CHAPTER TWO
ELECTRICAL & ELECTRONIC QUANTITIES
VOLTAGE, CURRENT & RESISTANCE
OHM'S LAW, ENERGY & POWER

Objectives:

- To learn the concept of electrical charge.
- To learn the concept of voltage.
- To learn the concept of current.
- To learn the concept of resistance.

1-1 Electrical Charge Q:

The most basic components of an electrical charge are the electron and the hole. The electron exhibits a negative charge while a hole (which is the absence of an electron) exhibits a positive charge. A material is negatively charged when it contains more electrons than holes. The opposite is true, a material is positively charged when it contains more holes than electrons.

The **symbol** for electrical charge is **'Q'** and its **unit** is the **Coulomb** which is abbreviated by the letter **'C'**.

A single Coulomb is the total charge accumulated by 6.25 × 10^{18} electrons.

This implies that a single electron has a charge of 1.6 × 10^{-19} C. Let N be the number of electrons and Q the charge associated with that N electrons. **Equations 2-1 & 2-2** helps to determine the total charge Q associated with a number of electrons N while **Equation 2-3 & 2-4** helps determine the number of electrons N associated with a certain charge Q. **Examples 2-1** and **Example 2-2** illustrate what is the charge associated with certain number of electrons and how many electrons correspond to certain electrical charges.

$$Q = \frac{N}{6.25 \times 10^{18}} \qquad (2-1)$$

$$Q = N \times 1.6 \times 10^{-19} \qquad (2-2)$$

$$N = \frac{Q}{1.6 \times 10^{-19}} \qquad (2-3)$$

$$N = Q \times 6.25 \times 10^{18} \qquad (2-4)$$

Where N is the number of electrons and Q is the charge associated with it.

Example 2-1:

How many coulombs of charge are associated with 75×10^{18} electrons?

Solution:

This could be solved in either one of two methods, depending on which equation to determine Q is used:

First method: Using Equation (2 - 1):

$$Q = \frac{N}{6.25 \times 10^{18}}.$$

$$Q = \frac{75 \times 10^{18}}{6.25 \times 10^{18}} = 12 \text{ Coulombs} = 12 \text{ C}$$

Second method: Using Equation (2-2)

$$Q = N \times 1.6 \times 10^{-19}$$

$$Q = 75 \times 10^{18} \times 1.6 \times 10^{-19} = 120 \times 10^{-1} = 12 \text{ Coulombs} = 12 \text{ C}$$

Example 2-2:

How many electrons are associated with a charge of 0.024 coulombs?

Solution:

This could be solved in either one of two methods, depending on which equation to determine Q is used:

First method: Using equation (2 - 3):

$$N = \frac{Q}{1.6 \times 10^{-19}}.$$

$$N = \frac{0.024}{1.6 \times 10^{-19}} = 1.5 \times 10^{17} \text{ Electrons.}$$

Second method: Using equation (2 - 4):

$$N = Q \times 6.25 \times 10^{18}.$$

$$N = 0.024 \times 6.25 \times 10^{18} = 1.5 \times 10^{17} \text{ Electrons.}$$

2-2 Voltage:

As indicated earlier, electrical charge can be either positively or negatively charged. Part of the characteristics of charge is that a force of attraction exists between a positive and a negative charge. If the positive and negative charges are separated from each other, they will posses a certain potential energy which is also known as the potential difference. This potential difference is commonly known in electrical terms as voltage and has the symbol "V". In equation form, V, W and Q are expressed by **Equation 2-5, 2-6 and 2-7.**

$$V = \frac{W}{Q} \qquad (2-5)$$

$$W = Q \times V \qquad (2-6)$$

$$Q = \frac{W}{V} \qquad (2-7)$$

Where:
V is the voltage expressed in volts (V).
W is expressed in Joules (J) and it is the work done to move the charge Q expressed in coulombs (C) from one point to another. More specifically, the potential difference between two points is equal to 1 Volt when 1 Joule of energy moves 1 Coulomb of charge.

Figure 2-1 shows the relationship between **W**, **Q** and **V**. and **example 2-3** through **example 2-5** further illustrate the relationship between W, Q and V.

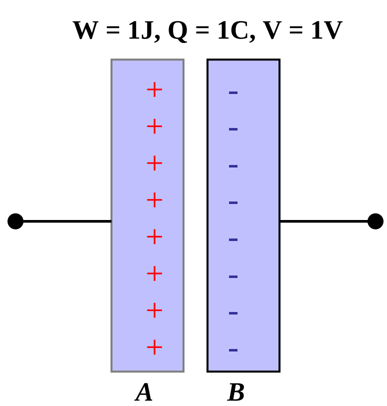


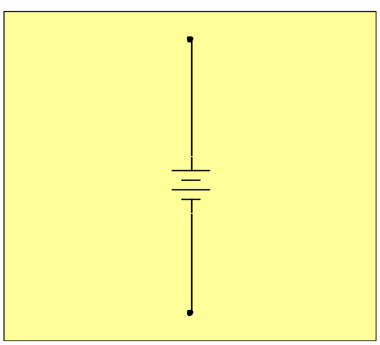
FIGURE 2-1. Using 1J to move 1C from A to B produces 1V.

