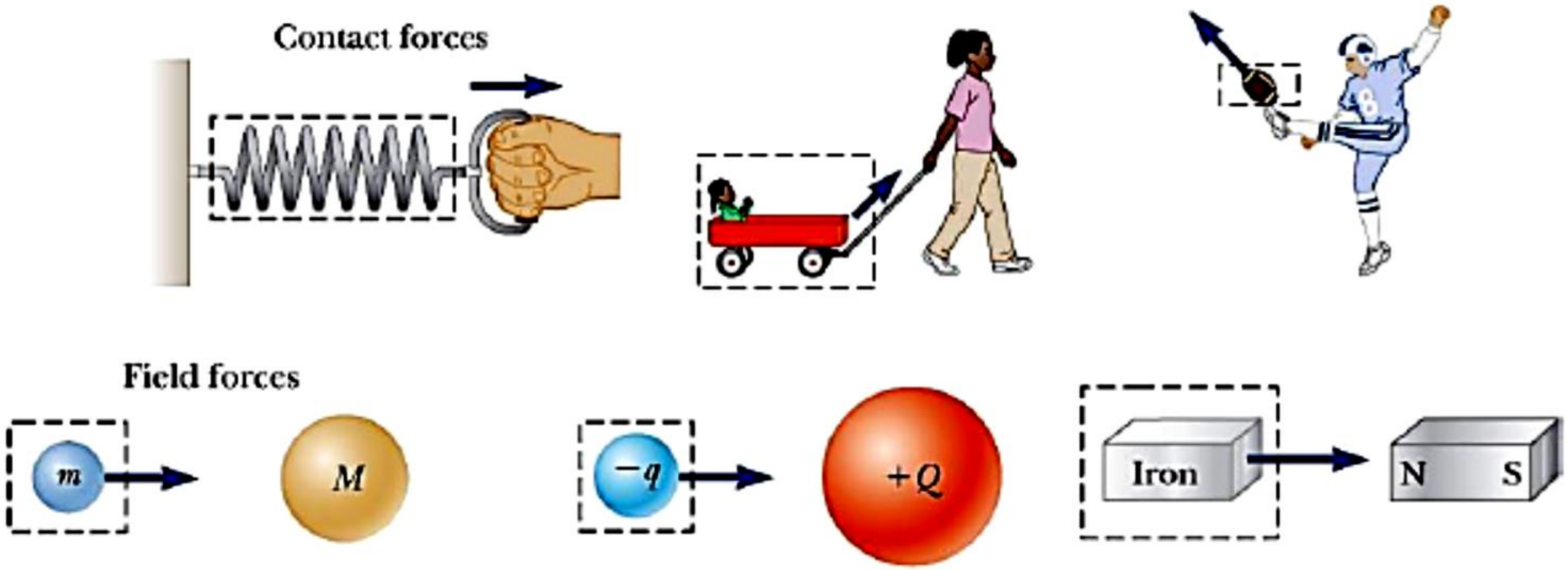
Chapter 2: Electric Field

- ✓ **Electric Field Due to a Point Charge**
- ✓ **Electric Fields Due to Multiple Charges**
- ✓ **Electric Field Lines**
- ✓ **Electric Field of a Continuous Charge Distribution**

Session 3:

- ✓ **Electric Field Due to a Point Charge**
- ✓ **Electric Fields Due to Multiple Charges**
- ✓ **Electric Field Lines**
- ✓ **Examples**

Introduction

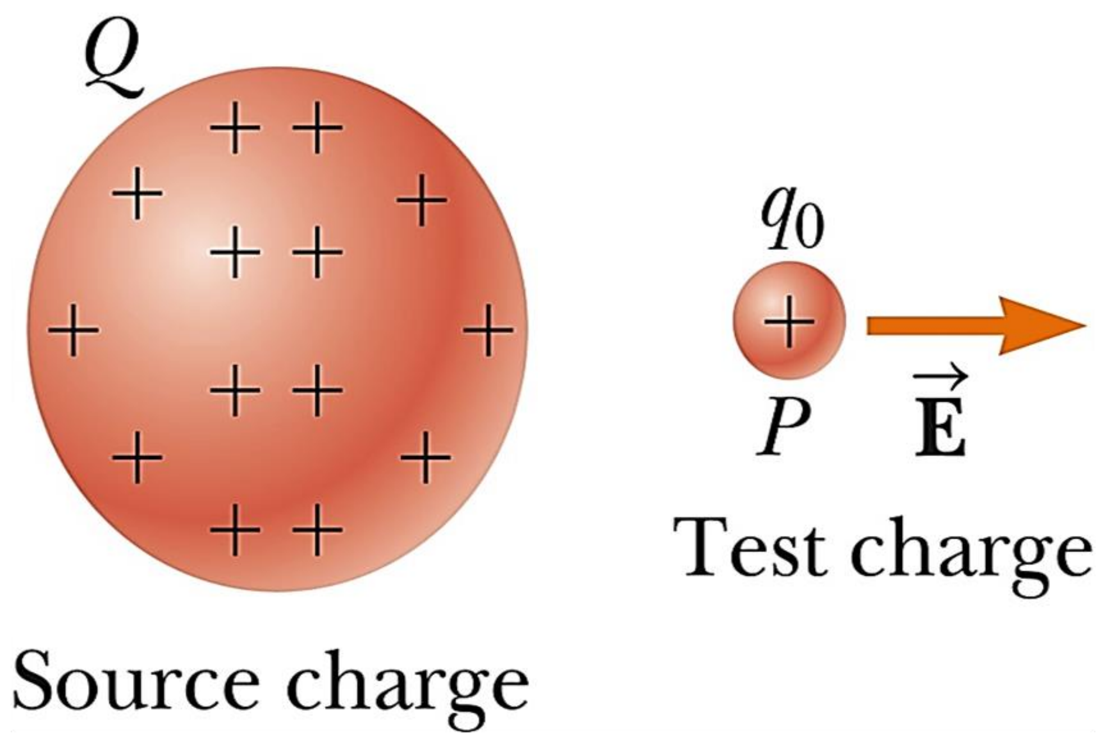


- ❑ The electric force is a **field force**.
- ❑ Field forces **can act through space**.
- ❑ An electric field is said to exist in the region of space **around a charged object**.
- ❑ When another charged object, the test charge, enters this electric field, an electric force acts on it.

Electric Field

❑ **The electric field is defined as the electric force on the test charge per unit charge.**

$$\vec{E} = \frac{\vec{F}_e}{q_o}$$



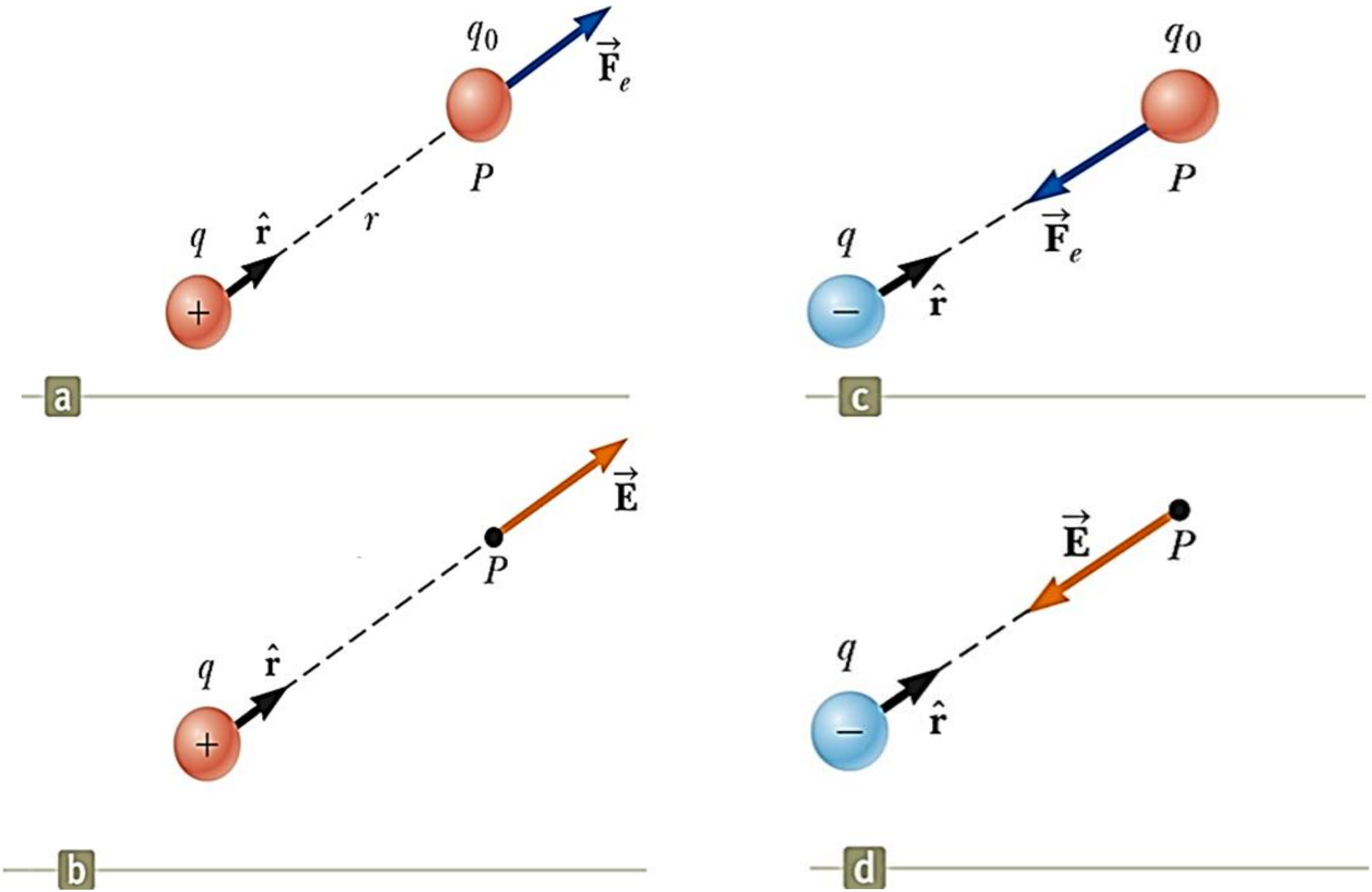
The SI units of $\vec{E}$ are N/C.

$$\vec{F}_e = q\vec{E}$$

This is valid for a point charge only.

