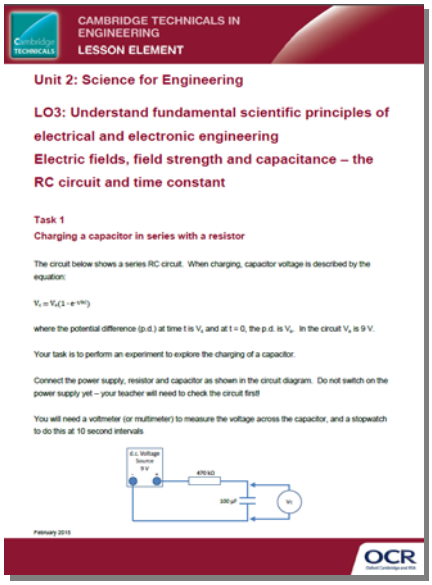
Unit 2: Science for Engineering

LO3: Understand fundamental scientific principles of electrical and electronic engineering

Electric fields, field strength and capacitance – the RC circuit and time constant

Instructions and answers for teachers

These instructions should accompany the OCR resource 'Electric fields, field strength and capacitance – the RC circuit and time constant' activity *which supports OCR Level 3 Cambridge Technicals in Engineering Level 3.*


CAMBRIDGE TECHNICALS IN ENGINEERING
LESSON ELEMENT

Unit 2: Science for Engineering

LO3: Understand fundamental scientific principles of electrical and electronic engineering
Electric fields, field strength and capacitance – the RC circuit and time constant

Task 1
Charging a capacitor in series with a resistor

The circuit below shows a series RC circuit. When charging, capacitor voltage is described by the equation:

$V_t = V_s(1 - e^{-t/RC})$

where the potential difference (p.d.) at time t is V_t and at t = 0, the p.d. is V_s. In the circuit V_s is 9 V.

Your task is to perform an experiment to explore the charging of a capacitor.

Connect the power supply, resistor and capacitor as shown in the circuit diagram. Do not switch on the power supply yet – your teacher will need to check the circuit first!

You will need a voltmeter (or multimeter) to measure the voltage across the capacitor, and a stopwatch to do this at 10 second intervals

d.c. Voltage Source 9 V
470 kΩ
100 µF
V_t

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OCR

The Activity:

In this activity the learners are tasked with undertaking some simple experiments using a voltage source, capacitor and resistor.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Suggested timings:

2 hours - An Excel spreadsheet is available to support these activities.

April 2015

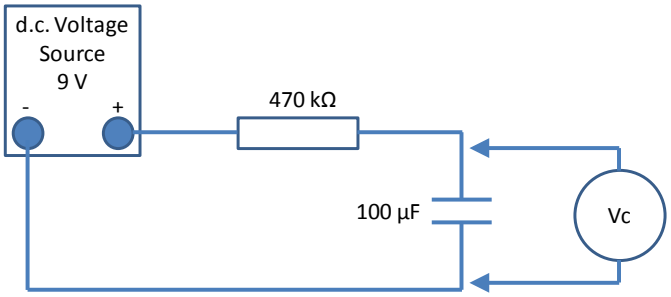
Activity 1

Charging a capacitor in series with a resistor

The teacher could set the context of where RC circuits might be found in everyday electrical items to produce time delays. This could be in form of a group discussion. Typical applications might include security light time delays, bathroom fan timers or intermittent car wipers.

Before undertaking the activity learners will probably need an introduction to, and some background information on RC circuits. Internet sources may prove useful in showing the theory behind RC circuit including charging a capacitor and time constant eg http://www.youtube.com/watch?v=pyfKKVkKngY

For Activity 1, learners are required to undertake a simple experiment using a voltage source, capacitor and resistor.



Learners will require:

- 9 V d.c. supply (could be a battery)
- 470kΩ resistor
- 100 µF capacitor
- Voltmeter (or multimeter on voltage range)
- Connecting wire
- Stopwatch or timer

The experiment requires learners to:

- Tabulate and plot (charging) voltage across the capacitor
- Comment on the shape of the graph – an exponential
- Determine the circuit time constant – given by RC
- Determine in how many time-constant periods the capacitor can be considered fully charged

The teacher should check that the circuit is correctly connected before the learner connects the supply.

The formula for capacitor voltage when charging is:

$$V_c = V_o(1 - e^{-t/RC})$$

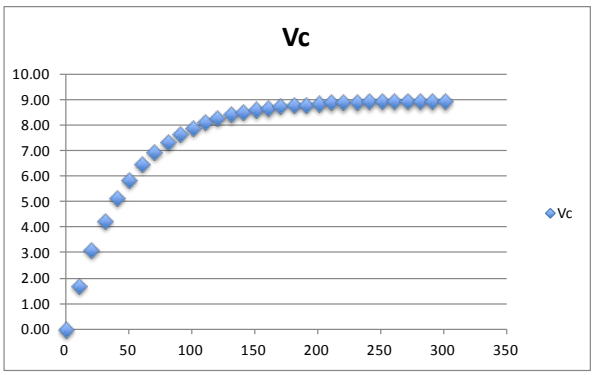
where the potential difference (p.d.) at time t is V_c and at t = 0, the p.d. is V_o. In the circuit V_o is taken as 9 V when the capacitor is fully charged.

Learners should use the formula for charging voltage $V_c = V_o(1 - e^{-t/RC})$ and tabulate and plot both calculated and measured values.

Learners can plot the graph using graph paper, or use software such as Microsoft Excel. This will develop learners' ICT skills.

