PHY 167 Recitation 1

Chapters 16, 17, 18

1) a) q_1 = negative ; q_2 = positive

b) $|F_{1y}| = |F_{2y}|$ (∵ no y-component in net force on charge at the origin.)

$\Rightarrow \frac{kq_1q}{d_1^2}\cos\theta = \frac{kq_2q}{d_2^2}$

$\Rightarrow q_1 = \frac{q_2 d_1^2}{d_2^2\cos\theta}$

c) $F_{net} = F_1 \sin\theta$

$\therefore = \frac{kq_1q}{d_1^2}\sin\theta$ — (1)

From b), obtain (ii)

$\frac{q_1}{d_1^2} = \frac{q_2}{d_2^2\cos\theta}$

Substitute into (1):

$F_{net} = k\frac{q_2 q \sin\theta}{d_2^2\cos\theta}$

$\tan 42° \times \frac{(9\times10^9)(1.2\times10^{-6})(3\times10^{-6})}{(0.2)^2}$

$\therefore F_{net} = 0.729$ N

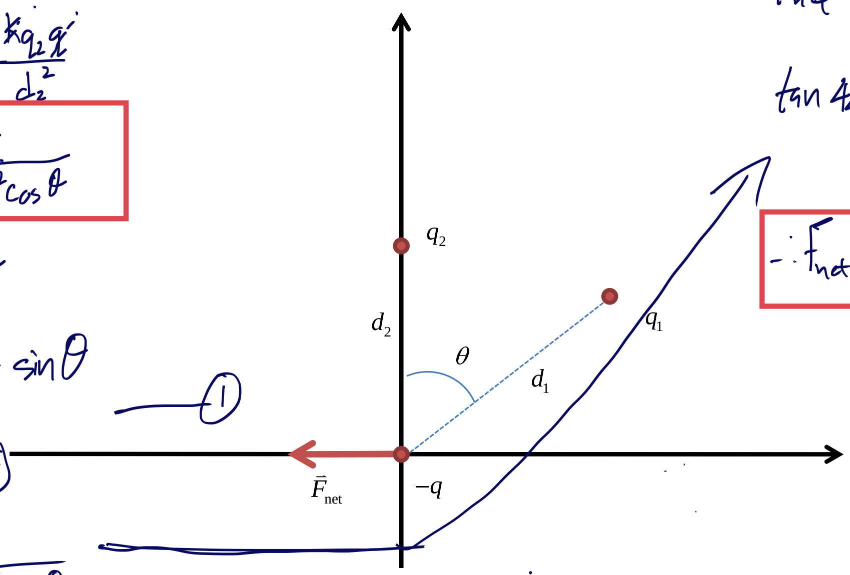

Figure 1: Picture of the setup in problem 1.

1.) A charge $-q$ is placed at the the origin. Charge q_2 is placed a distance d_2 from the origin along the $+y$-axis, and a charge q_1 is placed a distance d_1 from the origin, making an angle θ with the $+y$-axis. In this configuration, the net force on the charge q at the origin is in the $-x$-direction (see Figure 1).
(a.) What are the signs of the charges q_1 and q_2? q_1 = negative ; q_2 = positive
(b.) Solve for the charge q_1 in terms of the other quantities.
(c.) If $|q| = 1.2\mu C$, $|q_2| = 3\mu C$, $d_2 = 0.2$ m and $\theta = 42°$, what is the magnitude of the net force on q?

2) a) $\vec{E}_P = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$

$|\vec{E}_1| = \frac{kQ_1}{r_1^2} = \frac{9\times10^9 \cdot 6\times10^{-6}}{(0.52)^2} = 2\times10^5$ N/C

$|\vec{E}_3| = \frac{9\times10^9 \times 2\times10^{-6}}{(0.3)^2} = 2\times10^5$ N/C

