PHYS 122-Lecture 3:
More Electric Fields

- Review of Charge and Force
- Fields
- Examples

Mass ▶ Law ▶ Field

$$F_g = G\frac{|m_1 m_2|}{r^2}$$

Charge ▶ Law ▶ Field

$$F_E = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$$

$$F_E = k\frac{|q_1 q_2|}{r^2}$$

$$\left(F_E = \frac{1}{4\pi\epsilon}\frac{|q_1 q_2|}{r^2}\right)$$

Mass ▶ Law ▶ Field

$$F_g = G\frac{|m_1 m_2|}{r^2}$$

$$F_g = m_1\left(G\frac{|m_2|}{r^2}\right)$$

$$F_g = m_1 g_2$$

$$\boldsymbol{F_g} = m_1\boldsymbol{g}$$

Charge ▶ Law ▶ Field

$$F_E = \frac{1}{4\pi\varepsilon_o}\frac{|q_1 q_2|}{r^2}$$

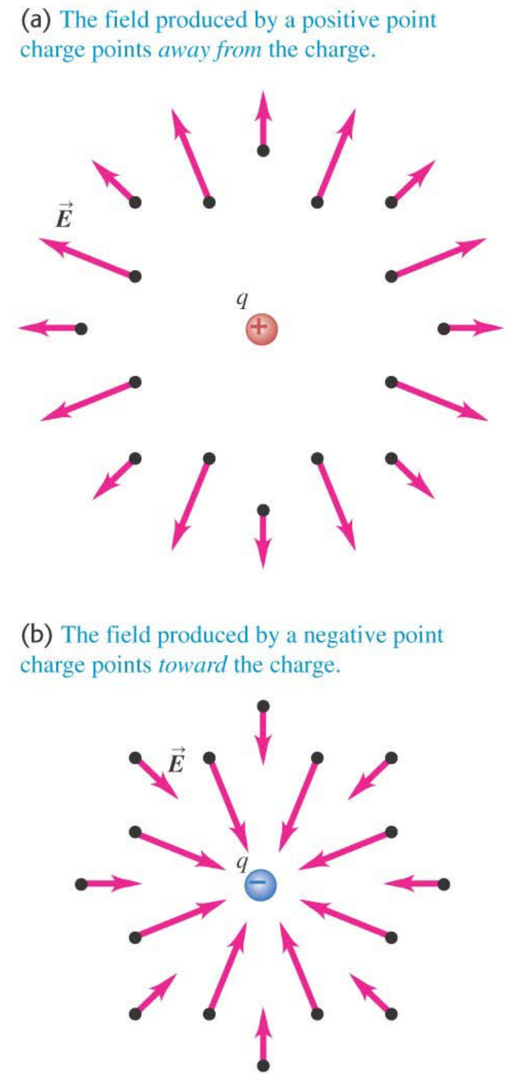
$$F_E = q_1\left(\frac{1}{4\pi\varepsilon_o}\frac{|q_2|}{r^2}\right)$$

