Monday Jan 23, 2017

Labatorials start this week

- Check your schedule
- Print write-up
- Prepare
- Take advantage of the small group (24 not 200 students in the room) and group work (3-4)
- Checkpoints test your understanding
- Come on time (late arrival = group working without you = mark deduction)

Last time

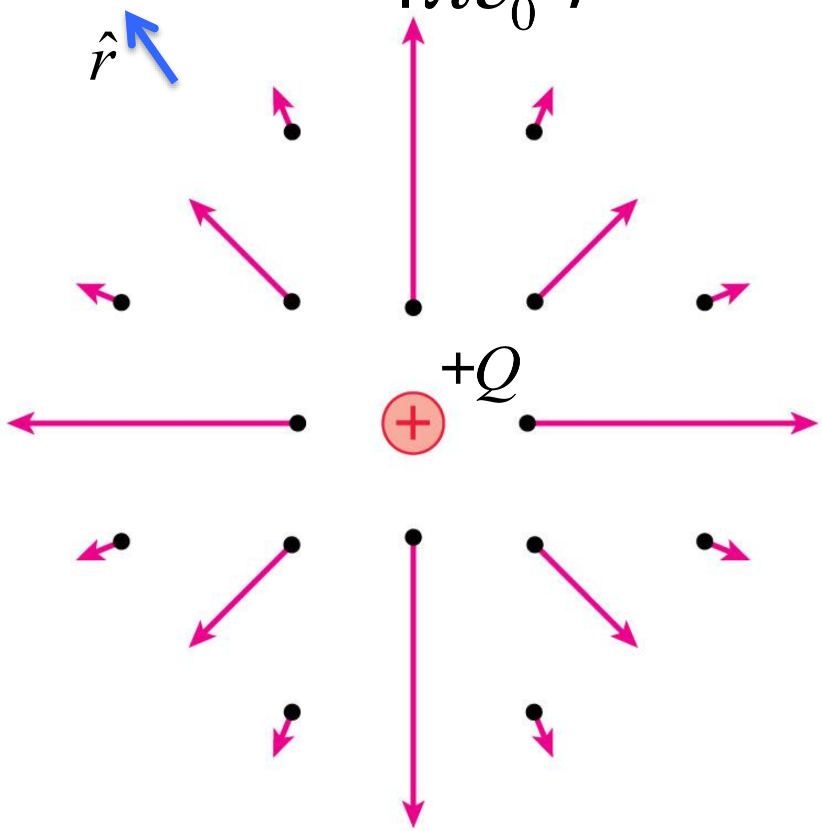
- The electric field: conceptually difficult but much more useful
- TopHat questions related to direction of net E-field
- Finishing up Coloumb's Law: Group Activity

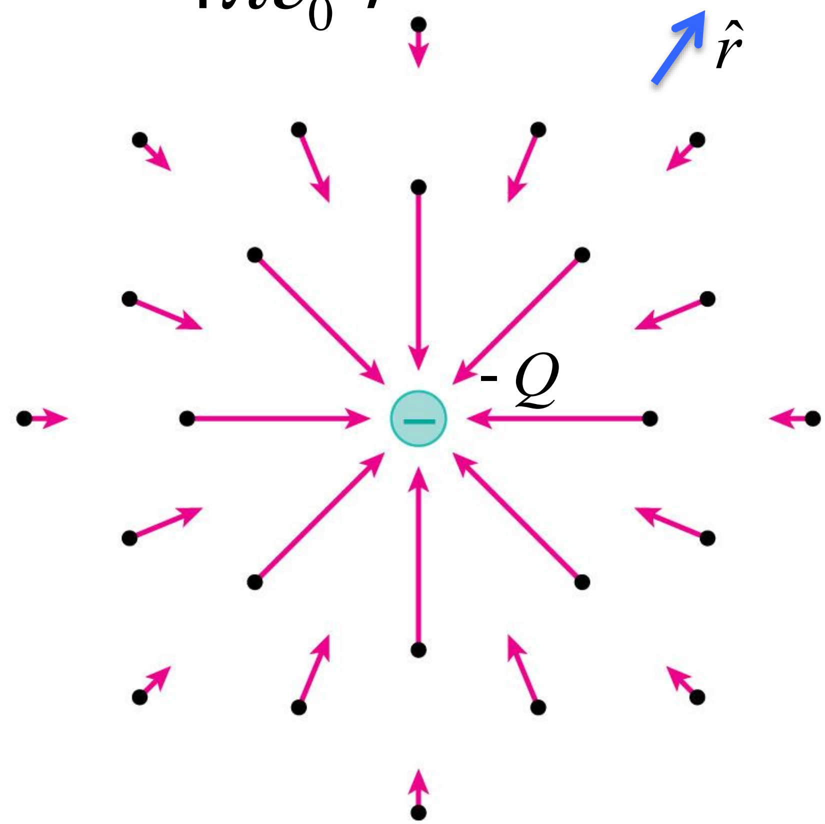
This time

- More on electric fields: how to calculate them
- Visualizing electric fields: electric field lines
- Example: electric field of a dipole.

