21.7: Electric Dipoles

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October 19, 2024

Definition: (Electric Dipoles) **Electric dipoles** are pairs of opposite point charges separated by a distance d.

When placed in an electric field, dipoles will not move, but experience a torque as they try to align with the field.

The torque is calculated with respect to the center of the dipole. If ϕ is the angle between the electric field and the dipole's axis, then the force acting on one charge is $\frac{qEd\sin\phi}{2}$, but since there are two charges, with torques acting in the same direction, the total torque on the dipole is

$$qEd\sin\phi$$

Definition: (Dipole Moment) We define the **electric dipole moment**, $\vec{p}$, as $p = q\vec{d}$, or the magnitude of the charges times the displacement between them. The unit for the dipole moment is Coulomb-meters.

We can now define $\tau = |\vec{p}|E\sin\phi$, or alternatively,

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

0.1 Potential Energy of a Dipole

The work done by torque is negative, because the angle ϕ is decreasing.

$$dW = \tau d\phi = -pE\sin\phi d\phi$$

and as such,

$$W = pE\cos(\Delta\phi) = -U$$

We can rewrite this as a dot product:

$$U = -\vec{p}\cdot\vec{E}$$

If a dipole isn't uniform, the net force on the dipole in a field may be nonzero.