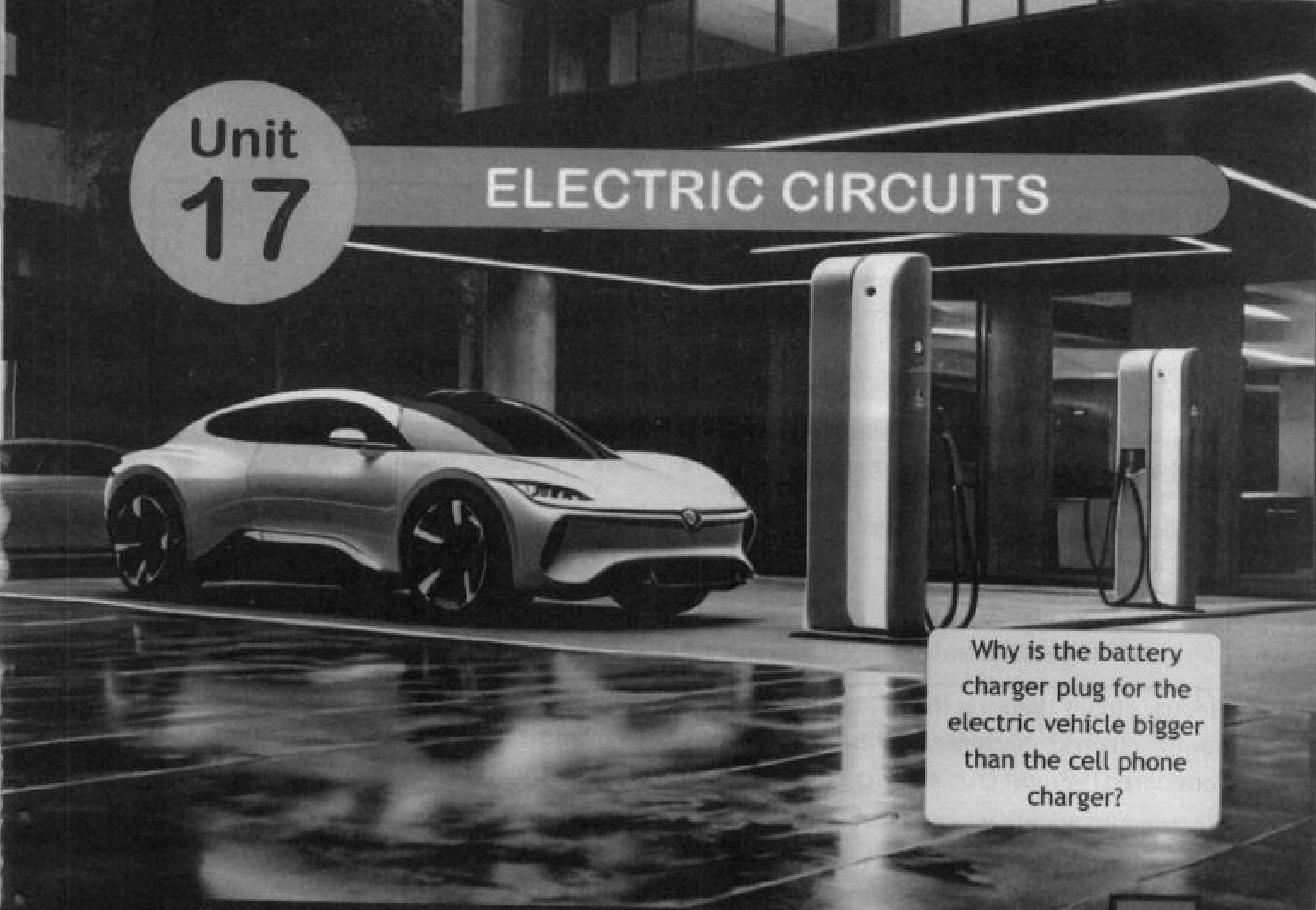
Unit 17

# ELECTRIC CIRCUITS



Why is the battery charger plug for the electric vehicle bigger than the cell phone charger?

## STUDENT LEARNING OUTCOMES

The students will:

- ✓ [SLO: P-10-E-30] Calculate the total e.m.f. where several sources are arranged in series.
- ✓ [SLO: P-10-E-31] State that the e.m.f of identical sources connected in parallel is equal to the e.m.f. of one of the sources.
- ✓ [SLO: P-10-E-37] Draw circuit diagrams.
- ✓ [SLO: P-10-E-38] Use common rules regarding current and voltage distribution in circuits to solve problems.
- ✓ [SLO: P-10-E-39] Calculate the combined resistance of two or more resistors in series.
- ✓ [SLO: P-10-E-40] Calculate the combined resistance of two resistors in parallel.
- ✓ [SLO: P-10-E-41] Calculate current, voltage and resistance in parts of a circuit or in the whole circuit.
- ✓ [SLO: P-10-E-42] Describe the action of negative temperature coefficient (NTC) thermistors and light-dependent resistors.
- ✓ [SLO: P-10-E-43] Analyze the function of variable potential dividers in circuits.
- ✓ [SLO: P-10-E-44] Justify and illustrate the use of color codes for resistors.
- ✓ [SLO: P-10-E-48] State common uses of electricity.
- ✓ [SLO: P-10-E-49] Justify the advantages of connecting lamps in parallel in a lighting circuit.
- ✓ [SLO: P-10-E-50] Use the equation, power = current × voltage P = IV to solve simple problems.
- ✓ [SLO: P-10-E-51] Use the equation energy = current × voltage × time E = IVt to solve simple problems.

- ✓ [SLO: P-10-E-52] Define the kilowatt-hour (kWh).
- ✓ [SLO: P-10-E-53] Explain the need to choose components with suitable power ratings.
- ✓ [SLO: P-10-E-54] Calculate the cost of using electrical appliances where energy unit is kWh.
- ✓ [SLO: P-10-E-55] State common electric hazards that may be caused from malpractice and lack of maintenance.
- ✓ [SLO: P-10-E-56] Explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings.
- ✓ [SLO: P-10-E-57] Explain what happens when a live wire touches a metal case that is earthed.
- ✓ [SLO: P-10-E-58] Explain why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed.
- ✓ [SLO: P-10-E-59] state that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire.
- ✓ [SLO: P-10-E-60] Explain why fuses and circuit breakers are connected into the live wire for the circuit to be switched off safely.
- ✓ [SLO: P-10-E-61] Explain why domestic supplies are connected in parallel.
- ✓ [SLO: P-10-E-62] Explain the damage that electric shock could do to a human being.

Electric circuit theory is the foundation for various branches of electrical engineering, including power, electric machines, control, electronics, communications, and instrumentation. It is considered the most crucial course for students studying electrical engineering.

Electric circuits play a crucial role in various devices such as radios, TVs, cell phones, power distribution systems, computers, and even the nervous systems of animals. There are different types of electric circuits that serve specific purposes, from illuminating a room to powering the high-speed trains. In this chapter, we delve into the fascinating world of electric circuits and explore their practical applications. As we embark on our circuit analysis journey, we will heavily rely on the power of circuit diagrams to unravel the mysteries of electricity.

## 17.1 CIRCUIT ELEMENTS AND DIAGRAMS

An electric circuit is an interconnection of electrical elements. Electric circuits are formed by connecting electrical components (elements) in a specific way.

A basic circuit, like the one shown in figure 17.1, typically includes conductors (often wires), a power source (like a battery), a Load (for instance a lamp), and a switch to turn the circuit on and off. This type of circuit can be used independently for various purposes like a torch light or a search light etc. The key thing to remember is that a circuit creates a closed loop, starting and ending at the same point.

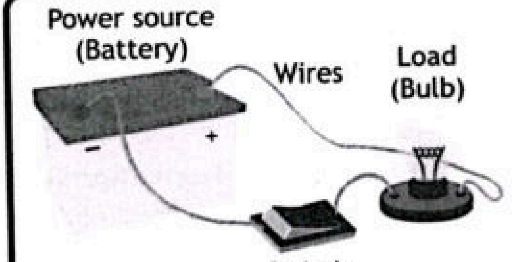
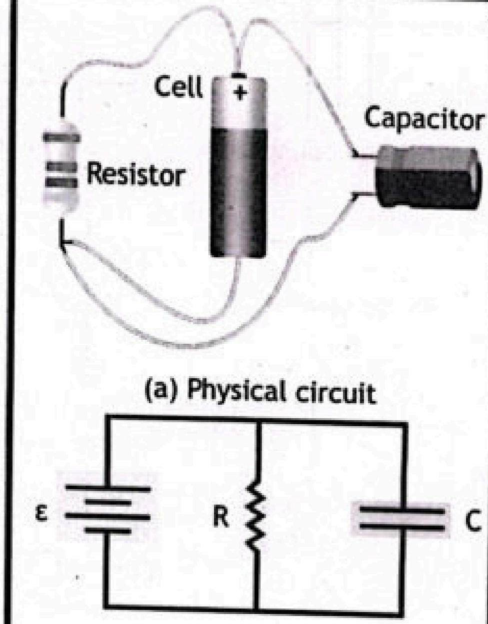



FIGURE 17.1 Simple Circuit

While bare copper wire can be used as a conductor for demonstration purposes, insulated wires are generally used for safety reasons.

Electric circuits consist of two types of elements: active elements and passive elements. Active elements can supply or generate energy (e.g., batteries, generators), while passive elements cannot generate energy; instead, they absorb, store, or dissipate energy (e.g., resistors, capacitors, inductors).

A circuit diagram is a simplified map showing how various components are interconnected and helps in understanding the flow of current. In a physical circuit, as shown in figure 17.2(a), components are connected with electrical wires, which are represented as straight lines in a circuit diagram, as shown in figure 17.2(b). Using symbols in a circuit diagram helps to recognize electric components and the flow of electricity. Such diagrams provide a fundamental understanding of electrical systems and the relationships between voltage, current, and resistance.



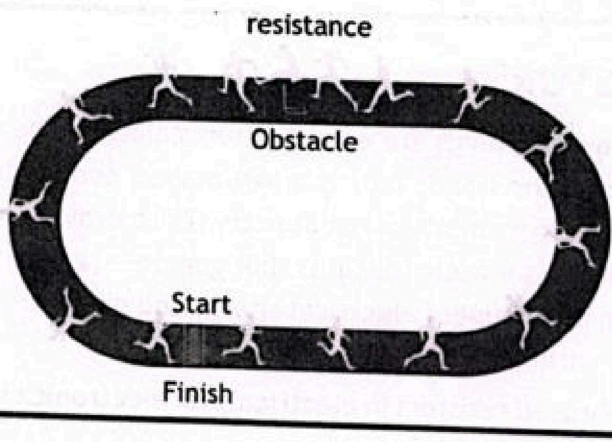
(b) Circuit diagram

FIGURE 17.2 Circuits Through Diagrams

Figure 17.3 shows the symbols used to represent different electric and electronic components that are used in a circuit diagram.