$$F_E = q_1 E_2$$

$$\boldsymbol{F_E} = q_1\boldsymbol{E}$$

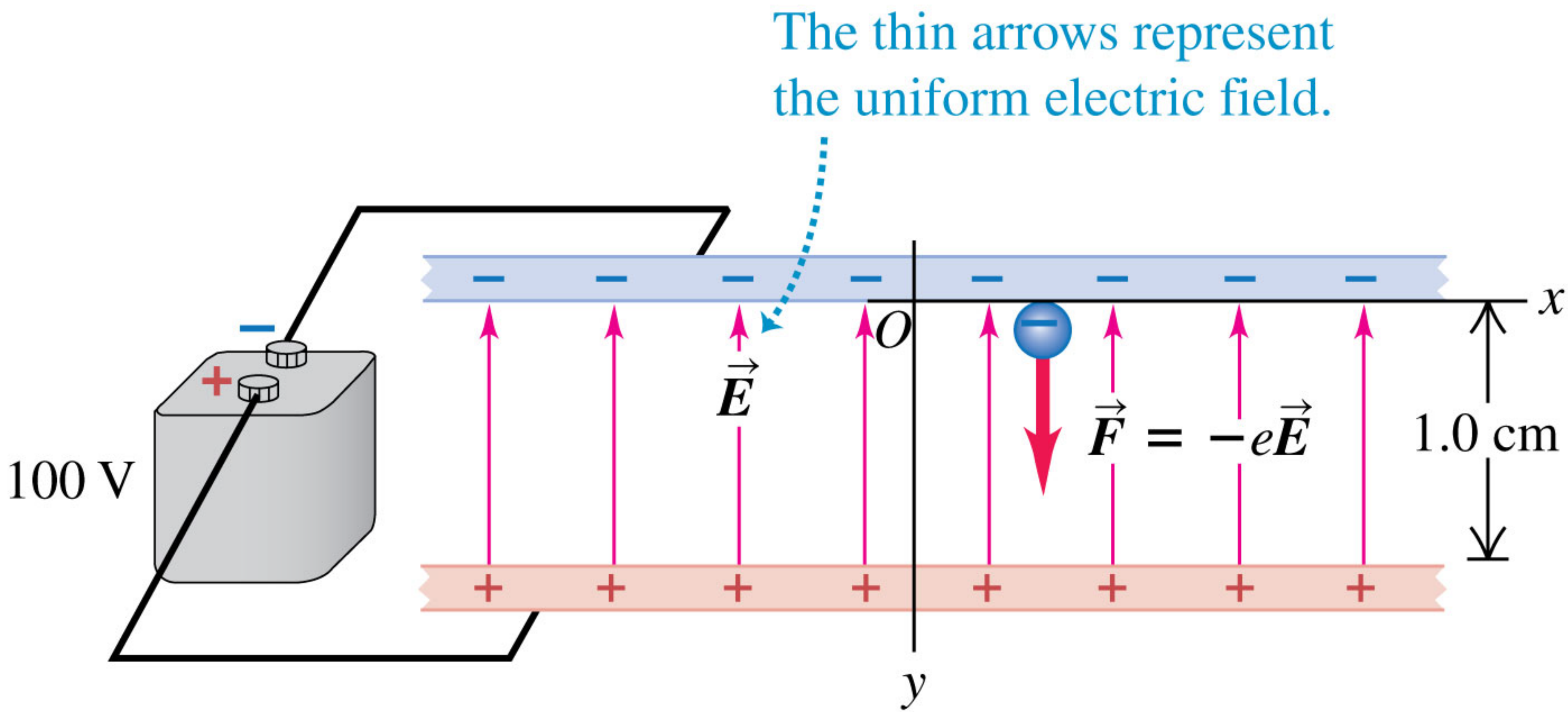
Electric field of a point charge

- Follow the discussion in the text of the electric field of a point charge, using Figure 21.18 at the right.
- Follow Example 21.5 to calculate the magnitude of the electric field of a single point charge.



Electron in a uniform field

- Example 21.7 requires us to find the force on a charge that is in a known electric field. Follow this example using Figure 21.20 below.



Integral Form

$$E = \frac{1}{4\pi\varepsilon_o}\frac{|q|}{r^2}$$

$$E_i = \frac{1}{4\pi\varepsilon_o}\frac{|q_i|}{r^2}$$

$$E_T = \sum_i \frac{1}{4\pi\varepsilon_o}\frac{|q_i|}{r^2}$$

$$E_T = \int \frac{1}{4\pi\varepsilon_o}\frac{1}{r^2}dq$$

A word on dQ…

dQ is interpreted as "a little bit of charge"

Oftentimes, dQ is rewritten as:

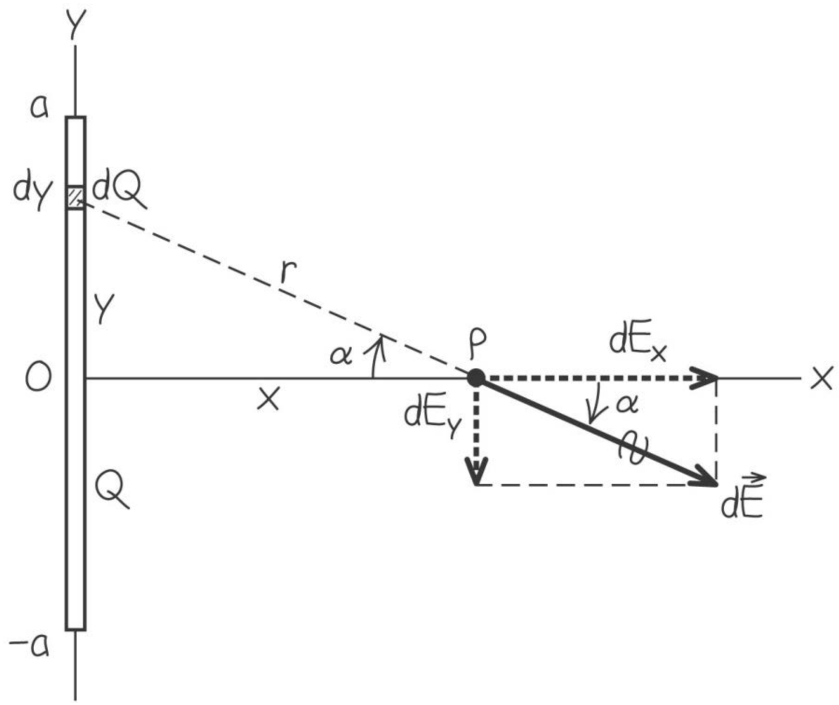
$$\delta Q = \rho \cdot \delta V$$
$$\delta Q = \sigma \cdot \delta A$$
$$\delta Q = \lambda \cdot \delta l$$

where

ρ is the volume charge density [charge/m^3]
σ is the surface charge density [charge/m^2]
λ is the line charge density [charge/m]

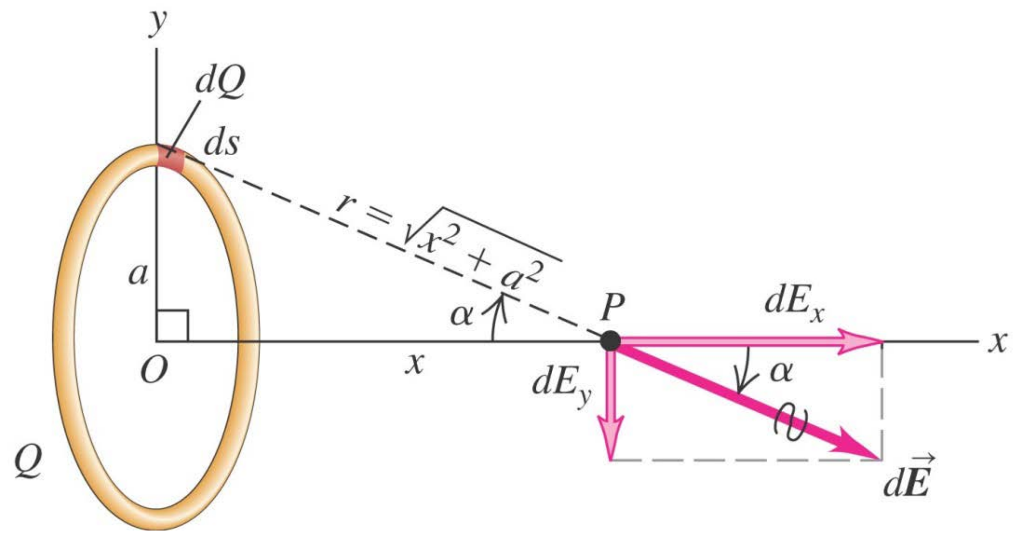
Field of a charged line segment

- Follow Example 21.10 and Figure 21.24 below.