In **Figure 2-1** the negative charges also called electrons go through a recombination process with the positive charges also called holes. This will eventually render the difference of potential to a zero value unless the flow of electrons is sustained through an independent energy source. When the potential difference is maintained, it is then called the **electromotive force**.

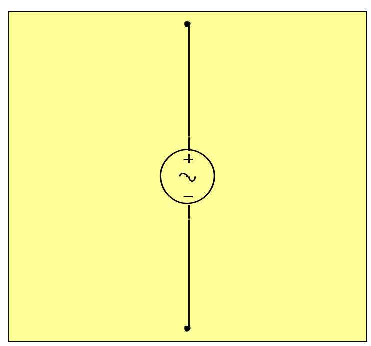
Typical devices that are considered as voltage sources are the **battery** which is a voltaic cell that converts chemical energy into electrical energy, the **electronic power supply** which converts AC voltage into DC voltage, the **solar cell** which is a photovoltaic cell that converts light energy into electrical energy and finally the **generator** which operates on the principal of electromagnetic induction to convert mechanical energy into electrical energy.

For all electronics components, there is always an Ideal and a practical case. This includes voltage sources. An ideal voltage source is one that can supply a constant voltage for an unlimited amount of time, regardless of the amount of current it must deliver. **Such a voltage source will have a zero-value internal resistance.** On the other hand, a none-ideal or practical voltage source is one that will change in value if the amount of current drawn from it changes. **This is because its internal resistance has none-zero for a value, and it drops a voltage across it that is dependent on the amount of current drawn.**

Whether ideal or none-ideal, voltage sources could be of two types, AC and DC voltage sources. DC voltages are ideally constant in value and could a positive or negative polarity. AC voltages on the other hand are voltages that alternate between positive and negative values in a periodic waveform pattern. Symbols for AC and DC voltage sources are shown in **Figure 2-2**.



2-2. a. Independent DC Voltage Source



2-2. b. Independent AC Voltage Source

FIGURE 2-2. AC And DC Voltage Sources Symbols.

Example 2-3:
How many volts are generated when 3 milli joules are required to move 0.5 uCoulombs between two points?

Solution:
From equation 2-5, the voltage V is given by:

$$V = \frac{W}{Q}$$

Therefore: $V = \frac{3mJ}{0.5uC}$ = (3/0.5) (m/u) (J/C) = 6 KVolts.

Example 2-4:
How many Joules (energy) are required to move 7 Coulombs of charge between two Points and produce a potential difference (voltage) of 4 Volt?

Solution:
From equation 2-6, the Energy required is given by:

$$W = Q \times V$$

Therefore: $W = 7C \times 4V$ = 28 Joules.

Example 2-5:
How many Coulombs (charge) are moved between two points when 5.75 Volts are generated when exerting an energy of 46 Joules?

Solution:
From equation 2-7, the Energy required is given by:

$$Q = \frac{W}{V}$$

Therefore: $Q = \frac{46J}{5.75V}$ = 8 Coulombs.

2-3 Current:

Recall from section 2-2 that the voltage is a difference of potential between two points. Any time there is a difference of potential across an element, then charges will move from one end of the element to the other end provided there is a closed loop path from that point to the other point. If the element is a perfect conductor, then those moving charges are electrons. In other elements which are classified as semiconductors, those moving charges could be positive ions (holes), negative ions (electrons) or both. Regardless of what charges constitute those movements, such movements are classified as current flow.

2-3.1 Conventional verses Electron Current Flow:

There are two schools of thought regarding in which direction current flows. One is the conventional current flow (adopted by scientists, physicist, and engineers); the other is the electron flow (adopted by technicians). The conventional current flow is a result of the movement of positive charges while the electron flow is the movement of electrons. Therefore, the direction of the conventional current flow is from positive to negative since this is how a positive charge moves. On the other hand, the direction of the electron current flow is from negative to positive since this is how an electron moves. **Figure 2-3** and **Figure 2-4** represent the conventional current flow and the electron current flow respectively. The Plus and Minus signs in the figures represent the voltage drops across the resistances. Notice from both figures that regardless which direction the current flows out of the voltage source, the voltage drops across the resistors have the same polarity. In this text, the electron current flow will be adopted when referring to current.

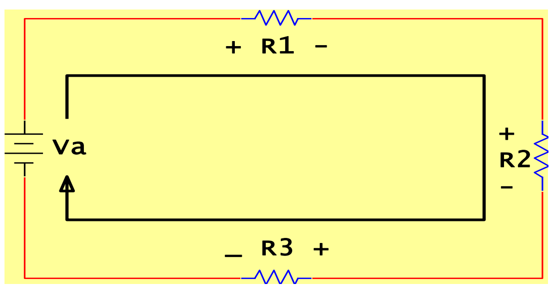


FIGURE 2-3. Conventional Current Flow from Positive to Negative

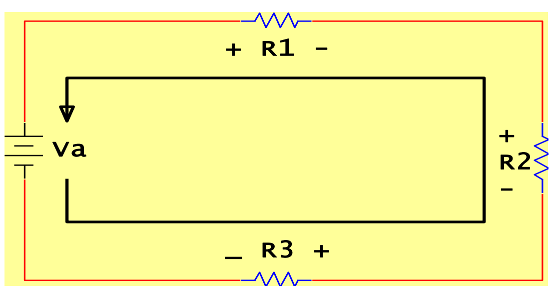


FIGURE 2-4. Electron Current Flow from Negative to Positive

2-3.2 Current Measurement Unit and Current Sources:

Current is the movement of charge. The unit of the current is the Ampere abbreviated as "A". By definition, the current I is equal to 1 Ampere when 1 Coulomb of charge flows past a certain point in one Second. So as an example, if 3 Coulombs flow past a certain point in 12 seconds, then the amount of current I is 3 Coulombs divided by 12 Seconds to yield a value of I = 0.25A. In equation form, the current I is given by Equation 2-8.

$$I = \frac{Q}{t} \qquad (2-8a)$$

$$Q = It \qquad (2-8b)$$

$$t = \frac{Q}{I} \qquad (2-8c)$$

Current sources are designed to source a constant current. In fact, an ideal current source is one that sources a constant current regardless of the amount of resistance in its path. Opposed to that are practical current sources which are actually electronic circuits can only maintain a constant current over a limited range of resistance values. All current sources specified in this text are considered to be ideal unless otherwise specified. The symbol for the current source is shown in **Figure 2-5**.

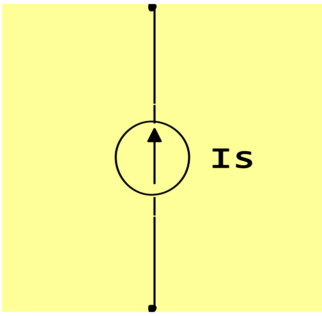


FIGURE 2-5. Independent Current Source Symbol

2-4 Resistance:

All electrical and electronic circuits have resistances. A resistance is defined as the opposition to the current flow. In a circuit, a higher resistance will yield a lower current for a certain applied voltage. On the other hand, a lower resistance will yield a higher current for that same applied voltage. In mathematical terms, the current and resistance are inversely proportional to each other.

A resistance is the quantity measure of the resistor component. It is abbreviated by “R”, and it has the ohms unit (Ω**).** Theoretically, it ranges in values from 0 Ω**s** (short circuit which is a wire) to very high resistor values in the Mega ohms to infinity (open circuit). Resistors are classified under two categories: Fixed and variable. Variable resistors are made to be adjusted form 0 ohms up to a value that is dependent on the actual variable resistor. Fixed resistors on the other hand are manufactured using different technologies such as: Carbon-composition resistors, film resistors, wire-wound resistors and surface-mount resistors. As this is a supplemental text, refer to your classroom text for a detailed discussion of resistor types and only the fixed carbon-composition resistors will be discussed in detail. The Resistor symbols for a fixed and variable value resistor are shown in Figure 2-6

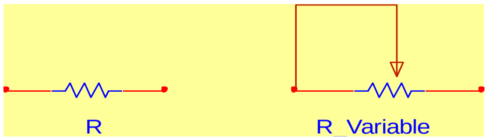


FIGURE 2-6. Fixed (Left) and variable resistor (Right) symbols

All resistors share three common characteristics that are important:

- The value of the resistor.
- The power rating.
- The tolerance of the resistance from its nominal value.

Such characteristics are determined at the time the resistance is manufactured.

2-4.1 Resistor power rating:

The opposition of the current flow in a resistor causes heat. If the resistor is not designed to properly dissipate the heat, there is a possibility that it can be damaged. The damage can range from a change in the resistance value to a complete disintegration of the resistor.

All resistors have power ratings which indicate the amount of power that they can dissipate without the risk of being damaged. If the amount of power dissipated exceeds the rated value, the resistor could be damaged. The resistor power ratings range from less than 0.1 W to a few hundreds of watts. Typical power ratings are 1/8, ¼, ½, 1 and 2 watts.

2-4.2 Resistor Tolerance:

All resistors cannot be manufactured to their precision nominal value. Rather, there is a certain degree of variation between the same resistors that are even manufactured by the same manufacturer and same process. The allowable amount of variation by the manufacturer is expressed as a percent of the resistor nominal value and it is called the **tolerance.** The most common resistor tolerances are: 1%, 2%, 5%, 10% and 20% and could be as low as 0.05%. All resistors that have a tolerance up to 2% are called **precision resistors**.

How can the resistance value of a resistor be determined? In some instances, and for some resistors, the value is printed on the resistors. However, for physically small resistors, this is impractical. Instead, color coding the resistance value is used.

2-4.3 Resistor Color Code:

Color coding resistors is used where it is impractical to print the resistance value on the resistor in such a way it is readable. Instead, colors are used to indicate the resistance value of a resistor. This is done by coloring the marking the resistors with 3 to 5 colored bands to indicate their values. **Table 2-1** indicates each color with its corresponding decimal digit value as well as the Band type regardless of its color.

Some resistors have 5-band identification which are used for higher precision (lower tolerance, 1%, 0.5%, 0.25%, 0.1%), to specify a third significant digit. The first three bands represent the significant digits, the fourth is the multiplier, and the fifth is the tolerance. Five-band resistors with a gold or silver 4th band are sometimes encountered, generally on older or specialized resistors. The 4th band is the tolerance and the 5th is the number of resistors that might fail per 1000 hours of operation.

To calculate a four-band resistance value based on the colors in Table 2-1, the bands are read from left to right and their associated digits or multipliers are used correspondingly. See examples 2-6 and 2-7 for calculating the resistance while adhering to the color codes.

Color	1st band	2nd band	3rd band (multiplier)	4th band (tolerance)	Failures / 1000 Hours
Black	0	0	$\times 10^0$		
Brown	1	1	$\times 10^1$	±1%	1%
Red	2	2	$\times 10^2$	±2%	0.1%
Orange	3	3	$\times 10^3$		0.01%
Yellow	4	4	$\times 10^4$		0.001%
Green	5	5	$\times 10^5$	±0.5%	
Blue	6	6	$\times 10^6$	±0.25%	
Violet	7	7	$\times 10^7$	±0.1%	
Gray	8	8	$\times 10^8$	±0.05%	
White	9	9	$\times 10^9$		
Gold			$\times 10^{-1}$	±5%	
Silver			$\times 10^{-2}$	±10%	
None				±20%	

Table 2-1. Description of 4 and 5 band resistor color codes.

Example 2-6
A 4-band resistor has the following-colored markings:
Red Violet Green Silver.
Find the value of its resistance.

Solution:
Referring to Table 2-1:

Red Violet Green Silver = **2 7** × **10^5** = **2.7 MΩ Nominal Value**
Red Violet Green Silver = **2 7** × **10^5** +/- **10%** yields:

A nominal value of **27 × 100000 Ω = 2700000.0 Ω = 2700000.0 Ω × 10^0 = 2.7 × 10^6 = 2.7 MΩ.**
A tolerance value of 0.1 × **2700000 Ω = 270000 Ω = 0.27 MΩ.**
A minimum value of **2700000 Ω - 270000 Ω = 2430000 Ω = 2.7 MΩ - 0.27 MΩ = 2.43 MΩ.**
A maximum value of **2700000 Ω + 270000 Ω = 2970000 Ω = 2.7 MΩ + 0.27 MΩ =2.97 MΩ.**
The range of values that the ohmmeter will indicate will be:
2.43 MΩ < R < 2.97 MΩ.

Example 2-7
A resistor has the following colored markings:
Blue Black Brown Gold.
Find the value of its resistance.

Solution:
Referring to Table 2-1:

Blue Black Brown Gold = **6 0** × **10^1** +/- **5%** yields:

A nominal value of 60 × **10 Ω = 600 Ω.**
A tolerance value of 0.05 × **600 = 30 Ω.**
A minimum value of **600 Ω - 30 Ω = 570 Ω.**
A maximum value of **600 Ω + 30 Ω = 630 Ω.**

2-5 Electrical Power:

All voltage and current sources produce energy which is consumed by electrical components. The rate at which energy is consumed is called Power. Power is dissipated in the form of heat when consumed by electrical components. In equation form, Power is given by Equation 2-9.

$$P = \frac{W}{t} \qquad (2-9a)$$

$$W = P \times t \qquad (2-9b)$$

$$t = \frac{W}{P} \qquad (2-9c)$$

Where:
P is the Power consumed and is expressed in Watts (W).
W is the amount of energy and is expressed in Joules (J).
t is the time through which the energy is supplied in Seconds.

Examples 2-8 through 2-10 further illustrate the relation between energy, power and time.

Example 2-8
How much power is dissipated if 125 J of energy are used over a period of 5 seconds?

Solution:
Referring to Equation 2-9a, the power P is given by:

$$P = \frac{W}{t}$$

$$\mathbf{P = \frac{125\ J}{5\ S} = 25\ W.}$$

Example 2-9
How much time is required for 90 J to produce 360 W?

Solution:
Referring to equation 2-9c, the time t is given by:

$$t = \frac{W}{P}$$

$$\mathbf{t = \frac{90\ J}{360\ W} = 0.25\ S.}$$

Example 2-10
How much energy is required to produce 5 W of power in a 200-ms time period?

Solution:
Referring to equation 2-9b, the Energy W is given by:

$W = P \times t$

$\mathbf{W = 5\ W \times 200\ ms = 1000\ mJ = 1\ J.}$

2-6 Ohm's Law:

In any electrical or electronic circuit, the applied voltage, the current produced and the circuit resistance are mathematically related. This relation states that the current is directly proportional to the applied voltage while at the same time it is inversely proportional to the resistance of the circuit. This relationship is called **Ohm's Law**. In equation form, ohm's law is expressed in Equation 2-10 and its alternates are shown in Equations 2-11 and 2-12.

$$I = \frac{V}{R} \qquad (2-10)$$

$$V = I \times R \qquad (2-11)$$

$$R = \frac{V}{I} \qquad (2-12)$$

Where:
V is the voltage across the resistance R expressed in Volts (V).
I is the current passing through R expressed in Amperes (A).
R is the resistance expressed in Ohms (Ω).

Example 2-11

An electric circuit has an applied voltage of 220 V and has a resistance of 50 Ω. How much current is flowing in the circuit?

Solution:

Referring to equation 2-10a the current I is given by the Ohm's Law equation:

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

$$\mathbf{I = \frac{220\ V}{50\ \Omega} = 4.4\ A}$$

Example 2-12

If a current of 125 ma is flowing through a resistor with a resistance of 30 Ω, how much voltage is dropped cross the resistor?

