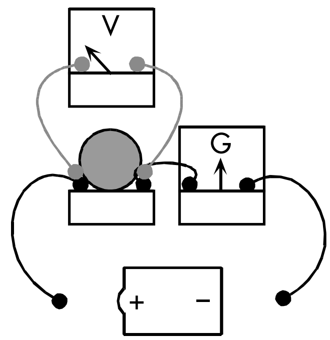
TechLab: Capacitor Curves

an investigation of capacitors in RC circuits

PERIOD	1.		
	2.		
GROUP	3.		
	4.		

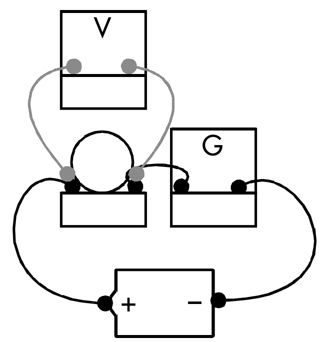
• Pre-Lab •

1. Consider a simple circuit consisting of a battery, a bulb, and some connecting wire. Suppose a voltmeter and a galvanometer (bi-directional ammeter) were added to the circuit to measure the voltage across and current through the resistor.



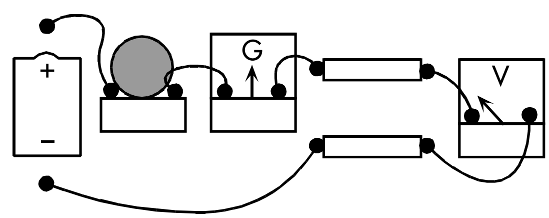
a. When the battery is disconnected, the bulb is unlit and there is no voltage and no current. (The galvanometer needle points straight up when the current is zero. It will deflect to the right when it detects current to the right; it will deflect to the left when it detects current to the left.)

b. Describe the bulb and the meter readings when the battery is connected, and show the needle positions on the meters in the diagram.



c. If the battery were reversed, the bulb would still light. What would happen to the reading on the galvanometer?

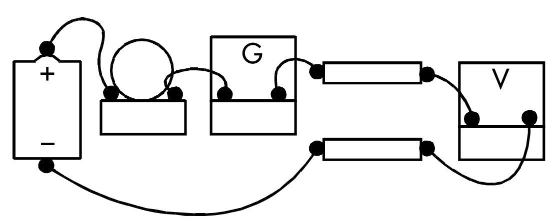
2. Consider a pair of uncharged parallel plates. A voltmeter is attached across the plates and a galvanometer is connected to one plate. A bulb is connected in series with the galvanometer and a battery is added to complete the circuit.



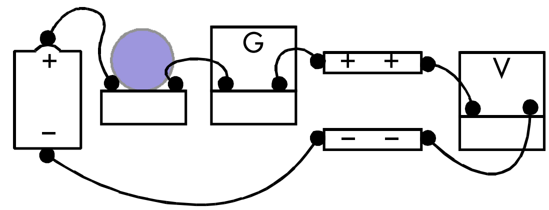
a. When the battery is disconnected, the bulb is unlit; there is no voltage across the plates and no current through the wire.

b. Describe the bulb and the meter readings when the battery is connected, and add needles to the meters in the diagrams

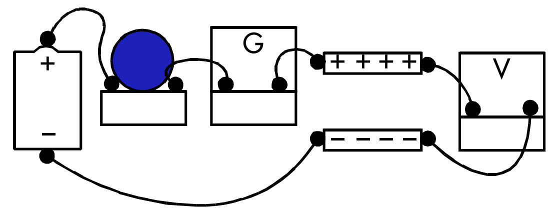
i. Right when the battery is first connected.



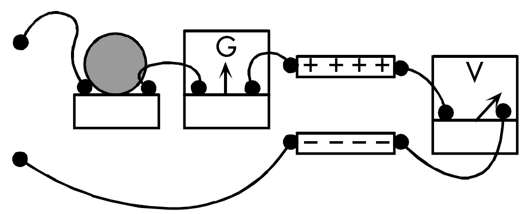
ii. A little while later, when the plates have reached about half their charging capacity.



iii. Much later, after the plates have reached their full charging capacity.

