

◆ TERMS & DEFINITIONS

Term	Definition
Electric Dipole	A pair of equal and opposite charges separated by a small distance.
Dipole Moment (\vec{p})	A vector quantity pointing from negative to positive charge, measuring dipole strength.
Axial Line	The line passing through both charges of the dipole.
Equatorial Line	The line perpendicular to the dipole axis and passing through the midpoint.
Uniform Electric Field	An electric field that has the same magnitude and direction at every point.
Torque on Dipole	A turning effect experienced by a dipole in an electric field.

◆ SYMBOLS

Symbol	Meaning
q	Magnitude of each charge in dipole
$2a$	Distance between charges (dipole length)
\vec{p}	Dipole moment vector = $q \times 2a$
r	Distance from center of dipole to field point
θ	Angle between \vec{p} and \vec{E}
\vec{E}	Electric field vector
$\vec{\tau}$	Torque vector

◆ CONSTANTS

Constant	Symbol	Value	Unit
Vacuum permittivity	ϵ_0	8.854×10^{-12}	$C^2/N \cdot m^2$

◆ FORMULAS

1. Dipole Moment

$$\vec{p} = q \times 2a \cdot \hat{p}$$

- Vector from $-q$ to $+q$
- Units: C·m

2. Electric Field due to Dipole

(i) On Axial Line:

$$E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{2p}{r^3}$$

(ii) On Equatorial Line:

$$E_{\text{equatorial}} = \frac{1}{4\pi\epsilon_0} \cdot \frac{p}{r^3} \quad (\text{opposite to } \vec{p})$$

(iii) General Point:

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \cdot \frac{1}{r^3} [3(\vec{p} \cdot \hat{r})\hat{r} - \vec{p}]$$

3. Torque on Dipole in Uniform Electric Field

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

- Magnitude: $\tau = pE \sin \theta$
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4. Potential Energy of Dipole in Uniform Electric Field

$$U = -\vec{p} \cdot \vec{E} = -pE \cos \theta$$

5. Net Force on Dipole

- In uniform \vec{E} : Net force = 0
 - In non-uniform \vec{E} : Dipole experiences a net force (direction depends on gradient)
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