FUNDAMENTALS OF ELECTRICAL AND ELECTRONIC ENGINEERING

OUTLINE (LECTURES 1&2)

LECTURE 1

INTRODUCTION TO EEE
BASIC CONCEPTS AND DEFINITIONS

LECTURE 2

OBJECTIVES OF THE COURSE

1

- ✓ Students should understand basic concept in Electrical Engineering: Charges, Current, Resistor, Voltage, Power, Energy.

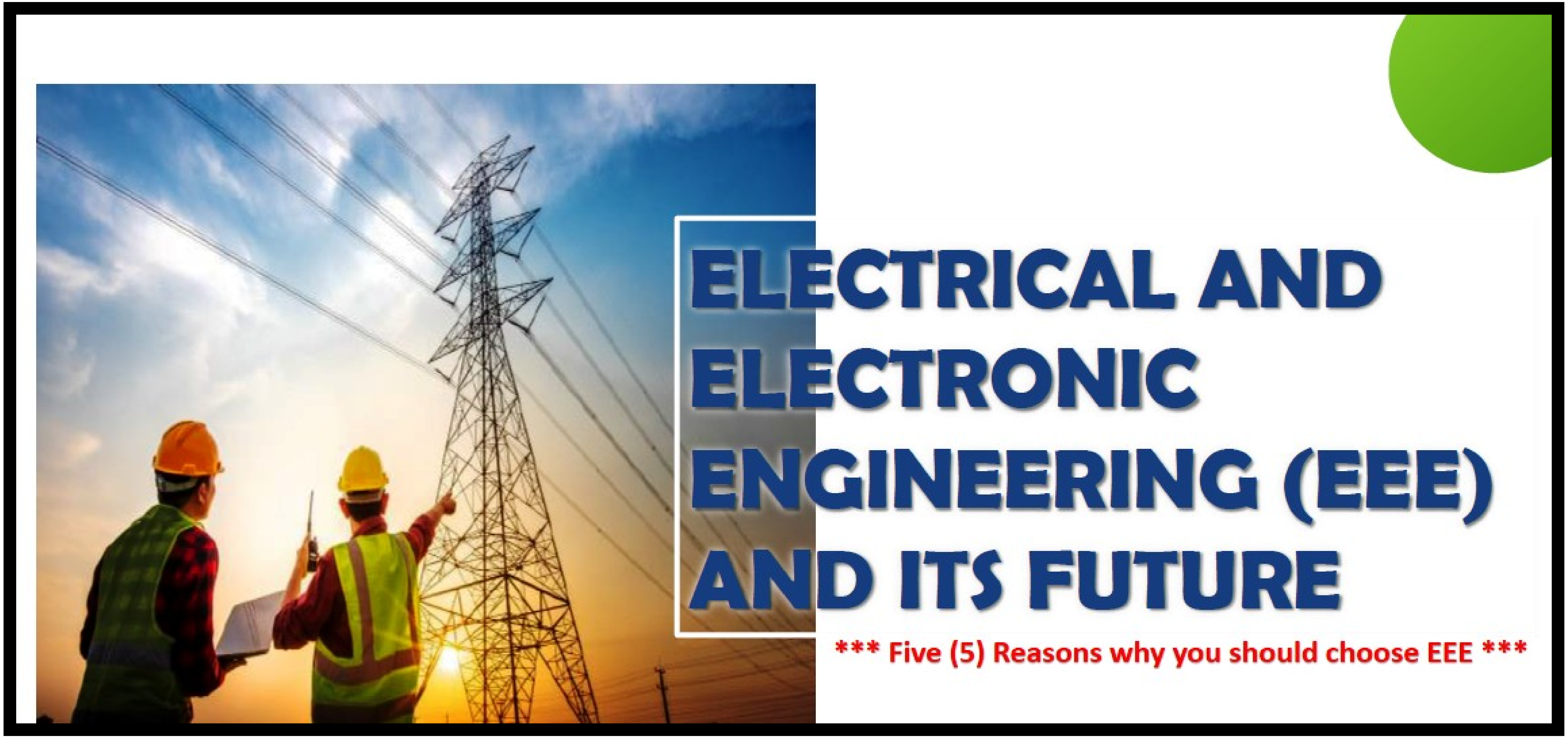
2

- ✓ Students should also understand the principles of ohms law

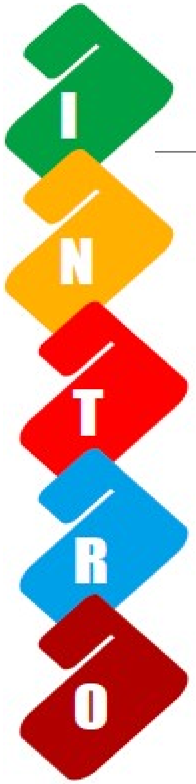
3

- ✓ Students should be exposed to the practical applications of those laws

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING



OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING



Electricity is integral to modern life - power generation, transport, medicine, quantum information, computing, artificial intelligence (AI), cryptography, communications, the list is endless.

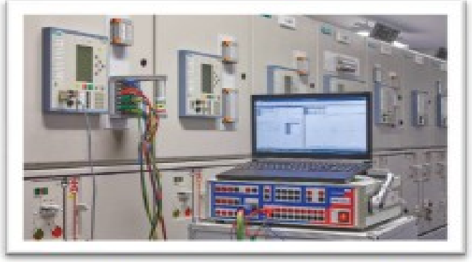
Electrical Electronic Engineering (EEE) is all about learning and making device and equipment that uses electricity and electronics. The students of EEE get an opportunity to contribute to the growth of technology and the course itself facilitates new research ideas. It helps them develop an entrepreneurial mindset.

There are many reasons why many students prefer Electrical and Electronics Engineering and make it their career. These reasons contribute to the growth of the field itself. It is important to understand those reasons to understand the future of this field.

Accra Institute of Technology (AiT), one of the top EEE Engineering colleges in Ghana works round the clock to provide optimum quality of education to the students.

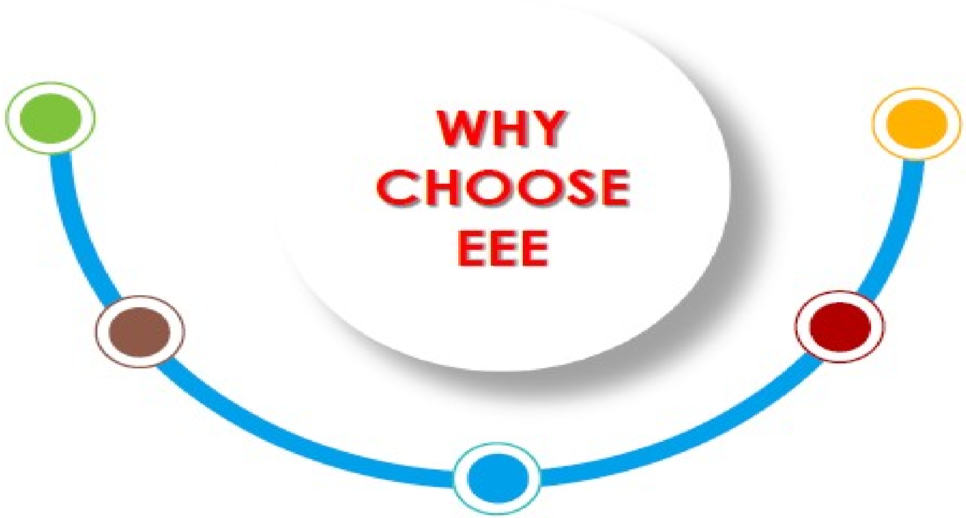
OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

Developing New Technologies



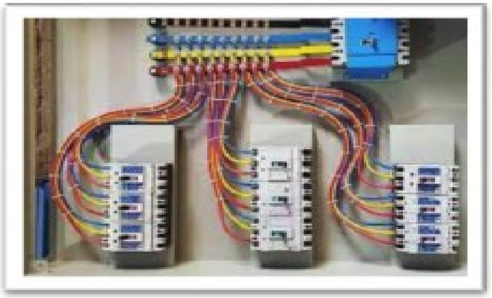
Demand in the Industry

Contribution to the Society

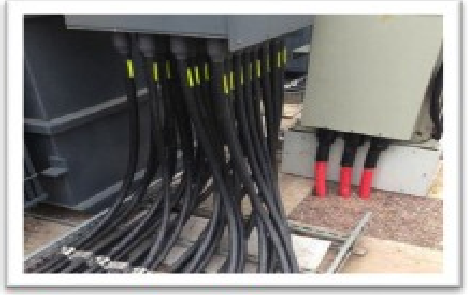


Electrical engineering graduates face much better job prospects than many students who graduate with degrees in the humanities. In 2017, the Federal Reserve Bank of New York reported that electrical engineers with a graduate degree enjoy a 46.4 percent share of the market.

Similarly to the Bureau, the Federal Reserve Bank of New York reports an unemployment rate of 3.3 percent and a median wage for new electrical engineers of $68,000.



