Lecture 26

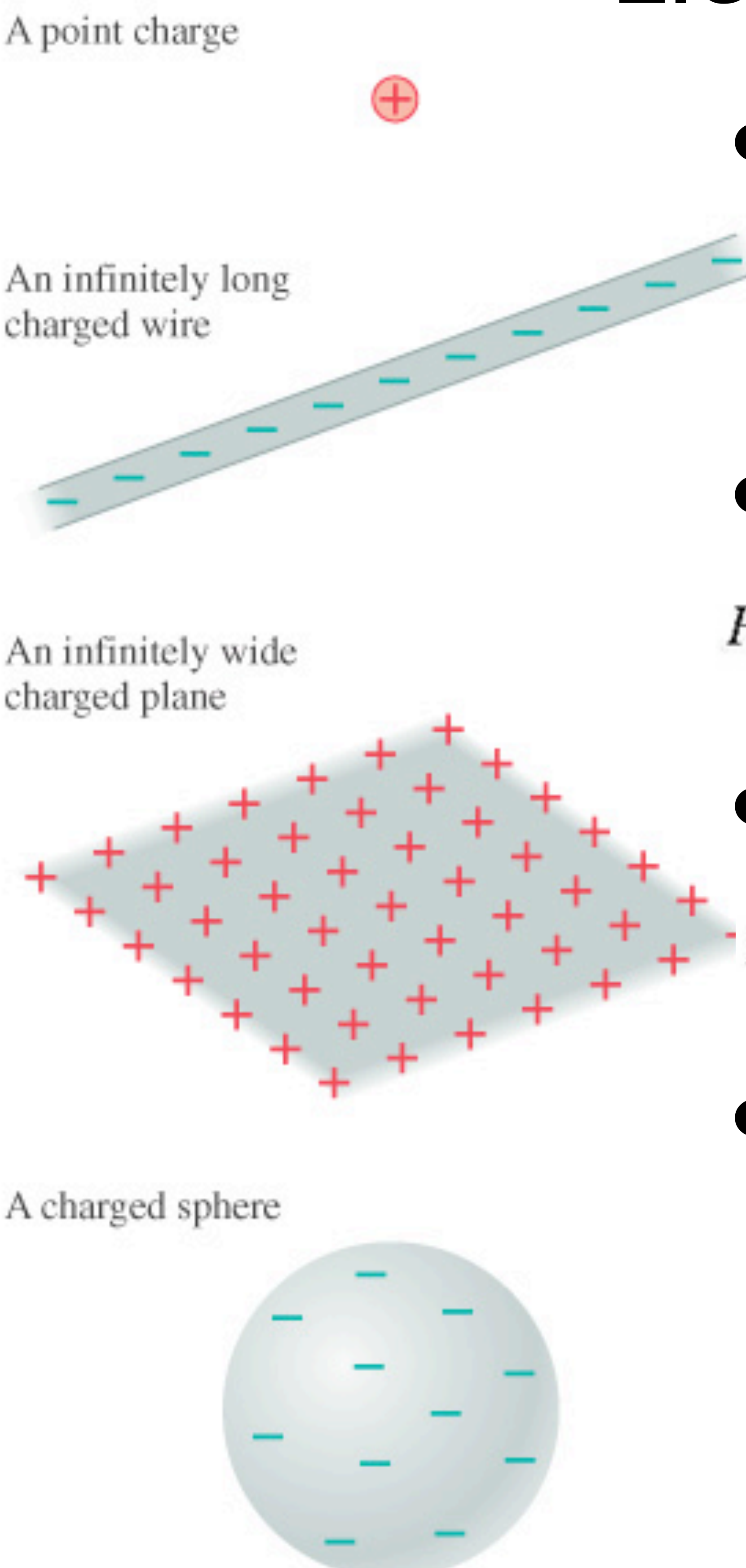
- Chapter 26 (The Electric Field)

  $\bar{E}$ due to configuration of (source) charges (today)

  parallel plate capacitor (uniform $\bar{E}$)

