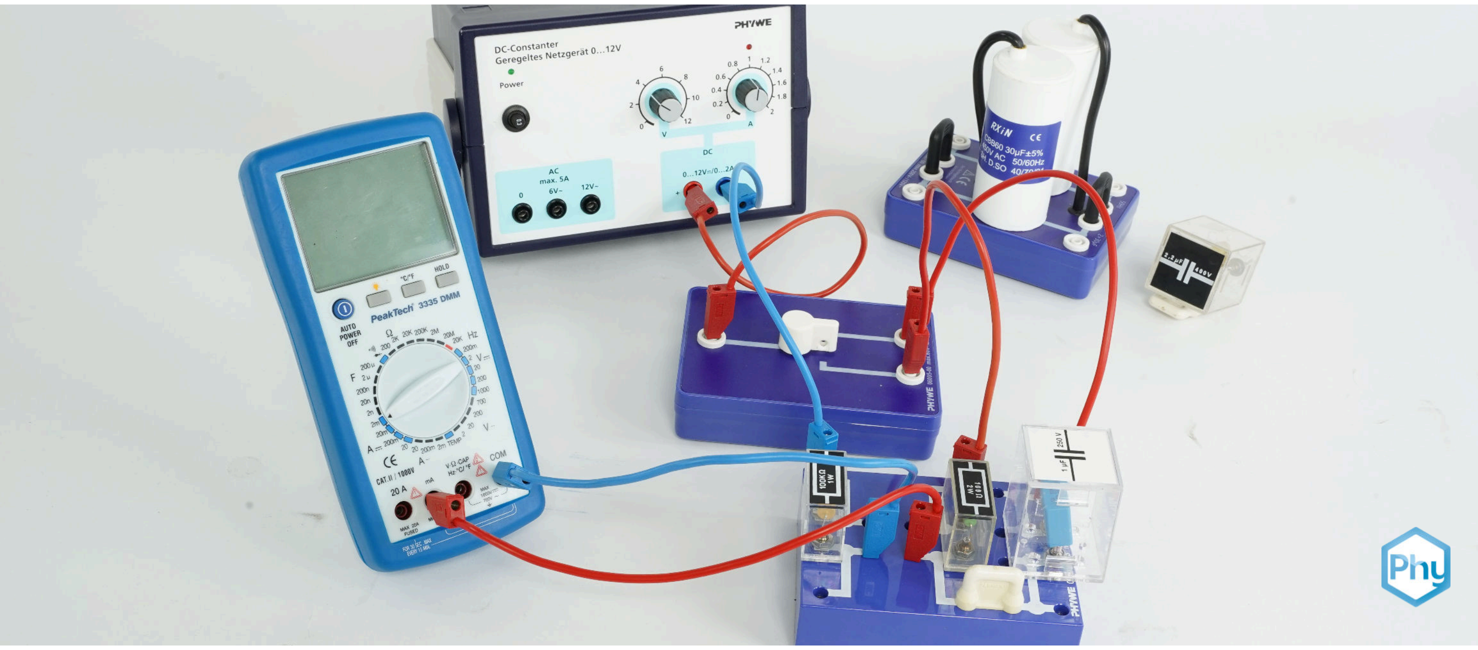
# Charging curve of a capacitor / charging and discharging of a capacitor



| | | | |
|---|---|---|---|
| Physics | Electricity & Magnetism | Electric current & its effects | |
| Physics | Electricity & Magnetism | Simple circuits, resistors & capacitors | |
| Applied Science | Engineering | Electrical Engineering | Properties of Electrical Devices |
| Applied Science | Engineering | Renewable Energy | Basic Principles |

| Difficulty level | Group size | Preparation time | Execution time |
|---|---|---|---|
| easy | - | 20 minutes | 30 minutes |

This content can also be found online at:

http://localhost:1337/c/64abba68c78b0a0002325fc1

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# General information

## Application

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One expample for the use of capacitors are radios

Capacitors are essential components in many everyday devices as they can store and discharge electrical energy. They are found in electronic circuits, motors, audio equipment, and power supply networks. A specific example is a computer, where capacitors are used in the power supply circuit to smooth the current and filter out disturbances. They are also present in radios, where they serve to tune into specific frequencies. Overall, capacitors contribute to the efficient and stable operation of our technology.



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## Other information (1/2)

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**Prior knowledge**

The prior knowlege required for this experiment is found in the theory section.

**Main principle**

A capacitor is charged by way of a resistor. The current is measured as a function of time and the effects of capacitance, resistance and the voltage applied are determined.

## Other information (2/2)

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**Learning objective**

The goal of this experiment is to investigate the characteristics of capacitors.

