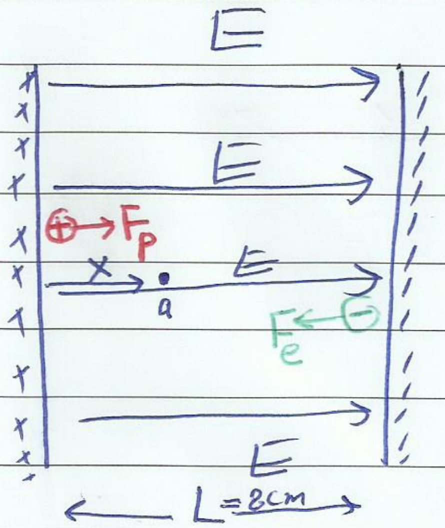
Chapter 22 - Discussion Problems

(22-7) Find their distance from +plate, when they pass each other



They will pass each other at point ⓐ a distance ⓧ from +plate
they pass each other after ⓣs

$F_p = m_p a_p$

$eE = m_p a_p \Rightarrow a_p = \frac{eE}{m_p}$

$\Delta X = V_0 t + \frac{1}{2} a_x t^2$

$X = 0 + \frac{1}{2}\left(\frac{eE}{m_p}\right)t^2$ ① $\qquad X = \frac{1}{2}\frac{eE}{m_p}t^2$ ①

For electron $a_e = \frac{-eE}{m_e}$

$X - L = \frac{1}{2}\left(\frac{eE}{m_e}\right)t^2$ ② $\quad$ L-X = distance covered by electron

Add ① + ② $\quad \rightarrow L - X = \frac{1}{2}\left(\frac{eE}{m_e}\right)t^2$ ②

$X + (L - X) = \frac{1}{2}\frac{eE}{m_p}t^2 + \frac{1}{2}\frac{eE}{m_e}t^2$

$L = \frac{1}{2}eEt^2\left(\frac{1}{m_p} + \frac{1}{m_e}\right)$ ③ $\Rightarrow t^2 = \frac{2L}{eE} \div \left(\frac{1}{m_p} + \frac{1}{m_e}\right)$

Solve ③ and ①

$\frac{2L}{eE} \div \left(\frac{m_p + m_e}{m_p m_e}\right)$

in ① $\leftarrow$ $t^2 = \frac{2L}{eE} \times \frac{m_p m_e}{m_p + m_e}$

$X = \frac{1}{2}\frac{eE}{m_p}\left[\frac{2L}{eE} \cdot \frac{m_p m_e}{m_p + m_e}\right]$

$X = L\left(\frac{m_e}{m_p + m_e}\right) = 0.08\left(\frac{9.11 \times 10^{-31}}{1.67 \times 10^{-27} + 9.11 \times 10^{-31}}\right)$

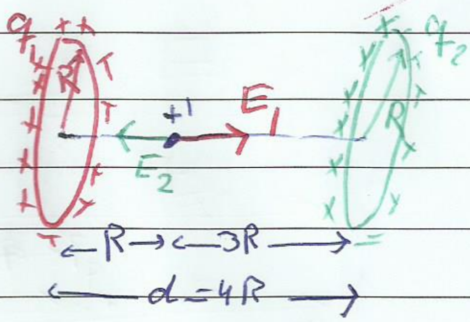
$= 0.08(5.45 \times 10^{-4})$

$X = 4.4 \times 10^{-5}$ m

(22-9) $\vec{E}_P = \vec{E}_1 + \vec{E}_2$

$0 = \vec{E}_1 + \vec{E}_2$

$\vec{E}_1 = -\vec{E}_2$



q_1 + q_2 are ⊕
q_1 + q_2 are ⊖ } $\Rightarrow \frac{q_1}{q_2} = +?$

From the Lecture $E_{ring} = \frac{kqx}{(x^2+R^2)^{3/2}}$

$$\vec{E}_1 = \frac{kq_1R}{(R^2+R^2)^{3/2}} = \frac{kq_1R}{(2)^{3/2}R^3} = \frac{kq_1}{(2)^{3/2}R^2}\,(\hat{i})$$

