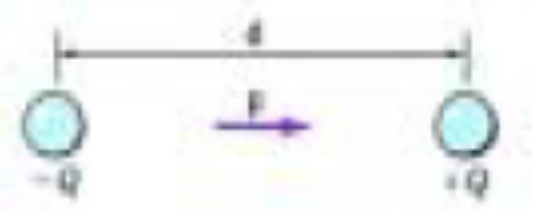
Lecture - 18

- Capacitance C is defined as: $C \equiv \frac{Q}{V}$
- The work necessary to charge a capacitor upto charge Q: $W = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$

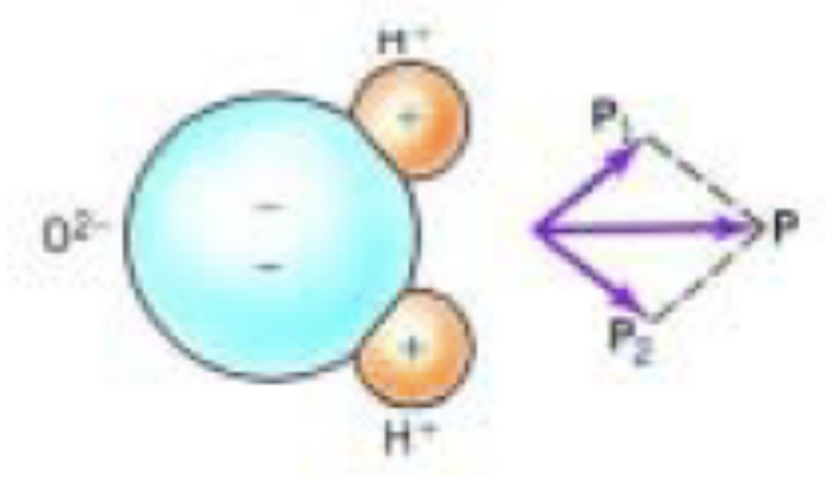
Dipoles

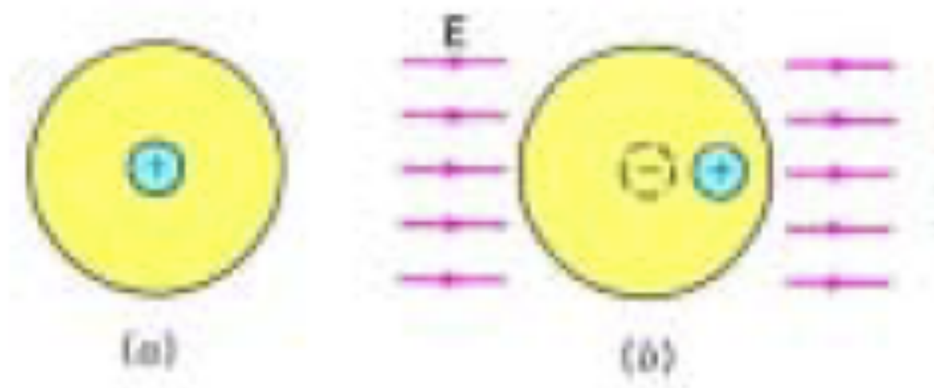


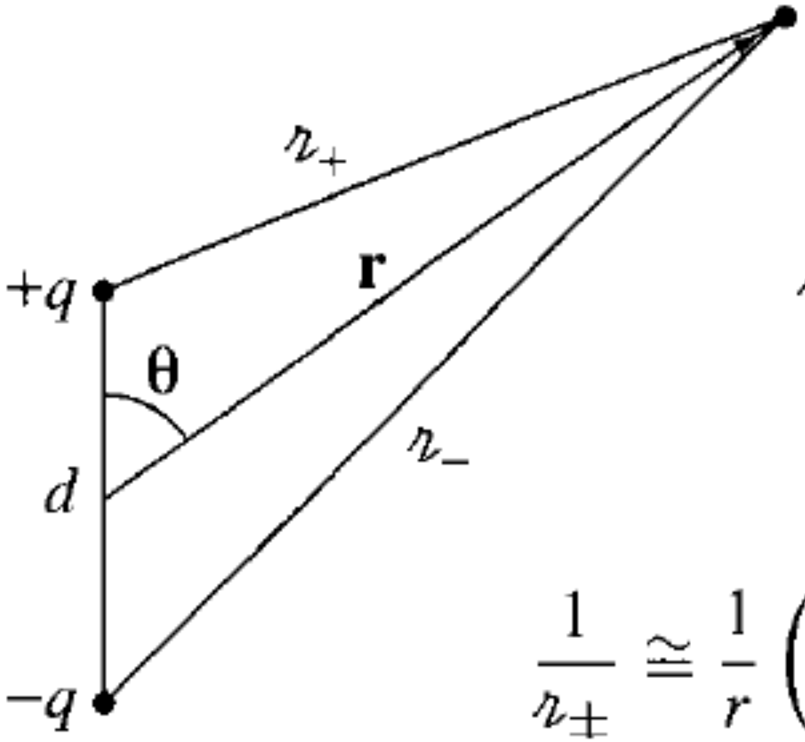
What is dipole? The arrangement of a pair of equal and opposite charges separated by some distance is called an electric dipole.