Good Salary



Opportunities across the Globe

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

DEVELOPING NEW TECHNOLOGIES

A EEE graduate is responsible for creating new technologies in a variety of industries. The students who are interested in making new inventions and getting involved in the development of unique technologies are bound to choose the EEE course. The services of the EEE engineers are required in the field of robotics, transport, healthcare, and construction

DEMAND IN THE INDUSTRY

The need for people who are able to create and control electrical systems has increased in recent years due to the immense growth of technology. This creates a huge demand for EEE graduates in different industries across the world and they all are paid a very good salary.

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

CONTRIBUTION TO THE SOCIETY

The EEE engineers get a wonderful opportunity to create new systems which benefits the society. If we take smartphones for example, the growth of it has enhanced our way of communication. The improvements in the medical industry has helped to diagnose and treat patients quickly and effectively.

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

OPPORTUNITIES ACROSS THE GLOBE

The Electrical and Electronics engineers receive great job opportunities from top companies across the globe. They also get a chance to study in foreign countries. It is one of the reasons why people who are interested in studying and working abroad choose this course as their career.

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

GOOD SALARY

Electrical and Electronics engineers receive high salaries due to the demand for their support on a regular basis. Society requires them to solve their everyday electrical needs. Due to this reason, the students who are interested in securing a job with higher pay opt for the EEE course.

OVERVIEW OF ELECTRICAL/ELECTRONICS ENGINEERING

In conclusion: Since this is a field in which engineers can work in various industries, the scope of EEE is immense and the graduates in this course have a great opportunity to secure their wonderful future by working with top organizations or starting their own businesses and becoming entrepreneurs.

Studies predict excellent future employment prospects with continued job security and a rise in crossover opportunities and diversification.

There are certain expectations from Electrical engineers in the industry. If the graduates can upgrade their skills in order to meet the expectations, they will have a prosperous future in the field.

BASIC CONCEPTS AND DEFINATIONS

INTRODUCTION

Given an electrical network, the network analysis involves various methods. The process of finding the network variables namely the voltage and currents in various parts of the circuit is known as network analysis. Before we carry out actual analysis it is very much essential to thoroughly understand the various terms associated with the network. In this chapter we shall begin with the definition and understanding in detail some of the commonly used terms.

BASIC CONCEPTS AND DEFINATIONS

HIGHLIGHTS OF ELECTRIC POWER DEVELOPMENTS

Ampère began by repeating Oersted's work, and before the end of **September 1820**, had made a discovery of his own:

1827 Alessandra Volta devised the first electric battery.

The Resistance was discovered by the year 1827 from Georg Simon Ohm, a German electrician.

1830 Sir Humphrey Davy discovered electromagnetism and the arc light.

1831 Michael Faraday demonstrated the process of magnetic induction.

1880 Thomas A. Edison invented a practical incandescent bulb and discovered that lamps could be connected in parallel, permitting one or more to be turned off without disconnecting the whole system.

1882 Edison's Pearl Street electric generating station was placed in operation in New York City.

1888 Nikola Tesla secured patents for an induction motor and for a new Poly phase alternating current system.

1888 After organizing the Westinghouse Electric Company in 1886, George Westinghouse was granted a contract to provide generators for the Niagara hydroelectric project, the first such project in history.

BASIC CONCEPTS AND DEFINATIONS

CHARGE

The most basic quantity in an electric circuit is the electric charge. We all experience the effect of electric charge when we try to remove our wool sweater and have it stick to our body or walk across a carpet and receive a shock.

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C). Charge, positive or negative, is denoted by the letter q or Q.

We know from elementary physics that all matter is made of fundamental building blocks known as atoms and that each atom consists of electrons, protons, and neutrons. We also know that the charge
'e' on an electron is negative and equal in magnitude to 1.602x10-19 C, while a proton carries a positive charge of the same magnitude as the electron and the neutron has no charge. The presence of equal numbers of protons and electrons leaves an atom neutrally charged.

BASIC CONCEPTS AND DEFINATIONS

Electrical Charge

Definition

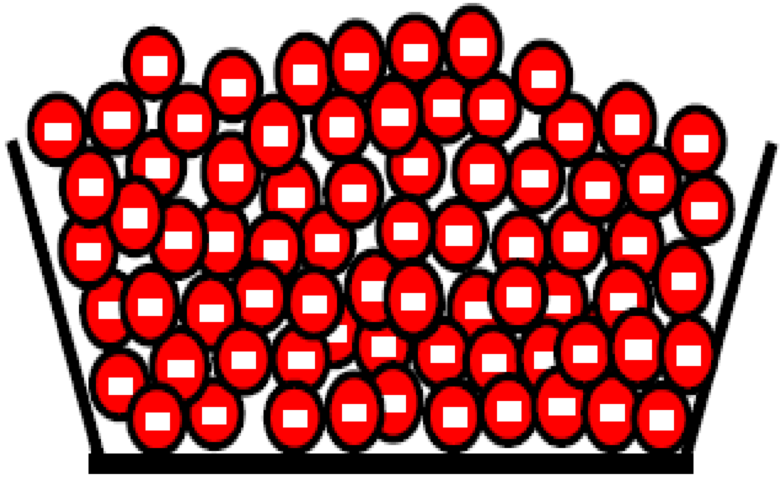
Unit of Electrical Charge Coulomb

6.3×10^{18} electrons $\triangleq$ 1 Coulomb

or

Electrical charge / electron = $1/(6.3 \times 10^{18})$ Coulomb

= 1.602×10^{-19} Coulomb



ELECTRICAL CURRENT

Current can be defined as the motion of charge through a conducting material, measured in Ampere (A). Electric current, is denoted by the letter i or I.

The unit of current is the ampere abbreviated as (A) and corresponds to the quantity of total charge that passes through an arbitrary cross section of a conducting material per unit second. Mathematically,

$$I = \frac{Q}{t} \text{ or } Q = It$$

Where *Q* is the symbol of charge measured in Coulombs (C), I is the current in amperes (A) and t is the time in second (s).

The current can also be defined as the rate of charge passing through a point in an electric circuit. Mathematically,

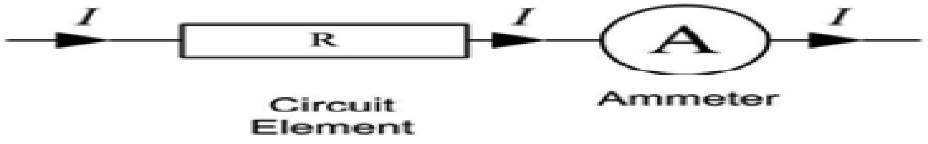
$$i = \frac{dq}{dt}$$

The charge transferred between time t_1 and t_2 is obtained as

$$q = \int_{t_1}^{t_2} i\,dt$$

A constant current (also known as a direct current or DC) is denoted by symbol I whereas a time-varying current (also known as alternating current or AC) is represented by the symbol *i* or *i* (*t*). Figure 1.1 shows direct current and alternating current.

Current is always measured through a circuit element as shown in Fig. 1.1



ELECTRICAL CURRENT

Two types of currents:
1) A direct current (DC) is a current that remains constant with time.
2) An alternating current (AC) is a current that varies with time.

