February 24, 2015

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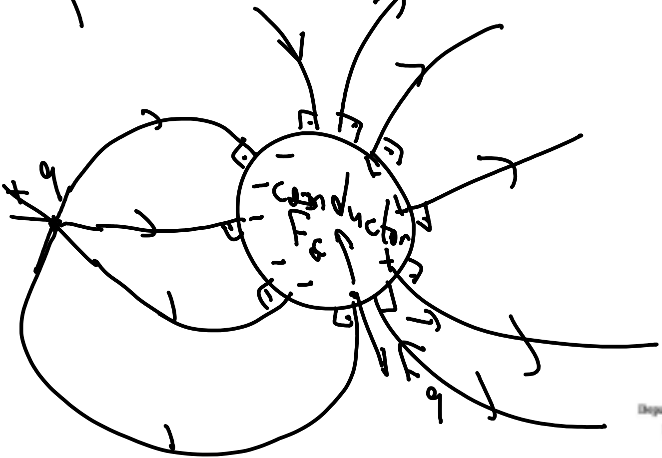
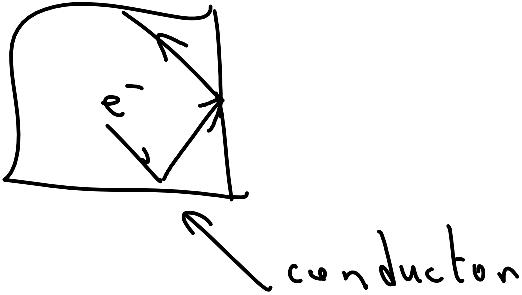
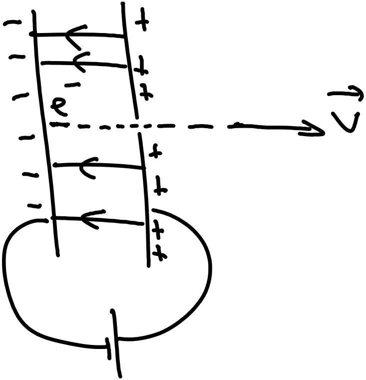



e⁻
conductor

Electron Gun

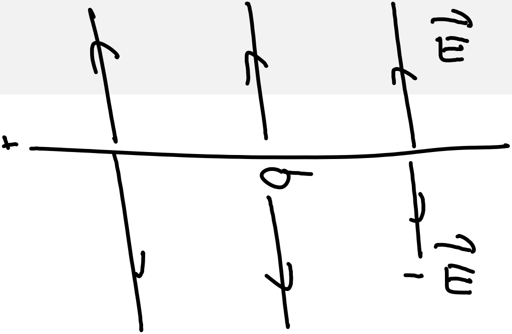


$$|\vec{E}| = \frac{\sigma}{\varepsilon_0}$$

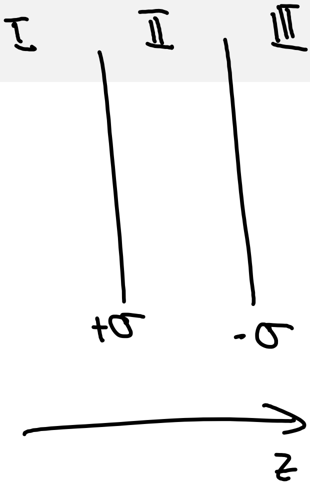
$$\vec{F} = q\vec{E}$$
$$= (-e)\left(-\hat{z}\frac{\sigma}{\varepsilon_0}\right)$$
$$= \hat{z}\left(\frac{e\sigma}{\varepsilon_0}\right)$$

$$\vec{a} = \frac{\vec{F}}{m_e} = \hat{z}\left(\frac{e\sigma}{m_e\varepsilon_0}\right)$$

$$\vec{r}(t) = \frac{1}{2}\vec{a}t^2 = \hat{z}\left(\frac{e\sigma}{m_e\varepsilon_0}t^2\right)$$



$$|\vec{E}| = \frac{\sigma}{2\varepsilon_0}$$



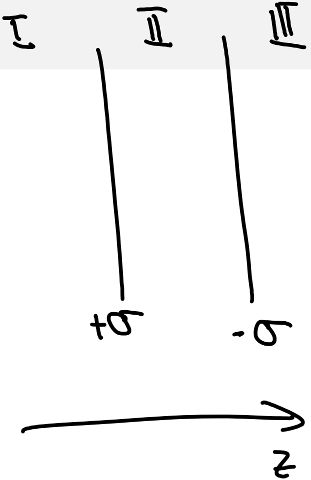
$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