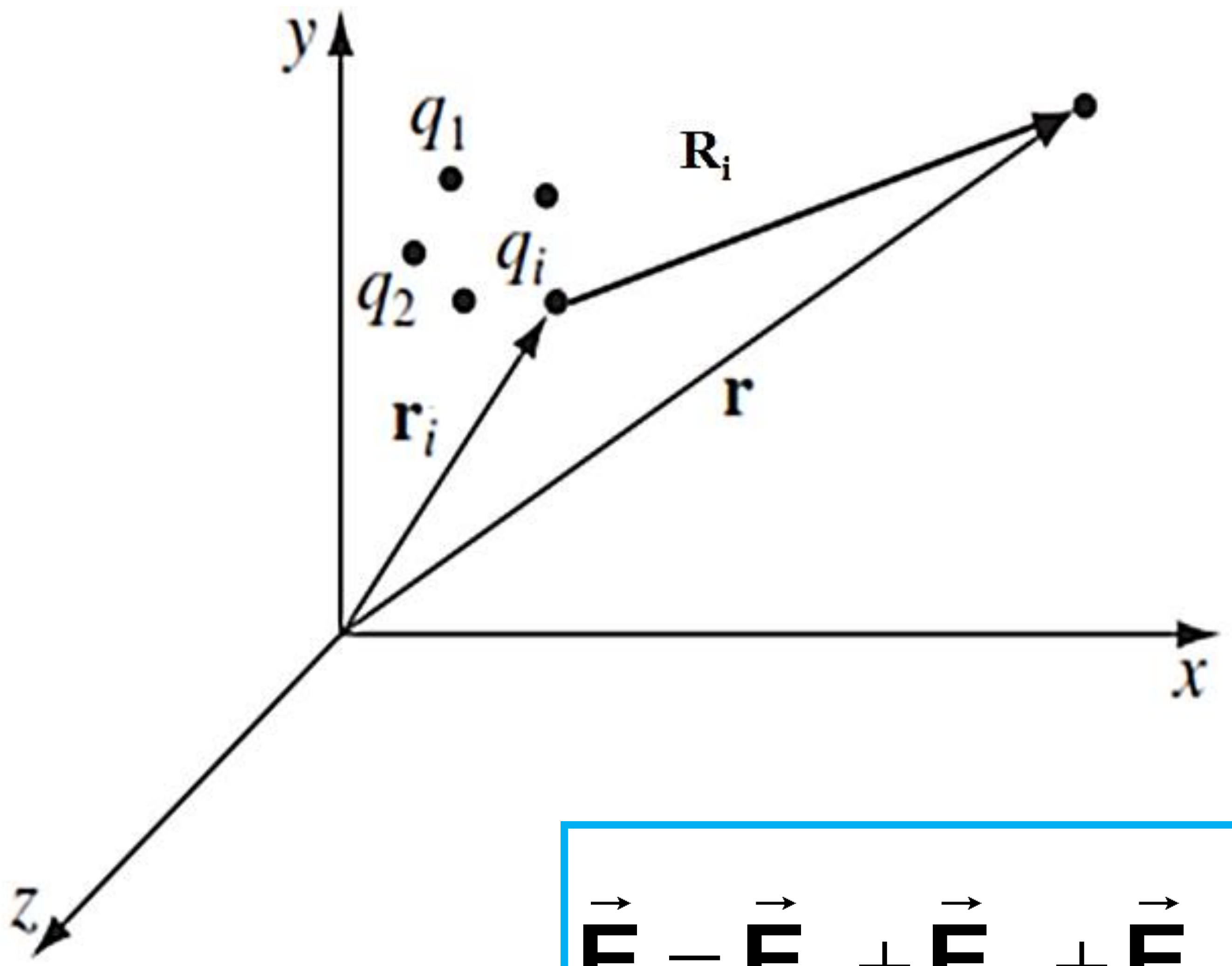
Electric Field Due to a Point Charge

$$\vec{\mathbf{F}}_e = k_e \frac{q q_o}{r^2} \hat{\mathbf{r}} \quad \Rightarrow \quad \vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}_e}{q_o} = k_e \frac{q}{r^2} \hat{\mathbf{r}}$$



