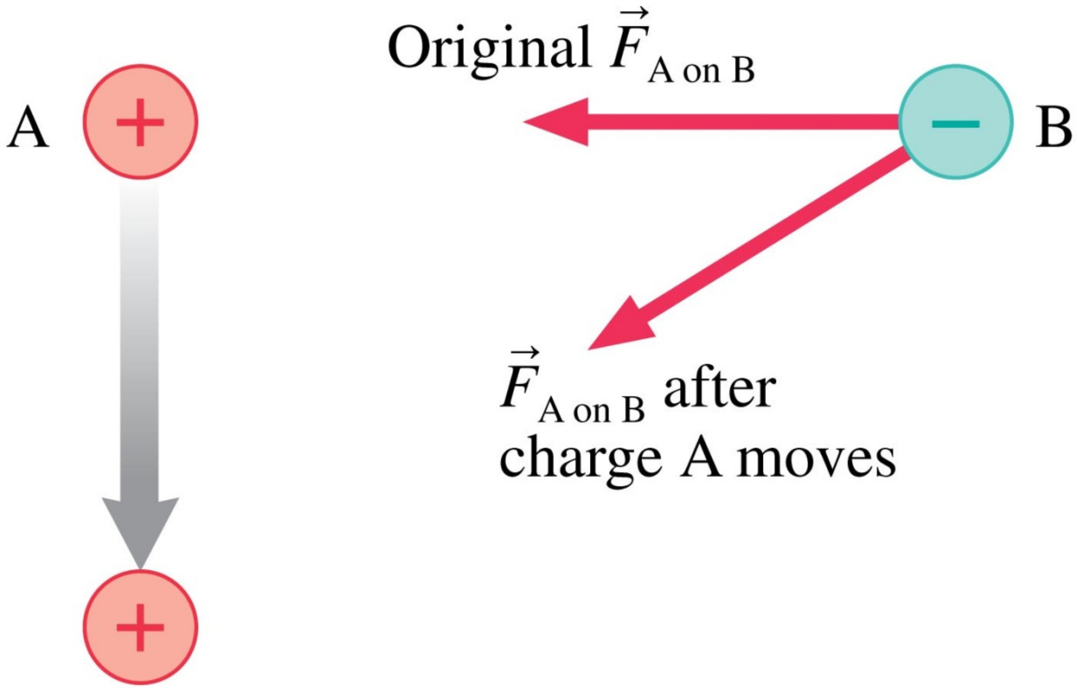
- Let's try it with gravity (weight force)

Action-at-a-Distance Forces

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

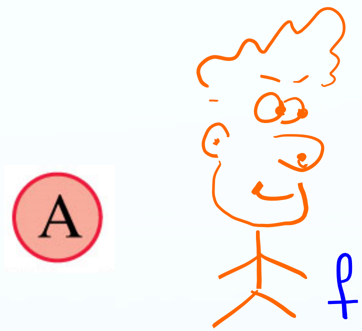
- No contact.
- No apparent **mechanism**.

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**.



+

A creates field around it →

from the force that A applies on + charge, I realize A is here.

