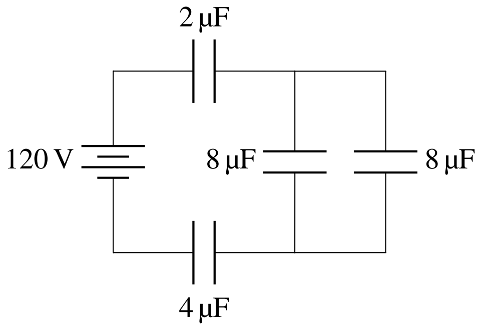
Student #: ____________________________ Student Name: ___________________________________

AP PHYSICS C: CIRCUIT ANALYSIS, PART 2

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\,\mathrm{m/s^2}$ in all problems.

Questions 1–2

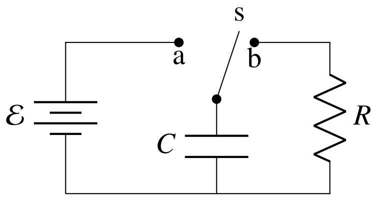


1. The equivalent capacitance of this circuit is
   (A) $7/4\,\mu\mathrm{F}$
   (B) $4/7\,\mu\mathrm{F}$
   (C) $21/16\,\mu\mathrm{F}$
   (D) $10\,\mu\mathrm{F}$
   (E) $22\,\mu\mathrm{F}$

2. The charge stored on the $2\,\mu\mathrm{F}$ capacitor is most nearly
   (A) $6\,\mu\mathrm{C}$
   (B) $12\,\mu\mathrm{C}$
   (C) $22\,\mu\mathrm{C}$
   (D) $36\,\mu\mathrm{C}$
   (E) $120\,\mu\mathrm{C}$

Question 3–4

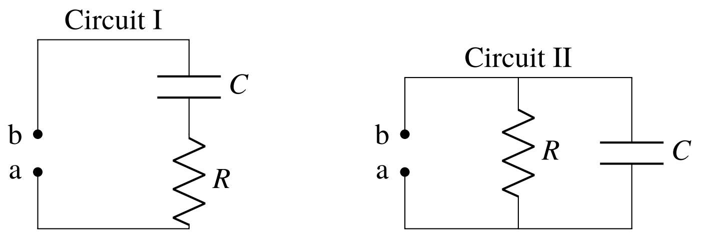
The circuit shows a capacitor, a battery, and a resistor. Switch S is first connected to point a to charge the capacitor, then a long time later switched to point b to discharge the capacitor through the resistor.



3. The time constant τ for discharging the capacitor through the resistor could be decreased (faster discharge) by
   (A) placing another resistor in series with the first resistor
   (B) placing another resistor in parallel with the first resistor
   (C) placing another capacitor in parallel with the first capacitor
   (D) placing another battery in series in the same direction with the first battery
   (E) increasing both R and C

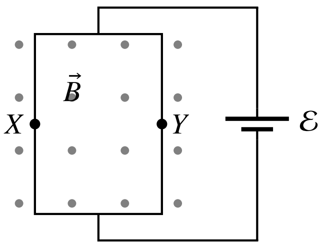
4. The maximum current through the resistor is
   (A) $\mathcal{E}/2R$
   (B) $\mathcal{E}/R$
   (C) $\mathcal{E}/RC$
   (D) $\mathcal{E}/2RC$
   (E) $C\mathcal{E}/R$

5. Circuit I and Circuit II shown each consist of a capacitor and a resistor. A battery is connected across a and b, and then removed. Which of the following statements is true of the circuits?



   (A) Circuit I and Circuit II will both retain stored energy when the battery is removed.
   (B) Neither Circuit I nor Circuit II will retain stored energy when the battery is removed.
   (C) Only Circuit I will retain stored energy when the battery is removed.
   (D) Only Circuit II will retain stored energy when the battery is removed.
   (E) Current will continue to flow in both circuits after the battery is removed.