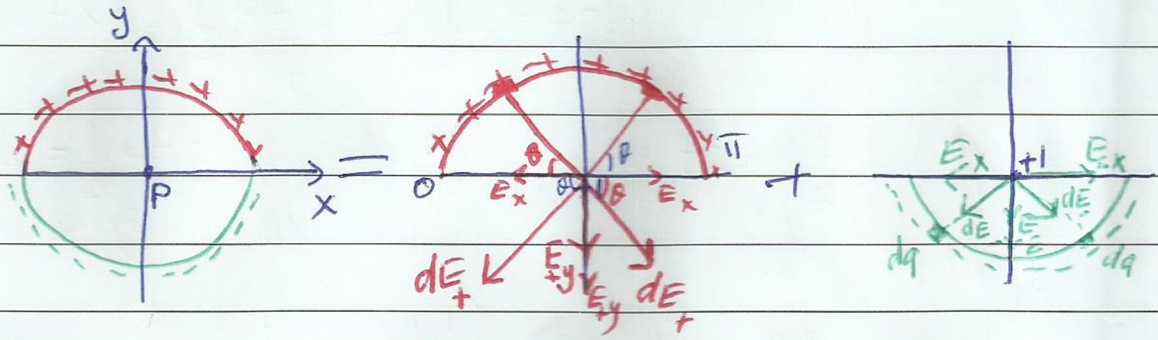
$$\vec{E}_2 = \frac{kq_2(3R)}{(9R^2+R^2)^{3/2}} = \frac{kq_2(3R)}{(10)^{3/2}R^3} = \frac{3kq_2}{(10)^{3/2}R^2}\,(-\hat{i})$$

$E_1 = E_2$

$$\frac{kq_1}{(2)^{3/2}R^2} = \frac{3kq_2}{(10)^{3/2}R^2} \Longrightarrow \frac{q_1}{q_2} = 3\left(\frac{2}{10}\right)^{3/2} = 3\left(\frac{1}{5}\right)^{3/2} = 3(0.089)$$

$$\frac{q_1}{q_2} = +0.27$$

(22-11)



$R = 4.25\,cm$

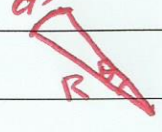
$q = 15\,pC$

$\vec{E}_P$?

$(E_+)_x = 0$ from symmetry
(E_+) downward

$(E_-)_x = 0$
$(E_-)_y$ downward

$dE_+ = k\frac{dq}{R^2}$



$dE_{+y} = k\frac{dq}{R^2}\sin\theta$ downward

$(E_+)_y = \int dE_{+y}$

$= k\int \frac{dq}{R^2}\sin\theta$, $dq = \lambda ds = \lambda R d\theta$, $\lambda = \frac{q}{\pi R}$

-

$$(E_+)_y = k\int_0^{\pi} \frac{(\lambda R\, d\theta)}{R^2}\sin\theta = \frac{k\lambda}{R}\int_0^{\pi}\sin\theta\, d\theta = \frac{k\lambda}{R}\left[-\cos\theta\right]_0^{\pi}$$

$$= -\frac{k\lambda}{R}\left[\cos\pi - \cos 0\right] = -\frac{k\lambda}{R}\left[(-1)-(1)\right] = -\frac{2k\lambda}{R}$$

$(E_+)_y = (-)\dfrac{2k\lambda}{R}$ from upper

$(E_-)_y = (-)\dfrac{2k\lambda}{R}$ from lower

$E_y = (-)\dfrac{4k\lambda}{R} = -\dfrac{4k}{R}\dfrac{q}{\pi R} = -\dfrac{4kq}{\pi R^2}$ total

$E_y = (-)\dfrac{4q}{4\pi\epsilon_0 \cdot \pi R^2} = \dfrac{-q}{\epsilon_0 \pi^2 R^2}$

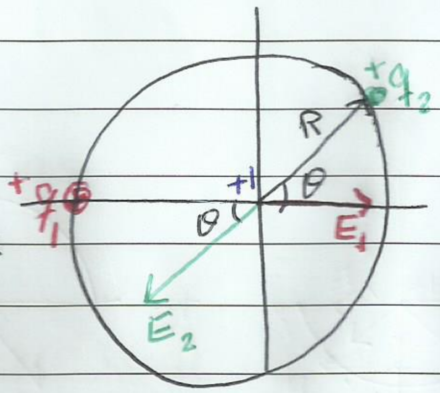
$E_y = (-)\left[\dfrac{15\times10^{-12}}{(8.85\times10^{-12})(\pi)^2(4.25\times10^{-2})^2}\right] = -95\ N/C$

