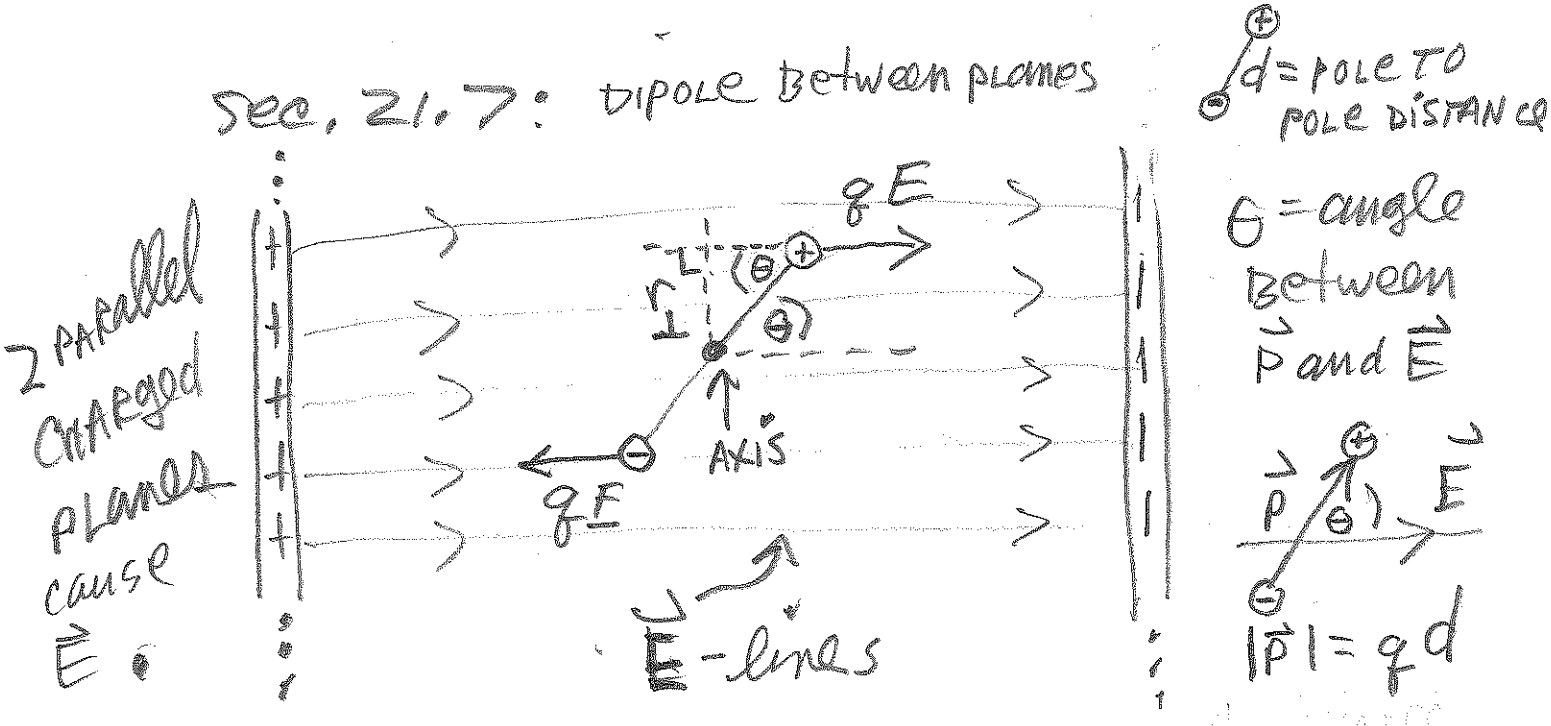
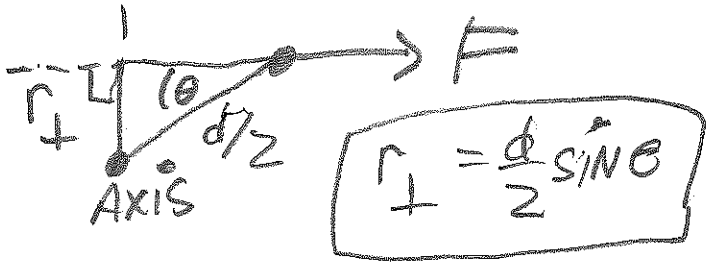
Section 21.7 Dipoles

Applications: electromagnetic radiation in your body which is 70% H_2O - a POLAR molecule, the ammonia molecule, and a general analogy to MRI

(magnetic resonance imaging
⇒ see magnetic dipoles in CH 27 - p903: $\vec{\tau} = \vec{\mu} \times \vec{B}$
just like $\vec{\tau} = \vec{p} \times \vec{E}$ in CH 21)





$\vec{\tau}$ (OUT OF PAGE)