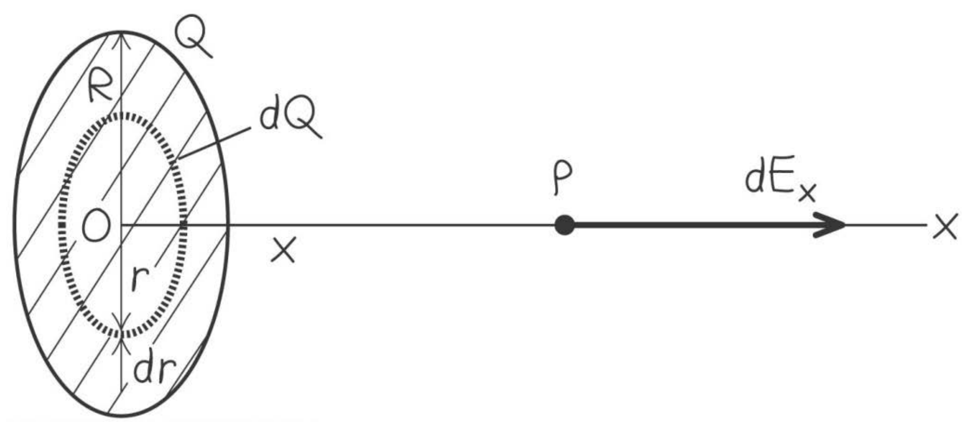
Field of a ring of charge

- Follow Example 21.9 using Figure 21.23 below.



Field of a uniformly charged disk

- Follow Example 21.11 using Figure 21.25 below.



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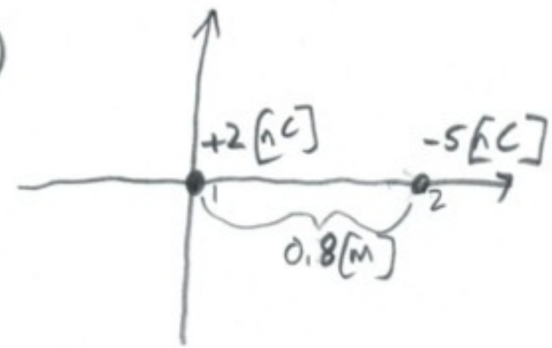
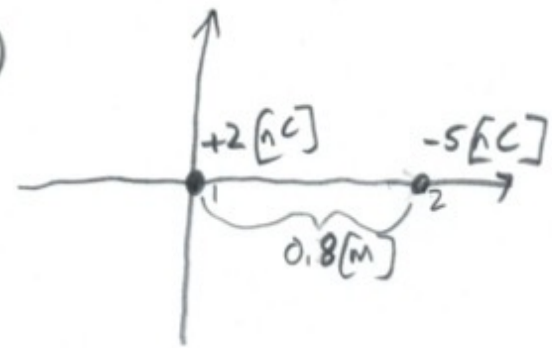
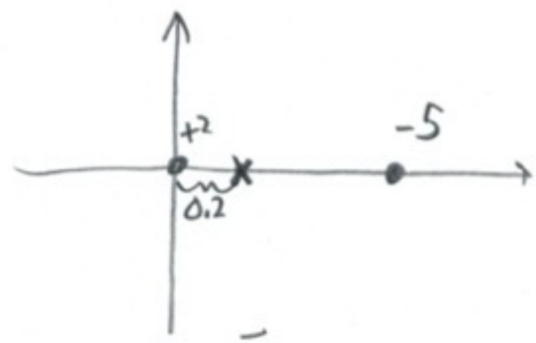
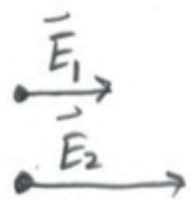


35



a)





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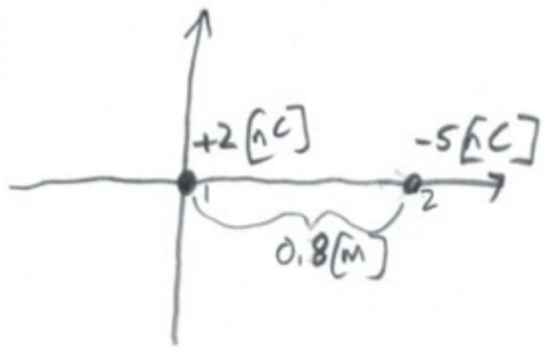
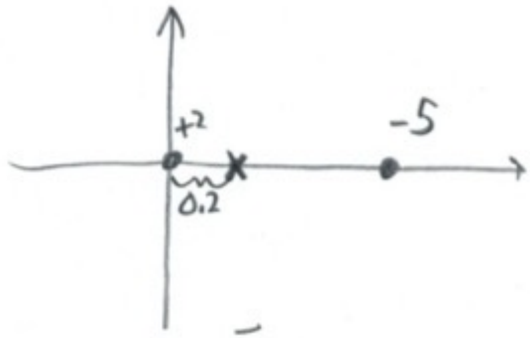
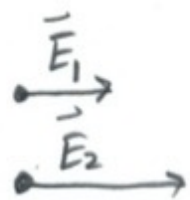


a)



