PHYWE	**How does the charging/discharging process take place on capacitors?**	EEP 5.2	S

Problem

Investigate the voltage curve for a capacitor during charge/discharge as well as the factors which effect the rate of charge/discharge and what effect these factors have on the rate.

Equipment

Plug-in board	06033.00	1
On/off switch	39139.00	1
Changeover switch	39169.00	1
Resistor, 10 kΩ	39104.30	1
Resistor, 47 kΩ	39104.38	1
Electrolytic capacitor, 47 µF, bipolar	39105.45	1
Electrolytic capacitor, 470 µF, bipolar	39105.47	1
Wire building block	39120.00	4
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1
Stopwatch	03071.01	1

Set-Up and Procedure

First Experiment

— Set up experiment as shown in Fig. 1. On/off switch should be set to off position and changeover switch should be flipped to position 1. Select measurement range of 10 V- on voltmeter.

— Switch on power supply unit and set direct voltage to 10 V.

— Switch on charging circuit by switching on/off switch to on position and observe voltmeter. Note observations under (1).

— Siwtch on discharging circuit by flipping changeover switch to position 2. Observe voltmeter once again and note observation under (2).

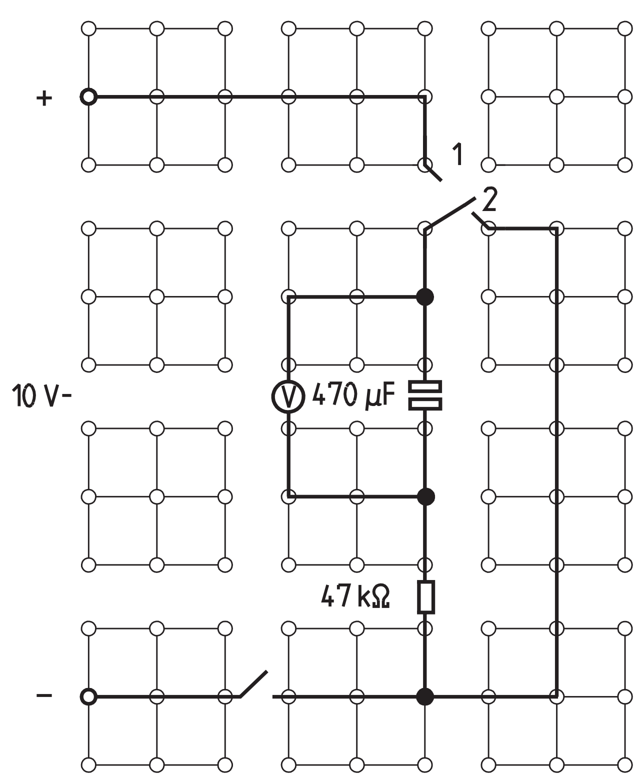
— Short circuit capacitor for a few seconds using a connecting cable (25 cm). Remove short circuit when voltage on capacitor is U_C = 0 V.

— Flip changeover switch to position 1 and, starting at 0 V, take measurements of the capacitor voltage U_C in 10 second intervals. Note measurements in Table 1. Note: Taking measurements requires intense concentration and, probably, a bit of practice. If the first series of measurements fails, briefly short circuit the capacitor and repeat the measurements.

— Flip changeover switch to position 2 and take measurements of capacitor voltage in 10 second intervals. Enter values in Table 1.

— Interrupt charging circuit by turning the on/off switch to off position.

Fig. 1



Second Experiment

- Put changeover switch in position 1. Switch on charging circuit and measure the time it takes for the capacitor voltage to reach U_c = 6 V. Enter time in Table 2.
- Turn on/off switch to off position. Discharge capacitor and replace with 47 μF capacitor.
- Turn charging circuit on and, once again, measure the time it takes until U_c = 6 V. Note time.
- Replace 47 kΩ resistor with 10 kΩ resistor and repeat measurement.
- Replace 47 μF capacitor with 470 μF capacitor and repeat measurement.
- Switch power supply unit off.

Observations and Measurement Results

(1)

(2)

Table 1

t /s	0	10	20	30	40	50	60
Charging: U_C/V							
Discharging: U_C/V							

Table 2

R /kΩ	C /μF	t /s
47	470	
47	47	
10	47	
10	470	

Evaluation

1. In Fig. 2, draw a graph using the measurements in Table 1 for charging and discharging.
2. Explain the curve of these graphs and/or the observations you noted under (1).

