

Storing And Releasing Charge In A Circuit

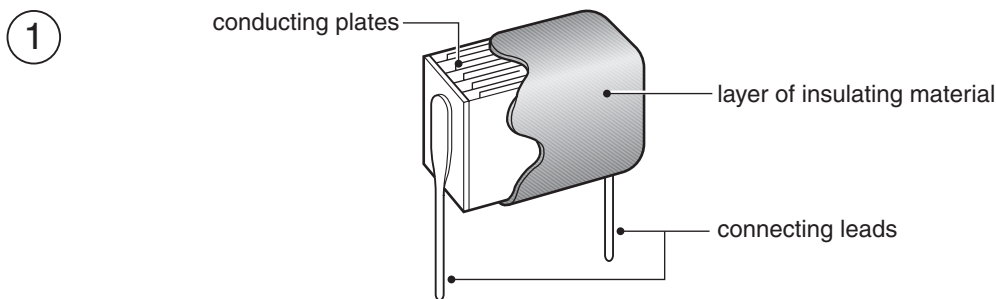


Topic

The characteristics of capacitors

Introduction

A capacitor is a device that can retain and release an electric charge, and is used in many circuits. There are many types of capacitor, but they all have the same basic features – a pair of conducting plates separated by layers of insulating material (see diagram 1 below). Capacitance is measured in farads (F) and, as this experiment involves relatively large capacitances (necessary to study the way they charge and discharge over time), electrolytic capacitors are used (these have a positive and a negative terminal). Unlike that across a resistor, the voltage measured across a capacitor in a circuit rises gradually. In this experiment, you will charge and discharge a capacitor in a circuit.



Schematic diagram showing the structure of a capacitor

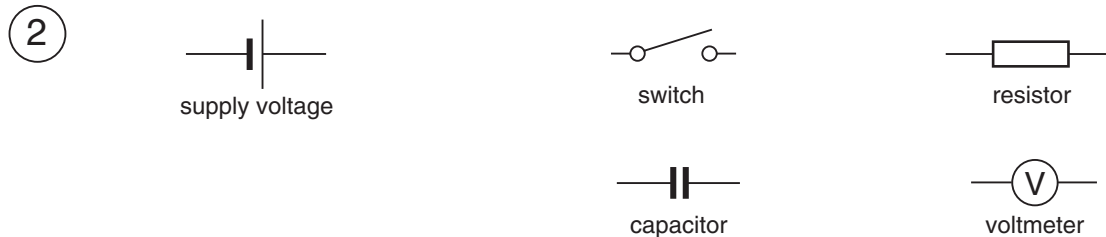
Time required

30 minutes for Part A
20 minutes for Part B

Materials

9 volt battery
clip leads
470 μF 16V electrolytic capacitor
220 μF 16V electrolytic capacitor
2.2 μF 16V electrolytic capacitor
15 kilohm resistor (0.25 watts)
knife switch (single pole, single throw type)
voltmeter
stopwatch measuring in seconds
graph paper

Electronic components are available from suppliers such as RadioShack (<http://www.radioshack.com>). The appearance of the components may vary among suppliers. Simple wiring diagrams and circuit diagrams are given in this experiment to show the arrangement of the components. Diagram 2 below shows the symbols used in the circuit diagrams in this experiment.



Symbols used in circuit diagrams

Safety note

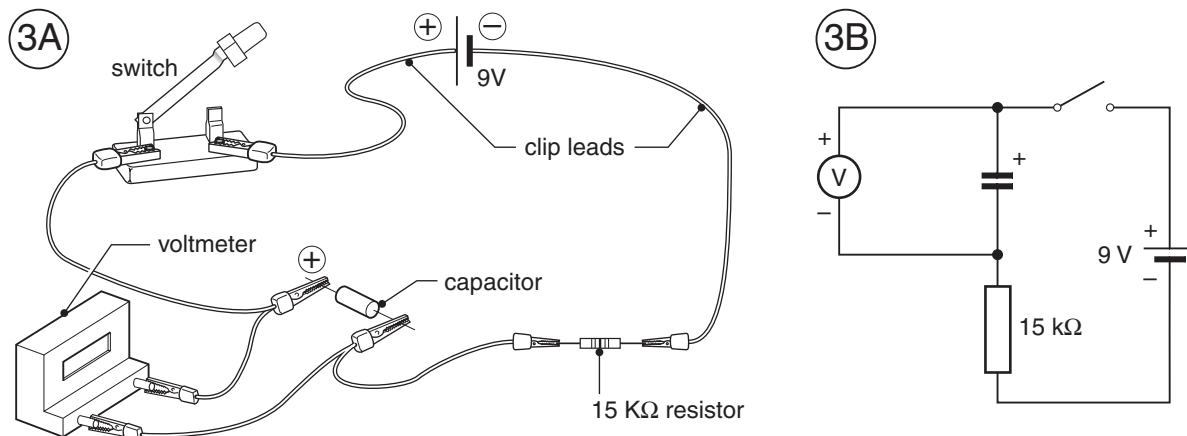


Do not use an electrical outlet.

