INTRODUCTION

**1.1 LUMPED CIRCUIT MODELLING**

An electric circuit is an interconnection of electrical elements.

**1.1.1 TERMS USED IN CIRCUITS**

1. **Network**: A network is an interconnection of elements or devices. A circuit is a network providing one or more closed paths.

2. **Branch**: A branch represents a single element in the network (such as a voltage source or a resistor). A branch could be said to represent any two terminal element (with a positive and negative) side.

3. **Node**: A node is the point of connection (or I’ll like to say, wire of connection) between two or more branches.

4. **Loop**: A loop is any closed path in a circuit. A loop is formed by starting at a node, passing through a set of nodes and returning to the starting node without passing through any node more than once. A loop is said to be independent if it contains at least one branch which is not a part of any other independent loop.

Independent loops or paths result in independent sets of equations.

**Note**: A network with b branches, n nodes and l independent loops will satisfy the fundamental theorem of network topology

1.2 CIRCUIT ELEMENTS

There are two types of circuit elements

1. Passive Elements: Not capable of generating energy. E.g. resistors, capacitors, inductors

2. Active Elements: Capable of generating energy E.g. Generators, Batteries and operational amplifiers.

The most important active elements are Voltage sources and Current Sources

**1.3 CURRENT**

Current has to deal with the flow of charges [because charges are mobile]. When a conducting wire (consisting of several atoms) is connected to a battery (a source of electromotive force), the charges are compelled to move; This motion of charges creates electric current.

It is conventional to take the current flow as the movement of positive charges. That convention was introduced by Benjamin Franklin.

However, now we know that in metallic conductors current is due to negative charges but we will use the convention for the meantime

Electric current is the time rate of change of charge, measured in amperes(A)

Also,

**1.3.1 TYPES OF CURRENT**

There are multiple types of current but for this level, we are concerned with just two; which are:

1. Alternating current (I)

2. Direct Current

**1.3.1.1 ALTERNATING CURRENT**

Alternating current is a time varying current because it varies sinusoidally with time. It is sometimes written as AC. It is represented with small I

**1.3.1.2 DIRECT CURRENT**

Direct Current is a current that remains constant with time. It is sometimes written as DC. It is represented with the capital I by convention

**1.3.2 CHARGE**

Since we have defined current as the flow of charge, it is important to know what charge means.

Charge is an electrical property of the atomic particles of which matter consists, measured in **coulombs** C.

**1.3.2.1 RELATIONSHIP BETWEEN CHARGE AND CURRENT**

When given current as a function of time,

Matter is made of fundamental building blocks called **atoms**. Each atom consists of **electrons**, **protons** and **neutrons**. The charge of an electron is given as . The charge of a proton is just the positive value of this . The presence of equal number of protons and electrons means that the atom is **neutrally charged**.

The unit of charge is **Coulomb** . In 1C of charge, there are .

According to experimental observations, the only charges that occur in nature are integral multiples of electronic charge .

**1.3.3 THE LAW OF CONSERVATION OF CHARGE**

The law of conservation of charge states that charge can neither be created not destroyed, only transferred.

The algebraic sum of the electric charges in a system does not change.

**1.4 VOLTAGE**

**Voltage** (or **potential difference**) is the energy or work required to move a unit charge through an element (from point a to b), measured in volts (V)

Volts was named in honour of the Italian physicist Alessandro Antonio Volta (1745 – 1827), who invented the first voltaic battery.

Note: Keep in mind that electric current is always through an element and that electric voltage is across the element or between two points

**1.5 POWER AND ENERGY**

Power is the time rate of expending or absorbing energy, measured in **watts**

Passive sign convention is satisfied when the current enters through the positive terminal of an element and , if the current enters through the negative terminal,

1.6 ENERGY

Energy is the capacity to do work, measured in **Joules**.

Energy can also be defined as the product of power and time for simple cases.

Energy in calculus form can be written as:

1.6.1 LAW OF CONSERVATION OF ENERGY

This states that energy can neither be created nor destroyed but can be transformed from one form to another.

The law of conservation of energy must be obeyed in any electric circuit. For this reason, the algebraic sum of power in a circuit, at any instant of time, must be zero

The electric power utility companies measure energy in **watt-hours(Wh)**, where

**1.7 SOURCES**

A source in an electric circuit is usually an active circuit element that usually pushes power into the ciruit

1.7.1 KINDS OF SOURCES

1. Independent

2. Dependent sources

**1.7.1.1 INDEPENDENT SOURCES**

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

There are two major independent sources namely:

1. Voltage Sources

2. Current Sources

An ideal independent voltage source delivers to the circuit whatever current is necessary to maintain its terminal voltage. In practice , there is no ideal source however, sources such as batteries and generators may be regarded as approximations to ideal voltage sources.

The symbol [plus and minus inside a circle] and [terminals positive and negative] can both be used to express dc voltages.