  motion of (other) charges in $\bar{E}$

Electric Field Models



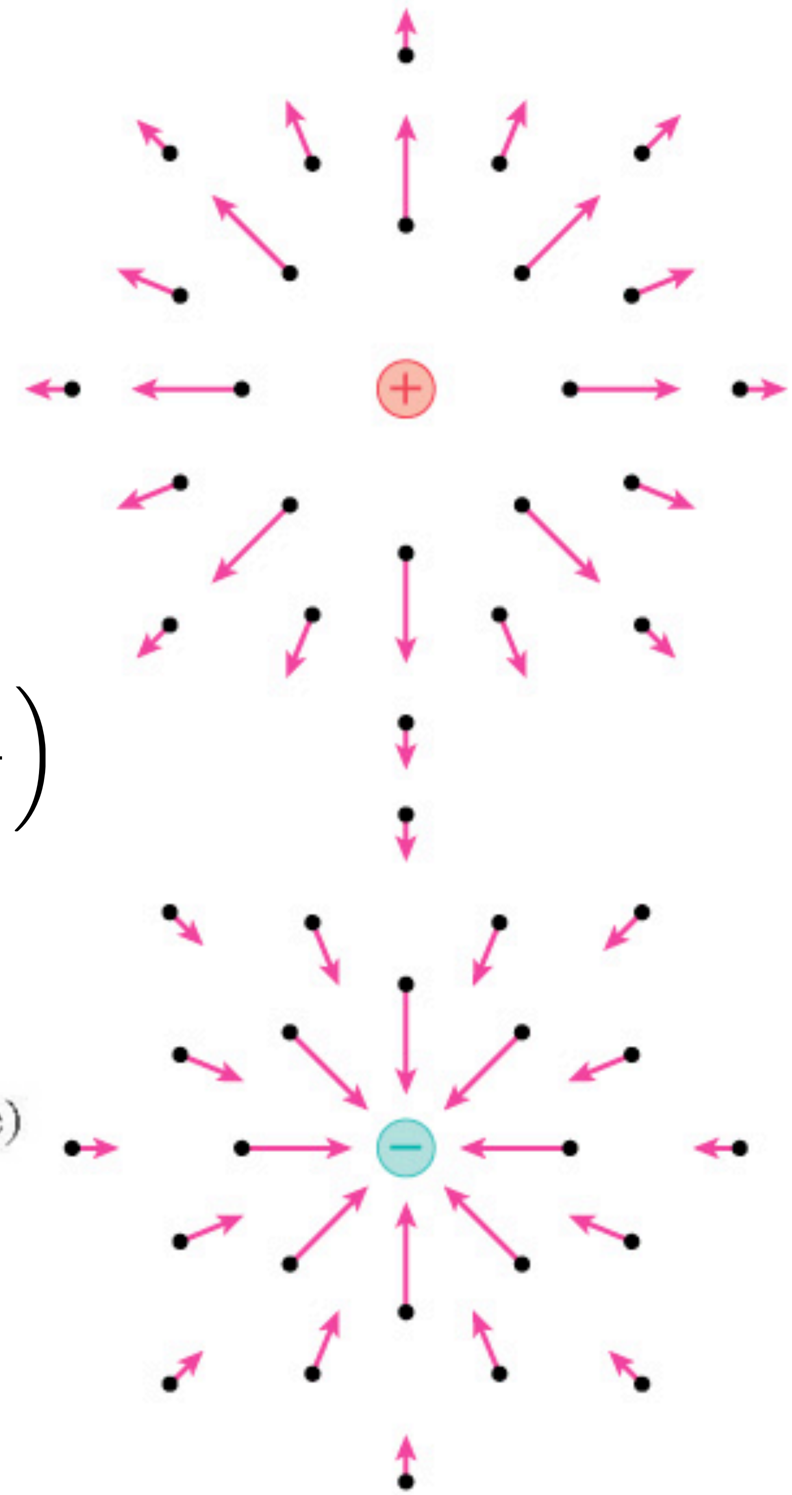
- good <u>approx</u>. for small charged object, real wire
- Coulomb's law

$$F_{1\text{ on }2} = F_{2\text{ on }1} = \frac{K|q_1||q_2|}{r^2} \left(K = \frac{1}{4\pi\epsilon_0}\right)$$

- $\bar{E}$ due to <u>point charge</u>

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

- <u>limiting cases</u> (check + simpler formula): like $\bar{E}$ point charge very far ($\gg$ size)