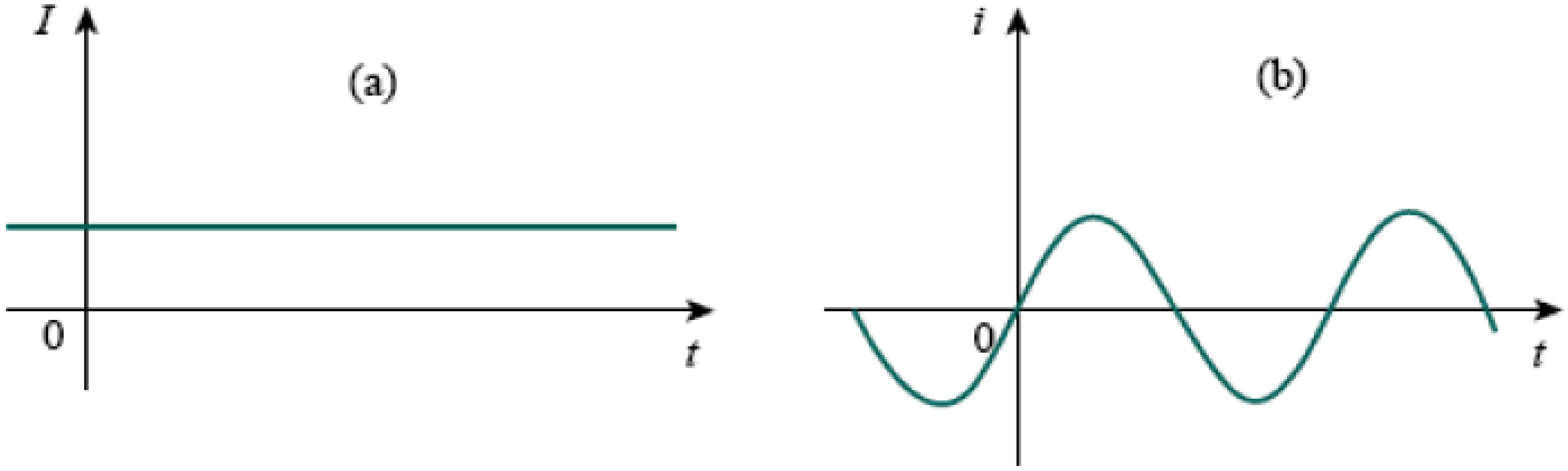
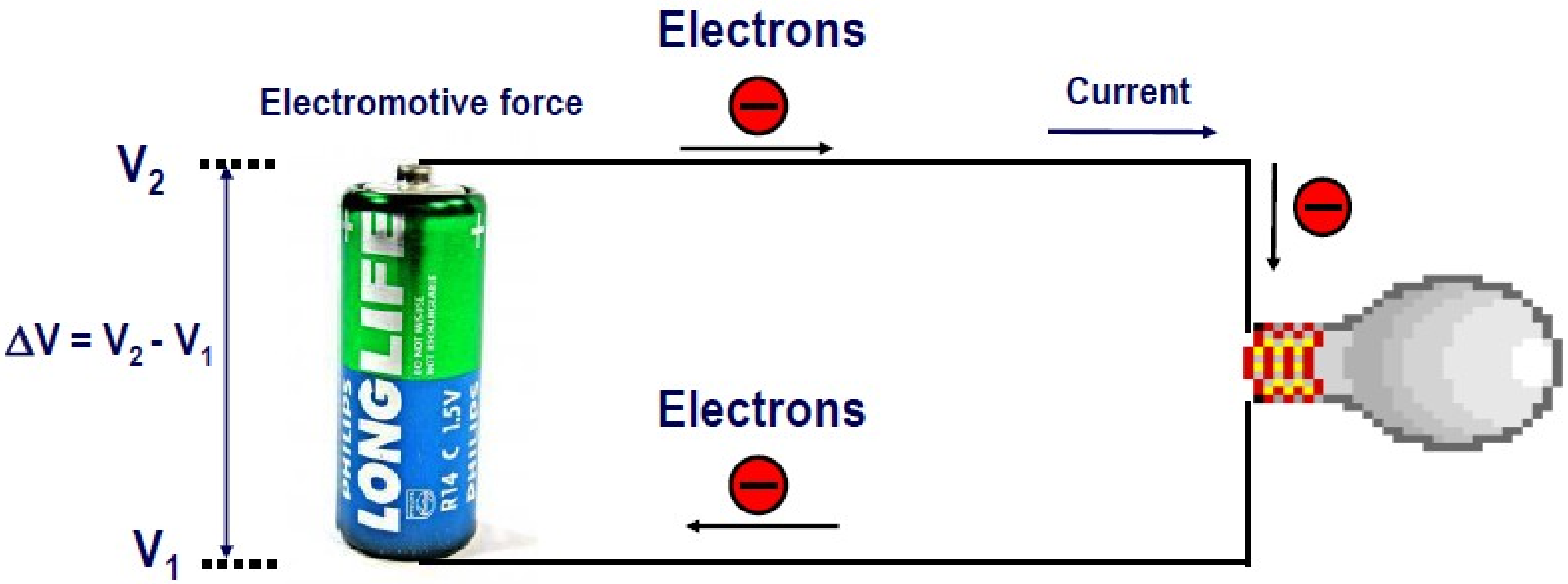


Fig. 1.2Two common types of current: (a) direct current (DC), (b) alternative current (AC)

