# Physics 2 - HW 3 Solution

## Problem 1

1) a) $E = ?$, at $t = 2R_1$


$$\oint E \cdot dA = \frac{q_{enc}}{\epsilon_0}$$

$$E(2\pi r L) = \frac{Q_1}{\epsilon_0}$$

$$E = \frac{Q_1}{2\pi\epsilon_0 r L}$$

$$Q_1 = 3.4 \times 10^{-12} C$$

$$L = 11.0m$$

$$r = 2R_1 = 2 \times 1.3 \times 10^{-3} m$$

$$E = \frac{2Q}{4\pi\epsilon_0 r L} = \frac{(9 \times 10^9)(2)(3.4 \times 10^{-12})}{(2 \times 1.3 \times 10^{-3})(11)} = 2.14\, N/C$$

.

(b) Radially outward.

(c) E at $r = 12R_1 = 12 \times 1.3 \times 10^{-3} = 15.6 \times 10^{-3} m$.

$$\oint E \cdot dA = \frac{q_{enc}}{\epsilon_0}$$

$$q_{enc} = Q_1 + Q_2 = Q_1 + (-2Q_1) = -Q_1$$

$$E(2\pi r)L = -\frac{Q}{\epsilon_0}$$

$$E = -\frac{Q}{2\pi r\epsilon_0 L} = -\frac{k2Q}{rL}$$

$$E = -\frac{(9\times 10^9)(2)(3.4\times 10^{-12})}{(15.6\times 10^{-3})(11)} = 0.356N/C$$

(d) Directed radially inward.
(e) on interior surface it will have

$$Q_{int} = -Q_1 = -3.4\times 10^{-12}C$$

(b) on exterior

$$Q_{ext} = +Q_1 + Q_2 = 3.4\times 10^{-12} - 6.8\times 10^{-12}$$

$$Q_{ext} = -3.4\times 10^{-12}C$$

# Problem 2

(a) If it takes work to move a positive charge then the difference in potential is positive. If the field does work on a positive charge, then the difference in potential is negative.
As

$$V_B - V_A = \frac{U}{q}$$

$$V_B - V_A = \frac{3.94\times 10^{-19}}{1.6\times 10^{-19}} = 2.5\,\text{volts}$$

In this case field did work on a negative charge so the difference in potential is positive.

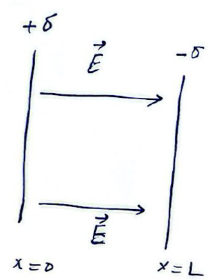
(b)

$$V_C - V_A = 2.5\,\text{volts}$$

(c)

$$V_C - V_B = 0$$

## Problem 3




$$F = -eE$$

$$E = \frac{F}{-e}$$

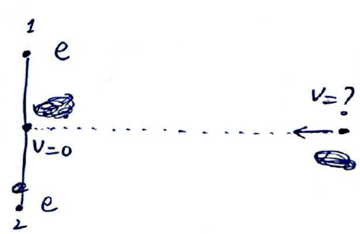
$$E = \frac{3.9 \times 10^{-15}}{1.6 \times 10^{-19}}$$

$$E = 24,000\,\text{N/C}$$

$$V = -\int_0^L \vec{E} \cdot d\vec{x} = (24,000) \int_0^L dx = (24,000)(L)$$

$$V = (24,000)(0.12) = 3000\,\text{Volts}$$

## Problem 4




$$E = K = \frac{1}{2}mv^2$$

$$E = U = \frac{kee}{(\frac{0.02}{2})} + \frac{kee}{(\frac{0.02}{2})}$$

$$U = \frac{2ke^2}{0.02} + \frac{2ke^2}{0.02}$$

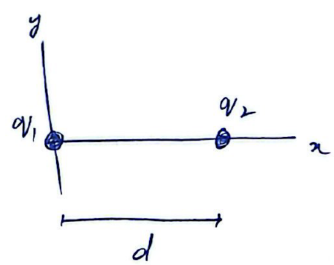
$$= \frac{4ke^2}{0.02}$$

$$\frac{1}{2}mv^2 = \frac{4ke^2}{0.02}$$

$$v = \frac{8ke^2}{(0.02)(m)} = \frac{8 \times (9 \times 10^9)(1.6 \times 10^{-19})^2}{(0.02)(9.1 \times 10^{-31})}$$

$$\boxed{v = 318\, m/s}$$

# Problem 5




As $E = 0$, at $x = \frac{d}{4}$

$$\frac{kq_1}{\left(\frac{d}{4}\right)^2} = \frac{kq_2}{\left(d - \frac{d}{4}\right)^2}$$