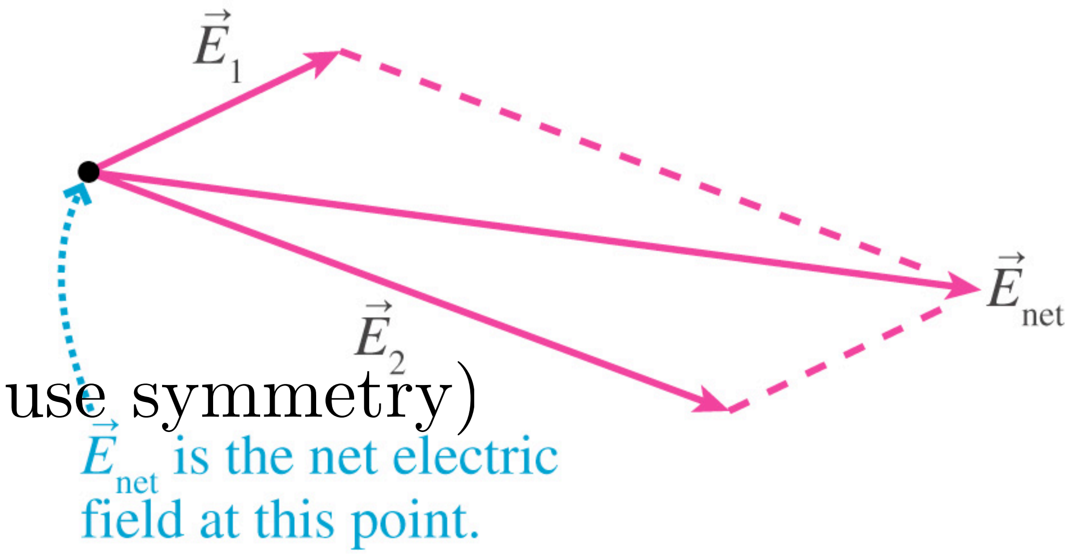
Electric Field of Multiple Charges

- Principle of superposition

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

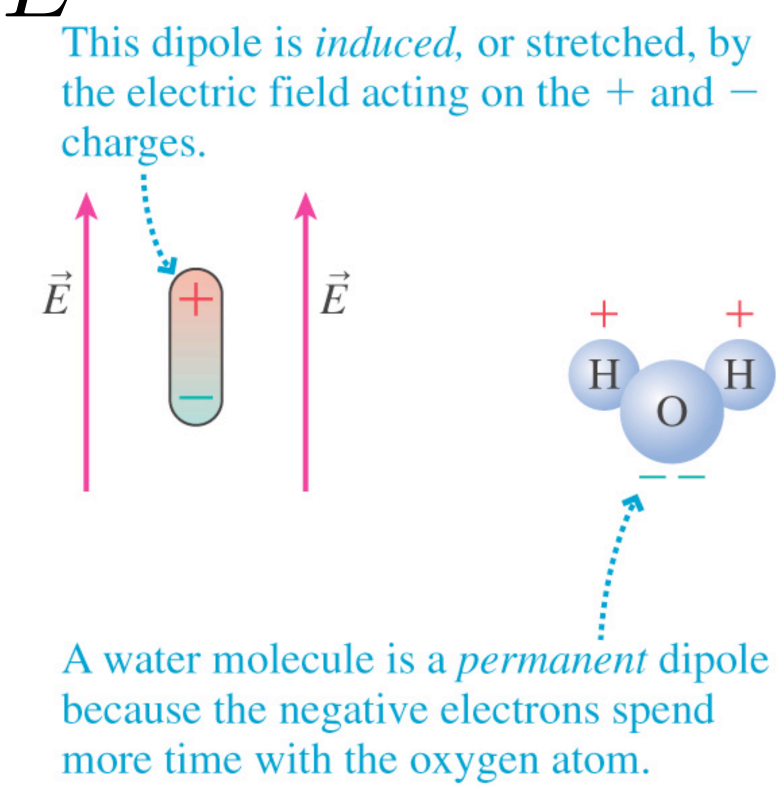
$$+\bar{F}_{\text{on } q} = \bar{F}_{1 \text{ on } q} + \bar{F}_{2 \text{ on } q} \Rightarrow \bar{E}_{net} = \sum_i \bar{E}_i$$