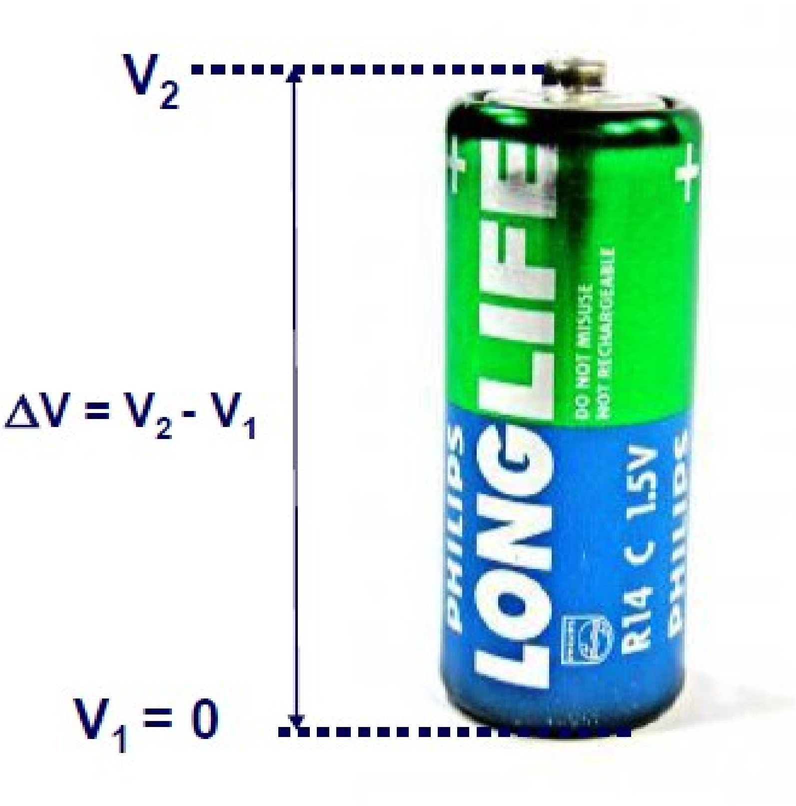
PRACTICAL APPLICATION OF CURRENT & CHARGES

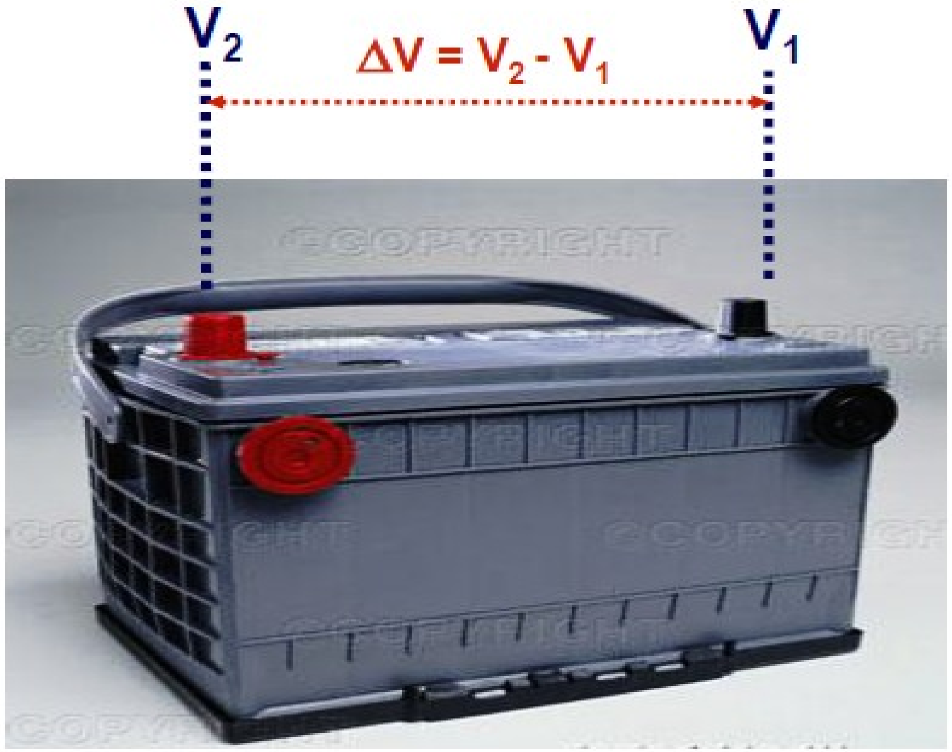
Electrical Current - Basic Principle



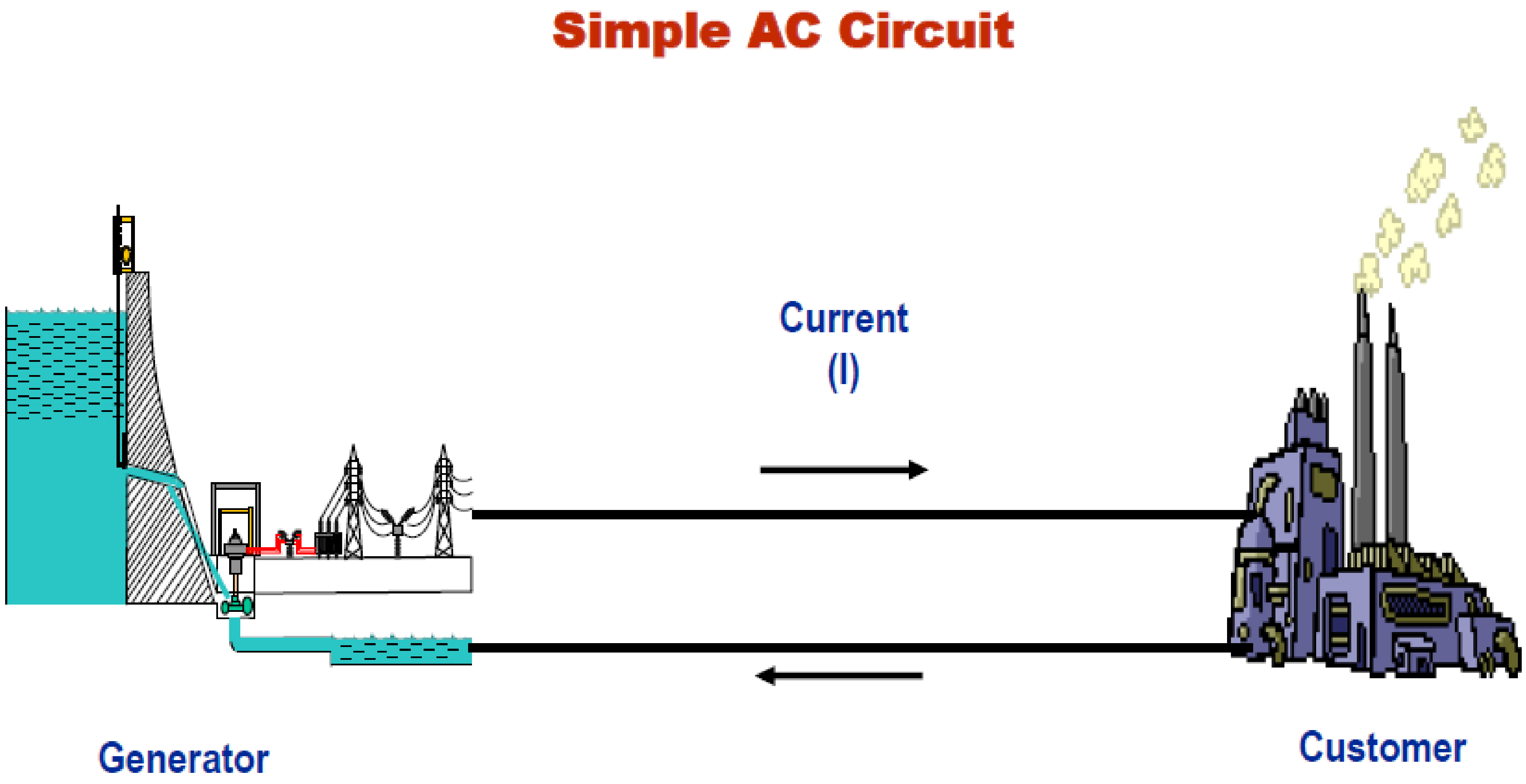
PRACTICAL APPLICATION OF CURRENT & CHARGES

Electrical Current
DC (Direct Current) Sources





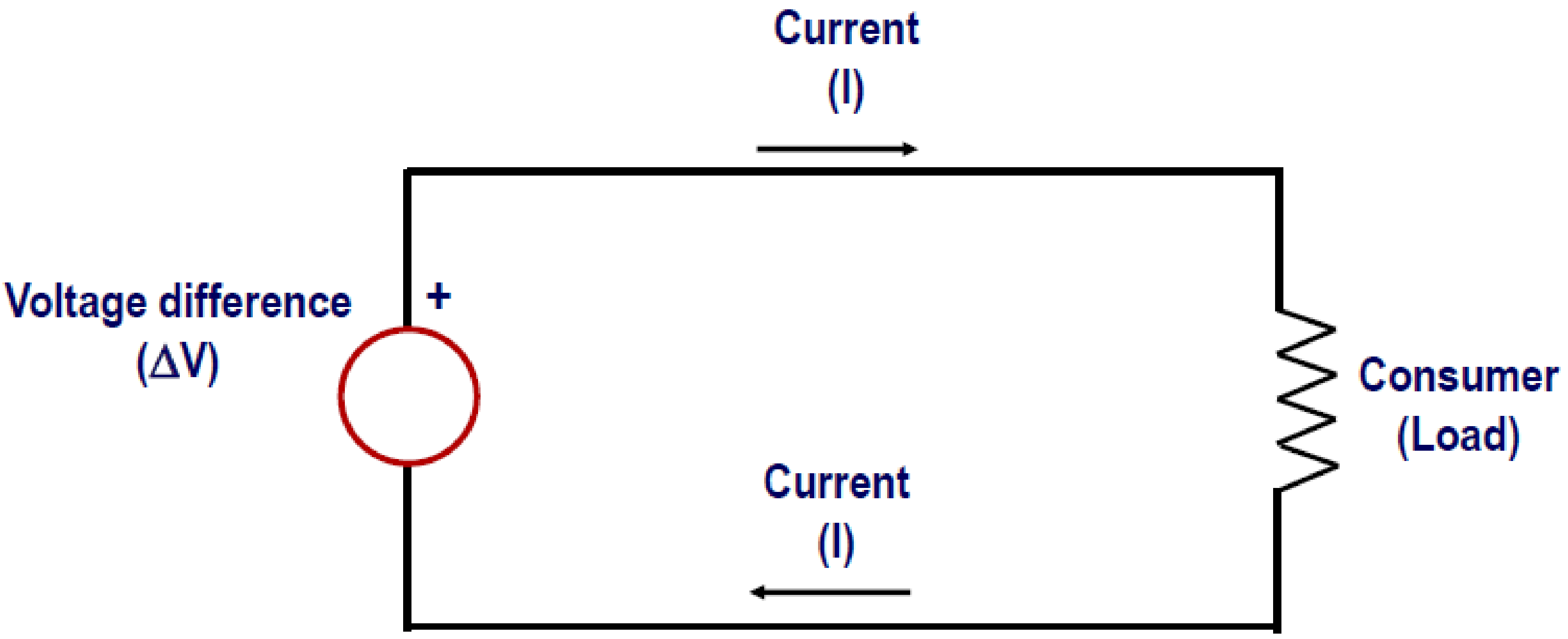
PRACTICAL APPLICATION OF CURRENT & CHARGES



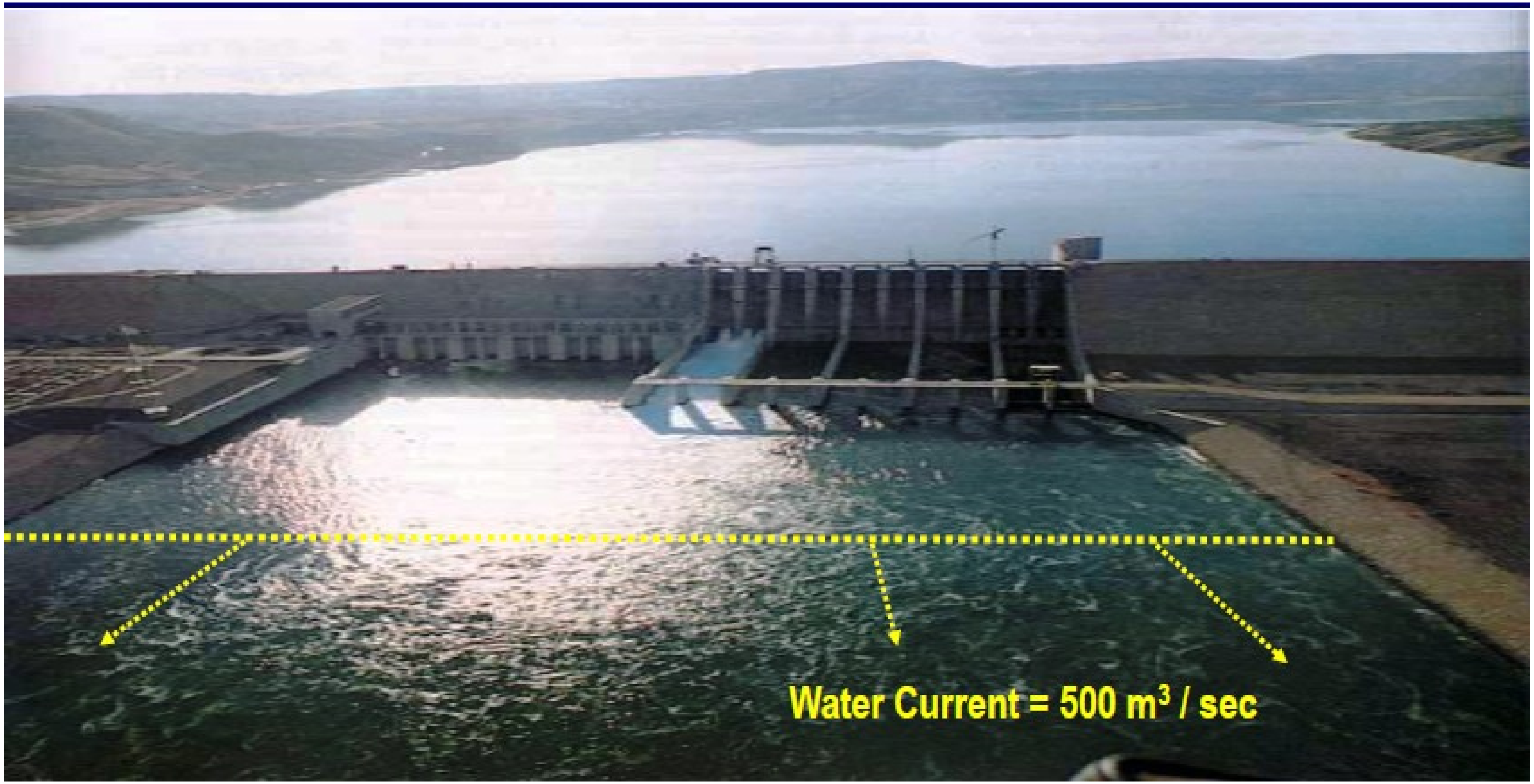
PRACTICAL APPLICATION OF CURRENT & CHARGES

Electrical Current

Current = no. of electrons transferred / time duration $I = \Delta Q / \Delta t$ *1 Amp = 1 Coulomb / 1 Seconds*	Charge = Current x Time duration $\Delta Q = I \times \Delta t$



PRACTICAL APPLICATION OF CURRENT & CHARGES



PRACTICAL APPLICATION OF CURRENT & CHARGES

EXAMPLE 1:

Determine the current in a circuit if a charge of 80 coulombs passes a given point in 20 seconds (s).