$$\frac{q_1}{\left(\frac{d}{4}\right)^2} = \frac{q_2}{(3d/4)^2}$$

$$16q_1 = \frac{16q_2}{9}$$

$$q_1 = \frac{q_2}{9}$$

Let's find a point somewhere on the x-axis where:

$$V = 0.$$

$$V = \frac{kq_1}{x} + \frac{kq_2}{x - d}$$

$$\frac{kq_1}{x} + \frac{kq_2}{x-d} = 0$$

$$\frac{q_2}{9x} + \frac{q_2}{x-d} = 0$$

$$\frac{1}{9x} + \frac{1}{x-d} = 0$$

$$x - d = -9x$$

$$+d = 10x$$

$$x = +\frac{d}{10}$$

# Problem 6

Now potential at point x anywhere along the x-axis is

$$v = \frac{k5e}{|x|} + \frac{k(-15e)}{|x-d|}$$

to find x for which $V = 0$

$$0 = \frac{k5e}{|x|} + \frac{k(-15e)}{|x-d|}$$

$$0 = \frac{1}{|x|} - \frac{3}{|x-d|}$$

$$|x| = \frac{1}{3}|x-d|$$

Squaring both sides to get rid of absolute value

$$9x^2 = x^2 - 2xd + d^2$$

$$8x^2 + 2xd - d^2 = 0$$

$$8x^2 + 4xd - 2xd - d^2 = 0$$

$$4x(2x+d) - d(2x+d) = 0$$

$$(4x-d)(2x+d) = 0$$

$$x = \frac{d}{4}, \quad x = -\frac{d}{2}$$

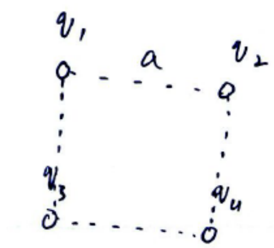
As

$$d = 24\,cm, \quad (Given)$$

$$x = 6\,\text{cm}, \quad x = -12\,\text{cm}$$

## Problem 7

The work required to setup this configuration will be equal to the potential energy of this configuration.




$$U_1 = \frac{kq_1q_2}{a}, \quad U_2 = \frac{kq_1q_3}{a}$$

$$U_3 = \frac{kq_1q_4}{a\sqrt{2}}, \quad U_4 = \frac{kq_2q_3}{a\sqrt{2}}$$

$$U_5 = \frac{kq_2q_4}{a}, \quad U_6 = \frac{kq_3q_4}{a}$$

$$U = U_1 + U_2 + U_3 + U_4 + U_5 + U_6 = \text{Work required.}$$

Since

$$q_1 = 2.3 \times 10^{-12}C, \quad q_1 = q_4, \quad q_1 = -q_2 \quad q_1 = -q_3$$

$$U_1 = -\frac{kq^2}{a}, \quad U_2 = -\frac{kq^2}{a}, \quad U_3 = \frac{kq^2}{a\sqrt{2}}, \quad U_4 = \frac{kq^2}{a\sqrt{2}}$$

$$U_5 = -\frac{kq^2}{a}, \quad U_6 = -\frac{kq^2}{a}$$

$$U = -\frac{kq^2}{a} - \frac{kq^2}{a} + \frac{kq^2}{a\sqrt{2}} + \frac{kq^2}{a\sqrt{2}} - \frac{kq^2}{a} - \frac{kq^2}{a}$$

$$U = -\frac{4kq^2}{a} + \frac{2kq^2}{a\sqrt{2}} = (-4+\sqrt{2})\frac{kq^2}{a}$$

Putting values

$$U = -1.92 \times 10^{-13} J$$

# Problem 8

Since $V$ of a full disk

$$V = \frac{\sigma}{2\epsilon_0}\left(\sqrt{Z^2+R^2} - Z\right)$$

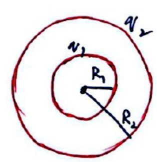
in our case

$$V = \frac{1}{4}\left(\frac{\sigma}{2\epsilon_0}\sqrt{D^2+R^2} - D^2\right)$$

Putting values

$$V = 4.71 \times 10^{-5} V$$

# Problem 9



$$R_1 = 0.5m, \quad R_2 = 1.0m$$

$$q_1 = 2 \times 10^{-6} C$$

$$q_2 = 1 \times 10^{-6} C$$

(a) $E$ at $r = 4.0m$

$$E = \frac{k(q_1+q_2)}{r^2} = \frac{(9\times 10^9)(3\times 10^{-6})}{(4)^2}$$

$$E = 1687.5\, N/C$$

b)

$$E = \frac{kq_1}{r^2} = \frac{(9\times10^9)(2\times10^{-6})}{(0.7)^2} = 36734.7$$