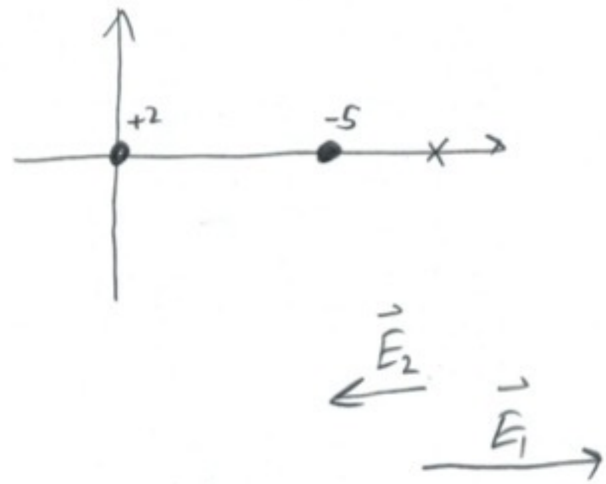


$$\vec{E}_T = \vec{E}_1 + \vec{E}_2$$

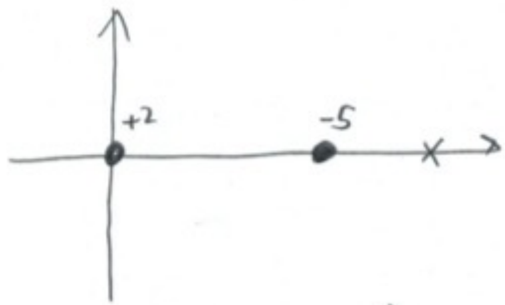
$$= \frac{1}{4\pi\epsilon_0} \frac{|q_1|}{r_{1x}^2} \hat{\imath} + \frac{1}{4\pi\epsilon_0} \frac{|q_2|}{r_{2x}^2} \hat{\imath}$$

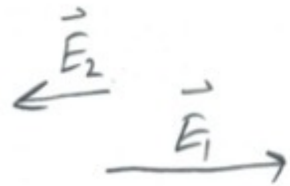
$$= 574.2 \left[\frac{N}{C}\right] \hat{\imath}$$

b) $x = 1{,}2$ [m]



b) $x = 1.2\ [m]$



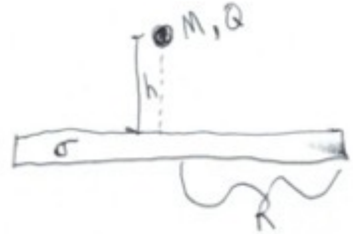


$$\vec{E}_T = \vec{E}_1 + \vec{E}_2$$

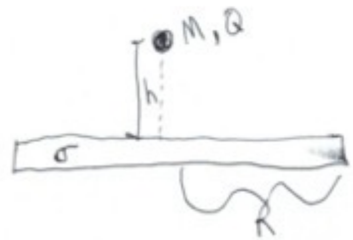
$$= \frac{1}{4\pi\epsilon_0}\frac{|q_1|}{r_{1x}^2}\hat{i} + \frac{1}{4\pi\epsilon_0}\frac{|q_2|}{r_{2x}^2} -\hat{i}$$

$$= -268\left[\frac{N}{C}\right]$$

76



(76)



$$\Sigma F_y = 0 = -F_g + F_E$$

$$0 = -Mg + Q\left(\frac{\sigma}{2\epsilon_0}\left(1 - \frac{1}{\sqrt{\left(\frac{R}{z}\right)^2 + 1}}\right)\right)$$

Solve for z, where z = h

(76)

$$\Sigma F_y = 0 = -F_g + F_E$$

$$0 = -Mg + Q\left(\frac{\sigma}{2\epsilon_0}\left(1 - \frac{1}{\sqrt{\left(\frac{R}{z}\right)^2 + 1}}\right)\right)$$