Electric field of point charges

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





+ charge: $\vec{E}$ points away from Q

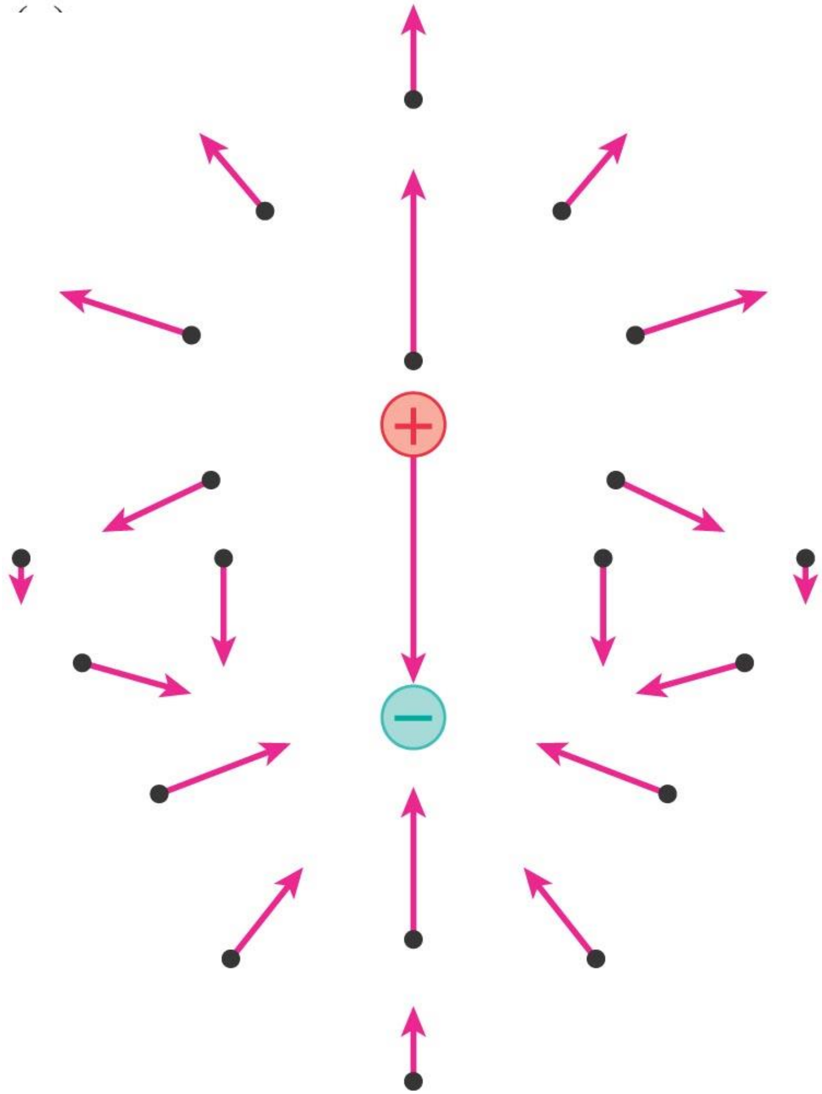
– charge: $\vec{E}$ points toward –Q

Electric Field Vectors

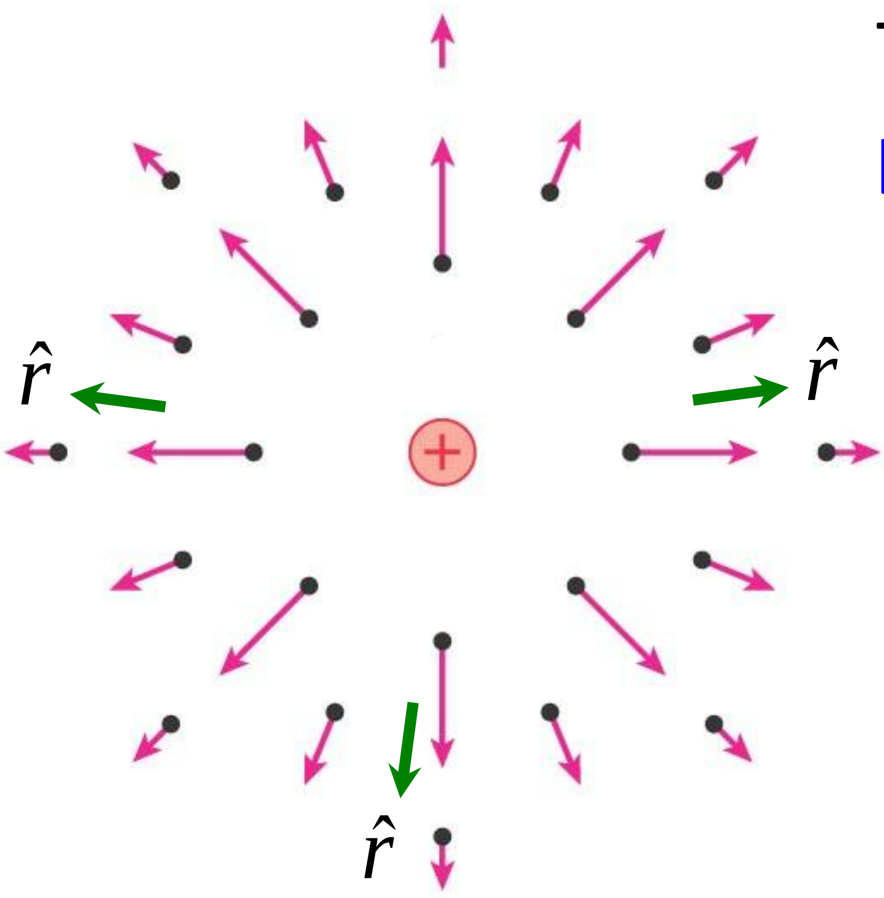
The vector represents the magnitude and direction of the electric field **at that point**.

But $\vec{E}$ is not a spatial quantity that stretches from one end of the arrow to the other.

