Experiment I: Electromotive force and internal resistance

Experiment Aim: Students will describe the magnitude of resistance and define the EMF (electromotive force) of a cell.

Experimental tools and materials: Ampere meter, voltmeter, resistances, cell.

BASIC PRINCIPLES:

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.

The ratio of the voltage applied across a resistor's terminals to the intensity of current in the circuit is called its resistance, and this can be assumed to be a constant (independent of the voltage) for ordinary resistors working within their ratings.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. When specifying that resistance in an electronic design, the required precision of the resistance may require attention to the manufacturing tolerance of the chosen resistor, according to its specific application. The temperature coefficient of the resistance may also be of concern in some precision applications. Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require heat sinks. In a high-voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

Practical resistors have a series inductance and a small parallel capacitance; these specifications can be important in high-frequency applications. In a low-noise amplifier or pre-amp, the noise characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor. They are not normally specified individually for a particular family of resistors manufactured using a particular technology. A family of
discrete resistors is also characterized according to its form factor, that is, the size of the device and the position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

**Color Codes**

There are ten internationally recognized standard colours used for identifying the values of a range of electronic components. Each is assigned a numerical value between 0 (zero) and 9 (nine) in the following order; black, brown, red, orange, yellow, green, blue, purple, grey, white.

Because these are most commonly used for identifying resistor values, this range of colours is often referred to as the "resistor colour codes".

Two other colours are also widely used; gold and silver, commonly as tolerance markings on resistors (along with certain other colours), but they also double up as division factor markings for resistances below 10 Ohms. Their assigned tolerance values are ±5% for gold and ±10% for silver. As division factors their values are ÷10 and ÷100 respectively.

The figure below shows a four colour banded resistor, together with a conversion chart to enable you to calculate the value of any of this type. All of the colours must be converted to their assigned values in order to calculate the resistance, and the result is always produced in Ohms.
Voltage

Voltage is electric potential expressed in volts. Similarly, potential difference expressed in volts is often called voltage difference or often referred to as voltage across two points or across an electrical component. The terms electric potential, potential, and potential difference are terms more often used by physicists. Since these quantities are almost always expressed in volts (or some related unit such as millivolts), engineers, electricians, hobbyists, and common people usually use the term voltage instead of potential. Furthermore, in practical applications, electrical force, electric field, and electrical potential energy of charged particles are not discussed nearly as often as voltage, power, and energy in a macroscopic sense.

Current

Electric current, often called just current, is the movement of charge in a conductor (such as a wire) or into, out of, or through an electrical component. Current is quantified as a rate of positive charge movement past a certain point or through a cross-sectional area. Simply put, current is quantified as positive charge per unit time. However, since current is a vector quantity, the direction in which the current flows is still important. Current flow in a given direction can be positive or negative; the negative sign means that positive charges move opposite of the given direction. The quantity of current at a certain point is typically symbolized by a capital or small letter I with a designation which direction the current I is moving. The SI unit of current is the ampere (A), one of the fundamental units of physics. See ampere for the definition of ampere. Sometimes, ampere is informally abbreviated to amp. The definition of a coulomb (C), the SI unit of charge, is based on an ampere. A coulomb is the amount of positive charge passing a point when a constant one ampere current flows by the point for one second. The second is the SI unit of time. In other words, a coulomb equals an ampere-second (A·s). An ampere is a coulomb per second (C/s).

Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship:

$$R = \frac{V}{I}$$

where I is the current through the conductor in units of amperes, V is the potential difference measured across the conductor in units of volts, and R is the resistance of the
conductor in units of ohms. More specifically, Ohm’s law states that the R in this relation is constant, independent of the current.

EXPERIMENT PROCEDURE

- Set up the electric circuit in the Figure 1. Connecting the various resistance between points A and B and read the ampermeter the current intensity for each resistance (R1, R2, R3). Record the table.

- Plot a graph of V against I. This is the current-voltage characteristics of the cell. The characteristics is shown as straight line in Figure 2.

To derive the equation relating EMF, terminal PD, current and internal resistance use Kirchhoff’s 2nd Law. As charge goes around the circuit the sum of EMFs must equal the sum of voltage drops leading to:

\[ E = IR + Ir \]

The terminal voltage is equal to \( IR \) so this can be rearranged to give:

\[ V = E - Ir \]

and interpreted as terminal voltage = EMF – ‘lost volts’.

**NOTE:** Use different resistors and record I values and calculate V values. Don’t leave the circuit connected for long when the resistance is low (current high) because this will run the cell down quickly. Plot a graph of V against I. E is the intercept on the V axis. The gradient is \(-r\).
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<th>R (ohm)</th>
<th>I (Ampere)</th>
<th>V (Volt)</th>
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