Procedure

Be careful to observe the marking on the capacitor and to insert it in the circuit the correct way around (i.e., the positive terminal of the capacitor connected through the switch to the positive pole of the power supply).

Part A: Charging up



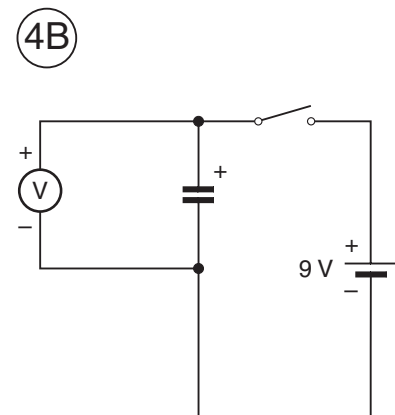
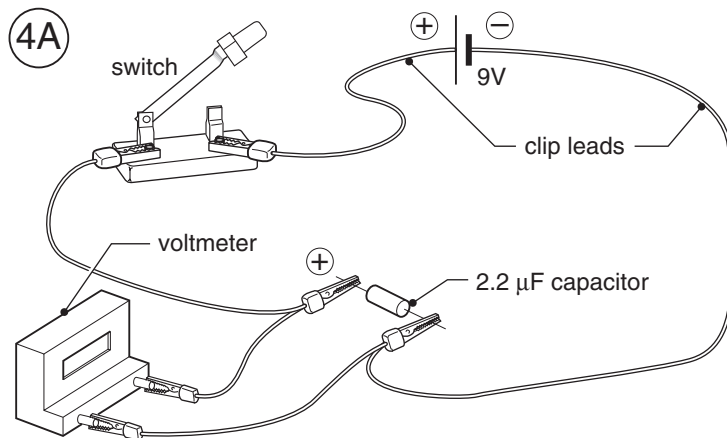
Wiring diagram (A) and circuit diagram (B) for Part A

1. Connect the circuit as shown in diagram 3 above using the $470\ \mu\text{F}$ capacitor and with the switch open. Be careful to connect the capacitor correctly.
2. If the voltage reading is not zero, it shows that the capacitor retains a charge from a previous application. You will need to discharge this charge. To do this, touch both leads of the capacitor with the ends of a connecting lead at the same time. This will allow the charge to equalize between the two plates of the capacitor.

3. Close the switch and record the voltage reading in data table A below for the times shown.
4. Repeat steps 1 to 3 using the 220 μF capacitor.
5. Use your results to plot a graph of voltage against time for each capacitor. Plot time (in seconds) on the x-axis and voltage (in volts) on the y-axis of your graph.
6. Test the voltage of the battery and compare it with the maximum voltage reached by the capacitors.

DATA TABLE A		
Time after closing the switch (seconds)	Voltage reading with 470 μF capacitor	Voltage reading with 220 μF capacitor
initial		
5		
10		
15		
20		
25		
30		
40		
50		
60		
70		

Part B: Discharging



Wiring diagram (A) and circuit diagram (B) for Part B

1. Connect the circuit as shown in diagram 4 on the previous page using the $2.2\ \mu\text{F}$ capacitor and with the switch open. Be careful to connect the capacitor correctly. Close the switch.
2. Very shortly after closing the switch, the capacitor will have charged up (the voltage stops rising).
3. Open the switch and record the voltage reading in data table B below for the times shown.
4. Use your results to plot a graph of voltage against time. Plot time (in seconds) on the x-axis and voltage (in volts) on the y-axis of your graph.

DATA TABLE B	
Time after closing the switch (seconds)	Voltage reading (volts)
initial	
5	
10	
15	
20	
25	
30	
40	
50	
60	
70	
80	
90	
100	
120	
140	
160	
180	

Analysis

Part A: Charging up

1. Are your graphs of time against voltage the same shape for both capacitors?
2. The time constant of a capacitor gives a measure of the time taken for the voltage of a capacitor to increase when being charged. The time constant can be calculated from the graph and is the number of seconds taken for a capacitor to reach a charge of: total voltage change \times 0.63. From the graph, find the number of seconds taken by each capacitor to reach this voltage.
3. How does the voltage of the battery compare with the maximum voltage reached by the capacitors?

Part B: Discharging

1. How does the shape of the graph plotted compare with the graphs from Part A?

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Part A: Charging up

1. Although the two graphs are not the same (the 220 μF capacitor reached its highest value quicker than the 470 μF capacitor), the graphs are the same shape for both capacitors and take the form of a type of exponential function.
2. The time constant can also be calculated by multiplying the value of the capacitor in farads by the resistance of the resistor in series with it in ohms.

For the 470 μF capacitor: time constant = $470 \times 10^{-6} \times 15,000 = 7$ seconds.

Compare the results you obtained from your graph and the calculation in Part A with your results obtained using this formula.

3. The capacitors should reach the same voltage as the battery.

Part B Discharging

1. The graph is similar to those obtained in Part A, but it falls rather than rises. It is also an exponential curve.