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

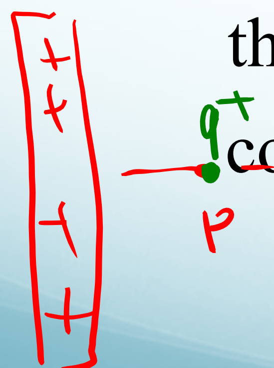
Electric fields

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

F_{AB}

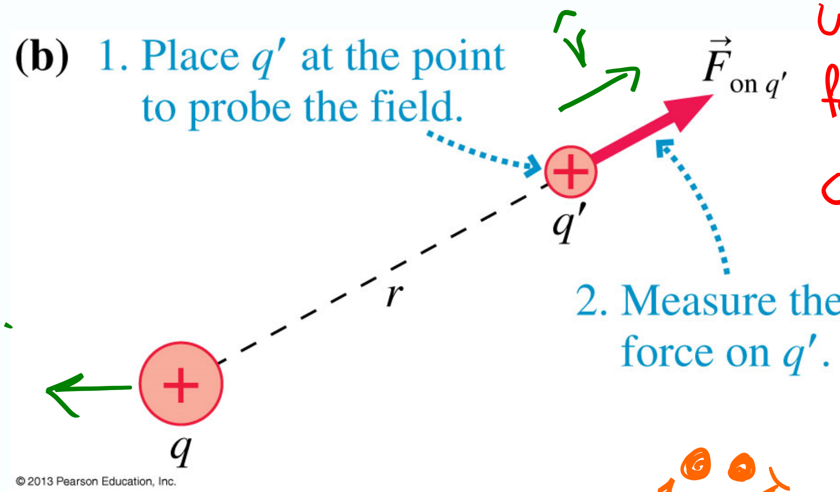
$E_A = \frac{F_{AB}}{q_B}$

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



E ?

For a point charge



what is the field of q?

we know expression for force $\vec{F}_{q\,on\,q'}$, from coulomb's law

every thing is the same for $\vec{E}$, just remove q'

$$\vec{E}_{of\,q} = k\frac{q}{r^2}\hat{r}$$

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

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

field of q

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

like force, we have superposition principle for field =>

Add up the fields like vectors: superposition principle

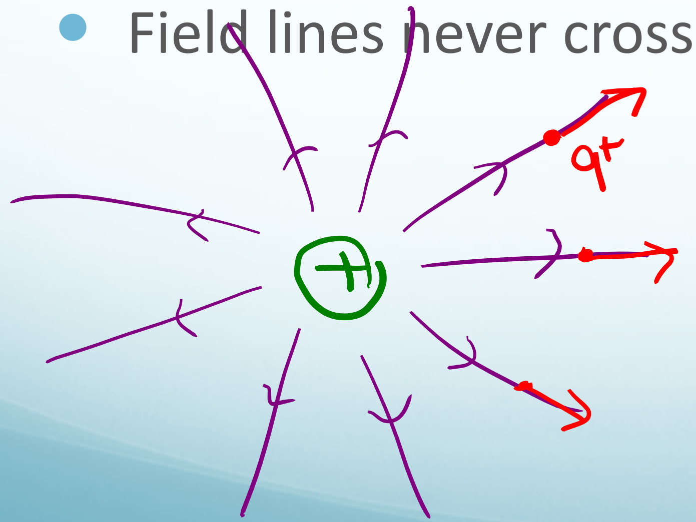
- We can add up all of the forces on a charge, and divide out the charge

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

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

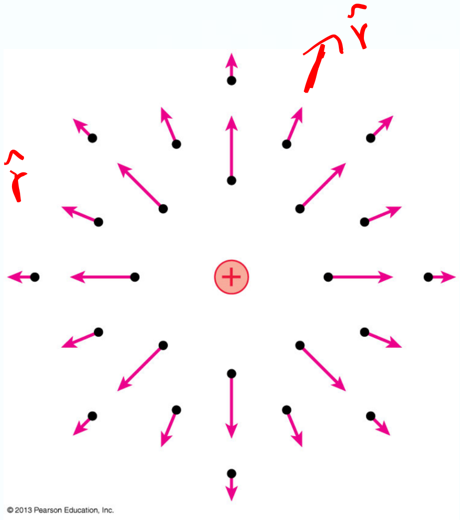
Field lines

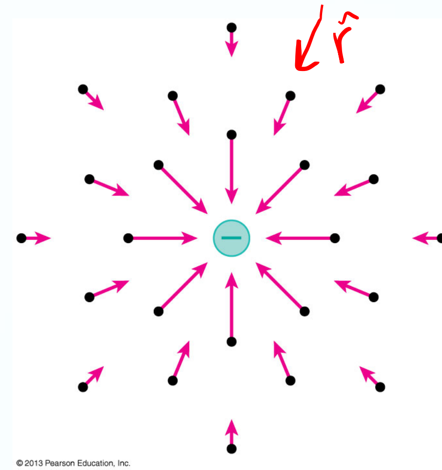
- Field lines show the density of a field.
- They' re lines with arrows showing the direction of the field.
- The density of field lines gives an idea of how strong the field is.
- Field lines never cross