Solution:

Referring to equation 2-11, the Voltage V is given by the ohm's law Equation:

$$V = I \times R$$

$$\mathbf{V = 125\ ma \times 30\ \Omega = 3750\ mV = 3.75\ V.}$$

Example 2-13

If a certain resistor allows 20 ma when 4.5 V are applied across it. Then what is Its resistance?

Solution:

Referring to equation 2-12, the Resistance is given by:

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

$$\mathbf{R = \frac{4.5\ V}{20\ ma} = 225\ \Omega.}$$

2-7 Power, Current, Voltage, Resistance Equations:

At this point it is only convenient to represent relating **voltage**, **current**, **resistance** and **power** with a series of equations. These equations are shown in T**able 2-2**.

Quantity	Voltage V	Current I	Resistance R	Power P
Equations For Each Quantity	$V = IR$	$I = \frac{V}{R}$	$R = \frac{V}{I}$	$P = VI$
	$V = \frac{P}{I}$	$I = \frac{P}{V}$	$R = \frac{P}{I^2}$	$P = \frac{V^2}{R}$
	$V = \sqrt{PR}$	$I = \sqrt{\frac{P}{R}}$	$R = \frac{V^2}{P}$	$P = I^2R$

Table 2-2. Equations for P, V, I & R

2-8 Solved Problems:

1) Which of the following statements comply with Ohm's law?

a- Voltage is equal to the resistance times current.
b- Current is equal to the resistance times voltage.
c- Voltage is equal to the resistance times the square of the current.
d- Resistance is equal to the current divided by the voltage.

Solution:

Ohm's law is represented by one equation and its alternates which are equations 2-10, 2-11 and 2-12. They are given as:

$$I = \frac{V}{R} \qquad (2-10)$$

$$V = I \times R \qquad (2-11)$$

$$R = \frac{V}{I} \qquad (2-12)$$

Where:

V is the voltage across the resistance R expressed in Volts (V).
I is the current passing through R expressed in Amperes (A).
R is the resistance expressed in Ohms (Ω).

Equation 2-11 clearly shows that the voltage is given as the current times the resistance. Therefore, the answer is "**voltage is equal to the resistance times current".**

---

2) What happens to the current through a resistor when the voltage across it is tripled?

a- Halve.
b- Double.
c- Triple.
d- Does not get affected.

Solution*:*

Again, Ohm's law is represented by one equation and its alternates which are equations 2-10, 2-11 and 2-12. They are given as:

$$I = \frac{V}{R} \qquad (2-10)$$

$$V = I \times R \qquad (2-11)$$

$$R = \frac{V}{I} \qquad (2-12)$$

Where:
V is the voltage across the resistance R expressed in Volts (V).
I is the current passing through R expressed in Amperes (A).
R is the resistance expressed in Ohms (Ω).

Equation 2-10 clearly shows that the current through a resistance R is directly proportional to the voltage across it (i.e. when the voltage increases, the current also increases by the same factor and when the voltage decreases, so does the current by the same factor). Therefore the answer is "**When the voltage is tripled, so will the current".**

---

3) The current in a circuit is 4 A. How will that current change when?

a- The voltage is increased by 25%.

b- The voltage is tripled.

c- The voltage is decreased by 35%.

Solution:

Recall from equation 2 – 10 that the current is directly proportional to the voltage. Both quantities will increase or decrease by the same factor.

$$I = \frac{V}{R} \qquad (2-10)$$

Therefore in:

a- The voltage is increased by 25%.

The current will also increase by 25%. The increase in the value of the current is 25% of 4 A = 0.25 × 4 A = 1 A.

The resulting current value is then:

4A + 1A = 5A.

b- The voltage is tripled.

The current will also triple (multiplied by a factor of 3). The tripled current value will be:

4A × 3 = 12A.

c- The voltage is decreased by 35%.

The current will also decrease by the same percentage which is 35%. The decrease in the current value is then 35% of 4A = 0.35 × 4A = 1.4A.

The resulting current value is then:

4A – 1.4A = 2.6A.

---

4) A given circuit has 250 mA flowing through it. What will happen to the current when?

a- The resistance is increased by 10 %.

b- The resistance is decreased by 30%.

c- The resistance is doubled.

Solution:

From equation 2 – 10, the current is inversely proportional to the resistance (i.e. When the resistance is increased, the current will be decreased by the same factor and when the resistance is decreased, the current will be increased). Therefore in:

a- The resistance is increased by 10 %.

The current will decrease by 10%. The decrease in the current value is:

10% of 250 mA= 0.1 × 250 mA = 25 mA.
The resulting value of the current is then:
250 mA – 25 mA = 225 mA.

b- The resistance is decreased by 30%.
The current will increase by 30%. The increase in the current value is:
30% of 250 mA= 0.3 × 250 mA = 75 mA.
The resulting value of the current is then:
250 mA + 75 mA = 325 mA.

c- The resistance is doubled.
If the resistance doubles, the current will halve since the value of the current is inversely proportional to the resistance and the resistance is increase by a value of 2.
The resulting value of the current is then:
250 mA ÷2 = 125 mA.

---

5) Power is defined as:
a- Friction.
b- Energy consumed.
c- The rate at which the energy is consumed.

Solution:
From equation 2 - 9a shown, it is clear that power is the rate at which energy is used.

$$P = \frac{W}{t} \qquad (2 - 9a)$$

Therefore, the answer is "a","**the rate at which energy is consumed"**.