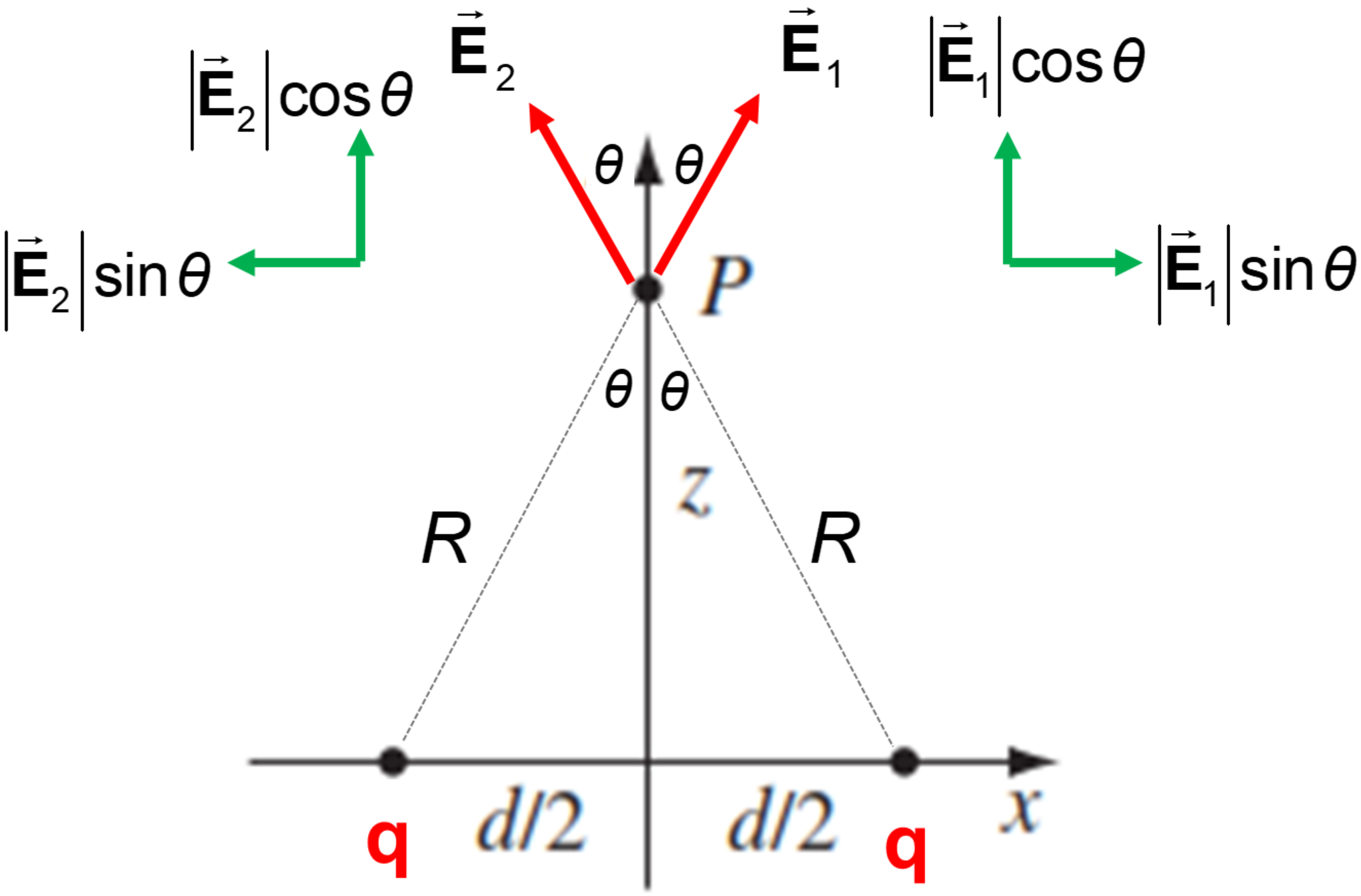
Electric Fields Due to Multiple Charges

At any point *P*, the total electric field due to a group of source charges equals the vector sum of the electric fields of all the charges.



$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2 + \vec{\mathbf{E}}_3 + \ldots = k_e \sum_i \frac{q_i}{R_i^{\,2}} \, (\hat{\mathbf{r}}_i)$$

Ex 1. Charges $q_1 = +q$ and $q_2 = +q$ are located on the x axis as shown in Figure. Find the electric field at the point P, which is at position **(0, z)**.



$$\vec{E}_p = \vec{E}_1 + \vec{E}_2$$

$$|\vec{E}_1| = |\vec{E}_1| = |\vec{E}| = k_e \frac{q}{R^2}$$

$$\vec{E}_p = 2|\vec{E}|\cos\theta \;\; \hat{z}$$

$$\cos\theta = \frac{z}{R}$$

$$\vec{E}_p = \frac{2k_e q z}{R^3}\;\hat{z} = \frac{2k_e q z}{(z^2 + (\frac{d}{2})^2)^{\frac{3}{2}}}\;\hat{z}$$

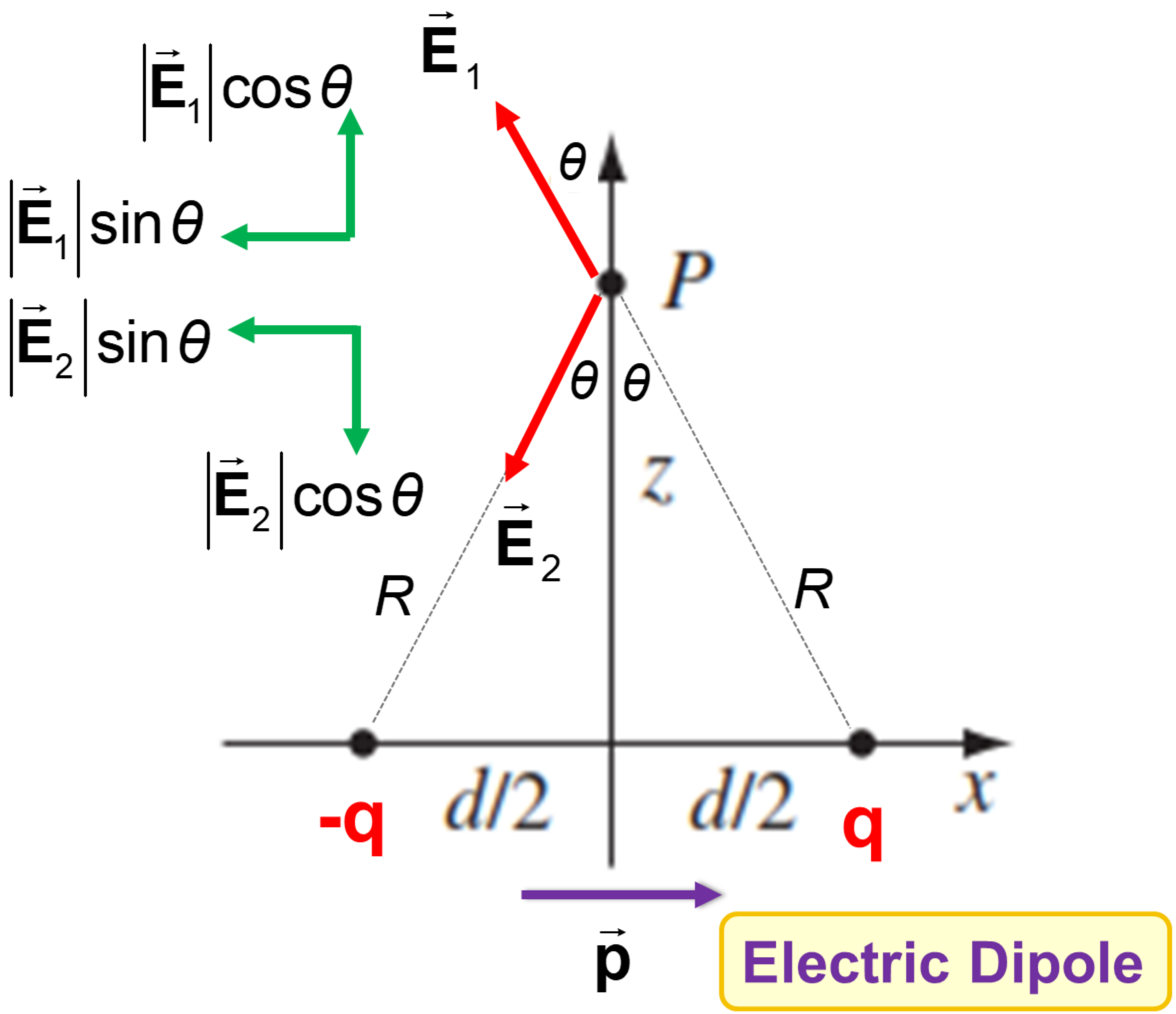
Ex 2. Charges $q_1 = +q$ and $q_2 = -q$ are located on the x axis as shown in Figure. Find the electric field at the point P, which is at position (0, z).

$$\vec{E}_p = \vec{E}_1 + \vec{E}_2$$

$$|\vec{E}_1| = |\vec{E}_1| = |\vec{E}| = k_e \frac{q}{R^2}$$

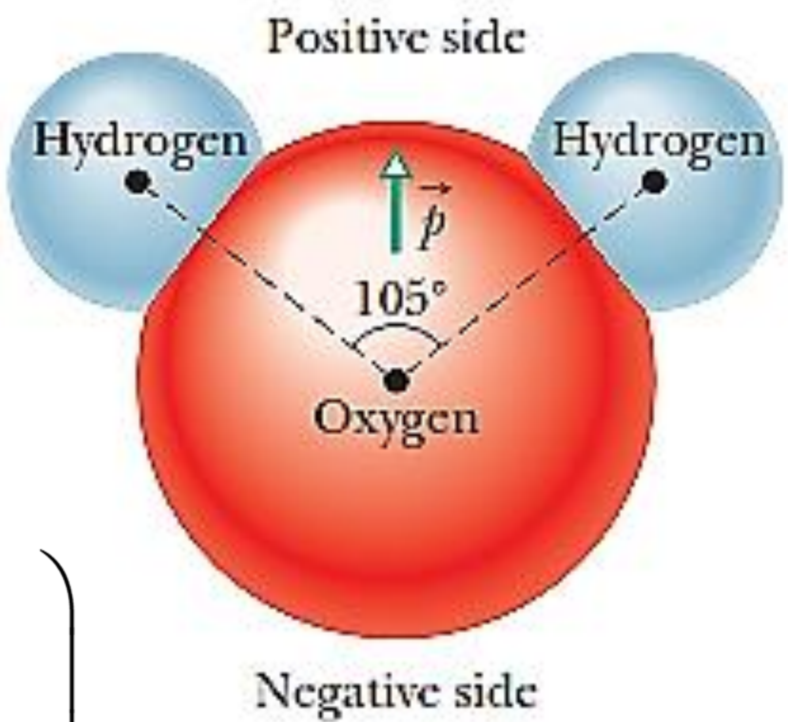
$$\vec{E}_p = 2|\vec{E}|\sin\theta \; (-\hat{x})$$