$|\vec{E}_2| = 4\times|\vec{E}_3| = 8\times10^5$ N/C

$E_{net,x} = \vec{E}_2 + \vec{E}_3 = 10\times10^5$ N/C

$E_{net,y} = \vec{E}_1 = 2\times10^5$ N/C

$E_{net} = \sqrt{E_x^2 + E_y^2} = \sqrt{10^2 + 2^2}$

$= \sqrt{104} = 10.2$ N/C

$r_2 = r_3 = 0.3$ m

$r_1 = \sqrt{0.6^2 - 0.3^2} = 0.52$ m

$\theta = \tan^{-1}\left(\frac{2\times10^5}{10\times10^5}\right)$

$= 11.3°$ from +x-axis

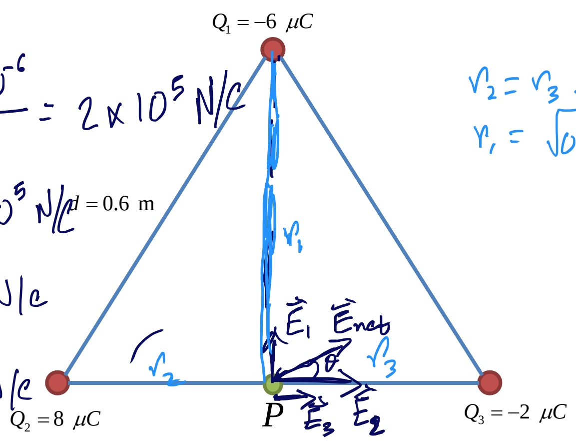

Figure 2: Picture of the setup in problem 2.

... That was only part (a)!

b) $V_P = V_1 + V_2 + V_3 = \frac{KQ_1}{r_1} + \frac{KQ_2}{r_2} + \frac{KQ_3}{r_3} = 9\times10^9 \times 10^{-6}\left(\frac{8}{0.3} + \frac{-2}{0.3} + \frac{-6}{0.52}\right)$

$\therefore V_P = 16153.85\ V$

c) Work done $= q\Delta V = q(V_P - V_\infty) = 3\times10^{-6}(16154 - 0) = 0.0485\ J$

2.) Three charged particles are located at the corners of an equilateral triangle (all sides are the same length). See Fig.2.
(a.) Calculate the net electric field (magnitude and direction) at the point P located in the middle of the triangle base.
(b.) Calculate the electric potential at the point P.
(c.) Calculate the minimum work done to move a charge $q = 3\ \mu C$ from very far away to the point P.
(d.) Calculate the electrostatic force (magnitude and direction) exerted on q when it is placed at point P.

d) $\vec{F} = q\vec{E} = (3\times10^{-6})(10.2) = 3.06\times10^{-5}\ N$, direction: $\theta = 11.3°$ from +x-axis

3.) Answer the following:

(a.) A parallel plate capacitor is connected to a battery. While it stays connected to the battery, a dielectric material with $K = 4$ is inserted between the plates. Explain how the following quantities will change (increase or decrease) and by what factor: 1.) charge on each plate, 2.) capacitance, 3.) voltage, and 4.) electric energy. Justify your answers.

(b.) A parallel plate capacitor is charged and then disconnected from the battery. Explain how the following quantities will change (increase or decrease), and by what factor, if the distance between the plates double: 1.) charge on each plate, 2.) capacitance, 3.) voltage, and 4.) electric energy stored. Justify your answers.

4.) A 100 W lightbulb is connected to a 120 V source.
(a.) What is the resistance of the lightbulb?
(b.) How much current flows through the lightbulb?
(c.) During what time interval does 1 C of charge pass through the lightbulb?
(d.) What is the cost of running the lightbulb continuously for 30 days, assuming the electric company charges \$ 0.11 per kilowatt-hour?

3) a)
- Connected to a battery means the Voltage (V) remains constant.
- Dielectric with $K=4$ means Capacitance (C) increases by a factor of 4.
- $Q = CV$. $\therefore$ Q increases by factor of 4 as well.
- Electric Potential energy $= \frac{1}{2}CV^2$ (EPE) $\therefore$ EPE also increases by a factor of 4.

b)
- Disconnected from battery means the charge is trapped in the plates of the capacitor, $\therefore Q =$ constant.
- $C = \frac{\varepsilon_0 A}{d}$. $\therefore$ if d doubles, C halves. (C decreases by a factor of 2)
- $Q = CV$, with $Q =$ constant and C decreasing ×2, V must increase by ×2.
- $E.P.E = \frac{1}{2}QV$, with $Q =$ constant & V increasing ×2, E.P.E also increases by ×2.

4) $P = 100\ W$, $V = 120V$

a) $R = ?$

$P = V^2/R$

$\Rightarrow 100 = 120^2/R$

$\Rightarrow R = 120^2/100 = 144\ \Omega$

b) $I = ?$ $P = IV$ or $V = IR$

$100 = 120(I)$

$I = \frac{100}{120} = 0.833\ A$

c) $t = ?$ for $Q = 1C$

$Q = It$

$\Rightarrow 1 = 0.833(t)$

$\therefore t = 1.20\ s$

d) cost for 30 days @ \$0.11 /KWhr

$= \$0.11/KWhr \left(\frac{100\ W}{1000\ W/KW} \times 30 \times 24\ hrs\right)$

$= \$\ 7.92$