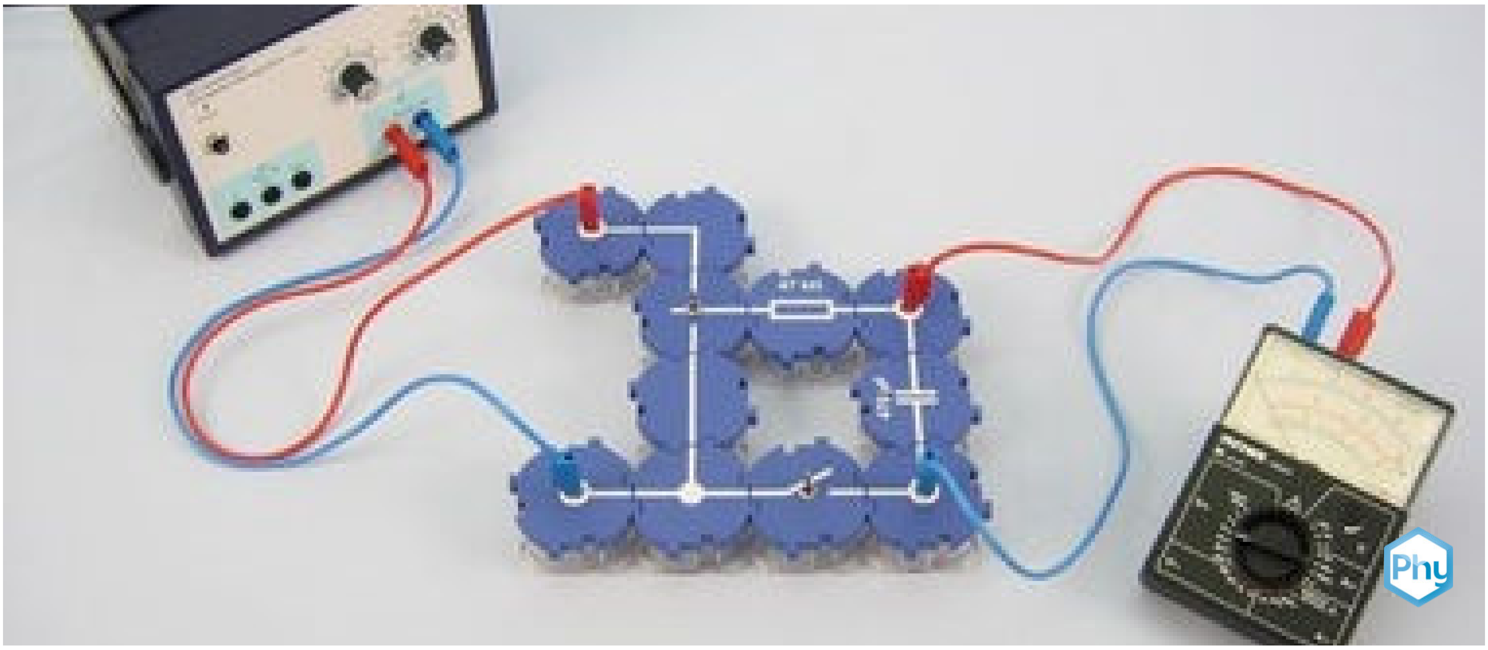
Charging and discharging a capacitor



Physics | Electricity & Magnetism | Simple circuits, resistors & capacitors

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

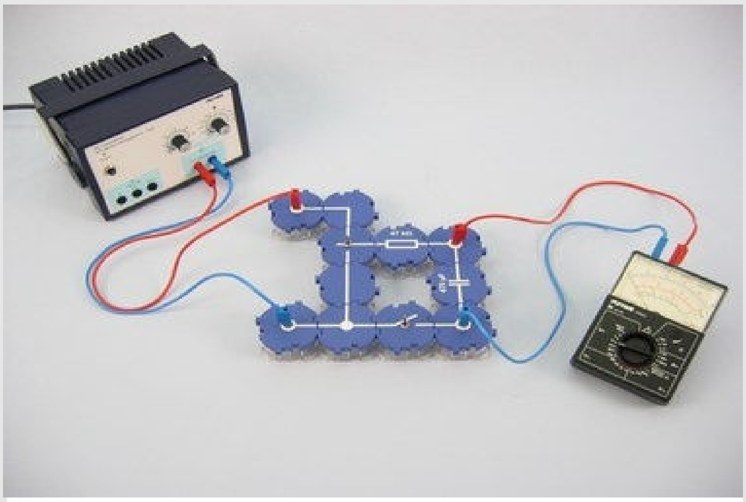
http://localhost:1337/c/5f4eb7c038db8d0003265c8a

PHYWE

Teacher information

Application

PHYWE



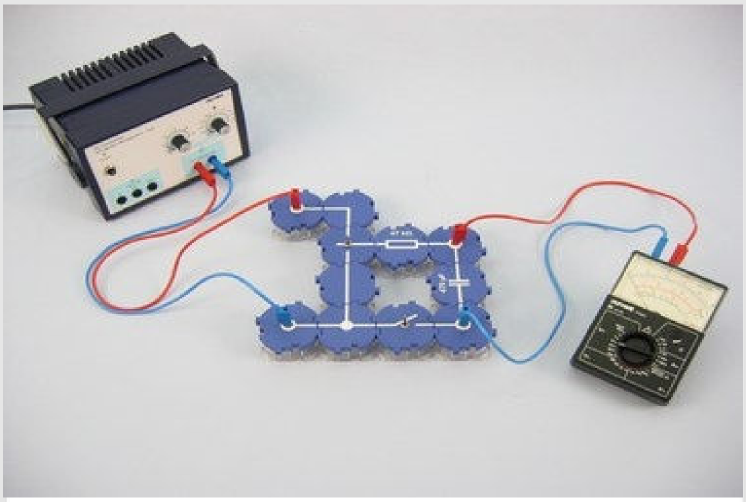
Experiment set-up

A capacitor is a standard electrical component. When DC voltage is applied, charge and thus energy is stored in the capacitor, with the stored energy being present in the form of the resulting internal electric field. The amount of charge a capacitor can hold depends on its design and the voltage applied and is called its capacitance: $C = Q/U$.

In this experiment the charging and discharging process of a capacitor is investigated.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Application


Experiment set-up

A capacitor is a standard electrical component. When DC voltage is applied, charge and thus energy is stored in the capacitor, with the stored energy being present in the form of the resulting internal electric field. The amount of charge a capacitor can hold depends on its design and the voltage applied and is called its capacitance: $C = Q/U$.

In this experiment the charging and discharging process of a capacitor is investigated.

Other teacher information (1/3)

Prior knowledge

The students should know that the electrical component capacitor can store charge and thus electrical energy and should know the basic properties of electrical circuits.

Scientific principle

The function applies to the charging process:

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

The function applies to the discharge process:

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

For the half-life τ applies:

$$U_0/2 = U_0 \cdot (1 - e^{-\frac{\tau}{RC}})$$

$$\Rightarrow 1/2 = e^{-\frac{\tau}{RC}}$$

$$\Rightarrow \tau = \ln 2 \cdot RC$$

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other teacher information (2/3)

Learning objective

The first part of the experiment concentrates on the time course of the capacitor voltage during charging and discharging. For this purpose, first qualitative statements are obtained and then the voltage curve during charging and discharging is recorded quantitatively.

The second part of the experiment aims at semi-quantitative relationships between the capacitor voltage U_C the charging resistor R, the capacity C of the capacitor and time t during the charging process.

Tasks

The students study the voltage curve on a capacitor during charging and discharging, and on which variables and in what way the speed at which these processes occur depends.

Other teacher information (3/3)

Notes

By the values of C and R of the available components, the charging and discharging processes initially take place relatively quickly. Teachers and students should therefore carefully prepare the quick reading of measured values with the pointer in motion. Consistent attention must be paid to ensuring that each capacitor is completely discharged before each charging process.

The series of measurements determined by the individual groups of students may differ significantly due to the tolerances of the nominal values of the capacities. Furthermore the measuring instrument influences because of its internal resistance R_i the loading and unloading operations. During charging, the charging resistor R and R_i a voltage divider. Therefore, the voltage at the capacitor, which is connected in parallel to the measuring instrument, can only exceed the partial voltage $U_C = U_0 \cdot (R_i/(R+R_i))$. reach. An increase in the charging resistance to achieve longer charging times is therefore not advisable, because this would only result in lower values of U_C become available. During discharging, the measuring instrument parallel to the capacitor accelerates the discharging process.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Safety instructions

PHYWE

The general instructions for safe experimentation in science lessons apply to this experiment.

