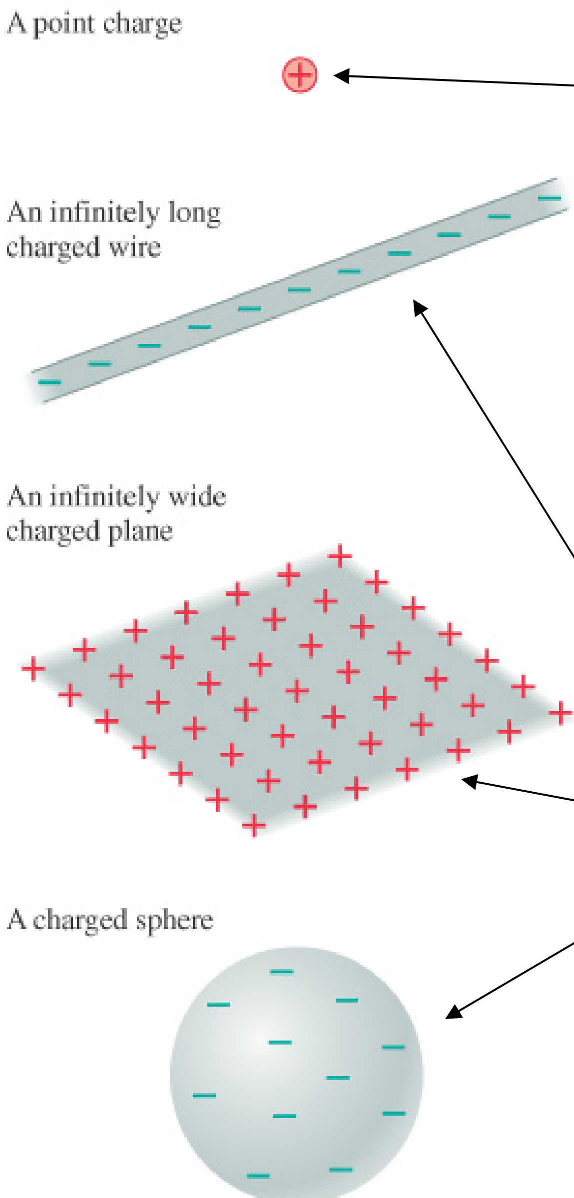
Lecture 3: Chapter 26 (Beginning), September 1 2005

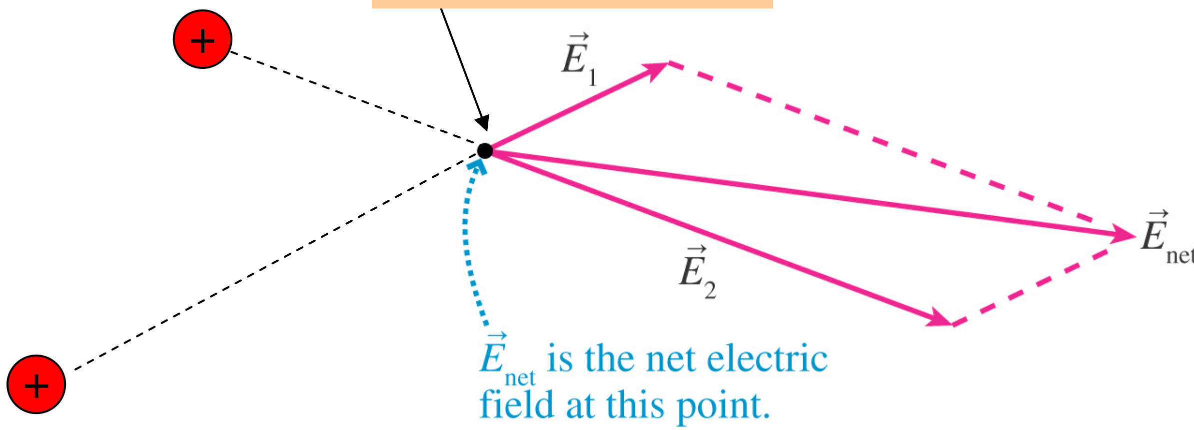


$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r} \quad \text{(electric field of a point charge)} \quad (25.15)$$

Coulomb's Law only describes el. field created by a point charge…

How can we find electric fields created by more complicated distributions of charges?