(11-24) $R = 43\ cm = 0.43\ m$

$q_1 = +2\ \mu C$

$q_2 = +6\ \mu C$

Find θ? For $E_{center} = 2\times10^5\ N/C$



$\vec{E_1} = \dfrac{kq_1}{R^2}$, as shown

$\vec{E_2} = \dfrac{kq_2}{R^2}$ as shown $\quad \vec{E_1} + \vec{E_2} = \vec{E}$

$$(E)_x = E_{1x} + E_{2x} = \frac{kq_1}{R^2} + \frac{-kq_2\cos\theta}{R^2} = \frac{k}{R^2}(q_1 - q_2\cos\theta)$$

$$= \frac{9\times10^9}{(0.43)^2}(2\times10^{-6} - 6\times10^{-6}\cos\theta)$$

$$(E)_y = E_{1y} + E_{2y} = 0 + \frac{-kq_2\sin\theta}{R^2} \qquad E_y = -\frac{kq_2}{R^2}\sin\theta$$

$$E_x = \frac{9\times10^9}{(0.43)^2}(2\times10^{-6})\left[1 - 3\cos\theta\right]$$

$$E_y = \frac{9\times10^9 \times 6\times10^{-6}}{(0.43)^2}\sin\theta$$

$E_x = 9.73\times10^4\left[1 - 3\cos\theta\right]$ (1)

$E_y = (-2.92\times10^5\ N/C)\sin\theta$

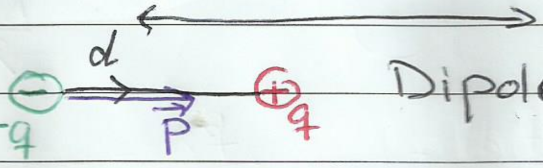
$$E^2 = E_x^2 + E_y^2$$

$$(2\times10^5)^2 = \left[9.73\times10^4(1-3\cos\theta\right]^2 + \left[2.92\times10^5\sin\theta\right]^2$$

$$4\times10^{10} = 9.47\times10^9(1-3\cos\theta)^2 + 8.53\times10^{10}\sin^2\theta$$

$$0.47 = 0.11(1-3\cos\theta)^2 + \sin^2\theta$$

Continue

(22-40) 

Dipole consists from

$q = 2e$

$d = 0.85\,nm$

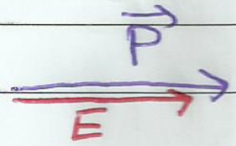
$E = 3.4\times10^6\ N/C$

Find τ:

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

a) $\vec{E} \parallel \vec{P}$

$$p = qd = 2ed = 2(1.6\times10^{-19})(0.85\times10^{-9})$$
$$= 2.72\times10^{-28}\ C.m$$



$\theta = 0$

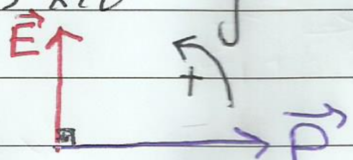
$$\tau = pE\sin0 = 0$$

Extra Find U? for Parall case

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

$$U_0 = (-)(2.72\times10^{-28})(3.4\times10^6)\cos0$$
$$= (-)\,9.25\times10^{-22}\ J$$

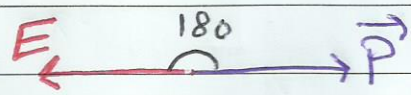
b) $\vec{E} \perp \vec{P}$



$$\vec{\tau} = \vec{p}\times\vec{E}$$
$$= (2.72\times10^{-28})(3.4\times10^6)\sin90$$
$$= 9.25\times10^{-22}\ N.m \text{ Counterclockwise}$$

Find $U_{90} = -\vec{p}\cdot\vec{E} = -pE\cos90 = 0$

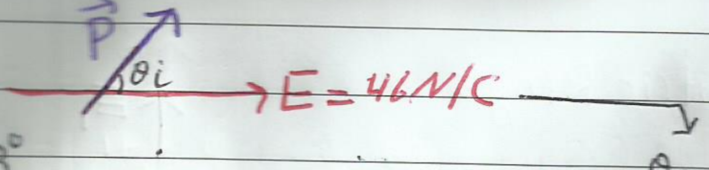
c) Antiparallel



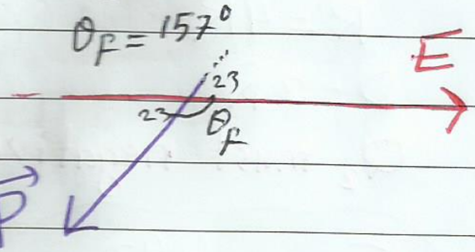
$$\vec{\tau} = \vec{p}\times\vec{E} = pE\sin180 = 0$$

$$U_{180} = -\vec{P}\cdot\vec{E} = -pE\cos180 = -(2.72\times10^{-28})(3.4\times10^6)(-1)$$
$$= +\,9.25\times10^{-22}\ J$$

