Announcements

- Homework
  - Video Homework due tonight!
  - Webwork HW2 due on Wednesday, posted after class today
- Start of "normal" labs this week!
  - Two possible manuals this week depending on Glowscript experience
  - You don't need to print them out, you can access and read them on your computers in the lab if you want
- Polling: `rembold-class.ddns.net`

A Review Question:

A $10\,\mu\text{C}$ charge is located at the point $\langle 1,2,3\rangle$m. If this is the only charged object in the region, what is the magnitude of the electric field at the point $\langle 2,4,5\rangle$m?

A) $-1\times 10^{4}\,\text{N}/\text{C}$

B) $0\,\text{N}/\text{C}$

C) $1\times 10^{-4}\,\text{N}/\text{C}$

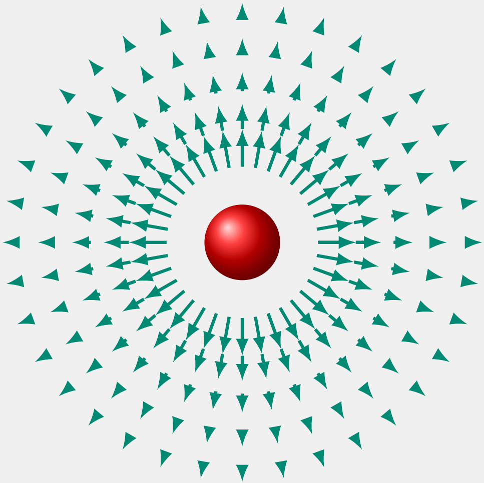
D) $1\times 10^{4}\,\text{N}/\text{C}$

The story so far...

- For a point charge:

$$\vec{\mathbf{E}} = \frac{1}{4\pi\epsilon_0}\frac{q_1}{|\vec{\mathbf{r}}|^2}\hat{\mathbf{r}}$$

  - Positive charges have the electric field pointing away from them
  - Negative charges have the electric field pointing toward them
- Strength of field drops quickly with distance
- Spherically symmetric



Added 'Em Up

- What happens when we have multiple point charges?

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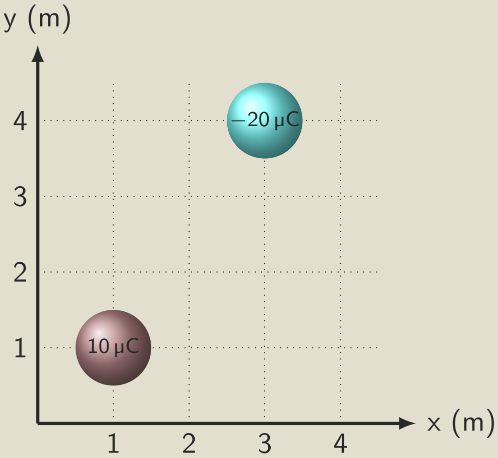
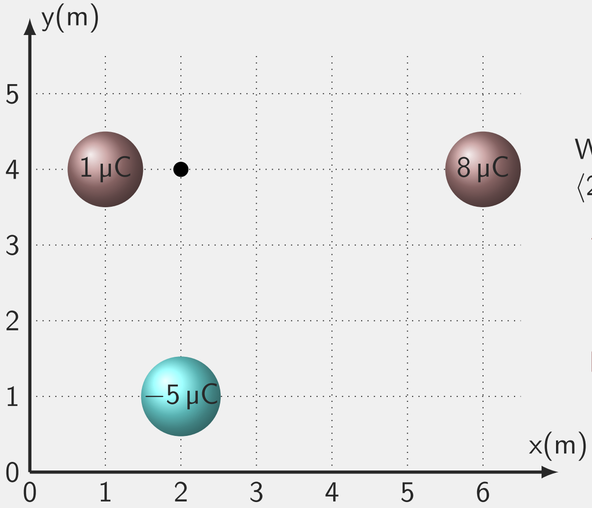
- What happens when we have multiple point charges?
- Forces from different sources add
- Electric fields are just forces divided by charge
  - So Electric fields from different sources should also add
- Called the Superposition Principle
  - When considering the electric field due to a system of charges, the total electric field is the vector sum of all the individual contributions.

$$\vec{\mathbf{E}}_{net} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \vec{\mathbf{E}}_3 + \cdots$$

A Super Example

Consider the charge distribution to the right. What is the net electric field at the point (1,4)?