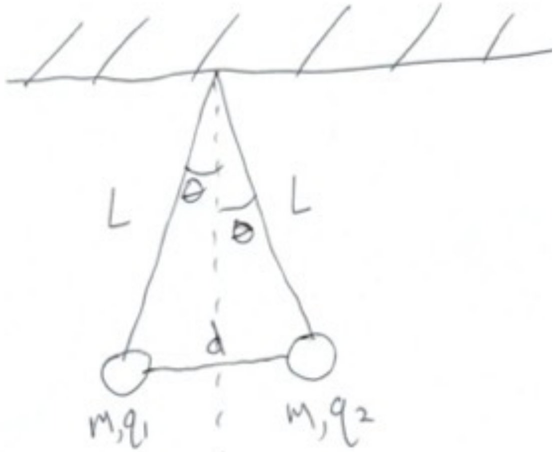
Solve for z, where $z = h$

mess!

let $v = \frac{2Mg\epsilon_0}{Q\sigma}$

$$z = h = \frac{R(1-v)}{\sqrt{v(2-v)}}$$

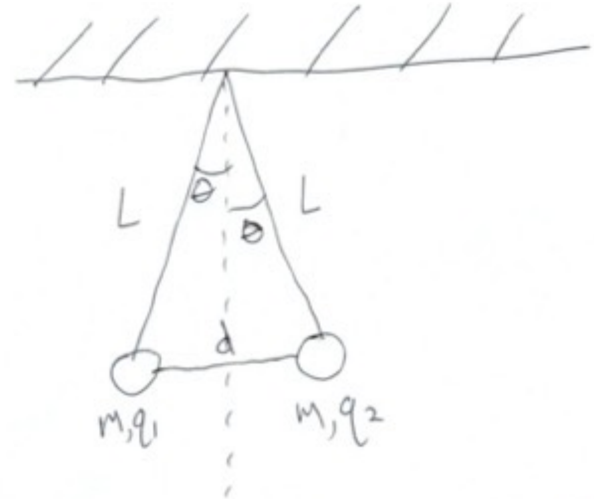
(60)



$q_1 = q_2 = q$

Show $d = \left(\frac{q^2 L}{2\pi\epsilon_0 m g}\right)^{\frac{1}{3}}$

(60)



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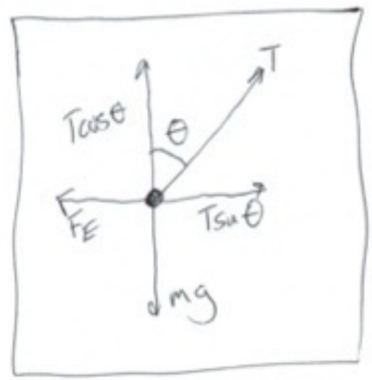
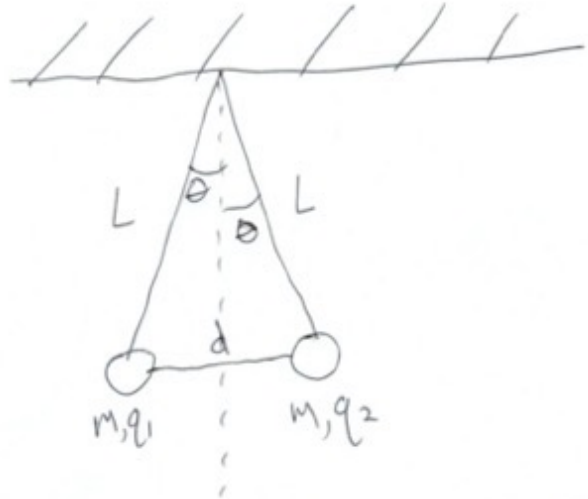
Show $d = \left(\dfrac{q^2 L}{2\pi \epsilon_0 m g}\right)^{\frac{1}{3}}$