Principle of Superposition

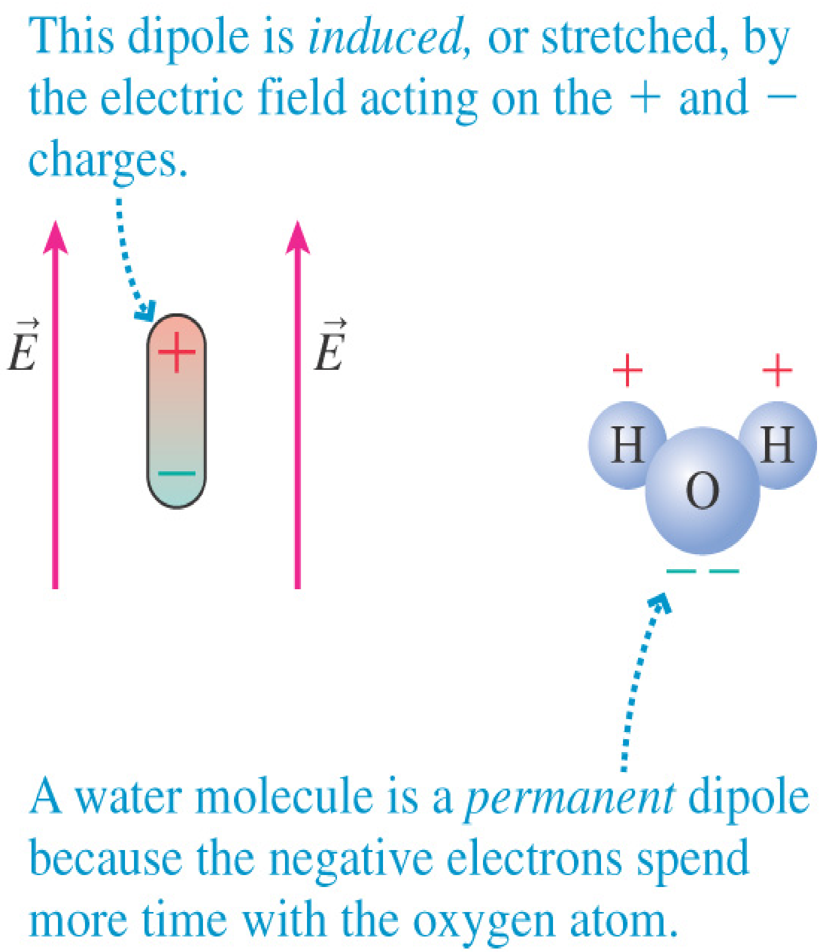


$$\boldsymbol{E}_{net} = \boldsymbol{F}_{net}/q = \boldsymbol{F}_{1on\ q}/q + \boldsymbol{F}_{2on\ q}/q + \ldots = \boldsymbol{E}_1 + \boldsymbol{E}_2 + \ldots = \Sigma \boldsymbol{E}_i$$

- We can divide our charge distribution into infinitely large number of infinitely small charges
- Each small charge can be considered as a *point* charge
- This means that Coulomb law can be applied
- When we can find net ***E*** is a ***vector sum*** of el. fields due to each charge (principle of superposition)