What is the net electric field at the point $\langle 2, 4, 0\rangle$?

A. $\langle 4500, -5000, 0\rangle$ N/C

B. $\langle -4500, -5000, 0\rangle$ N/C

C. $\langle -4500, 5000, 0\rangle$ N/C

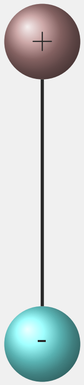
D. $\langle 13500, -5000, 0\rangle$ N/C

Upcoming:

Understanding the Dipole

Why should we care?

- The vast bulk of matter has a neutral charge
  - If it didn't, we'd see the extreme strength of the electric field on a much more everyday level
- Neutral means having the same (or approximately the same) amount of positive charge as negative charge
- A dipole consists of one positive charge and one negative charge
  - Simplest form for us to look at neutral matter



A Dipole

A Conceptual Picture

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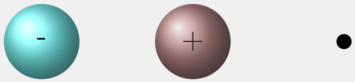

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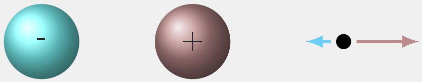

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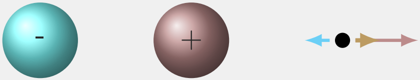

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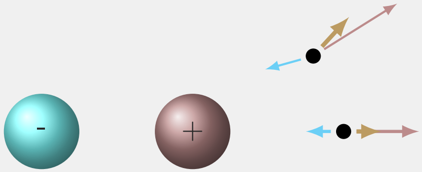

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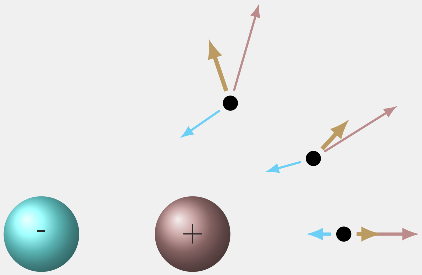

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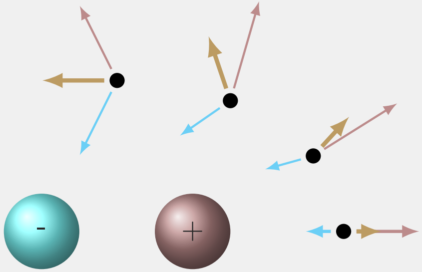

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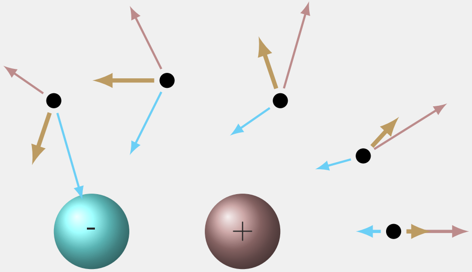

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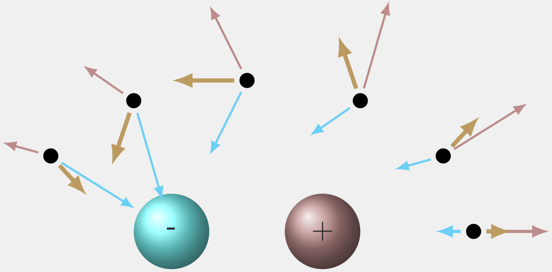

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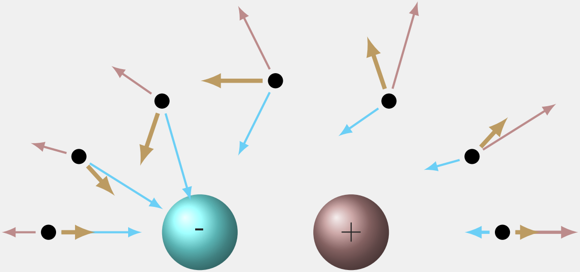

