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.

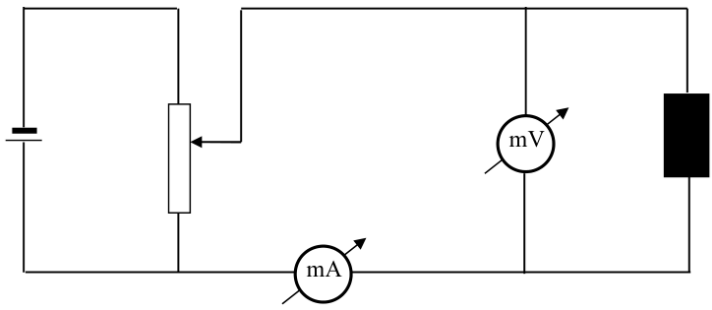


Fig. 8

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).

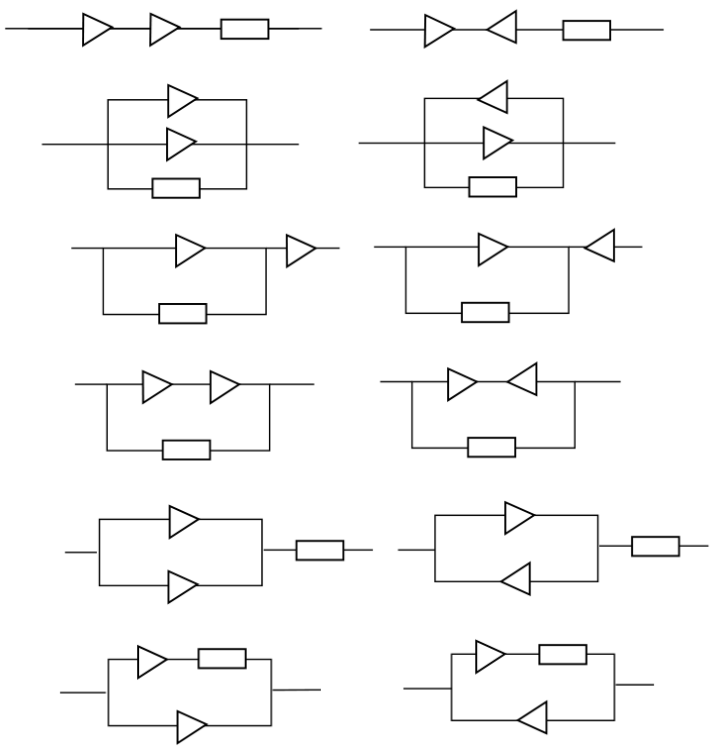


Fig. 9

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

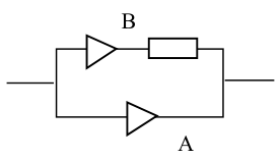


Fig. 10

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 trough 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 — up to 1 point
5. Taking class of measuring instruments into account — up to 1 point

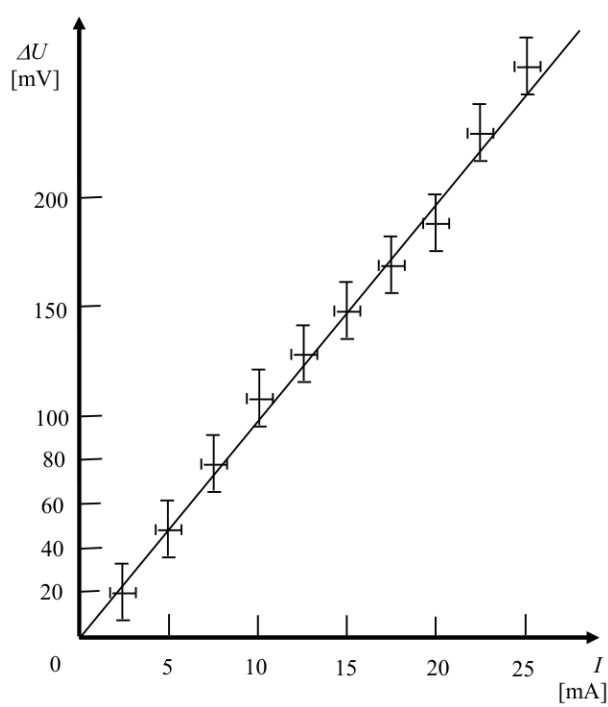


Fig. 11