DRAFT - Investigating charging and discharging of capacitors

Why do this?
Resistor Capacitor (RC) circuits are a feature of all A-Level Physics exam boards. Often an incorrect value of either resistor or capacitor might be chosen to make readings of the capacitor charge/discharge quite difficult to obtain. This guide will show how to set up and give recommended values for the Capacitor and Resistor to make reading the voltage across a charging/discharging capacitor easier. Different resistor networks in series/parallel can also be constructed allowing students to review their work on resistance from earlier in their studies.

Possible curriculum links: techniques and procedures to investigate the charge and the discharge of a capacitor using both meters and data-loggers.

This Practical Procedure draws on information from the following guidance. Latest versions of these resources should be consulted for additional information and/or updates.
• Laboratory handbook: Section 9 (page 928 Cells and Batteries)

Suitability
A-Level

Suggested apparatus and materials
✓ A 100uF electrolytic capacitor (a voltage rating above maximum voltage of the power supply/cell being used) (2200uF if using multi meters)
✓ 3-5 x 10kΩ resistor (larger values such as 47kΩ if manually taking readings with multimeters and stopwatches)
✓ Component holders (see GL150)
✓ Connecting leads
✓ D Cell battery with holder or low voltage power supply
✓ A digital storage oscilloscope/voltage logger OR digital multimeter

Notes
• Electrolytic capacitors may explode if non-vented and inserted into a circuit with the wrong polarity.
• The cell or power supply must not exceed the voltage rating of the capacitor, and additionally must not exceed 40 VDC.
• If manually taking voltage readings across the capacitor (e.g every 10 seconds, a larger time constant is needed (see Physics notes).
• See GLXXX for details on how to make a USB Voltage logger.

Outline method with control measures
• Ensure the polarity of the capacitor is correct with respect to the battery/power supply.

Procedure
1. Set up the circuit as per the circuit diagram leaving one terminal of the battery/power supply disconnected.
2. Insert leads from the oscilloscope/volt sensor/multimeter across the capacitor.
3. Switch your meter/oscilloscope to the suitable measuring parameters – for instance if using a 1.5V D-Cell, then voltage setting on the oscilloscope should be something of
the order 500mV per division. If using a digital storage oscilloscope using the roll function of the time base will be most useful here (see associated video).

4. Complete the circuit by connecting the lead to the battery/power supply and observe the charging of the capacitor via the oscilloscope or meter. Take readings at suitable intervals if manually obtaining data with a meter/stopwatch.

5. To discharge the capacitor. Use the flying lead to connect the circuit diagram as below.

![Circuit Diagram]

Expected observations/results

Plotting a graph of Voltage against Time should yield an exponential growth/decay curve as follows:

![Graph of Voltage against Time]

RC circuit charge/discharge cycle (100uF / 10kOhm)
Physics notes
Resistor-Capacitors circuits (RC circuits) have a property called the ‘time-constant’ which is defined as:

\[ T = R \times C \]

It is the time it takes for voltage across the capacitor to charge to approximately 67% of the supply voltage (or conversely for the voltage across a capacitor to decay to approximately 37% of the supply voltage value).

It is thus important to choose Resistance and Capacitance values accordingly. The below table shows recommended components depending if you want a ‘fast’ charge/discharge, and a ‘slow’ charge discharge (if using the multimeter/stopwatch method). Choose components close to these values.

<table>
<thead>
<tr>
<th>Method</th>
<th>Fast (RC &lt; 1second)</th>
<th>Slow (RC ~100 seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor / Ω</td>
<td>10k</td>
<td>47-100k</td>
</tr>
<tr>
<td>Capacitor / μF</td>
<td>100</td>
<td>2200</td>
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</table>