Field lines:

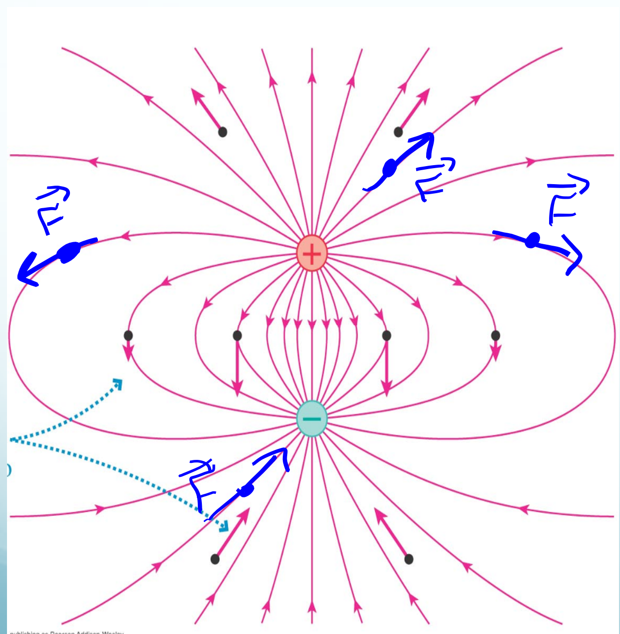
$\vec{E} = k\frac{|q|}{r^2}\hat{r}$

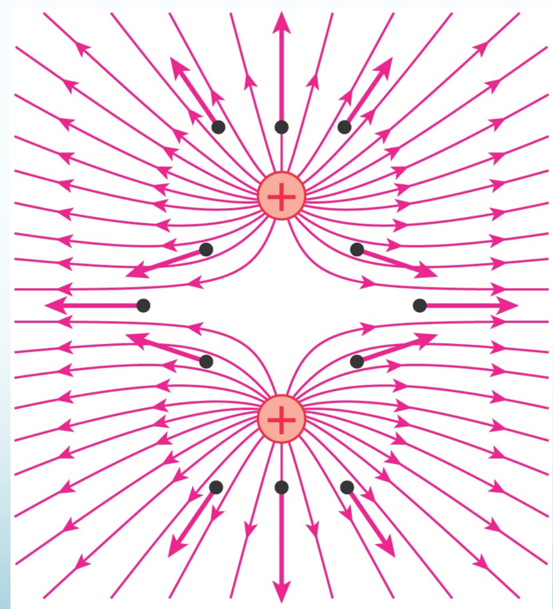




$\vec{E} = k\frac{|q|}{r^2}\hat{r}$