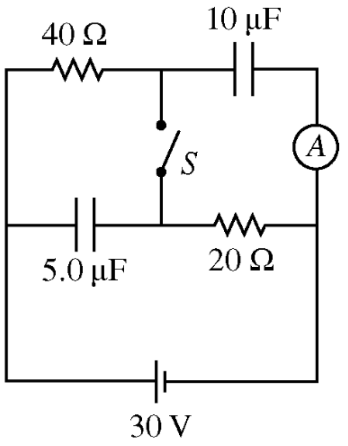
6. A thin sheet of copper is placed in a uniform magnetic field. A battery is connected to the top and bottom ends of the copper sheet, so that conventional current flows from the top to the bottom of the sheet. Points X and Y are on the left and right sides of the sheet, respectively. Which of the following statements is true?



(A) Point X is at a higher potential than point Y.
(B) Point Y is at a higher potential than point X.
(C) Point X and point Y are at equal potential.
(D) Point X is at zero potential, and point Y has a positive potential.
(E) Point Y is at zero potential, and point X has a negative potential.

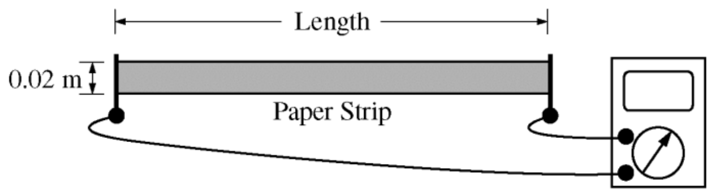
AP PHYSICS C: ELECTRIC CIRCUITS
SECTION II
5 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.



1. In the circuit illustrated above, switch S is initially open and the battery has been connected for a long time.
   (a) What is the steady-state current through the ammeter?
   (b) Calculate the charge on the $10\,\mu F$ capacitor.
   (c) Calculate the energy stored in the $5.0\,\mu F$ capacitor.

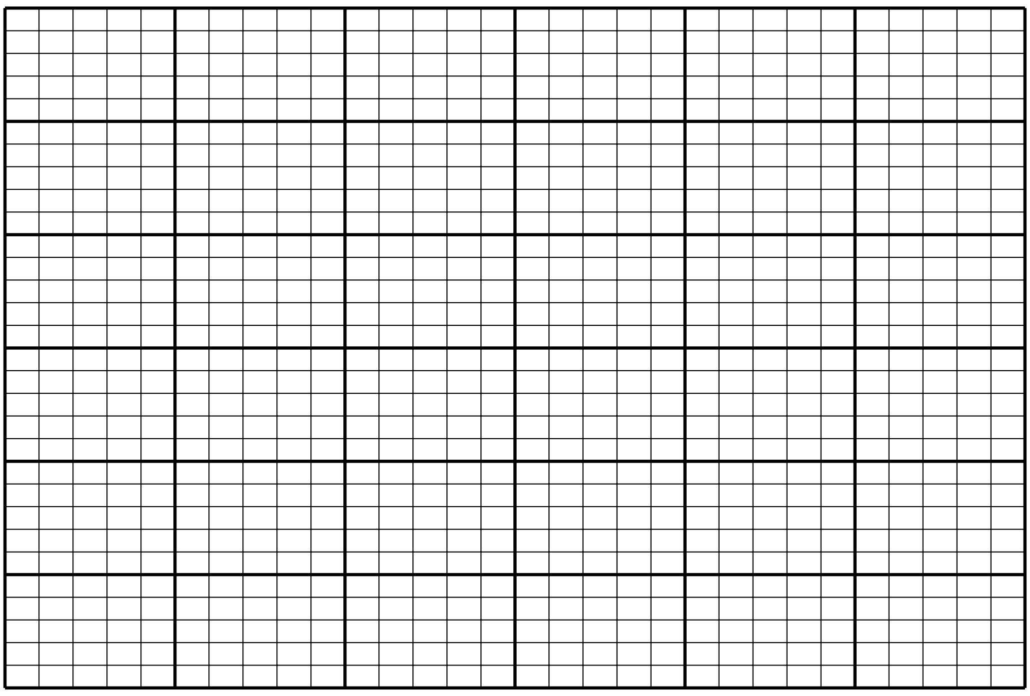
   The switch is now closed, and the circuit comes to a new steady state.
   (d) Calculate the steady-state current through the battery.
   (e) Calculate the final charge on the $5.0\,\mu F$ capacitor.
   (f) Calculate the energy dissipated as heat in the $40\,\Omega$ resistor in one minute once the circuit has reached steady state.



