TAP 126- 2: Measuring the charge on a capacitor

See also TAP 126-3

Relating quantities

You will use a coulomb meter to measure the quantity of charge stored on a capacitor and to investigate how this varies with the applied voltage. This leads to measurements of capacitance.

You will need

- ✓ digital coulomb meter
- ✓ digital multimeter
- ✓ capacitors 0.1 μF, 0.22 μF, 0.047 μF
- ✓ clip component holder
- ✓ potentiometer, 1 kΩ
- ✓ spdt switch
- ✓ power supply, 5 V dc or 6 V battery pack
- ✓ leads, 4 mm

The activity

In this experiment a voltage supply is connected across the terminals of a capacitor and the resulting charge stored by the capacitor is measured directly using a coulomb meter.

Choose a capacitor of 0.1 μF, insert it in the component holder and assemble this circuit.
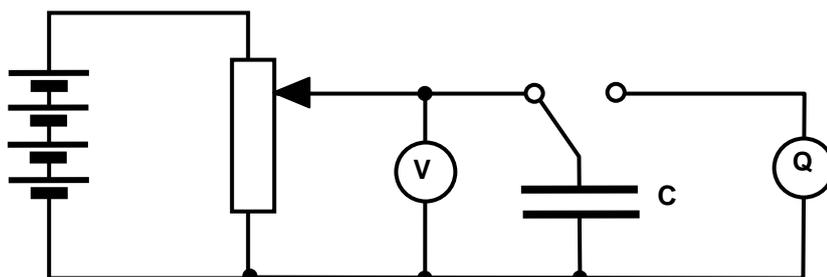
Adjust the voltage output from the potentiometer to 0.5 V. Place the switch into the left-hand position. This applies the voltage across the terminals of the capacitor with the result that it becomes charged. The amount of charge on the capacitor is shown by the coulomb meter when the switch is moved to the right-hand position. Record the values of voltage and charge and enter them in the table below.

Repeat the procedure to obtain a series of readings for the voltages shown in the table.

pd / V	Capacitor 1 Charge / nC	Capacitor 2 Charge / nC	Capacitor 3 Charge / nC
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0			

Repeat the experiment with different values of capacitance.

Analysing the results

Plot the readings for charge against voltage on common axes for the three capacitors.

Do the shapes of your graphs support the idea that the charge stored varies in proportion to the voltage applied? Explain your reasoning.

Calculate the gradient of each graph. The value obtained is a measure of the value of the capacitance in each case. Compare this with the value marked on the side of the capacitor. (It may seem rather odd measuring something which you apparently know already, but individual capacitors are notorious for having capacitance values slightly different from that printed on their outside. The marked value is only a rough guide. This is particularly so for electrolytic capacitors which often differ by more than 10%. The experimental method described here generally gives a much more precise measure of the value of an individual capacitor.)

Thinking about the theory

Since capacitance is defined as $C = Q / V$, we can write $Q = CV$. Thus, for a graph of Q against V the gradient is equal to C.

Comparing the graphs of Q against V with the different capacitors in your experiment, which graph stores the most charge at a given voltage? Does this correspond to the largest value capacitor? Explain your reasoning.

Things to remember

1.   The graphs show that the charge stored on a capacitor varies in direct proportion to the voltage applied.

2.   The value of a capacitor can be calculated from the gradient of a Q versus V graph.

3.   When comparing capacitors, the magnitude of the charge stored on a capacitor at a given voltage is larger for a larger value capacitor.

Practical advice

The coulomb meter is a useful instrument for measuring the charge stored on small-value capacitors. A typical coulomb meter can measure up to 2 mC. For voltages of up to 6 V this implies that it can be used with capacitors up to a maximum value of 0.3 mF.

The use of the coulomb meter described here enables students to explore the proportionality between Q and V fairly directly with the minimum of calculation. The measurements are of a generally better precision than those associated with the transient currents involved with discharging capacitors.

Alternative approaches

If time is short, this could be done as a demonstration with little modification. The experiment could be conducted with the capacitor markings hidden, so that the objective could be more sharply focused on obtaining a measurement of the capacitor value. A spreadsheet could be used for recording the results and evaluating the gradients of the graphs.

External references

This activity is taken from Advancing Physics Chapter 10, 110E

Student experiment – second alternative

TAP 126-3: Using a reed switch to measure capacitance