EXAMPLE 2:

Determine the total charge entering a terminal between t=1 s and t=2 s if the current passing the terminal is Ii = (3t ^2 − t) A.

PRACTICAL APPLICATION OF CURRENT & CHARGES

Determine the current in a circuit if a charge of 80 coulombs passes a given point in 20 seconds (s).

Solution:

$$I = \frac{Q}{t} = \frac{80}{20} = 4\ A$$

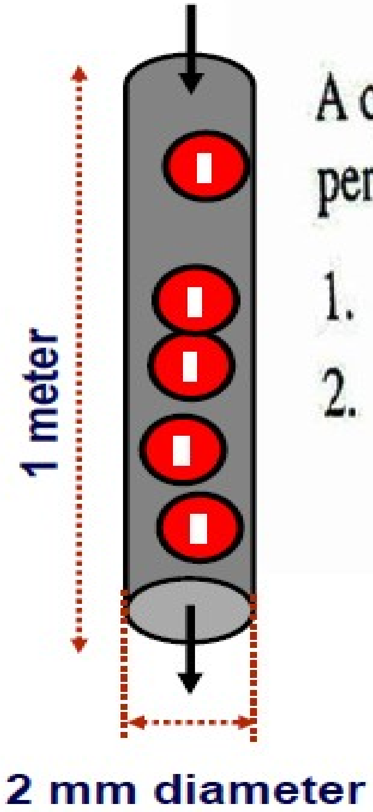
Determine the total charge entering a terminal between t=1 s and t=2 s if the current passing the terminal is i= $(3t^2-t)$ A.

Solution:

$$q = \int_{t=1}^{t=2} i dt = \int_{1}^{2} (3t^2 - t) dt = \left(t^3 - \frac{t^2}{2}\right)_1^2 = (8-2) - \left(1 - \frac{1}{2}\right) = 5.5C$$

PRACTICAL APPLICATION OF CURRENT & CHARGES

Example: Electrical Current

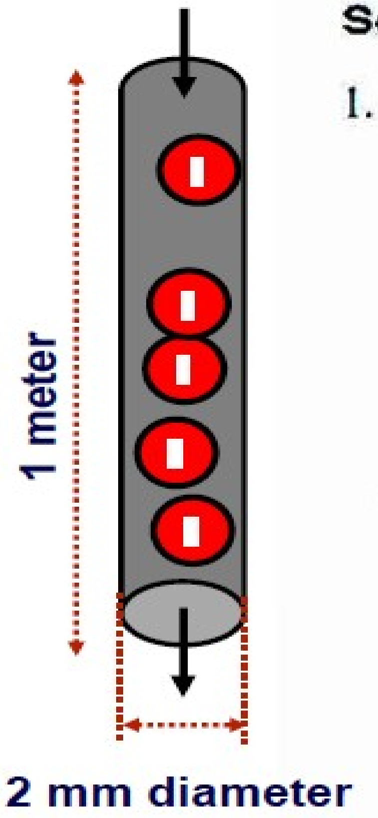


A cylindrical conductor is 1 m long and 2 mm in diameter and contains 10^{29} free carriers per cubic meter.

1. Find the total charge of the carriers in this wire.
2. If the wire is used in a circuit, find the current flowing in the wire if the average velocity of the carriers is 19.9×10^{-6} m/s.

PRACTICAL APPLICATION OF CURRENT & CHARGES

Example: Electrical Current



Solution:

1. In order to compute the total charge contributed by the electrons, we first need to compute the volume of the conductor.

$$\text{Volume} = \text{Length} \times \text{Cross-sectional area}$$

$$= \pi r^2 L = \pi \left(\frac{2 \times 10^{-3}}{2}\right)^2 (1)$$

Next we compute the charge by determining the total number of charge carriers in the conductor as follows:

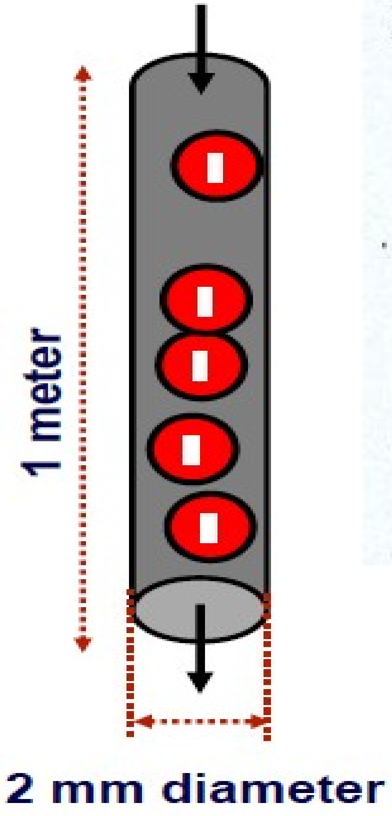
$$\text{Charge} = \text{Volume} \times \frac{\text{Charge}}{\text{Unit volume}}$$

$$Q = \pi \left(\frac{2 \times 10^{-3}}{2}\right)^2 (1)(-1.602 \times 10^{-19}\ \text{C})\left(10^{29}\ \frac{\text{carriers}}{\text{m}^3}\right)$$

$$= -50.33 \times 10^3\ \text{C}$$

PRACTICAL APPLICATION OF CURRENT & CHARGES

Electrical Current



2. If the carriers move with an average velocity of 19.9×10^{-6} m/s, the magnitude of the total current flow in the wire can be computed by considering that current is the flow of charge per unit time:

$$\text{Current} = \text{Charge density per unit length (C/m)} \times \text{Carrier velocity (m/s)}$$

$$= \frac{50.33 \times 10^3}{1} \times 19.9 \times 10^{-6}$$

$$= 1 \text{ A}$$

VOLTAGE OR POTENTIAL DIFFERENCE

To move the electron in a conductor in a particular direction requires some work or energy transfer. This work is performed by an external electromotive force (emf), typically represented by the battery in Fig. 1.3. This emf is also known as voltage or potential difference. The voltage v_{ab} between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b.

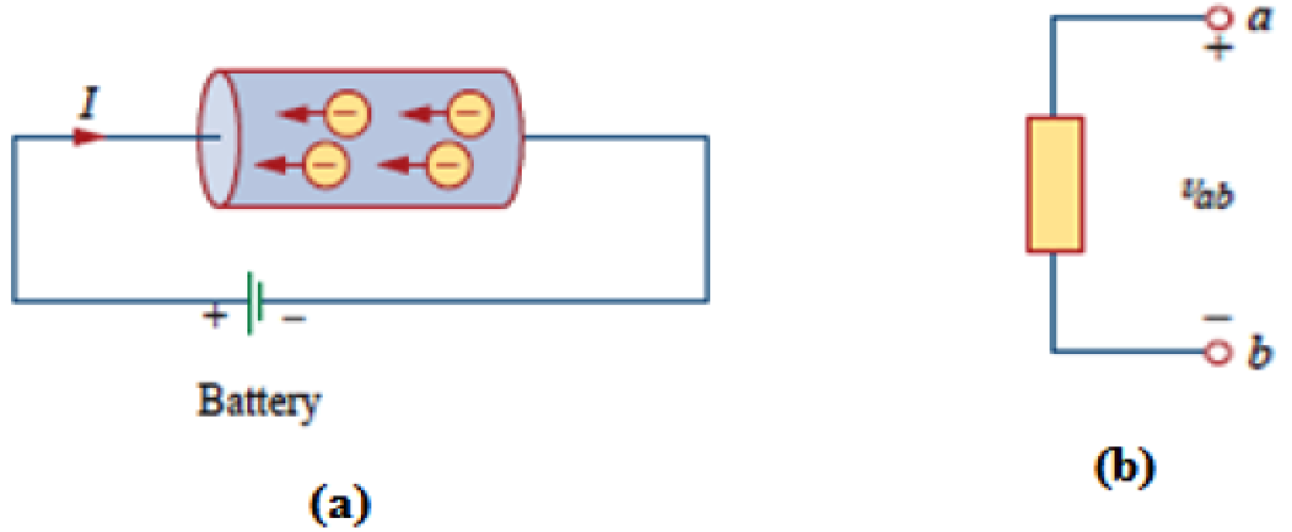


Fig. 1.3(a) Electric Current in a conductor, (b)Polarity of voltage v_{ab}

Voltage (or potential difference) is the energy required to move charge from one point to the other, measured in volts (V). Voltage is denoted by the letter v or V.

VOLTAGE OR POTENTIAL DIFFERENCE: MATHEMATICALLY

$$v_{ab} = \frac{dw}{dt}$$

where w is energy in joules (J) and q is charge in coulombs (C). The voltage v_{ab} or simply V is measured in volts (V).