$\Sigma F_x = 0$ $\Sigma F_y = 0$

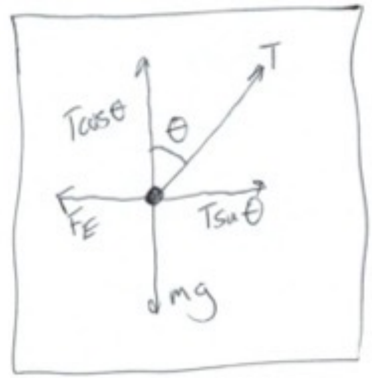
$\Sigma F_x = 0 = T\sin\theta - F_E$ $\Sigma F_y = 0 = T\cos\theta - mg$

(60)



$$q_1 = q_2 = q$$

Show $d = \left(\dfrac{q^2 L}{2\pi \epsilon_0 mg} \right)^{\frac{1}{3}}$



$$\sum F_x = 0 \qquad \sum F_y = 0$$

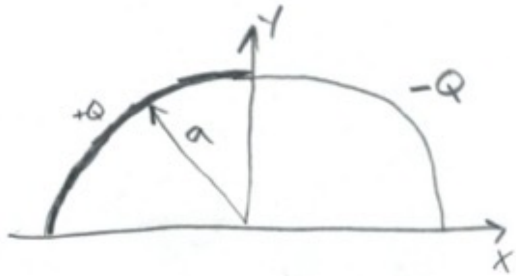
$$\sum F_x = 0 = T\sin\theta - F_E \qquad \sum F_y = 0 = T\cos\theta - mg$$

$$\frac{mg\sin\theta}{\cos\theta} = F_E = \frac{kq^2}{d^2}$$

But $\tan\theta \approx \sin\theta \approx \theta$, so

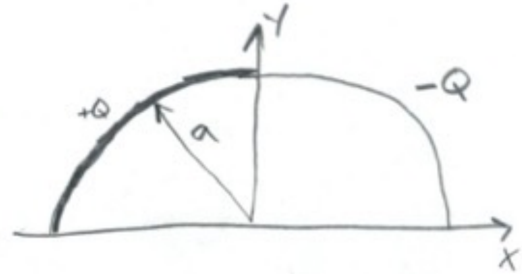
$$\boxed{d^3 = \frac{2kq^2 L}{mg}}$$

(84)



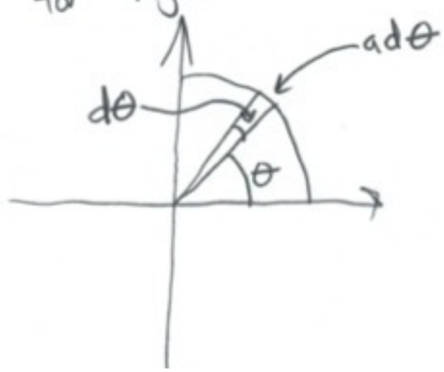
Need to add $\vec{E}_{right}$ and $\vec{E}_{left}$ loop segments

84



Need to add $\vec{E}_{right}$ and $\vec{E}_{left}$ loop segments

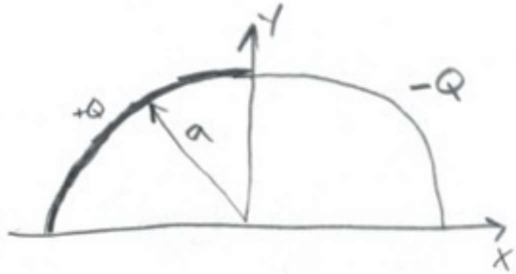
for right:



$$dQ = \left(\frac{a\,d\theta}{\frac{1}{2}\pi a}\right)Q$$

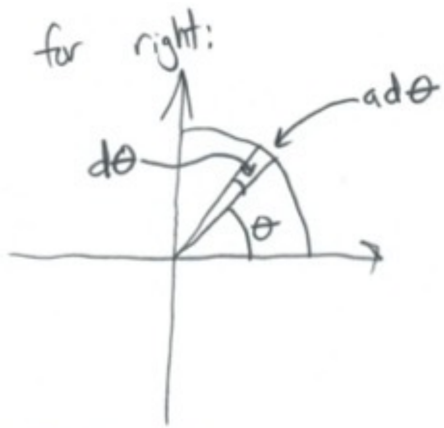
$$dQ = \frac{2Q}{\pi}d\theta$$

(84)



