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General Physics 122 - Exam 2 – April 5, 2019

Time started _____ Time ended _____

Place taken _____

PLEASE READ ALL THE INSTRUCTIONS THROUGH FIRST!!!!

- To receive full credit for a problem, your work must convincingly demonstrate that you understand the physics involved behind the problem. That means not only providing the correct answer but showing how you obtained your answer.
- Questions represent a mix of conceptual and quantitative issues. Questions are scored according the rubric on the next page
- You may not consult the textbook, your notes, or any source of information other than the equations below.
- You may choose any continuous, uninterrupted 3-hour period in which to take this exam.
- You may use a calculator provided it is not programmed with course-specific information.
- It is important that your answers be neat and clear. Legible handwriting and clear exposition are required, not optional
- Include raw algebraic equations and identify variables. Include units (m, s, m/s, etc.) in calculations and carry them through.
- Box your final answers to help me locate and identify them quickly
- Use only one side of each page of paper.
- Use your own, lined paper. Nothing written on this exam will be graded.
- Do not use paper ripped from a spiral-bound notebook with jagged edges.
- Do not write your name on any of the pages other than this cover sheet.
- Start each answer on a new sheet of paper.
- When finished, place this entire exam atop your responses arranged in sequential order, straighten all the edges neatly, and staple them together before handing them in.
- You must turn in the exam to Dr. Pontius unless other arrangements have been made.
- **I reserve the right to assign additional penalties for violating these instructions.**

*Signing the honor code also affirms that you are taking the exam during a time period that does not conflict with any other academic obligations.*

Honor code:

*Don't Panic!*

Reminder: Show all your work. Explain thoroughly and justify everything.

Grading rubric:

| Level of demonstrated understanding | Example | Score |
|---|---|---|
| Complete | Correct, fully justified reasoning and answer | 10 |
| | Correct reasoning; minor computational mistakes or omissions; reasonable answer | 9 |
| Partial | Some physics errors or a correct setup but no or incomplete execution; substantial omissions | 7 |
| | Major physics errors or partial justification provided even if answer is correct; major omissions | 5 |
| Little to none | Little of relevance or no justification provided even if answer is correct | 3 |
| | Very little of relevance; moderately interesting B. S. | 1 |
| | Blank or just a restatement of the question | 0 |

$$\vec{F}_{12} = k_e \frac{Q_1 Q_2}{r^2} \hat{r} \qquad k_e = \frac{1}{4\pi\varepsilon_o} \qquad \vec{F}_E = q\vec{E} \qquad E = \frac{\sigma}{\varepsilon_o}$$

$$\vec{E} = \sum_i k_e \frac{Q_i}{r_i^2} \hat{r} \qquad \Delta V = I R \qquad Q = C \Delta V \qquad R = \rho \frac{L}{A}$$

$$\Delta V = -\int \vec{E} \cdot d\vec{s} \qquad \Delta V = k_e Q \left[ \frac{1}{r_A} - \frac{1}{r_B} \right] \qquad U = 1/2\, Q \Delta V \qquad C = \kappa C_o$$

$$I = \frac{dQ}{dt} \qquad \Delta V = E \Delta x \qquad \Delta U = q\Delta V \qquad P = I \Delta V$$

$$V_\infty = \sum_i k_e \frac{Q_i}{r_i} \qquad R = \sum_i R_i \qquad \frac{1}{R} = \sum_i \frac{1}{R_i} \qquad \Delta V = I R$$

$$C = \sum_i C_i \qquad \frac{1}{C} = \sum_i \frac{1}{C_i} \qquad C = \frac{1}{2k_e \ln(b/a)} \qquad C = \frac{\varepsilon_o A}{d}$$

Data that may or may not be of value to you:

$e = 1.60 \times 10^{-19}$ C

$k_e = 8.99 \times 10^9$ N·m$^2$/C$^2$

$\mu_o = 4\pi \times 10^{-7}$ T· m/A

$\mu F = 10^{-6}$ F

1 amu $= 1.67 \times 10^{-27}$ kg

$R_E = 6370$ km

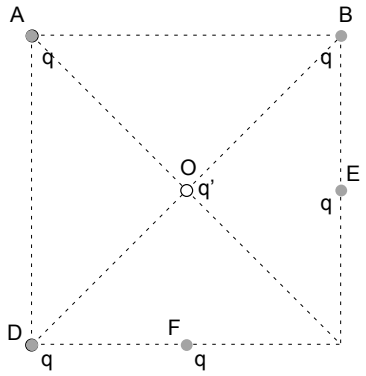
$G = 6.673 \times 10^{11}$ N·m$^2$/kg$^2$

$\varepsilon_o = 8.85 \times 10^{-12}$ C$^2$/N·m$^2$

$nT = 10^{-9}$ T

$m_e = 9.11 \times 10^{-31}$ kg

1. Five equal positive charges of q are placed on a square at the labeled positions as illustrated.




A sixth positive charge q' is placed at the center O. First, explain qualitatively what direction of the resultant force on q' must be, then solve for its exact value. This problem is best worked algebraically, but you may work with numbers if you wish*, taking $q = 1.4173 \times 10^{-7}$ C, the length of the sides as $L = 42.42$ mm, and $q' = 2.7291 \times 10^{-9}$ C. Show all work.