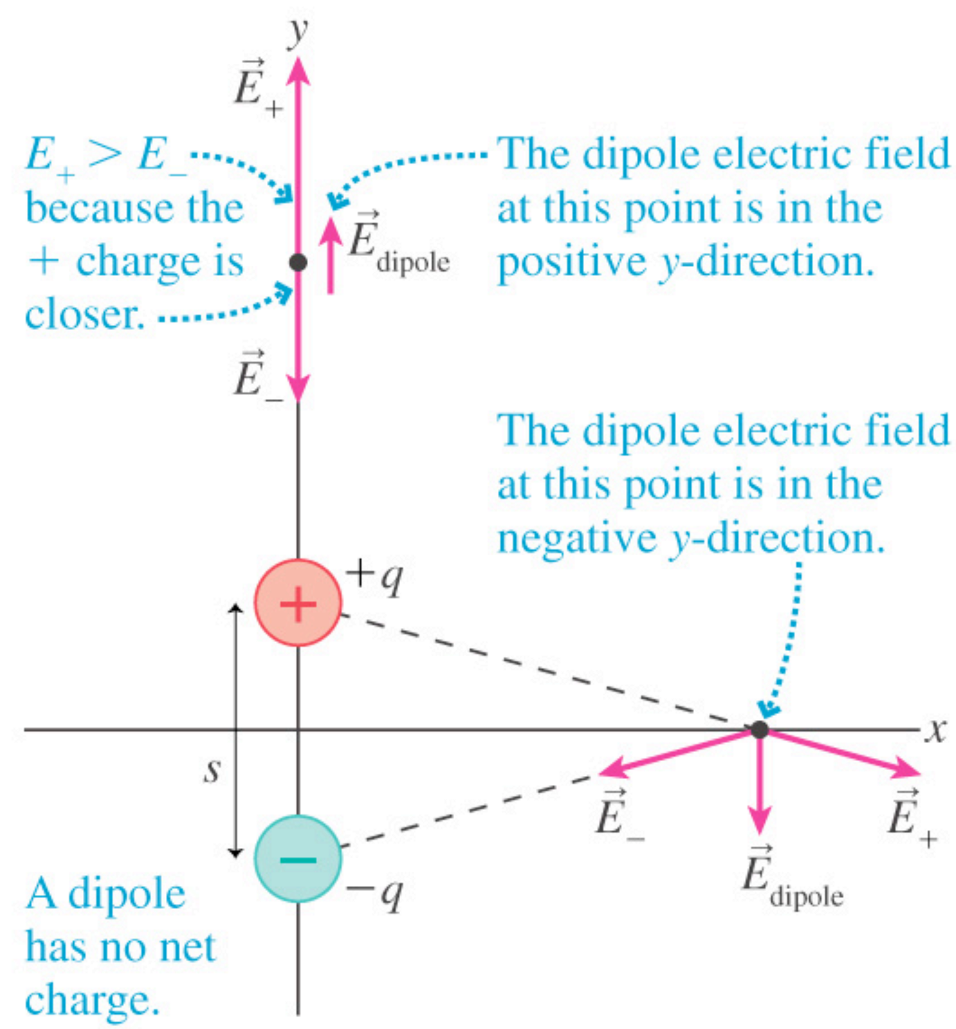
Strategy: picture..., identify P, find $\bar{E}_i$, $\sum_i \bar{E}_i$ (use symmetry)



- Electric field of a dipole (two opposite charges separated by small distance s): no net charge, but does have a net $\bar{E}$

$$
\begin{aligned}
&(E_{dipole})_y \\
= \;& (E_+)_y + (E_-)_y \\
= \;& \frac{1}{4\pi\epsilon_0}\frac{q}{(y-1/2s)^2} + \\
& \frac{1}{4\pi\epsilon_0}\frac{-q}{(y-1/2s)^2} \\
= \;& \frac{q}{4\pi\epsilon_0}\frac{2ys}{(y-1/2s)^2\,(y-1/2s)^2}
\end{aligned}
$$





Electric Field of a Dipole

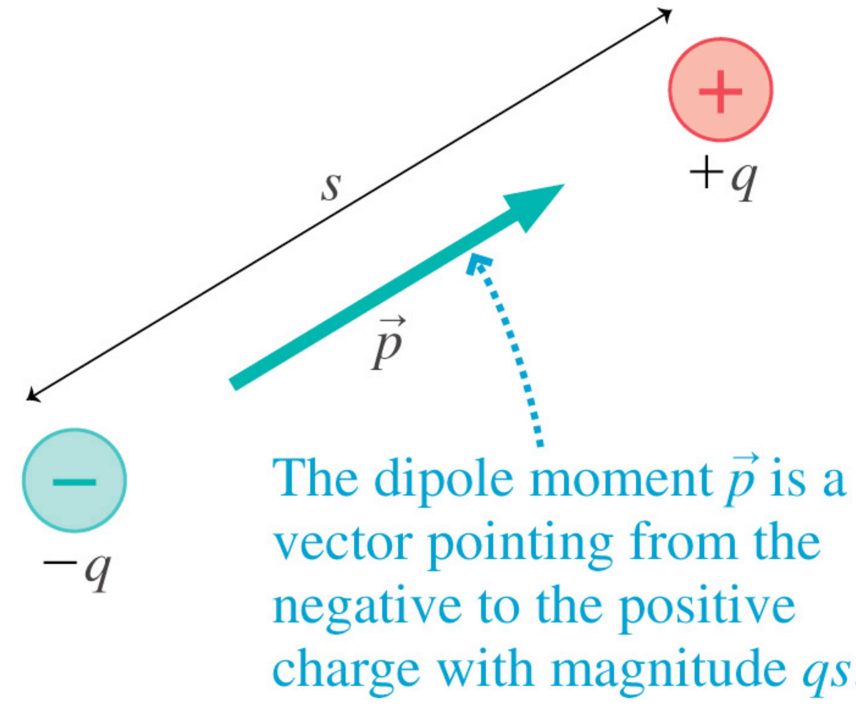
- For y >> s: $(E_{dipole})_y \approx \frac{1}{4\pi\epsilon_0}\frac{2qs}{y^3}$