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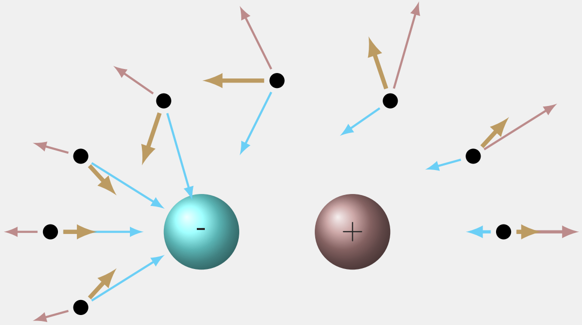

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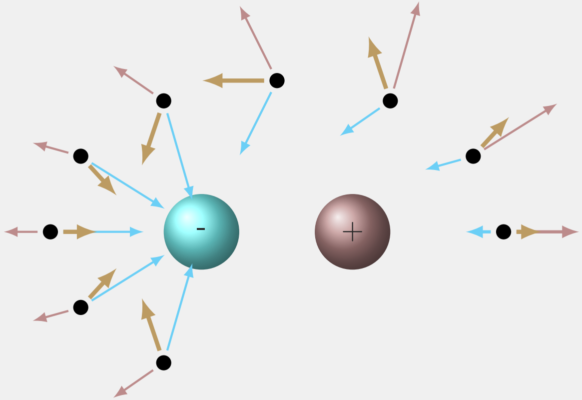

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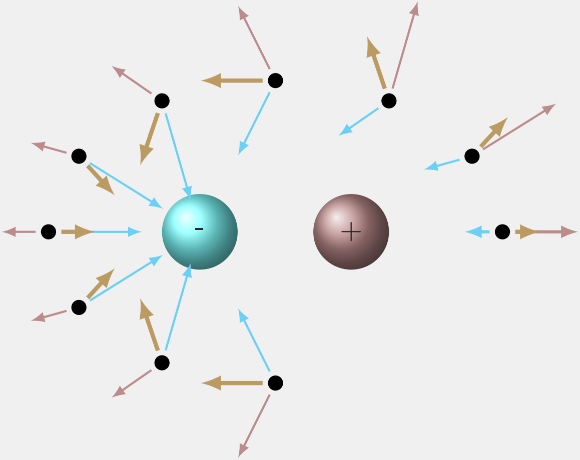

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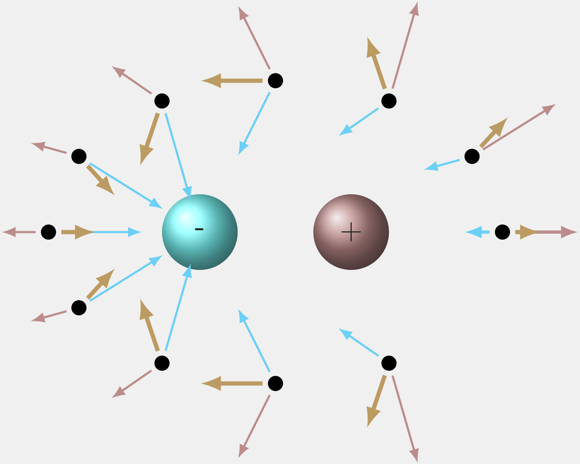

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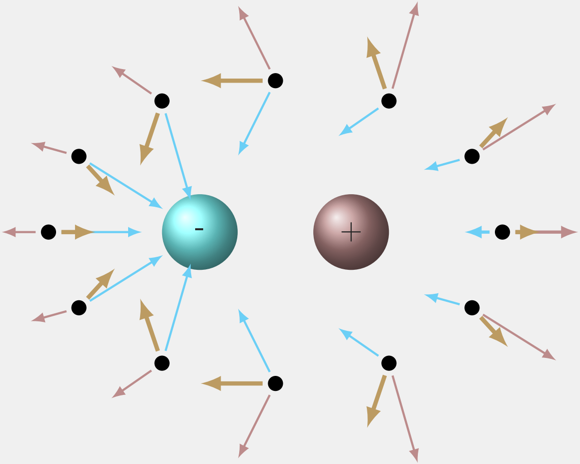