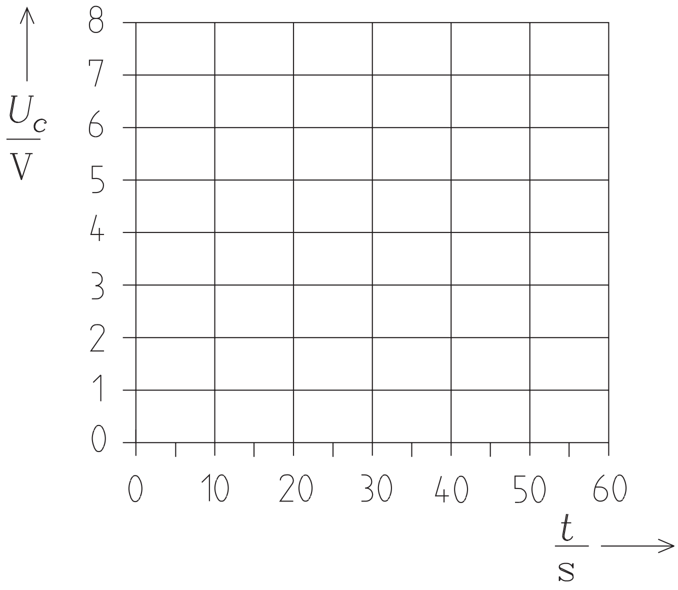


Fig. 2

3. Explain the relationship between the time it takes to charge the capacitor and the capacity C as well as the relationship between the time necessary for charging and resistance R (designated as charging resistance).
   Explain why the relationship must be so.

Room for notes

(How does the charging/discharging process take place on capacitors?)

Problem

The students know that capacitors can store electrical energy.

The first experiment focuses on the time factor involved with capacitor voltage when charging and discharging. First, qualitative aspects are determined. Next, the voltage curve for charging and discharging is determined quantitatively.

The second experiment is targeted at semi-quantitative relationships between capacitor voltage U_C, the charging resistance R, the capacity C of the capacitor, and the time t it takes to charge.

Notes on Set-Up and Procedure

Due to the values for C and R of the components used in this experiment, the capacitors will charge and discharge relatively rapidly at first. For this reason, the instructor and students should be prepared to take measurements in rapid succession from the constantly changing indicator. Make absolutely sure that each capacitor is discharged before charging.

Observations and Measurement Results

(1) Voltage on the capacitor rises rapidly at first, then more slowly until (nearly) leveling off.

(2) Voltage drops sharply at first, then more slowly until (nearly) reaching the value 0 V.

Evaluation

1. See Fig. 2.
2. The difference between the connected voltage and the capacitor voltage U_C, measuring 0 V at first, is greatest when the charging circuit is switched on, resulting in a relatively large current flow. The difference gets smaller and smaller the more the capacitor charges. Therefore, the current and also the increase in U_C get smaller and smaller.
3. The larger the capacity with a constant charging resistance R, the longer it takes to charge the capacitor; for, more charge carriers must flow to a capacitor with larger capacity until it is fully charged.
   The greater the charging resistance R, with constant capacity C, the longer it takes to charge the capacitor; for, a larger charging resistance only allows for a minimal current.

Fig. 2

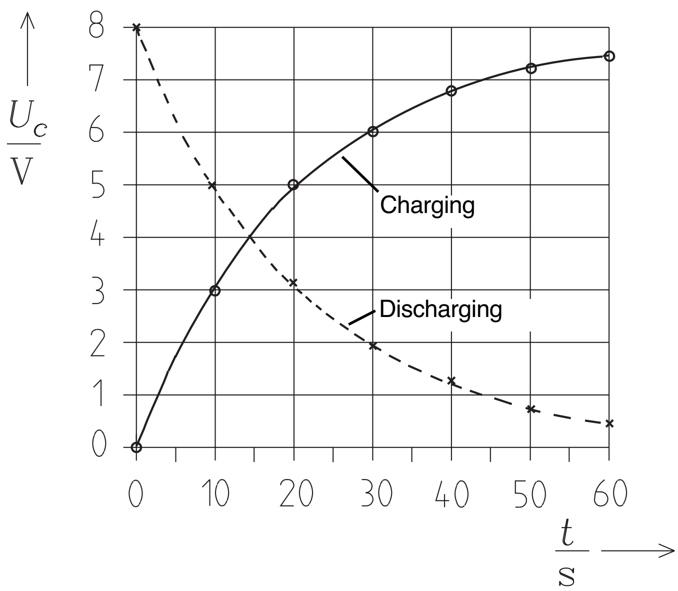


Table 1

t /s	0	10	20	30	40	50	60
Charging: U_C/V	0	3	5	6.1	6.8	7.3	7.6
Discharging: U_C/V	8	5	3.2	1.9	1.3	0.7	0.4

Table 2

R /kΩ	C /µF	t /s
47	470	28
47	47	4
10	47	1
10	470	6

Charging and Discharging Capacitors

(How does the charging/discharging process take place on capacitors?)

Notes

Most likely, the series of measurements taken by the students will differ greatly from one another. This is primarily due to the large tolerance ranges inherent to the nominal values for the capacities.

Due to its internal resistance R_i, the meter has an influence on both charging and discharging. When charging, the charging resistance R and R_i form a voltage divider. Therefore, voltage on the capacitor, connected in parallel to the meter, can only attain a maximum partial voltage of $U_C = U_0 \cdot R_i/(R + R_i)$. Increasing the charging resistance to lengthen the charging times is not practical because it only allows even smaller values for U_C. The meter connected in parallel to the capacitor accelerates discharging. The charging and discharging time curves for voltage and current correspond to the time curves of numerous natural growth and decay processes.

The following function applies for discharging:

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

and for charging:

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

After time t = R · C, voltage has approached its final value up to the e-th amount. This time is referred to as the time constant τ of the circuit.