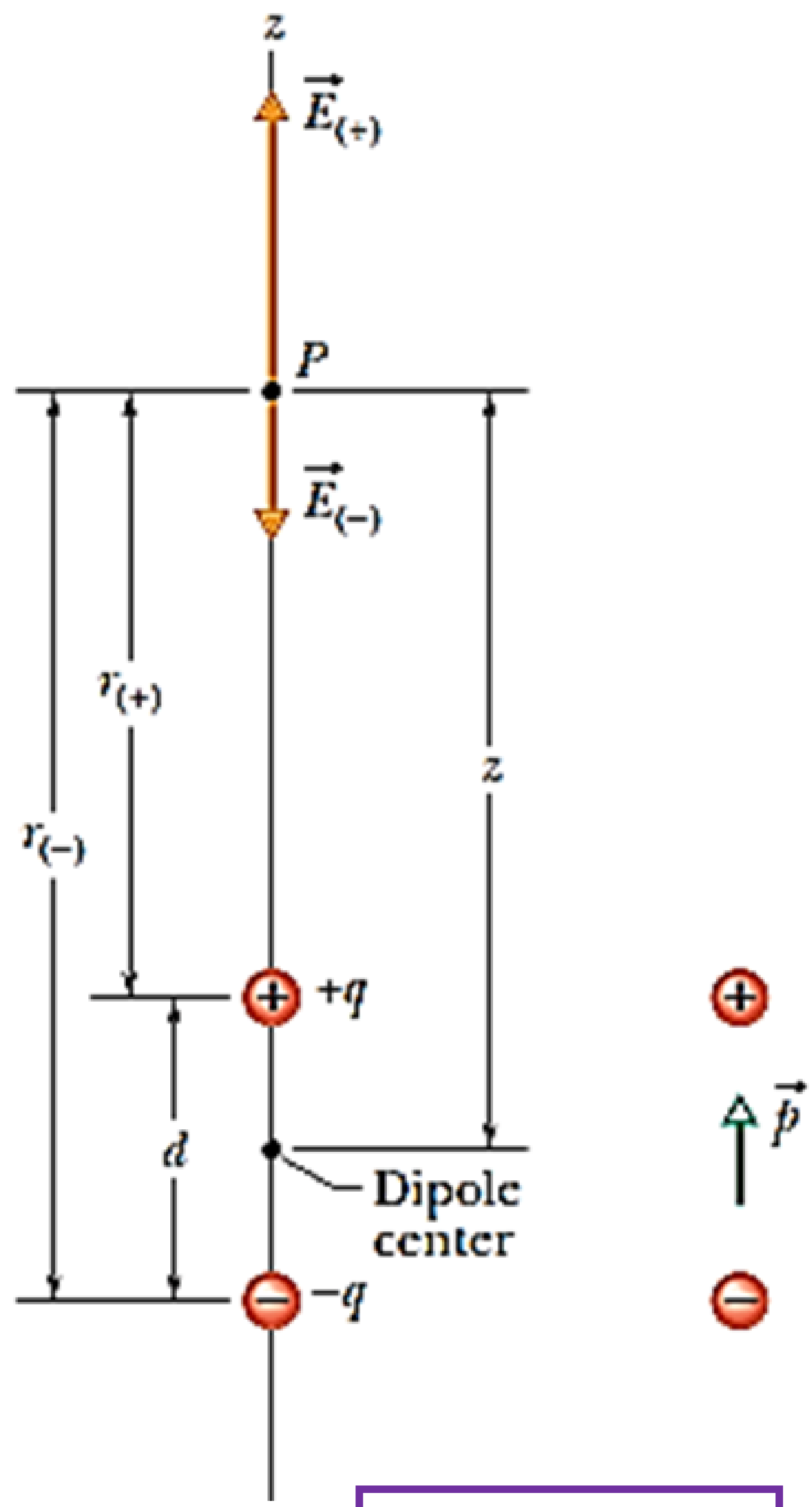
$$\sin\theta = \frac{d}{2R}$$



$$\vec{E}_p = \frac{k_e q d}{(z^2 + (\frac{d}{2})^2)^{\frac{3}{2}}} \; (-\hat{x}) = \frac{k_e p}{(z^2 + (\frac{d}{2})^2)^{\frac{3}{2}}} \; (-\hat{x})$$

Ex 3. Find the electric field of an **electric dipole** at the point P, which is at position **(0, z) on its axis**.





$$\vec{\mathbf{E}}_p = \vec{\mathbf{E}}_+ + \vec{\mathbf{E}}_-$$

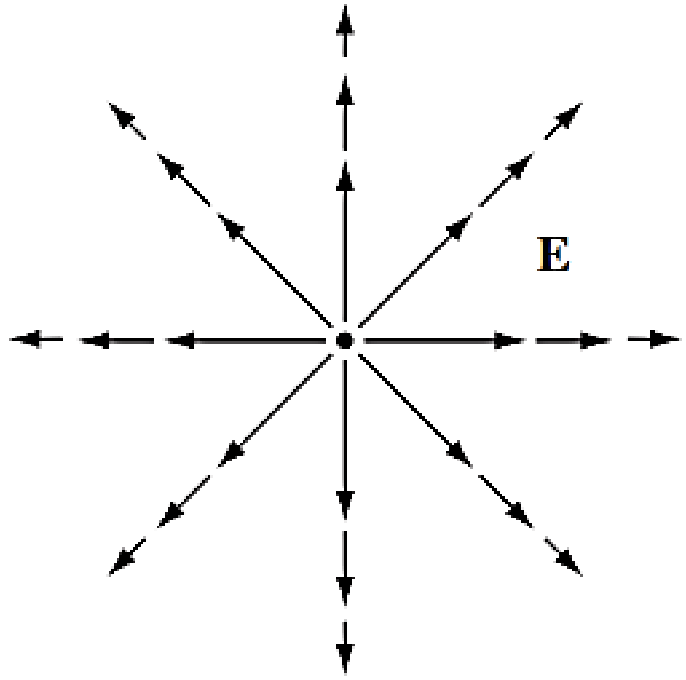
$$\vec{\mathbf{E}}_p = (\hat{z})\left(\frac{k_e q}{(z-\frac{d}{2})^2} - \frac{k_e q}{(z+\frac{d}{2})^2}\right)$$