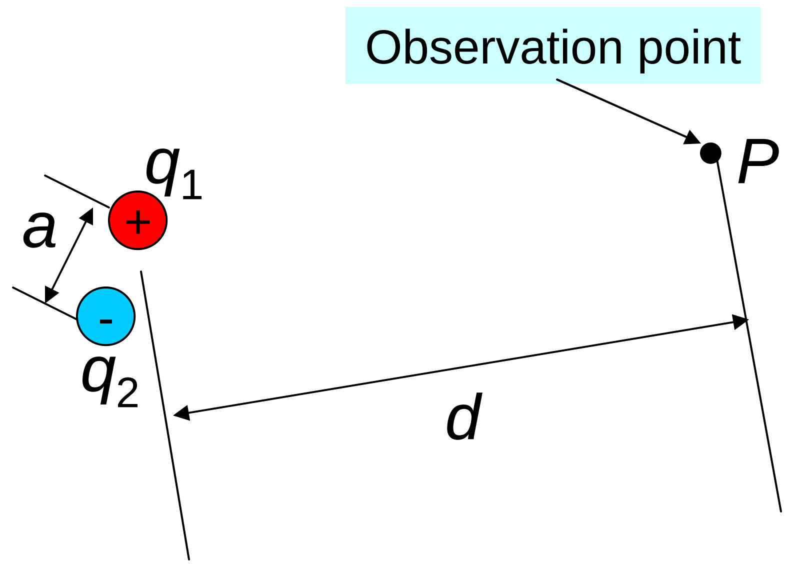
Electric Field of a Dipole

Induced and permanent dipoles



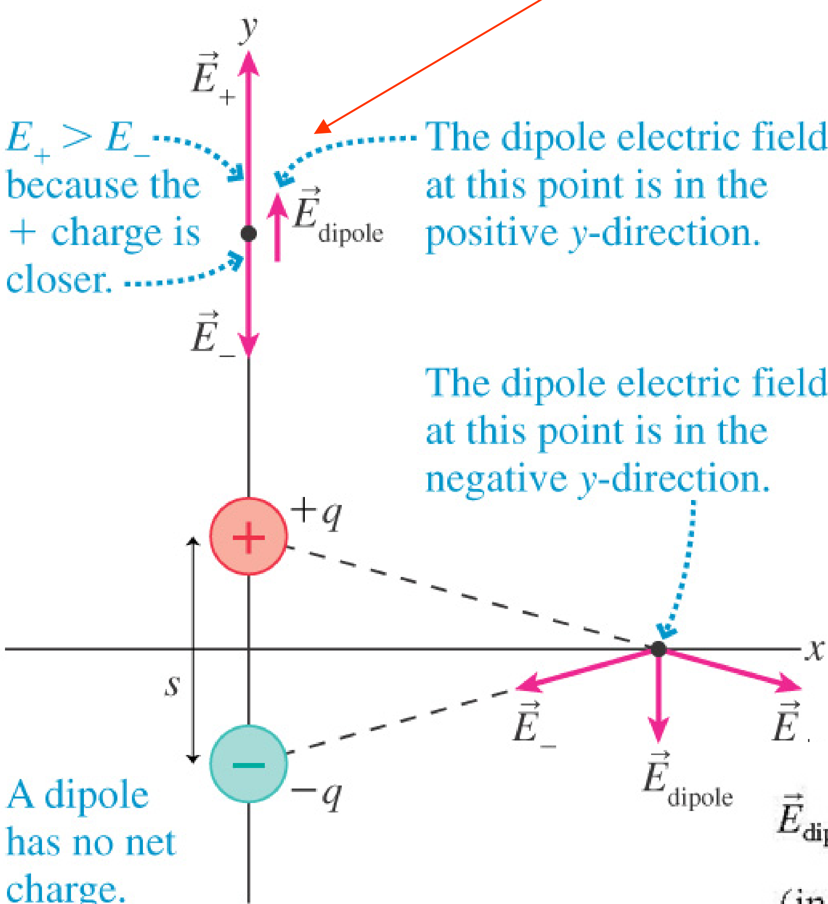
Limiting Cases

What is the simple way of modeling any distribution of charges with finite size (*a*) if we would like to find el. field at very long distance *d*>>*a*?