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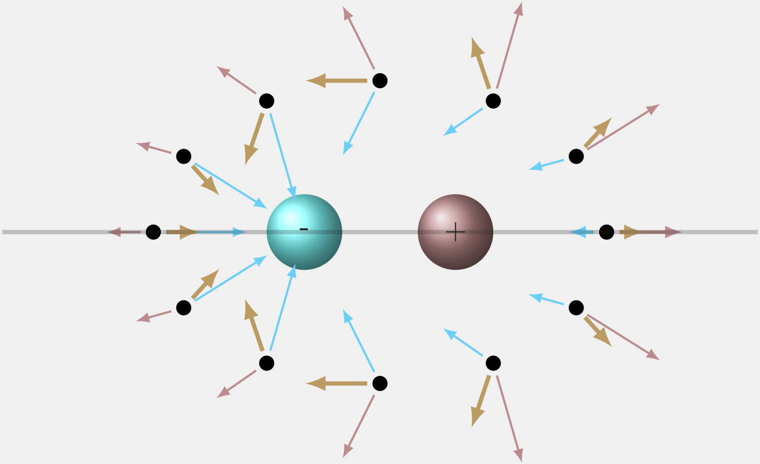

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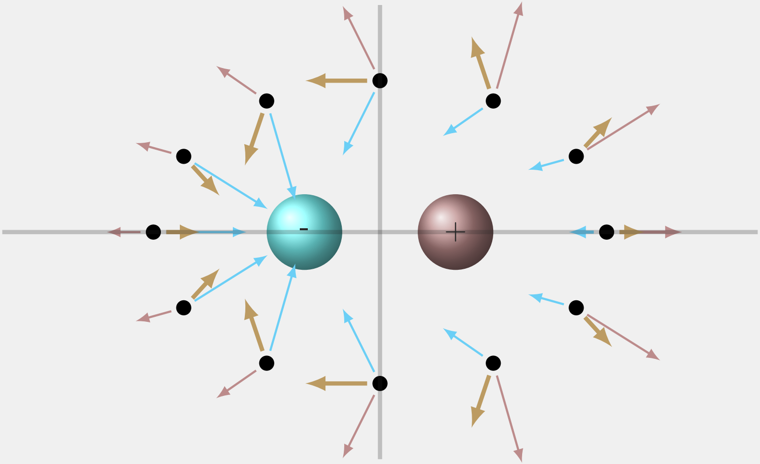

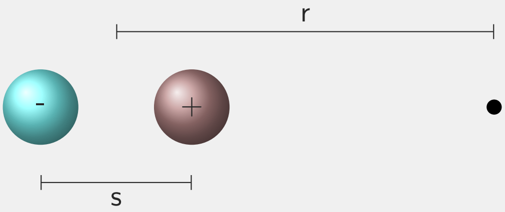

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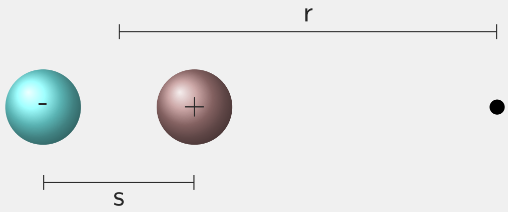
Along the Axis: Attaching Numbers



$$\left|\vec{\mathbf{E}}_{net}\right| = E_+ + E_- = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{(r-\frac{s}{2})^2} + \frac{-q}{(r+\frac{s}{2})^2}\right) = \frac{1}{4\pi\epsilon_0}\frac{2qsr}{(r-\frac{s}{2})^2(r+\frac{s}{2})^2}$$