Answers to questions:

1. The graph will be an exponential function:



2. The time constant for the circuit is RC (learners will need to know that resistance in is in kilo-ohms and capacitance is in microfarads in order to calculate this). The time constant is 47 seconds.

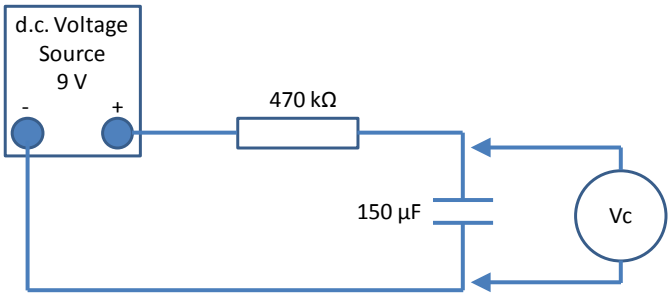
3. Learners should be able to identify that it takes approximately 235 seconds for the capacitor to charge fully, and this is approximately 5 x time constants.

4. Errors between calculated and measured values will most likely be due to measurement errors and tolerances of components.

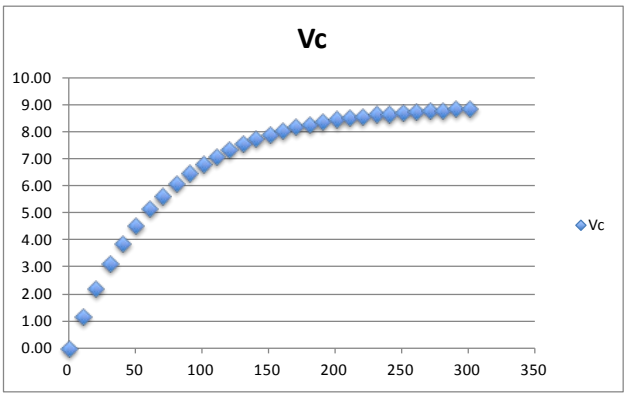
Activity 2

Effects of varying the value of C in the circuit

In Activity 2, learners will repeat the experiment from Activity 1 this time with a larger value capacitor (150 µF)



Answers to questions:



1. The shape of the graph is still an exponential – but in this case the capacitor takes longer to charge up.

2. The time constant for this circuit is 70.5 seconds.

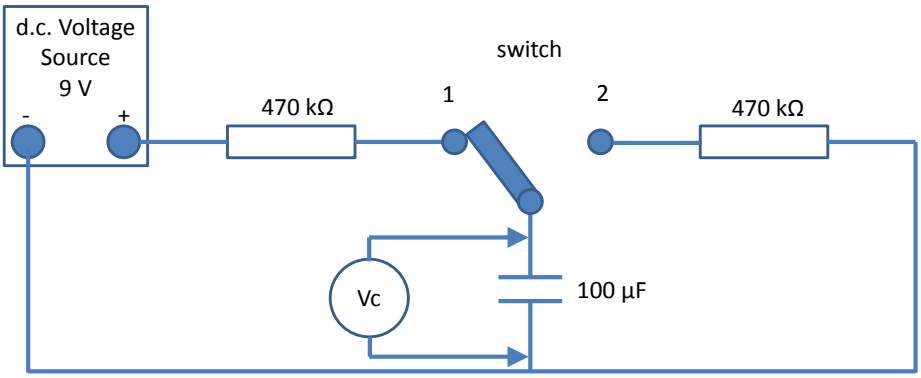
3. Following on from Activity 1 – the capacitor can be considered charged in 5 x time constants, which is 352.5 seconds. The capacitor does not fully charge in 300 seconds.

4. If C cannot be changed in the circuit then another way of altering the time constant is by varying R. This is what is typically what is done in everyday appliances where a variable resistor is used to alter the time delay.

Activity 3

Discharging a capacitor in series with a resistor

In Activity 3 learners are required to repeat Activity 1 and to investigate **discharging** of a capacitor.

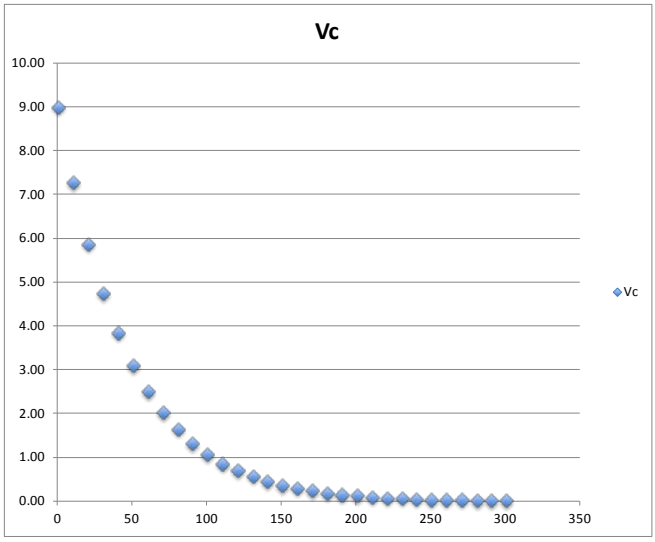


Answer to questions:

Learners are required to tabulate and plot both calculated and measured values. The formula for voltage across the capacitor when discharging is:

$$V_c = V_o e^{-t/RC}$$

where the potential difference at time t is V_c and at $t = 0$, the p.d. is V_o. In the circuit V_o is 9 V.



1. The shape of the graph is an exponential showing discharging.

2. The time constant and time to fully discharge are identical to that for charging in Activity 1.

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