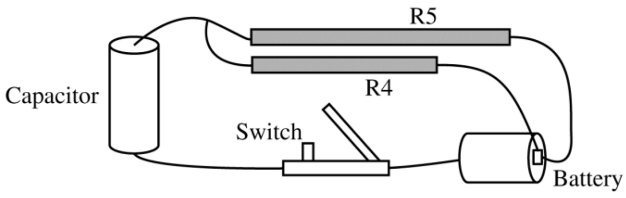
2. A physics student wishes to measure the resistivity of slightly conductive paper that has a thickness of 1.0×10^4 m. The student cuts a sheet of the conductive paper into strips of width 0.02 m and varying lengths, making five resistors labeled R1 to R5. Using an ohmmeter, the student measures the resistance of each strip, as shown above. The data are recorded below.

Resistor	R1	R2	R3	R4	R5
Length (m)	0.020	0.040	0.060	0.080	0.100
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



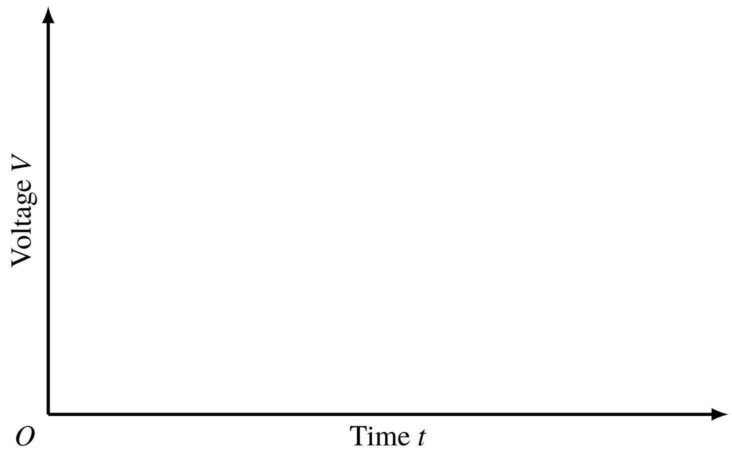
(b) Using the graph, calculate the resistivity of the paper.

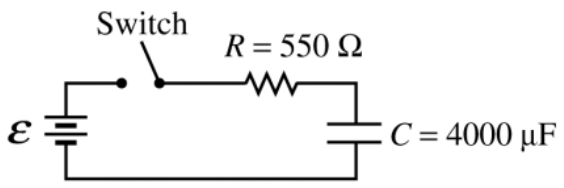


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

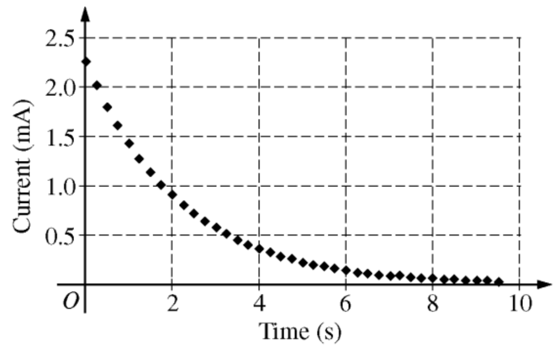
(c) Calculate the time constant of the circuit.

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.





3. A student sets up the circuit above in the lab. The values of the resistance and capacitance are as shown, but the constant voltage $\mathcal{E}$ delivered by the ideal battery is unknown. At time $t = 0$, the capacitor is uncharged and the student closes the switch. The current as a function of time is measured using a computer system, and the following graph is obtained.

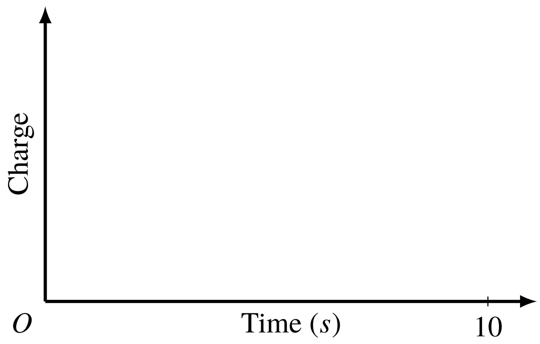


(a) Using the data above, calculate the battery voltage $\mathcal{E}$.