**Tasks**

To measure the charging current over time:

1. using different capacitance values $C$, with constant voltage $U$ and constant resistance $R$.
2. using different resistance values ($C$ and $U$ constant)
3. using different voltages ($R$ and $C$ constant).

To determine the equation representing the current when a capacitor is being charged, from the values measured.



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## Theory (1/2)

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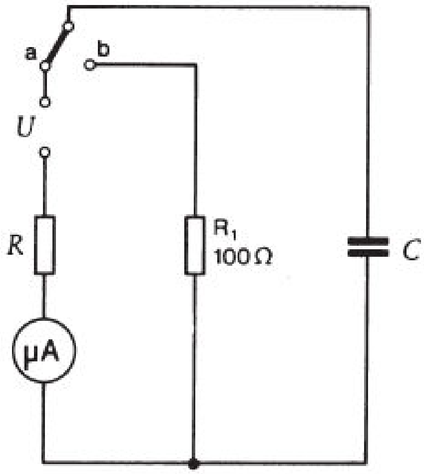
The course of current wit time, $I(t)$, when a capacitor $C$ is charged through a resistor $R$ at a fixed voltage $U$ is determined from Kirchhoff's laws:

$$I(t) = \frac{U}{R} e^{\left(\frac{t}{RC}\right)} \quad (1)$$




Capacitor charging circuit a) charging b) discharging

## Theory (2/2)

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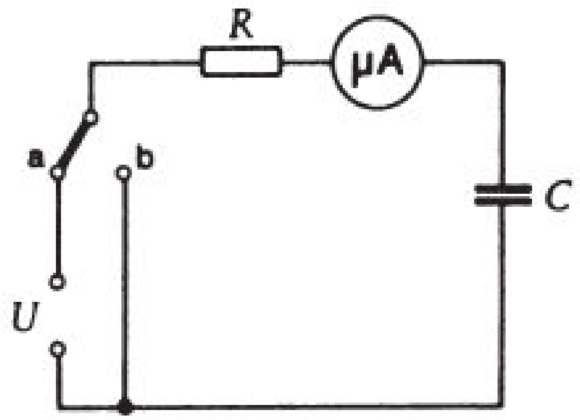
If discharging curves are to be measured as well, the circuit as shown in the figure will be used.

Another experiment which could be carried out would be to determine unkown capacitance values from the charging and discharging curves with known resistance and charging function, or conversely to determine large resistance values at known capacitance.




Circuit for recording charging and discharging curves.



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# Equipment

| Position | Material | Item No. | Quantity |
|---|---|---|---|
| 1 | Connection box | 06000-00 | 2 |
| 2 | Two-way switch, single pole | 06005-00 | 1 |
| 3 | Capacitor, 2 x 30 µF | 06007-00 | 1 |
| 4 | Resistor 100 Ohm, 1W, G1 | 39104-63 | 1 |
| 5 | Resistor 1 MOhm, 1W, G1 | 39104-52 | 4 |
| 6 | brigde plug | 06027-07 | 2 |
| 7 | Capacitor 1 microF/ 100V, G2 | 39113-01 | 1 |
| 8 | Capacitor 4,7microF/ 100V, G2 | 39113-03 | 1 |
| 9 | PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A | 13506-93 | 1 |
| 10 | Digital stopwatch, 24 h, 1/100 s and 1 s | 24025-00 | 1 |
| 11 | Digital multimeter, 600V AC/DC, 10A DC, 20MΩ | 07124-12 | 1 |
| 12 | Connecting cord, 32 A, 250 mm, red | 07360-01 | 3 |
| 13 | Connecting cord, 32 A, 250 mm, blue | 07360-04 | 4 |



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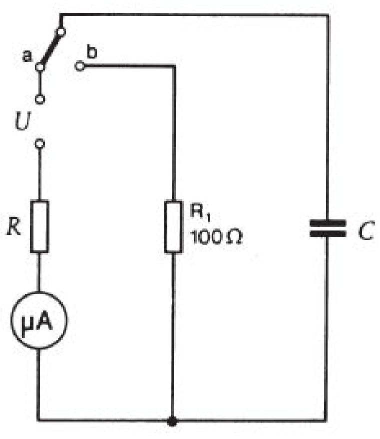
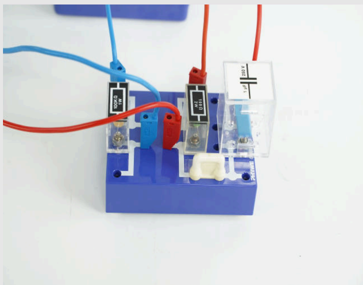
# Setup and Procedure

## Setup




- Set up the experiments as shown in the figures.
- Various resistance values $R$ are established by series connection. The internal resistance of the digital multimeter and the setting time can be disregarded.
- $R_1$ is a protective resistor which limits the current when discharging (switch setting b).