Electric Field Along and Perpendicular to the Dipole Axis

$$\vec{E}_{\text{dipole}} \approx \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3} \quad \text{(on the axis of an electric dipole)} \qquad (26.11)$$



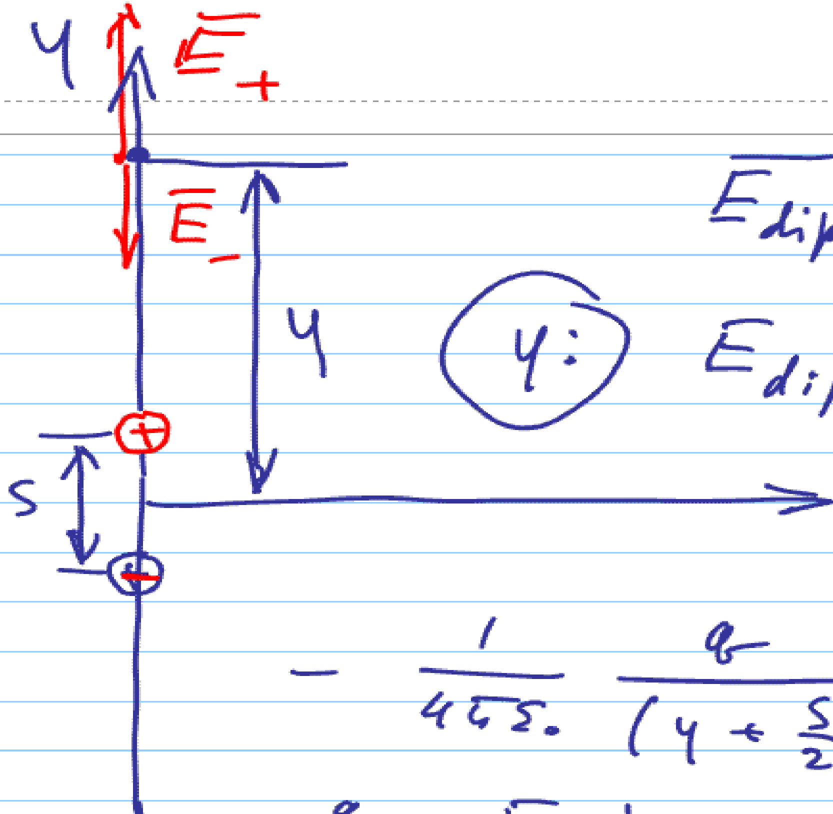
Dipole Moment: p = *qs*, from the negative to the positive charge

$$\vec{E}_{\text{dipole}} \approx -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3} \qquad (26.12)$$

(in the plane perpendicular to an electric dipole)

Electric Field Along the Dipole Axis: Solution

Note Title 9/1/2005



$$\bar{E}_{dipole} = \bar{E}_+ + \bar{E}_-.$$

from the geometry

y: $$E_{dipole} = E_+ - E_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(y-\frac{s}{2}\right)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(y+\frac{s}{2}\right)^2} =$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{\left(y-\frac{s}{2}\right)^2} - \frac{1}{\left(y+\frac{s}{2}\right)^2}\right] =$$

Solution Continuation

$$= \frac{q}{4\pi\varepsilon_0} \frac{y^2 + ys + \left(\frac{s}{2}\right)^2 - y^2 + ys - \left(\frac{s}{2}\right)^2}{\left(y - \frac{s}{2}\right)^2 \cdot \left(y + \frac{s}{2}\right)^2} =$$

$$= \frac{q \cdot 2ys}{4\pi\varepsilon_0 \left(y - \frac{s}{2}\right)^2 \cdot \left(y + \frac{s}{2}\right)^2} = \frac{q \cdot 2ys}{4\pi\varepsilon_0 \cdot y^4} = \frac{q \cdot 2s}{4\pi\varepsilon_0 \cdot y^3} =$$

$$y \gg s \qquad \left(y - \frac{s}{2}\right)^2 \cdot \left(y + \frac{s}{2}\right)^2 \longrightarrow y^4$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{2q \cdot s}{y^3} = \boxed{\frac{1}{4\pi\varepsilon_0} \frac{2\bar{p}}{y^3}}$$

Magnitude: $|\bar{p}| = q \cdot s$, direction of $\bar{p}$ is from $\ominus$ to $\oplus$ charge

Why does the el. field of a dipole decay stronger ($\sim y^{-3}$) than the field of a single charge ($\sim y^{-2}$) ?

End of Lecture 3
Reading: Entire Chapter 26
Home Work 1 and 2 in Mastering Physics