---

6) To create 2.2 C of charge, how many electrons must be removed from an object?

Solution:
Every 1 C of charge created is equivalent to the removal of 6.25×10^{18} electrons. So to create 2.2 C of charge, the number of electrons that have to be removed is:

2.25 C × (6.25 × 10^{18} per 1C) = 13.75 × 10^{18} electrons.

---

7) What number of electrons is required to produce a charge of 475 mC?

Solution:

Again, every 1 C of charge created is equivalent to the removal of 6.25×10^{18} electrons. So to create 475 mC, the number of electrons needed is:

475 mC × (6.25 × 10^{18} per 1C) = 2.97 × 10^{18} electrons.

---

8) How many Coulombs are equivalent to 0.05 × 10^{15} electrons?

Solution:

Every 6.25×10^{18} electrons are equivalent to a charge of 1 Coulomb. So the number of coulombs equivalent to 0.05×10^{15} is:

0.05 × 10^{15} × (1C per 6.25 × 10^{18}), or stated another way it is given as:
0.05 × 10^{15} ÷ 6.25 × 10^{18} = 0.008 × 10^{-3} C = 8 × 10^{-6} C = 8 μ C.

---

9) How many Coulombs are created by the removal of 18.75 × 10^{18} electrons from an object?

Solution:

Again, every 6.25×10^{18} electrons are equivalent to a charge of 1 Coulomb. So the number of coulombs created by removing 18.75×10^{18} electrons from an object is:
18.75 × 10^{18} × (1C per 6.25 × 10^{18}), or stated another way it is given as:
18.75 × 10^{18} ÷ 6.25 × 10^{18} = 3 C.

---

10) Which of the following is measured in Volts?

Current,
Voltage,
Electromotive Force (emf),
Potential Difference,
Resistance.

Solution:

Voltage, potential difference and electromotive force are the only quantities that are measured in Volts. Current is measured in Amperes while Resistance is measured in Ohms. The EMF is required to maintain a potential difference which is also known as the voltage across the two points where there is a difference of potential.

---

11) If a certain conductor has 5 Coulombs passing through it in 0.25 seconds, then how much current is flowing through it?

Solution*:*
In this problem, the amount of charge Q is 5 C. This charge crosses virtually any point in the conductor every t = 0.25 seconds. Utilizing equation 2-8a, the current I, is given by:

$I = \frac{Q}{t}$, where:

Q is the charge and t is the time. Substituting Q = 5C and t = 0.25S yields:

$I = \frac{5C}{0.25S} = 20A$.

---

12) How much current is flowing in a conductor if 500 µC pass a given point in 100 mS?

Solution*:*
Also in this problem, the amount of charge Q is 500 µC. Again, this charge crosses virtually any point in the conductor every t = 100 mS. Utilizing equation 2-8a, the current I, is given by:

$I = \frac{Q}{t}$. Where:

Q is the charge and t is the time. Substituting Q = 5C and t = 0.25S yields:

$I = \frac{5\ \mu C}{100\ mS} = \frac{5\times10^{-6}\ C}{100\times10^{-3}\ S} = 50\times10^{-6}\ A = 50\ \mu A.$

---

13) When current passes through a certain point in a conductor, charge is transferred. If a current of 300 mA flows past a certain point for 2 S, then how much charge will be transferred?

Solution*:*
In this problem, the amount of current is 300 mA and the time is 2 Seconds. To find the charge transferred equation 2-8b has to be utilized, the charge Q is given by:

$Q = I \times t$. Where:

I is the current and t is the time within which the current passed by a certain point. Substituting I = 300mA and t = 2 Seconds yields:

Q = 300 mA × 2 Seconds = 600 mC.

---

14) What is the amount of charge transferred if a current of 3.75 A flows past a certain point in a wire for 3 minutes?

Solution*:*
Also in this problem, equation 2-8b has to be utilized. Utilizing equation 2-8b, the charge Q is given by:

Q = I × t. Where:

I is the current and t is the time within which the current passed by a certain point. Substituting I = 3.75A and t = 3 minutes = 3 ×60 Seconds = 180 Seconds, yields:

Q = 3.75A × 180 Seconds = 675 C (Coulombs).

---

15) A current of 2A flowing past a certain point in a conductor resulted in a transfer of charge of 3.5 C. How long did that current flow past that point?

Solution*:*
For this problem, equation 2-8c has to be utilized. Utilizing equation 2-8c, the time t is given by:

$t = \frac{Q}{I}$. Where:

Q is the charge transferred and I is the current flow. Therefore, substituting the values of Q and I, t is given by:

$t = \frac{3.5C}{2A} = 1.75$ **S (Seconds).**

---

16) How much time is required for a current of 275 mA to pass through a certain point in order for 3.2 C to be transferred?

Solution*:*
Again, for this problem, equation 2-8c has to be utilized. Utilizing equation 2-8c, the time t is given by:

$t = \frac{Q}{I}$. Where:

Q is the charge transferred and I is the current flow. Therefore, substituting the values of Q and I, t is given by:

$t = \frac{3.2C}{275mA} = 116.36$ **S (Seconds).**

---

17) What is the value of the resistance of a 4 band resistor with the following color codes?