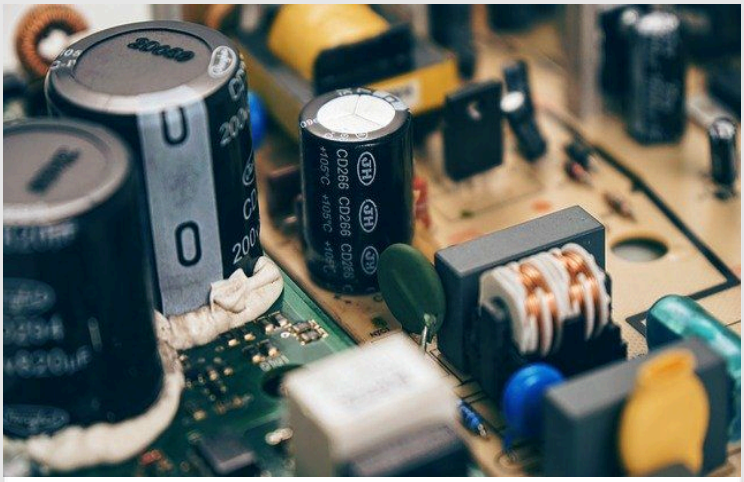
PHYWE

Student Information

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Motivation

PHYWE



Capacitors on a circuit board

Capacitors are built into virtually all electrical devices such as computers, smartphones and tablets, as they can store charge and thus energy and have special charging and discharging properties. Capacitors come in various forms. The simplest form is the so-called plate capacitor, while cylindrical capacitors are usually used on circuit boards.

In this experiment you will investigate the characteristics of the charging and discharging process of a capacitor and on which factors it depends.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

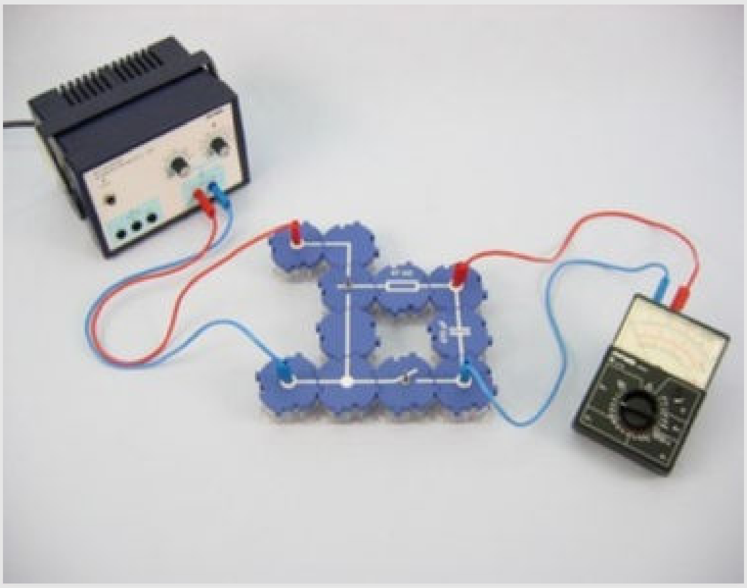
Position	Material	Item No.	Quantity
1	Straight connector module, SB	05601-01	1
2	Angled connector module, SB	05601-02	1
3	T-shaped connector module, SB	05601-03	1
4	Junction module, SB	05601-10	2
5	Angled connector module with socket, SB	05601-12	2
6	On-off switch module, SB	05602-01	2
7	Change-over 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	Analog multimeter, 600V AC/DC, 10A AC/DC, 2 MΩ, overload protection	07021-11	1
15	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
16	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Equipment

Position	Material	Item 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

Set-up



- Set up the experiment according to the figures on the right.
- First use the $R = 47\ k\Omega$ resistor and the capacitor with a capacity of $C = 470 \mu F$.
- Open the circuit breaker and move the switch to the upper position.
- Select a sufficiently large voltage measuring range (DC voltage) on the measuring instrument.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Procedure (1/3)

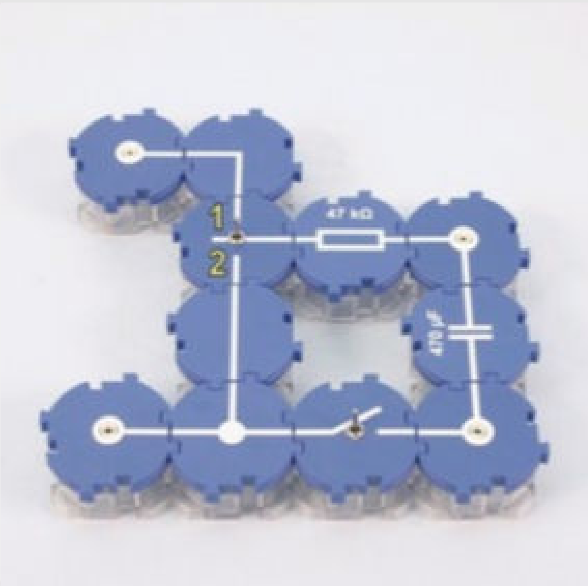
PHYWE

- Switch on the power supply unit and set it to 12 V DC. Select 2 A on the current limiter.
- Close the charging circuit by operating the circuit breaker and observe the voltage on the voltmeter. Discharge the capacitor by moving the switch to the lower position and continue to observe the voltage.
- Short-circuit the capacitor for a few seconds using a 25 cm connecting cable. Remove the cable and thus the short circuit again when the voltage at the capacitor $U_C = 0V$ and the capacitor is completely discharged.