Instead, think of $\vec{E}$ as a spatial quantity at every point with a direction at that point given by the arrow.



Electric Field building blocks



The electric field around a **point charge, q,** is given by

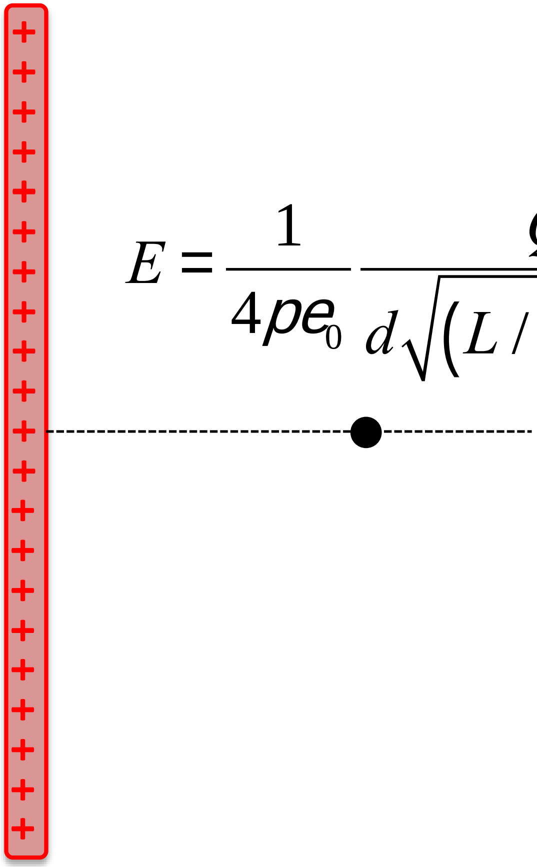
$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}}$$

$\hat{r}$ is a **unit vector** that always points **away from** q.

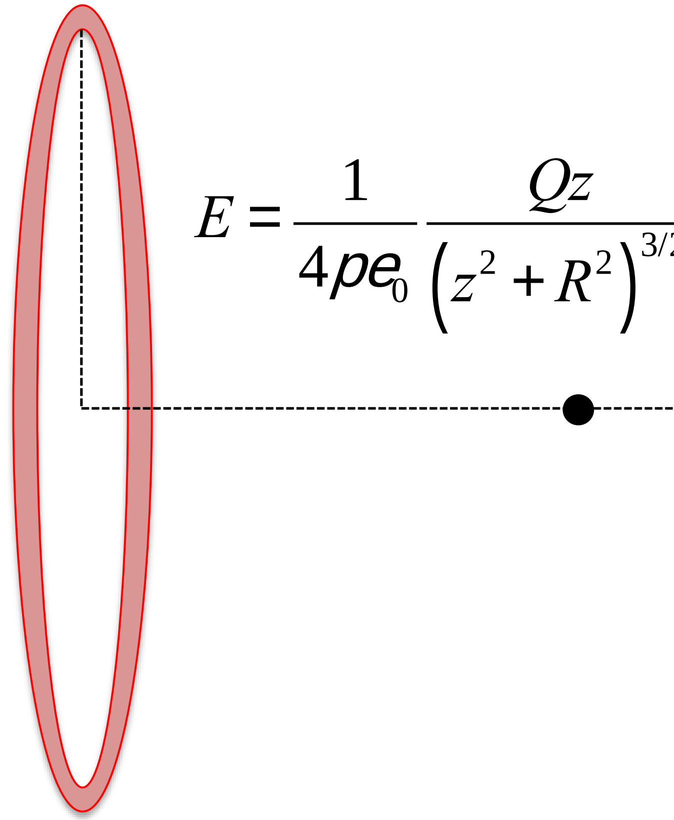
We can use this with superposition to find the electric field of more complicated objects.

