EXPERIMENT PROCEDURE

- **Record the change in the capacitor voltage over time while a capacitor is charging by measuring the time taken to reach specific points.**
- **Record the change in the capacitor voltage over time while a capacitor is discharging by measuring the time taken to reach specific points.**
- **Determine resistance and capacitance by measuring the times it takes to charge and discharge and make a comparison with known external parameters.**

OBJECTIVE

Determine the charging and discharging times.

SUMMARY

The discharge curve of a capacitor is to be derived by measuring the times taken for certain voltages to be reached to obtain sample points. The charging curve is to be measured in the same way. The measurements will then be used to determine data regarding the resistors and capacitors being used.

REQUIRED APPARATUS

Quantity	Description	Number
1	Charge and Discharge Apparatus (230 V, 50/60 Hz)	**1017781 or**
	Charge and Discharge Apparatus (115 V, 50/60 Hz)	**1017780**
1	Capacitor 1000 µF, 16 V, P2W19	**1017806**
1	Resistor 10 kΩ, 0.5 W, P2W19	**1012922**
Additionally required:		
1	Digital Multimeter P1035	**1002781**

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GENERAL PRINCIPLES

In a DC circuit, current only flows through a capacitor while it is being turned on or off. The current causes the capacitor to charge when the circuit is switched on until it reaches the full voltage applied. When the circuit is turned off, the capacitor is discharged until its voltage falls to zero.

For a DC circuit with capacitance C, resistance R and DC voltage U_0, the following applies when the circuit is switched on:

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

The following applies when the circuit is switched off:

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

In both cases the time constant is

(3) $$\tau = R \cdot C$$

To check these relationships, the time to reach certain pre-determined comparison voltages is measured during the course of the experiment. A stopwatch is started at the same time as the circuit is switched on or off and then stopped by means of a comparator circuit once the comparison voltage has been reached. By measuring the times for various comparison voltages, the charging and discharging curves can be sampled and plotted point by point.

In practice, the following time is also of interest:

(4) $$t_{5\%} = -\ln(5\%) \cdot R \cdot C \approx 3 \cdot R \cdot C$$

This is the time it takes for the capacitor voltage to reach 5% of the initial voltage U_0 during discharge or to reach within 5% of the final value U_0 when charging. By measuring $t_{5\%}$ it is possible to determine the parameters R and C, for example.

EVALUATION

For a known external resistance R_{ext}, the external capacitance C_{ext} can be calculated using the time $t_{5\%}$ by means of Equation (4):

$$C_{ext} = \frac{t_{5\%}}{3 \cdot R_{ext}}$$

The external capacitance determined in this way will be connected in parallel with the internal capacitance C_{int} in order to determine the latter by comparing the charging and discharging times.

Finally the three remaining unknown internal resistances $R_{int,\,i}$ can be obtained from the relevant charging and discharging times:

where i = 1, 2, 3

$$R_{int,\,i} = \frac{t_{5\%,\,i}}{3 \cdot C_{int}}$$

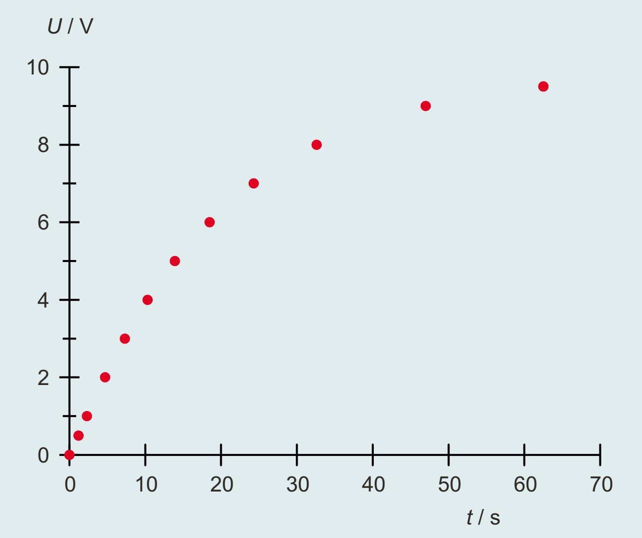

Fig. 1: Charging curve for internal RC pair

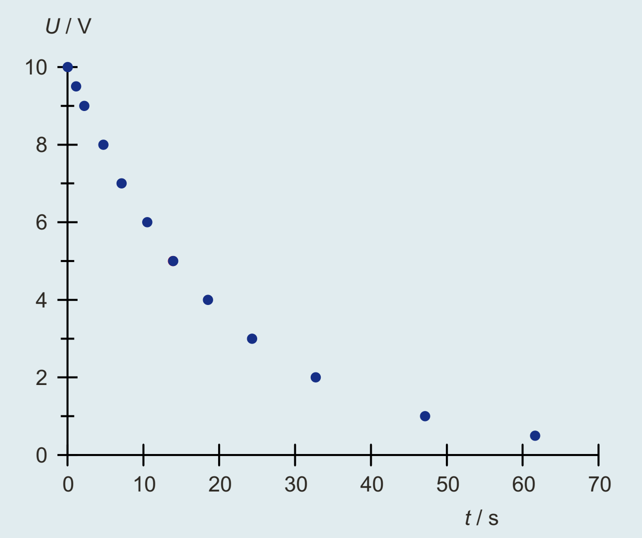

Fig. 2: Discharging curve for internal RC pair