Name: ______________________________

PH122 – Exam 2 – March 9, 2018

Time Started __________ Time Ended __________ Place Taken __________

Instructions and Notes – You will lose points if you do not comply.

- You are only allowed three hours (or a pre-arranged accommodation) to take this exam. Pay careful attention to time! If you go over time, I will deduct points in proportion to how much time you go over the allotted amount.
- You are allowed one 8.5 inch by 11 inch piece of paper, with whatever information you choose to include on the front and back, as your only source of information outside of this exam paper. You may not consult your textbook, notes, or any other source of information.
- You are allowed to use a scientific calculator, but it must not be programmed with course-specific information. You may not use a cell phone as a calculator, but you can use it as a clock. (Keep it silent!)
- Unless you have made other arrangements, you will take the exam in one of the general physics laboratories (SSC111 or SSC115).
- Answer all questions on your own loose-leaf paper (not torn out of a spiral notebook).
- You may use only the front side of each sheet to answer the questions. If your answer goes longer than one page, continue on the front of a new sheet of paper and indicate that it is a continuation of that question's answer.
- Answers to each question (not each question part) must start on a new sheet of paper.
- Your answers should be clear, well explained, and legible. It is your job, not mine, to ensure that I understand your answer. If you have a muddled answer and time remains at the end of the test, re-write it neatly on a new sheet of paper and submit the clear answer.
- Box final answers to calculation/symbolic questions so I can easily locate your answer.
- The grading rubric is listed on the back of this page. You must demonstrate that you understand the physics involved in the problem in order to receive full credit. A correct answer is not sufficient. You must show how you obtained that answer.
- Show enough detail in algebraic manipulations to ensure I can follow your work.
- Include units in all calculations and include them through all steps of a calculation. I will deduct points for correct solutions for which you do not include units with numerical values through every step of the solution!!!
- When you finish the exam, arrange all answer sheets in order and staple them together with these exam sheets on top.

Sign That You Have Upheld
The Honor Code During This Exam: ______________________________

Grading Rubric

Each problem will be graded on a 10-point scale. The table below shows examples of how I will assign points.

<u>High Level of Understanding Demonstrated</u>

10 points:	correct answer and explanation
9 points:	correct reasoning with a reasonable answer but minor computational errors

<u>Partial Understanding Demonstrated</u>

7 points:	physics errors (or correct setup but incomplete execution)
5 points:	major physics errors (or partial justification provided even if answer is correct)

<u>Little to No Understanding Demonstrated</u>

3 points:	little relevant work (or no justification provided even if the answer is correct)
1 point:	very little relevant work
0 points:	no relevant work, recopy of the problem statement with no additional work

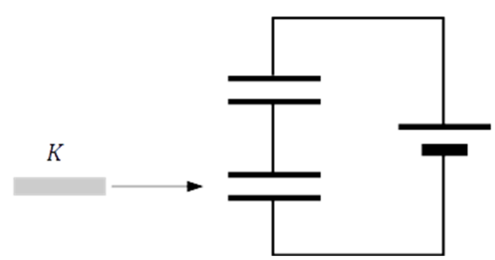
Constants

$k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$ $\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$ $e = 1.6 \times 10^{-19}\ \mathrm{C}$

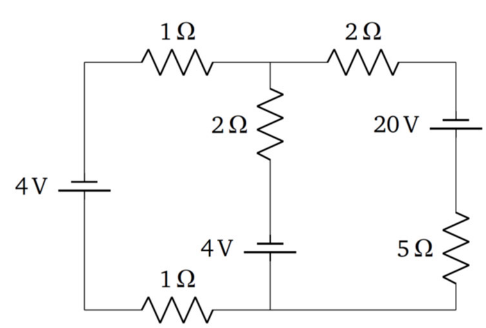
$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$ $m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ g=9.8 N/kg

Questions

1. The diagram on the right shows two identical fully charged capacitors connected in series with an ideal battery. When a dielectric slab (dielectric constant K) is inserted between the plates of the lower capacitor, explain what happens to each of the following quantities for each capacitor: capacitance, potential difference, stored charge, and stored energy. (*I.e.* does each quantity increase, decrease, or stay the same?) Thoroughly explain and justify your answers.



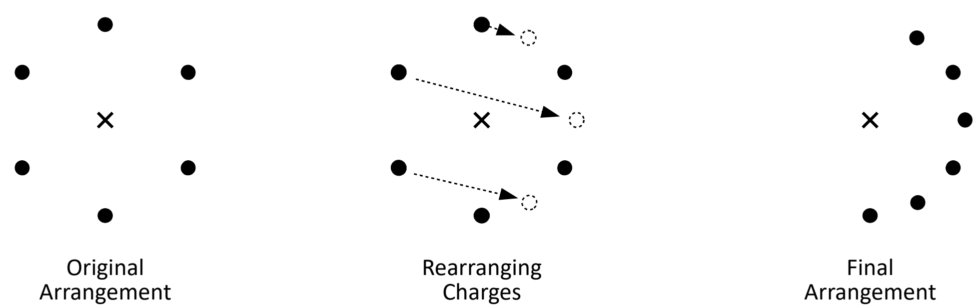
2. The diagram below shows a circuit with ideal EMFs and resistances as shown. Reproduce this figure on your paper and compute the magnitude and direction of the current through the 5Ω resistor. Compute also the *total power* delivered by all three batteries. Make sure to draw and label currents, identify loops, and work through loops and junctions. I won't give credit if I can't follow your work!



3. Six equal positive charges $+q$ are arranged, equally-spaced, in a circle. For simplicity, assume that the charges are located in the 2, 4, 6, 8, 10, and 12-o'clock positions as shown in the diagram, below *left*. Consider three quantities:

   (a) $V(\vec{\mathrm{r}}_0)$ – the electric potential at the center of the circle (marked by an "×"),
   (b) $\vec{\mathrm{E}}(\vec{\mathrm{r}}_0)$ – the electric field at the center of the circle, and
   (c) U_{Tot} – the *total* potential energy of the arrangement.

   You don't need to calculate anything explicitly yet, but you should know how to calculate these quantities; and you may find that your considerable physics knowledge will help you figure out what some of the values are.



   Now imagine moving some charges while keeping others in place, as shown above *middle*, until the six charges end up arranged at the 1, 2, 3, 4, 5, and 6-o'clock positions, as shown in the diagram above *right*.

   Explain how each of the three quantities under consideration ($V(\vec{\mathrm{r}}_0)$, $\vec{\mathrm{E}}(\vec{\mathrm{r}}_0)$ and U_{Tot}) changes when you rearrange the charges. (Note: $V(\vec{\mathrm{r}}_0)$ and $\vec{\mathrm{E}}(\vec{\mathrm{r}}_0)$ are still evaluated at the "×" point.) You don't need to calculate exact expressions, but you need to explain *how* and why the values change. Account for changes in value, magnitude, and direction as appropriate, and justify your answers. This is mostly a qualitative conceptual question. I'm looking for a careful analysis in terms of potentials, fields, forces, energies, etc.

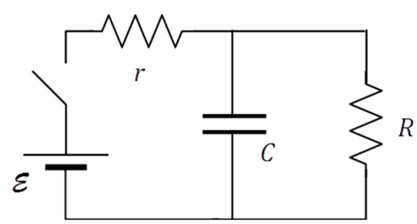
4. Here's a hypothetical way to measure an unknown resistance. Connect an unknown resistance R and a known resistance R_0 in series with an ideal EMF $\mathcal{E}$. Use an ideal voltmeter to measure the potential difference across R_0. Call this potential difference ΔV_0. *Derive* an expression for the unknown resistance R in terms of R_0, $\mathcal{E}$, and ΔV_0. Of course you need to draw the circuit and explain your procedure.

5. Physicist Robert Millikan used a neat trick to measure small charges (such as the charge of an electron). He sprayed drops of oil into the evacuated space between two large metal plates with a potential difference between them. Many times, an oil drop would have either extra electrons, giving it a net negative charge, or some electrons stripped away, giving it a net positive charge. By adjusting the voltage, he could make each drop rise or fall. He could even suspend them in place by ensuring that the electric and gravitational forces on the drop are equal. Consider such an apparatus in which the plates are separated by a distance of 1 cm. A microscopic oil drop of mass $m = 5.00 \times 10^{-15}$ kg is found to remain suspended between the plates when the potential difference between the plates is 1020 V, with the top plate at higher potential.

   (a) Draw a diagram of the situation that includes electric field lines and forces on the oil drop.

   (b) Determine the net charge on the oil drop, in coulombs. Does the oil drop have extra electrons on it or were some electrons stripped away? How many electrons?

6. We only briefly discussed current "through" a capacitor in class, but the concept is straightforward. Current flowing through a capacitor is equal to the rate at which the capacitor charges. *I.e.* if current enters the positive plate of the capacitor the charge of the capacitor increases. If current leaves the positive plate of the capacitor, then the charge of the capacitor decreases. If no current passes through the capacitor, the charge is constant. Consider the circuit on the right, in which an ideal EMF $\mathcal{E}$ is connected to two resistors, r and R, and a capacitor, C, as shown.



   (a) Suppose that the capacitor is initially *uncharged*, and consider what happens immediately after the switch is closed, before any charge accumulates on the capacitor. What is the potential difference across the capacitor, ΔV_C, and each resistor, ΔV_r and ΔV_R? How much current is passing through the capacitor, I_C, and each resistor, I_r and I_R? All answers should be in terms of $\mathcal{E}$, r, and/or R only.

   (b) Eventually the capacitor will become fully charged, after which the charge will remain constant over time. At this point, what is the potential difference across the capacitor and each resistor? How much current is passing through the capacitor and each resistor? All answers should be in terms of $\mathcal{E}$, r, and/or R only.

   Extra Credit (Do not attempt until you've completed the rest of the exam)
   Using your answers above, draw four graphs that show how the following quantities change over time: the current through each resistor, the current through the capacitor, and the total charge of the capacitor. You already know these quantities at $t = 0$ from part (a), and as $t \longrightarrow \infty$ from part (b). Guess the behavior at times in between.