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

- <u>dipole moment</u>:$\bar{p} = (qs,\ \text{from negative to positive})$

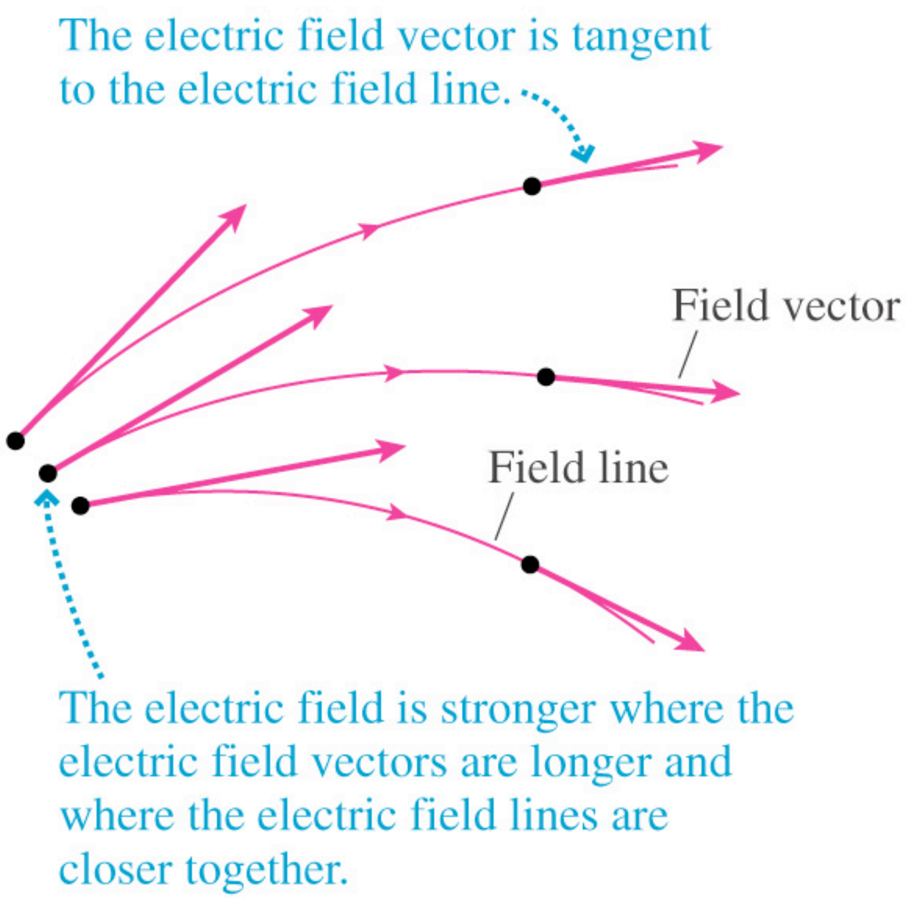
$$\vec{E}_{\text{dipole}} \approx -\frac{1}{4\pi\epsilon_0}\frac{\vec{p}}{r^3}$$