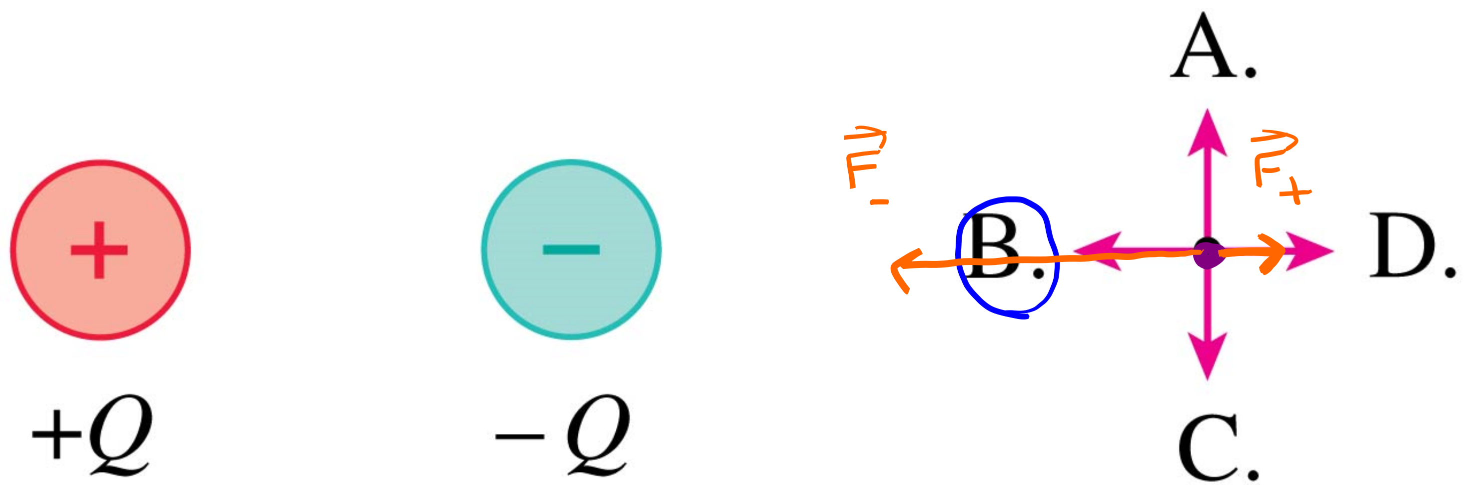
Force is tangent to field lines





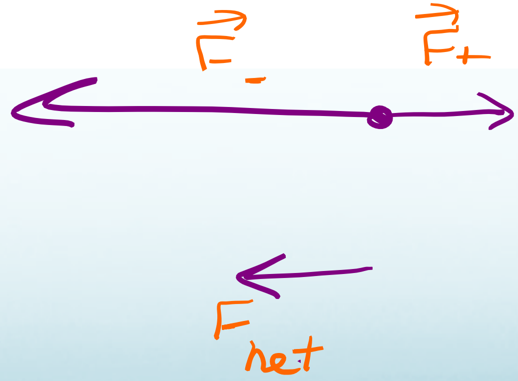
Top Hat Question:

What is the direction of the electric field at the dot?