***Brown Black Red Gold*.**

Solution*:*
Referring to Table 2-1 and matching the band place with the proper decimal digits yields:

***Brown Black Red Gold* = 1 0 × 10^2 +/- 5%** yields:

A nominal value of **10 × 100 Ω = 1000 Ω = 1 K Ω.**
A tolerance value of **0.05 × 1000 Ω = 50 Ω.**
A minimum value of **1000 Ω - 50 Ω = 995 Ω.**
A maximum value of **1000 Ω + 50 Ω = 1050 Ω.**

---

18) What is the value of the resistance of a 4 band resistor with the following color codes?

***Orange Orange Red Silver*.**

Solution*:*
Referring to Table 2-1 and matching the band place with the proper decimal digits yields:

***Orange Orange Red Silver* = 3 3 × 10^2 +/- 10%.** yields:

A nominal value of **33 × 100 Ω = 3300 Ω = 3.3 K Ω.**
A tolerance value of **0.1 × 3300 Ω = 330 Ω.**
A minimum value of **3300 Ω - 330 Ω = 2970 Ω.**
A maximum value of **3300 Ω + 330 Ω = 3630 Ω = 3.63 K Ω.**

---

19) What is the value of the resistance of a 4 band resistor with the following color codes?

***Blue** Gray Yellow **4rth Band has no color**.*
Find the value of its resistance.

Solution*:*
Referring to Table 2-1 and matching the band place with the proper decimal digits yields:

Blue** Gray Yellow **No Color **=6 8 × 10^4 +/- 20%** yields:

A nominal value of **68 × 10000 Ω = 680000 Ω = 680 KΩ.**
A tolerance value of **0.2 × 680000 Ω = 13600 Ω = 13.6 KΩ.**
A minimum value of **680 KΩ - 13.6 KΩ = 666.4 KΩ.**
A maximum value of **680 KΩ + 13.6 KΩ = 693.6 KΩ.**

---

20) What is the value of the resistance and the failure rate of a 5 band resistor with the following color codes?

Red** Violet **Green** Orange **Blue** **Brown
Find the value of its resistance.

Solution*:*
Referring to Table 2-1 and matching the band place with the proper decimal digits yields:

Red** Violet **Green** Orange **Blue** **Brown **= 2 7 5 × 10^3 +/- 0.25% of the nominal value. The color code yields:**

A nominal value of **275 × 1000 Ω = 275000 Ω = 275 KΩ.**
A tolerance value of **0.025 × 275000 Ω = 6875 Ω = 6.875 KΩ.**
A minimum value of **275 KΩ - 6.875 KΩ = 268.125 KΩ.**
A maximum value of **275KΩ + 7.875 KΩ = 281.875 KΩ.**

The fifth band has a brown color which indicates that the failure rate is 1 resistor out of every 100 resistors every 1000 hours.

---

21) How much power is dissipated when 75 J of energy are used within a period of 2.5 S?

Solution*:*
Referring to Equation 2-9a, the power P is given by:

$$P = \frac{W}{t}$$

$$\mathbf{P = \frac{75\ J}{2.5\ S} = 30\ W}$$

---

22) How much time is needed to exert 10.38 J of energy if a rate of 200 mW is to be obtained?

Referring to equation 2-9c, the time t is given by:

$$t = \frac{W}{P}$$

$$\mathbf{t = \frac{10.38\ J}{200\ mW} = 51.9\ S}$$

---

23) For an electrical circuit, how much power is dissipated when 50 V is applied across a 5 Ω resistance?

Solution:
From the **"Power P"** Column in **Table 2-2**:

$$P = \frac{V^2}{R}.$$

Substituting values:

$$\mathbf{P = \frac{(50\ V)^2}{5\ \Omega} = 500\ W}$$

---

24) If a resistance of 4.3 KΩ has a 75 mA passing through it, then how much power does it dissipate?

Solution:
From the **"Power P"** Column in **Table 2-2**:

$$P = I^2R.$$

Substituting values:

$$\mathbf{P = (75\ mA)^2 \times 4.3\ K\Omega = 24.1875\ W.}$$

---

25) **For an electrical circuit, how much power is delivered when an applied 50V causes a current of 15 mA to flow through the circuit?**

Solution:
From the **"Power P"** Column in **Table 2-2**:

$$P = VI.$$

Substituting values:

$$\mathbf{P = 50\ V \times 50\ mA\ = 2500\ mW = 2.5\ W.}$$

---

26) **What is the value of the current that must flow through a 3.2 KΩ resistor in order to produce 259.2 mW of power?**

Solution:
From the **"Current I"** Column in **Table 2-2**:

$$I = \sqrt{\frac{P}{R}}.$$

Substituting values:

$$\mathbf{I = \sqrt{\frac{259.2\ mW}{3.2\ K\Omega}}\ = 9\ mA}$$

---

27) **What is the value of the current passing through a 6.8 KΩ resistor that has 500 mV across it?**

Solution:
From the **"Current I"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{I = \frac{500\ mV}{6.8\ K\Omega} = 73.53\ \mu A.}$$

---

28) **What amount of current flows through a 4 MΩ that has 200 V across it?**

Solution:
From the **"Current I"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{I = \frac{200\ V}{4\ M\Omega} = 50\ \mu A.}$$

---

29) **What amount of current flows through a resistor that dissipates 1.75 W of power when it has 200 mV across it?**

Solution:
From the **"Current I"** Column in **Table 2-2**:

$$I = \frac{P}{V}.$$

Substituting values:

$$\mathbf{I = \frac{1.75\ W}{200\ mV} = 8.75\ A.}$$

---

30) **How much voltage is across a 350 KΩ resistor has 100 mA flowing through it?**

Solution:
From the **"Voltage V"** Column in **Table 2-2**:

$$V = IR$$

Substituting values:

$$\mathbf{V = 100\ mA \times 350\ K\Omega = 350\ V.}$$

31) How much voltage is required to produce 200 mW in a 270 Ω resistor?

