Charging a capacitor

With many schools electing to do what we might call "core" experiments for their Higher Assignments, we thought it would be worth revisiting some of these to give advice on equipment and component values. We are aiming to help teachers and technicians here - beware of passing this material unedited to students. You could be giving them too much information. It is not designed to be a "second source". We have an evolving document on the Higher Physics area of our website that features a number of what we consider to be suitable experiments. This article showcases one example - charging a capacitor.

Charge versus potential difference

The first experiment investigates the relationship between the charge on a capacitor and the potential difference across it. Measuring charge on a capacitor can be difficult to do. There are charge-measuring instruments called coulombmeters but they can only measure very small charges. We do have a protocol for such an experiment. Please get in touch if you are interested.

In this version of the experiment, we use a variable resistor to keep the charging current constant. We make a note of this current, and find charge *Q* after a time *t* using the relationship:

$Q = It$

Equipment required:

- 1000 µF capacitor
- 100 kΩ linear (not logarithmic) variable resistor
- Smooth dc power supply set to around 5 V, or 3 x 1.5 V batteries wired in series
- Voltmeter
- Ammeter (must be able to read to 0.001 mA or better)
- Stop clock/phone timer

Connect the components as shown in Figure 1 below. If your capacitor is polarity-sensitive (i.e. it matters which leg is connected to the positive side of the circuit as is the case with most electrolytic capacitors), make sure you connect it correctly. It helps to have more than one person working on this experiment.

Make sure the variable resistor is set to around its mid-point before switching on. What we don't want is a very low resistance when the capacitor is uncharged. "Short" the capacitor, i.e. connect one side directly to the other. The voltmeter should show a potential difference of 0 V across the capacitor.

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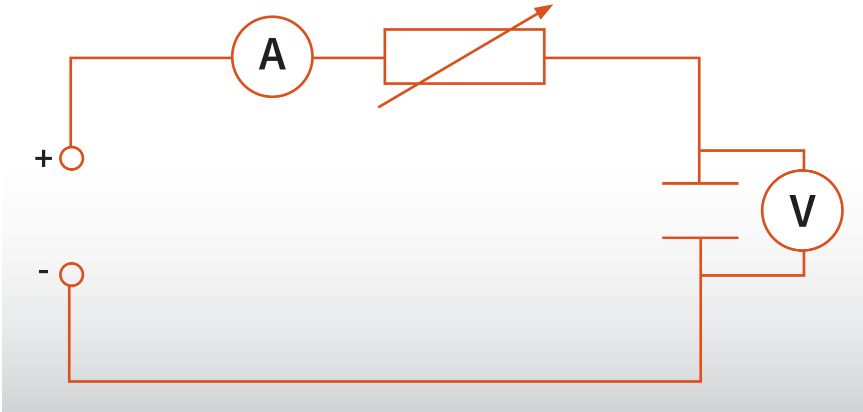

Figure 1 - Capacitor charging circuit.

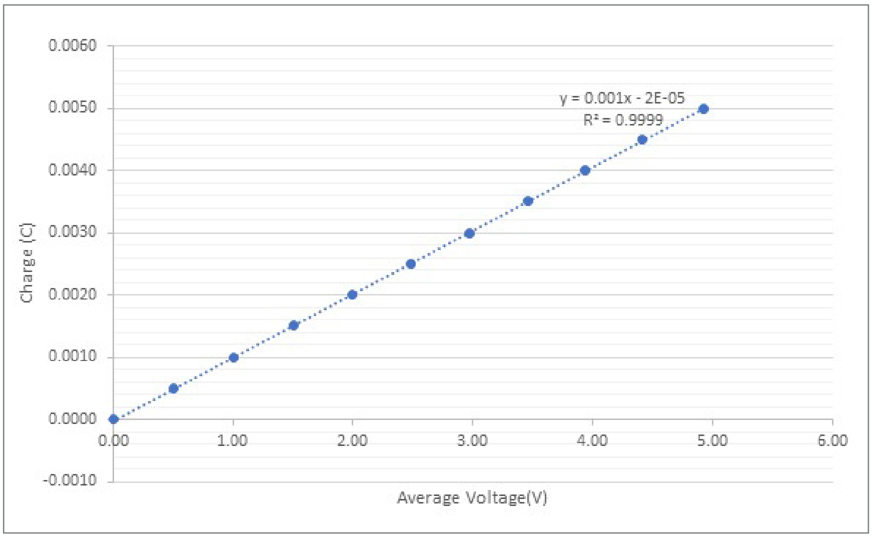

Figure 2 - Charge versus V.

Record the potential difference across the capacitor as 0 V at time 0 seconds.

Adjust the variable resistor until the current on the ammeter is 0.050 mA. This current is suggested because, for the component values shown, the capacitor should take about 100 seconds to charge. 10 readings can be taken, each separated by 10 seconds.