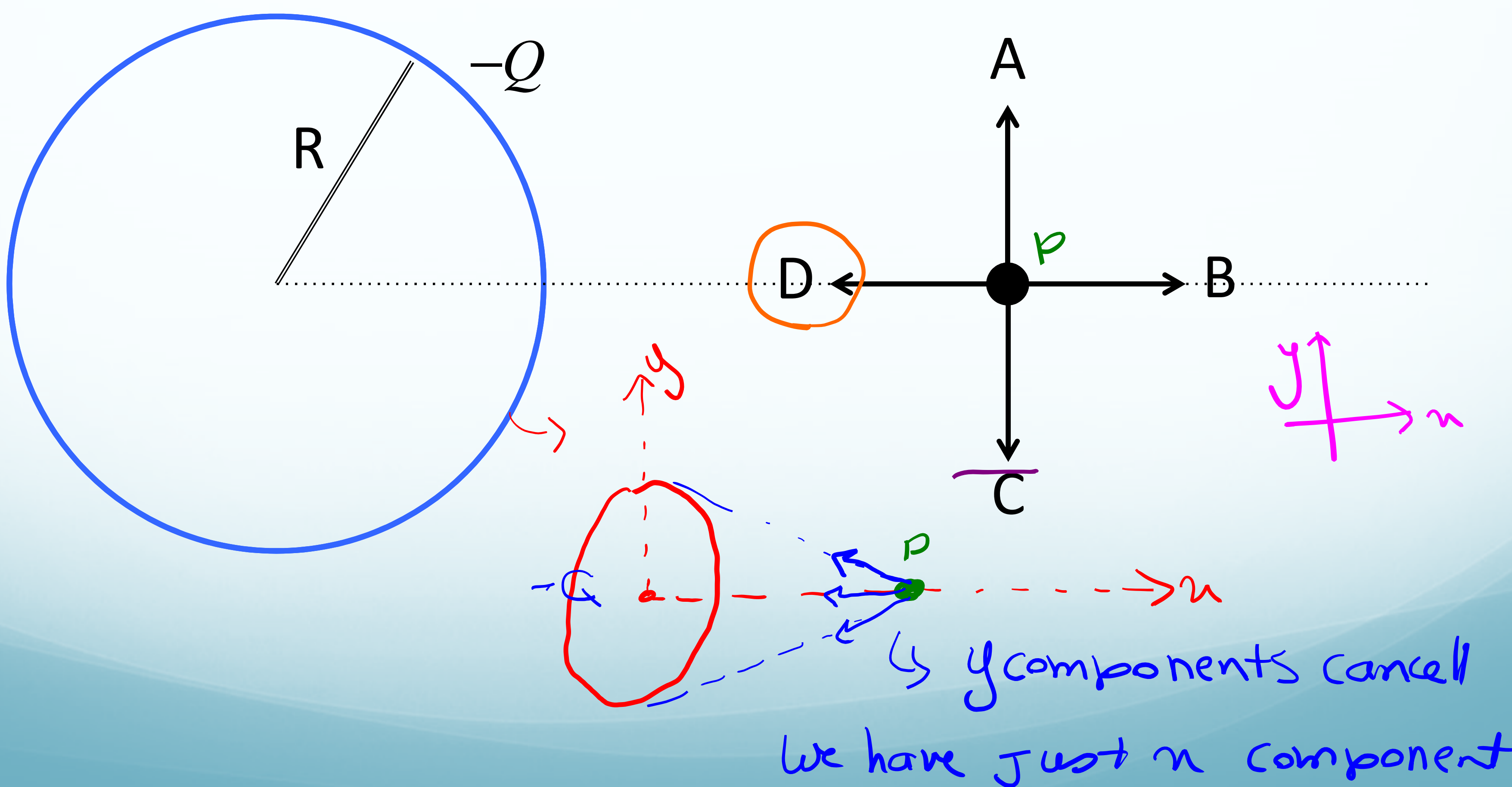


97% correct

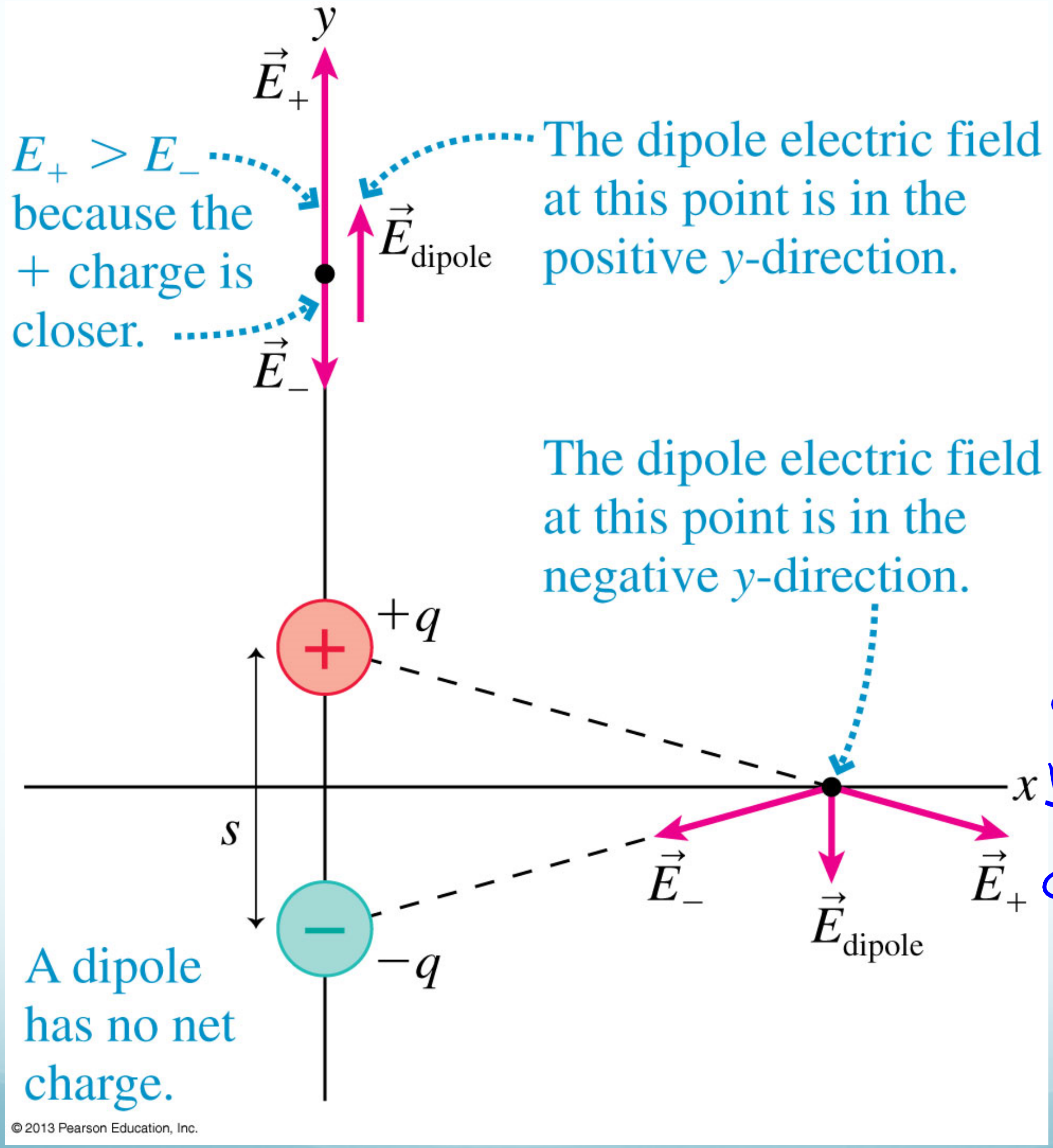
Excellent



What is the direction of the electric field at the point indicated? (point p)