**SCIENCE TIDBITS**

Electricity loves to travel in closed loops called circuits! Imagine it like a race track for electrons—these tiny particles zoom around the circuit but must start and end at the same point. If there's a break in the track (an open circuit), the electrons come to a halt, and nothing happens. But if the path is complete, they speed along, powering lights, gadgets, and so much more!



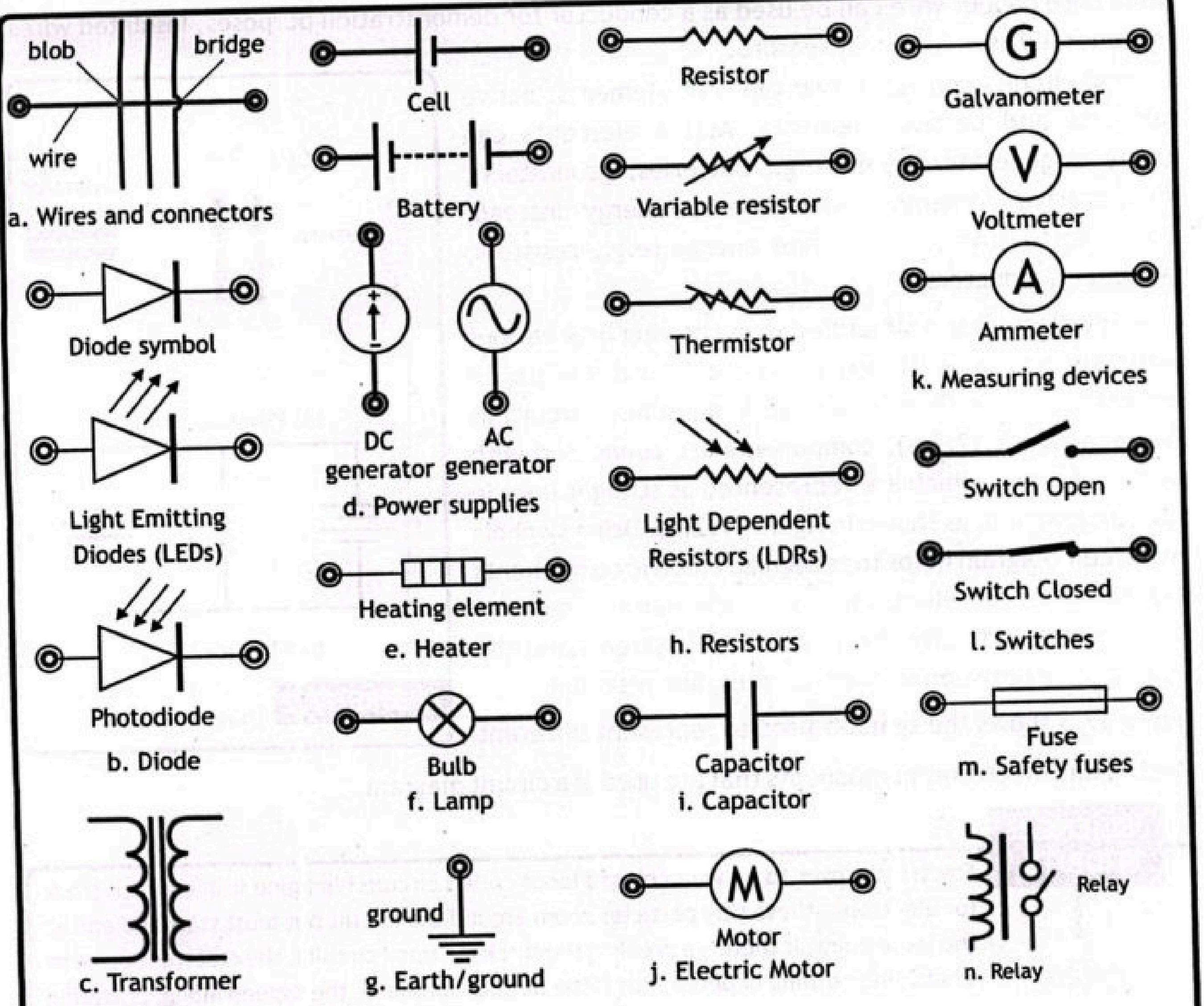



FIGURE 17.3 Circuit symbols for various devices

## 17.2 RESISTORS

Tiny components in electronics are essential for managing the flow of electricity. Among these components, the resistor stands out as a key player, controlling the current in a circuit. The component of an electric circuit whose function is to provide a specified value of resistance is called a resistor. Unlike some components that generate power, resistors are considered passive. They consume a small amount of electrical energy and dissipate it as heat, thereby regulating the overall power flow within the circuit.

The most commonly used resistors in electrical and electronic circuits are carbon resistors. Since a carbon resistor is quite small, it is more convenient to use colour code indicating the resistance value than to imprint the numerical value on the case. Carbon resistors consists of a ceramic core, on which a thin layer of crystalline carbon is deposited as shown in figure 17.4.

Table 17.1 RESISTOR COLOUR CODES

| Color | Number | Multiplier | Tolerance |
|---|---|---|---|
| Black | 0 | $10^0$ | |
| Brown | 1 | $10^1$ | |
| Red | 2 | $10^2$ | |
| Orange | 3 | $10^3$ | |
| Yellow | 4 | $10^4$ | |
| Gree | 5 | $10^5$ | |
| Blue | 6 | $10^6$ | |
| Violet | 7 | $10^7$ | |
| Gray | 8 | $10^8$ | |
| White | 9 | $10^9$ | |
| Silver | | $10^{-1}$ | ± 05 % |
| Gold | | $10^{-2}$ | ± 10 % |
| Colourless | | | ± 20 % |

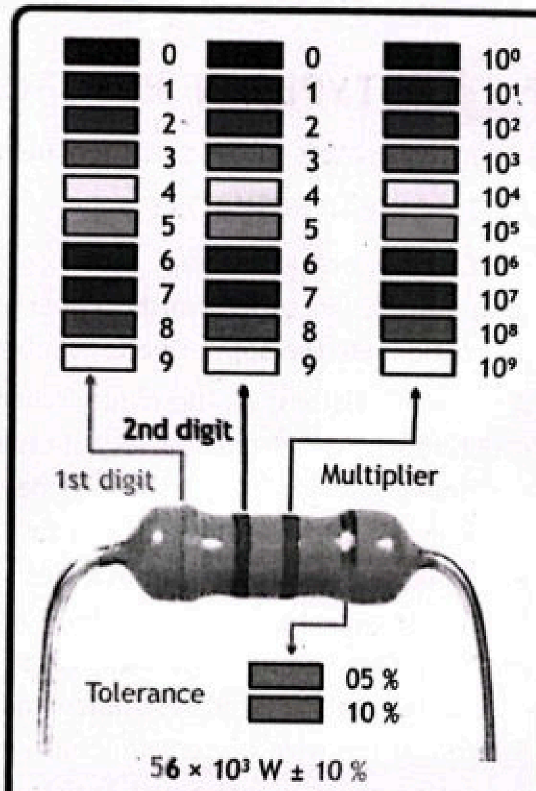
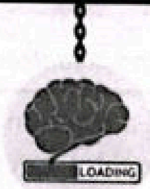


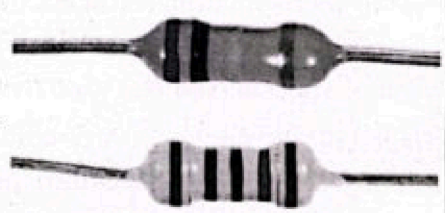
FIGURE 17.4 Carbon Resistor

These resistors are cost-effective, reliable, and small in size. Color bands are utilized to represent the resistance value based on the guidelines provided in Table 17.1. Usually three color bands are employed to signify the resistance values: the first two bands represent the significant figures of resistances, the third band indicates the decimal multiplier following them. The fourth band, either silver or gold, indicates the tolerance of the resistor. It must be noted that if there is

**SCIENCE TIDBITS**




While reading the colour code, hold the resistor with colour bands to your left. Resistors never start with a metallic band on the left. In order to remember the colour code, the following mantra may be helpful.



**BB ROY GBVGW**

no fourth band, the tolerance is 20 %.

For the resistor shown in Figure 17.5, the first digit is 5 (for green), the second digit is 6 (for blue), decimal multiplier is 3 (for orange) written as $10^3$ and tolerance = 5% (gold). The value of resistance is $56 \times 10^3$ or 56 kΩ with the tolerance value 5 % collectively written as $56 \times 10^3 \pm 5\%$.

## 17.3 TYPES OF RESISTORS

Normally resistors can be classified into two types namely linear resistor and non-linear resistor.

### 17.3.1 LINEAR RESISTORS

Linear resistors are resistors whose values change as a function of applied voltage and temperature. In other words, linear resistors are resistors whose current value is precisely proportional to the applied voltage (obey Ohm's Law). There are two types of linear resistors.

**A. Fixed Resistors:** As the name indicates fixed resistors have a single resistance value. Fixed resistors are made from a variety of resistor materials. The most common material used to make a resistor is carbon. A fixed resistor may be readily attached to the circuit and can handle high voltages. However, they are, less stable, which means their temperature coefficient is quite high.

**B. Variable Resistors:** Variable resistors have the general characteristic of allowing the resistance value to be adjusted. Usually a mechanical movement is used to modify the resistance. High stability and high accuracy resistors are always wire wound. As the resistance of wire of certain length has fixed resistance and increasing the length of the wire, increases resistance. Therefore the wire of certain length of known resistance is wound around and enclosed in an insulating cover to make such resistors. These resistors can also be made variable by putting a sliding contact, which can vary the length of the wire and thus resistance as shown in figure 17.5.

Generally nickel and chromium are used as wire material because of their low temperature coefficient of resistance. They are called rheostats when they are used as a variable resistance to regulate the current in a circuit. They are termed as potentiometers when they are used as a variable voltage divider. A potential divider is a circuit that divides a voltage into two or more smaller voltages. Using potential divider, we can obtain a variable potential difference from a fixed voltage applied. **'A circuit that produces an output voltage ($V_{out}$) that is a fraction of its input voltage ($V_{in}$) is called potential divider'.** It is a simple and fundamental circuit in electronics used to generate a voltage that is a fraction of its input voltage.

