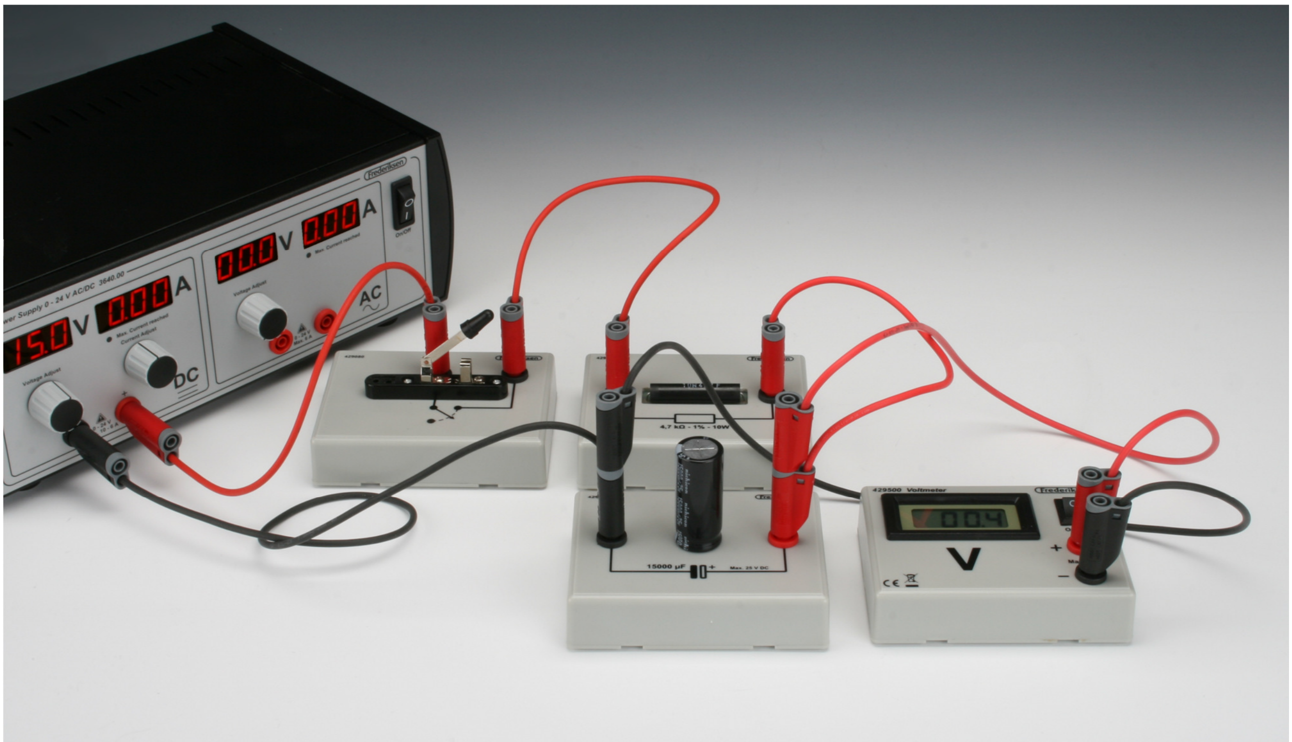
Capacitor – Charging and discharging

Experiment number	136230-EN	*Topic*	Electricity, capacitor				
Version	2019-02-11 / HS	*Type*	Student exercise	*Suggested for*	Grade 10+	*p.*	1/4



Objective

To investigate the discharging and charging curves for a capacitor and determine the capacitance.

Principle

With the components used, the voltage variations can be followed using a stopwatch and a voltmeter. Plotting the measurements in a spreadsheet enables us to find an exponential trend line and to find the capacitance from that.

Equipment

(Detailed equipment list on p. 4)

Capacitor 15 000 µF
Resistor 4.7 kΩ, 1 %
Voltmeter
Knife switch
Power supply
Lab leads
Stopwatch

Capacitor and resistor

Capacitors have numerous uses in electronics. Very large capacitors (like the one used here) are typically just required to be “large enough”, leading to rather lax tolerances on the specified capacitance.

Resistors are easier to produce with tight tolerances. The resistor used has a tolerance of 1 %.

Procedure

1 – Discharging

We will first study the discharging of the capacitor, as this is the simplest to analyse.

Turn the power supply down to 0 V and build the circuit as shown on the drawing. Turn on the switch.

Adjust the power supply to e.g. 15 V. Don't change this setting from now on – we will need the same voltage in part 2.

The capacitor C is now charged to this voltage.

When we in a while turn the switch off, the capacitor will discharge through the resistor R.

Read the initial voltage U_0 precisely.

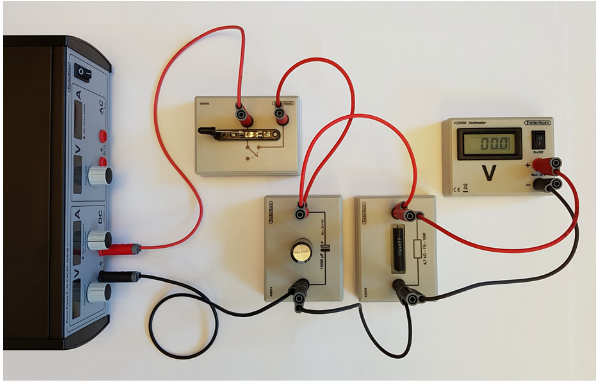
Start the stopwatch and turn the switch off simultaneously.

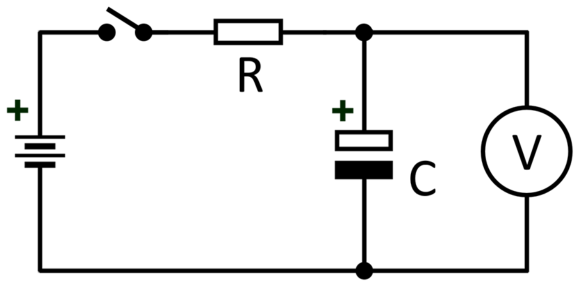
For *every 10 seconds*, you must read the voltage as precisely as possible – it will drop quite fast initially.

Continue for 4 to 5 minutes.

Use for instance a table like this for the results:

U_0:		V
t / s	U / V	





In the schematics, the power supply is drawn as a battery.

Notice the switch: It must disconnect the power supply from the rest of the setup – it is not enough just to shut off the power supply!

2 – Charging

Connect the voltmeter directly to the power supply and check that the voltage is precisely as before (U_0). If not: Adjust it.

By now, the capacitor is almost completely discharged. To discharge It completely, short it with a wire. Prepare the rest of the circuit and, remove this wire as one of the last operations.

Make sure the switch is off and build the circuit as shown on the drawing. Remember to remove the wire that shorts the capacitor.

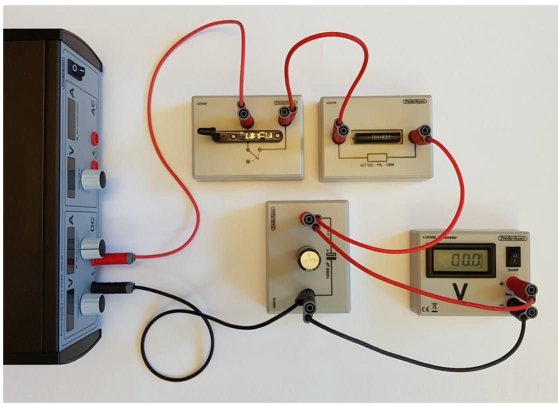
Start the stopwatch and turn the switch on simultaneously.

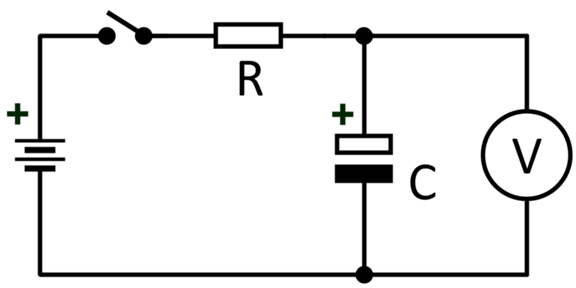
For *every 10 seconds*, you must read the voltage as precisely as possible – it will rise quite fast initially.

Continue for 4 to 5 minutes.

Use for instance a table like this for the results – the last column is filled out later:

U_0:		V
t / s	U / V	$U_0 - U$ / V





Theory

When a capacitor is discharged through a resistor, its voltage decreases like this:

$$U = U_0 \cdot \exp\left(-\frac{t}{R \cdot C}\right)$$

where U_0 is the initial voltage and t is the time.

In other words, the voltage decreases exponentially as a function of time.

When a capacitor is charged through a resistor that is connected to a voltage U_0 , the voltage over the capacitor rises like this:

$$U = U_0 \cdot \left(1 - \exp\left(-\frac{t}{R \cdot C}\right)\right)$$

If you rewrite this expression, you will see that the entity $U_0 - U$ decreases exponentially as a function of time.

Calculations

Use a spreadsheet for these calculations.

1 – Discharging

Plot the data points in both a normal linear coordinate system and on a coordinate system with a logarithmic y-axis.

Fit the data with an exponential function (i.e. add a “trend line” of type Exponential). Choose to show the formula and *adjust the number of decimals displayed* in order to determine the parameters precisely.

From the parameters in the formula for the fitted curve and the known resistance, you can now calculate the capacitance *C*.

2 – Charging

For all data points, calculate the entity U_0 - U. Plot this as you did with U in part 1 and use the same procedure to determine the functional parameters. Finally, calculate again a value for *C*.

Discussion and evaluation

Describe the graphs of the experimental results – compare with what you expect, based on the theory.

As the same capacitor is used, the two calculated values for C for resp. discharging and charging should be identical.

Is this the case here? Are possible deviations larger than can be explained from experimental uncertainties?

Teacher's Notes

Concepts used

Voltage
Resistance
Capacitance

Mathematical skills

Equation solving
Exponential functions
Spreadsheets, fitting

About the equipment

It is important that a rather precise resistor is used as the precision of the measurements depend on that. As can be seen from the equipment list, there are no further requirements of this kind.

If the voltage supply chosen cannot deliver 15 V, the students should simply be informed. Other voltages can also be used.

Electrolytic capacitors are not ideal capacitors. In fact, they can behave in bizarre ways.

For instance, the voltage may rise a bit over an electrolytic capacitor that has been briefly discharged to zero through a short circuit. This is the reason that in this lab, the capacitor is first discharged slowly, followed by a short circuit, before the charging experiment starts. This will minimize this kind of "memory effects".

Detailed equipment list

Specifically for the experiment

429310	Capacitor 15 000 µF (or previous model: 430070)
429230	Resistor 4.7 kΩ 10 W 1% (or previous model: 420561)
429080	Knife switch (or similar: 429090, 414500, 429050 …)
429500	Voltmeter, digital, DC

Standard lab equipment

364000	Power supply, AC and DC, 0-24 V
105710	Safety cable 25 cm, black
105711	Safety cable 25 cm, red (2 stk.)
105720	Safety cable 50 cm, black (2 stk.)
105721	Safety cable 50 cm, red (2 stk.)