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## Procedure

To measure the charging current over time:

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To determine the equation representing the current when a capacitor is being charged, from the values measured.

# Evaluation



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# Evaluation (1/7)

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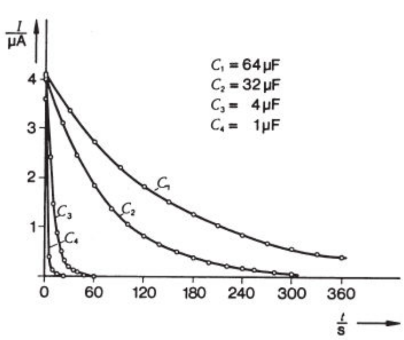


Fig. 1: Course of current with time at different capacitance values; voltage an resistance are constant $U = 9V, R = 2,2 M\Omega$

The dependence of the current on the capacitance, the resistance and the voltage should be worked out from the measured values obtained by systematically varying the parameters.

1. First plot the measured values direct (Fig. 1) and then semilogarithmically (Fig. 2).

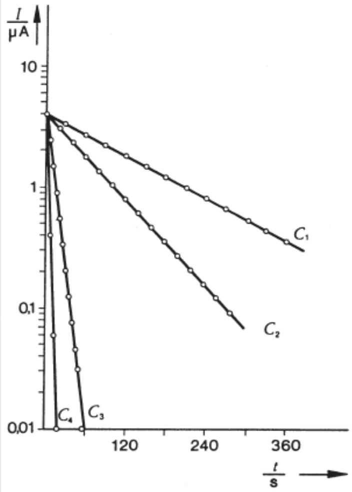


Fig 2: as Fig.1 but plotted semilogarithmically

# Evaluation (2/7)

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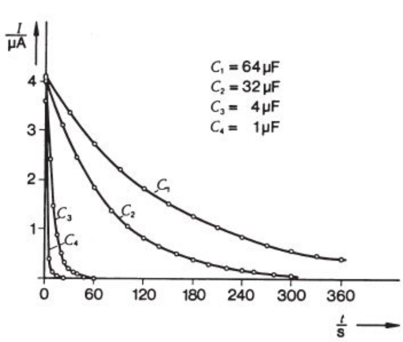


Fig. 1: Course of current with time at different capacitance values; voltage an resistance are constant $U = 9V, R = 2,2 M\Omega$

According to the figures the function takes the general form:

$$I(t) = I_0(U,R)e^{\alpha(U,R,C)\cdot t}$$

$I_0$ is not dependent on $C$ as all curves begin at the same current values.

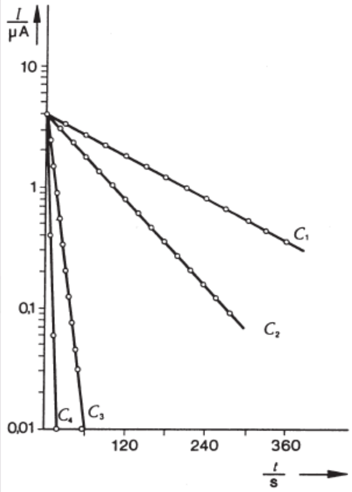


Fig 2: as Fig.1 but plotted semilogarithmically



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## Evaluation (3/7)

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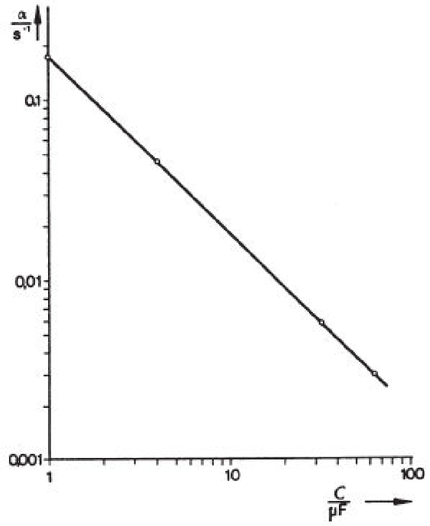


Fig. 3: $\alpha$ as a function of capacitance.

To investigate the dependence of the exponent on the capacitance, the slopes of the straight lines in Fig. 3 are plotted against capacitance, on a log-log basis.