FIGURE 17.5 *Variable resistors (Rheostat and potentiometer)*

When a fixed voltage 'V' is applied across the ends of a wire wound variable resistor, and 'R' is the total resistance of wire AB, as shown in figure 17.6, then by Ohm's Law, the current 'I' is:

$$I = \frac{V}{R} \quad \boxed{1}$$

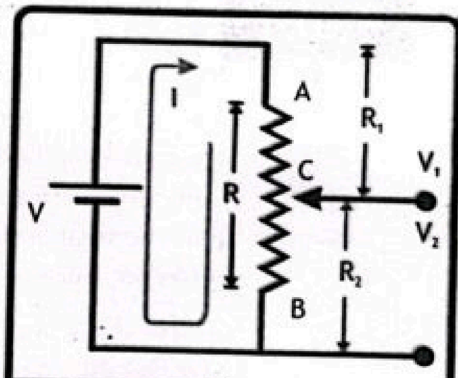


FIGURE 17.6 Potential divider

Since slider contact 'C' can slide over resistance 'R'. If '$R_2$' is the resistance of the portion of wire between the contact 'B' and 'C', then the potential difference '$V_2$' is given as:

$$V_2 = IR_2 \quad \boxed{2}$$

similarly, $V_1 = IR_1 \quad \boxed{3}$

Dividing equation 3 by equation 2, we get: $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ — 17.1

putting equation 1 in equation 2, we get: $V_2 = \frac{R_2}{R} V$ — 17.2

Thus, the potential difference '$V_2$' is some fraction of the total potential applied depending upon the position of the sliding contact. By moving sliding contact the potential difference can be varied from zero to 'V'.

Since '$V_2$' is the output voltage '$V_{out}$' and V is the input voltage '$V_{in}$' and resistance $R = R_1 + R_2$, therefore equation '17.2' can also be written as:

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

As a special case if $R_1 = R_2 = r$, then: $V_{out} = \frac{r}{r+r} V_{in}$ or $V_{out} = \frac{r}{2r} V_{in}$

Therefore, $V_{out} = \frac{1}{2} V_{in}$

This means that the input voltage is split into two equal halves at the output.

Potential dividers are commonly used in electronics to adjust the level of a voltage signal or to measure voltage accurately. It is used in the volume control knob of music systems. Sensory circuits using light-dependent resistors and thermistors also use potential dividers.

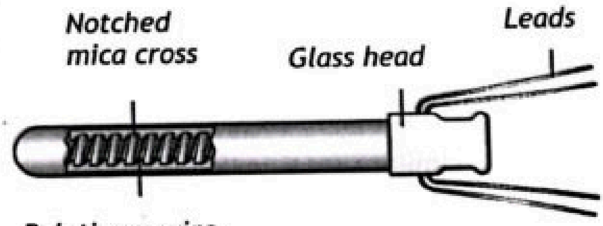
### 17.3.2 NON-LINEAR RESISTORS

In non-linear resistors the resistance value fluctuates in response to temperature, light, or voltage. Theses resistors are further divided as thermistors, varistors and photo resistors.

**A. Thermistor:** *A thermistor is a type of resistor whose resistance varies significantly with temperature.*

**SCIENCE TIDBITS**

**Resistance thermometers**, also called Resistance Temperature Detectors (RTDs), are sensors used to measure temperature by correlating the resistance of the RTD elc ..nt with temperature. Most RTD elements consist of a length of fine coiled wire, wrapped around a ceramic or glass core. The RTD element is made from a pure material such as Platinum, Nickel, Copper that has a predictable change in resistance as the temperature changes; it is this predictable change that is used to determine temperature.




Platinum is the best metal for RTDs because it follows a very linear resistance-temperature relationship and it follows the R vs T relationship in a highly repeatable manner over a wide temperature range. The unique properties of platinum make it the material of choice for temperature standards with the range from - 185 °C to 630 °C.

Thermistor (figure 17.7) is short for thermal-resistor, device which have heat sensitive resistance, thus the temperature coefficient of thermistor is very high. The material used in a thermistor is generally a semiconductor ceramic or polymer.


Circuit symbol

FIGURE 17.7

*Thermistor and its circuit symbol*

Thermistors are of two types;

- **Positive Temperature Coefficient (PTC)** thermistors increases its resistance with the increase of temperature and
- **Negative Temperature Coefficient (NTC)** thermistors decreases its resistance with the increase of temperature.

Thermistors of different sizes and shapes are formed according to the need of the industry. Their sensitivity to change in temperature enables them to perform many functions as given below.

a. **Inrush current limiter:** An inrush current limiter or input surge current, is the peak current drawn by an electrical device when powered on. For example, incandescent bulbs have high inrush currents until their filaments heat up. NTC thermistors can limit inrush current in power supply circuits by initially exhibiting high resistance, which restricts large currents during startup.

b. **Over heating Alarm:** NTC thermistors can trigger alarms when the temperature of motor, transformer, or generator windings rises. They maintain high resistance at lower temperatures, allowing minimal current flow. As temperature increases, resistance drops, allowing more current to flow to an alarm system. This principle is also applicable in fire alarms and thermostats.

c. **Temperature Measurement:** Thermistors provide precise temperature measurements due to their high temperature coefficient. Their resistance changes with temperature, enabling effective detection and response to temperature variations.

**B. Varisters (VDR):** Varisters (figure 17.8) are voltage dependent Resistors (VDR) which are used to eliminate the high voltage transients. They are type of variable resistors used to protect circuits from destructive voltage spikes.

When voltage increases (due to lighting or line faults) across a connected sensitive device or system, then it reduces the level of voltage to a secure level i.e. it changes the level of voltages. Varistors are typically made from metal oxide materials, with zinc oxide (ZnO) being the most common. They consist of a ceramic body composed of zinc oxide grains, which are interspersed with other metal oxides such as bismuth, cobalt, and manganese. The grain boundaries act as the non-linear junctions that give the varistor its voltage-dependent characteristics.

FIGURE 17.8

*Varistor and its circuit symbol*

**C. Light Dependent Resistor (LDR):** Light Dependent Resistor (LDR), also known as Photo Resistor or photocell, is a light-sensitive device that changes resistance based on the intensity of light as shown in figure 17.9. In low light conditions, LDRs have high resistance, which decreases as light intensity increases.

They are commonly used in light-sensing applications, with materials like cadmium sulfide and lead sulfide used to make them. The surface of the LDR is designed to be exposed to light, with a serpentine pattern to increase light exposure. LDRs sense light levels and adjust resistance accordingly, making them useful in various applications like automatic lighting control, photography, and security systems.

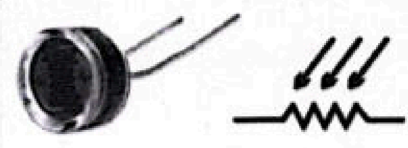


FIGURE 17.9

*Photo-resistor and its circuit symbol*

Light Dependent Resistors (LDRs) are versatile and cost-effective components used to detect and respond to changes in light levels. Their simplicity and wide range of applications make them valuable in many fields.

## 17.4 COMBINATION OF RESISTORS

For any combination of resistors that obey Ohm's law, we can always find a single resistor that could replace the combination and result in the same total current and potential difference. The resistance of this single resistor is called the equivalent resistance of the combination. For series and parallel combinations, we can derive general equations for the equivalent resistance.

### 17.4.1 RESISTORS IN SERIES

In a series circuit, there is only one path for the charges to follow, so the same current flows in each device. In such a circuit, the voltage is divided among the devices: the voltage on the first device plus the voltage on the second device, and so on, equals the voltage of the power supply. For example, if three lightbulbs with the same resistance are connected in series to a 12-volt battery, the voltage on each bulb is 4 volts. If the bulbs had different resistances, each one's "share" of the voltage would be proportional to its resistance. If the resistors are in series, as shown in figure 17.10, the current I must be the same in all of them.

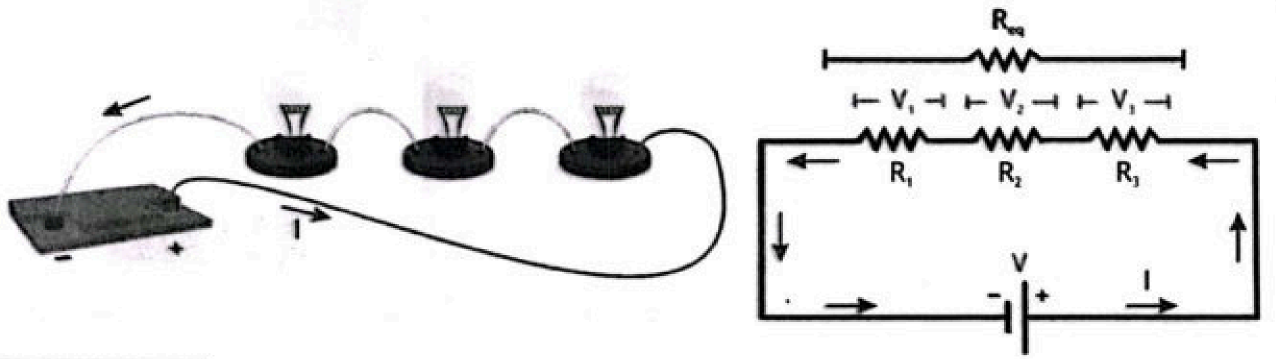



FIGURE 17.10 Series combination of resistors.

If '*V*' is the combined potential difference, by applying Ohm's law (*V* = *IR*) to each resistor, we have:

$$V_1 = IR_1, \qquad V_2 = IR_2 \qquad \text{and} \qquad V_3 = IR_3$$

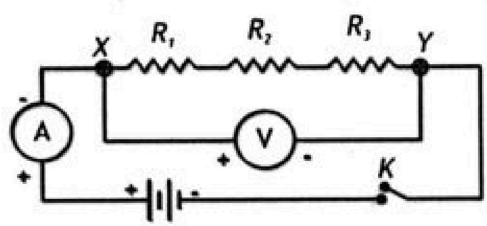
The potential difference V is the sum of individual potential difference across each resistor, Hence:

$$V = I(R_1 + R_2 + R_3) \qquad \text{or} \qquad \frac{V}{I} = R_1 + R_2 + R_3$$

Since the equivalent resistance '$R_{eq}$', is given as: $R_{eq} = \dfrac{V}{I}$

**MINI LAB**

Join three resistors of different values in series. Connect them with a battery, an ammeter and a plug key, as shown in Fig. 11.6. You may use the resistors of values like 1 Ω, 2 Ω, 3 Ω etc., and a battery of 6 V for performing this activity. Plug the key. Note the ammeter reading.




Change the position of ammeter to anywhere in between the resistors. Note the ammeter reading each time. Do you find any change in the value of current through the ammeter?