1 volt = 1 joule/coulomb = 1 newton-meter/coulomb

Fig. 1.3 shows the voltage across an element (represented by a rectangular block) connected to points a and b. The plus (+) and minus (-) signs are used to define reference direction or voltage polarity. The v_{ab} can be interpreted in two ways: (1) point a is at a potential of v_{ab} volts higher than point b, or (2) the potential at point a with respect to point b is v_{ab} . It follows logically that in general

$$v_{ab} = -v_{ba}$$

Voltage is always measured across a circuit element as shown in Fig. 1.4

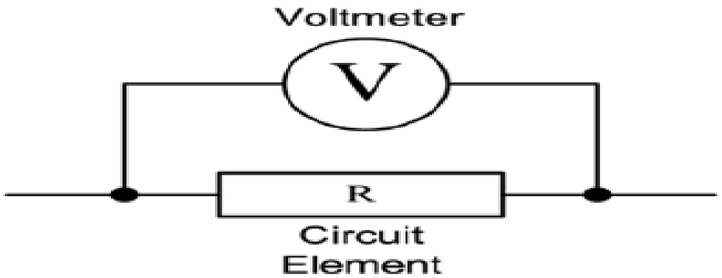


Fig. 1.4 Voltage across Resistor (R)

VOLTAGE OR POTENTIAL DIFFERENCE: MATHEMATICALLY

EXAMPLE 1

An energy source forces a constant current of 2 A for 10 s to flow through a lightbulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

VOLTAGE OR POTENTIAL DIFFERENCE: MATHEMATICALLY

EXAMPLE 1

Solution:

Total charge dq= i*dt = 2*10 = 20 C

The voltage drop is $v = \frac{dW}{dq} = \frac{2.3*10^3}{20} = 115\,V$

VOLTAGE OR POTENTIAL DIFFERENCE: PRACTICAL SUMMARY

Voltage

Definition

Power = Voltage x Current

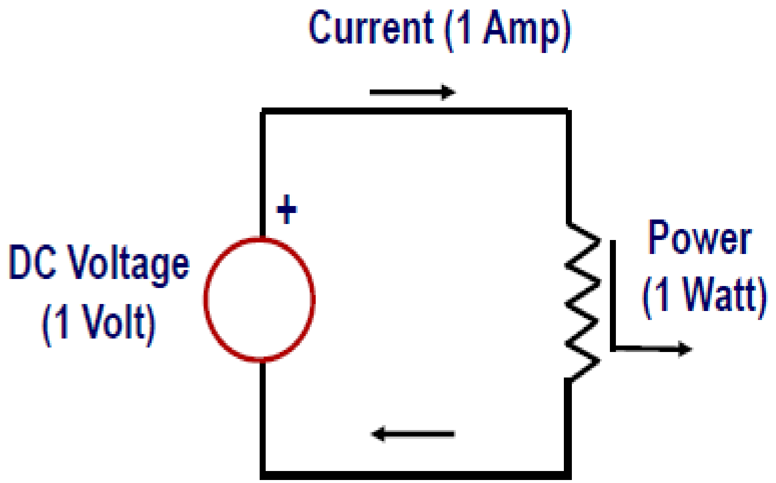
or

Voltage = Power / Current

or

V = P / I

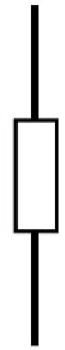
1 Volt = 1 Watt / 1 Amp



RESISTOR AND RESISTANCE

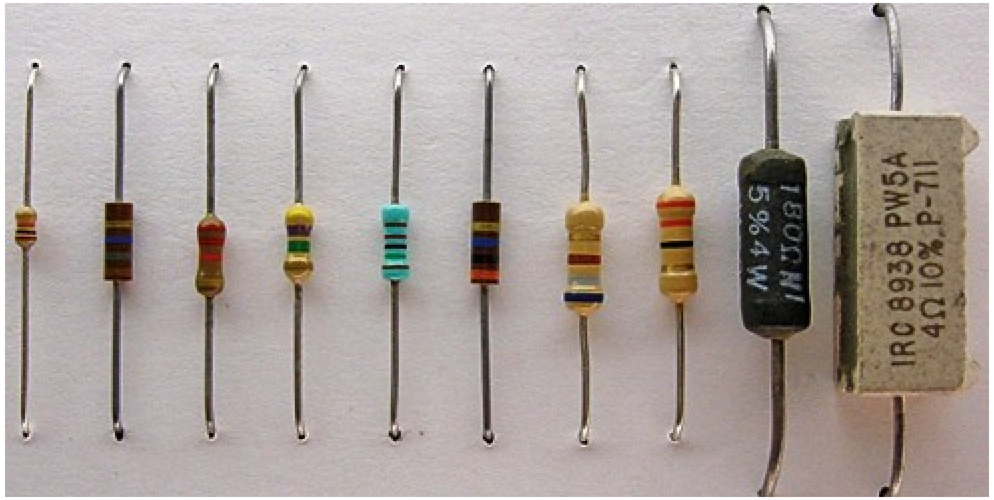
Resistors are used in virtually all electronic circuits and many electrical ones. Resistors, as their name indicates resist the flow of electricity, and this function is key to the operation most circuits.

There are two main circuit symbols used for resistors. The oldest one is still widely used in North America and consists of a jagged line representing the wire used in a resistor.
The other resistor circuit symbol is a small rectangle, and this is often termed the international resistor symbol and it is more widely used in Europe and Asia.



European
Resistor Symbol

North American
Resistor Symbol



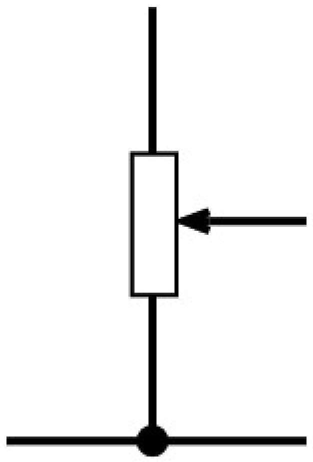
RESISTOR AND RESISTANCE

The first major categories into which the different types of resistor can be fitted is into whether they are fixed or variable. These different resistor types are used for different applications:

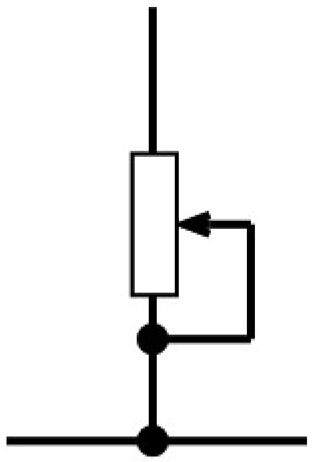
Fixed resistors: Fixed resistors are by far the most widely used type of resistor. They are used in electronics circuits to set the right conditions in a circuit. Their values are determined during the design phase of the circuit, and they should never need to be changed to "adjust" the circuit. There are many different types of resistor which can be used in different circumstances and these different types of resistor are described in further detail below.

RESISTOR AND RESISTANCE

Variable resistors: These resistors consist of a fixed resistor element and a slider which taps onto the main resistor element. This gives three connections to the component: two connected to the fixed element, and the third is the slider. In this way the component acts as a variable potential divider if all three connections are used. It is possible to connect to the slider and one end to provide a resistor with variable resistance.