A straight line with the slope $-0,98 \approx -1$ is obtained, so that:

$$I(t) = I_0(U,R)e^{\frac{\alpha'(U,R)}{C}t}$$

## Evaluation (4/7)

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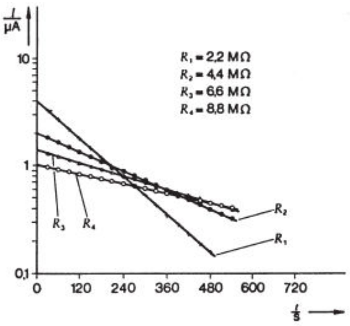


Fig. 4: Course of current with time at different resistance values; capacitance and voltage are constant at $64 \mu F$ and $9 V$ respectively.

2. Straight lines with different slopes and different starting points are obtained. The dependence of the exponent on $R$ is determined by plotting the log-log of the straight lines in Fig. 4.

A straight line with the slope -1.00 is obtained, so that

$$I(t) = I_0(U,R)e^{\frac{\alpha''(U)}{RC} \cdot t}.$$

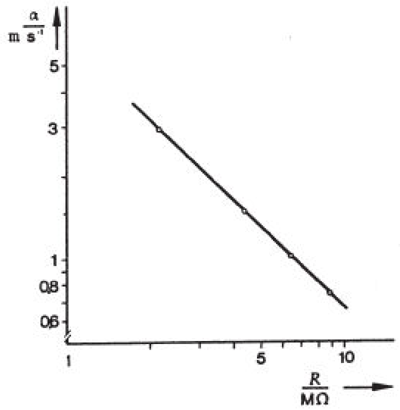


Fig. 5: Exponent $\alpha$ as a function of resistance $R$.



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## Evaluation (5/7)

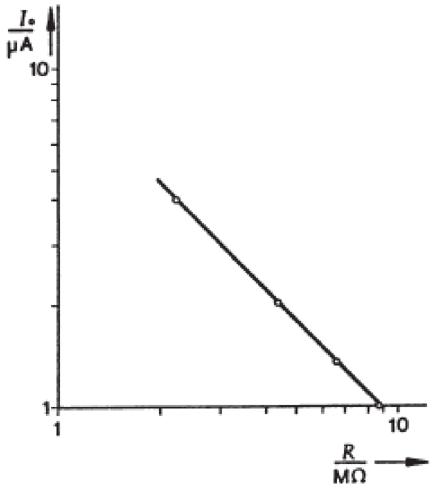


Fig. 6: Starting current $I_0$ of the measured values in Fig. 4 as a function of the resistance.

The straight line in Fig. 6 has a slope of $-0,99 \approx -1$ i.e.

$$I_0 = \frac{\beta(U)}{R}$$

## Evaluation (6/7)

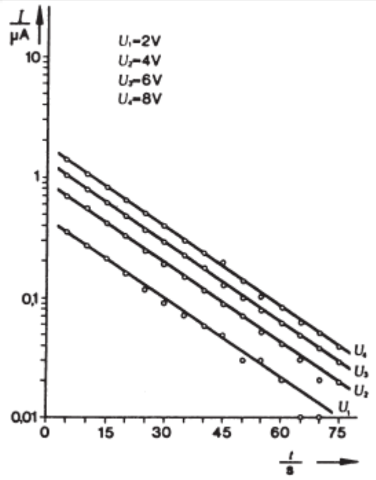


Fig. 7: course of current with time at various voltages $R = 4,4M\Omega, C = 4\mu F$.

3. All the straight lines in Fig. 7 have the same slope. The exponent is thus independent of the voltage $U$ (this statement can also be made on the basis of dimensions).

The slope of the straight line is:

$$0,058s^{-1} = \frac{1}{RC}$$

and therefore

$$RC = 17,24s.$$



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# Evaluation (7/7)

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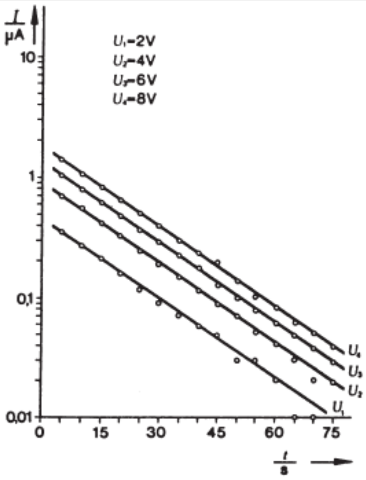


Fig. 7: course of current with time at various voltages $R = 4,4 M\Omega, C = 4 \mu F.$

The starting current values $I_0$ for the measured values in Fig. 7 are plotted directly against the voltage values $U$ in this case (Fig. 8).

A straight line with the slope $0,227 \frac{\mu A}{V} = \frac{1}{R}$

and therefore $R = 4,41 M\Omega$

is obtained. Taken together, therefore, all the measured values give equation:

$$I(t) = \frac{U}{R} e^{(\frac{t}{RC})} \quad (1)$$



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