TopHat Questions

Cases we've already seen

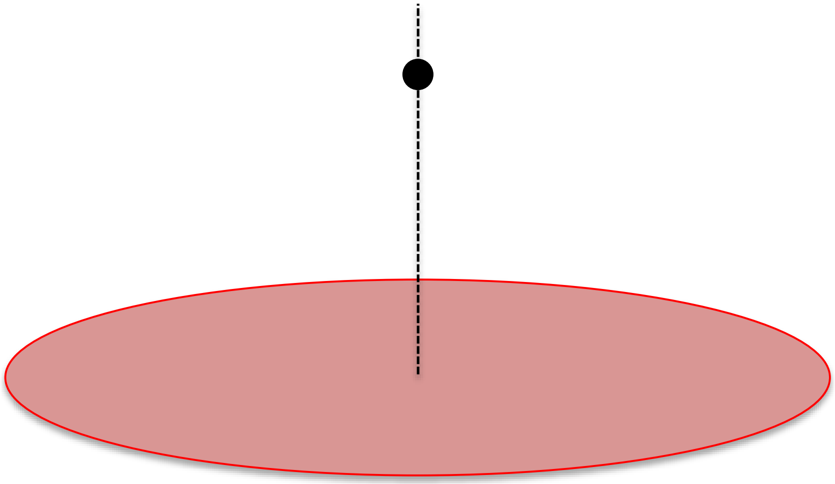


$$E = \frac{1}{4pe_0}\frac{Q}{d\sqrt{(L/2)^2 + d^2}}$$



$$E = \frac{1}{4pe_0}\frac{Qz}{\left(z^2 + R^2\right)^{3/2}}$$

Charged disk



$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2 + R^2}}\right]$$

Summary so far

If we think there is an electric field somewhere in space, then we can measure it by placing a charge q in the field. If q feels an electric force, then

$$\vec{E} = \frac{\vec{F}_{on\,q}}{q}$$ (How we have proceeded so far)

Or, if we know the electric field, then the electric force on any charge q placed in this field is

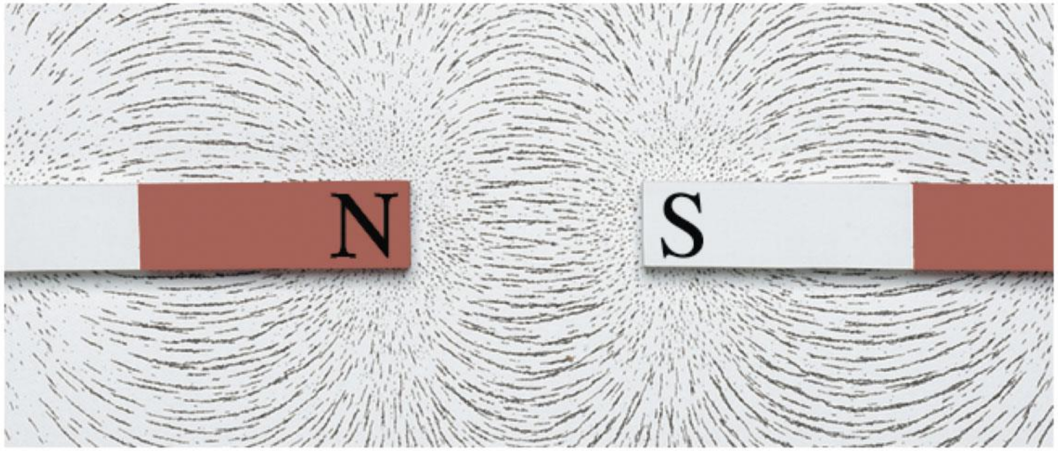
$$\vec{F}_{on\,q} = q\vec{E}$$ (How nature really works)

Full force on charged particle due to electromagnetic field:

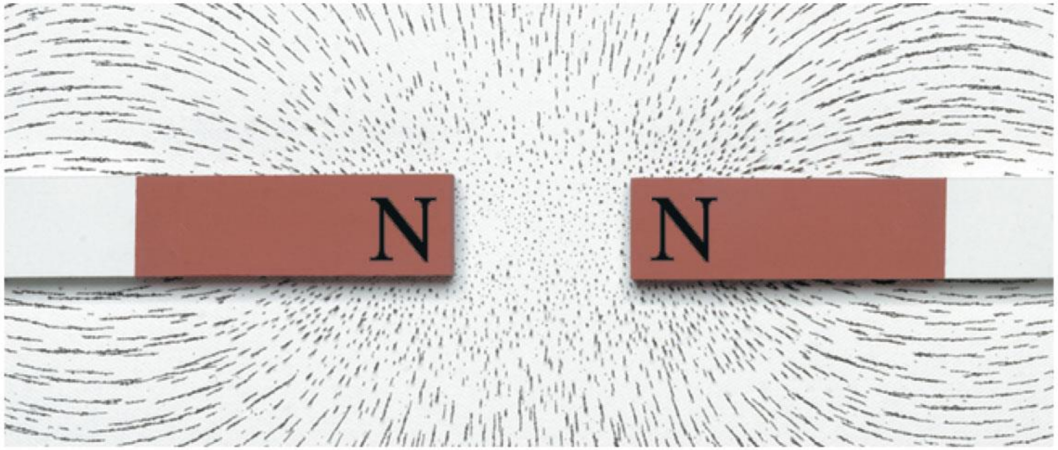
$$\boxed{\vec{F}_{on\,q} = q\vec{E} + q\vec{v} \times \vec{B}}$$

We'll come back to this

Visualizing E-field: field lines



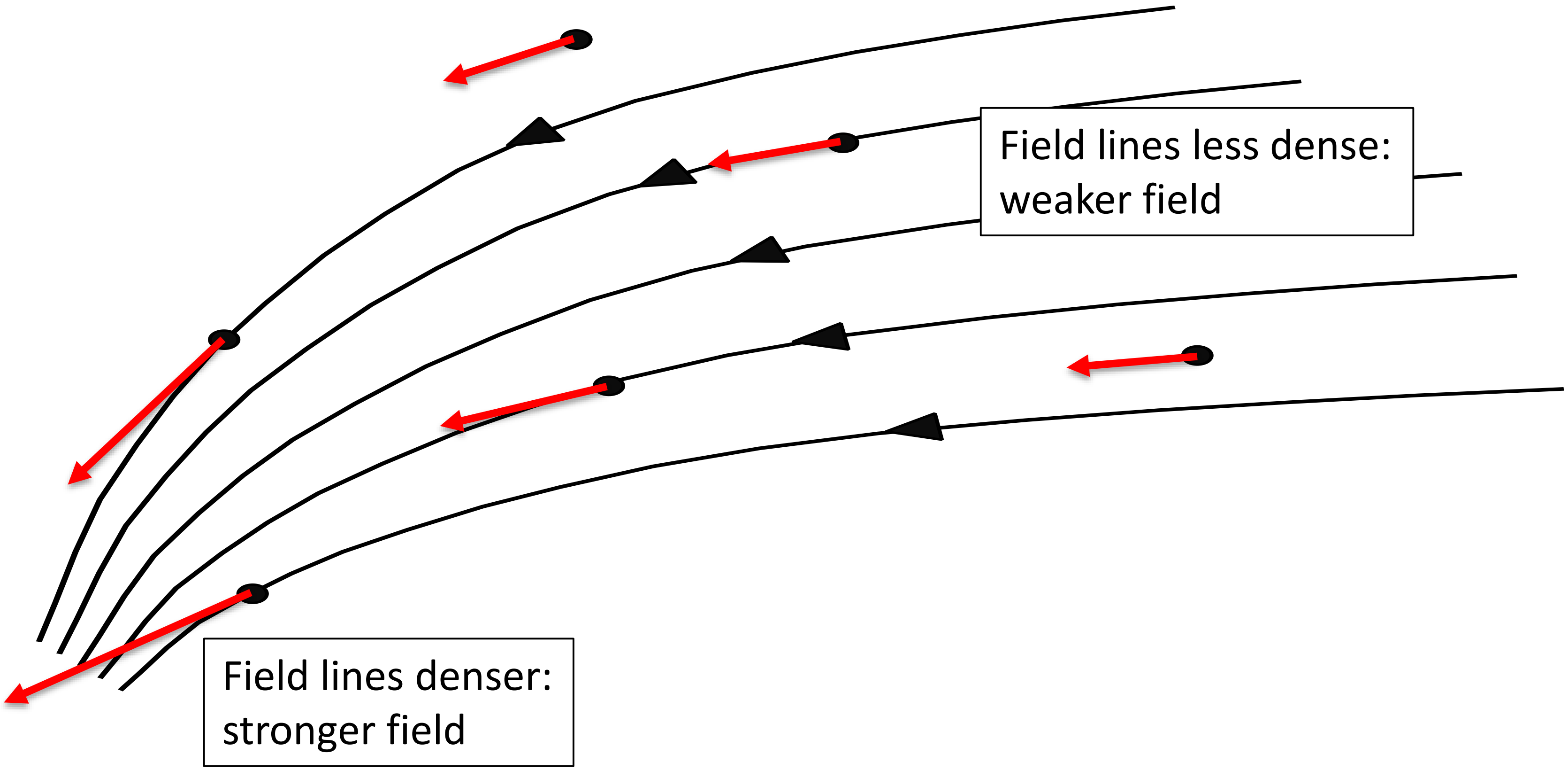
Magnetic field lines



You are already familiar with the idea that magnets set up a magnetic field. This can be demonstrated with iron filings on paper over top of a magnet.

Electric fields also have “field lines” but we have less intuition about them from everyday experience

Electric Field Lines

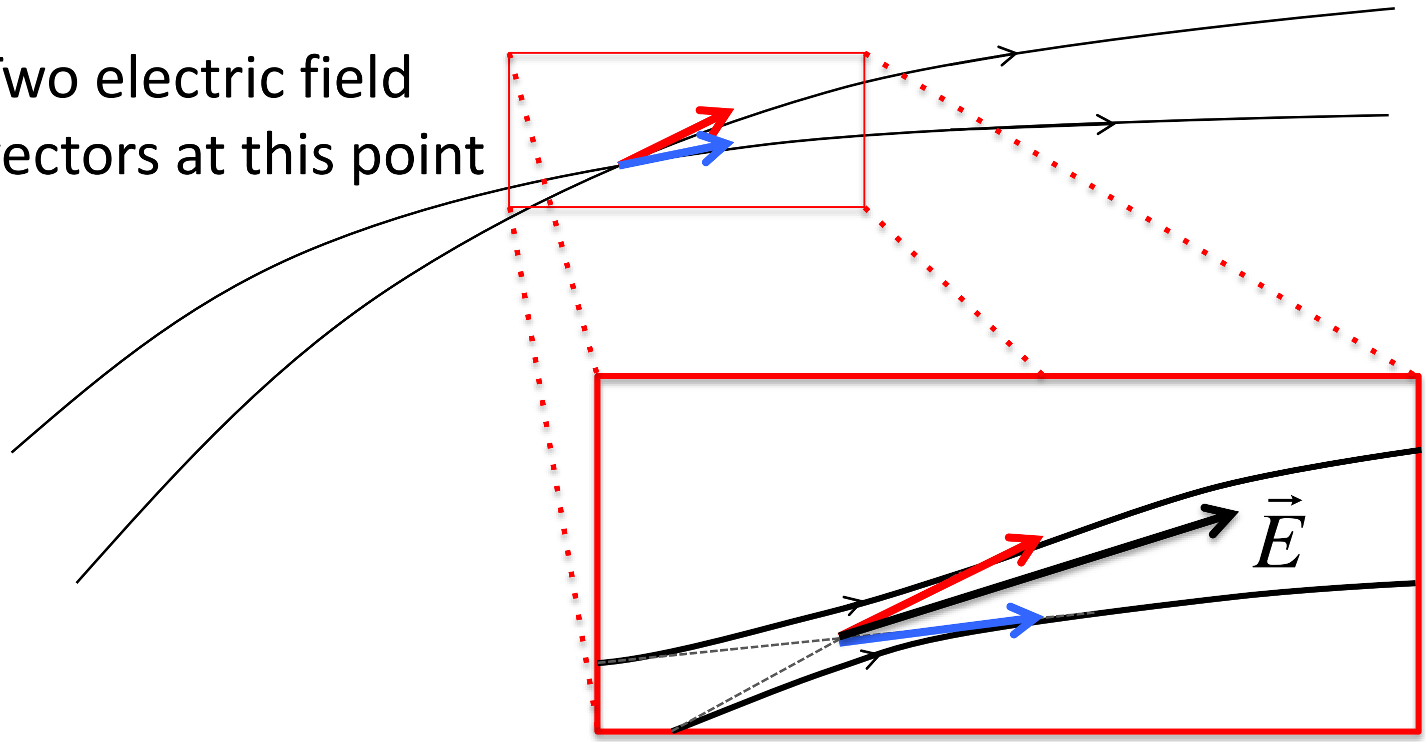


Electric field lines are continuous curves. The electric field vectors are tangent to the field lines

The denser the field lines, the stronger the field (magnitude of E)

Electric Field Lines Can't Cross

Two electric field vectors at this point



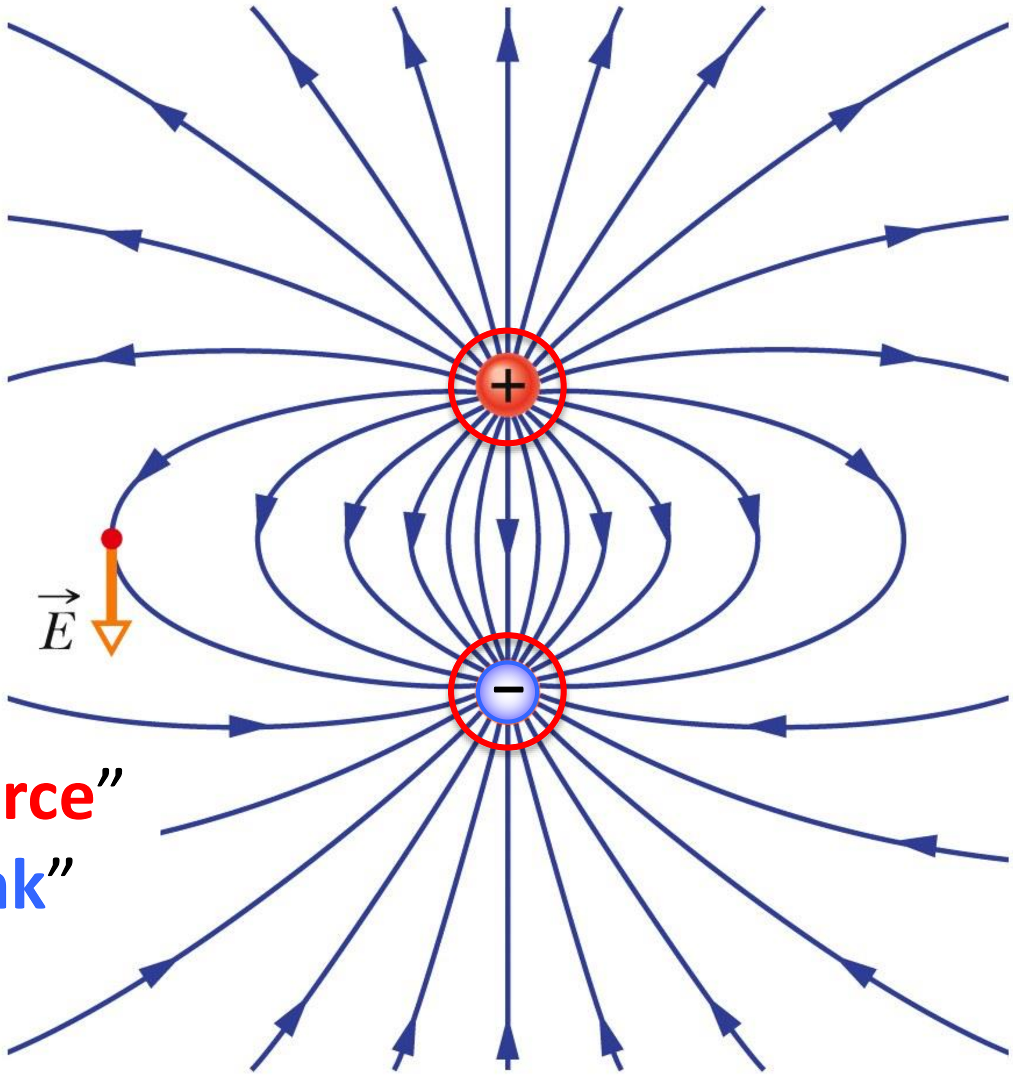
If field lines crossed, the electric field at that point would not be defined: superposition saves the day.

Sources and Sinks of Field Lines

Two charges of **equal magnitude** and **opposite sign**.

Field lines **start on +**
Field lines **end on –**

Positive charge called "**source**"
Negative charge called "**sink**"