(b) Calculate the voltage across the capacitor at time $t = 4.0$ s.

(c) Calculate the charge on the capacitor at $t = 4.0$ s.

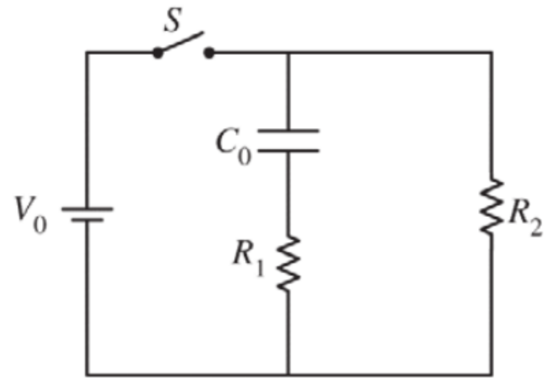
(d) On the axes below, sketch a graph of the charge on the capacitor as a function of time.



(e) Calculate the power being dissipated as heat in the resistor at $t = 4.0$ s.

(f) The capacitor is now discharged, its dielectric of constant $\kappa = 1$ is replaced by a dielectric of constant $\kappa = 3$, and the procedure is repeated. Is the amount of charge on one plate of the capacitor at $t = 4.0$ s now greater than, less than, or the same as before? Justify your answer.

____ Greater than ____ Less than ____ The same



4. In the circuit above, an ideal battery of voltage V_0 is connected to a capacitor with capacitance C_0 and resistors with resistances R_1 and R_2 , with $R_1 > R_2$. The switch S is open, and the capacitor is initially uncharged.

(a) The switch is closed at time $t = 0$. On the axes below, sketch the charge q on the capacitor as a function of time t. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

(b) On the axes below, sketch the current I through each resistor as a function of time t. Clearly label the two curves as I_1 and I_2 , the currents through resistors R_1 and R_2, respectively. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

The circuit is constructed using an ideal 1.5 V battery, an 80 μF capacitor, and resistors $R_1 = 150\,\Omega$ and $R_2 = 100\,\Omega$. The switch is closed, allowing the capacitor to fully charge. The switch is then opened, allowing the capacitor to discharge.

(c) The time it takes to charge the capacitor to 50 % of its maximum charge is Δt_C. The time it takes for the capacitor to discharge to 50 % of its maximum charge is Δt_D. Which of the following correctly relates the two time intervals? Justify your answer.

____ $\Delta t_C > \Delta t_D$ ____ $\Delta t_C = \Delta t_D$ ____ $\Delta t_C < \Delta t_D$

(d) i. Calculate the current through resistor R_2 immediately after the switch is opened.

ii. Is the current through resistor R_2 increasing, decreasing, or constant immediately after the switch is opened? Justify your answer.

____ Increasing ____ Decreasing ____ Constant

(e) i. Calculate the energy stored in the capacitor immediately after the switch is opened.

ii. Calculate the energy dissipated by resistor R_1 as the capacitor completely discharges.

5. You have been hired to determine the internal resistance of $8.0\,\mu F$ capacitors for an electronic component manufacturer. (Ideal capacitors have an infinite internal resistancethat is, the material between their plates is a perfect insulator. In practice, however, the material has a very small, but nonzero, conductivity.) You cannot simply connect the capacitors to an ohmmeter, because their resistance is too large for an ohmmeter to measure. Therefore you charge the capacitor to a potential difference of $10\,V$ with a battery, disconnect it from the battery and measure the potential difference across the capacitor every 20 minutes with an ideal voltmeter, obtaining the graph shown above.

   (a) Determine the internal resistance of the capacitor.

   The capacitor can be approximated as a parallel-plate capacitor separated by a $0.10\,mm$ thick dielectric with $\kappa = 5.6$.

   (b) Determine the approximate surface area of one of the capacitor "plates."

   (c) Determine the resistivity of the dielectric.

   (d) Determine the magnitude of the charge leaving the positive plate of the capacitor in the first $100\,min$.