$$E = 36735\,\mathrm{N/C}$$

c) $r = 0.2$

$$E = \frac{k(0)}{r^2} = 0$$

$$E = 0 \quad N/C$$

d) For $r > R$

$$V = \frac{k(q_1+q_2)}{r} = \frac{(9\times10^9)(3\times10^{-6})}{4}$$

$$V = 6750\,V$$

e)

$$V = \frac{k(q_1+q_2)}{r} = \frac{(9\times10^9)(3\times10^{-6})}{1}$$

$$V = 27,000\,V$$

f) For $r = 0.7m \quad (r < R)$

$$V = -\int_\infty^r E\,dr - \int_\infty^{R_2} E\,dr - \int_{R_2}^r E\,dr = -k(q_1+q_2)\left(-\frac{1}{r}\right)\Bigg|_\infty^{R_2} - kq_1\left(-\frac{1}{r}\right)\Bigg|_{R_2}^r$$

$$V = +\frac{k(q_1+q_2)}{R_2} + \frac{kq_1}{r} - \frac{kq_1}{R_2} = \frac{kq_2}{R_2} + \frac{kq_1}{r}$$

$$V = \left(9\times10^9\right)\left[\frac{1\times10^{-6}}{1} + \frac{2\times10^{-6}}{0.7}\right]$$

$$V = 34714\ V$$

g) For $r = 0.5\ m$

$$V = k\left[\frac{q_2}{R_2} + \frac{q_1}{r}\right] = \left(9\times10^9\right)\left[\frac{1\times10^{-6}}{1} + \frac{2\times10^{-6}}{0.5}\right]$$

$$V = 45,000\ V$$

h)For $r = 0.2\ m, \quad (r < R)$

$$V = -\int_{\infty}^{r} Edr = -\int_{\infty}^{R_2} Edr - \int_{R_2}^{R_1} Edr - \int_{R_1}^{r} Edr$$

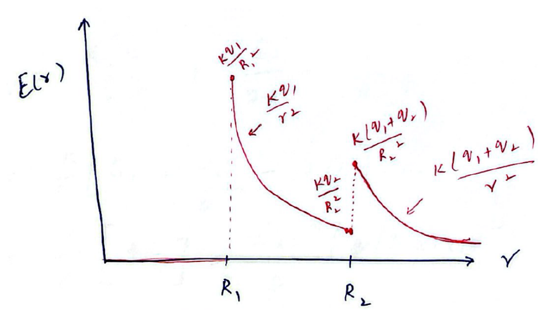
$$V = +\left[\frac{kq_2}{R_2} + \frac{kq_1}{R_1} - 0\right] = \frac{kq_2}{R_2} + \frac{kq_1}{R_1}$$

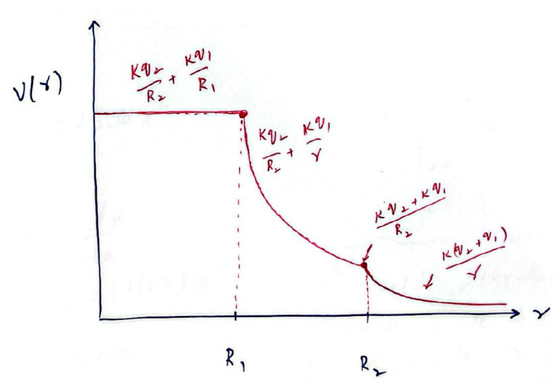
$$V = 45,000\ V$$

(i) Similarly

$$V = 45,000\ V$$

(j)





# Problem 10

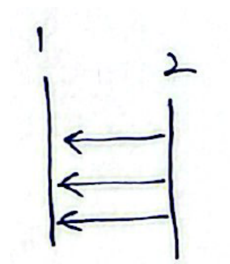
$$V = \frac{k}{R}\left[Q_1 + \frac{Q_2}{2R} + \frac{Q_3}{R}\right]$$

$$V = \frac{k}{R}\left[Q_1 + \frac{4Q_1}{2} - 2Q_1\right]$$

$$V = \frac{k}{R}[Q_1] = \frac{9 \times 10^9}{2}\left(7.21 \times 10^{-12}\right)$$

$$V = 0.0324V = 32.4mV$$

# Problem 11




$$V = 1500x^2$$

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

$$E = -2(1500)x$$

$$E = -3000x$$

(a)

$$x = 1.3 \times 10^{-2}m$$

$$E = -3000(1.3 \times 10^{-2})$$

$$\boxed{E = 3900\ V/m}, \quad Magnitude$$

(b) Field is directed from plate 2 to 1, opposite to x.