

Solution

At the beginning we perform preliminary measurements by using the circuit shown in Fig. 8. For two values of voltage U_1 and U_2 , applied to the black box in both directions, we measure four values of current: $I(U_1)$, $I(U_2)$, $I(-U_1)$ and $I(-U_2)$. In this way we find that:

1. The black box conducts current in both directions;
2. There is an asymmetry with respect to the sign of the voltage;
3. In both directions current is a nonlinear function of voltage.

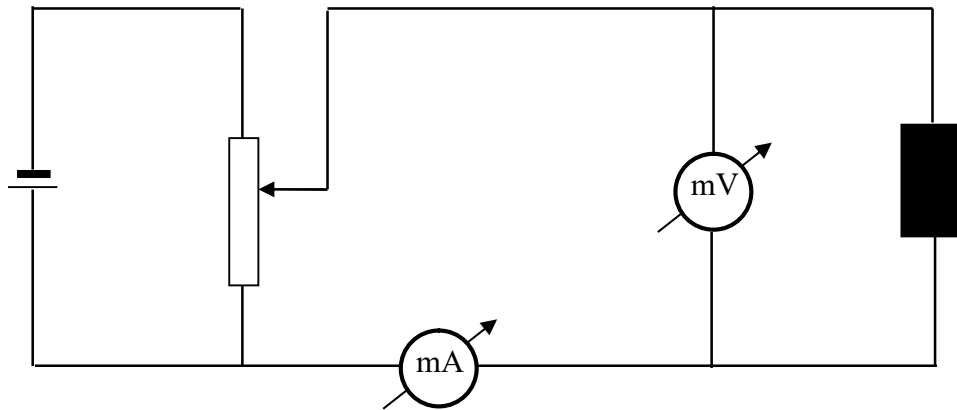
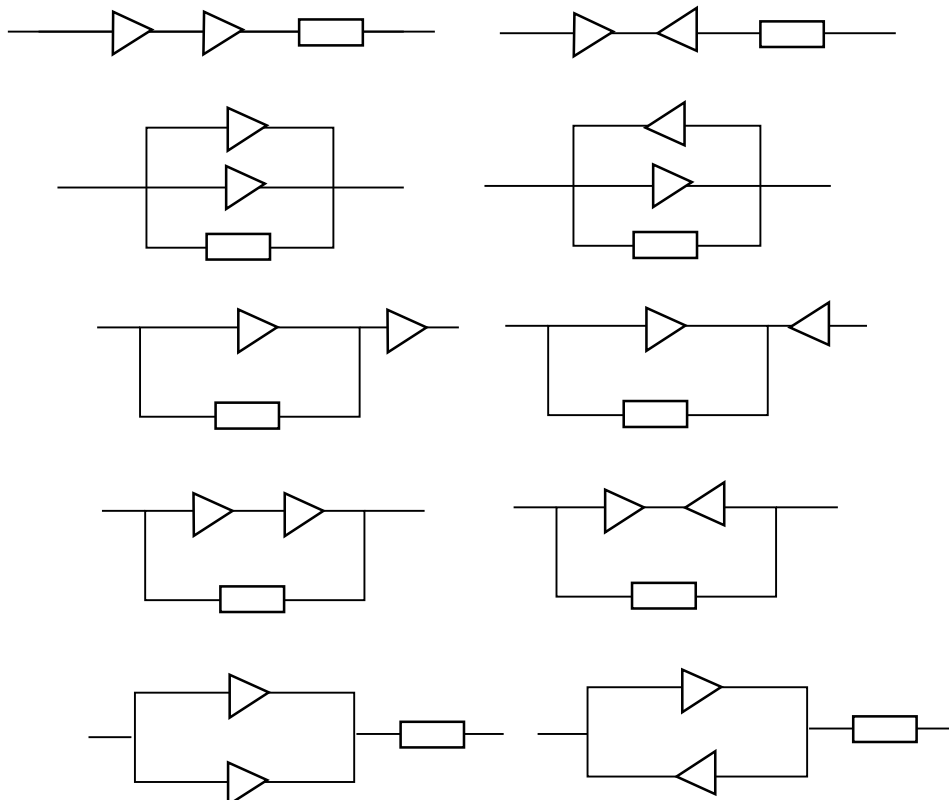


Fig. 8

The diodes and resistor can be connected in a limited number of ways shown in Fig. 9 (connections that differ from each other in a trivial way have been omitted).