Note: For the determination of the measured values in the following measurements, high concentration and possibly also some practice is required. If the first series of measurements is not successful, it can be repeated after briefly short-circuiting the capacitor. Always proceed as described above to charge and discharge the capacitor.

Procedure (2/3)

PHYWE



- Now measure the capacitor voltage $U_{C,1}$ starting from 0 V for the charging process (switch position 1) in 10 s intervals (total duration: one minute). Note your resulting measured values in the protocol.
- Wait until the capacitor is fully charged and then measure the capacitor voltage $U_{C,2}$ again at intervals of 10 s for the discharge process (changeover switch position 2). Note these measured values in the protocol again.
- Open the circuit by operating the circuit breaker and short circuit the capacitor again until the voltage indicates 0 V.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

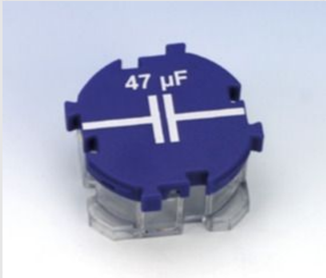
Tel.: 0551 604 - 0
Fax: 0551 604 - 107

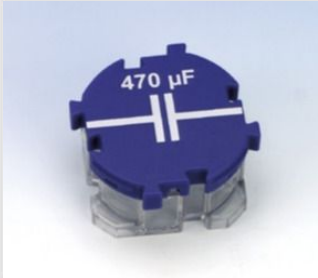
info@phywe.de
www.phywe.de

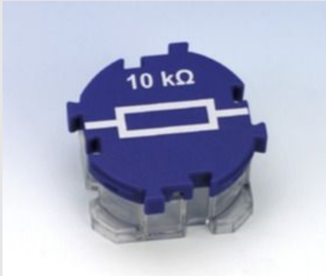
Procedure (3/3)

PHYWE

- Measure now for all combinations of the two resistors with one of the two capacitors the time periods t_1 (loading) and t_2 (discharge) until the capacitor voltage reaches the value $U_C = 6V$ has reached.
- Make sure that the voltage on the capacitor is always 0 V before charging and always short-circuit it to do so. Before discharging, the capacitor should be fully charged.
- Also note the respective duration in the protocol.
- Switch off the power supply unit after the last measurement.







PHYWE

Report

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Table 1

PHYWE

$t[s]$	$U_{C,1}\,[V]$	$U_{C,2}\,[V]$
0		
10		
20		
30		
40		
50		
60		

Enter your measured values for the different measurements in the tables. Calculate the half-lives according to $\tau = \ln 2 \cdot RC$ and enter them in the table as well.

$R[k\Omega]$	$C[\mu F]$	$t_1\,[s]$	$t_2\,[s]$	$\tau\,[s]$
47	47			
47	470			
10	47			
10	470			

Task 1

PHYWE

Record the measurement results for the first two measurement series graphically. Which function seems to be behind the course of the curve?

- ○ These are square gradients.
- ○ None of the other answers are correct.
- ○ These are exponential courses.
- ○ These are linear progressions.

Check

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Task 2

In which unit is the capacitance of a capacitor, for example, measured?

- $1\,C \quad (Coulomb)$
- $1\,F \quad (Farad)$
- $1\,V \quad (Volt)$
- $1\,A \quad (Ampere)$

Check

Task 3

How can the capacity C depending on the load Q, the voltage U and the amperage I and what does this mean for the physical dimension of the capacity?

- $C = Q/U \qquad 1\,F = 1\,C/V$
- $C = Q \cdot I \qquad 1\,F = 1C \cdot A$
- $C = Q \cdot U \qquad 1\,F = 1\,C \cdot V$
- $C = U/I \qquad 1\,F = 1\,V/A$

Check

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Task 4

PHYWE

Which of the following statements applies.

- [ ] The higher the resistance, the longer it takes to discharge the capacitor.
- [ ] The smaller the capacity of the capacitor, the longer it takes to discharge the capacitor.
- [ ] The greater the capacity of the capacitor, the longer it takes to discharge the capacitor.
- [ ] The smaller the resistance, the longer it takes to discharge the capacitor.

Check

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de