ELM: Electrical measurement techniques

Keywords: current, amperage, voltage, voltage drop, resistance, resistor, characteristic current-voltage curve, voltmeter, ammeter, Kirchhoff's law, parallel- and series circuits, internal resistance, voltage divider, equivalent circuit diagram, ideal and real current source, ideal and real voltage source, diode

1. Measurement of the characteristic current voltage curve of a load

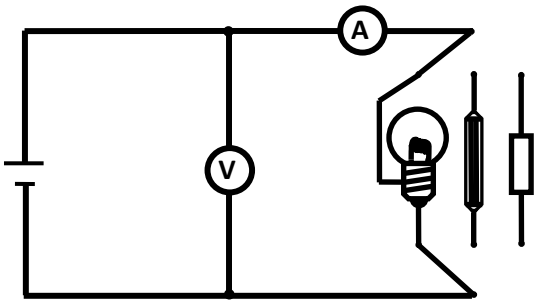

Fig. 1.: Circuit for measuring the characteristic current voltage curves of different loads. As loads a graphite rod, a light bulb and an ohmic resistor are used.

Tasks

- Assemble the circuit as shown in Fig. 1. Connect the volt- and ammeter in a suitable manner.
- Measure the characteristic current-voltage curves of an ohmic resistor, a light bulb and a graphite rod.

Pay attention to the limits of the light bulb and the graphite rod. The current on the graphite rod should not be greater than 1A. Stop the measurement in case the graphite rod begins smoke.

- Plot the data for the three loads in one graph.

For this purpose, the recorded data for each load must be normalized to the highest value measured for the respective load (why?). I.e. for each load you should plot I/I_{max} over $U/U_{max,}$ where I_{max} and U_{max} are the highest measured values for the respective load.

2. Measurement: loaded/unloaded voltage divider

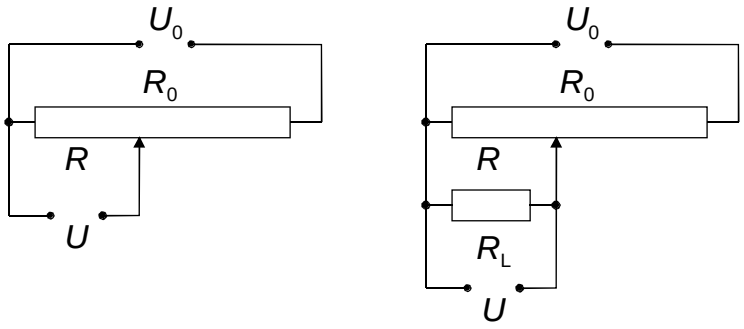

Fig. 2. Circuit serving as voltage divider. The voltage divider is realized with the help of a potentiometer. The left and right parts of the figure respectively show a potentiometer circuit with – and without an additional load resistor R_L.

Tasks

- Set up the circuit for the voltage divider.
A rotary potentiometer is available to construct the voltage divider (see Fig. 2 left side). The output voltage depends on the numbers of rotations of the potentiometer knob. The final value of the scale is s_0 = 10 rotations. Check the nominal value of the total resistance R_0 of the potentiometer using a multimeter.
To load the voltage divider a R=250Ω resistor is connected in parallel to the output terminals (see Fig. 2 right side). Verify the resistance value of the load resistor with a multimeter.

- Measure the dependence of the output voltage on the number of rotations for the unloaded voltage divider.

- Measure the dependence of the output voltage on the number of rotations for the loaded voltage divider.

Formula (1) gives the theoretically expected ratio U/U_0 between the input and output voltage of the loaded voltage divider in dependence on the ratio s/s_0, i.e. the normalized number of rotations.

$$\frac{U}{U_0} = \frac{\frac{R}{R_0}}{1+\frac{R}{R_0}\left(1-\frac{R}{R_0}\right)\frac{R_0}{R_L}} = \frac{\frac{s}{s_0}}{1+\frac{s}{s_0}\left(1-\frac{s}{s_0}\right)\frac{R_0}{R_L}} \qquad (1)$$

- Verify formula (1) theoretically by using the laws of total resistance.

- Plot the measured ratio U/U_0 against $R/R_0=s/s_0$ for the unloaded and loaded voltage divider together with the theoretically expected curves (s. Fig. 3) into one diagram.