However, only the symbol [plus and minus inside a circle] can be used to represent time-varying voltage source.

Similarly, an independent current source delivers to the circuit whatever voltage is necessary to maintain the designed current.

**1.7.1.2 DEPENDENT SOURES**

An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

Dependent sources are useful for modeling elements such as transistors, operational amplifiers and integrated circuits.

A current controlled voltage source could have a value of 10i because it depends on the current running through the element

Dependent sources are usually designated by diamond shaped symbols.

Since the control of the dependent source is achieved by a voltage or current of some other element in the circuit, and the source can be voltage or current

There are four types of dependent sources, namely:

1. A voltage controlled voltage source

2. A current controlled voltage source

3. A voltage controlled current source

4. A current controlled current source

**1.8 DEVICE LAWS**

For this year, we are going to be considering 3 device laws

1. Ohm’s Law

2. Kirchhoff’s Current Law

3. Kirchoff’s Voltage Law

**1.8.1 OHM’S LAWS**

Ohm’s law states that “The voltage across a resistor is directly proportional to the current flowing through the resistor”

It is mathematically defind as

(the mathematical form of ohm’s law)

Ohm defined the constant of proportionality for a resistor to be the resistance, (The resistance is a material property which can change if the internal or external conditions of the element are altered e.g. if there are changes in the temperature)

The resistance, R of an element denotes its ability to resist the flow of electric current, it is measured in ohms

Georg Simon Ohm (1787-1854), in 1826 experimentally determined the most basic law relating voltage and current for a resistor. Ohm’s work was initially denied by critics

To apply Ohm’s law, we must pay careful attention to the current direction and voltage polarity.

The direction of current and the polarity of voltage must conform with the passive sign convention. This implies that current flows **from a higher potential to a lower potential** in order for **v=iR**. If current flows from a lower potential to a higher potential,

Resistance, R is the physical property, or ability to resist current.

The resistance of any material with a uniform cross-sectional area A depends on A, its length A and the nature of the material.

We can represent resistance (as measured in the laboratory), in mathematical form.

Formula for resistance…

is the resistivity of the material in

Good conductors have low resistivities, while insulators like mica and paper have high resistivities.

Since R can range from zero to infinity, it is important that we consider the two extreme values of R. An element with R=0 is called a short circuit.

For a short circuit, .

This shows that the voltage is zero but the current could be anything. In practice, a short circuit is usually a connecting wire assumed to be a perfect conductor, Thus,

A **short circuit** is a circuit with resistance approaching zero.

Similarly, an element with is known as an **open circuit**.

For an open circuit

This indicates that the **current is zero** though the voltage could be anything.

An open circuit is a circuit element with resistance approaching infinity.

Not all resistors obey ohm’s law. A resistor that obeys Ohm’s law is known as a **linear resistor**. It has a constant resistance. Its graph is a straight line passing through the origin.

A non linear resistor does not obey Ohm’s law. Its resistance varies with current. Examples of devices with nonlinear resistances are the light bulb and the diode. Although all practical resistors may exhibit nonlinear behaviour under certain conditions, we will assume that all elements actually designated as resistors are linear.

A very useful quantity in circuit analysis is the reciprocal of resistance R, known as conductance and denoted by G:

Conductance is a measure of how well an element will conduct electric current. The unit of conductance is mho (ohm spelled backward), with the symbol (Ohm upside down).

Although engineers use mho, in this book we prefer to use the siemens(S), the SI unit of conductance.

Conductance is the ability of an element to conduct electric current

The power dissipated in a resistor is a nonlinear function of either current or voltage

Since R and G are positive quantities, the power dissipated in a resistor is always positive. Thus a resistor always absorbs power from the circuit. This confirms the idea that a resistor is a passive element, incapable of generating energy.

**KIRCHOFF’S LAWS**

Kirchoff’s laws were first introduced in 1847 by the German physicist Gustav Robert Kirchhoff (1824-1887). These laws are formally known as Kirchhoff’s Current Law (KCL) and Kirchoff’s Voltage Law(KVL)

**Kirchhoff’s Current Law**

This states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

Mathematically, KCL implies that

Where N is the number of branches to the node and i\_n is the nth current entering (or leaving) the node. By this law, currents entering a node may be regarded as positive, while currents leaving the node may be taken as negative or vice versa.

The sum of the currents entering a node is equal to the sum of the currents leaving the node.

**Kirchhoff’s Voltage Law (KVL)**

This states that the algebraic sum of voltages around a closed path (or loop) is zero

Questions

1. An electric iron draws 2A at 120V. Find its resistance. Answer: 60 ohms

2. The essential component of a toaster is an electrical element (a resistor) that converts electrical energy to heat energy. How much current is drawn by a toaster with resistance 15 ohms at 110V? Answer: 7.333A

3. A voltage source of is connected across a resistor. Find the current through the resistor and the power dissipated

Answer: