The charging and discharging of a capacitor

(Item No.: P1373500)

Curricular Relevance

Area of Expertise: Physik

Education Level: Klasse 7-10

Topic: Elektrizitätslehre

Subtopic: Eigenschaften elektrischer Bauelemente

Experiment: Laden und Entladen eines Kondensators

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	10 Minutes	2 Students

Additional Requirements:

- Stop watch

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional information

The students know that the electrical component "capacitor" can store electrical energy.
The first experiment concentrates on the change in the capacitor voltage over time during charging and discharging. Qualitative statements are first derived, then the change in the voltage during charging and discharging is quantitatively determined.
The second experiment deals with semi-quantitative relationships between the capacitor voltage U_C, the charging resistance R, the capacity of the capacitor C and the time taken for the charging process t.

Notes on setup and procedure

The charging and discharging will occur relatively quickly at first, because of the values of C and R of the components available. The teacher and the students should therefore carefully prepare for the quick reading of values with a moving pointer. It is absolutely necessary to ensure that each capacitor is discharged prior to charging.

Remarks

The measurement series which are determined by separate groups of students will usually differ greatly. This is primarily because of the large tolerances in the rated values of the capacitors.
The internal resistance of the measuring equipment Ri influences both the charging and discharging process. During charging, the charging resistance R and Ri make up a voltage divider. The voltage across the capacitor, which is connected in parallel to the measuring instrument, can therefore only reach the maximum voltage:

$$U_C = U_0 \cdot R_i / (R + R_i)$$

Increasing the charging resistance to attain longer charging times is therefore not practical, because it only results in even smaller values of UC being reached. The parallel connection of the measuring instrument accelerates the discharging process.
The time curves for voltage and current during the charging and discharging of a capacitor correspond to those of numerous natural growth and decay processes.
The following function is valid for the discharging process,

$$U(t) = U_0 \cdot e^{-t/RC}$$

and for the charging process :

$U(t) = U_0 \cdot (1 - e^{-t/RC})$.

After a time $t = R \cdot C$, the voltage has neared its end value up to the e-th amount. This time is called the cell constant of a circuit τ.

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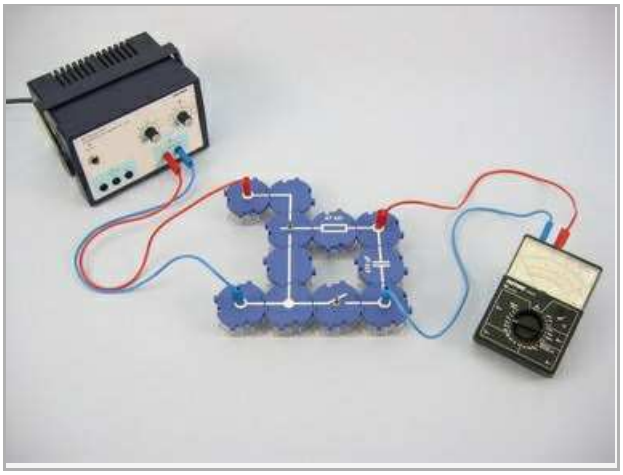
Task and equipment

Task

How does the capacitor charging/discharging process take place?

Examine how the voltage changes during the charging and discharging of a capacitor, and also determine on which factors the rate of these processes are dependent and the effects they have.



Equipment

Position No.	Material	Order No.	Quantity
1	Straight connector module, SB	05601-01	1
2	Angled connector module, SB	05601-02	1
3	T-shaped connector module, SB	05601-03	1
4	Junction module, SB	05601-10	2
5	Angled connector module with socket, SB	05601-12	2
6	On-off switch module, SB	05602-01	2
7	Change-over switch module, SB	05602-02	1
8	Resistor module 10 kOhm, SB	05615-10	1
9	Resistor module 47 kOhm, SB	05615-47	1
10	Capacitor module 47 µF non-polar electrolytic, SB	05645-47	1
11	Capacitor module 470 µF non-polar electrolytic, SB	05646-47	1
12	Connecting cord, 32 A, 500 mm, red	07361-01	2
13	Connecting cord, 32 A, 500 mm, blue	07361-04	2
14	Multi-range meter, analogue	07028-01	1
15	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
	Stop watch, digital, 24h, 1/100 s and 1 s	24025-00	1

Set-up and procedure

Set-up

First experiment

Set up the circuit as shown in Fig. 1 and Fig. 2 with the on/off switch open and the changeover switch at position 1; set the voltmeter measurement range to 10 V−.