Solution:
From the **"Voltage V"** Column in **Table 2-2**:

$V = \sqrt{PR}$.

Substituting values:

$$\mathbf{V = \sqrt{200\ mW \times 270\ \Omega} = 7.35\ V.}$$

32) If a resistor dissipates 2.15 W of power when it has 10.5 mA of current flowing through it, how much voltage is across it?

Solution:
Again from the **"Voltage V"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{V = \frac{2.15\ W}{10.5\ mA} = 204.76\ V.}$$

33) How much resistance does a circuit exhibit if an applied 15V to the circuit causes 20 mA of current to flow?

Solution:
From the **"Resistance R"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{R = \frac{15\ V}{20\ mA} = 7500\ \Omega = 7.5\ K\Omega.}$$

34) **What is the value of the resistance that will dissipate 100 mW when a voltage of 25 V is applied to it?**

Solution:
From the **"Resistance R"** Column in **Table 2-2**:

$$R = \frac{V^2}{P}$$

Substituting values:

$$\mathbf{R = \frac{(25\ V)^2}{100\ mW} = 6250\ \Omega\ = 6.25\ K\Omega\,.}$$

---

35) **What is the value of the resistance that will dissipate 250 mW when a current of 50 µA is passing through it?**

Solution:
From the **"Resistance R"** Column in **Table 2-2**:

$$R = \frac{P}{I^2}$$

Substituting values:

$$\mathbf{R = \frac{250\ mW}{(50\ uA)^2} = 100\ M\Omega\,.}$$

---

36) **For the circuit of Figure 2-7, find the value of the current I.**

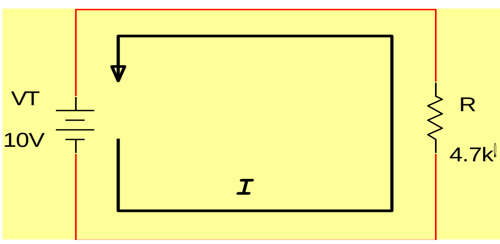


FIGURE 2-7

Solution:

From the **"Current I"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{I = \frac{10\ V}{4.7\ K\Omega} = 2.13\ mA.}$$

---

37) For the circuit of Figure 2-8, what is the resistance value that results in the value of the current shown?

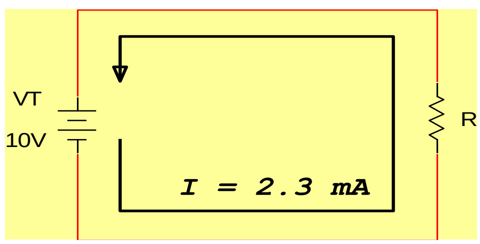


FIGURE 2-8

Solution:

From the **"Resistance R"** Column in **Table 2-2**:

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

Substituting values:

$$\mathbf{R = \frac{10\ V}{2.3\ mA} = 4347.82\ \Omega = 4.35\ K\Omega.}$$

---

38) For the circuit of Figure 2-9 what is the value of the applied voltage V_T that results in the value of the current for the resistance shown?

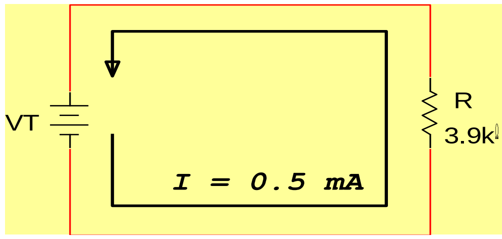


FIGURE 2-9

Solution:
From the **"Voltage V"** Column in **Table 2-2**:

$V = IR$

Substituting values:

$\mathbf{V = 0.5\ mA \times 3.9\ K\Omega = 1.95\ V.}$

---

39) A given resistance in a circuit converts 375 J of electrical energy into heat in 20 seconds. If the resistance has 0.5A flowing through it, then how much is the voltage across it?

Solution:
From Table 2-2, the voltage is given by any of the following equations:

$V = IR$ $\quad\quad V = \sqrt{PR}$ $\quad\quad V = \frac{P}{I}$

Since the resistance is not given in this problem, then the formula $V = \frac{P}{I}$ has to be used. Therefore, the value of the power P has to be obtained. P can be obtained by using equation 2-9a.

$P = \frac{W}{t}$, where: W = 375 J and t = 20 S.

Therefore: $P = \frac{375J}{20\ S} = 18.75\ W.$

With P and I known, V can be found by substituting their values in:

$\mathbf{V = \frac{P}{I} = \frac{18.75\ W}{0.5\ A} = 37.5\ V}$

This concludes Chapter two.