region I

$$\vec{E}_+ = -\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

$$\vec{E}_- = +\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

$$\vec{E}_I = 0$$



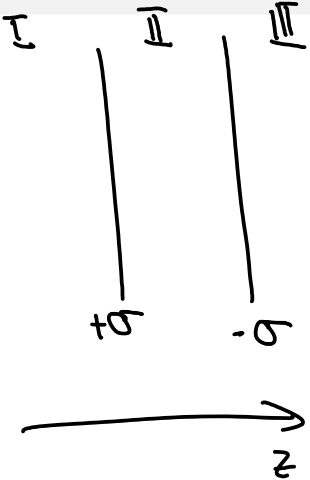
$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

region II

$$\vec{E}_+ = +\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

$$\vec{E}_- = +\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

$$\vec{E}_{II} = \hat{z}\,\frac{\sigma}{\varepsilon_0}$$



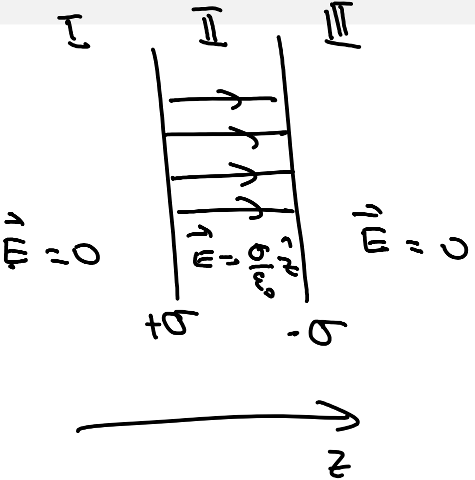
$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

region III

$$\vec{E}_- = -\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

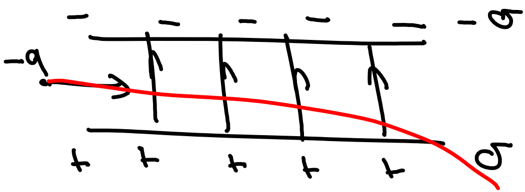
$$\vec{E}_+ = +\hat{z}\,\frac{\sigma}{2\varepsilon_0}$$

$$\vec{E}^{\,III} = 0$$



$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

Example



$$\vec{E} = \hat{z}\,\frac{\sigma}{\varepsilon_0}$$

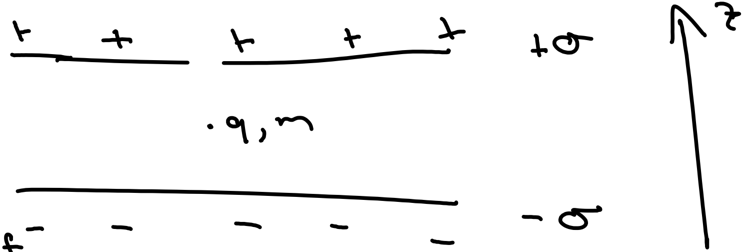
$$\vec{a} = \frac{q\vec{E}}{m}$$

$$\boxed{\vec{a} = \hat{z}\,\frac{q\sigma}{m\varepsilon_0}}$$

ignore gravity

$$\vec{r} = \frac{1}{2} a t^2$$

Example Millikan Exp



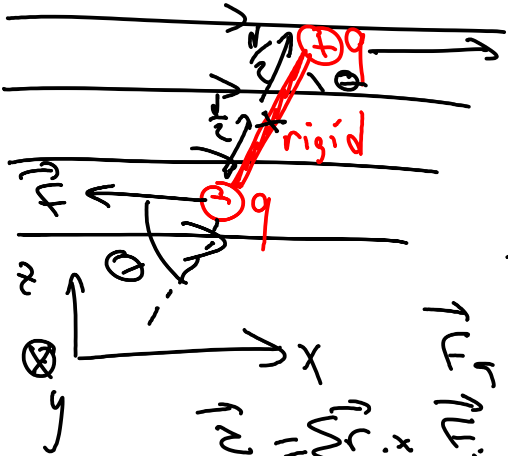
$$\vec{E} = -\frac{\sigma}{\varepsilon_0}\hat{z}$$

if

$$\vec{F}_T = q\vec{E} + m\vec{g} = \left(-\frac{q\sigma}{\varepsilon_0} - mg\right)\hat{z} = 0$$

$$\Rightarrow \boxed{q = -\frac{mg\varepsilon_0}{\sigma}} \Rightarrow$$ the droplet will not accelerate

Example (no gravity)