Fig. 1

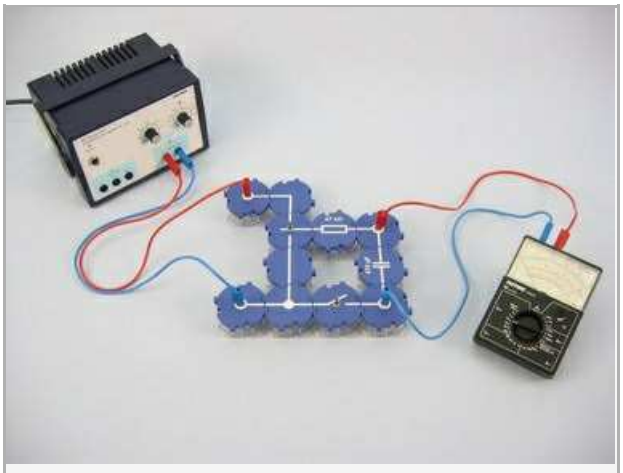


Fig. 2

Second experiment

Set up the experiment as shown in Fig. 3.

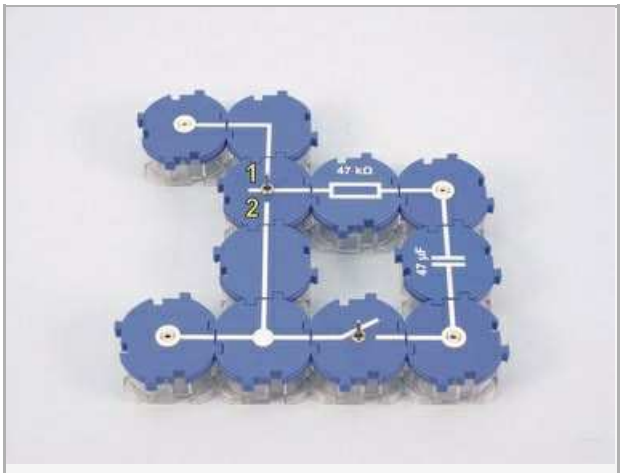


Fig. 3

Procedure

First experiment

- Switch on the power supply and set it at 10 V direct voltage.
- Use the on/off switch to close the charging circuit and observe the voltmeter; note what you observe under Result - Observations 1 in the report.
- Switch to position 2 to close the discharging circuit, again observe the voltmeter; note what you observe under Result - Observations 2.
- Short-circuit the capacitor for a few seconds with a 25 cm connecting cable and stop doing so when the voltage on the capacitor is U_C = 0 V.
- Move the changeover switch to position 1 and - starting from 0 V - read off the capacitor voltage U_C every 10 seconds and

enter the measured values in Table 1.

Note: Taking these measurements requires a lot of concentration, and possibly even some practice. Should you not be successful with the first series of measurements, briefly short-circuit the capacitor again and repeat the measurements.

Second experiment

- Move the changeover switch to position 1, close the charging circuit and measure the time taken for the capacitor voltage to reach the value U_C = 6 V. Enter the time in Table 2.
- Open the on/off switch, discharge the capacitor and replace it with the 47 µF capacitor (Fig. 4).

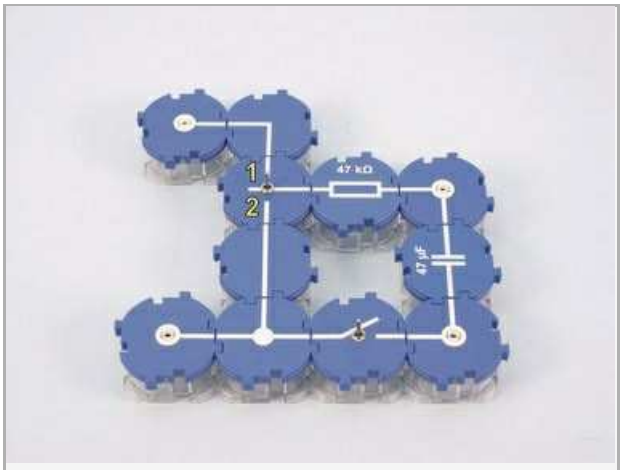


Fig. 4

- Close the charging circuit and again measure the time taken for UC = 6 V to be reached. Note the time taken (Table 2).
- Replace the 47 kΩ resistor by the 10 kΩ resistor (Fig. 5) and repeat the measurement.