Permanent dipole: such as molecules of HCl, CO, and H_2O.

Induced dipole: An electric field may also induce a charge separation in an atom or a nonpolar molecule.







$$V(\mathbf{r}) = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{\mathscr{r}_+} - \frac{q}{\mathscr{r}_-}\right)$$

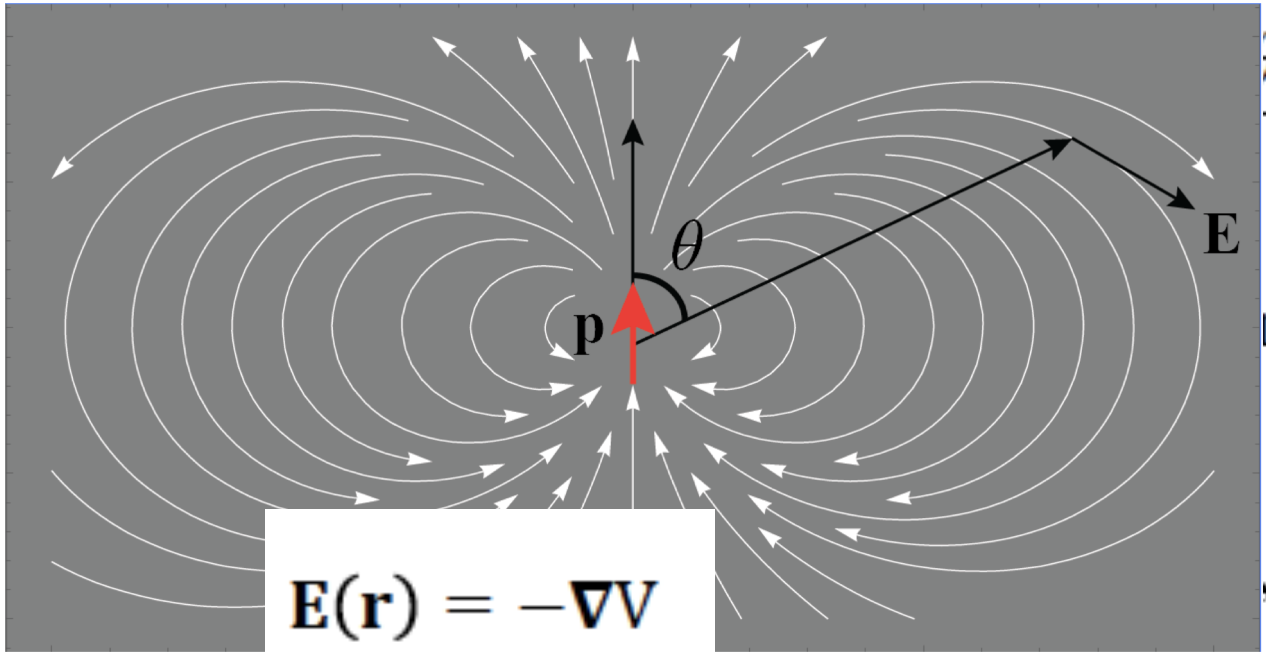
$$\mathscr{r}_\pm^2 = r^2 + (d/2)^2 \mp rd\cos\theta = r^2\left(1 \mp \frac{d}{r}\cos\theta + \frac{d^2}{4r^2}\right).$$

$$\frac{1}{\mathscr{r}_\pm} \cong \frac{1}{r}\left(1 \mp \frac{d}{r}\cos\theta\right)^{-1/2} \cong \frac{1}{r}\left(1 \pm \frac{d}{2r}\cos\theta\right).$$