Potentiometer



Variable resistor

RESISTOR AND RESISTANCE

Other types of resistor

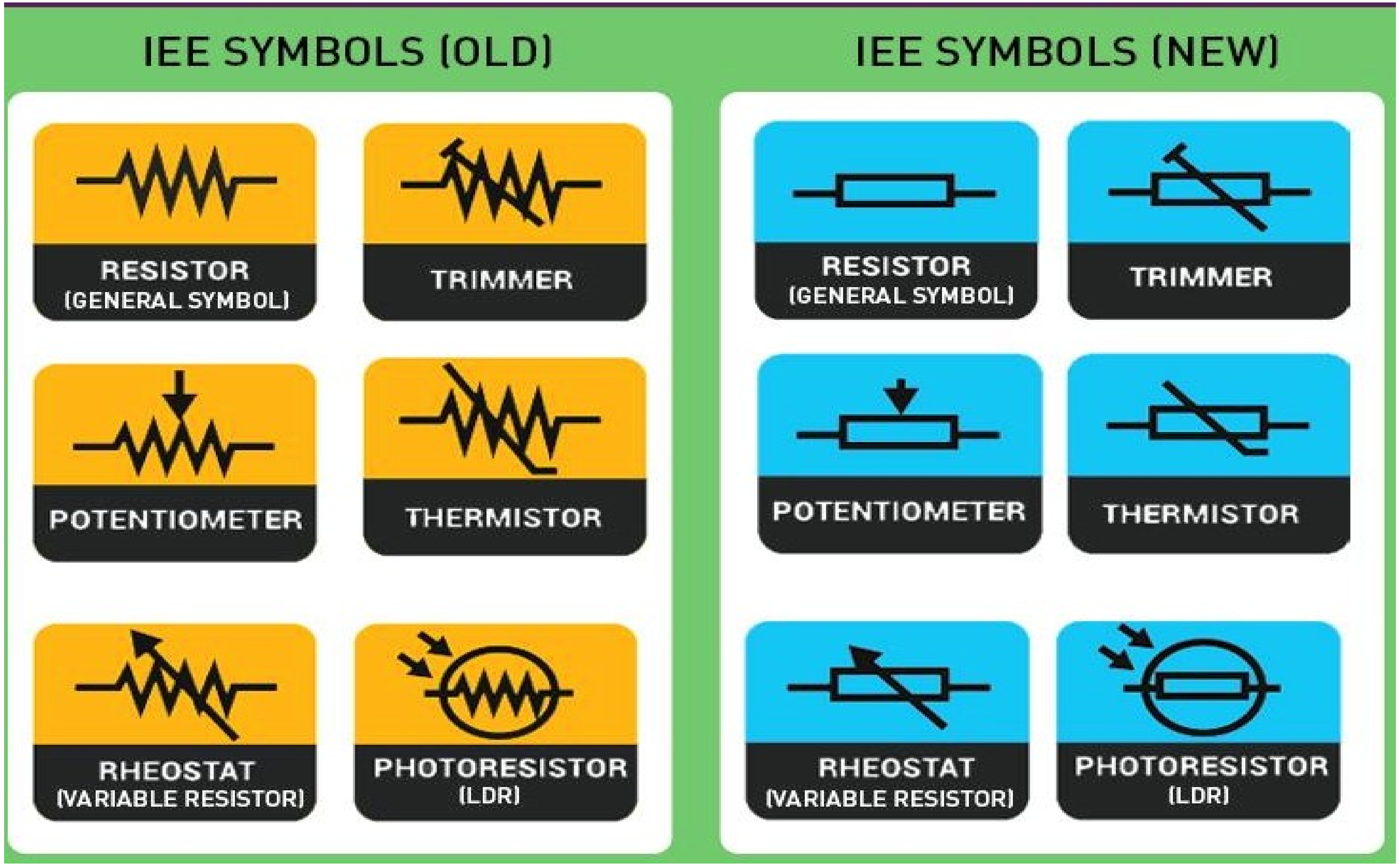
Whilst the majority of resistors are standard fixed resistors or variable resistors, there is a number of other resistor types that are used in some more niche or specialized applications.

Light dependent resistor / photo-resistor: Light dependent resistors or photo-resistors change their resistance with the level of light. They are used in a number of sensor applications and provide a very cost effective solution in many instances

Varistor: Varistors are available in a number of forms. Essentially these electronic components vary their resistance with the applied voltage and as a result they find uses for spike and surge protection. Often they may be seen described as Movistors, which is a contraction of the words **M**etal **O**xide **V**ar**istor**.

SUMMARY ON RESISTORS

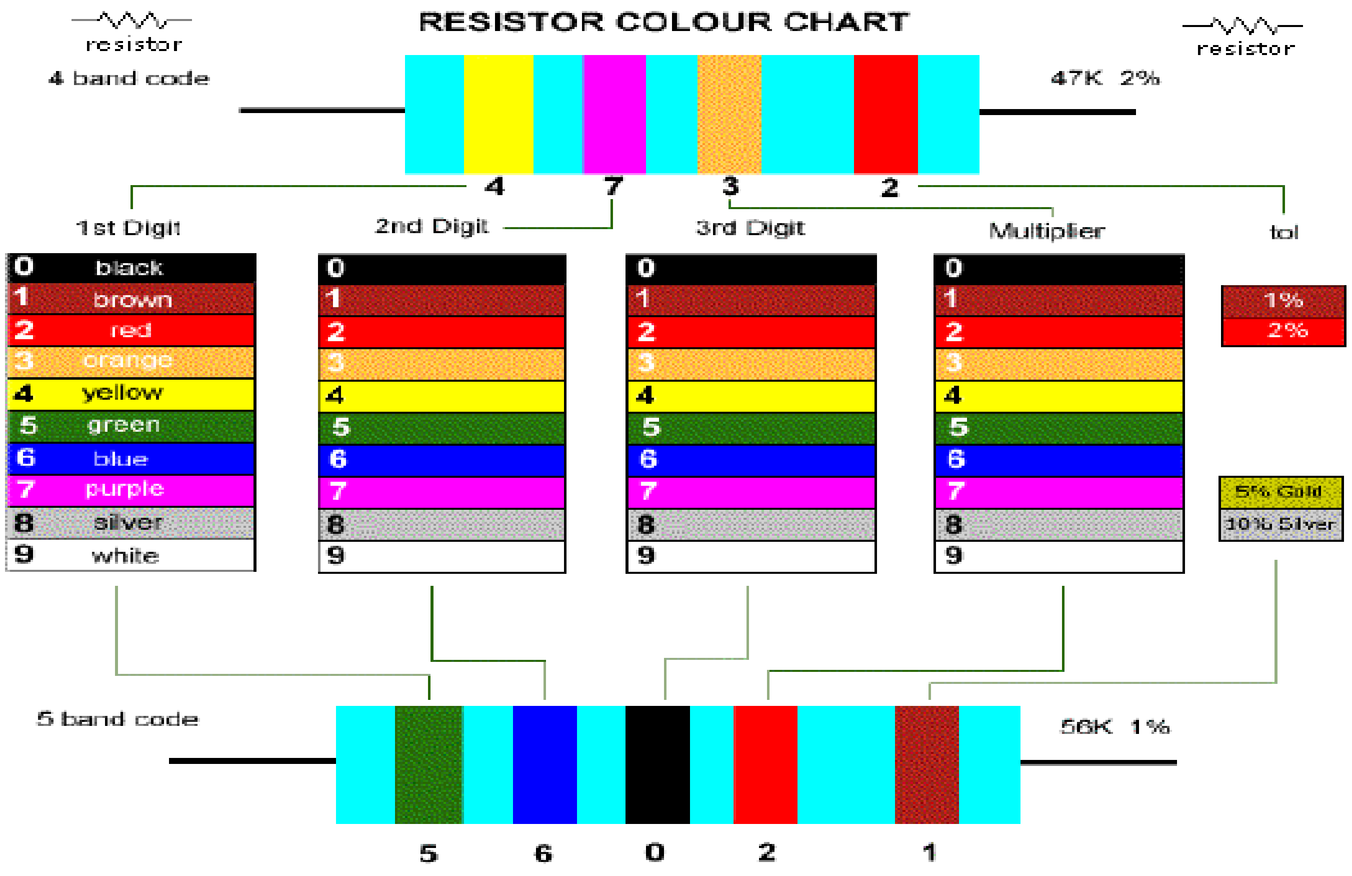
SUMMARY ON RESISTORS



RESISTOR AND RESISTANCE

Color Codes for Resistances

Rule



FORMULAS

In Current and Resistance we described the term ‘resistance and explained the basic design of a resistor. Basically, a resistor limits the flow of charge in a circuit and is an ohmic device where V=IR, R=V/I. Most circuits have more than one resistor. If several resistors are connected together and connected to a battery, the current supplied by the battery depends on the **equivalent resistance** of the circuit.

The equivalent resistance of a combination of resistors depends on both their individual values and how they are connected. The simplest combinations of resistors are series and parallel connections. In a **series circuit** the output current of the first resistor flows into the input of the second resistor; therefore, the current is the same in each resistor. In a **parallel circuit** all of the resistor leads on one side of the resistors are connected together and all the leads on the other side are connected together. In the case of a parallel configuration, each resistor has the same potential drop across it, and the currents through each resistor may be different, depending on the resistor. The sum of the individual currents equals the current that flows into the parallel connections.

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FORMULAS

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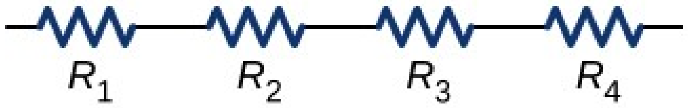
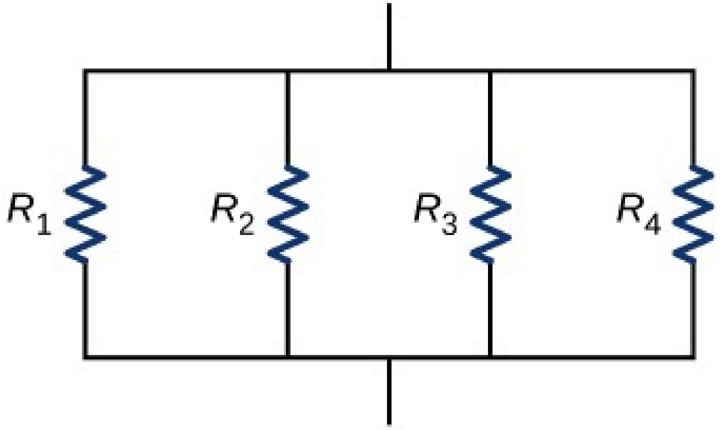