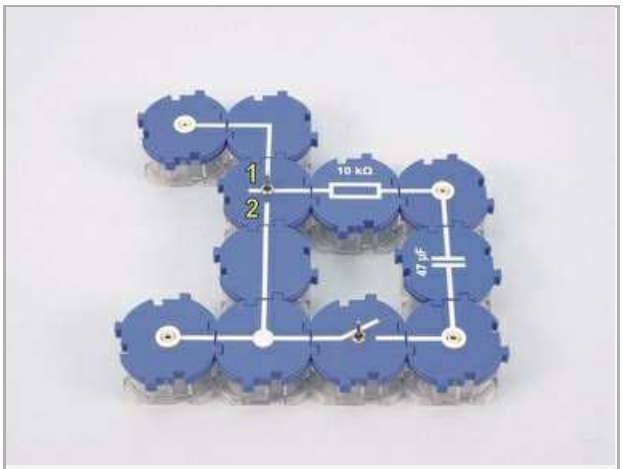


Fig. 5

- Replace the 47 µF capacitor with the 470 µF capacitor (Fig. 6) and repeat the measurement.

Fig. 6

- Switch off the power supply.

Report: The charging and discharging of a capacitor

Result - Observations 1

Note your observations.

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Result - Observations 2

Note your observations.

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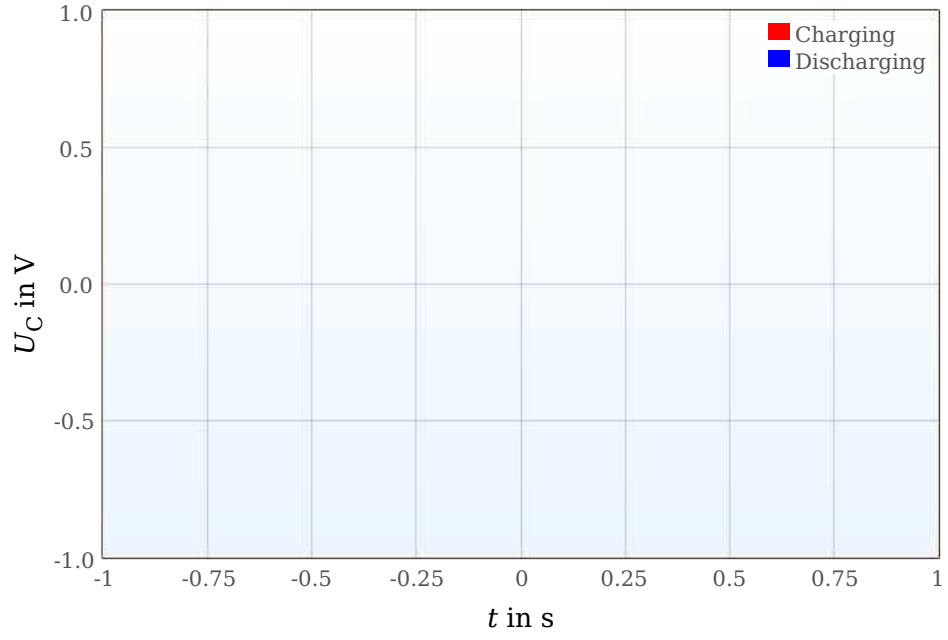
Result - Table 1

Record your measured values.

	Charging	Discharging
t in s	U_C in V	U_C in V
0	1 ±0	1 ±0
10	1 ±0	1 ±0
20	1 ±0	1 ±0
30	1 ±0	1 ±0
40	1 ±0	1 ±0
50	1 ±0	1 ±0
60	1 ±0	1 ±0

Number1



Result - Table 2

Record your measured values.

R in kΩ	C in µF	t in s	τ in s
		1 ±0	1 ±0
		1 ±0	1 ±0
		1 ±0	1 ±0
		1 ±0	1 ±0

Evaluation - Question 1

Refer to the chart of Table 1. Explain the course of the curve for the charging process and the observations noted under Observations 1 respectively.

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Evaluation - Question 2

Express the dependence of the time taken for the charging process on the capacity C and on the resistance R (called the charging resistance) as "when - then" relationships. Explain why these relationships must be valid.

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Evaluation - Question 3

Calculate the time $\tau = R \times C$ for the values in Table 2 and compare them with the measured time taken t.

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