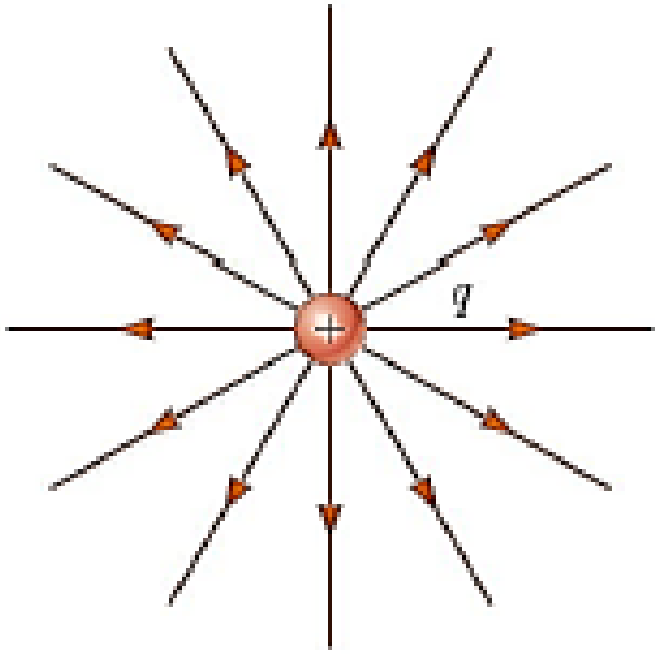
$$\vec{\mathbf{E}}_p = (\hat{z})\left(\frac{k_e q(2zd)}{(z^2-(\frac{d}{2})^2)^2}\right) = \frac{2k_e \vec{\mathbf{p}}\, z}{(z^2-(\frac{d}{2})^2)^2}$$