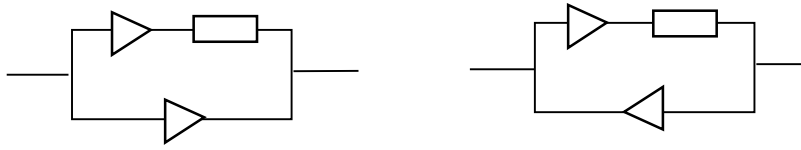


Fig. 9

Only one of these connections has the properties mentioned at the beginning. It is:

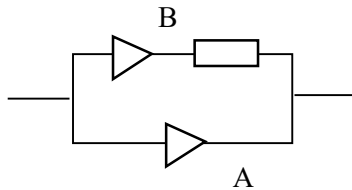


Fig. 10

For absolute values of voltages we have

$$U_R = U_B - U_A = \Delta U,$$

where U_R denotes voltage on the resistor when a current I flows through the branch B, U_A - voltage on the black box when the current I flows through the branch A, and U_B - voltage on the black box when the current I flows through the branch B.

Therefore

$$R = \frac{U_R(I)}{I} = \frac{U_B(I) - U_A(I)}{I} = \frac{\Delta U}{I}.$$

It follows from the above that it is enough to take characteristics of the black box in both directions: by subtraction of the corresponding points (graphically) we obtain a straight line (example is shown in Fig. 11) whose slope allows to determine the value of R .

The solutions were marked according to the following scheme (draft):

Theoretical part:

- | | |
|--|----------------|
| 1. Proper circuit and method allowing determination of connections the elements in the black box | up to 6 points |
| 2. Determination of R (principle) | up to 2 points |
| 3. Remark that measurements at the same voltage in both directions make the error smaller | up to 1 point |
| 4. Role of number of measurements (affect on errors) | up to 1 point |

Experimental part:

- | | |
|--|----------------|
| 1. Proper use of regulated resistor as potentiometer | up to 2 points |
| 2. Practical determination of R (including error) | up to 4 points |
| 3. Proper use of measuring instruments | up to 2 points |
| 4. Taking into account that temperature of diodes increases during | |

- measurements
5. Taking class of measuring instruments into account

up to 1 point
up to 1 point

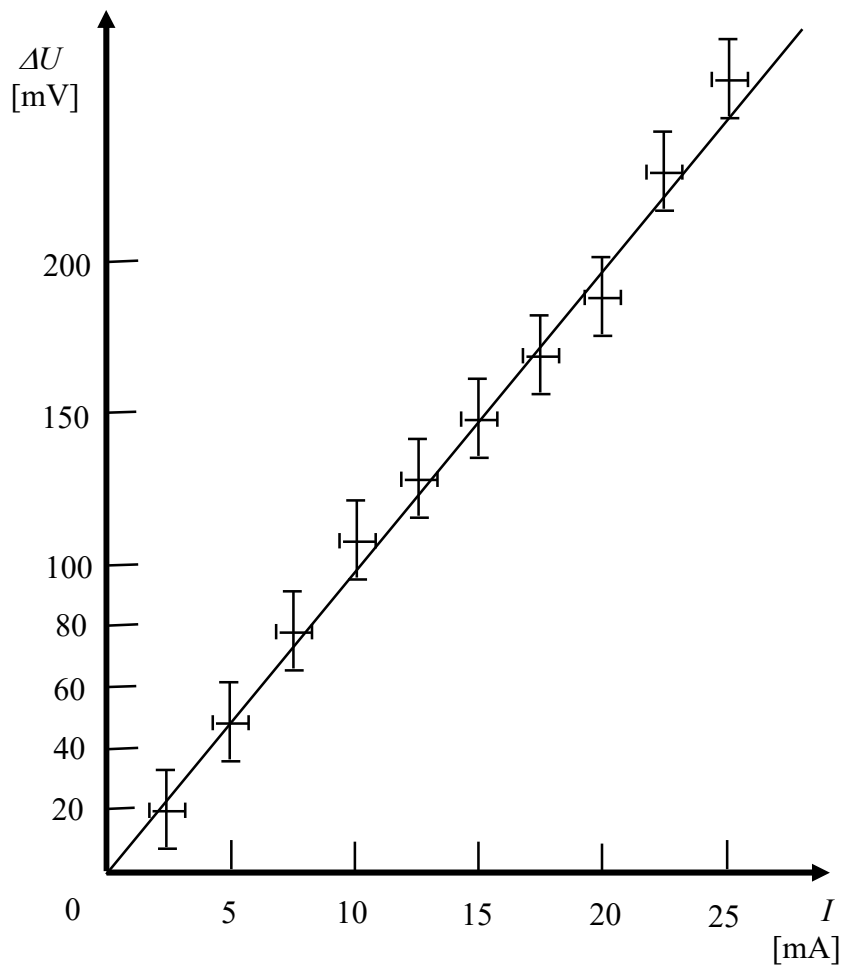


Fig. 11

Acknowledgement

Author wishes to express many thanks to Prof. Jan Mostowski for reading the text and for many valuable comments and remarks that allowed improving the final version.

Literature

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- [4] **W. Gorzkowski**, *VII Międzynarodowa Olimpiada Fizyczna*, Fizyka w Szkole, nr 3/75, pp. 23 – 28