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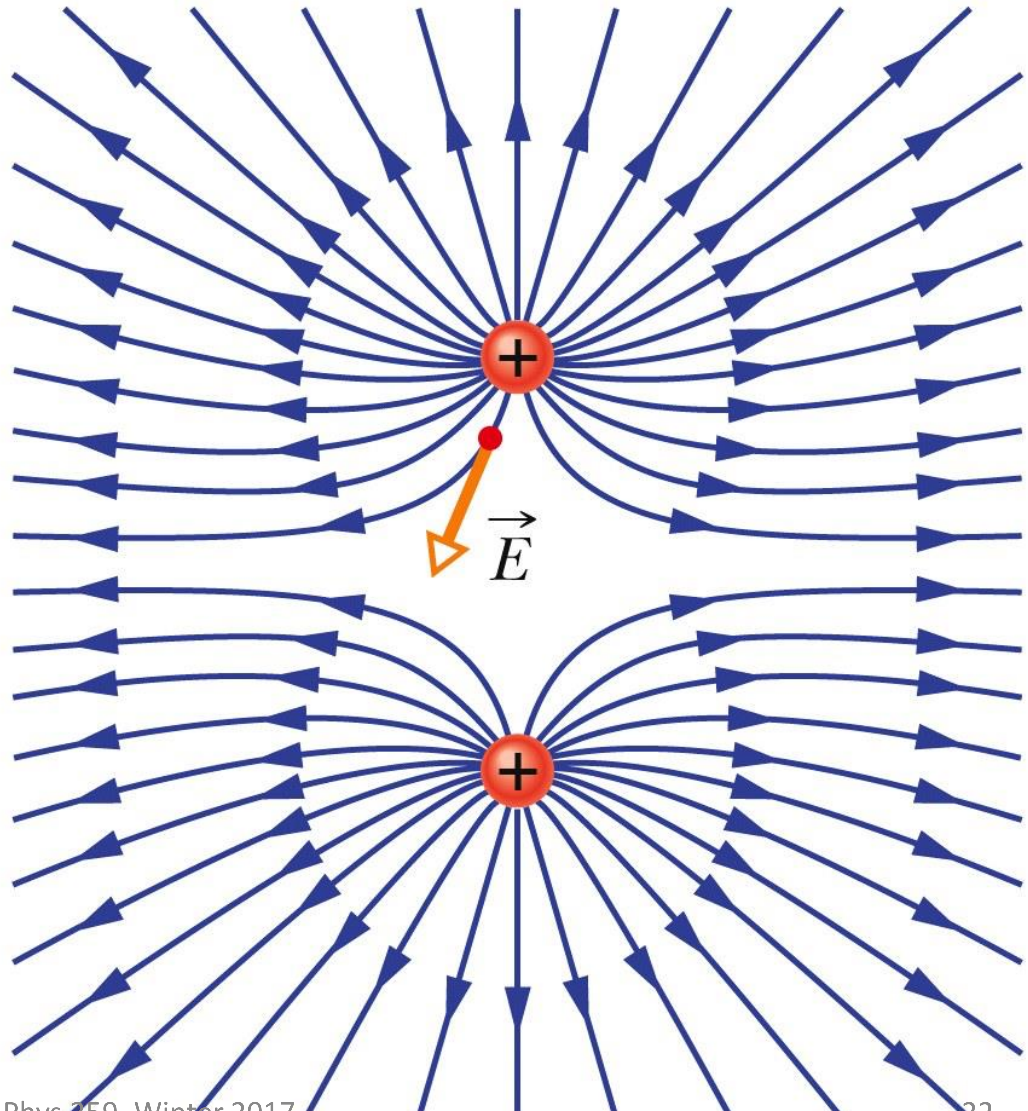
Electric Field Lines

The electric field lines around a pair of equal positive charges.

No negative charges for the field lines to end on. The field lines "repel" each other and all point outward.

Direction comes from superposition!



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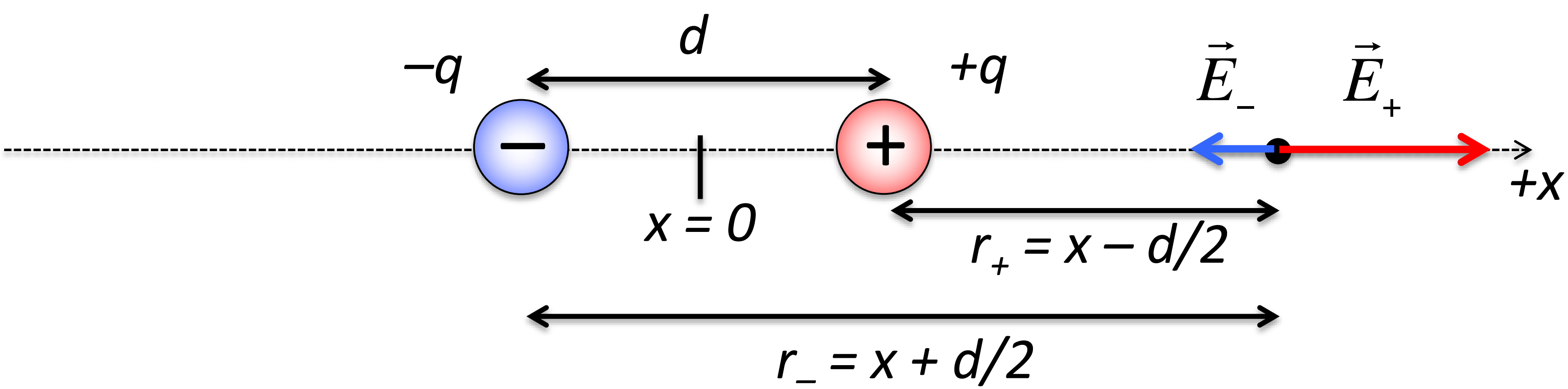
Electric Field of a Dipole Along Axis

What direction is the electric field at a point along the axis of an electric dipole?



Step 1: What are the distances r_+ and r_-?

Step 2: What are the individual fields E_+ and E_-?

Step 3: Use superposition to find the net field E_x.

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_+^2}\hat{i} \qquad \vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r_-^2}\hat{i}$$