Comparing equation 1 and equation 2, we get: $R_{eq} = R_1 + R_2 + R_3$ — 17.3

Hence, the equivalent resistance of any number of resistors (n) in series combination equals the sum of their individual resistances.

$$R_{eq} = R_1 + R_2 + R_3 + R_4 + \cdots\cdots + R_n \quad \text{— 17.4}$$

The equivalent resistance is always greater than any individual resistance.

## Example 17.1

Three resistors $R_1 = 10\,\Omega$, $R_2 = 20\,\Omega$ and $R_3 = 30\,\Omega$ are connected in series across a 20 V battery. Find equivalent resistance and voltage drop across each resistor.

**GIVEN:**

Potential difference '$V$' = 20 V

Resistance '$R_1$' = 10 Ω

Resistance '$R_2$' = 20 Ω

Resistance '$R_3$' = 30 Ω

**REQUIRED:**

Equivalent resistance '$R_{eq}$' = ?

Voltage drop '$V_1$' = ?

Voltage drop '$V_2$' = ?

Voltage drop '$V_3$' = ?

**SOLUTION:**

For series combination the equivalent resistance is given by: $R_{eq} = R_1 + R_2 + R_3$

putting values $R_{eq} = 10\Omega + 20\Omega + 30\Omega$ Therefore $\boxed{R_{eq} = 60\ \Omega}$ — ANSWER

For series combination of resistors, current remains same through all resistors, given by:

$$I_1 = I_2 = I_3 = \frac{V}{R_{eq}} \qquad \text{putting values, } I = \frac{20.0V}{60\Omega}$$

Therefore $I = 0.333A$

In series combination of resistors, the voltage drop splits among resistors.

Voltage drop across '$R_1$' is given by: $V_1 = IR_1$ putting values, $V_1 = 0.333\,A \times 10\Omega$

Therefore $\boxed{V_1 = 3.33V}$ — ANSWER

Voltage drop across '$R_2$' is given by: $V_2 = IR_2$ putting values, $V_2 = 0.333\,A \times 20\Omega$

Therefore $\boxed{V_2 = 6.67V}$ — ANSWER

Voltage drop across '$R_3$' is given by: $V_3 = IR_3$ putting values, $V_3 = 0.333\,A \times 30\Omega$

Therefore $\boxed{V_3 = 9.99V}$ — ANSWER

it is worth noting that $V_1 + V_2 + V_3 = 3.33 + 6.67 + 9.99 = 20\text{ V} = V$, that is voltage of the battery attached.

### 17.4.2 RESISTORS IN PARALLEL

In a parallel circuit, the current through the power supply is "shared" among the devices while each has the same voltage. The current flowing in the first device plus the current in the second device, and so on, equals the current output by the power supply. There is more than one path for the charges to follow, in this case, three. If one of the devices burns out or is removed, the others still function. The light-bulbs in multiple-bulb light fixtures are in parallel so that if one bulb

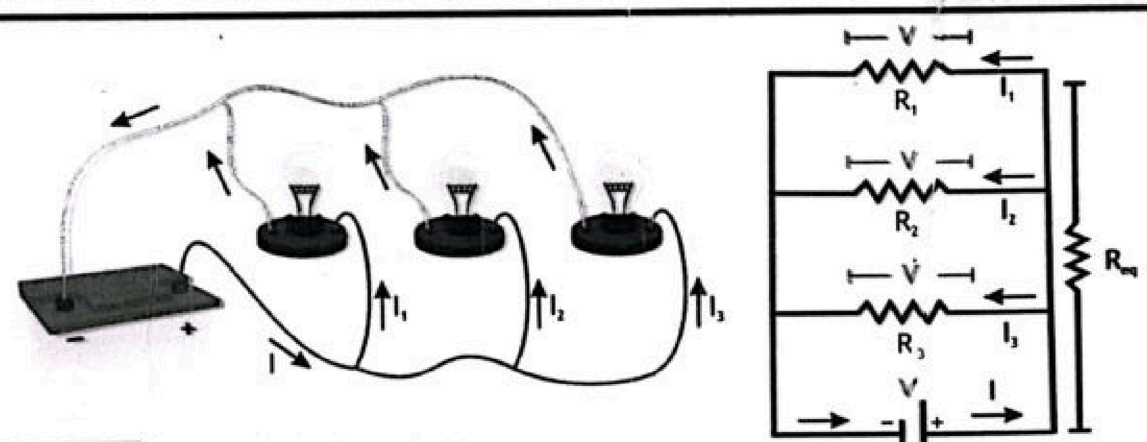



FIGURE 17.11 Parallel combination of resistors

burns out, the others remain lit. For resistors in parallel, as shown in figure 17.11, the potential difference between the terminals of each resistor must be the same and equal to V.

Let's call the currents in the three resistors '$I_1$', '$I_2$' and '$I_3$', then By Ohm's law, we have:

$$I_1 = \frac{V}{R_1}, \qquad I_2 = \frac{V}{R_2} \qquad \text{and} \qquad I_3 = \frac{V}{R_3}$$

Charge is neither accumulating at, nor draining out, thus, the total current '$I$' must equal the sum of the three currents in the resistors:

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) \qquad \text{or} \qquad \frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

But by definition, the equivalent resistance, is: $\frac{I}{V} = \frac{1}{R_{eq}}$

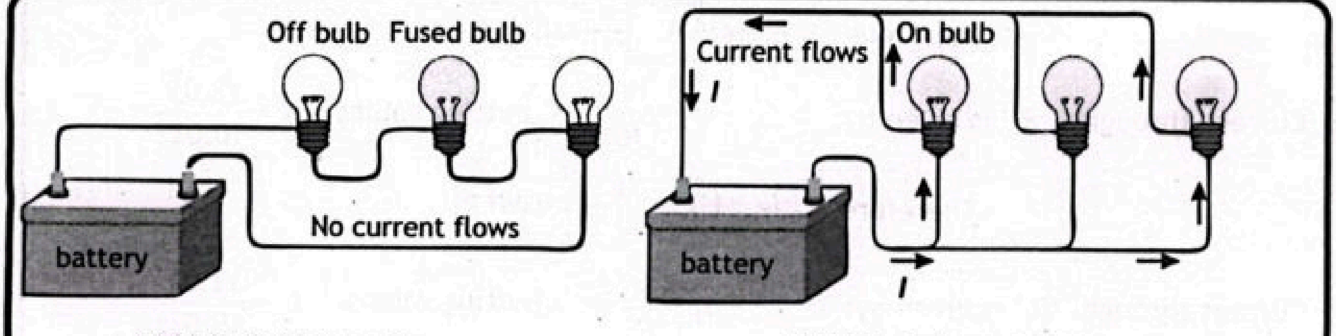
Therefore $$\frac{I}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \boxed{17.5}$$

For any number of resistors (n) in parallel, the reciprocal of the equivalent resistance equals the sum of the reciprocals of their individual resistances:

$$\frac{I}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \cdots\cdots + \frac{1}{R_n} \qquad \boxed{17.6}$$

The equivalent resistance is always less than any individual resistance. Household appliances are always connected in parallel so that even if one is switched off, the other devices could function properly.

The primary distinction between series and parallel connections lies in how they respond to component failure. In a series circuit, all components are connected along a single current pathway. If one element, such as a lamp fuse, fails, the entire circuit is interrupted, and all devices stop working (Figure 17.12 (a)). On the other hand, parallel circuits offer multiple independent paths for current to flow. Each device, like a lamp in your home, is directly connected to the power source. If one lamp fuse blows, the current simply redirects through the remaining branches, allowing the other lamps to continue shining (Figure 17.12 (b)). This redundancy makes parallel circuits ideal for powering multiple devices in homes and buildings. Even if one device malfunctions, the others remain operational.




(a) Light Bulbs in series

(b) Light Bulbs in Parallel

FIGURE 17.12 Series and parallel combination of light bulbs.

Additionally, parallel circuits provide individual control. You can turn off a single lamp without affecting the others, unlike in a series circuit where turning off one device disrupts the entire circuit. This independent control adds to the practicality and flexibility of parallel connections.

## Example 17.2

Three resistors $R_1 = 5.0\,\Omega$, $R_2 = 10.0\,\Omega$ and $R_3 = 15.0\,\Omega$ are connected in parallel across a 12.0 V battery. Find equivalent resistance and current passes through each resistor.

**GIVEN:**

Potential difference '$V$' = 12 V

Resistance '$R_1$' = 5.0 Ω

Resistance '$R_2$' = 10.0 Ω

Resistance '$R_3$' = 15.0 Ω

**REQUIRED:**

Equivalent resistance '$R_{eq}$' = ?

Current '$I_1$' = ?

Current '$I_2$' = ?

Current '$I_3$' = ?

**SOLUTION:**

For parallel combination, the equivalent resistance is given by: $\frac{I}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

putting values, $\frac{I}{R_{eq}} = \frac{1}{5.0\Omega} + \frac{1}{10.0\Omega} + \frac{1}{15.0\Omega} = \frac{11}{30.0\Omega}$

Therefore $\boxed{R_{eq} = 2.73\Omega}$ — ANSWER

For parallel combination of resistors, voltage drop remains same across all resistors, given by:

$$V_1 = V_2 = V_3 = 12.0V$$

Total current in the circuit is given by: $V_1 = IR_{eq}$ or $I = \frac{V}{R_{eq}} = \frac{12.0V}{2.73\Omega} = 4.4A$

In parallel combination of resistors, the current splits among resistors.

Current through '$R_1$' is given by: $I_1 = \frac{V}{R_1}$ putting values, $I_1 = \frac{12.0V}{5.0\Omega}$

Therefore $\boxed{I_1 = 2.4A}$ — ANSWER

Current through s '$R_2$' is given by: $I_2 = \frac{V}{R_2}$ putting values, $I_2 = \frac{12.0V}{10.0\Omega}$

Therefore $\boxed{I_2 = 1.2A}$ — ANSWER

Current through '$R_3$' is given by: $I_3 = \frac{V}{R_3}$ putting values, $I_3 = \frac{12.0V}{15.0\Omega}$

Therefore $\boxed{I_3 = 0.8A}$ — ANSWER

It is worth noting that $I_1 + I_2 + I_3 = 2.4\,A + 1.2\,A + 0.8\,A = 4.4\,A$, which is the total current flowing through the circuit.

## 17.5 COMBINATION OF EMF SOURCES

Combination of emf sources is referred to when two or more emf sources are connected in such a way that a combined effect of these sources is obtained. Normally, there are two possible combinations, series and parallel.

### 17.5.1 SERIES COMBINATION OF EMF SOURCES

When positive terminal of an emf source, like battery, is connected to negative terminal of another source and so on. Finally the negative terminal of the first emf source is connected to the positive terminal of the last source through other circuit elements like bulbs, fans etc. as shown in figure 17.13. Here four batteries are connected in series where the emf of all batteries are added and provide the resultant emf (6 V) to the external circuit.

Generally, for 'n' number of batteries connected, we can mathematically write:

$$\varepsilon_{net} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \cdots + \varepsilon_n \quad (17.7)$$

Series combination of emf sources is used when a higher voltage is required as compared to the voltage of available sources and no change in ampere-hour (Ah) values. If, for example, the above batteries are 1.5 V 2.5 Ah each. The equivalent rating when connected in series will be 6.0 V 2.5 Ah.

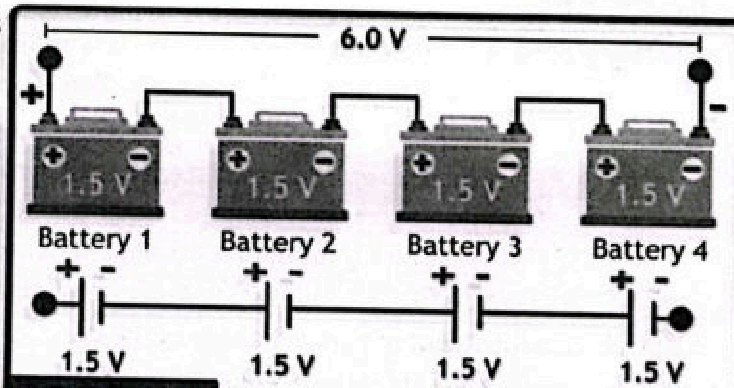



FIGURE 17.13 Series connection of batteries.

### 17.5.2 PARALLEL COMBINATION OF EMF SOURCES

In parallel combination of emf sources, the positive and negative terminals of all the sources are connected to each other respectively. Finally, the load is connected by taking one connection from positive terminal and one from negative terminal as shown in figure 17.14.

When identical sources (like 12 V in given figure) are connected in parallel, the equivalent emf is equal to the emf of one of the sources i.e. 12 V here. Generally, for 'n' number of batteries connected, we can mathematically write:

$$\varepsilon_{net} = \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \cdots = \varepsilon_n \quad (17.8)$$

Parallel combination of emf sources is used when a higher ampere-hour is required as compared to the available sources and no change in voltage values. If, for example, the above batteries are 12 V 2 Ah each, the equivalent rating when connected in parallel will be 12 V 6 Ah.

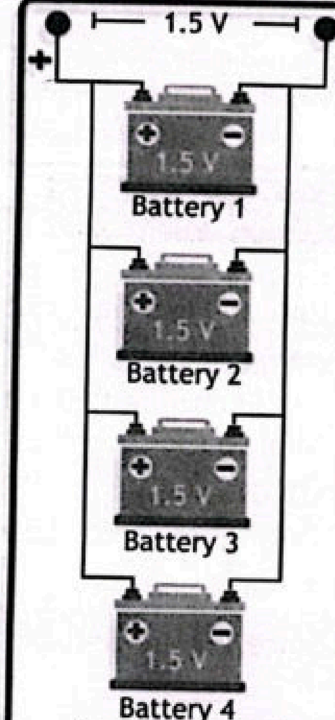
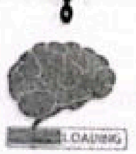



FIGURE 17.14 Parallel connection of batteries.

**SCIENCE TIDBITS**




When batteries are connected in series, their voltages add up, but if one battery is weaker, it can cause issues. The weaker battery may drain faster, which can limit the power of the entire system and reduce performance. It might also get overworked, leading to overheating or damage. Balancing batteries in series is important for safe and steady power output. To keep them balanced, we can use special circuits that monitor each battery's charge or occasionally charge each battery individually. Proper balancing ensures the system works efficiently and safely.

MINI LAB

**Materials:** Four lemons, copper wire (four copper strips), Four galvanized nails, Two alligator clips and a standard LED.

**Procedure:** In the first step, cut your copper wire into four 6-inch lengths. Strip about 1 inch of insulation from both ends of each wire. Roll and squeeze a lemon so that you break up the small juice packets inside it, but not enough to break the skin.

Figure 1

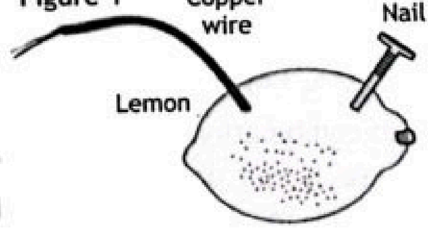
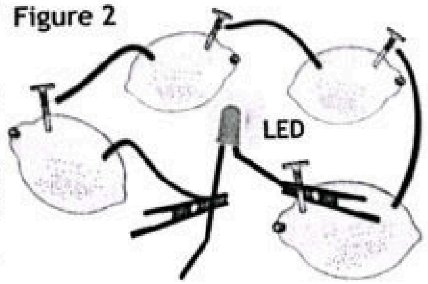



Figure 2




Use a nail to make one hole in one end, push a copper wire into that hole, and push the nail into the other end, as shown in figure 1. Repeat the process for the other lemons; each will become a separate battery. Connect the copper wire side of one lemon to the nail side of another lemon. Connect the long leg from the LED to the copper wire, and connect the short leg to the nail, as shown in figure 2.

## Example 17.3

A series combination consisting of 'n' number of identical cells. If each cell is of 0.4 V and the total emf in series combination is 12 V, find 'n'.

**GIVEN:**
emf of each cell '$\varepsilon$' = 0.4 V
Total emf in series '$\varepsilon_{net}$' = 12 V

**REQUIRED:**
Number of cells 'n' = ?

**SOLUTION:**
As in series combination the emfs of individual cells are added, so:

$$\varepsilon_{net} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \ldots + \varepsilon_n$$

Since, all the cells are identical, so $\varepsilon_{net} = n(\varepsilon)$ or $n = \frac{\varepsilon_{net}}{\varepsilon}$

putting values: $n = \frac{12V}{0.4V}$

Therefore $\boxed{n = 30}$ ANSWER

So, there are a total of 30 identical cells of emf 0.4 V that are arranged in series and give a total emf of 12 V.

## 17.6 ELECTRICITY AND ITS USES

Electricity is a versatile form of energy that serves numerous purposes in our daily lives. From providing illumination to powering electronic devices, its applications are vast and diverse

**A. Heating:** Electricity plays a crucial role in keeping us warm and cozy during colder months.

Electric heaters come in various forms, from portable space heaters to central heating systems in homes and buildings. These heaters work by converting electrical energy into heat, which is then distributed throughout the space to maintain a comfortable temperature. Similarly, electric stoves provide a convenient and efficient way to cook our meals by generating heat through electrical resistance in the stove's heating elements. Whether it's warming up a room or cooking a delicious meal, electricity ensures that we stay comfortable and well-fed, even in chilly weather.

**B. Lighting:** Electric lighting systems brighten up our surroundings, allowing us to see and navigate both indoors and outdoors, regardless of the time of day. In our homes, electric light bulbs illuminate our living spaces, providing ambiance and functionality for various activities such as reading, cooking, and socializing. Streetlights powered by electricity illuminate roads and pathways, enhancing safety and visibility for pedestrians and motorists during the night. Whether it's creating a warm and inviting atmosphere indoors or ensuring safety and security outdoors, electric lighting systems play a crucial role in our daily lives.

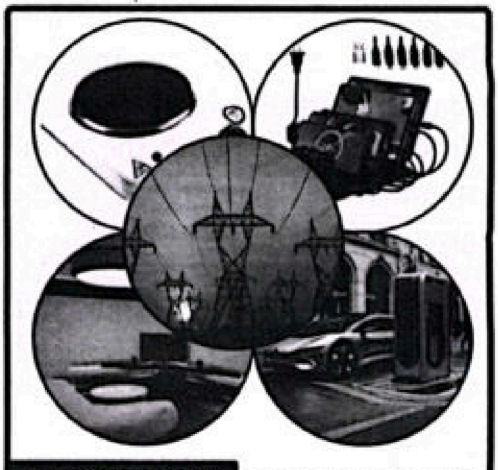


FIGURE 17.15 Uses of electricity

**D. Powering Motors:** Electric motors are the driving force behind a wide range of machinery, appliances, and transportation vehicles. From household appliances like washing machines and vacuum cleaners to industrial equipment such as conveyor belts and manufacturing machinery, electric motors provide the mechanical power needed to perform various tasks efficiently. In the automotive industry, electric motors power electric vehicles (EVs), offering a cleaner and more sustainable alternative to traditional internal combustion engines. Whether it's powering our everyday appliances or propelling us forward on our daily commutes, electric motors play a vital role in modern society.

**C. Battery Charging:** In today's digital age, portable electronic devices have become indispensable tools for communication, entertainment, and productivity. These devices, such as smartphones, laptops, and tablets, rely on rechargeable batteries to power their operations. Electricity powers the charging process, allowing us to replenish the energy stored in these batteries and keep our devices running smoothly. Whether we're at home, at work, or on the go, access to electricity for battery charging ensures that our devices remain functional and accessible whenever we need them.

**E. Powering Electronic Systems:** From the moment we wake up to the time we go to bed, we interact with numerous electronic devices powered by electricity. Computers enable us to work, communicate, and access information with ease. Televisions entertain us with a vast array of programs and content. Refrigerators keep our food fresh, while air conditioners maintain comfortable indoor temperatures. These electronic systems, along with countless others like smartphones, gaming consoles, and home automation devices, rely on electricity to function. By powering these electronic devices, electricity enhances our productivity, entertainment, and overall quality of life in the digital age.

## 17.7 ELECTRICAL ENERGY

When a voltage source e.g., a battery is connected to a device like bulb (or any other device), the source delivers some electrical energy to it. There will be a potential difference across both the ends of the device (a bulb is shown in the figure 17.16). This potential difference can be given from equation 14.2 as:

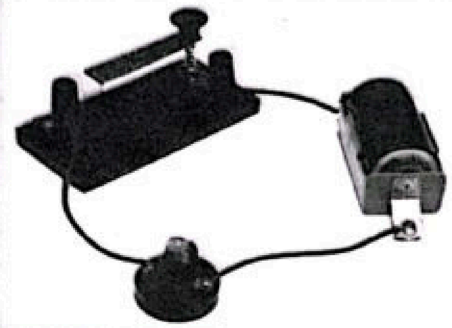


FIGURE 17.16 Electrical Energy

$$V = \frac{W}{q} = \frac{E}{q} \quad \text{or} \quad E = qV \quad \text{—} \boxed{1}$$

From the definition of electric current: $q = It$ —$\boxed{2}$

Putting equation 2 in equation 1: $E = It\,V$ —$\boxed{17.9}$

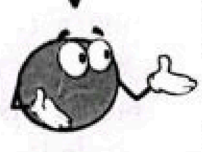
Equation 17.8 gives the equation for electrical energy consumed in a device. From Ohm's law '$V = IR$' therefore the electrical energy 'E' from equation 17.9 can also be written as:

$$E = I^2Rt \quad \text{—} \boxed{17.10}$$

From Ohm's law '$I = V/R$' therefore the electrical energy 'E' from equation 17.9 can also be written as:

$$E = \frac{V^2}{R}t \quad \text{—} \boxed{17.11}$$

**CAN YOU TELL?**



How we can use equation 7.8 for determining the unit of electrical energy as joule?

**UNIT OPENER?**

**Why is the battery charger plug for the electric vehicle bigger than the cell phone charger?**

The battery charger plug for an electric vehicle is larger than a cell phone charger due to power delivery and safety reasons. Electric cars require significantly more power to charge their larger batteries compared to phones. Electric vehicle chargers can deliver thousands of watts, ranging from 2.4 kW to 350 kW, while phone chargers typically deliver only 5W to 30W.

The larger size of the EV charger plug is necessary to handle the higher power safely, with thicker wires and larger connectors to accommodate the increased current flow. Additionally, EV chargers require extra safety features like overload protection and grounding to prevent overheating and electrical hazards, which take up more space in the plug design.

All the equations (17.9, 17.10 and 17.11) give relations for calculating electrical energy.

## Example 17.4

An electric iron working at a potential difference of 200 V draws 7 A of current. How much the electrical energy will it consume in 1 hour?

**GIVEN:**
Potential difference 'V' = 200 V
Current 'I' = 7 A
Time 't' = 1 hr = 60 × 60 s = 3600 s

**REQUIRED:**
Electrical energy 'E' =?

**SOLUTION:**
The electrical energy is given by: $E = ItV$

putting values, $E = (7\,A)\times(3600\,s)\times(200\,V) = 5{,}040{,}000\,J$

Therefore $\boxed{E = 5.04\times10^{6}\,J}$ ANSWER

Thus, the electric iron will consume 5.04 MJ of electrical energy in an hour.

## 17.8 ELECTRIC POWER

The rate at which electric work is done by the voltage source (i.e battery) in maintaining electric current in the electric circuit is called electric power of the circuit or The electrical energy consumed by a device per unit time s called electrical power. Mathematically:

$$P = \frac{E}{t} \quad \text{--- } \boxed{1}$$

As we know that electrical energy '$E = ItV$', putting in equation 1: $P = \frac{ItV}{t}$

Therefore $$P = IV \quad \text{--- } \boxed{17.12}$$

From Ohm's law '$V = IR$', putting in equation 17.12: $$P = I^2 R \quad \text{--- } \boxed{17.13}$$

Also from Ohm's law '$I = V/R$', putting in equation 17.12: $$P = \frac{V^2}{R} \quad \text{--- } \boxed{17.14}$$

All the three equations (17.11, 17.12 and 17.13) are equally valid for calculation of electric power. The SI units for electrical power is watt (W). A power of '$1\,W$' is said to be consumed in an electrical circuit if potential difference of '$1\,V$', causes a current of '$1\,A$' to flow through a circuit.

## Example 17.5

What is the power consumption of an electric toaster if its resistance is 19 Ω, and its operates on a household circuit with 200 V?

**GIVEN:**
Resistance 'R' = 19 Ω
Voltage 'V' = 200 V

**REQUIRED:**
Electric Power 'P' = ?

**SOLUTION:**
By Ohm's law, the current 'I', is: $I = \frac{V}{R}$ putting values $I = \frac{200\,V}{19\,\Omega}$ or $I = 10.5\,A$

The power 'P', can now be obtained by multiplying current and voltage, as: $P = IV$

putting values, $P = (10.5\,A) \times (200\,V)$ Therefore $P = 2100\,W$ ANSWER

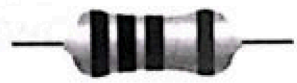
The power consumption of an electric toaster is 2100 W if its resistance is 19 Ω

## Example 17.6

The resistor has a value of 100 Ω and a power rating of ½ W. If the resistor is connected to a 10-V power supply, will it be damaged?

**GIVEN:**
Resistance 'R' = 100 Ω
Rated Power '$P_R$' = 0.5 W
Connected voltage 'V' = 10 V

**REQUIRED:**
Power dissipated 'P' = ?



**SOLUTION:**
We would calculate the amount of heat dissipated in resister by using formula for power dissipated in resistor.

$P = \frac{V^2}{R}$ putting values, $P = \frac{(10\,V)^2}{100\,\Omega}$

Therefore $P = 1\,W$ ANSWER

Because the resistor has a power rating of ½ W, and the amount of heat that will be dissipated is 1 W, the resistor will be damaged.

## Example 17.7

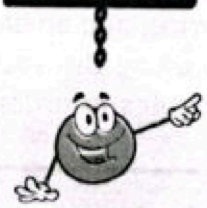
An Air Conditioner (of power 2200 W) is used for an average of 24 hours daily. How much electrical energy will it consume and what will be the cost of electricity for a month (30 days) if cost of electricity is Rs.25.0 / kWh?

**GIVEN:**
Electric power 'P' = 2200 W = 2.2 kW
Monthly Time 't' = 30 × 24 hours = 720 h
Tariff rate = PKR 25.0 /kWh

**REQUIRED:**
Energy consumed in kWh 'E' = ?
Cost of electricity 'C' = ?

**SOLUTION:**
The electric power is given by: $P = \frac{E}{t}$ or $E = P \times t$

**POINT TO PONDER**



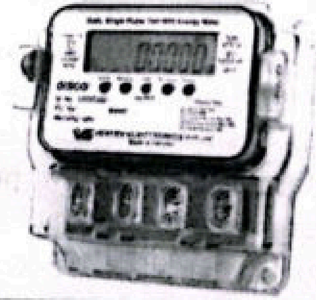
**Does the unit of electrical energy kilo-watt-hour (kWh) measure, electric energy or electric power?**

The unit kilowatt hour has a unit of power, which suggest that it might be unit of power. However, the unit kilowatt-hour (kWh), measures electric energy, not electric power.

Electric power is the rate at which electrical energy is transferred or consumed. It is measured in watts (W) or kilowatts (kW), where 1 kilowatt equals 1,000 watts.

Power is an instantaneous measurement, indicating how much energy is being used or generated at a specific moment in time. Electric Energy on the other hand is the total amount of electrical work done or energy consumed over a period of time. It is measured in kilowatt-hours (kWh) because electrical energy is consumed in homes and industry in large amounts for which joule is a small unit. Mathematically,

$$1 \text{ kW-hr} = 1000 \text{ W} \times 1\text{hr}$$
$$= 1000 \text{ J/s} \times 3600\text{s}$$
$$= 3.6 \times 10^6 \text{ J}$$



One kilowatt-hour represents the amount of energy consumed when a power of one kilowatt is used for one hour. For example, if a device rated at 500 watts (0.5 kW) operates for 2 hours, it will consume 1 kWh of energy (0.5 kW × 2 hours = 1 kWh).

putting values, $E = 2.2\,kW \times 720\,h$ Therefore $\boxed{E = 1584\,kWh}$ ANSWER

The total consumed energy is 1584 kWh (or 1584 commercial units), the cost of which can be calculated as:

$$Cost = E \times Tariff\ \ Rate = (1584\,kWh) \times (PKR.25.0)$$
$$\text{or} \quad Cost = 39{,}600\,rupees$$

The cost of electricity for an AC for the whole month is PKR. 39,600.

## 17.9 HOUSEHOLD CIRCUITS AND ELECTRIC SAFETY

Even though household circuits utilize alternating current, which hasn't been discussed yet, their functioning (along with numerous practical applications) can be comprehended by applying the same circuit principles just studied. In household wiring, the electrical elements should be connected in parallel. For example, when a bulb in a lamp in your kitchen burns out, other appliances on the same circuit, like the coffee maker, should still work. Additionally, household appliances and lights are typically designed to work at around 220 V. If they were connected in series, each appliance would only receive a fraction of 220 V.

### 17.9.1 HOUSEHOLD WIRING SYSTEM

A mains circuit is composed of three wires: a live wire (line wire), a neutral wire, and an earth wire as shown in figure 17.17. Each wire has a distinct function in guaranteeing the secure distribution and utilization of electricity. It is crucial to comprehend their roles in order to uphold electrical safety in residential and industrial environments.

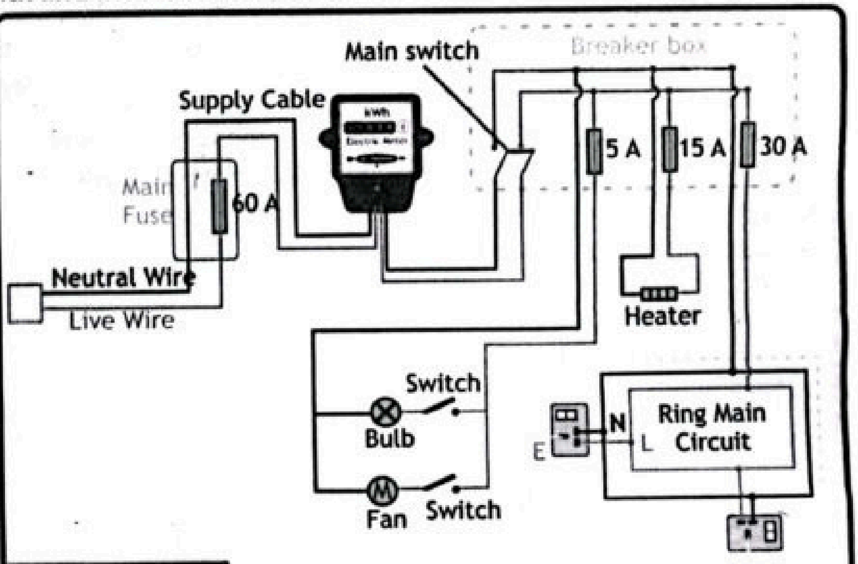


FIGURE 17.17 Basic household wiring

The live wire, also known as the line wire, is responsible for carrying the electrical current from the power source to the electrical devices or appliances. The live wire carries the potential difference or voltage that powers the electrical devices. The neutral wire, on the other hand, is responsible for completing the electrical circuit. It provides a return path for the electrical current back to the power source. It carries the same current as the live wire but with an opposite polarity. The earth wire, also known as the grounding wire, is a safety measure in case of electrical faults or malfunctions. The earth wire provides a low-resistance path for the electrical current to flow into the ground, preventing electric shocks and reducing the risk of fire. It acts as a safety backup, redirecting the current away from people or objects in case of a fault.

### 17.9.2 FUSES

To avoid overloading, current is restricted using fuses or circuit breakers. Fuses, (figure 17.18) found in older homes, Inside the fuse is a metal strip that melts when the current is larger than the rated value (the threads for example have specific to their current ratings). The melting of the strip opens the circuit, and the current drops to zero.

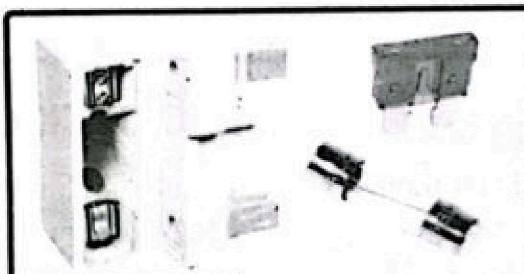


FIGURE 17.18 Some fuse types

### 17.9.3 CIRCUIT BREAKERS

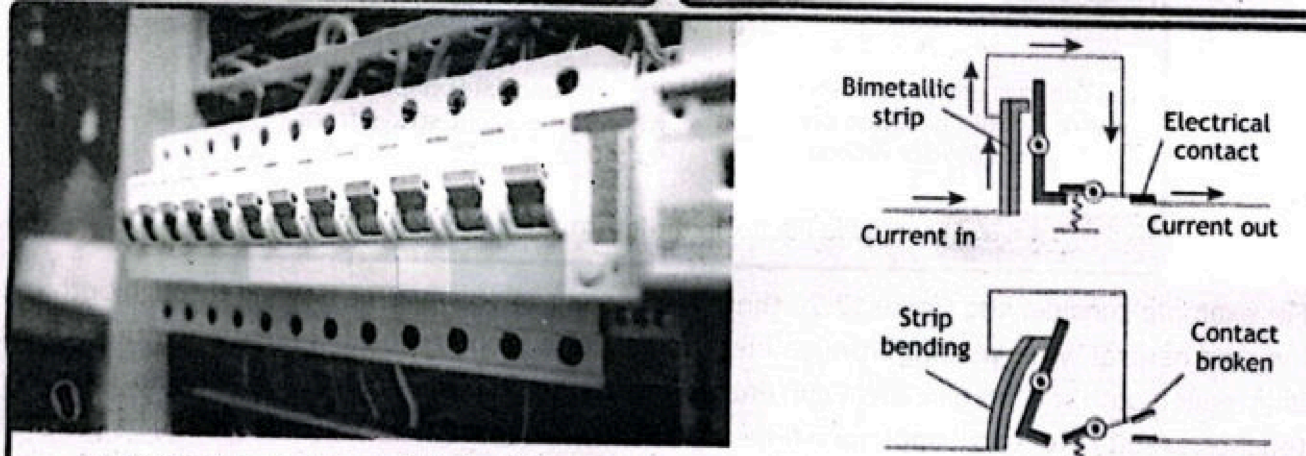
Newer homes exclusively use circuit breakers. One such type of circuit breaker utilizes a bimetallic strip as shown in figure. When the current flowing through the strip increases, it heats up and bends (figure 17.19). Once the current reaches its rated value, *the strip bends enough to*

**SCIENCE TIDBITS**

The electrical power produced (dissipated) by a resistor is $I^2R$. It depends on the square of the current. Hence, if current is doubled, the power will increase by four times. Similar explanation holds true for voltage also.

**SCIENCE TIDBITS**

A common misconception is that electrons are used up in an electric circuit, but this is not true. In reality, we pay the electric company for the energy needed to power our devices and move electrons through the circuit.




(a) A typical bank of household circuit breakers

(b) Circuit breaker with bimetallic strip

FIGURE 17.19 Circuit breaker

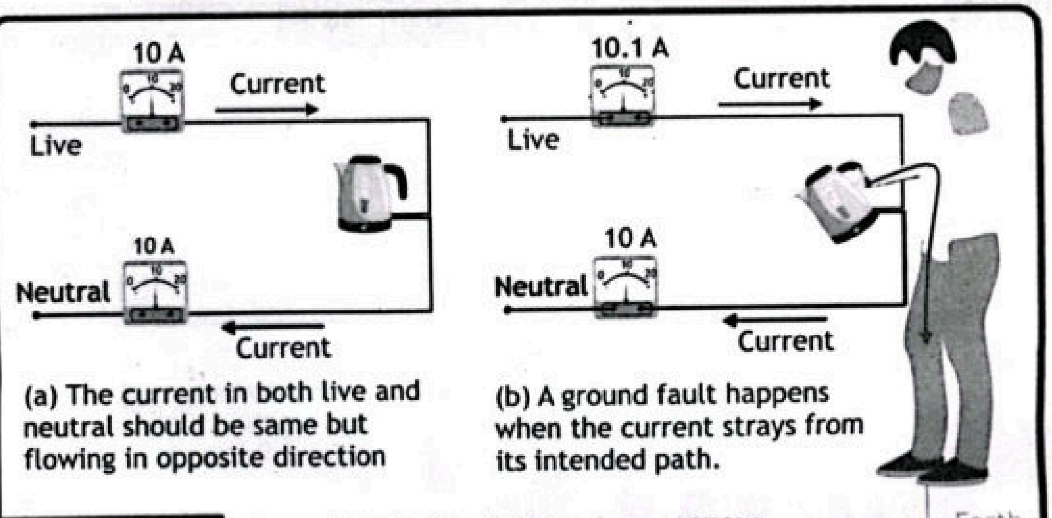
open the circuit (trip elements using magnetic principles also exist). Afterward, the strip cools down, allowing the breaker to be reset.

However, if a fuse blows or a circuit breaker trips, it indicates that the circuit is drawing excessive current. It is important to identify and fix the problem before replacing the fuse or resetting the circuit breaker. It is crucial not to temporarily replace a blown fuse with one that has a higher current rating. This is because it can lead to further damage or even fire hazards.

Adding a third grounding wire to the circuit helps prevent electric shocks by providing a low-resistance path through the metal casing of appliances. If a hot wire touches the casing, the circuit is completed through this wire, blowing the fuse or tripping the circuit breaker. In case of contact, the current would flow through the ground wire, minimizing harm to you.

### 17.9.4 RESIDUAL CURRENT DEVICES

Residual-Current Devices (RCDs), also known as Ground Fault Circuit Interrupters (GFCIs), are modern safety devices designed to protect against electric shock and reduce the risk of electrical fires. They do this by detecting differences in the electrical current between the live (hot) and neutral wires of a circuit. Ideally, the current in both wires should be equal but opposite in direction.




(a) The current in both live and neutral should be same but flowing in opposite direction

(b) A ground fault happens when the current strays from its intended path.

FIGURE 17.20 Ground Fault Circuit Interrupters (GFCIs)

For example consider the figure 17.20 there is a current of 10 amperes flowing through both the live and neutral wires passing through electric kettle. A ground fault happens when there is an unintended path for the electrical current to flow to the ground. Imagine someone accidentally touches a faulty electrical appliance (electric kettle), a new path for the current can be created through his body. Let's assume that there is a current of 0.1 ampere flowing through the person. This means that the live wire now carries a current of 10.1 amperes, while the neutral wire still has a current of 10 amperes.

To protect people from such situations, GFCIs are designed to detect this difference in current and interrupt the circuit when it detects a current difference of around 5 milliamperes (0.005 ampere). This helps to prevent electric shocks and potential harm to individuals.

### 17.9.5 ELECTRICAL HAZARDS

Electric hazards are often the result of negligence or lack of maintenance. Damaged insulation, overheating cables, damp conditions, and overloading of electrical outlets are among the common hazards encountered. Identifying these hazards and addressing them promptly through regular inspection and maintenance is crucial to prevent accidents and ensure safety.

Electric shock can have severe consequences on the human body, including burns, cardio-respiratory failure, and seizures. Understanding these effects underscores the importance of adhering to safety protocols and implementing preventive measures. First aid procedures should be known and readily available to mitigate the impact of electric shock incidents.

The amount of current passing through our body at a specific voltage is a complex question with no simple answer. The current flow is dependent on the resistance of the path it takes. Since different individuals have varying levels of resistance, it is difficult to give a definitive answer. Moreover, factors such as sweating on a hot day, which enhances conductivity due to saltwater, as well as one's diet and the length of the current path, also influence the body's resistance. Therefore, it is crucial to consider all these factors when assessing body resistance. Table 17.2 illustrates the effects of different amounts of current on the body. This data is general – as some people may have less tolerance to electricity than others.

**TABLE 17.2: THE EFFECTS OF ELECTRIC CURRENT ON THE BODY**

| Sr No. | Current in milliamperes (mA) | Effect on body |
|---|---|---|
| 1. | 2 to 3 | A slight tingling sensation |
| 2. | 9 to 10 | Moderately painful |
| 3. | 10 to 20 | Highly painful |
| 4. | 20 to 30 | A person to seize the line and be unable to let go of the circuit. |
| 5. | 30 to 40 | Causing muscular paralysis |
| 6. | 40 to 60 | Causing breathing difficulty |
| 7. | 60 to 100 | Breathing becomes extremely difficult |
| 8. | 100 to 200 | Generally cause death because the heart usually goes into fibrillation, a condition in which the heart begins to "quiver" and the pumping action stops. |

## SUMMARY

- **Electric Circuit** is a closed pathway through which electricity flows, typically consisting of a power source, wires, and components like resistors.
- **Resistor** is an electrical component that limits the flow of electric current in a circuit, measured in ohms (Ω).
- **Series Combination of Resistors** include connecting resistors end-to-end in a single path so that the same current flows through each.
- **Parallel Combination of Resistors** include connecting resistors side by side across the same voltage source, allowing multiple current paths.
- **Potential Divider** is a circuit arrangement used to divide a voltage into smaller fractions using resistors connected in series.
- **Electric Power** is the rate at which electrical energy is transferred or consumed in a circuit, measured in watts (W).
- **Electrical Energy** is the ability of electricity to do work or produce heat, measured in joules (J) or kilowatt-hours (kWh).

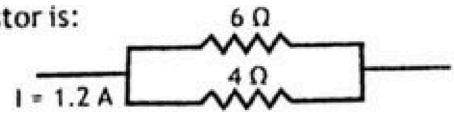
- **Kilowatt Hour (kWh)** is the unit of electrical energy commonly used to measure consumption or production over time, equal to one kilowatt of power used for one hour.
- **Electricity and Its Uses** include flow of electric charge through conductive materials, utilized for heating, lighting, powering devices, and various applications.
- **Electrical Safety** involves the practices and measures to prevent accidents and injuries related to electricity, including proper installation, maintenance, and following safety guidelines.

# EXERCISE

## MULTIPLE CHOICE QUESTIONS

**QI. Choose the best possible option in the following questions.**

1. Two resistances of 4 ohm are connected in parallel and this combination is connected to another 6 ohm resistance in series. The equivalent resistance will be:
   A. 4 Ω  B. 6 Ω  C. 8 Ω  D. 10 Ω
2. In series connection of resistors, the current across each resistor:
   A. increases  B. decreases
   C. remain the same  D. first increases then decreases
3. A resistor's first three colours are brown, black and red, its value is:
   A. 10 Ω  B. 10 kΩ  C. 200 Ω  D. 1000 Ω
4. The relation for electric power in a circuit is P =
   A. $IV$  B. $I^2R$  C. $V^2/R$  D. all of these
5. In the given figure, the current passing through 6Ω resistor is:
   A. 0.40 A  B. 0.48 A
   C. 0.72 A  D. 80 A



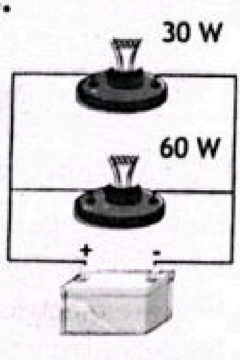

6. When four cells, each with an emf of 0.5 V, are connected in parallel, the net emf is:
   A. 4.5 V  B. 2.0 V  C. 0.75 V  D. 0.5 V
7. The purpose of grounding electrical systems is to:
   A. provide a path for current to flow  B. protect against electric shocks
   C. reduce electrical resistance  D. increase energy efficiency

8. The purpose of a circuit breaker is to:
   A. increase electrical resistance
   B. prevent electrical shock
   C. regulate voltage
   D. interrupt the flow of electricity in case of a fault
9. Which electrical element control the flow of the electric current in a circuit?
   A. conductor
   B. insulator
   C. Resistor
   D. capacitor
10. A and B are two bulbs connected in parallel. A is glowing brighter than B, then the relation between $R_A$ and $R_B$ is:
    A. $R_A > R_B$
    B. $R_A < R_B$
    C. $R_A = R_B$
    D. $R_A = 0$
11. The S.I unit for electrical power is:
    A. watt
    B. Joule
    C. volt
    D. kWh
12. A wire of resistance R is divided in 10 equal parts. These parts are connected in parallel, the equivalent resistance of such connection will be:
    A. 10 R
    B. R
    C. 0.1 R
    D. 0.01 R

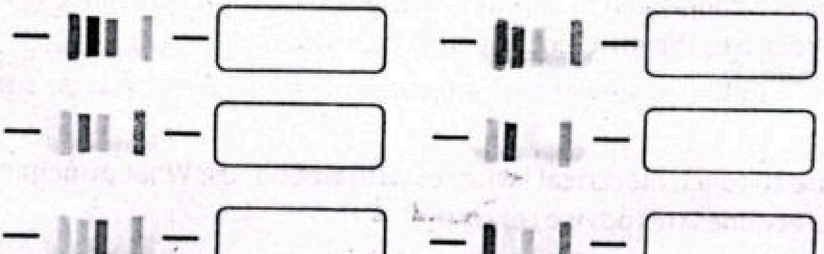
## CONSTRUCTED RESPONSE QUESTIONS

**QII. Follow the directions to respond to the following questions.**

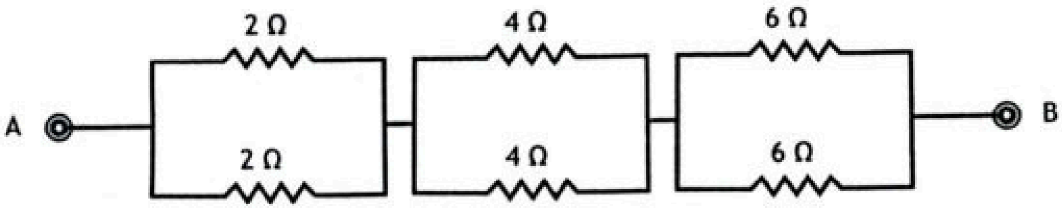
1. A battery of voltage V is connected to 30 W bulb and 60 W bulb as shown in the figure. (a) Identify brightest bulb (b) which bulb has greater resistance? (c) Suppose the two bulbs are connected in series, which bulb will glow brighter?



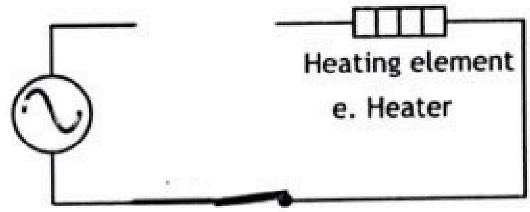

2. What is the value of resistance of the following resistors?

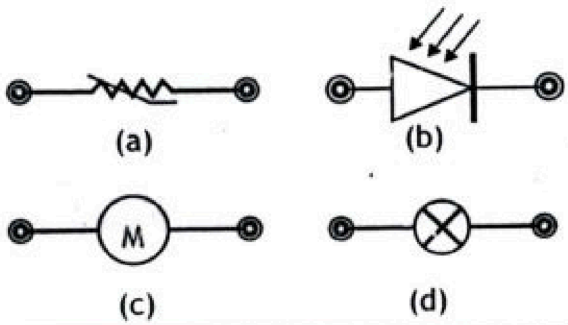


3. **Calculate the equivalent resistance between points A and B in the given circuit.**




4. Consider a circuit in which a heater is in series with the supply voltage. Which device out of the following should be placed to present a higher resistance initially, preventing large currents from flowing at turn-on?




## SHORT RESPONSE QUESTIONS

**QIII. Give a short response to the following questions.**

1. How does the color code on a carbon resistor provide information about its properties, and why is this method chosen over other labeling techniques?
2. Why are electrical devices in homes connected in parallel rather than in series? How would household functionality be impacted if they were connected in series?
3. When resistors are connected in parallel, why does the total resistance decrease? How does this principle relate to the efficiency of electrical systems?
4. How incorrect parallel placement of ammeters can damage circuits, suggesting ways to prevent this.
5. Why is it unsafe to touch electrical switches with wet hands? What principles of conductivity and human safety does this advice rely on?
6. What makes touching a live wire while barefoot on the ground particularly dangerous? How do the factors involved influence the severity of electrical shock?
7. How does a circuit breaker protect a household's electrical system? What might happen in the absence of a circuit breaker during a power surge or overload?

8. In what ways does grounding an appliance's case enhance user safety? How does grounding mitigate potential electrical hazards?
9. How does an appliance's wattage influence its energy consumption and operational cost? How can understanding this relationship help in making energy-efficient choices?
10. In what ways do electrical energy and electrical power differ in function and application? How do these differences impact our understanding and measurement of electricity?
11. How does the kilowatt-hour serve as a unit of energy consumption, and what steps can you take to convert energy usage from joules to kilowatt-hours?
12. Describe a situation in your daily life where electrical energy is essential. How does this energy transform to allow the device to perform its function?
13. What are three common sources of electrical energy, and how do their advantages and disadvantages influence our choice of energy sources?
14. Examine the effects and risks of connecting different emf sources in parallel, and suggest safe ways to combine power sources

## LONG RESPONSE QUESTIONS

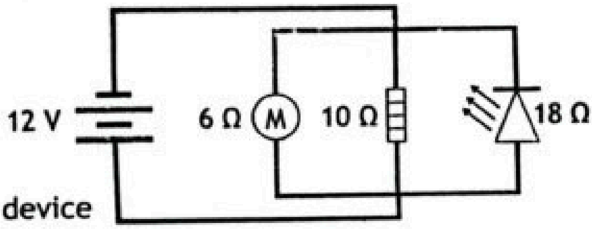
**QIV. Give a detailed response to the following questions.**

1. What is the significance of different types of resistors in electronic circuits, and how do their characteristics influence circuit design?
2. Explain the principles behind the series combination of resistances and illustrate how the total resistance changes when more resistors are added?
3. How does the concept of equivalent resistance in parallel circuits differ from that in series circuits, and what practical applications can you identify for each?
4. Discuss the effects of connecting emf sources in series or parallel and their practical uses.
5. In what ways can electric power be measured, and why is it important to understand the different formulas for calculating power in electrical systems?
6. What are the common hazards associated with household electricity, and how can individuals effectively mitigate these risks through safety measures?
7. In what various ways is electricity utilized in everyday life, and how has its application evolved over time?
8. Describe the working principle of a potential divider and discuss its practical uses in electronic circuits?
10. What are thermistors, and how do their types (NTC and PTC) differ in terms of functionality and applications in temperature sensing and control?

## NUMERICAL RESPONSE QUESTIONS

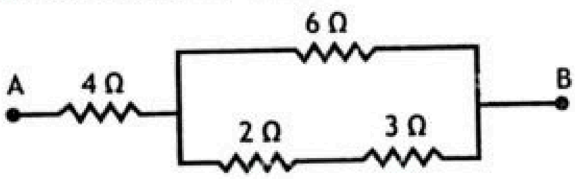
**QV. Solve the questions given below.**

1. A fan, a heater and an LED bulb are connected to a battery as shown in the figure.
   (a) Find equivalent resistance
   (b) Calculate the current passing through each device



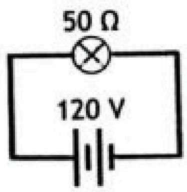

(Ans. (a) 3.1 Ω, (b) 2 A, 1.2 A, 0.67 A)

2. Three resistors $R_1$ = 8 Ω, $R_2$ = 12 Ω and $R_3$ = 18 Ω are connected in parallel. Calculate the total resistance of the combination. (Ans. 3.789 Ω)
3. A device with a resistance of 10 Ω is connected to a 120 V power source. Calculate the power consumed by the device. (Ans. 1440 W)
4. A light bulb with a power rating of 60 W is switched on for 5 hours. Calculate the electrical energy consumed by the light bulb. (Ans. 300 Wh)
5. One hundred identical cells are connected in series, each of emf 0.2 V. What will the resultant emf when these identical cells are connected in series? When parallel?
   (Answer: 20 V, 0.2 V)
6. In the circuit shown, what is the value of the total resistance of the circuit between points A and B?



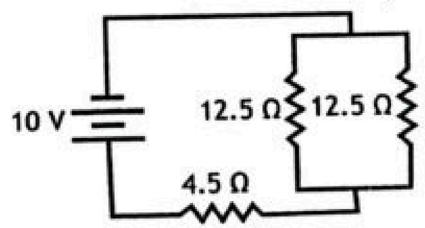

(Ans. 6.73 Ω)

7. Calculate the
   (a) power consumed,
   (b) current flowing through and
   (c) electrical energy consumed by the bulb in the given figure.




(Ans. 288W, 2.4 A, 1440 Wh)

8. Calculate the total resistance of the circuit shown in the figure:




(Ans. 10.75 Ω)