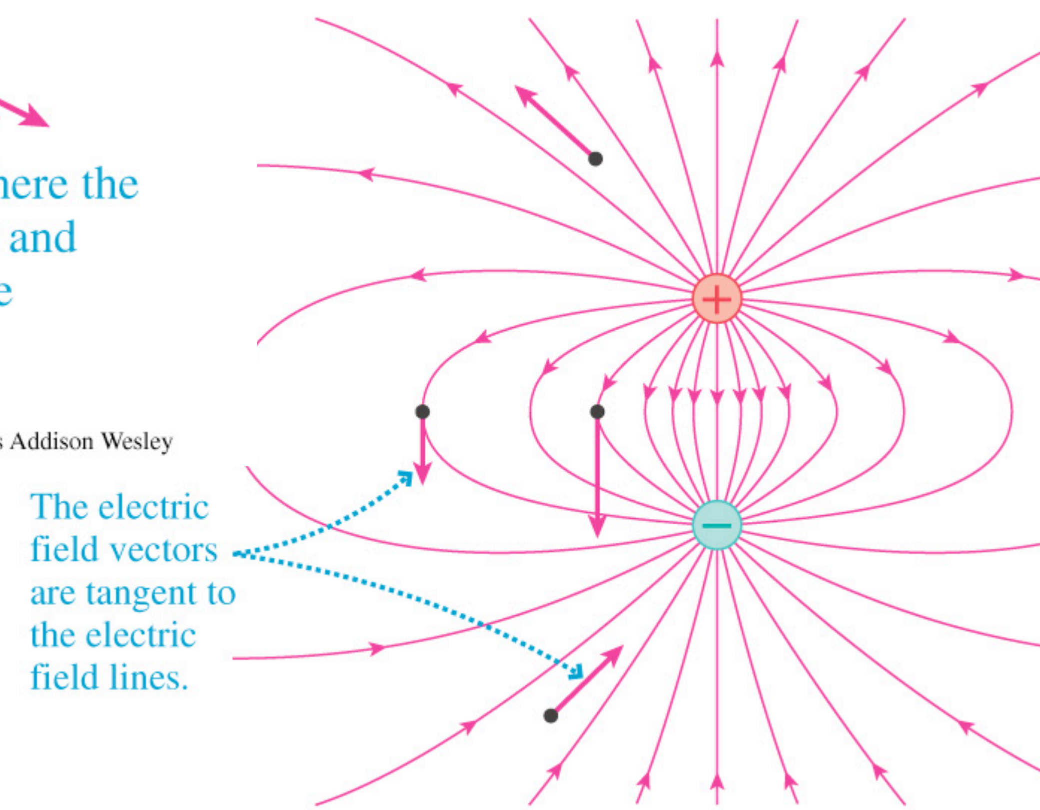
(in the plane perpendicular to an electric dipole)



Picturing $\bar{E}$

- draw vectors or lines
- tangent: direction of $\bar{E}$
- closer together for larger $\bar{E}$
- starts on +ve, end -ve
- can<u>not</u> cross (unique direction at point)





Electric Field of a Continuous Charge Distribution

- even if charge is discrete, consider it continuous, describe how it's distributed (like density, even if atoms
- Strategy (based on of point charge and principle of superposition)

divide Q into point-like charges ΔQ

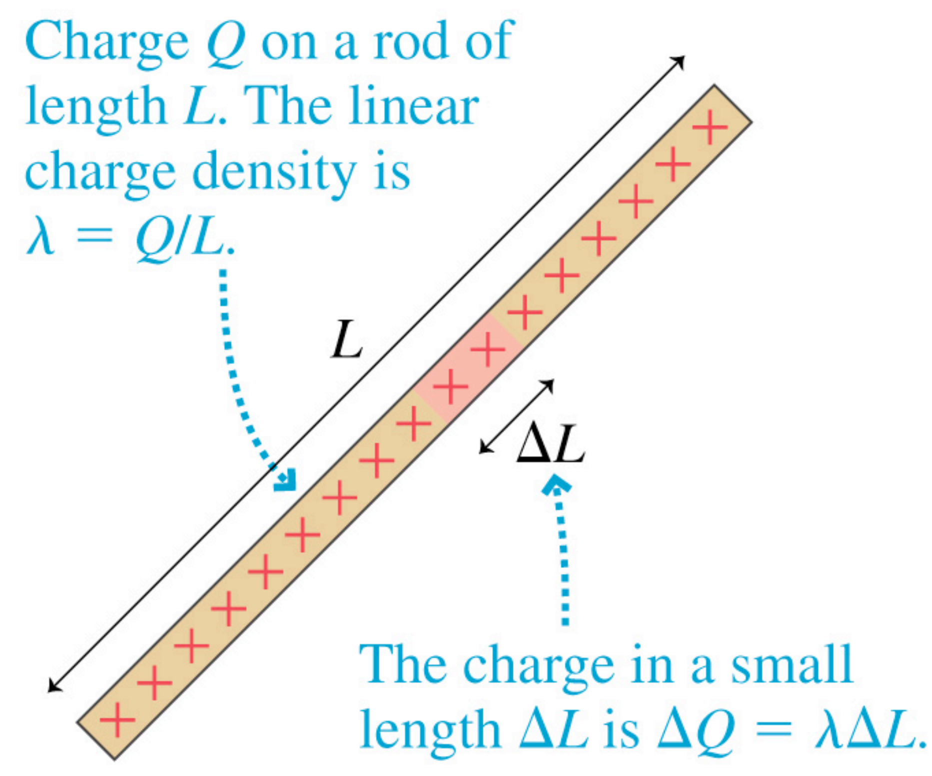
find $\bar{E}$ due to ΔQ

convert sum to integral:

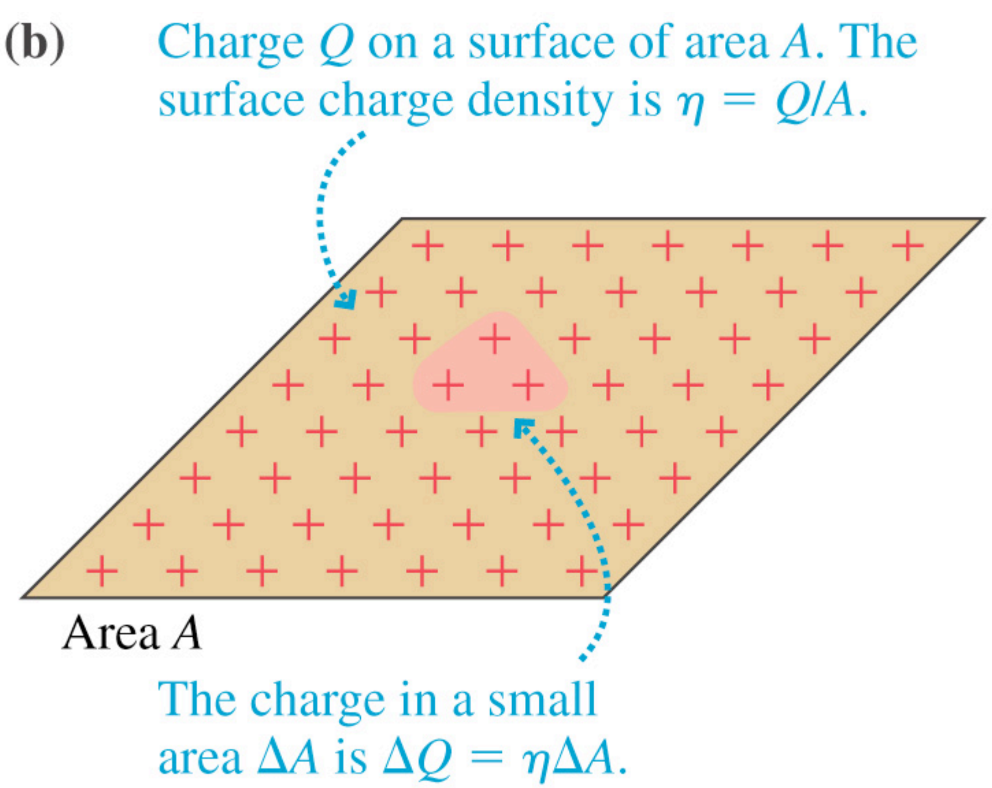
$$\Delta Q \rightarrow \text{density } \times dx$$

$(x \text{ describes shape of } \Delta Q)$

(a)

