Name: ______________________________ DISC: ________ Score: _____ / 20

Instructions:
- Do your own work.
- Answer the questions below in the space provided.
- ***Make sure you show all your work and any equations that you use***.
- Please place a box around your answers.
- Remember to give the correct units with all numerical answers

Q1	Q2	Q3	Q4
5	5	10	5

R	C
$70\,\Omega$	$4.1 \times 10^{-6}\,F$

1. The discharging of a capacitor is described by the following equation: $Q = Q_o e^{-\left(\frac{t}{RC}\right)}$. Using the information in the above table, how long (in seconds) does it take the for the charge to decay to $Q = \frac{1}{8}Q_0$?

Answer: 5 pts

This is a problem which uses our logarithm and exponent rules:

$$\frac{1}{8}Q_0 = Q_0 e^{-\left(\frac{t}{RC}\right)} = e^{-\left(\frac{t}{70\times4.1\times10^{-6}}\right)} = e^{-\left(\frac{t}{2.78\times10^{-4}}\right)}$$

$$\ln\frac{1}{8} = -\frac{t}{2.78\times10^{-4}}$$

$$\ln 1 - \ln 8 = -\frac{t}{2.78\times10^{-4}}$$

$$-\ln 8 = -\frac{t}{2.78\times10^{-4}}$$

$$2.78\times10^{-4}\times\ln 8 = t$$

$$t = 0.000578s = 578\,\mu s$$

2. The following two questions examine your mastery of two important concepts in electrodynamics.
   a. In your own words, explain the difference between a *conductor* and an *insulator*:

Answer: 2 pts

A conductor is a material with loosely bound electrons that can move easily. Metals are an example of conductors.

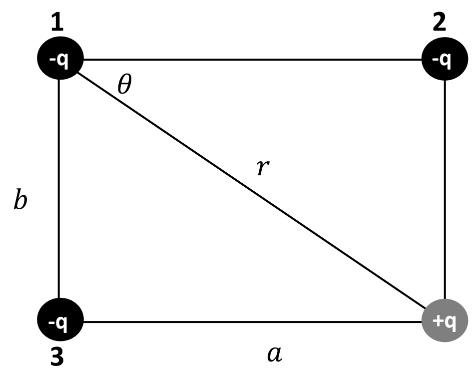
Insulators are materials with tightly bound electrons that don't move easily. Glass is an example of an insulator.

   b. If a metallic sphere is to be charged by *conduction*, how would you do it:

To charge a metallic sphere by conduction, a charge object, like a rod, must be brought into contact with the sphere allowing charges to transfer from the charged object to the uncharged sphere. Charges were separated by conduction in the discussion problem.

Answer: 3 pts.

3. Consider the charge distribution in the diagram below:



a. Calculate the magnitude of the force experienced by the charge $+q$ from the charge labeled **1:**

Value for r: 1 pt.
Force F: 3 pts.

q	a	b	k	F
$2.0 \times 10^{-9}\ C$	$1.3\ nm$	$0.5\ nm$	$9\ \times 10^9 \dfrac{Nm^2}{C^2}$	$k\dfrac{q_1 q_2}{r^2}$

To find the force on the positive charge from the charged labeled 1, we use Newton's Law:

$\boldsymbol{F = \frac{kq_1q_2}{r^2}}$**. We need to find $\boldsymbol{r}$ first:** $\boldsymbol{r = \sqrt{a^2+b^2} = \sqrt{1.3^2+0.5^2} = 1.39\ nm}$**, or** $\boldsymbol{r^2 = 1.94\ nm^2}$

Substitute: $\boldsymbol{F = \frac{(9\times10^9)(2.0\times10^{-9})(2.0\times10^{-9})}{1.94\times10^{-18}} = \frac{(9\times4)}{1.94}\times10^9 = 18.56\times10^9 N}$

Dipole: 2 pts

b. The charge combination $(+q, q_1)$ forms an *electric dipole.* Why?
The charge combination $\boldsymbol{(+q, q_1)}$ is an electric dipole because an electric dipole is two charges of the same magnitude ($\boldsymbol{q = 2.0\times10^{-9}, q_1 = -2.0\times10^{-9}C}$) but opposite sign separated by a known and usually small distance. This charge configuration meets this definition.

$\vec{p}$: 1 pt.
F_d: 3 pts.

c. Using the definition of the *electric dipole moment* ($\vec{\boldsymbol{p}} = q\vec{\boldsymbol{d}}$) find:

i. $\vec{\boldsymbol{p}}$ (be sure to include the direction):

$\boldsymbol{\vec{p} = (2.0\times10^{-9}\ C)(1.39\times10^{-9}\ m) = 2.0\times1.39\times10^{-18} C\ m = 2.78\times10^{-18} C\ M}$

ii. The total force on the dipole F_d:

$\boldsymbol{291.1\times10^9 N, \theta = 98.4^\circ}$ **See work on next page.**

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To find the force on the electric dipole:

1) **Find the force on q_1 from charge q_2:**

$$F_{12} = \frac{kq_1q_2}{a^2} = \frac{kq^2}{a^2} = \frac{(9\times10^9)(2.0\times10^{-9})^2}{(1.3\times10^{-9})^2} = \frac{(9\times4)}{1.69}\times 10^9 N = 21.3\times10^9 N \text{, directed to the left}$$

2) **Find the force on q_1 from charge q_3:**

$$F_{13} = \frac{kq_1q_2}{b^2} = \frac{kq^2}{b^2} = \frac{(9\times10^9)(2.0\times10^{-9})^2}{(0.5\times10^{-9})^2} = \frac{(9\times4)}{0.25}\times 10^9 N = 144\times10^9 N \text{, directed upward}$$

3) **Find the force on q from charge q_2:**

$$F_{12} = \frac{kq_1q_2}{b^2} = \frac{kq^2}{b^2} = \frac{(9\times10^9)(2.0\times10^{-9})^2}{(0.5\times10^{-9})^2} = \frac{(9\times4)}{0.25}\times 10^9 N = 144\times10^9 N \text{, directed upward}$$

4) **Find the force on q from charge q_3:**

$$F_{13} = \frac{kq_1q_2}{a^2} = \frac{kq^2}{a^2} = \frac{(9\times10^9)(2.0\times10^{-9})^2}{(1.3\times10^{-9})^2} = \frac{(9\times4)}{1.69}\times 10^9 N = 21.3\times10^9 N \text{, directed to the left}$$

5) **Now add the components:**

Left Directed (x-components):

$$2\times 21.3\times10^9 N = 42.6\times10^9\ N$$

Upward Directed (y-components):

$$2\times 144\times10^9 N = 288\times10^9 N$$

Magnitude of net force:

$$F = \sqrt{(42.6\times10^9)^2 + (288\times10^9)\char`^2} = \sqrt{(42.6^2+288^2)\times10^{18}} = 291.1\times10^9 N$$

The direction:

$\tan\theta = \frac{288\times10^9}{-42.6\times10^9} = -6.76 = -81.58° = 98.4°$ **Notice, the negative sign on the left-directed components (defining right to be positive).**