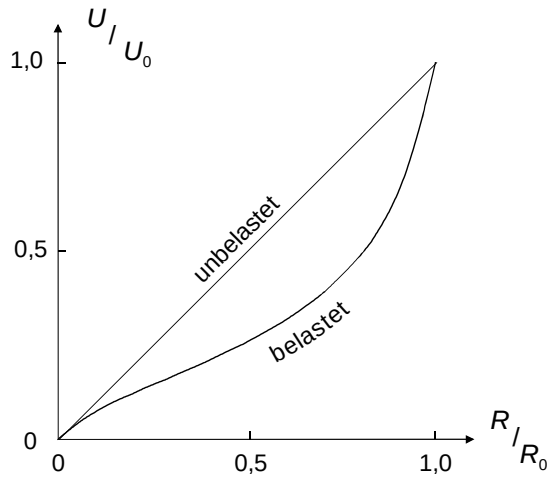

Fig. 3 Potentiometer's voltage without (above) and with (below) an additional load resistance.

3. Measurement of the characteristic current- and voltage curve of a diode

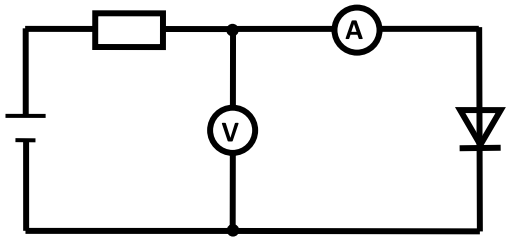

Fig. 4. Circuit for the measurement of the characteristic current voltage curve for the diode (in direction of flow)

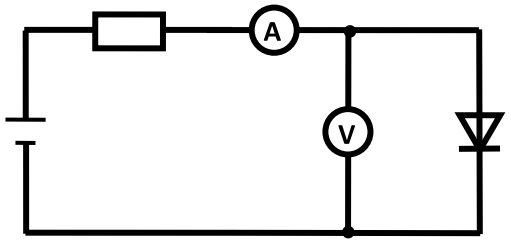

Fig. 5. Alternative Circuit for the measurement of the characteristic current voltage curve for the diode (in direction of flow)

Tasks

- Set up the circuit as shown in Fig. 4. Measure the characteristic current voltage curve for the diode along and opposite to the direction of flow. Make sure to record sufficient data points in regions where the shape of the characteristic curve changes strongly.
- Set up the circuit as shown in Fig. 5. Measure the characteristic current voltage curve for the diode along and opposite to the direction of flow. Make sure to record sufficient data points in regions where the shape of the characteristic curve changes strongly.

In the circuit shown in Fig. 4 the ammeter displays directly the amperage of the current that flows through the diode. On the other hand, the voltmeter shows the value of the voltage drop over the diode and the ammeter. Therefore the value of the displayed voltage drop is approximately the value of the voltage drop across the diode only under certain conditions.
How can the actual value of the voltage drop over the diode be calculated from the displayed value of the voltage drop?
In the circuit shown in Fig. 5 the voltmeter displays directly the voltage drop over the diode. On the other hand, the ammeter shows the amperage of the current that flows through the diode and the voltmeter. Therefore the value of the displayed amperage is approximately the amperage of the current that flows through the diode only under certain conditions.
How can the actual amperage that flows through the diode be calculated from displayed amperage?

- Calculate in either case from the measured values the actual values of the voltage drop over the diode and of the current that flows through the diode.
- Plot the measured and calculated values into one diagram.

4. Questions for preparation

The following section summarizes some questions and remarks about the most important terms, definition and concepts related to the topics covered here. Some questions about measurement instruments and their handling can be found here. Please use suitable literature to read about terms unknown to you. Please formulate and notice questions about issues that remained unclear to you during the preparation for the experiment.

- Kirchhoff's Laws: Derive of the total electrical resistance in series- and parallel circuits of resistors with help of Kirchhoff's laws.
- Resistance: What is the difference between the physical quantity "electrical resistance" and a physical system subject to Ohm's law?
- Voltage divider: Explain how voltage dividers work. What is the most simplest circuit

that realizes a voltage divider?

- How is a voltmeter correctly connected to an electric circuit?
  How is an ammeter correctly connected to an electric circuit?

- Internal resistance: What is the internal resistance of an ideal voltmeter?
What is the internal resistance of an ideal ammeter?
How does the internal resistance of the real measurement and source devices influence the results of measurements?
Specify a simple equivalent circuit diagram for a real voltage source.
Specify a simple equivalent circuit diagram for a real current source.

Literature:
Feel free to use further sources which are well suited for your needs

1. https://www.physik.fu-berlin.de/studium/lehre/gp/dateien/gp-doku/GP1-Script-English.pdf
GP-Script pp. 18-21