The charging and discharging of a capacitor

(Item No.: P1382100)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Electricity

Subtopic: Properties of electrical components

Experiment: The charging and discharging of a capacitor

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	20 Minutes	2 Students

Additional Requirements:

Experiment Variations:

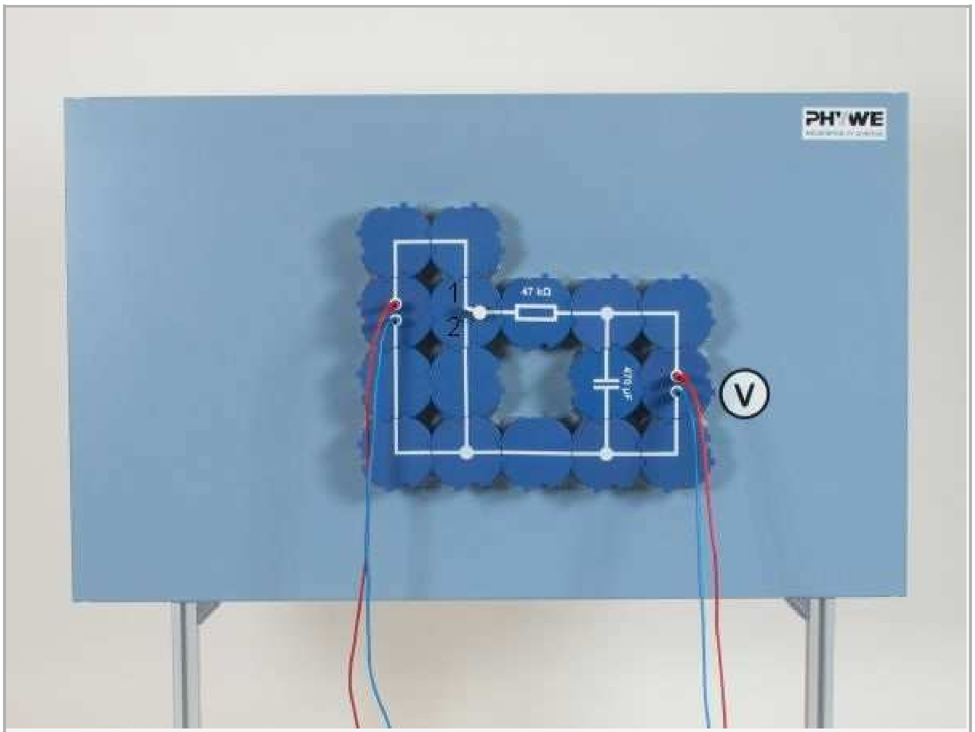
Keywords:

Introduction

Overview

The change in the voltage over time when a capacitor is charged and discharged is to be examined.

To maintain consistency with regard to the equipment used throughout the set of experiments described in this handbook, the experimental procedure described below is that for demonstration measurement equipment.



Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	Demo Physics board with stand	02150-00	1
2	Connector, straight, module DB	09401-01	3
3	Connector, angled, module DB	09401-02	5
4	Connector, T-shaped, module DB	09401-03	3
5	Connector interrupted, module DB	09401-04	2
6	Switch, change-over, module DB	09402-02	1
7	Resistor 47 kOhm,module DB	09415-47	1
8	Capacitor(ELKO)0.047 mF,module DB	09445-47	1
9	Capacitor(ELKO),0.1 mF,module DB	09446-10	1
10	Capacitor(ELKO),0.47 mF,module DB	09446-47	1
11	Connecting cord, 32 A, 1000 mm, red	07363-01	2
12	Connecting cord, 32 A, 1000 mm, blue	07363-04	2
13	PHYWE power supply, universal DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5 A	13500-93	1
14	Electr.symbols f.demo-board,12pcs	02154-03	1
15	Multimeter ADM2, demo., analogue	13820-01	1

Tasks

The change in the voltage over time when a capacitor is charged and discharged is to be examined.

Set-up and procedure

- Connect up the circuit as shown in Fig. 1; place the demo clock directly alongside the voltmeter, to simplify the simultaneous reading of time and voltage.

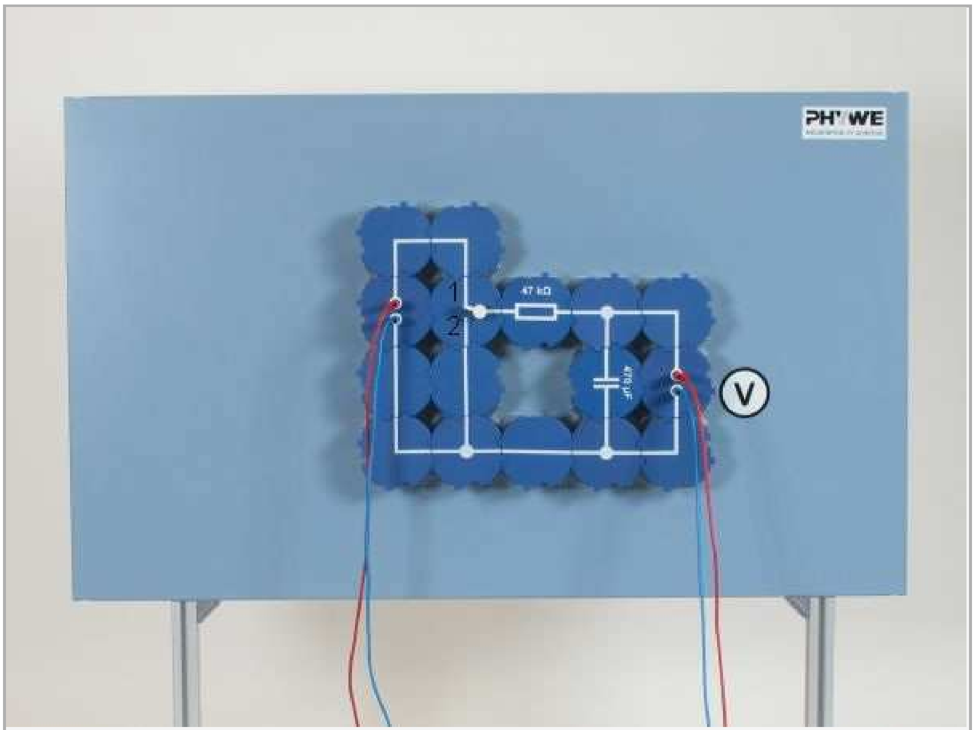


Fig. 1

- Bring the changeover switch to position 2 (discharge); set the voltage U_0 of the power supply and the voltmeter measurement range to 10 V.
- Switch the changeover switch from position 2 to position 1 and simultaneously start the clock.
- During the charging process, read off the value of the voltage every 5 seconds and enter the values in Table 1.
- As soon as there is no longer a recognizable increase in the voltage, switch the changeover switch from position 1 to position 2 and simultaneously start the clock.
- Read off the value of the voltage at the same time interval as above and enter the values in Table 1.
- Replace the 470 µF capacitor by the 100 µF capacitor.
- When charging, measure the time t_1 taken for the voltage to increase from 0 V to 6.3 V; when discharging, measure the time t_2 taken for the voltage to decrease from 10 V to 3.7 V; after measurement, enter the times taken in Table 2.
- Carry out the same measurement using the 47 µF capacitor.

Theory and evaluation

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t / s	0	5	10	15	20	25	30	35	40	45	50	55	60
Charging: $\frac{U_c}{V}$	0.0	1.3	3.0	4.2	5.2	6.0	7.4	7.8	8.0	8.3	8.6	8.9	9.0
Discharging: $\frac{U_c}{V}$	9.7	8.3	7.0	5.8	4.6	3.8	3.2	2.4	1.7	1.4	1.0	0.8	0.7

Evaluation

As can be seen from the voltage-time plots for charging and discharging (Fig. 2), the capacitor voltage first increases very rapidly at the start of the charging process, but the nearer the capacitor voltage U_C approaches the applied voltage U_0, the less the voltage increase in the same time interval.
During discharging, the capacitor voltage first decreases very rapidly and then approaches the zero value ever more slowly.
There is no linear relationship between the time and the voltage during the charging and the discharging of a capacitor.

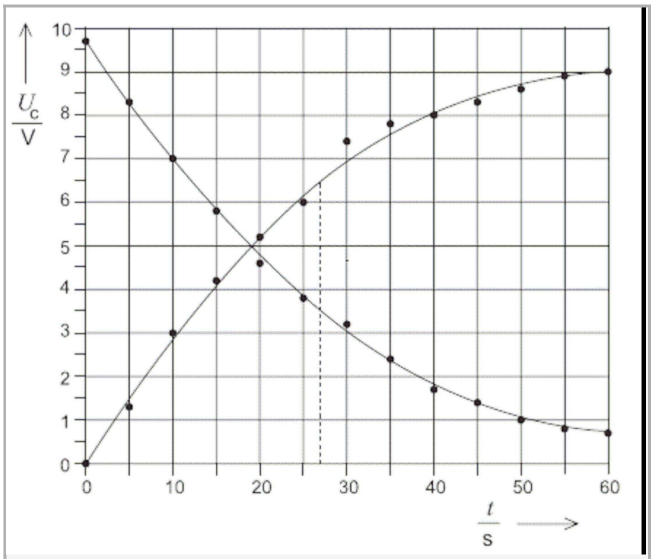

Fig. 2

The discharging process can be described by the exponential law:

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

Whereby $e = 2.718...$ is the base of natural logarithms. After a time $t = R \cdot C$, the voltage drops to the value U_0/e ≈37% $\cdot U_0$. The time $t = R \cdot C$ is called the time constant τof the RC circuit. In this experiment, $\tau = R \cdot C = 47k\Omega \cdot 470\mu F = 22.1.$ After this time, the voltage has only 37% of its initial value, i.e. 3.7 V.The value of $\tau = 27$ s given by the plot of the measured values is in good agreement for the time constant. For the charging process,

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

is valid. The calcuated time constants are given in Table 3.

C / µF	t_1/s	t_2/s
100	5.6	5.3
100	5.1	5.3
47	2.5	2.7
47	2.7	3.0

R / kΩ	C / µF	τ / s
470	470	22.1
470	100	4.7
470	47	2.2

Remarks

The ADM 2 has a very high internal resistance and so has practically no influence on the charging and discharging processes. Should a measuring instrument with lower internal resistance be used, it is necessary to consider that its internal resistance R_i forms a voltage divider with the load resistance R. The capacitor voltage can therefore only reach the value $U = U_0 \cdot R_i/(R_i + R)$, despite charging for any longer length of time. The internal resistance is in parallel to the capacitor during the discharging process, so that the discharging process is shortened by the measuring instrument.