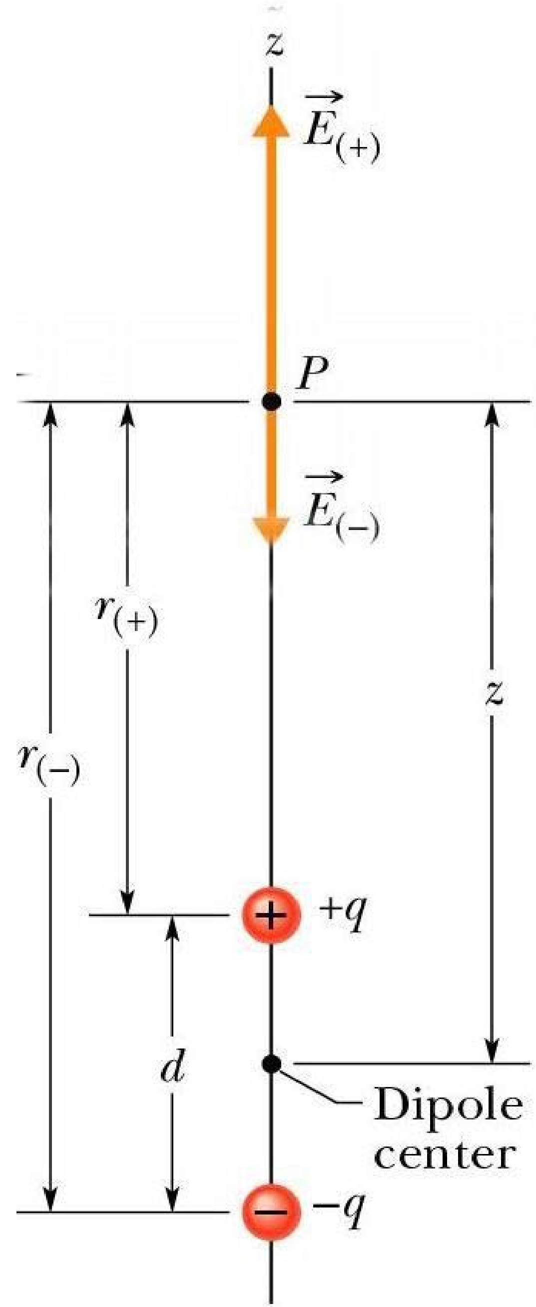
Electric Dipole

- Electric dipole – two equal magnitude, opposite charged particles separated by distance d
- What's the electric field at point P due to the dipole?



Electric Dipole

- Approximate *E* field for a dipole is

$$E = \frac{2\,kqd}{z^3}$$

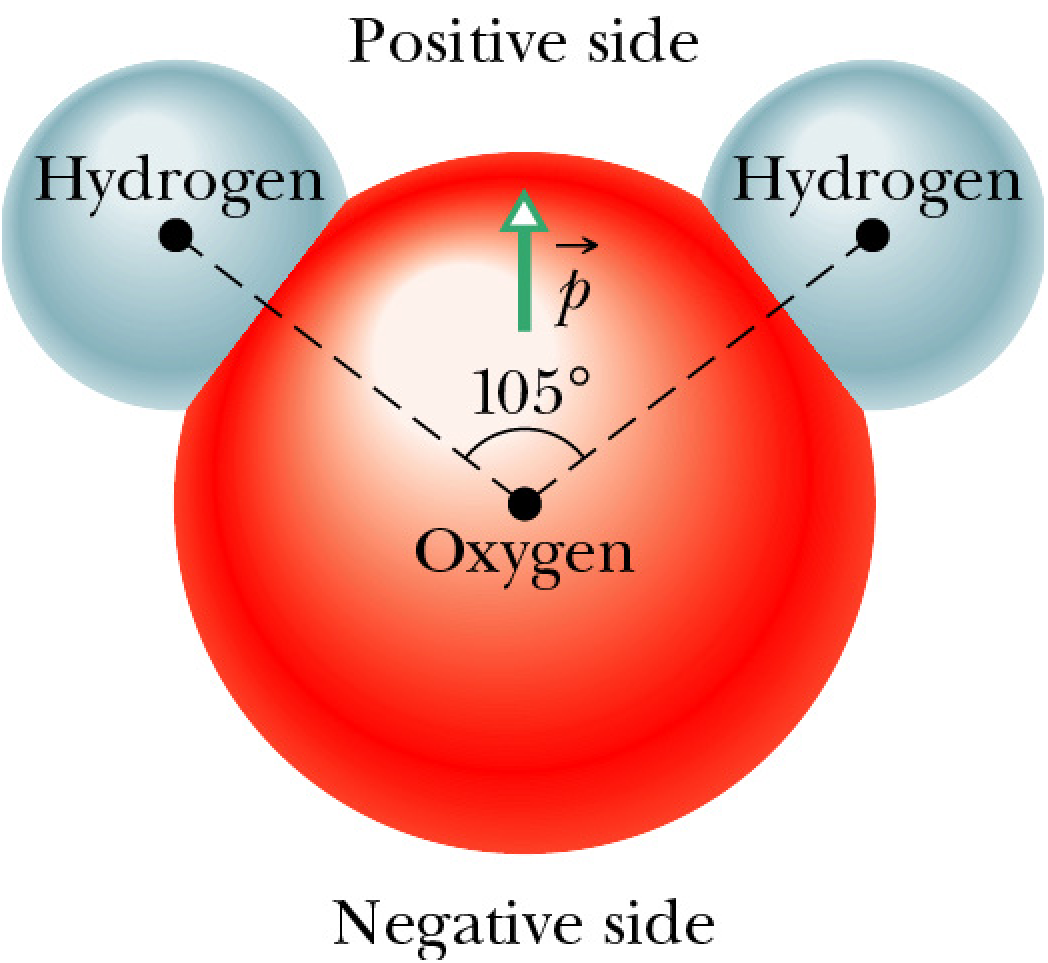
- Define electric dipole moment, *p* as,

