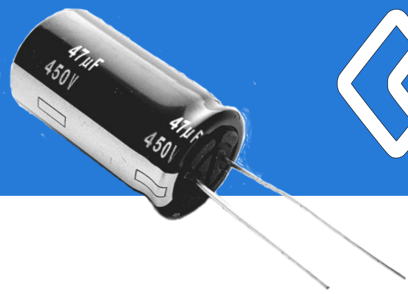
Capacitor time constant



Apparatus

Voltage sensor

Current sensor

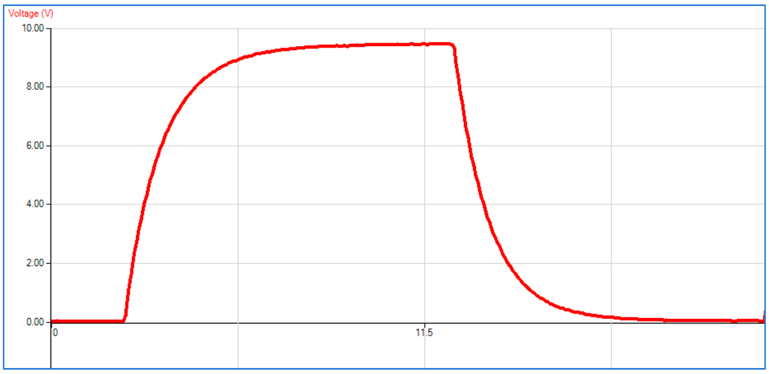
Capacitors (4700 or 1000uF) and others

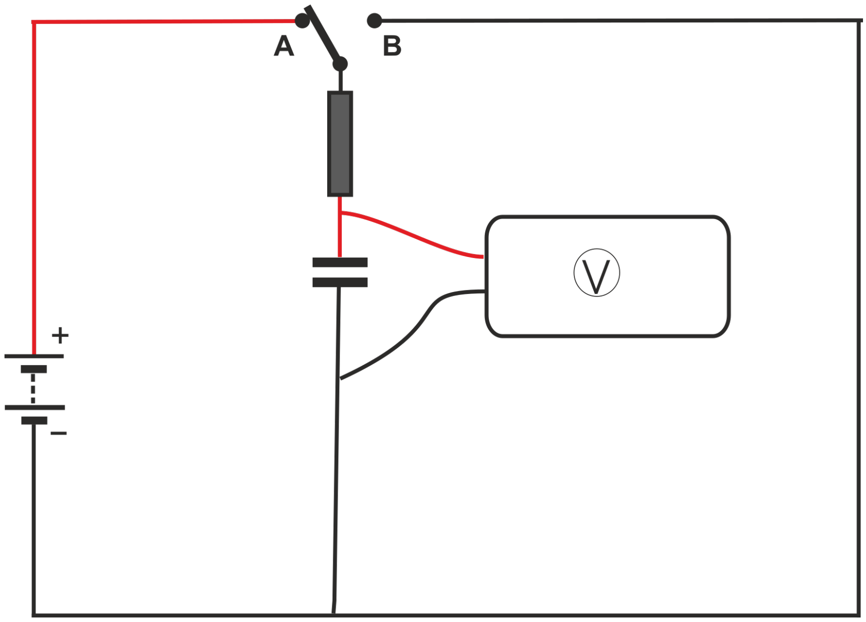
Resistors (50 to 100 Ω) and others

Patch leads

Electric circuit kit

Dry cells (3 x 1.5 V)





Method.

1. Set up the capacitor charge and discharge circuit. If you use a physical switch watch out for “switch bounce”. A flying lead is often easier and more effective.

2. Check the polarity of the capacitor to the battery.

3. Use a data recording set up of 20 ms between samples to collect the data.

4. Position the switch or flying lead to discharge and leave.

5. Click on start, collect a few seconds of the discharge voltage, then connect the circuit to charge by moving the switch.

6. When the voltage reaches the battery voltage, switch to discharge and continue to collect data until the discharge voltage is reached. Collect a few more seconds of data at discharge then stop the collection.

7. Save the data.

8. You should have collected something similar to the sample graph at the top of the page.

Discharging $V = V_{max} e^{-t/CR}$

Charging $V = V_{max}(1-e^{-t/CR})$

The time constant "T" is derived from these equations:

$T = C \times R$

Theory

The time constant of a capacitor - resistor (CR) is used as a measure of the length of time needed to charge a capacitor to within a defined percentage of its final maximum value.

The time constant is C x R

R is the value of the resistor in Ohms.

C is the value of the capacitor in Farads.

The time constant is defined as the time take to reach 63.2% of its final maximum voltage value when charging. For the discharge state of the CR circuit the time constant is the time taken to fall to 63.2% of the full charge voltage (alternatively the time taken to reach 36.8% of the full charge voltage).

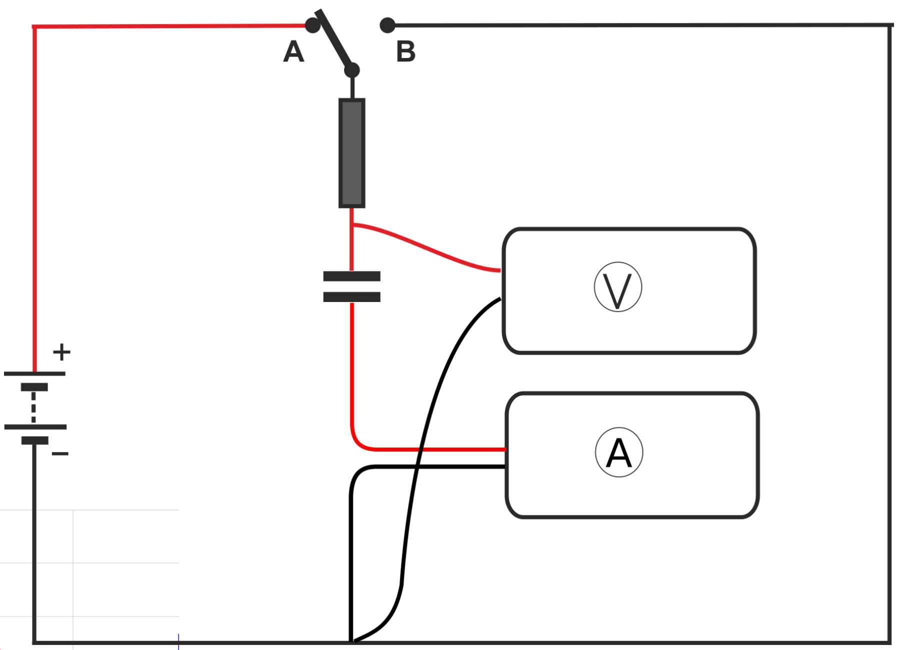
These values are derived from the mathematical constant e which is used in describing the function of voltage across the capacitor with respect to time.

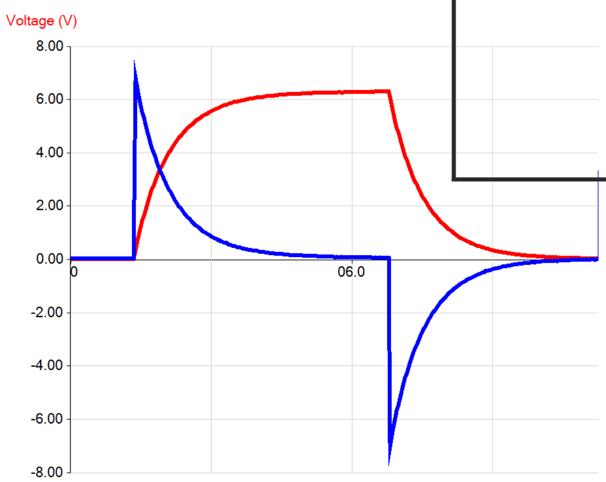
For most cases the values of 63 and 37% can be used for quick calculations.

Introducing a current sensor and working with energy stored and power.

Set up the circuit as shown. The voltage sensor goes across the capacitor and the current sensor is in series.

To collect data use the same setup as in the charge - discharge method.



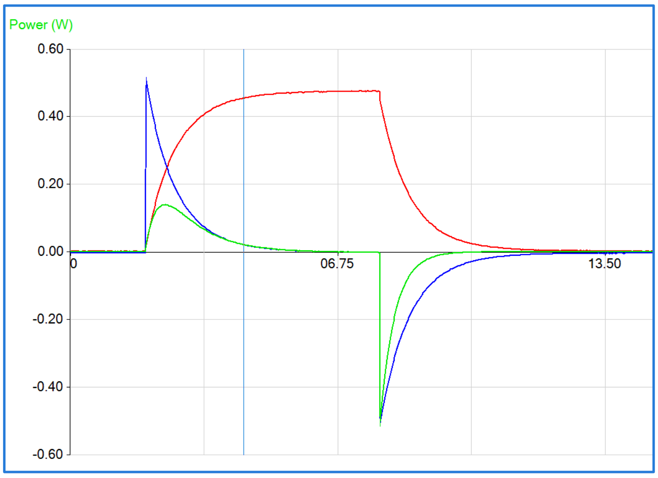


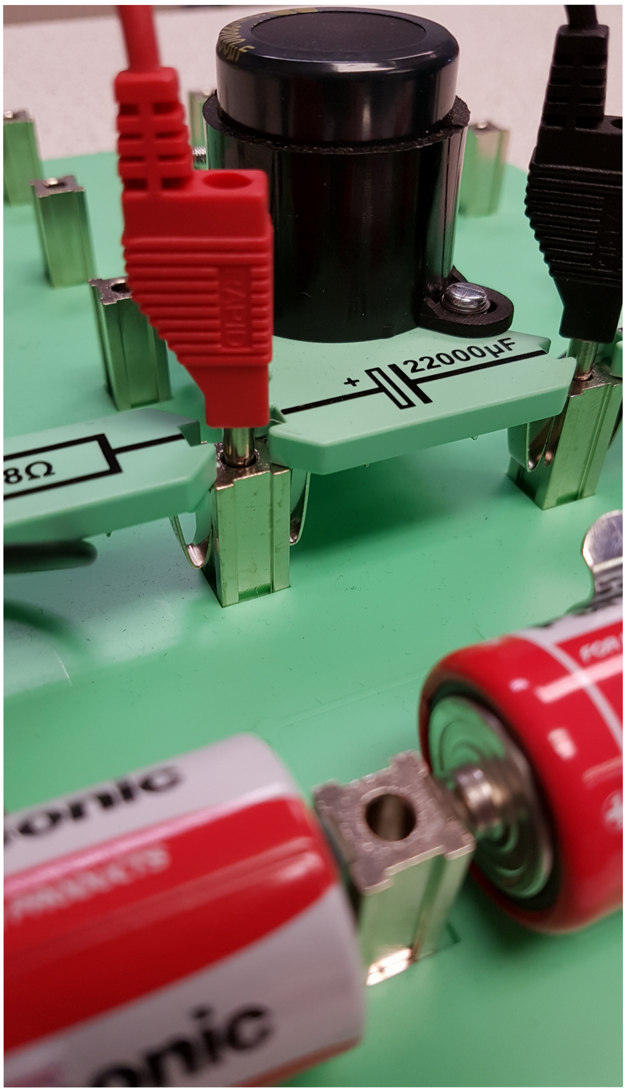
Typical data collected for one charge - discharge cycle with a voltage and current sensor attached.

Note the current graph is vectorised and shows direction of flow

Treatment of data.

1. Apply the power calculation (P = A xV)
2. Modify the axis to get all three graphs on the same zero axis.
3. Use the area tool to find the areas under the power curve. This will give you energy transfer.
4. Use $E=½CV^2$ to calculate energy stored.
5. Compare energy stored to energy transferred and then the efficiency of the capacitor as an energy storage device





Use this practical set up to....

1. Demonstrate charge and discharge of a capacitor
2. Use the lab data to develop and explain the time constant of a capacitor resistor circuit.
3. Use the collected lab data to calculate the time constant and compare to theoretical value, then question differences.
4. Link mathematical theory to practical experience.
5. Find the energy stored, transferred and then the efficiency of the capacitor as a storage device.
6. Transfer the data to a spreadsheet and plot the log linear plot to find the time constant.

Practical notes

The practical is makes very good use of class time and produces good repeatable data. As the logger is collecting the data you do not have to use components that give large time constants, short time constants allow many repeats in a short period and exploration of combinations of CR to prove theory.

The key is choosing the correct combination of capacitor an resistor to give a good charge and discharge cycle over a realistic time interval. Refer to table below for example values.

Use dry cells in good condition for the work, be very wary of standard school power supplies, the output of d.c. Is often in name only - the use of a data logger and voltage sensor will reveal that far too often the output is either not fully rectified or poorly smoothed. This will overlay a confusing ripple in the data as the voltage fluctuates on the charge cycle.

This is a good example of where using a data logger can add significantly to the learning experience.

Capacitance (uF)	Resistance (Ω)	Time constant (s)
10,000	100	1.0
4,700	220	1.03
1,000	1,000	1.0
470	2,200	1.03
330	3,300	1.09
220	4,700	1.03