$\vec{F}'$, $\vec{F} = q\vec{E}$

$|\vec{F}| = |\vec{F}'|$ since $\vec{E}$ is uniform

$\vec{F} = -\vec{F}'$

$\vec{F}_T = \vec{F} + \vec{F}' = 0$

$\vec{\tau} = \sum \vec{r}_i \times \vec{F}_i$

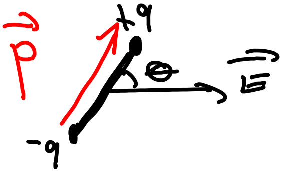
$$|\vec{\tau}| = |\vec{r} \times \vec{F}| = |\vec{r}|\,|\vec{F}| \sin\phi$$

$$\vec{\tau}_{tot} = ?$$

$$|\vec{\tau}_+| = \frac{d}{2}\, q E \sin\theta \qquad \vec{\tau}_+ = \frac{d}{2} q E \sin\theta\, \hat{y}$$

$$|\vec{\tau}_-| = |\vec{\tau}_+| \qquad \vec{\tau}_- = \frac{d}{2} q E \sin\theta\, \hat{y}$$

$$\vec{\tau}_{tot} = (qd)(E) \sin\theta\, \hat{y}$$



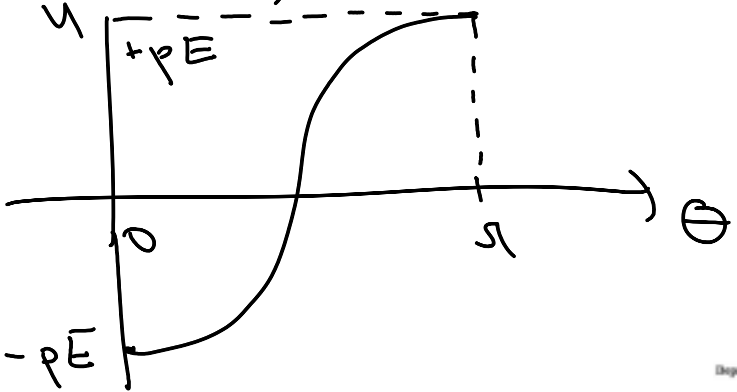
$\vec{p}$: dipole moment

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

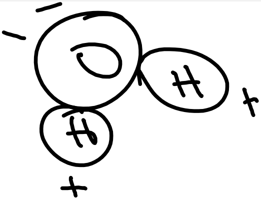
$$U = -\vec{p} \cdot \vec{E}$$

$$U = -pE\cos\Theta = pE(-\cos\Theta)$$

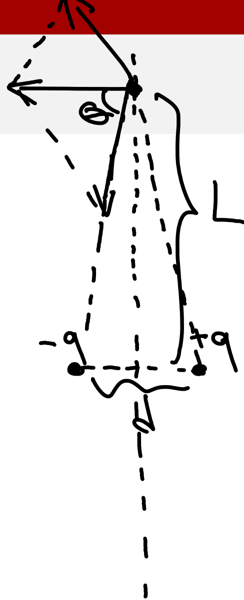
$$\min(-\cos\Theta) = -1 \Rightarrow \Theta_{min} = 0$$




+
e⁻
+
−
H
H
4e⁻
+2
H
+



O
H
H
+
+



$$|\vec{E}_+| = |\vec{E}_-| = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d}{2}\right)^2+L^2}$$

$$|\vec{E}_T| = 2E_-\cos\theta$$

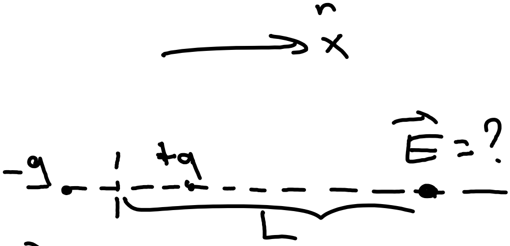
$$= \frac{\cancel{2}}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d}{2}\right)^2+L^2}\frac{d/\cancel{2}}{\left[\left(\frac{d}{2}\right)^2+L^2\right]^{1/2}}$$

$$L \gg d \longrightarrow \frac{(qd)}{L^3}\frac{1}{4\pi\varepsilon_0}$$

$$|\vec{E}_T| \simeq \frac{1}{4\pi\varepsilon_0}\frac{p}{L^3}$$

$$\vec{E}_T \simeq -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{L^3}$$

Example



$$\vec E = \frac{1}{4\pi\varepsilon_0}\frac{q}{(L-\frac{d}{2})^2}\hat x + \frac{1}{4\pi\varepsilon_0}\frac{q}{(L+\frac{d}{2})^2}(-\hat x)$$

$$= \frac{q}{4\pi\varepsilon_0}\frac{(2dL+d^2/2)}{(L-\frac{d}{2})^2(L+\frac{d}{2})^2}\hat x \overset{d\ll L}{=} 2\frac{(qd)}{4\pi\varepsilon_0}\frac{1}{L^3}\hat x$$

$$\vec E = 2\frac{1}{4\pi\varepsilon_0}\frac{1}{L^3}\vec p$$