$$\vec{p} = q\,\vec{d}$$

- The direction of *p* and *d* is from the negative to positive

- E field along dipole axis at large distances (z>>d) is

$$E = \frac{2kp}{z^3}$$



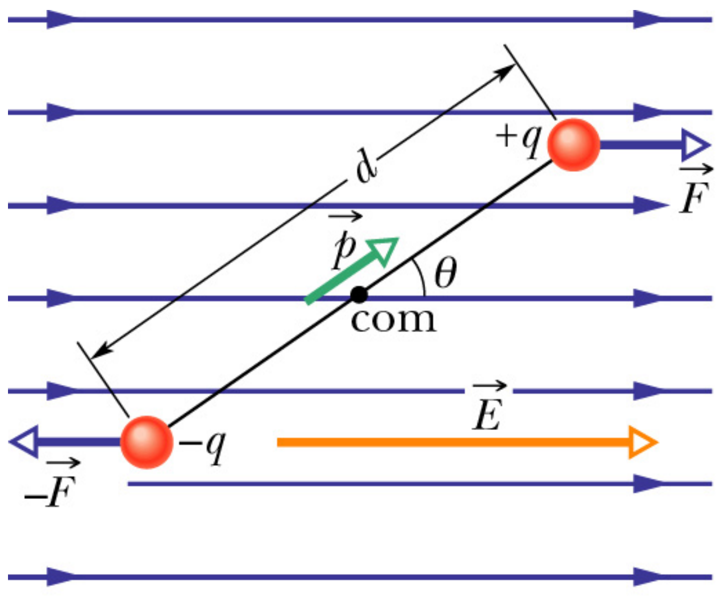
Positive side
Hydrogen
Hydrogen
$\vec{p}$
105°
Oxygen
Negative side

Electric Dipole in an E-field

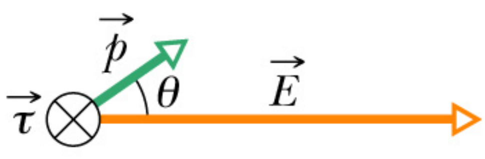
- What happens when a dipole is put in an electric field? (com = center of mass)

- Net force, from uniform *E*, is zero

- But force on charged ends produces a net torque about its center of mass



(a)



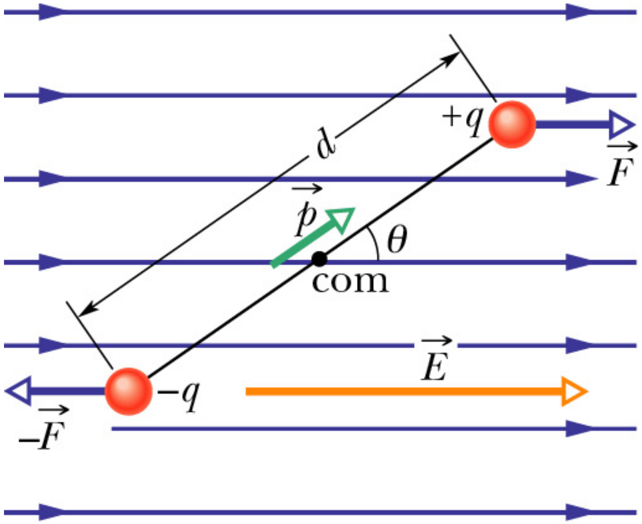
(b)

Torque on an Electric Dipole

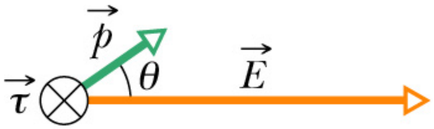
- Definition of torque $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} = rF\sin\phi$