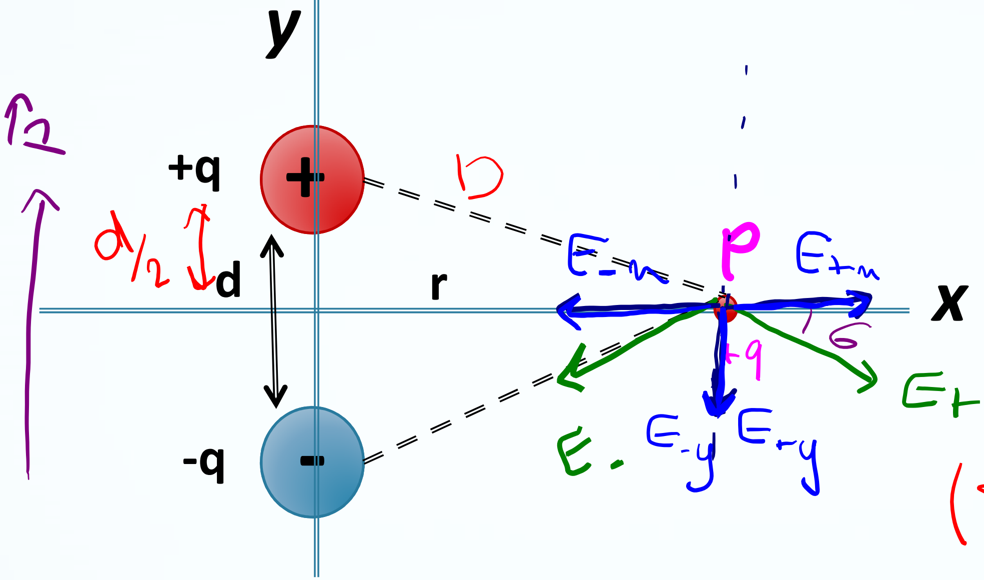


The electric field of a dipole



dipole → a positive charge beside a negative charge

⊕ $\xleftrightarrow{s}$ ⊖



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

$$(E_{net})_y = (E_+)_y + (E_-)_y \quad (-\hat{j})$$

let's find $(E_+)_y$ & $(E_-)_y$

(same process as force)

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

$$\vec{E}_y = \vec{E}_{+y} + \vec{E}_{-y} \rightarrow \vec{E}_y = -\frac{1}{4\pi\varepsilon_o}\left(\frac{q}{(\frac{d}{2})^2 + r^2} + \frac{q}{((\frac{d}{2})^2 + r^2)^{3/2}}\right)\hat{j}$$

$\vec{p} \Rightarrow$ vector

we can put $\vec{p}$

& don't need $\hat{j}$

$\vec{p} = qd$ & direction: from − to + charge

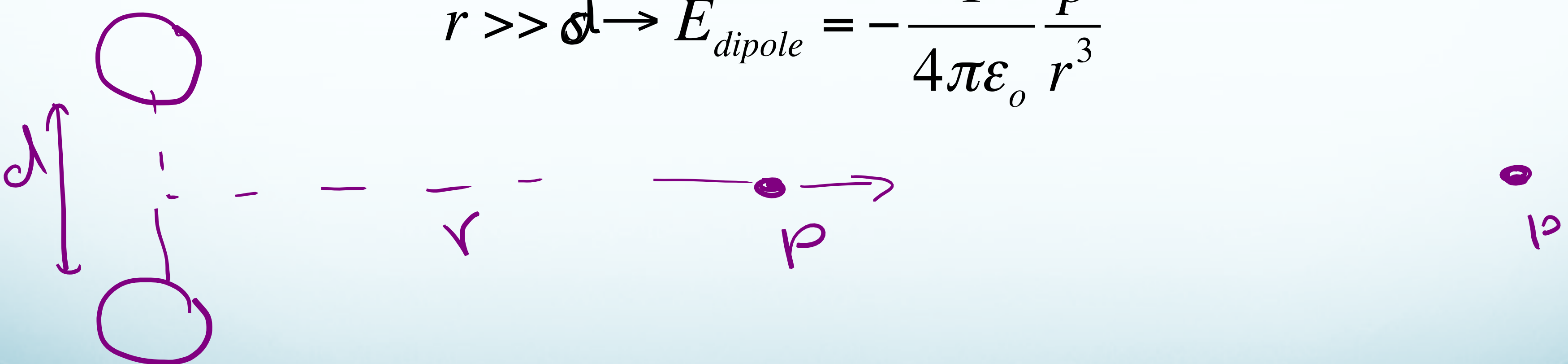
$$(\vec{E}_{dipole})_y = -\frac{q}{4\pi\varepsilon_o}\frac{2(d/2)}{((d/2)^2 + r^2)^{3/2}}\hat{j} \Rightarrow \vec{E}_{dipole} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{((d/2)^2 + r^2)^{3/2}}$$

On the bisecting plane of the electric dipole:

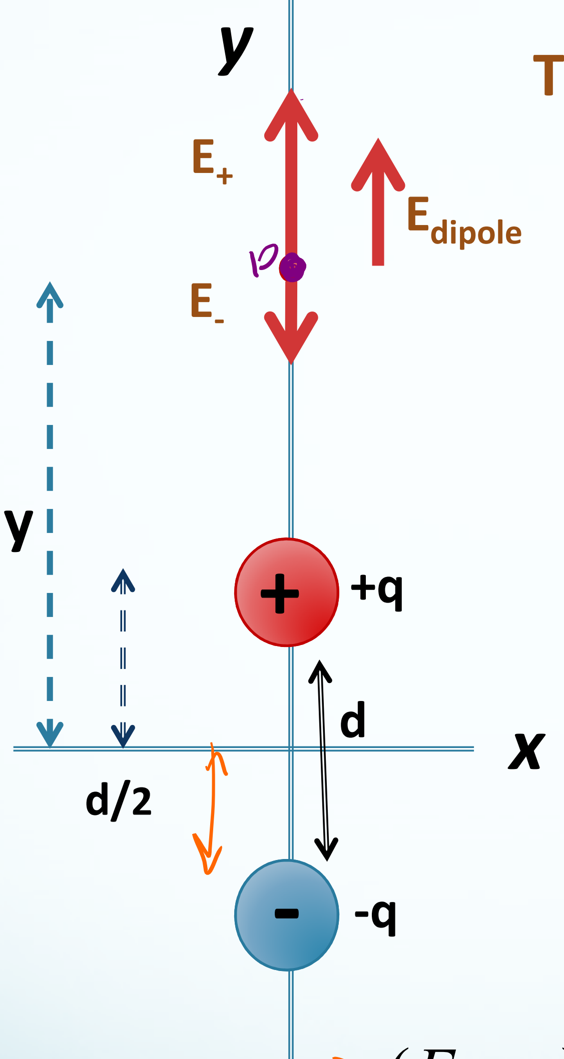
$$\vec{E}_{dipole} = -\frac{1}{4\pi\varepsilon_o}\frac{\vec{p}}{((\cancel{d}/2)^2 + r^2)^{3/2}}$$

Limiting case:

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



The field along the axis of the dipole



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

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

$$E_{+y} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(y-(\frac{d}{2}))^2}$$

$$E_{-y} = \frac{1}{4\pi\varepsilon_0}\frac{-q}{(y+(\frac{d}{2}))^2}$$

E_{+y} + E_{-y}

net

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

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

On the axis of electric dipole:

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

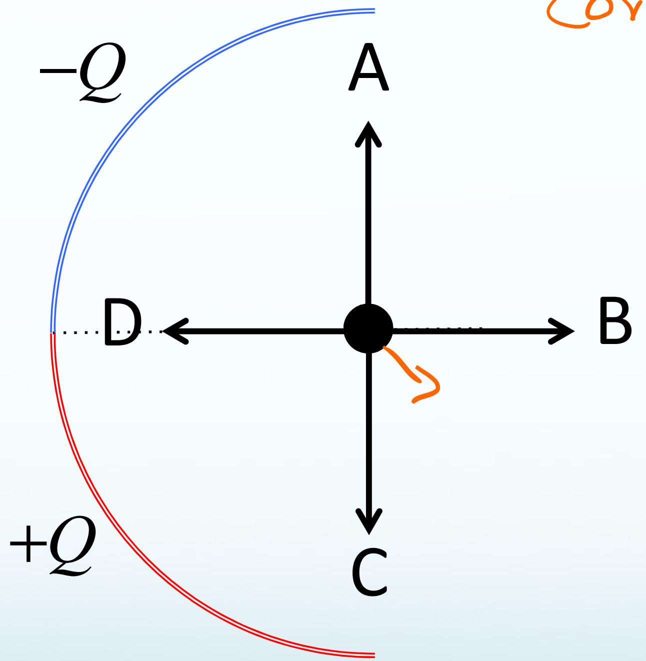
Limiting case:

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

Y is the distance from the center of dipole → r

Top Hat Question

What is the direction of the electric field at the point indicated?



Correct answer → A

% 95 correct

very good

This section we talked about:

Chapter 22.1-3

See you on Wednesday