

TAP 126- 1: Charging a capacitor at constant current

Background to the experiment

When a capacitor is charged by connecting it to a battery or other dc power supply, the current in the circuit gradually falls to zero. The rate at which this happens depends on both the capacitance of the capacitor and the presence of any resistance in the circuit. If the resistance of the circuit is high, the current will be correspondingly small and the capacitor will charge up more slowly than if there were less resistance in the circuit.

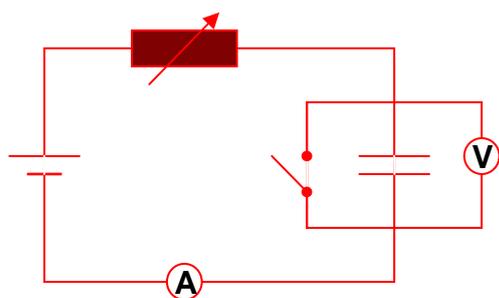
Using a variable resistor, with a bit of manual dexterity, you can keep the current constant and time how long it takes to charge a capacitor. By knowing both the time and the current, you can determine the charge stored on the capacitor.

Then, by charging the capacitor to different voltages, you can establish experimentally the relationship between the amount of charge and the pd across the capacitor resulting from it.

You will need

- ✓ a partner
- ✓ power supply, 5 V dc
- ✓ digital multimeter, used as ammeter
- ✓ digital multimeter, used as voltmeter
- ✓ capacitor, 470 μF
- ✓ potentiometer, mounted with 4 mm sockets, 100 k Ω
- ✓ leads, 4 mm plus shorting switch
- ✓ hand-held stop watch

Constant current charging



Watch the supply pump a fixed number of coulombs onto each capacitor plate each second.

How is the charge on one plate changing with time? So how is the pd changing with time?
Can you think of a way to show this?

Examining the results

From the current and time measurements, you can use $Q = It$ to determine the amount of charge which flowed onto the capacitor plates. If you do this for cunningly chosen measurements, you are now in a position to examine the relationship between the charge and the pd across the capacitor which results from the redistribution of charge on its surfaces. A

quick look at the results will show that more charge is needed to raise the pd to a greater value.

Outcomes

1. You will understand better the process by which a capacitor is charged.
2. By focusing on the simplicity of charging at a constant current, you can see how the redistribution of charge results in a potential difference across the capacitor.
3. You will be able to see that this leads to the relationship 'pd across a capacitor is proportional to the charge stored on one plate of the capacitor'.

Practical advice

Before showing students this demonstration, they should be aware of current as a flow of charge in a circuit and have tackled some of the problems involving the calculation of charge and the use of $Q = I t$. They might be shown initially what happens when the capacitor is charged without changing the resistance, i.e. that the current gradually falls, and this should simply be introduced as a nuisance at this stage. They need to be clear that the variable resistance is there simply to allow you to keep the current constant. No other explanation is necessary at this stage.

Close the switch and use the variable resistor to set the ammeter to some convenient value, e.g. 100 mA. When you are ready, remove the shorting link across the capacitor, start timing and adjust the control on the variable resistor to maintain the current at the value you have set. You will probably have to practise this a few times – it can be quite tricky. Carry on adjusting the resistor for as long as you can. Connect the digital voltmeter briefly across the capacitor to measure the pd that has been generated by the redistribution of charge.

Record the charging current and the time as well as the pd across the capacitor. You will probably wish to repeat this measurement at least once or twice to allow for the difficulty you have in keeping the current constant.

You might repeat this process using different pds, if you want to take it further, or to use a computer-based oscilloscope to get plots of charging current / time and pd across capacitor / time.

You will probably not have time to do the demo in great detail, but it is well worth the effort to practise a bit at keeping the current steady – surprisingly difficult if you have not done it before.

Explain the function of the short circuit link across the capacitor, which allows you to set the initial charging current to a convenient value. You will have already taught that the capacitor is an unusual device, which does not permit a flow of current through it. You will also have to explain away that you eventually run out of control when you have reduced the resistance to zero and the current will then fall. A simple and effective, but not totally accurate procedure is to keep on timing until the current has fallen to half the initial value. For an appropriate group of able students, this could be an additional teaching point.

If you have done the experiment reasonably carefully, and have results for different pds, students can plot a graph of Q against pd

If you have time, it is a good idea to let students have a try as well.

Alternative approaches

The approach will depend on students' prior knowledge. If they already know $Q = CV$, then the activity becomes one in showing that the different gradients of the graph relate to different values of the capacitance. You may wish to direct students to use it from this standpoint, particularly if there is time for students to do the experiment themselves.

External references

This activity is taken from Advancing Physics Chapter 10, 120D