- For dipole rewrite it as

$$\tau = xF\sin\theta + (d - x)F\sin\theta$$
$$= d\ F\sin\theta = (qd)(F/q)\sin\theta$$



(a)

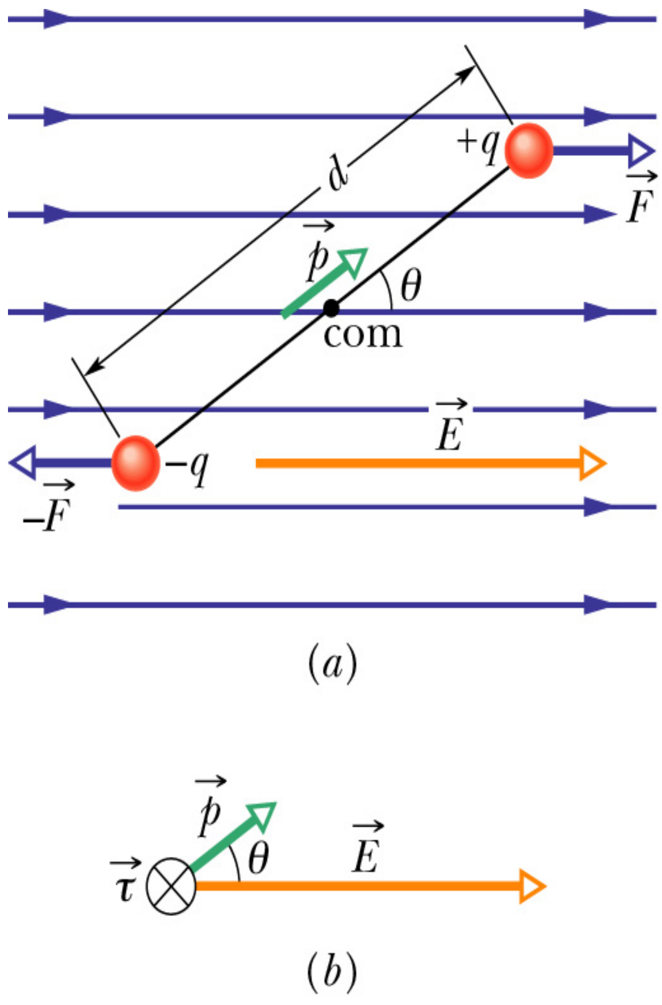


(b)

Thus: $\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$

Torque on an Electric Dipole

- Torque acting on a dipole tends to rotate *p* into the direction of *E*
- Associate potential energy, *U*, with the orientation of an electric dipole in an *E* field
- Dipole has least *U* when *p* is lined up with *E*



Energy Stored in an Electric Dipole

- Remember

$$U = -W = -\int_{90}^{\theta} \tau d\theta = \int_{90}^{\theta} pE \sin\theta d\theta$$

- Potential energy of a dipole

$$U = -pE\cos\theta = -\mathbf{p} \bullet \mathbf{E}$$

- *U* is least (greatest) when p and E are in same (opposite) directions

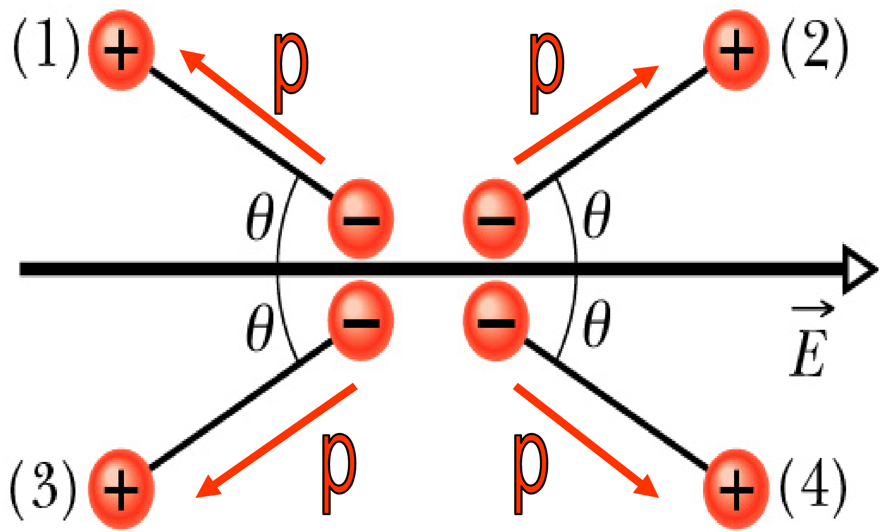
Exercise

- Rank a) magnitude of torque and b) U, greatest to least

$$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E} = pE \sin\theta$$

- a) Magnitudes are same

$$U = -\mathbf{p} \bullet \mathbf{E} = -pE\cos\theta$$



- U greatest at θ=180
- b) 1 & 3 tie, then 2 &4