(*I will think less of you, but because I grade blindly, I won't know who you are.)

2. A pair of charges both of magnitude $Q$ are at fixed positions a distance $2R$ from each other.

i. Assuming they are both positive, is there an electric field at the position exactly midway between them? Is there an electric potential there? Discuss the work required to move a third positive particle of charge $q$ from its initial position in a galaxy far, far away and place it at rest exactly midway between the two original charges. Explain the significance of its sign and discuss your reasoning throughout.

ii. Repeat, now assuming the two original charges are of opposite signs but letting the third charge still be positive.

Note that while analogies and metaphors are very good for getting your intuition going on these problems, your complete answer must include explanations in terms of electrical phenomena.

3. Consider the circuit diagram show below in the left frame, which has been established long enough to be in a steady state. Explain your logic as you carry out the following.

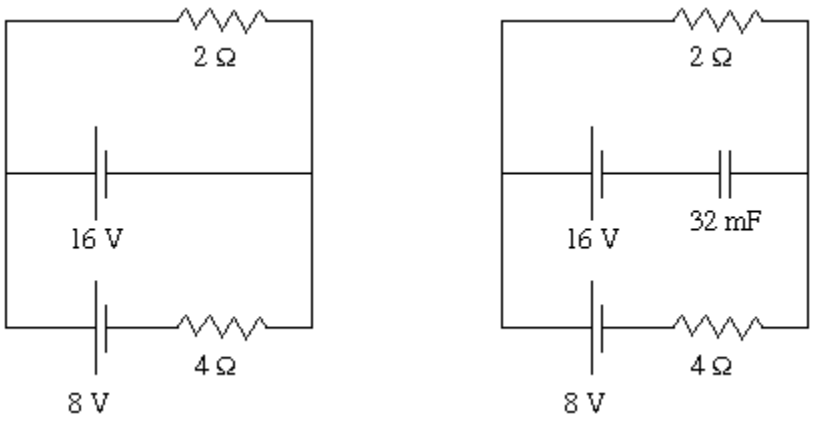
   a) Calculate the currents in the upper ($I_1$), middle ($I_2$), and bottom ($I_3$) horizontal wires and specify the direction (left or right) of each.

   b) Calculate the power dissipated in each resistor.

Next, a 32mF capacitor is inserted into the circuit in the middle branch at the position shown in the right frame and the circuit is again given sufficient time to come to a steady state.

   c) Calculate all the currents again, again specifying directions.

   d) Calculate the energy stored in the capacitor.




4. Consider a pair of resistors connected in series with each other in a single loop with a power supply of fixed emf $\mathcal{E}$. One resistor has a fixed resistance $R_f$, while the other resistor is a variable resistor of varying resistance $R_v$. Initially, $R_v << R_f$, but $R_B$ is gradually increased until the inequality is reversed, so that $R_f << R_v$. Describe how the power dissipated in each of the individual resistors changes as $R_v$ is increased, and explain why. Also compare the powers to each other. I'm looking for a comprehensive and insightful explanation, not just a list of vaguely related facts.

5. A total electric charge of 5.00 nC is distributed uniformly over the surface of a metal sphere with a radius of 20.0 cm. The potential is zero at a point at infinity. Explain your reasoning throughout.

   i. Find the value of the potential at 49.0 cm from the center of the sphere.

   ii. Find the value of the potential at 20.0 cm from the center of the sphere.

   iii. Find the value of the potential at 16.0 cm from the center of the sphere.

6. Consider a pair of parallel-plate capacitors connected in series, as shown in the figure below. The combination is originally attached to a battery at the terminals (small circles). Both capacitors start out with their plates separated only by air, but during the experiment a dielectric material is inserted between the plates of capacitor B. Consider what happens when the dielectric is inserted under each of the following conditions.

i. The capacitor combination is detached from the battery before the dielectric is inserted

ii. The capacitor combination remains attached to the battery while the dielectric is inserted

For each capacitor in each situation, explain whether the follow quantity increases, decreases, or remains the same: capacitance, potential drop, charge, energy. Explain the logic underlying those conclusions. I'm not looking for simple equation crunching, I want lucid explanations in terms of what a capacitor does and how a dielectric influences that.