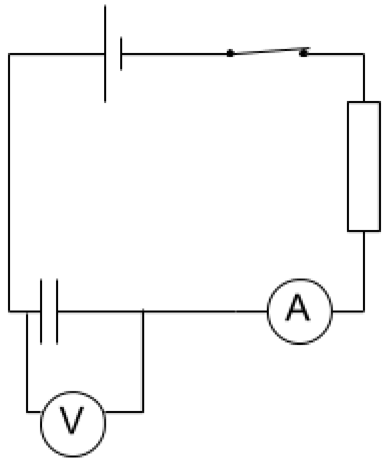
OCR B Physics A-Level

PAG 9.1

Investigating the charge and the discharge of a capacitor

Equipment
- Capacitor
- Resistor
- Cell
- Voltmeter
- Switch
- Stopwatch
- Ammeter
- Voltmeter



<u>Charging a Capacitor</u>

Method
1. Set up the circuit as shown in the diagram.
2. Close the switch to charge the capacitor, record the voltage and current at time t = 0 and at 5 s intervals as the capacitor charges until about 120s have passed. This may be made easier by working in pairs.
3. Repeat the experiment twice more and record the voltage and current for each time again.

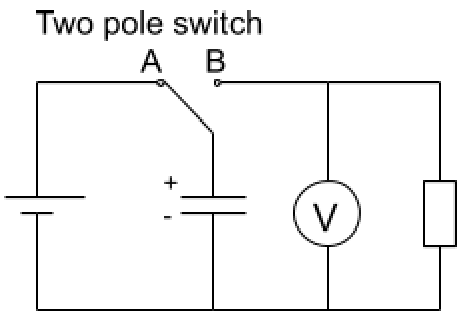
Graphs and Calculations
- Calculate the mean voltage and mean current for each time.
- Plot a graph of voltage against time, this graph will show an exponential growth curve that obeys the relationship
  $V = V_0(1 - e^{\frac{-t}{RC}})$
  where V is voltage, V_0 is the p.d across the capacitor when fully charged, t is the time since charging began (s), R is the resistance of the fixed resistor and C is the capacitance of the capacitor.
- Plot a graph of current against time, this graph will show an exponential decrease that obeys the relationship $I = I_0 e^{\frac{-t}{RC}}$ where I is current and I_0 the initial current.
- The area under the I-t graph gives the charge stored by the capacitor.

Using Data Loggers
- Connect both a voltage sensor and current sensor to a data logger. The stopwatch is no longer needed as the data logger has an internal timer.
- Connect the data logger to a computer which can plot graphs using the data collected.
- The computer can be used to calculate the charge on the capacitor over time after the current has fallen to 0.
- A log-linear plot of ln(I) against time can be plotted, which forms a straight line graph with negative gradient as:
  $$\ln I = \ln(I_0\, e^{-\frac{t}{RC}})$$
  $$\ln I = \ln I_0 - \frac{t}{RC}$$ (using the rules: log(ab)=log(a)+log(b) and ln(e)=1)
  If you plot a graph of ln(I) against t, the gradient of this graph is $\frac{-1}{RC}$, and the y-intercept is $\ln(I_0)$.

Notes

- The time constant can be found from the exponential growth curve by finding t when the voltage is approximately 63% of the maximum voltage (the voltage of the battery). It can also be found by calculating the negative reciprocal of the gradient of the graph of ln(I) against t.

<u>Discharging a Capacitor</u>



Method

1. Set up the apparatus as shown in the diagram.
2. Set the switch to the A position to allow the capacitor to fully charge.
3. Move the switch to the B position and start the stopwatch. Observe and record the voltage reading V at time t = 0 and at 5 s intervals as the capacitor discharges until about 120s have passed.
4. Repeat the experiment twice more and obtain the average V at each t.
5. (Note that the experiment can be repeated for different resistors or capacitors to investigate how the time constant varies with resistance and capacitance).

Graphs and Calculations

- Calculate the natural logarithm of V at each t and tabulate this.
- Plot a graph of ln(V) against t and draw a line of best fit forming a straight line graph with a negative gradient equal to -1/RC as derived below

$V = V_0 e^{\frac{-t}{RC}}$ this is the exponential relationship between V and t

$\ln V = \ln V_0 e^{\frac{-t}{RC}}$ take natural logs of both sides

$\ln V = \ln V_0 + \ln e^{\frac{-t}{RC}}$ use the law ln(ab) = ln(a) + ln(b)

$\ln V = \ln V_0 - t/RC$ as $\ln e^x = x$

This equation is in the form y=mx+c with y = V, **m = -1/RC** x = t and c = $\ln V_0$

- The capacitance of the capacitance can now be found given that the resistance of the fixed resistor is known.

Safety

- Ensure the capacitor is connected with the correct polarity and that its voltage rating exceeds the voltage of the battery used to prevent it from exploding and releasing harmful chemicals.

Notes

- You can also plot a graph of V against t which will give an exponential decay curve. The time constant can be found from this by finding t when the voltage is approximately 37% of the original voltage (the voltage of the battery).