Remove the short and simultaneously start the timer. Throughout this experiment, the variable resistor must be adjusted to keep the current at a fixed value. A small variation will not cause problems.

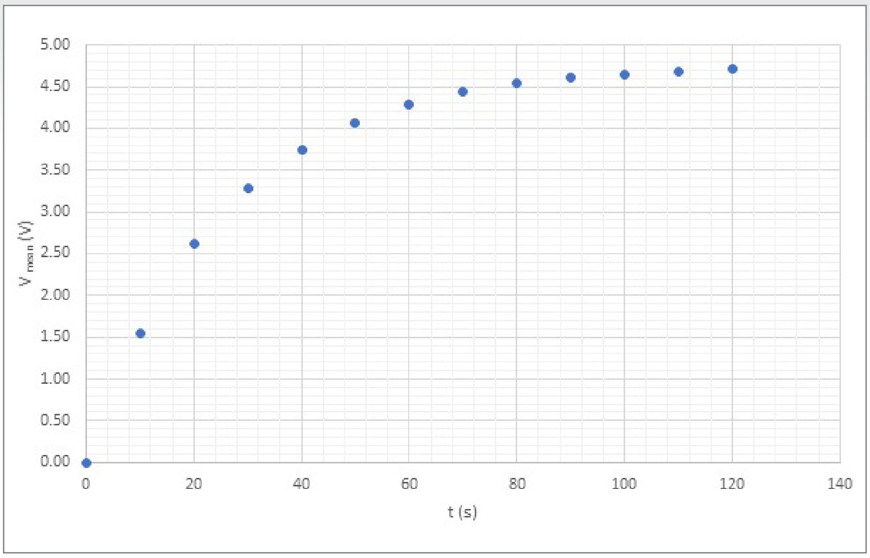

Figure 3 - Potential difference versus time.

Record the potential difference across the capacitor every 10 seconds.

You should now have a table of potential difference versus time. In order to study the relationship between potential difference and charge, charge must be found from $Q = It$, where I is the constant current.

Figure 2 shows a sample graph. These results were obtained with a charging current of 0.05 mA. The capacitor had a capacitance of 1000 μF. Although V was the dependent variable, it has been plotted on the horizontal axis because the gradient of the graph should then be the capacitance.

Note that we have chosen fairly large markers on the graph for clarity in this publication. Your students should follow SQA guidance on graph drawing with regard to marker size and type and also gridline spacing.

Potential difference versus time

The graph in Figure 3 was obtained by setting the circuit current, with the capacitor shorted, to 0.200 mA. With the short removed, V was recorded every 10 seconds. In this experiment, the current was left to its own devices - no attempt was made to keep it constant. An alternative investigation would be to look at circuit current versus time.

Advanced Higher extensions

Though beyond Higher, it is interesting to study the graph of $\ln(V_0 - V)$ versus time, where V_0 is the supply voltage. Such a graph is shown in Figure 4.

The gradient of the graph should be $1/RC$ where R is the resistance and C is the value of the capacitor. RC is also known as the circuit time constant. The potential difference across the capacitor should reach 2/3 of the supply voltage after RC seconds, and be fully charged by $5RC$. <<

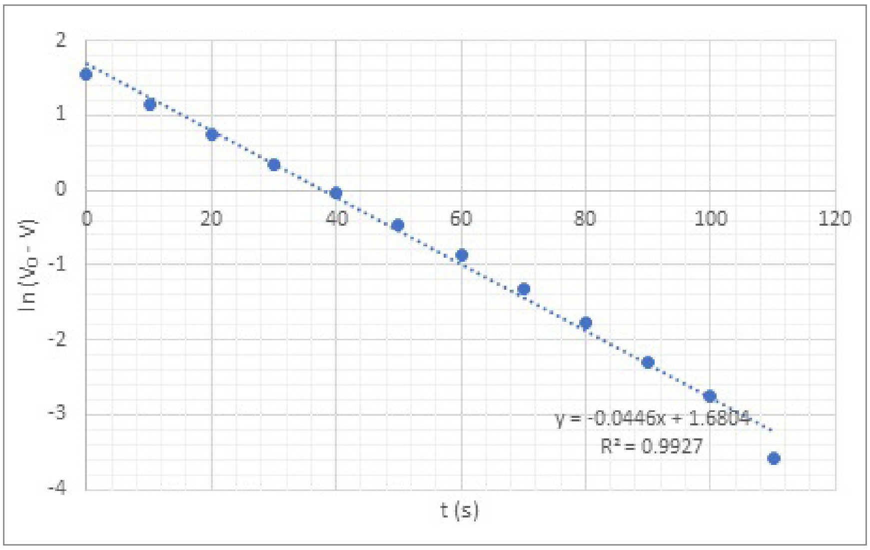

Figure 4 - Logarithmic graph.