$r \gg d.$

$$\frac{1}{\mathscr{r}_+} - \frac{1}{\mathscr{r}_-} \cong \frac{d}{r^2}\cos\theta,$$

$$V(\mathbf{r}) \cong \frac{1}{4\pi\epsilon_0}\frac{qd\cos\theta}{r^2}.$$



$$\mathbf{E}(\mathbf{r}) = -\boldsymbol{\nabla} \mathrm{V}$$

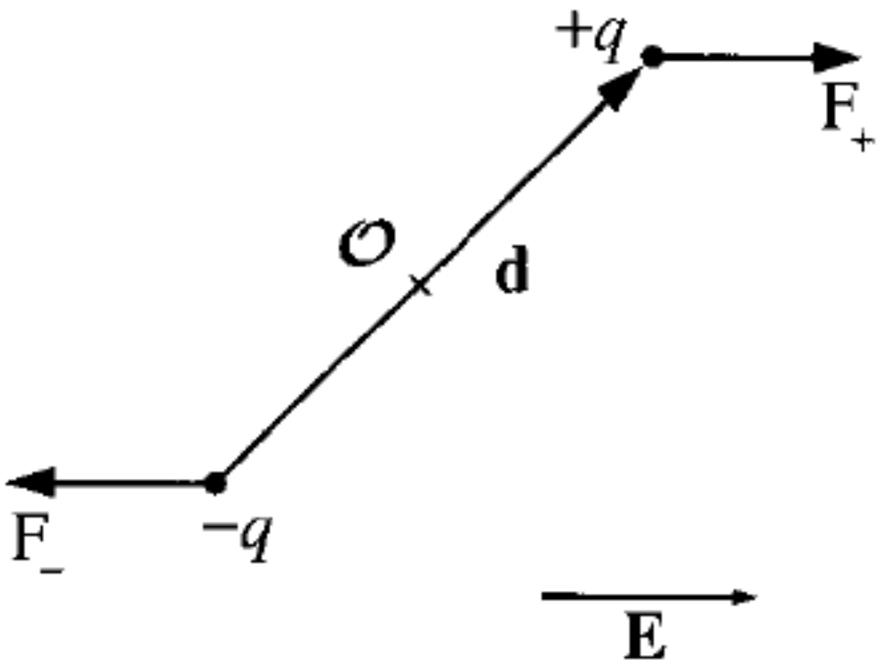
$$\theta = \frac{1}{4\pi\varepsilon_0}\frac{\hat{\mathbf{r}}\cdot\mathbf{p}}{r^2} = \frac{p}{4\pi\varepsilon_0}\frac{\cos\theta}{r^2}$$

ng form negative charge to the positive charge.

$$, \theta) = \frac{\hat{\mathbf{r}}\cdot\mathbf{p}}{4\pi\epsilon_0 r^2} = \frac{p\cos\theta}{4\pi\epsilon_0 r^2}.$$

$$\begin{aligned}
E_r &= -\frac{\partial V}{\partial r} = \frac{2p\cos\theta}{4\pi\epsilon_0 r^3}, \\
E_\theta &= -\frac{1}{r}\frac{\partial V}{\partial\theta} = \frac{p\sin\theta}{4\pi\epsilon_0 r^3}, \\
E_\phi &= -\frac{1}{r\sin\theta}\frac{\partial V}{\partial\phi} = 0.
\end{aligned}$$

$$\boxed{\mathbf{E}_{\mathrm{dip}}(r,\theta) = \frac{p}{4\pi\epsilon_0 r^3}(2\cos\theta\,\hat{\mathbf{r}} + \sin\theta\,\hat{\boldsymbol{\theta}}).}$$



$$\mathbf{F}_+ = q\mathbf{E},$$

$$\mathbf{F}_- = -q\mathbf{E}$$

$$\begin{aligned}\mathbf{N} &= (\mathbf{r}_+ \times \mathbf{F}_+) + (\mathbf{r}_- \times \mathbf{F}_-) \\ &= [(\mathbf{d}/2) \times (q\mathbf{E})] + [(-\mathbf{d}/2) \times (-q\mathbf{E})] = q\mathbf{d} \times \mathbf{E}.\end{aligned}$$

$$\boxed{\mathbf{N} = \mathbf{p} \times \mathbf{E}.}$$

Most everyday objects belong to one of two large classes: **conductors** and **insulators** (or **dielectrics**)

Conductors : Substances contains an “unlimited” supply of charges that are free to move about through the material.

Dielectrics : all charges are attached to specific atoms or molecules. All they can do is move a bit within the atom or molecule.

Dielectrics : Microscopic displacements are not as dramatics as the wholesale rearrangement of charge in conductor, but their **cumulative effects** account for the characteristic behavior of dielectric materials.