(22-41)



$\theta_i = 23°$



$P = 3.02 \times 10^{-25}$ C.m

How much W required to turn the Dipole 180°

$\theta_i = 23° \longrightarrow \theta_f = 157°$

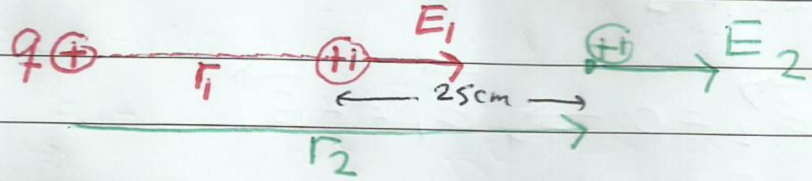
$$W^{E}_{i \to f} = -\Delta U = -[U_f - U_i]$$

$$W^{\text{external agent}}_{i \to f} = \Delta U$$
$$= U_f - U_i$$
$$= (-\vec{P}\cdot\vec{E})_f - (\vec{P}\cdot\vec{E})_i$$

$$= (-PE\cos 157) - (-PE\cos 23)$$
$$= [(-3.02 \times 10^{-25})(46)(-0.92)] - [(-3.02 \times 10^{-25})(46)(0.92)]$$
$$= [+1.28 \times 10^{-23}] - [-1.28 \times 10^{-23}]$$

$$= +2.56 \times 10^{-23} \text{ J}$$

(22-45)



$E_1 = \frac{kq}{r_1^2}$ ①, $r_1 = 50$cm, $E_1 = 2$ N/C

$E_2 = \frac{kq}{r_2^2}$ ②, $r_2 = 75$cm, E_2?

$$\frac{②}{①} \longrightarrow \frac{E_2}{E_1} = \frac{kq}{r_2^2} \div \frac{kq}{r_1^2} = \frac{kq}{r_2^2} \cdot \frac{r_1^2}{kq}$$

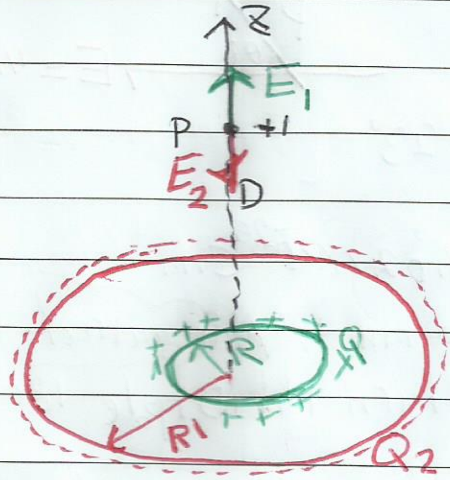
$$\frac{E_2}{E_1} = \left(\frac{r_1}{r_2}\right)^2 \Rightarrow E_2 = E_1\left(\frac{r_1}{r_2}\right)^2 = \left(\frac{0.5}{0.75}\right)^2(2)$$
$$E_2 = 0.89 \text{ N/C}$$

(22-26) 2 Concentric Rings

$R' = 4R$

$D = 2R$

Q₂ must negative



$$E_{ring} = \frac{kqz}{(z^2+R^2)^{3/2}} \rightarrow z = 2R$$

from the lecture

$$E_1 = \frac{kQ(2R)}{((2R)^2+R^2)^{3/2}} \quad \text{upward } +Q$$

$$E_2 = \frac{kQ_2(2R)}{[(2R)^2+(4R)^2]^{3/2}}, \; R' = 4R$$

$$E_1 = \frac{2kQR}{(5R^2)^{3/2}} \quad \text{upward}$$

$$E_2 = \frac{2kQ_2R}{[20R^2]^{3/2}} \quad \text{downward}$$

$$\vec{E}_1 + \vec{E}_2 = 0 \Rightarrow \vec{E}_1 = -\vec{E}_2$$

$$E_1 = E_2$$

$$\frac{2kQR}{(5R^2)^{3/2}} = \frac{2kQ_2R}{[20R^2]^{3/2}} \Rightarrow \frac{Q}{(5R^2)^{3/2}} = \frac{Q_2}{[20R^2]^{3/2}}$$

$$Q_2 = Q\left[\frac{20R^2}{5R^2}\right]^{3/2} = [4]^{3/2} Q = 8Q$$

$$Q_2 = -8Q$$