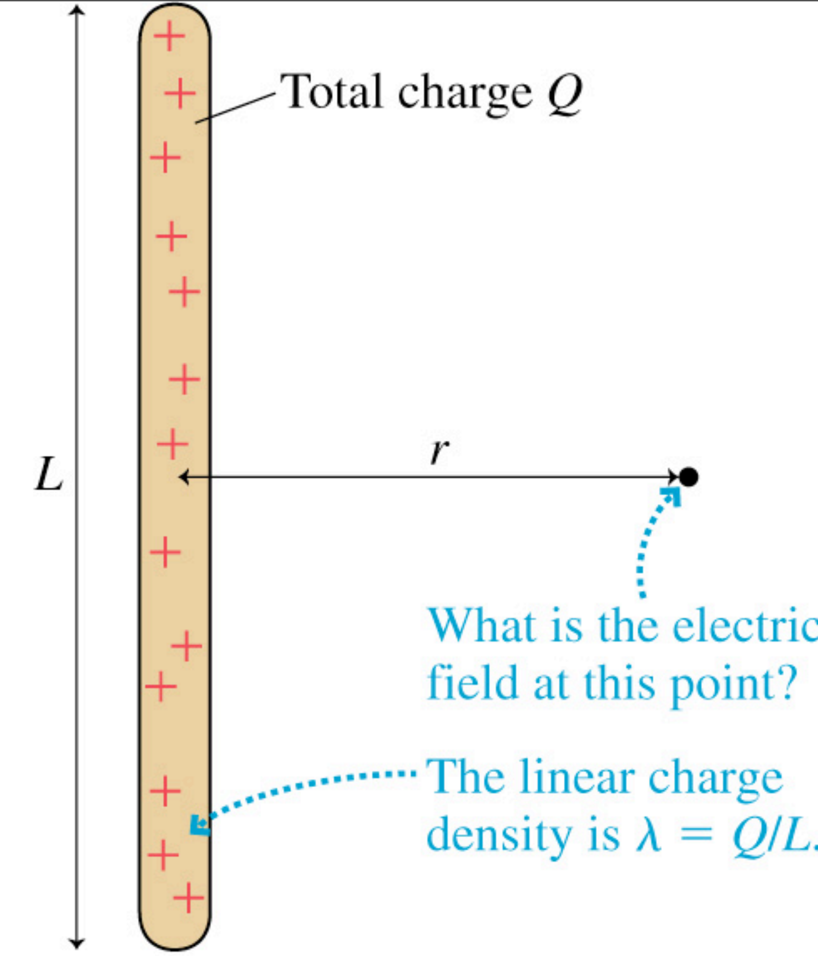


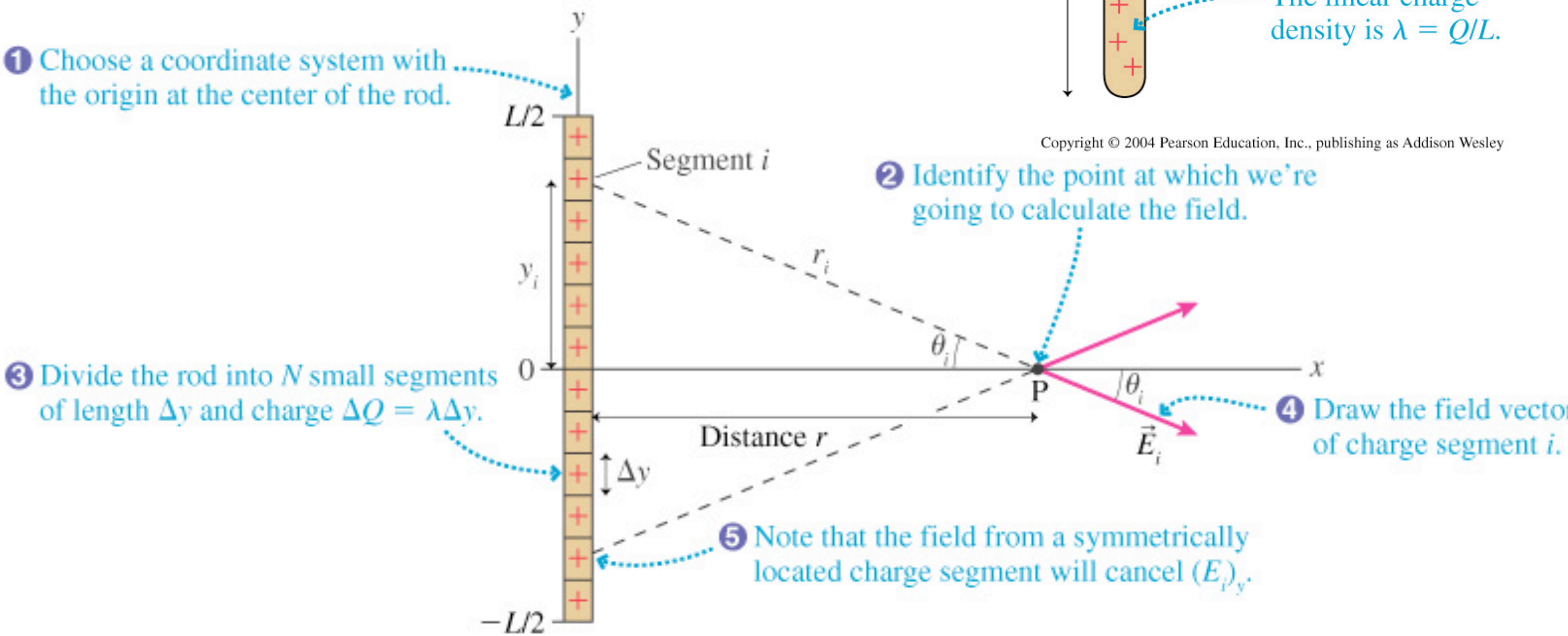
(b)



Electric Field of a Line of Charge

- Problem
- Strategy
- Solution...: $E_{rod} = \frac{1}{4\pi\epsilon_0}\frac{|Q|}{r\sqrt{r^2+(L/2)^2}}$





Infinite line of charge: $E_{line} = \lim_{L\to\infty}\frac{1}{4\pi\epsilon_0}\frac{|Q|}{r\sqrt{r^2+(L/2)^2}} = \frac{1}{4\pi\epsilon_0}\frac{|Q|}{rL/2} = \frac{1}{4\pi\epsilon_0}\frac{2|\lambda|}{r}$