$r_\perp = \frac{d}{2}\sin\theta$

$|\tau_z| = |\vec{\tau}| = 2 r_\perp \cdot F$

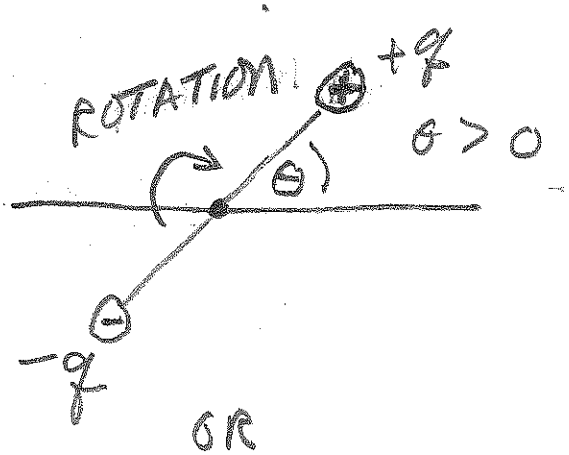
$|\vec{\tau}| = 2 \cdot \frac{d}{2} \cdot \sin\theta \cdot qE$

$|\vec{\tau}| = |\tau_z| = d\sin\theta\, qE$

$|\tau_z| = pE\sin\theta$

$p = q \cdot d$

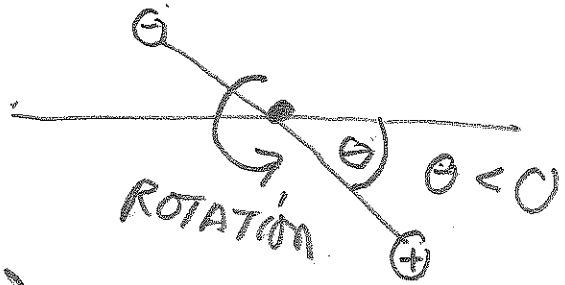
$\boxed{\tau_z = -pE\sin\theta}$



$\tau_z < 0$ IF ↻

$\tau_z > 0$ IF ↺

OR



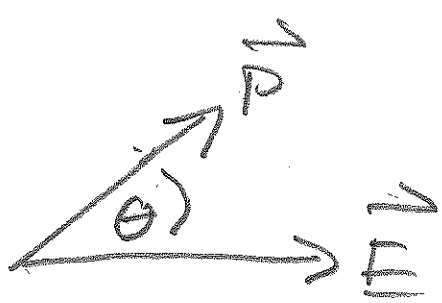
VECTOR FORM:

$\vec{\tau} = \vec{p} \times \vec{E}$

$|\vec{p}| = qd$

Use right hand rule for $\vec{\tau}$-direction.

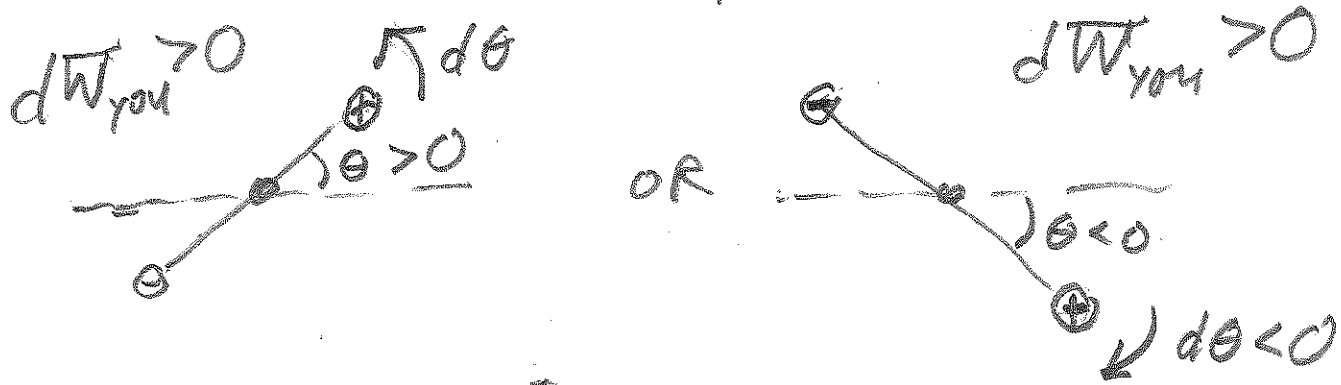
$|\vec{\tau}| = pE\sin\theta$



$p = |\vec{p}|, \quad E = |\vec{E}|$

Potential energy: $U = -pE\cos\theta$

$dU \equiv dW_{you}$ = work you do to twist dipole $d\theta$ against the torque of fields.



$dW_{you} = pE\sin\theta\, d\theta = -\hat{\tau}_z \cdot d\theta$

NOTE: $-\hat{\tau}_z \cdot d\theta = -(-pE\sin\theta)d\theta = pE\sin\theta d\theta$

Review Math 1, 2: CONSTANT

$$U = \int dW_{you} + C$$

$$U = \int PE \sin\theta \, d\theta + C$$

$$U = -PE\cos\theta + C$$

Let's get C through book's choice:

AT $\theta = 0$, let $U = -PE$.

THUS, $U(0) = -PE = -PE\cos 0 + C$

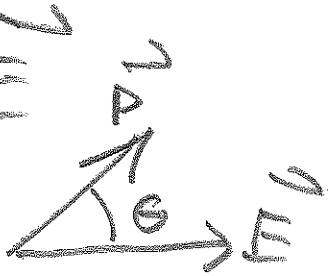
BUT $\cos 0 = 1$

THUS $U(0) = -PE = -PE + C$

and $C = 0$.

$$\Rightarrow U(\theta) = -PE\cos\theta$$

VECTOR FORM: $U(\theta) = -\vec{P} \cdot \vec{E}$



PLOT: