1 Electric Circuit

An electric circuit basically consists of a voltage source, a load, and a path for current between the source and the load as shown in Fig 1-1.

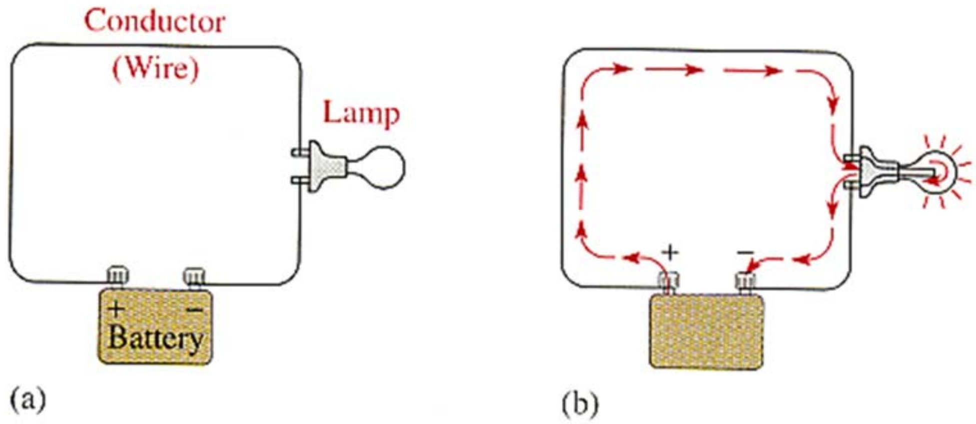


Fig 1-1 A simple electric circuit.

Fig 1-2 Schematic circuit for Figure 1-1.

2 Voltage, V

The **difference in potential energy of the charges** in an electric circuit is the potential difference or voltage.

Voltage is the driving force in electric circuits and which establishes current.

This energy, to create the potential difference, can be obtained from battery, electronics power supply, solar cell and generator.

3 Unit of Voltage

The unit of voltage is **volt**, symbolized by **V**.

4 Current, I

Electrical current is defined as the rate of flow of electrons in a conductor or semiconductor materials.

The voltage in a circuit provides the energy for the electrons to flow.

The current results in the work being done in an electric circuit.

Electron Flow

Electron Flow occurs when electrons moves out of the negative terminal, through the circuit and into the positive terminal of the source.

Conventional current flow

Conventional Current occurs when current flows out of the positive terminal, through the circuit and into the negative terminal of the source. This was the convention chosen during the discovery of electricity.

5 Unit of Current

The unit of current is **ampere**, symbolized by **A**.

Smaller Units of Current (mA and μA)

Usually in electronic circuits, the value of the current is far less than one ampere. The smaller values of current are expressed by metric system prefixes **milli (m)** and **micro (μ).**

1×10^{-3} A ($\frac{1}{1000}$ th of an ampere) --- 1 mA

1×10^{-6} A ($\frac{1}{1000000}$ th of an ampere) --- 1 μA

6 Basic types of electronic measuring instruments

- Voltmeter
- Ammeter
- Ohmmeter

7 Safety precautions when handling and using measuring instruments

A **voltmeter** is used for measuring the electrical potential difference between two points in an electric circuit.

The voltmeter is connected across the component for which the voltage is to be found.

The negative terminal of the meter must be connected to the negative side of the circuit, and the positive terminal of the meter to the positive side of the circuit.

An **ammeter** is used for measuring the current flow in the electrical circuit.

The most common way to measure current in a circuit is to break the circuit open and insert an "ammeter" in series (in-line) with the circuit so that all electrons flowing through the circuit also have to go through the meter.

Note: Always set the meter range to the highest when measuring unknown voltage or current.

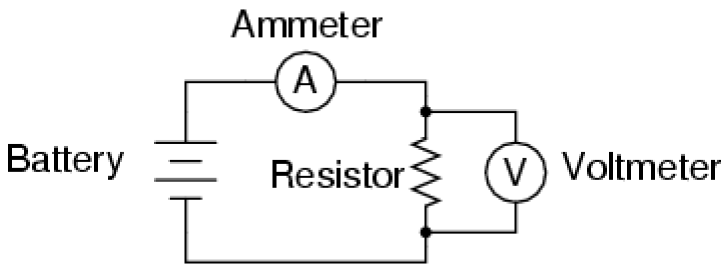
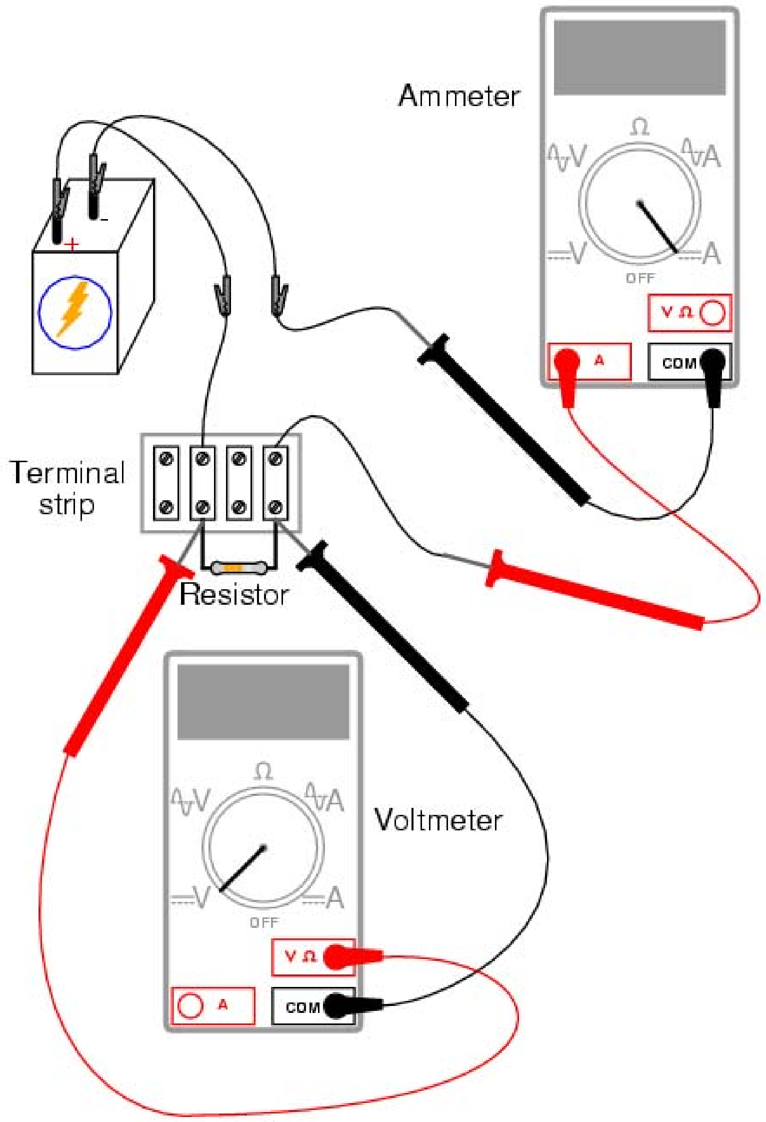


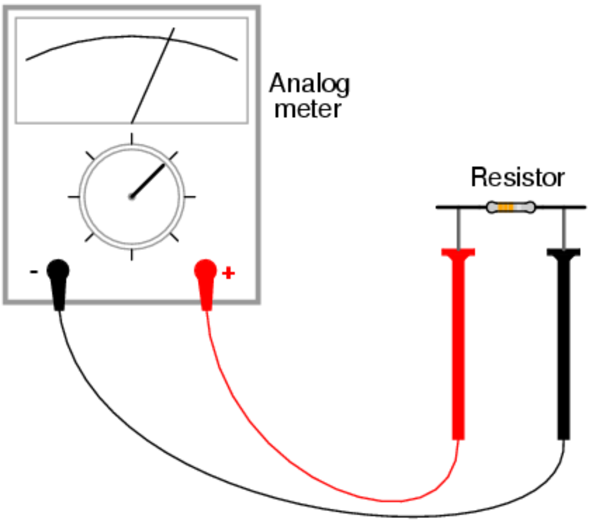
Fig 7-1 Schematic Diagram of the ammeter and voltmeter



Illustration

Resistance Measurement

An **ohmmeter** is used to measure the resistance of the resistor. For measurement, the ohmmeter is connected across the resistor. The resistor must first be removed or disconnected from the circuit, as shown in the diagram below.



Illustration

8 Convert from one metric unit to another

There is a huge range of values encountered in electrical and electronic engineering between a maximum value and a minimum value of a standard electrical unit. For example, resistance can be lower than 0.01Ω's or higher than 1,000,000Ω's. By using multiples and submultiple's of the standard unit we can avoid having to write too many zero's to define the position of the decimal point. The table below gives their names and abbreviations.

Prefix	Symbol	Multiplier	Power of Ten
Terra	T	1,000,000,000,000	10^{12}
Giga	G	1,000,000,000	10^{9}
Mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
none	none	1	10^{0}
centi	c	1/100	10^{-2}
milli	m	1/1,000	10^{-3}
micro	μ	1/1,000,000	10^{-6}
nano	n	1/1,000,000,000	10^{-9}
pico	p	1/1,000,000,000,000	10^{-12}

So, to display the units or multiples of units for either a Resistance, Current or Voltage we would use as an example:

- 1kV = 1 kilo-volt - which is equal to 1,000 Volts.
- 1mA = 1 milli-amp - which is equal to one thousandths (1/1000) of an Ampere.
- 47kΩ = 47 kilo-ohms - which is equal to 47 thousand Ohms.
- 100uF = 100 micro-farads - which is equal to 100 millionths (1/1,000,000) of a . Farad.
- 1kW = 1 kilo-watt - which is equal to 1,000 Watts.
- 1MHz = 1 mega-hertz - which is equal to one million Hertz.

To convert from one prefix to another it is necessary to either multiply or divide by the difference between the two values. For example, convert 1MHz into kHz.

Well we know from above that 1MHz is equal to one million (1,000,000) hertz and that 1kHz is equal to one thousand (1,000) hertz, so one 1MHz is one thousand times bigger than 1kHz. Then to convert Mega-hertz into Kilo-hertz we need to multiply mega-hertz by one thousand, as 1MHz is equal to 1000 kHz. Likewise, if we needed to convert kilo-hertz into mega-hertz we would need to divide by one thousand. A much simpler and quicker method would be to move the decimal point either left or right depending upon whether you need to multiply or divide.

9 Ohm's Law

Ohm's Law states that, in an electric circuit, the current passing through a conductor between two points is directly proportional to the potential difference (i.e voltage drop or voltage) across the two points, and inversely proportional to the resistance of the conductor.

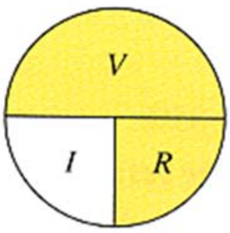
It is usually formulated as V = IR, where V is the voltage, I is the current and R is the resistance of the conductor.

10 Use Ohm's Law to determine voltage, current or resistance

Formula for current

Ohm's law can be stated as follows :

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



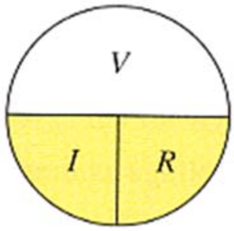
For a constant value of R, if the value of V is increased, the value of I increases; if V is decreased, I decreases.

Using this equation, you can calculate the current if the values of voltage and resistance are known.

Formula for Voltage

Ohm's law can also be stated another way. By re-arranging the previous equation, we will get an equivalent form of Ohm's law as follows:

$$\boxed{V = I\,R}$$

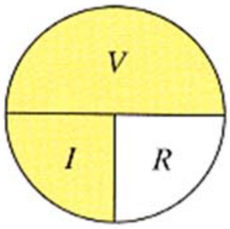


With this equation, you can calculate voltage if current and resistance are known.

Formula for Resistance

There is one more equivalent way to state Ohm's law by re-arranging the previous equation.
That is,

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



This form of Ohm's law is used to determine resistance if voltage and current values are known.

Remember, all these three formulae are equivalent. They are simply three different ways of expressing Ohm's law.

Calculating Current

Ohm's law can be used to find current when voltage and resistance are known.

In the following examples, the formula $I = \frac{V}{R}$ is used.

In order to get **current in amperes**, you must express the **value of voltage in volts and value of resistance in ohms.**

Example 1

Calculate the current in Fig 10-1(a).

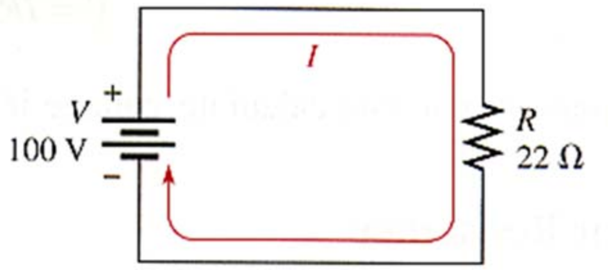


Fig 10-1(a)

Solution: Use the formula $I = \frac{V}{R}$

$I = \frac{V}{R}$ **=** $\frac{100V}{22\Omega}$ **= <u>4.55 A</u>**

There is 4.55 A of current in this circuit.

Example 2

Calculate the current in Fig 10-1(b)

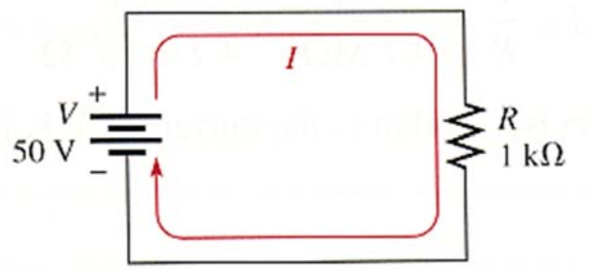


Fig 10-1(b)

Solution: Remember that 1 kΩ is the same as 1 x 10^3 Ω.

$I = \frac{V}{R}$ **=** $\frac{50V}{1k\Omega}$ **=** $\frac{50V}{1 \times 10^3 \Omega}$ **=** 50 x 10^{-3} A = **50 mA**

Calculating Voltage

Ohm's law can be used to find voltage when current and resistance are known.
In the following examples, the formula $V = IR$ is used. To obtain voltage in volts, you must express the value of I, in amperes and the value of R, in ohms.

Example 3

Refer to Fig 10-1(c), calculate the voltage needed to produce 5A of current?

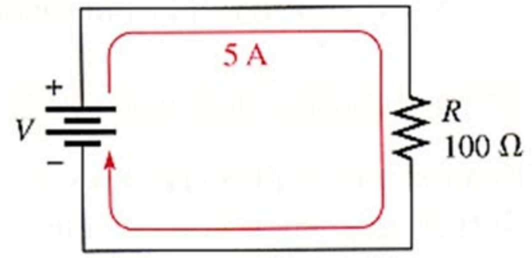


Fig 10-1 (c)

Solution: $V = IR$; **V =** (5 A) (100 Ω) = **500 V**

Thus, 500 V are required to produce 5 A of current though a 100 Ω resistor.

Example 4

Calculate the voltage across the resistor in Fig 10-1(d)?

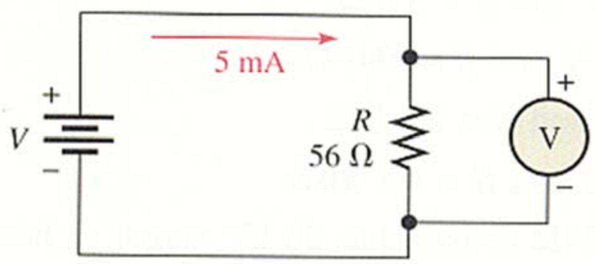


Fig 10-1(d)

Solution: Five milliamperes equals 5×10^{-3} A.

$V = IR$ **=** (5 mA) (56 Ω) = (5×10^{-3} A) (56 Ω) = 280×10^{-3} V = **280 mV**

Calculating Resistance

Ohm's law can be used to find resistance when voltage and current are given.

In the following examples, the formula $R = \frac{V}{I}$ is used.

To get **resistance in ohms**, you must express the **value of I in amperes and the value of V in volts**.

Example 5

Refer to Fig 10-1(e), how much resistance is needed to draw 3.08A of current from the battery?

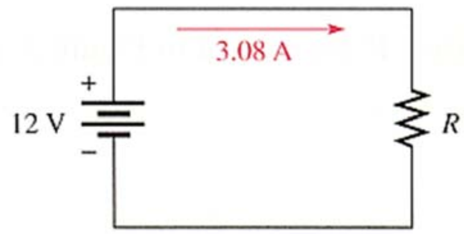


Fig 10-1(e)

Solution: $R = \frac{V}{I}$ = $\frac{12V}{3.08A}$ = **3.90 Ω**

Example 6

The ammeter reading in Fig 10-1(f) indicates 4.55mA and the voltmeter reads 150V. What is the value of R?

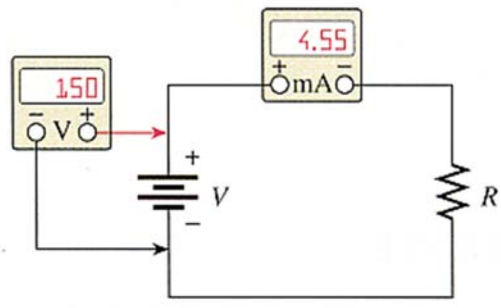


Fig 10-1(f)

Solution: 4.55 mA equals 4.55 x 10^{-3} A. Substitute the voltage and current values into the formula, $R = \frac{V}{I}$.

$$R = \frac{V}{I} = \frac{150\,V}{4.55\,mA} = \frac{150\,V}{4.55 \times 10^{-3}\,A} = 33 \times 10^{3}\,\Omega = \underline{\mathbf{33\,k\Omega}}$$

11 Ohm's law in Series and Parallel Circuits

Current in Series Circuit

The same amount of current flows through all the points in a series circuit.

The current through each resistor in a series circuit is the same as the current through all the other resistors that are in series with it.

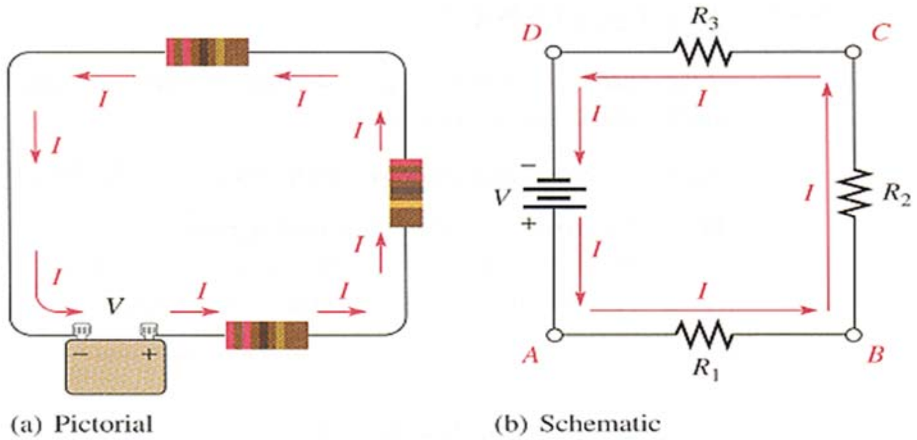


Fig 11-1 Fig 11.1(a)

Refer to Fig 11-1. Current going into any point in a series circuit is the same as the current going out of that point.

Refer to Fig 11-1(a). Three resistors connected in series to a voltage source. At any point in this circuit, the current is the same throughout as illustrated in Fig 11.1(a) by the current directional arrows at points A, B, C and D.

Total Series Resistance

The total resistance of a series circuit is equal to the sum of the resistances of each individual series resistor.

When more resistors are connected in series, the resistor values add because each resistor offers opposition to the current in direct proportion to its resistance. Thus, every time a resistor is added in series, the total resistance increases.

Series Resistance Formula

For any number of individual resistors connected in series, the total resistance is the sum of each of the individual values.

$$R_T = R_1 + R_2 + R_3 + \ldots.. + R_n$$

Where R_T is the total resistance and Rn is the last resistor in series string ('n' can be any positive integer equal to the number of resistors in series).

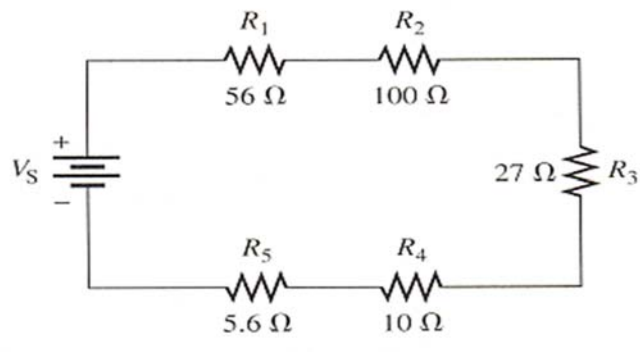


Fig 11-1(b) 5 resistors in series.

For example, In Fig 11-1(b) there are five resistors in series and therefore n = 5. Thus, the total resistance formula is,

$$R_T = R_1 + R_2 + R_3 + R_4 + R_5$$
$$R_T = 56\ \Omega + 100\ \Omega + 27\ \Omega + 10\ \Omega + 5.6\ \Omega = 198.6\ \Omega$$

12 Voltage in a Series Circuit

For any number of individual resistors connected in series across a voltage source, the sum of the voltages across each resistor is equal to the source voltage.

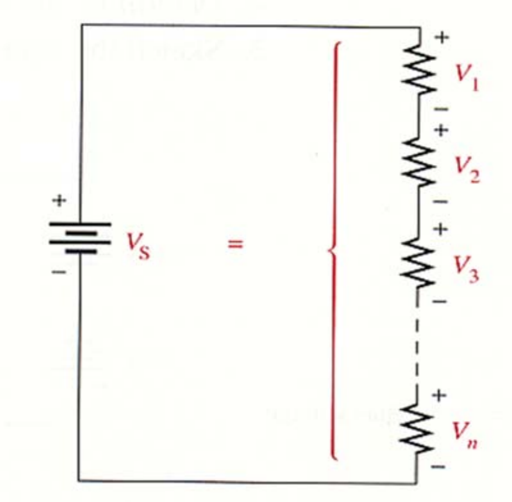


Fig 12-1(a) Sum of voltage drops equals the source voltage.

$$V_S = V_1 + V_2 + V_3 + \ldots\ldots + V_n$$

Where ‘n’ is the number of resistors in the circuit and V_S is the voltage of the source.

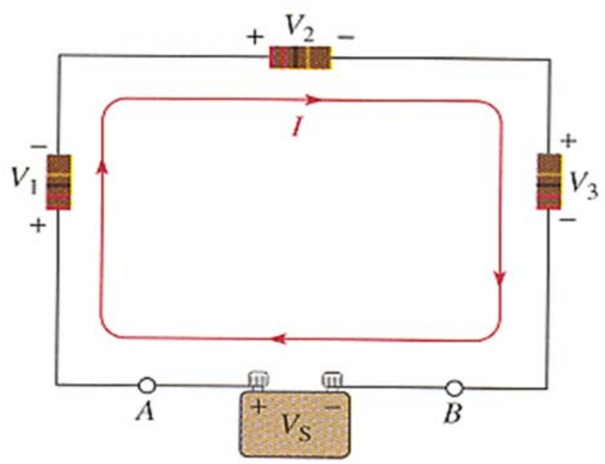


Fig 12-1(b) Three resistors in series connected across a voltage source V_S.

For example, in Fig 12-1(b) there are three resistors connected in series across a voltage source, V_S.

Thus the total voltage, V_S is given by,

$$V_S = V_1 + V_2 + V_3$$

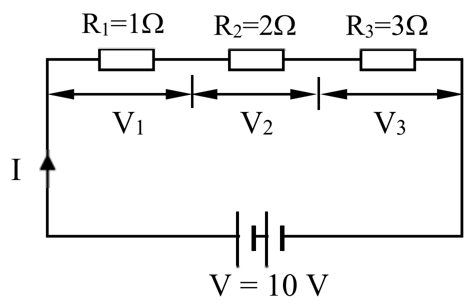
The characteristics of a series circuit are:

(a) Current through all the resistors is the same.
(b) The voltage applied to the circuit = the sum of the voltages across each resistor.
(c) Voltage drop across each resistor = current x individual resistance.
(d) Total resistance = sum of individual resistance
(e) Total resistance is greater than the largest value of the individual resistance.

Example 7

Three resistors of 1Ω, 2Ω and 3Ω respectively are connected in series. Calculate the total resistance of the circuit.
If a P.D. (potential difference) of 10V is applied to the circuit, calculate the current and the voltage drop across each resistor.

Solution:



Total resistance, $R_T = R_1 + R_2 + R_3$

$= 1 + 2 + 3$

$= 6\ \Omega$

Current, $I = \frac{V}{R_T} = \frac{10}{6} = \underline{\underline{1.67\ A}}$

$V_1 = IR_1 = 1.67 \times 1 = \underline{\underline{1.67\ V}}$

$V_2 = IR_2 = 1.67 \times 2 = \underline{\underline{3.33\ V}}$

$V_3 = IR_3 = 1.67 \times 3 = \underline{\underline{5\ V}}$

Exercise

Three resistors of 40Ω, 60Ω and XΩ respectively are connected in series. The combination is connected across the 50 V supply. If the voltage drop across the 40Ω resistor is 16 V. Determine the current in the circuit and the unknown resistor, X.

13 Current and Voltage in Parallel Circuit

Current in Parallel Circuit

A parallel circuit provides more than one path for current to flow.

The total current in any parallel circuit is the sum of all the branch currents. For example, the circuit in Fig 13-1(a), the total current (I_T) from the source into Junction A, is equal to the sum of the branch currents I_1, I_2 and I_3. Thus,

$$I_T = I_1 + I_2 + I_3$$

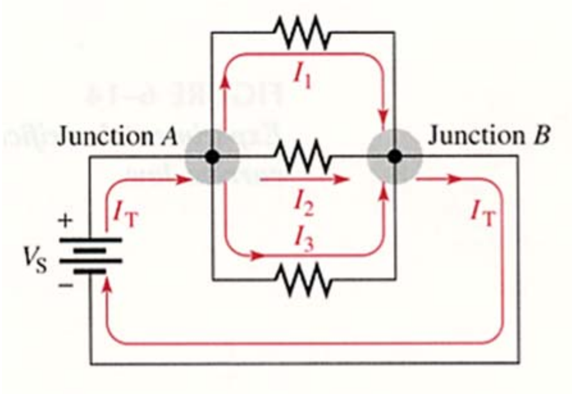


Fig 13-1(a)

Example 9

The branch currents in Fig 13-1(b) are known. Determine the total current, I_T.

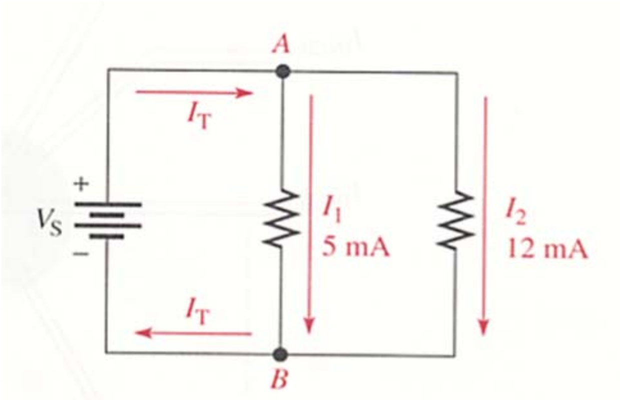


Fig 13-1(b)

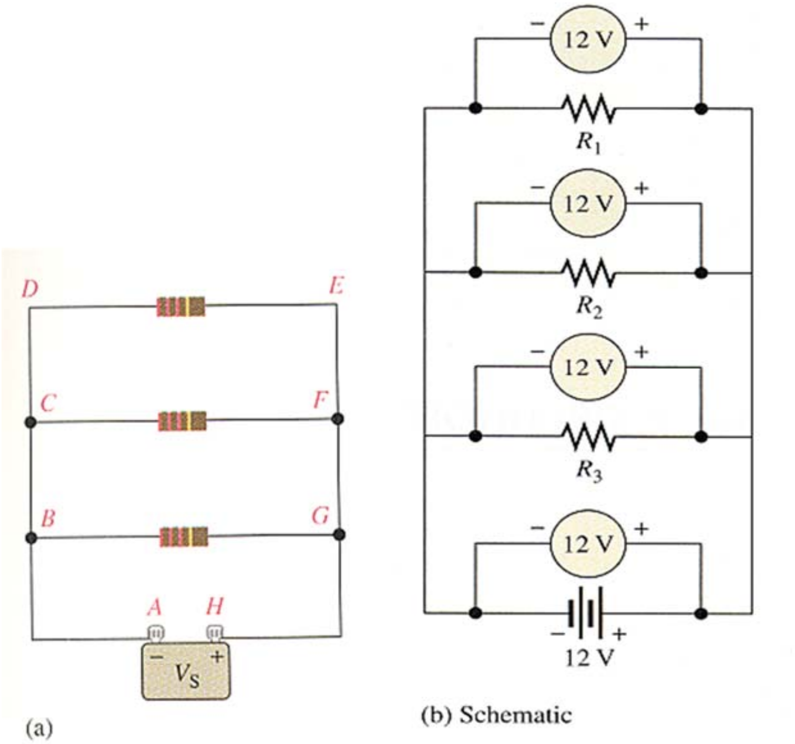
Solution:

The total current I_T is the sum of the two branch currents.
So the total current into point A is

$$I_T = I_1 + I_2 = 5 \text{ mA} + 12 \text{ mA} = \underline{\mathbf{17\ mA}}$$

Voltage across the Parallel Resistors

The voltage across any branch of a parallel circuit is equal to the voltage across any of the other branches in parallel.



Voltage across the parallel branches is the same.

Points A, B, C and D along the left side of the parallel circuit are electrically the same because the voltage is same along this line.

You can think of all these points as being connected by a single wire to the negative terminal of the battery.

Points E, F, G and H along the right side of the circuit are all at a voltage equal to that of the positive terminal of the source.

Thus, voltage across each parallel resistor is the same, and each is equal to the source voltage.

<u>Example 10</u>

Determine the voltage across each resistor in Fig 13-1(c).

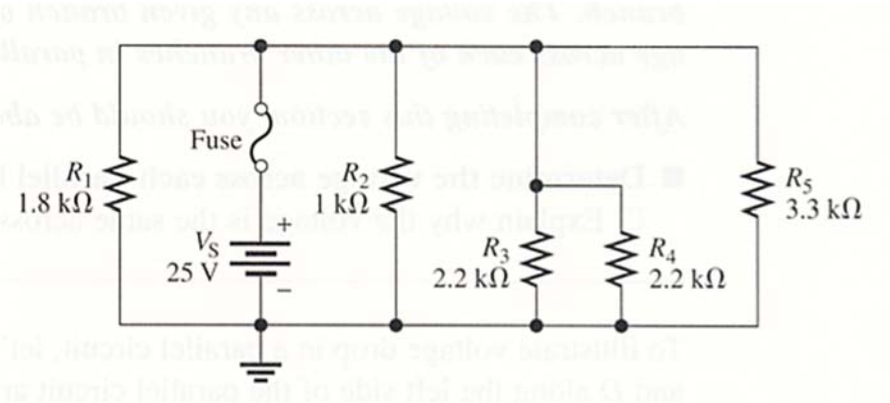


Fig 13-1(c)

Solution:

The five resistors are in parallel, so the voltage drop across each one is equal to the applied voltage. There is no voltage drop across the fuse.

$V_1 = V_2 = V_3 = V_4 = V_5 =$ **25 V**

Total Parallel Resistance

When resistors are connected in parallel, the total resistance of the circuit decreases. The total resistance of a parallel circuit is always less than the value of the smallest resistor. For example, if a 10 Ω resistor and a 100 Ω resistor are connected in parallel, the total resistance is less than 10 Ω.

Formula for Total Parallel Resistance

The circuit in Fig 13-1(d) shows a general case of 'n' resistors in parallel (n can be any number).

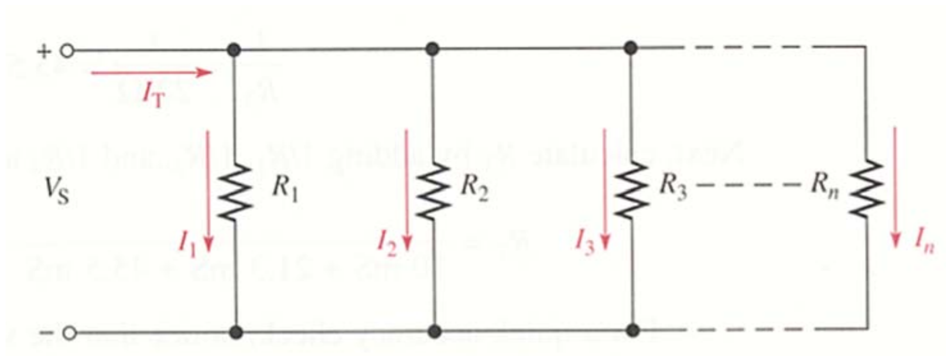


Fig 13-1(d) Circuit with 'n' resistors in parallel.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots\ldots + \frac{1}{R_n}$$

Characteristics of a parallel circuit are:

(a) The voltage across each resistor is the same.
(b) Total current = Sum of individual current
(c) The reciprocal of the total resistance = sum of the reciprocal of each resistance
(d) Total resistance is smaller than the lowest individual resistance.

Example 11

Three resistors of 1Ω, 1.5Ω and 2Ω are joined in parallel and they share a current of 10A. Find the p.d. across them and the current in the three resistors.

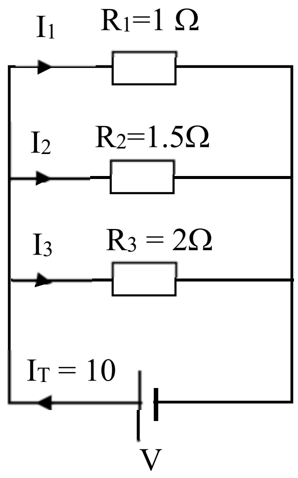


Fig 13-1(e)

Solution:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R3} = \frac{1}{1} + \frac{1}{1.5} + \frac{1}{2} = 2.167$$

$$R_T = \frac{1}{2.17} = 0.461\,\Omega$$

$$V = I_T R_T = 10 \text{ x } 0.461 = \underline{\underline{4.61\text{ V}}}$$

$$\text{Voltage across } R_1 = \text{Voltage across } R_2 = \text{Voltage across } R3 = \underline{\underline{4.61\text{ V}}}$$

$$I_1 = \frac{V}{R_1} = \frac{4.61}{1} = \underline{\underline{4.61\text{ A}}}$$

$$I_2 = \frac{V}{R_2} = \frac{4.61}{1.5} = \underline{\underline{3.07\text{ A}}}$$

$$I_3 = \frac{V}{R_3} = \frac{4.61}{2} = \underline{\underline{2.305\text{ A}}}$$

14 Current Divider Rule

A parallel circuit acts as a current divider because the total current entering the circuit divides into several individual branch currents.

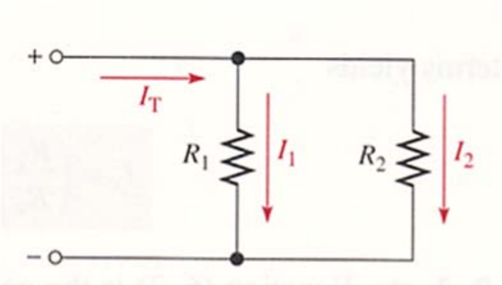


Fig 14-1(a) Total current divides between two branches.

In Fig 14-1(a), the total current I_T is divided into two branch currents I_1 and I_2.

The value of I_1 is inversely proportional to the value of R_1 and similarly the value I_2 is inversely proportional to the value of R_2.

In other words, the branches with higher resistance have less current, and branches with lower resistance have more current.

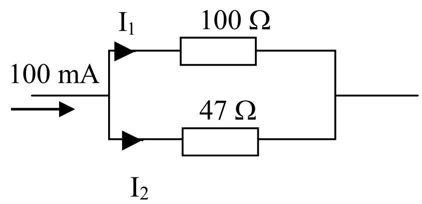
If two resistors are connected in parallel as shown in Fig 14-1(a), then

$$I_1 = \left(\frac{R_2}{R_1 + R_2} \right) I_T$$

$$I_2 = \left(\frac{R_1}{R_1 + R_2} \right) I_T$$

<u>Example 12</u>

Find the current I_1 and I_2



<u>Solution</u>:

$$I_1 = \frac{47}{100 + 47} \text{ x } 100 = \underline{\underline{31.97 \text{ mA}}}$$

$$I_2 = \frac{100}{100 + 47} \text{ x } 100 = \underline{\underline{68.03 \text{ mA}}}$$

or $I_2 = I_T - I_1 = 100 - 31.97 = \underline{\underline{68.03 \text{ mA}}}$

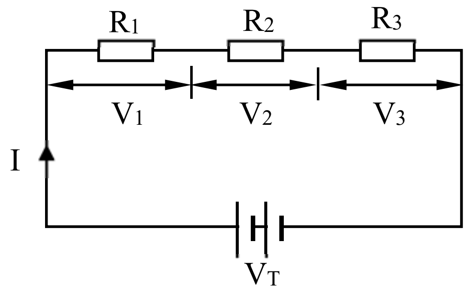
Exercise

Two resistors 100 Ω and 140 Ω are connected in parallel. The total current is 10 A. Find the current through the two resistors.

15 Voltage and resistance in voltage divider circuits

Voltage Divider Rule

When more than one resistor are connected in series as shown in figure below, the sum of the voltages across these resistors will be equal to the voltage of the source. And the voltage across each resistor is given by:



$$V_1 = \frac{R_1}{R_T} V_T$$

$$V_2 = \frac{R_2}{R_T} V_T$$

$$V_3 = \frac{R_3}{R_T} V_T$$

Where R_T is the sum of all three resistances. That is, $R_T = R_1 + R_2 + R_2$

Thus, the voltage drop across any resistor or combination of resistors in a series circuit is equal to the ratio of that resistance value to the total resistance, multiplied by the source voltage.

<u>Example 13</u>

A voltage divider has two resistors $R_1 = 82\Omega$ and $R_2 = 64\Omega$ and connected to a 10V dc supply. Determine the voltage across R_1 and voltage across R_2 in the voltage divider.

<u>Solution:</u>

$$\text{Voltage across R}_1 = \frac{R_1}{R_1 + R_2} V_T$$

$$= \frac{82}{82 + 64} \times 10 = \underline{\underline{5.62\ \text{V}}}$$

$$\text{Voltage across R}_2 = \frac{R_2}{R_1 + R_2} V_T$$

$$= \frac{64}{82 + 64} \times 10 = \underline{\underline{4.38\ \text{V}}}$$

Exercise

A circuit has two resistors R_1 = 100Ω and R_2 = 80Ω connected in series and is connected to a 50V dc supply. Determine the voltage across R_1 and voltage across R_2 using voltage divider rule.

16 Potentiometer as an Adjustable Voltage Divider

Potentiometer is a variable resistor with three terminals.

A potentiometer connected to a voltage source is shown in Fig 18-11(a) with the schematic shown in Fig 18-1(b).

Notice that the two end-terminals are labeled 1 and 2. The adjustable terminal or wiper is labeled 3.

The potentiometer acts as a voltage divider, which can be illustrated by separating the total resistance into two parts as shown in Fig 18-1(c).

The resistance between terminal 1 and terminal 3 (R_{13}) is one part, and the resistance between terminal 3 and terminal 2 (R_{32}) is the other part.

So this potentiometer actually is a two-resistor voltage divider that can be manually adjusted.

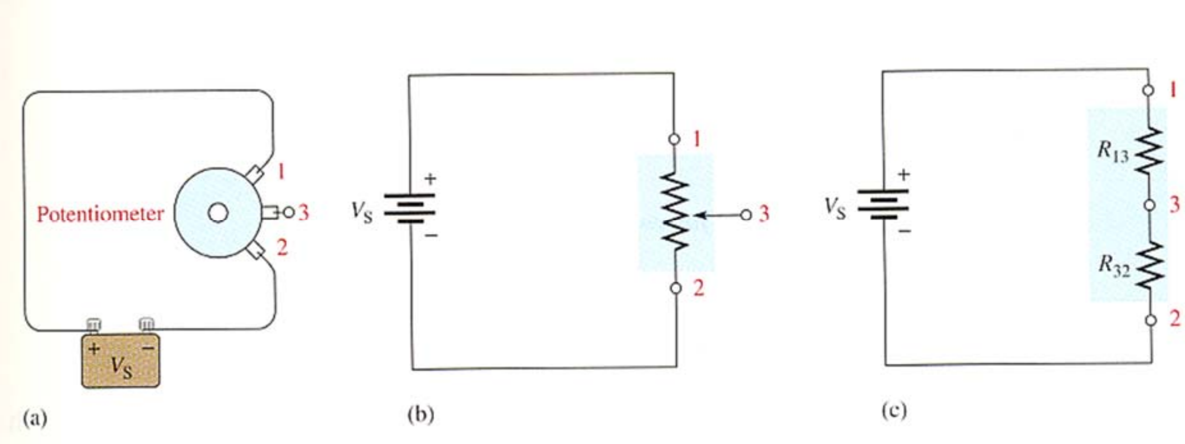


Fig 16-1 The Potentiometer as a voltage divider.

17 Power and energy in electrical circuits
Energy and power

Power

$$P = V\,I$$
$$P = I^2\,R$$
$$P = V^2 / R$$

Power is the rate of doing work. The faster the work is done, the more power is required.

Power is represented by, **P** and its unit is **Watts (W)** or **Joules/second (J/s).**

One watt of power is obtained when a current of one ampere passes through a potential difference of one volt.

Energy

Energy = Power (P) x Time (t)

Energy is the capacity for doing work.

Energy may exist in several forms and may be changed from one form to another.

A lead-acid cell changes chemical energy to electrical energy on discharge and vice-versa on charge. A generator changes mechanical energy to electrical energy; an electric radiator converts electrical energy to heat energy, and etc.

Work cannot be done without energy being used, and the amount of work done is a measure of the energy used. The electrical energy taken from a source depends on the electrical power of the appliance and the length of time used.

Energy is represented by, **E** and its unit is **Joules (J)** or **Watt- second (Ws)**
when we deal with a large amount of energy.

It is often convenient to express it in **kilowatt-hours** (kWh) rather than in joules.

1 kWh = 1000 Watt-hours
= 1000 x 3600 watt-second (or Joules)
= 3600000 Joules
= 3.6 mega-joules (MJ)

Cost of energy:
The cost of electrical energy is calculated by multiplying the number of units of energy consumed in kWh and the cost per unit.
1 unit = 1 kWh

18 Power in a Series and Parallel Circuit

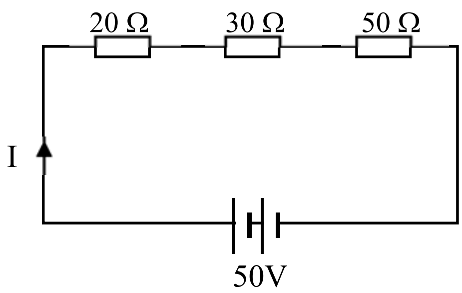
18-1 Power in a Series Circuit

The total amount of power in a series circuit is equal to the sum of the powers in each resistor in series.

$$\begin{aligned} \textit{Total}\text{ power}, P_T &= P_1 + P_2 + P_3 + ... \\ &= \mathrm{I}^2 R_1 + \mathrm{I}^2 R_2 + \mathrm{I}^2 R_3 + ... \\ &= \frac{\mathrm{V}_1^{\ 2}}{R_1} + \frac{\mathrm{V}_2^{\ 2}}{R_2} + \frac{\mathrm{V}_3^{\ 2}}{R_3} + ... \\ &= \mathrm{I}^2 R_T = \frac{\mathrm{V}_\mathrm{T}^{\ 2}}{R_T} \end{aligned}$$

Example 13

Determine the total amount of power and the power dissipated in the 30Ω resistor.



Solution:

Total resistance, R_T = 20 + 30 + 50

= 100 Ω

Total power = $\frac{V^2}{R_T} = \frac{50^2}{100} = \underline{\underline{25\,W}}$

Current, I = $\frac{V}{R_T} = \frac{50}{100} = 0.5\ A$

Power dissipated by 30 Ω resistor

= 0.5^2 X 30 = $\underline{\underline{7.5\,W}}$

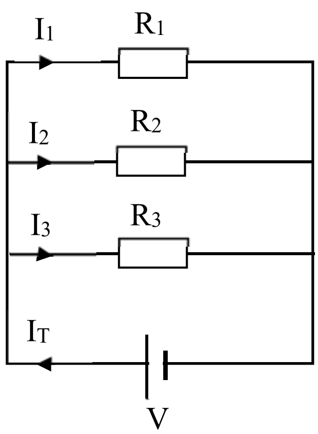
Exercise

A 60Ω and XΩ resistors are connected in series across the 30V supply. If the current is 0.2 A, determine:

(a) the total resistance;
(b) the unknown resistance;
(c) the voltage across each resistor;
(d) the power dissipated in each resistor;
(e) the total power.

18-2 Power in a Parallel Circuit

The total amount of power in a parallel circuit is equal to the sum of the powers in each resistor in parallel.



$$P_T = P_1 + P_2 + P_3$$

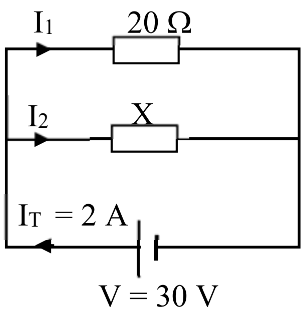
$$= I_1^2 R_1 + I_2^2 R_2 + I_3^2 R_3$$

$$= I_T^2 R_T = VI_T = \frac{V^2}{R_T}$$

Example 14

A 20Ω and XΩ resistors are connected in parallel across a 30V supply. If the total current is 2A, determine:

(a) the total resistance;
(b) the unknown resistance;
(c) power dissipated in each resistor;
(d) the total power.



Solution:

$$(a)\ \text{Total resistance, } R_T = \frac{V}{I_T}$$

$$= \frac{30}{2} = \underline{\underline{15\,\Omega}}$$

$$(b)\ \frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{X}$$

$$\frac{1}{X} = \frac{1}{R_T} - \frac{1}{R_1} = \frac{1}{15} - \frac{1}{20} = 0.0167$$

$$\therefore\ X = \frac{1}{0.0167} = \underline{\underline{60\,\Omega}}$$

$$(c)\ \text{Power consumed by } 20\,\Omega \text{ resistor}$$

$$= \frac{V^2}{R_1} = \frac{30^2}{20} = \underline{\underline{45\,\text{W}}}$$

$$\text{Power consumed by } X\,\Omega \text{ resistor}$$

$$= \frac{30^2}{60} = \underline{\underline{15\,\text{W}}}$$

$$(d)\ \text{Total power} = 45 + 15 = \underline{\underline{60\ \text{W}}}$$

Exercise

A colour television rated at 1600 W operates for 5 hours a day for 30 days.
(a) What is the total energy consumed?
(b) What is the monthly consumption cost if the cost per unit is 18 cents?