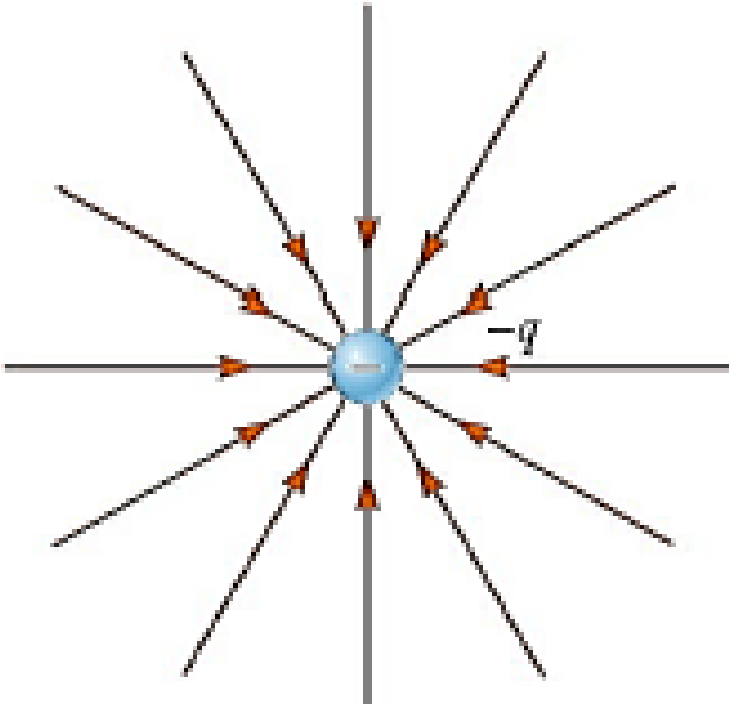
$$\vec{\mathbf{p}} = qd\,(\hat{z})$$

$$z \gg d \qquad \vec{\mathbf{E}}_p \approx \frac{2k_e \vec{\mathbf{p}}}{z^3}$$

Electric Fields Lines



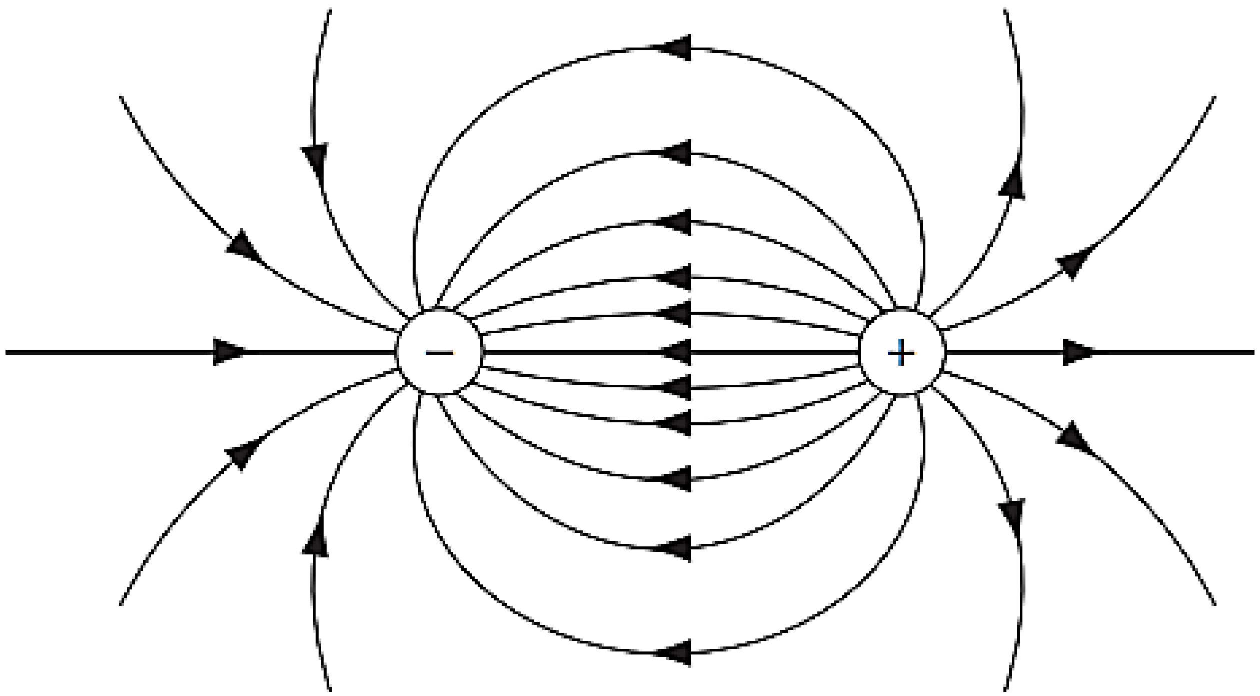




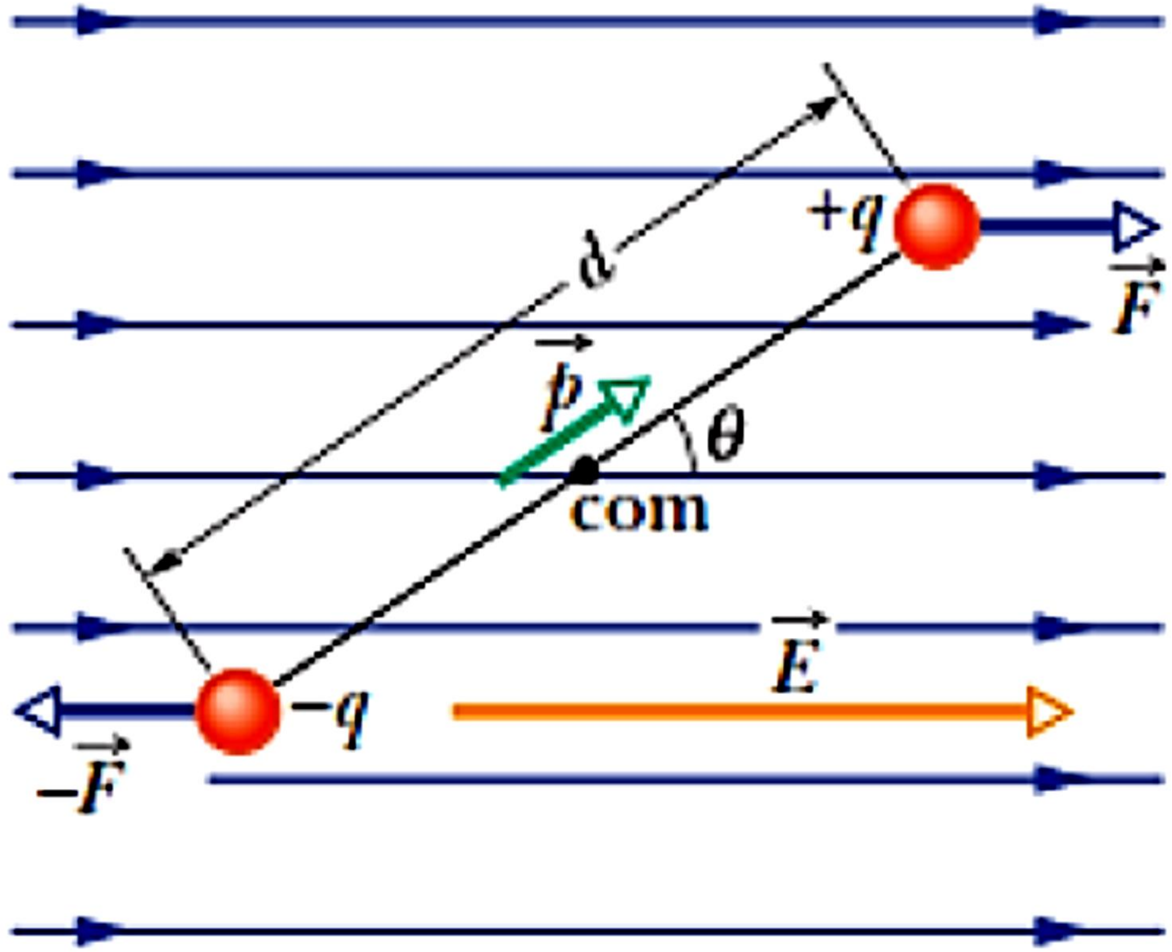
Point Charge (Electric Monopole)

$$\vec{\mathbf{E}} = k_e \frac{q}{r^2}\hat{\mathbf{r}}$$

Electric Dipole



Dipole in an Electric Field



$$\tau_{net} = F\frac{d}{2}\sin\theta + F\frac{d}{2}\sin\theta = Fd\sin\theta$$

$$\tau_{net} = (qE)d\sin\theta = qd\,E\sin\theta = pE\sin\theta$$

$$\boxed{\vec{\tau}_{net} = \vec{\mathbf{p}} \times \vec{\mathbf{E}}}$$