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Electric field & Potential

Electric field : Electric field at any point may be defined as the force experienced by a unit positive charge placed at that ~~time~~ point.

$$\vec{E} = \frac{\Delta \vec{F}}{\Delta q}$$ Newton per coulomb

Potential : The electric potential at any point in an electric field is defined as the work done in taking a unit positive charge from infinitely to that point against the electrical forces.

$$E = -\frac{dV}{dx}$$

Electric dipole : An electric dipole is a system of two point charges of equal magnitude but opposite nature seperated by infinitesimally small distance.

Dipole moment : An electric dipole moment (P) is defined as a vector whose magnitude is $2ql$ and which is directed from negative charge to the positive charge, i.e $P = 2ql\hat{p}$ where $\hat{p}$ is the unit vector along the axis of the dipole.

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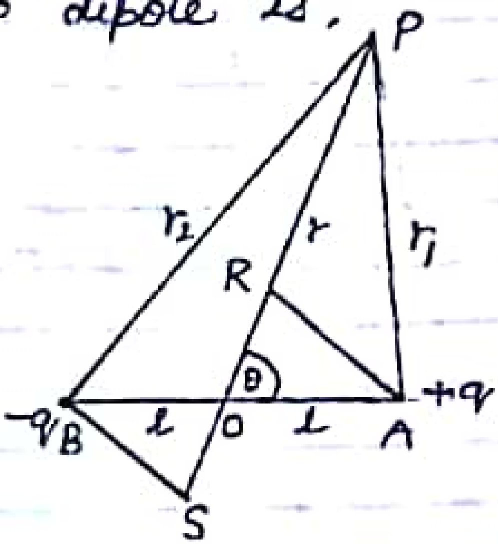
Potential at a point due to dipole :

Let us consider an electric dipole consisting of $-q$ and $+q$ seperated by a distance $2l$. Then the potential at $P(r, \theta)$ due to dipole is,



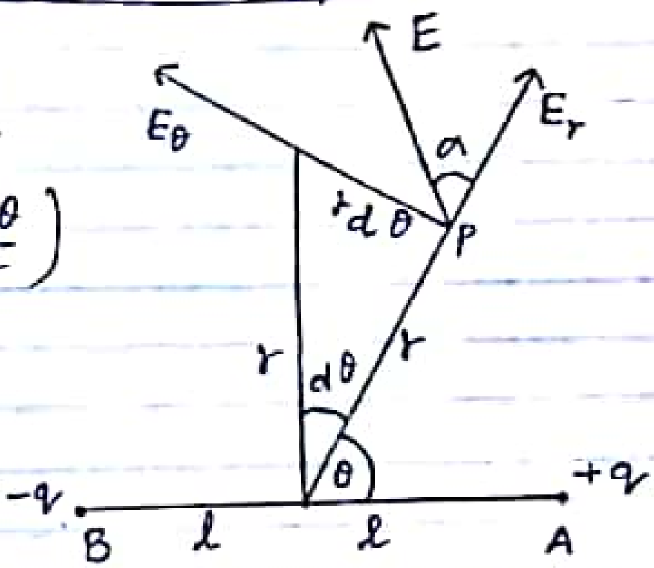
$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{r_1} - \frac{q}{r_2}\right) = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r - l\cos\theta} - \frac{1}{r + l\cos\theta}\right)$$

$$= \frac{q}{4\pi\epsilon_0} \frac{2l\cos\theta}{r^2 - l^2\cos^2\theta}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{P\cos\theta}{r^2}$$ (neglecting $l^2\cos^2\theta$ which is small).

Intensity at any point due to a dipole :



Potential at $P = \frac{1}{4\pi\epsilon_0} \cdot \frac{P\cos\theta}{r^2}$.

$$E_r = -\frac{dV}{dr} = \frac{-d}{dr} \cdot \frac{1}{4\pi\epsilon_0}\left(\frac{P\cos\theta}{r^2}\right)$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{2P\cos\theta}{r^3}.$$

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and $E_\theta = -\frac{dv}{r\,d\theta} = -\frac{1}{r}\frac{d}{d\theta}\cdot\frac{1}{4\pi\epsilon_0}\left(\frac{P\cos\theta}{r^2}\right)$.

$$= \frac{1}{4\pi\epsilon_0}\cdot\frac{P\sin\theta}{r^3}.$$

$$\therefore E = \sqrt{E_r^2 + E_\theta^2} = \frac{1}{4\pi\epsilon_0}\sqrt{\frac{4P^2\cos^2\theta + P^2\sin^2\theta}{r^6}}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{P}{r^3}\cdot\sqrt{1+3\cos^2\theta}$$

$$\tan\alpha = \frac{E_\theta}{E_r} = \frac{4\pi\epsilon_0}{4\pi\epsilon_0}\cdot\frac{M\sin\theta/r^3}{2M\cos\theta/r^3}$$

$$= \frac{1}{2}\tan\theta$$

$$\therefore \alpha = \tan^{-1}\left(\frac{1}{2}\tan\theta\right).$$

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