I. BASICS OF ELECTRICAL CIRCUITS

The resistance R is defined by the Ohm's law as $R = V/I$, where $V = \phi_2 - \phi_1$ is the difference between electrical potentials ϕ_2 and ϕ_1 at the two ends of the resistor, and I is the electrical current through the resistor, see Fig. 1.

For resistors connected in series, see Fig. 2, the same current flows through all the resistors. Correspondingly, we can write

$$R_1 = \frac{\phi_2 - \phi_1}{I}, \quad R_2 = \frac{\phi_3 - \phi_2}{I}, \quad R_3 = \frac{\phi_4 - \phi_3}{I}. \tag{1}$$

If you add the above equations, you obtain

$$R_1 + R_2 + R_3 = \frac{\phi_4 - \phi_1}{I} = \frac{V}{I}. \tag{2}$$

Thus, the total resistance of the circuit in Fig. 2 is the sum of all resistances. Also, note that the potential difference across the whole circuit is equal to the sum of potential differences across each resistor, that is $V = (\phi_2 - \phi_1) + (\phi_3 - \phi_2) + (\phi_4 - \phi_3)$.

When resistors are connected in series, the larger the resistance, the larger the potential difference across this resistor.

For resistors connected in parallel, see Fig. 3, the currents flowing through each resistor is different. However, the potential difference $V = \phi_2 - \phi_1$ across each resistor is the same. Correspondingly, we can write

$$\frac{1}{R_1} = \frac{I_1}{V}, \quad \frac{1}{R_2} = \frac{I_2}{V}, \quad \frac{1}{R_3} = \frac{I_3}{V}. \tag{3}$$

Obviously $I = I_1 + I_2 + I_3$, so we obtain

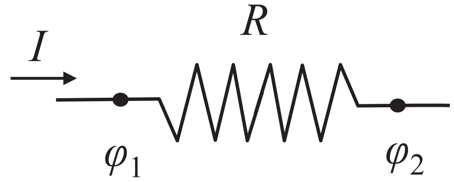

FIG. 1: Resistance and Ohm's law.

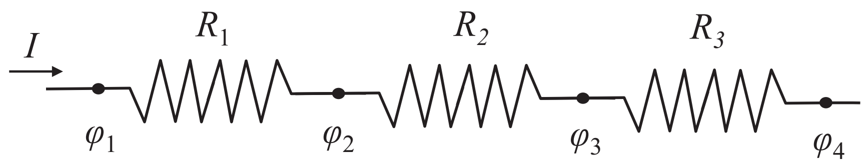

FIG. 2: Connection in series.

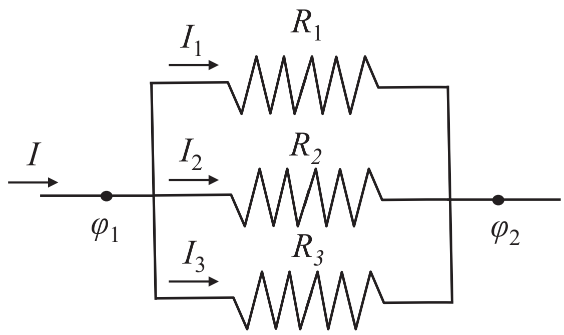

FIG. 3: Connection in parallel.

$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{I}{V}, \tag{4}$$

Thus, the inverse of the total resistance of the circuit in Fig. 3 is the sum of inverses of all resistances.

When resistors are connected in parallel, the smaller the resistance, the larger the current through this resistance.

More often you have a situation where resistances are connected both in series and par-

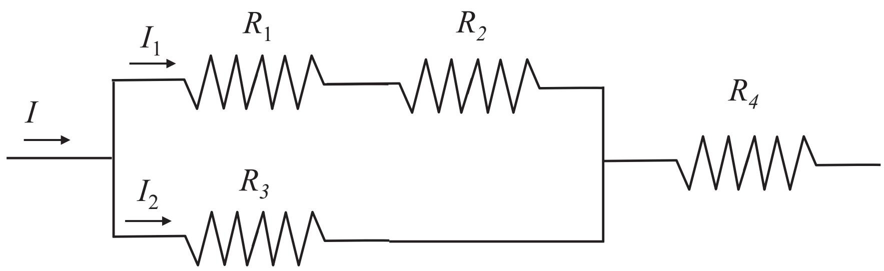

FIG. 4: Example circuit.

allel, e.g. see Fig. 4. It is important to be able to analyze circuits like this because the resistances can represent internal resistances of your measuring devices, such as voltmeters and ammeters. Taking into account internal resistances of your measuring devices is very important to obtain correct results from your measurements. Typically, the commercial voltmeters and ammeters have internal resistances of 10 MOhm and 0.5 Ohm, respectively. But it might vary for different devices.

A. Exercise

As an exercise, consider two circuits in Fig. 5. The internal resistances of voltmeter and ammeter are R_V and R_A, respectively.

(1) Which one of the two circuits would you use to measure resistance $R >> R_V$?

(2) Which one of the two circuits would you use to measure resistance $R << R_A$?

(3) Which one of the two circuits would you use to measure resistance $R_A << R << R_V$?

(4) Which one of the two circuits would you use to measure resistance $R \approx R_A$?

(5) Which one of the two circuits would you use to measure resistance $R \approx R_V$?

(6) Can you find a way to improve the measuring circuits in Fig. 5?

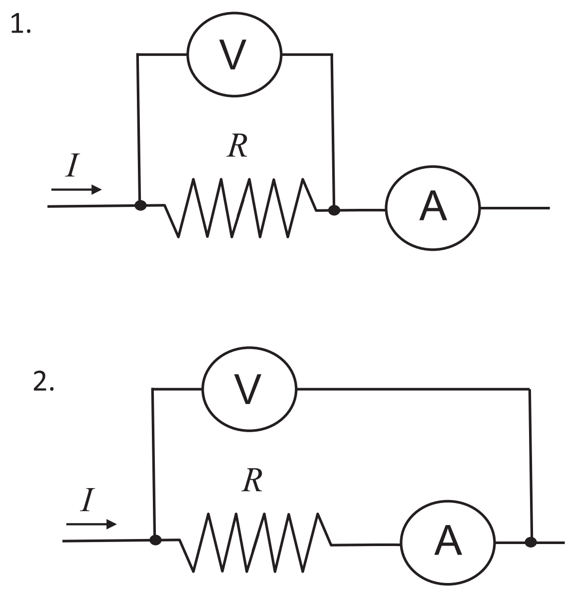

FIG. 5: Which circuit is better?