Need to add $\vec{E}_{right}$ and $\vec{E}_{left}$ loop segments

for right:



$$dQ = \left(\frac{a\, d\theta}{\frac{1}{2}\pi a}\right) Q$$

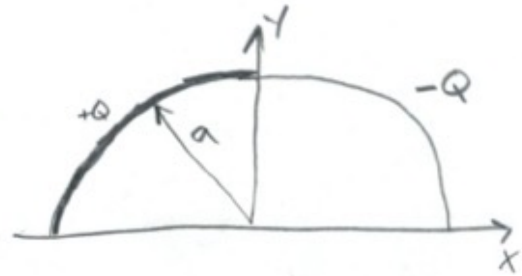
$$dQ = \frac{2Q}{\pi} d\theta$$

This is problem 83

$$dE = \frac{1}{4\pi\epsilon_0} \frac{|dQ|}{a^2}$$

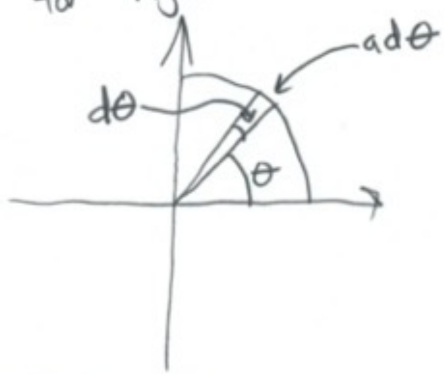
$$= \frac{Q}{2\pi^2\epsilon_0 a^2} d\theta$$

(84)



Need to add $\vec{E}_{right}$ and $\vec{E}_{left}$ loop segments

for right:



$$dQ = \left(\frac{a\,d\theta}{\frac{1}{2}\pi a}\right) Q$$

$$dQ = \frac{2Q}{\pi} d\theta$$

This is problem 83

$$dE = \frac{1}{4\pi\epsilon_0} \frac{|dQ|}{a^2}$$

$$= \frac{Q}{2\pi^2\epsilon_0 a^2} d\theta$$

$$dE_x = dE\cos\theta = \frac{Q}{2\pi^2\epsilon_0 a^2} \cos\theta \, d\theta$$

$$E_x = \int dE_x = \int \frac{Q}{2\pi^2\epsilon_0 a^2} \cos\theta \, d\theta$$

$$E_x = \frac{Q}{2\pi^2 \epsilon_0 a^2}$$

$$E_x = \frac{Q}{2\pi^2 \epsilon_0 a^2}$$

$$dE_y = dE \sin\theta = \frac{Q}{2\pi^2 \epsilon_0 a^2} \sin\theta \, d\theta$$

$$E_y = \int dE_y = \int \frac{Q}{2\pi^2 \epsilon_0 a^2} \sin\theta \, d\theta$$

$$E_y = \frac{Q}{2\pi^2 \epsilon_0 a^2}$$

$$E_x = E_y$$

$$E_x = \frac{Q}{2\pi^2 \epsilon_0 a^2}$$

$$dE_y = dE \sin\theta = \frac{Q}{2\pi^2 \epsilon_0 a^2} \sin\theta \, d\theta$$

$$E_y = \int dE_y = \int \frac{Q}{2\pi^2 \epsilon_0 a^2} \sin\theta \, d\theta$$

$$E_y = \frac{Q}{2\pi^2 \epsilon_0 a^2}$$

$$E_x = E_y$$

right is − charge,

$$\vec{E}_{x_r} = +E_x \, \hat{i}$$

$$\vec{E}_{y_r} = +E_y \, \hat{j}$$

left is + charge,

$$E_{x_L} = E_x \, \hat{i}$$

$$E_{y_L} = E_y \, -\hat{j}$$

$$\vec{E}_x = \vec{E}_{x_r} + \vec{E}_{x_L} = 2 \cdot \frac{Q}{2\pi^2 \epsilon_0 a^2} \hat{i}$$

$$\vec{E}_y = \vec{E}_{y_r} + \vec{E}_{y_L} = 0$$