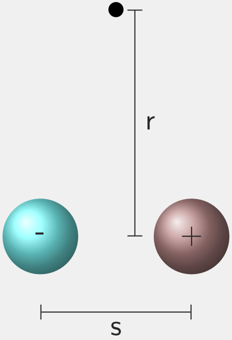
Taking a step back

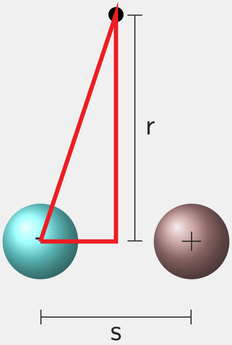
- In practice, dipoles themselves are generally very tiny
  - Think of a Hydrogen atom with it's proton and electron
- So the size of the dipole is usually much much smaller than the distance to we are measuring the electric field at
  - In math terms: $s \ll r$
- We thus make the approximation that:

$$\left|\vec{\mathbf{E}}_{net,axis}\right| = \frac{1}{4\pi\epsilon_0}\frac{2qsr}{(r-\frac{s}{2})^2(r+\frac{s}{2})^2} \approx \frac{1}{4\pi\epsilon_0}\frac{2qs}{r^3}$$

- You'll always have to determine the direction by looking at the dipole itself (since it could be oriented any particular direction)

Perpendicular to the Axis: More Numbers

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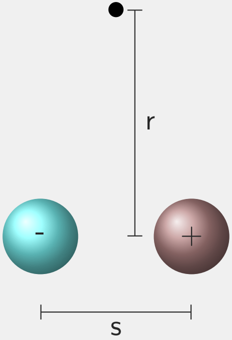
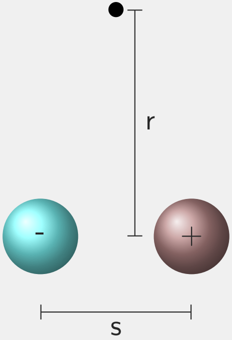


$$\hat{\mathbf{r}}_+ = \frac{\langle -\frac{s}{2}, r, 0\rangle}{\sqrt{\left(\frac{s}{2}\right)^2 + r^2}}$$

$$\hat{\mathbf{r}}_- = \frac{\langle \frac{s}{2}, r, 0\rangle}{\sqrt{\left(\frac{s}{2}\right)^2 + r^2}}$$

Perpendicular to the Axis: More Numbers



$$\hat{\mathbf{r}}_+ = \frac{\left\langle -\frac{s}{2}, r, 0 \right\rangle}{\sqrt{(\frac{s}{2})^2 + r^2}}$$

$$\hat{\mathbf{r}}_- = \frac{\left\langle \frac{s}{2}, r, 0 \right\rangle}{\sqrt{(\frac{s}{2})^2 + r^2}}$$

$$\vec{\mathbf{E}}_+ = \frac{1}{4\pi\epsilon_0}\frac{q}{(\frac{s}{2})^2 + r^2} \cdot \frac{\left\langle -\frac{s}{2}, r, 0 \right\rangle}{\sqrt{(\frac{s}{2})^2 + r^2}}$$

$$\vec{\mathbf{E}}_+ = \frac{1}{4\pi\epsilon_0}\frac{-q}{(\frac{s}{2})^2 + r^2} \cdot \frac{\left\langle \frac{s}{2}, r, 0 \right\rangle}{\sqrt{(\frac{s}{2})^2 + r^2}}$$

Simplifying the Perpendicular

- Y-components equal and opposite $\Rightarrow$ cancel
- X-components equal and the same direction $\Rightarrow$ double
- Results in

$$\vec{\mathbf{E}}_{net,\perp} = \frac{1}{4\pi\epsilon_0}\frac{-qs}{[(\frac{s}{2})^2 + r^2]^{3/2}}\langle 1, 0, 0\rangle$$

- Again, if $r \gg s$, then this simplifies to become:

$$\left|\vec{\mathbf{E}}_{net,\perp}\right| = \frac{1}{4\pi\epsilon_0}\frac{qs}{r^3}$$