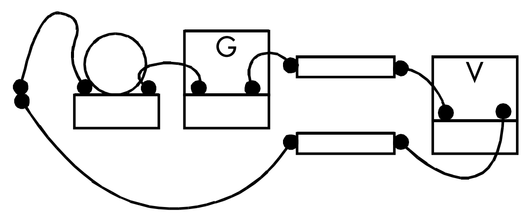


3. At this point, one plate has a considerable positive charge and the other has a considerable negative charge, Next, the battery is removed. At this point, the bulb is unlit, there is no current through the wire, but there is a potential across the plates. Next, the wires leading to it are connected to each other. This creates a path from the positive plate to the negative plate. Of course, for charge to move from one plate to the other, it must pass through the bulb.

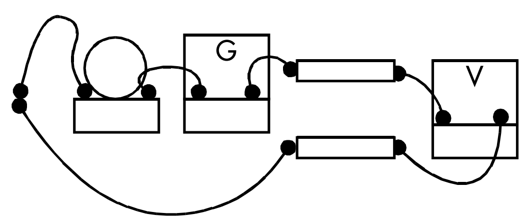


a. Describe the bulb and the meter readings as the capacitor discharges, add needles to the meters in the diagrams, and show the charges on the parallel plates.

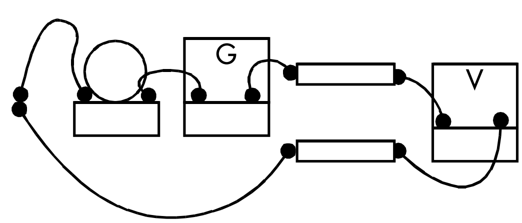
i. Right when the battery leads are connected.



ii. A little while later, when the plates have discharged about halfway.



iii. Much later, when the charge is completely gone (the plates have neutralized each other).



4. The parallel plates represent

__A. a battery
__B. a capacitor
__C. a resistor
__D. a pair of magnets
__E. a molecular dipole
__F. what parallel people parallel eat from

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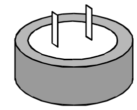
• Purpose •

In this activity, you will investigate the voltage and current associated with a capacitor as it charges and discharges in a resistor-capacitor (*RC*) circuit.

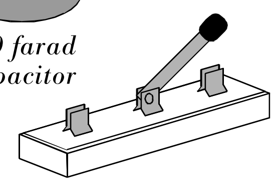
• Apparatus •

INITIAL PROCEDURE

___ 1.0 F capacitor
___ 2 C- or D-cell batteries
___ single throw double pole switch
___ DC ammeter (0-1 A)
___ mini bulbs in sockets [6.3 V]
___ 3 battery connectors (optional)
___ DC voltmeter (0-10 V)
___ connecting wires



1.0 farad capacitor

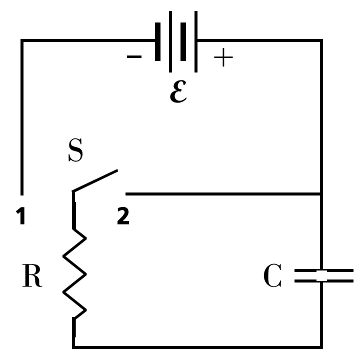


single throw double pole switch

COMPUTER PROCEDURE (Get these later)

___ computer with data analysis software (DataStudio)
___ interface device (USB Link)
___ current/voltage sensor

• Initial Procedure • (The Low Tech Observations)



1. Connect the circuit shown. Note: the switch is in an open (up) position during circuit construction. Once the circuit is connected, observe its operation.
   a. When the switch is in position 1, the capacitor is charging. Observe the bulb for several seconds. Describe what happens to the bulb.

   b. Sketch an estimate of light vs. time on.

   c. When the switch is in position 2, the capacitor is discharging. Observe the bulb for several seconds. Describe what happens to the bulb.

   d. Make a rough sketch of light vs. time while the capacitor is discharging.

2. Correctly connect a voltmeter and an ammeter to the **capacitor** (not the bulb) to monitor the voltage across it and the current through it. If you are not sure how to connect the meters, refer to *PhyzLab: , on the Range.*

a. Observe and describe the voltage and current as the capacitor **charges**. [Remember: if the needle goes the wrong way, switch the connections to it.]

i. Sketch voltage vs. time and current vs. time graphs.

ii. What is the maximum voltage that the capacitor attains in the charging process?___________________

iii. What is the potential (voltage) of the batteries connected in series?_______________________________

iv. How do the values listed in parts ii and iii compare to each other?

b. Observe and describe the voltage and current as the capacitor **discharges**.

i. Sketch voltage vs. time and current vs. time graphs. [Remember: if the needle goes the wrong way, switch the connections to it.]

ii. Compare the direction of current when the capacitor is charging to when it discharges. Explain the result.

3. Describe the physical meaning of each of the following characteristics of the voltage and current graphs. [Some of these are more physically meaningful than others.] It helps to think about the units when interpreting these quantities.

a. The slope of the voltage vs. time graph. (People that know calculus call this dV/dt.)

b. The area bounded by the voltage vs. time graph. (People that know calculus call this $\int V\,dt$.)

c. The slope of the current vs. time graph. (People that know calculus call this dI/dt.)

d. The area bounded by the current vs. time graph. (People that know calculus call this $\int I\,dt$.)

• Computer Procedure • (The High Tech Observations)

4. a. Replace the voltmeter and ammeter connections in the circuit with connections to the current/voltage sensor.

b. Connect the current/voltage sensor to the interface device.

c. Connect the interface device to the computer.

d. Start DataStudio. Open Activity: "2.07 Capacitor Curves."

5. Make sure the capacitor is completely discharged. (Touch opposite ends of a wire to both terminals at the same time.) Put the switch in an open (up) position.

6. Click the on-screen "Start" button to initiate data sampling. Put the circuit switch into position "1" to begin charging the capacitor. Allow the sampling to continue while the capacitor reaches its full charging potential.

7. While the sampling continues, lift the switch out of position 1 and in an open (up) position for a few seconds. Then put the circuit switch into position "2" to discharge the capacitor. Continue sampling until the potential is zero (or very nearly zero).

8. Use the "Scale to Fit" tool (in the upper left of the **graph** window) to maximize each graph. (Click once within a graph to make that graph active, then click the "Scale to fit" button.)

9. Use DataStudio's Note Tool to label points on the graph at which the charging and discharging processes began. Use the handles on the sides of each placed note to shrink the note to an appropriate size. Use the pointer on each note to indicate the appropriate point on the graph.

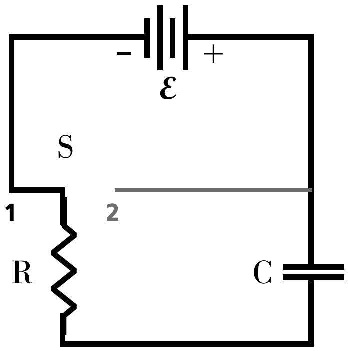
10. Save your experiment using the "Save Activity As..." Command (in the File menu). Name the file by unit number, lab title, and period-group. For example: "2.07 Capacitor Curves 3E." Save it in the appropriate designated folder.

11. Print the graph. In the File menu, select "Page Setup..." Select Landscape orientation (not Portrait) and click OK. Secure a PhyzBlessing. Print a copy of the graphs for each member of the group.

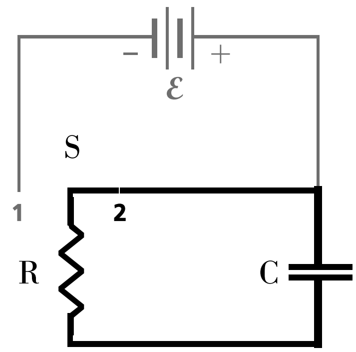
• Analysis •

1. Add arrows to the diagrams below to show the direction in which current flows when the circuit is configured to

a. charge the capacitor.



b. discharge the capacitor.



2. Which statement best characterizes the current when an uncharged capacitor is being charged?
__A. The current is constant for several seconds and then cuts off abruptly.
__B. The current slowly increases until it reaches a constant value.
__C. The current slowly decreases until it reaches zero.

3. Why does the flow of charge follow this pattern during the charging phase? Hint: refer to the discussion of charging parallel plates near the beginning of *PhyzSpringboard: Capacitance.*

4. Which statement best characterizes the current when a charged capacitor is discharged through a resistor?
__A. The current is constant for several seconds and then cuts off abruptly.
__B. The current slowly increases until it reaches a constant value.
__C. The current slowly decreases until it reaches zero.

5. Why does the flow of charge follow this pattern during the discharging phase?

6. Determine an experimental value for the capacitance of the capacitor.

a. What is the maximum electric potential of the capacitor? Use your graph to determine this.

b. What is the value of the charge separated in the capacitor when the capacitor is at full charge and full potential? (Hint: recall your responses in Procedure Question 3. If desired, use the "Slope Tool" to determine the slope of a graph at a specific point. If desired, find the area bounded by a curve by selecting the desired section of the graph and using the "Statistics Tool: Area." Select a section by clicking down and dragging across the section.)

c. Given the potential V and charge Q, determine an experimental value for the capacitance C of the capacitor.

d. Calculate the percent **error** between the experimental value and accepted value of capacitance.