Physics 114 – Practice Test for Midterm 1 - Solutions
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Conceptual Question 1:

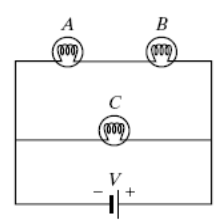
Suppose a positive point charge q is located at the center of a spherical metal shell. What charges appear on

(a) the outer surface and
(b) the inner surface of the sphere?
(c) Suppose you bring an (uncharged) metal object near the sphere. Will your answers to parts (a) or (b) above change? Will the way charge is distributed over the sphere change?

(a) The positive charge in the center is going to attract an equal amount of negative charges ($-q$) from the metal shell to its inner surface.
(b) Since the shell is neutral, this is going to leave $+q$ on the outer shell. There will not be any charges within the shell.
(c) When the metal object is brought close, the attraction between the negative charges in the object and the positive charges on the outer surface of the shell will cause the charges to rearrange themselves but the total amounts will not change.

Conceptual Question 2:

The following circuit has three identical light bulbs connected to an ideal battery.



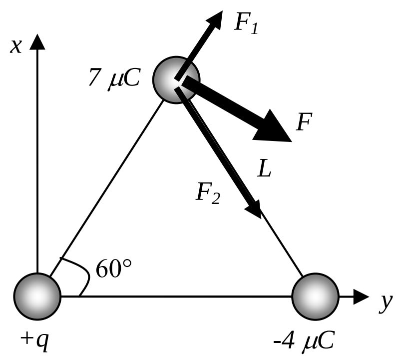
(a) How do the brightnesses of the three bulbs compare?
(b) Which draws the most current?
(c) What happens to the brightness of A and B when C is unscrewed?
(d) What happens to the brightness of B and C if A is unscrewed?

(a) The series combination of A and B are in parallel with C and the battery. Therefore, both the combination and C have same potential difference across them. However, for the upper branch, this potential difference is divided between A and B. So C will be brighter than A and B which have equal brightness.
(b) Since the equivalent resistance of A and B is larger than C, most of the current supplied by the battery will go through C.
(c) If C is unscrewed, the upper branch will still be connected to the battery and the current through it will not change. The brightnesses will remain the same (remember the demo of 4 light bulbs connected in parallel.)
(d) When A is unscrewed, the upper branch is an open circuit and no current flows through it and consequently through B. B goes dark. C remains unchanged because it is still connected to the same battery.

Problem 1:

Three charged particles are located at the corners of an equilateral triangle as shown in the figure below (q = 2.00 μC, L = 0.50 m).

(a) Calculate the total electric force on the 7.00 μC charge.
(b) Calculate the electric field at the position of the 2 μC charge.
(c) What is the total electric potential energy associated with this arrangement?



$$\vec{F} = \vec{F}_1 + \vec{F}_2$$

$$F_x = F_{1x} + F_{2x} \text{ and } F_y = F_{1y} - F_{2y}$$

$$F_{1x} = k_e \frac{(2\mu C)(7\mu C)}{(0.5m)^2}\cos 60° = 0.252N$$

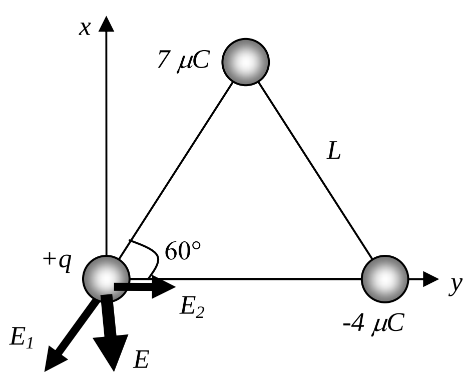
$$F_{2x} = k_e \frac{(4\mu C)(7\mu C)}{(0.5m)^2}\cos 60° = 0.503N$$

$$F_{1y} = k_e \frac{(2\mu C)(7\mu C)}{(0.5m)^2}\sin 60° = 0.436N$$

$$F_{2y} = k_e \frac{(4\mu C)(7\mu C)}{(0.5m)^2}\sin 60° = 0.872N$$

So, $F_x = 0.252 + 0.503 = 0.755N$ and $F_y = 0.436 - 0.872 = -0.436N$

$$\boxed{F = \sqrt{F_x^2 + F_y^2} = 0.872N} \text{ and } \boxed{\angle F = \arctan\left(\frac{F_y}{F_x}\right) = -30°}$$



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

$$E_x = E_{2x} - E_{1x} \text{ and } E_y = -E_{1y}$$

$$E_{1x} = k_e \frac{7\mu C}{(0.5m)^2}\cos 60° = 1.26 \times 10^5 \ N/C$$

$$E_{2x} = k_e \frac{4\mu C}{(0.5m)^2} = 1.44 \times 10^5 \ N/C$$

$$E_{1y} = k_e \frac{7\mu C}{(0.5m)^2}\sin 60° = 2.18 \times 10^5 \ N/C$$

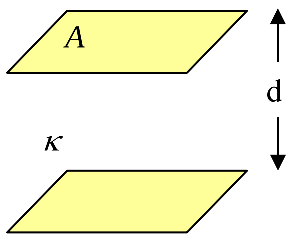
So, $E_x = 1.8 \times 10^4 \ N/C$ and $E_y = -2.18 \times 10^5 \ N/C$

$$\boxed{E = \sqrt{E_x^2 + E_y^2} = 2.19 \times 10^5 \ N/C} \text{ and } \boxed{\angle E = \arctan\left(\frac{E_y}{E_x}\right) = -85.3°}$$

$$\boxed{U = k_e\left(\frac{(2\mu C)(7\mu C)}{0.5m} + \frac{(2\mu C)(-4\mu C)}{0.5m} + \frac{(-4\mu C)(7\mu C)}{0.5m}\right) = -0.396J}$$

Problem 2:

A parallel-plate capacitor is constructed using a dielectric material whose dielectric constant is 3.00 and whose dielectric strength is 2.00 x 10^8 V/m. The desired capacitance is 0.25 μF, and the capacitor must withstand a maximum potential difference of 4000 V. Find the minimum area of the capacitor plates. What is the maximum energy that can be stored in this capacitor?



$$E_{\max} = 2\times10^{8}\, V/m$$

$$\Delta V_{\max} = 4000V = E_{\max} d \text{ then, } d = \frac{4000}{2\times10^{8}} = 2\times10^{-5}\, m$$

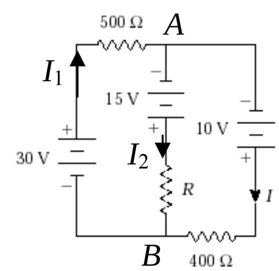
$$C = \kappa\frac{\varepsilon_0 A}{d} \text{ then, } \boxed{A = \frac{Cd}{\kappa\varepsilon_0} = \frac{\left(2.5\times10^{-6}\right)\left(2\times10^{-5}\right)}{(3)\left(8.85\times10^{-12}\right)} = 1.88m^2}$$

$$\boxed{U = \frac{1}{2}C(\Delta V)^2 = \frac{1}{2}\left(2.5\times10^{-6}\right)(4000)^2 = 0.2J}$$

Problem 3:

Consider the circuit on the right.

(a) Write down a complete set of equations to determine the currents in the circuit.
(b) If I = 30 mA, determine the magnitude and direction of the current in the 500-Ω resistor.
(c) Find the value of R.



With the currents as shown, and taking the left and right loops clockwise; the equations are:

$$\boxed{\begin{aligned} &I_1 = I + I_2 \\ &30 - 500I_1 + 15 - RI_2 = 0 \\ &RI_2 - 15 + 10 - 400I = 0 \end{aligned}}$$

If I = 30mA, the total potential drop between A and B from the right branch will be:

$V_A - V_B = 400I - 10 = 2V$

Now looking at the left branch,

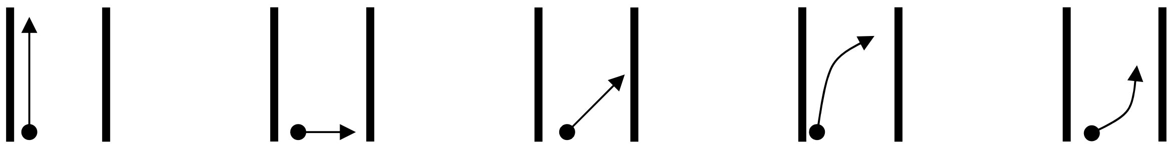
$V_A - V_B = 2V = 30 - 500I_1$. Then, $\boxed{I_1 = 56mA}$ in the direction shown.

$I_2 = I_1 - I = 56mA - 30mA = 26mA$

$V_A - V_B = 2V = RI_2 - 15$. Then, $\boxed{R = 654\Omega}$

Multiple Choice Questions:

1. A positively charged particle is moving in the $+y$-direction when it enters a region with a uniform electric field pointing in the $+x$-direction. Which of the diagrams below shows its path while it is in the region where the electric field exists? The region with the field is the region between the plates bounding each figure. The field lines always point to the right. The x-direction is to the right; the y-direction is up.



(a) *(b)* *(c)* *(d)* *(e)*

2. When a positive charge is released and moves along an electric field line, it moves to a position of

- *(a)* lower potential and lower potential energy.
- *(b)* lower potential and higher potential energy.
- *(c)* higher potential and lower potential energy.
- *(d)* higher potential and higher potential energy.
- *(e)* greater magnitude of the electric field.

3. The capacitance of a parallel-plate capacitor can be increased by:

- *(a)* increasing the charge
- *(b)* decreasing the charge
- *(c)* increasing the plate separation
- *(d)* decreasing the plate separation
- *(e)* decreasing the plate area

4. How much energy is dissipated as heat during a two-minute time interval by a 1.5-kΩ resistor which has a constant 20 V potential difference across its leads?

- *(a)* 58 J
- *(b)* 46 J
- *(c)* 32 J
- *(d)* 72 J
- *(e)* 16 J

5. Most telephone cables are made of copper wire of either 24 or 26 gauge. If the resistance of the 24-gauge wire is 137 Ω/mile and the resistance of 26-gauge wire is 220 Ω/mile, what is the ratio of the diameter of 24-gauge wire to that of 26-gauge wire?

- *(a)* 1.6
- *(b)* 1.3
- *(c)* 0.62
- *(d)* 0.79
- *(e)* 0.88