(a) Resistors connected in series

(b) Resistors connected in parallel

$$R_{total} = R_1 + R_2 + R_3 + \ldots\ldots + R_n$$

Resistors in Parallel Formula

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots + \frac{1}{R_n}$$

Where,

- $\frac{1}{R_{total}}$ *is the sum of all the individual resistances.*

RESISTANCE

Resistance Formula

Resistance Formula

$$R = \rho \, \ell / A$$

where, R is the resistance of conductor,

ρ is the resistivity coefficient,

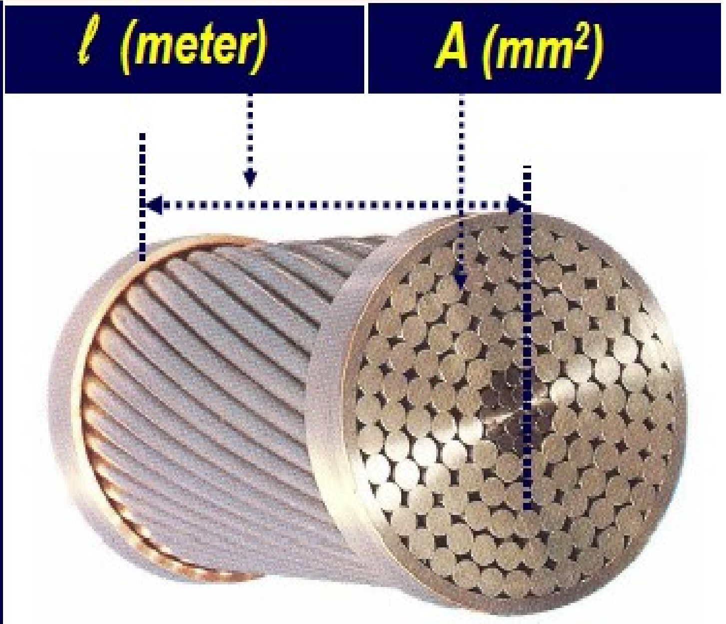
ρ = 1 / 56 Ohm-mm²/m (Copper)

1 / 32 Ohm-mm²/m (Aluminum)

ℓ (m) is the length of the conductor

A (mm²) is the cross sectional area of the conductor

ACSR Conductor
(Aluminum Conductor Steel Reinforced)



RESISTANCE

Resistivity Coefficients of Various Metals

Formula			
$\rho = 1 / 56$ Ohms/meter (Copper) $= 0.0178571$ Ohm-mm²/m			

$$R = \rho \ell / A$$

where, R is the resistance of conductor,
ρ is the resistivity coefficient,
$\rho = 1 / 56$ Ohm-mm²/m (Copper)
$1 / 32$ Ohm-mm²/m (Aluminum)
ℓ (m) is the length of the conductor
A (mm²) is the cross sectional area of the conductor

Resistivity Coefficients

Material	Resistivity Coefficient	Resistance
	Ohm-mm²/m	Ohms/feet
Silver	0.0162	0.00094
Copper	0.0172	0.00099
Gold	0.0244	0.00114
Aluminum	0.0282	0.00164
Mercury	0.9580	
Brass	0.0700	0.00406
Nickel	0.7800	0.00452
Iron	0.1000	0.00579
Platinium	0.1000	0.00579
Steel	0.1180	0.00684
Lead	0.2200	0.01270

RESISTANCE

Example

Calculate the resistance of a copper cable with length 3200 meters and cross section 240 mm^2

RESISTANCE

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Resistance Formula

Example

Calculate the resistance of a copper cable with length 3200 meters and cross section

240 mm^2

Solution

$R = (1 / 56)\ 3200 / 240 = 0.238$ Ohms

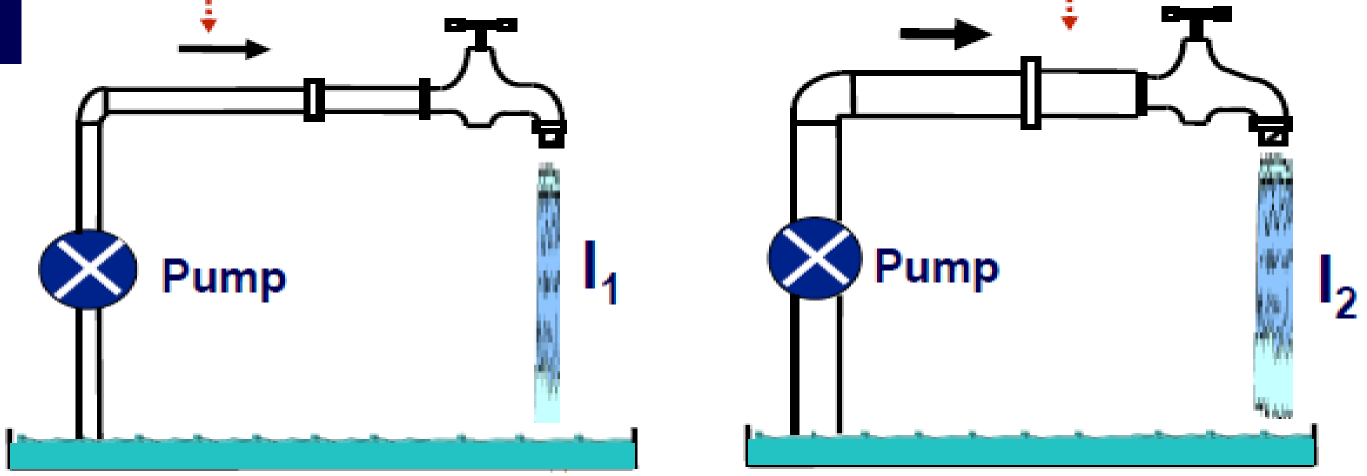
PRACTICAL INFERENCE OF RESISTORS AND RESISTANCE

Resistance

Definition

Resistance is the reaction of a pipe against water flow

Resistance R_1	$R_1 > R_2$	Resistance R_2



Current I_1	$I_2 > I_1$	Current I_2

PRACTICAL INFERENCE OF RESISTORS AND RESISTANCE

Resistance

Definition

Resistance is the reaction of a conductor against electrical current

Resistance R_1
Current I_1

Resistance R_2
Current I_1

$R_1 > R_2$ $\quad$ $I_1 < I_2$

PRACTICAL INFERENCE OF RESISTORS AND RESISTANCE

Insulator

Insulator
Insulator is a material with almost infinite resistance
Insulators are used to support HV lines and conductors
In practice, all materials have resistances. Hence, they conduct a certain amount of current when a voltage is applied to the terminals. **Insulator are materials that conduct only a very small amount of current, even when an extremely high voltage is applied to the terminals.**

HV side

Ground side

PRACTICAL INFERENCE OF RESISTORS AND RESISTANCE

Applications of Resistor

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Following are the applications of resistors:

Wire wound resistors find applications where balanced current control, high sensitivity, and accurate measurement are required like in shunt with ampere meter.

Photo-resistors find application in flame detectors, burglar alarms, in photographic devices, etc.
Resistors are used for controlling temperature and voltmeter.

Resistors are used in digital multi-meter, amplifiers, telecommunication, and oscillators.

They are also used in modulators, demodulators, and transmitters.

SUMMARY OF FORMULAS
POINTS TO NOTE

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SUMMARY ON CHARGE (Q)
MEASURED IN COULOMB (C)

6.3 X 10^18 = 1Coulomb
Therefore we can say
1 electron = 1.602 x 10^-19C

Q at arbitrary level

$Q = It$; Where I = current(A) and t = time (s)

Q at different time

The charge transferred between time t_1 and t_2 is obtained as

$$q = \int_{t_1}^{t_2} i\,dt$$

SUMMARY ON CURRENT (I)
MEASURED IN AMPERE (A)

" CURRENT" when Calculating Charge per Time

$I = Q/t$; where Q = Charge and t = time

CURRENT when being defined as the rate of charge passing through a point:

$i = dq/dt$; where dq and dt = derivative of charge and time respectively (thus change in charge with respect to charge in time from one point to another)

CURRENT in OHMS LAW APPLICATION

$i = V/R$; where V = voltage and R = Resistance

SUMMARY OF FORMULAS
POINTS TO NOTE

.

SUMMARY ON RESISTANCE (Q)
MEASURED IN OHM (Ω)

RESISTANCE IN PRACTICAL MATERIALS

$R = PL/A$; where P= resistivity coefficient , L = length of the material and A = Cross Sectional area

RESISTANCE in OHMS LAW APPLICATION

$R = V/I$; where V= voltage and I = current

SUMMARY ON VOLTAGE OR P.D (V)
MEASURED IN VOLTS (V)

VOLTAGE when calculating energy consumed in the circuit per time:

$V = dw/dt$; dw = change in energy with respect to dt = change in time

VOLTAGE drop at any point

$V = dw/dq$; dw = change in energy, dq = change in charge

CURRENT in OHMS LAW APPLICATION

$V= IXR$; where I= Current and R = Resistance

SUMMARY OF FORMULAS
POINTS TO NOTE

SUMMARY ON POWER (P)
MEASURED IN WATTS (W)

POWER in energy consumption devices

$P = w/t$; where w=energy and t = time

ALSO

$P = dw/dt$

POWER in OHMS LAW APPLICATION

$P = VXI$

; $P=Ri^2$; $P=V^2/R$; where V= voltage and I = current and R = resistance

SUMMARY ON ENERGY (w)
MEASURED IN JOULES (J)

ENERGY absorb or supplied from a time to another;

$$\boxed{w = \int_0^t p\,dt = \int_0^t vi\,dt}$$

Where P = POWER and V = VOLTAGE, i = CURRENT

ENERGY in OHMS LAW APPLICATION

w = POWER X TIME

$w = P X t$


Thank You
For Your
Attention