1. EEG 211 (Fundamentals of Electrical Engineering I) 2units

* Circuit Law: Kirchhoff’s Laws, Thevenin’s Theorem, Norton’s Theorem, Superposition Theorem, Millman’s Theorem, Rosen’s Theorem.
* Network problems arising in Energy Distribution
* Methods of analysis suitable for the problems in Network theory in terms of currents, voltages, energy/volt amperes, Loop and Nodal analysis.
* Resistors, Electric field and capacitors, Magnetic fields and Inductance
* Energy stored in capacitors and Inductors
* Electromagnetic Induction and Magnetic forces, self and mutual Inductance
* Electrochemical power sources
* Pre-requisite: FSC 115

EEG 211

An electric circuit is an interconnection of electrical elements

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

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 .

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.

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)

DC – Direct Current is a current that remains constant with time

By convention, the capital lettter I is used to represent DC. While a time-varying current called alternating current. Alternating current varies sinusoidally with time.

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

POWER

In practical, we will like to know how much power a material can handle. From experience, we know that a 100W bulb is brighter than a 60Watt bulb.

Power is the time rate of expending or absorbing energy, measured in watts(W)

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,

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

Energy is the capacity to do work, measured in joules (J)

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

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

IMPORTANT ACTIVE ELEMENTS

Voltage sources

Current Sources

KINDS OF SOURCES

Independent

Dependent sources

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. 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.

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

A current controlled voltage source

A voltage controlled current source

A current controlled current source

CIRCUIT LAWS

OHM’S LAWS

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.

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

Ohm defined the constant of proportionality for a resistor to be the resistance, R (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 mathematical form of ohm’s law)

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,

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, v=iR=0.

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 R={%infinite} 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.

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:

NODES BRANCHES AND LOOPS

Network: A network is an interconnection of elements or devices

A circuit is a network providing one or more closed paths.

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

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

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.

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

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

SERIES RESISTORS AND VOLTAGE DIVISION

Characteristics of resistors in series

1. The same current flows through them

2. The total voltage is equal to the sum of voltages across a resistor

The equivalent resistance of any number of resistors connected in series is the sum of individual resistances

To determine the voltage across each resistor

PARALLEL RESISTORS AND CURRENT DIVISION

Characteristics of resistors in parallel

1. They have the same voltage across them

2. The total current is equal to the sum of currents

For two resistors,

For conductances, Conductances in parallel behave as a single conductance whose value is equal to the sum of the individual conductances.

For resistors in series,

Principle of current division for resistors in parallel

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METHODS OF ANALYSIS

1. Nodal analysis

2.

3.

NODAL ANALYSIS WITH CURRENT SOURCES

This provides a general procedure for analysing circuits using node voltages as the circuit variables. Choosing node voltages instead of element voltages as circuit variables is convenient and reduces the number of equations one must solve simultaneously.

To simplify matters, we assume that circuits do not contain voltage sources but has reference nodes.

STEPS

1. Select a node as the reference node or datum node (commonly called ground) and it is assumed to have zero potential.

2. Assign voltages v\_1, v\_2, ..., v\_{n-1} to the remaining n-1 nodes. The voltages are referenced with respect to the reference node.

3. Apply KCL to each of the nodereference nodes.

4. Use Ohm’s law to express the branch currents in terms of node voltages

5. Solve the resulting simultaneous equations to obtain the unknown node voltages

Current flows from higher potential to lower potential

When you perform KCL, you have an equation of currents

Use the above equation to form an equation of currents in terms of volts and resistances

NODAL ANALYSIS WITH VOLTAGE SOURCES

A supernode is formd by enclosing a (dependent or independent) voltage source connected between two nonreference nodes and any elements connected in parallel

Note the following about supernodes

1. The voltage source inside the supernode provides a constraint equation needed to solve for the node voltages

2. A supernode has no voltage of its own

MESH ANALYSIS

Here, we use mesh currents.

Mesh analysis is only for planar circuits.

A planar circuit is one that can be drawn on a plane with no branches crossing one another

A Mesh is a loop which does not contain any other loops within it. The current through a mesh is known as mesh current.

We use KVL is mesh analysis.

Steps

1. Assign mesh currents to the n meshes

2. Apply KVL to each of the n meshes. Use ohm’s law to express the voltages in terms of the mesh currents.

3. Solving the resulting n simultaneousl equations to get the mesh currents

MESH ANALYSIS WITH CURRENT SOURCES

1. When a curr

THEVENIN THEOREM

We want to determine the current I\_L from through the resistor R\_L. First we need to calculate the thevenin resistance and thevenin voltage.

To find the thevenin resistance...

Replace the independent voltage source with a short circuit.

Replace the independent current source with an open circuit.

To find the thevenin voltage,

You keep the circuit as it is and then remove the load resistance R\_L

SUPERPOSITION THEOREM

This principlr states that the voltage across (or current through) an element in a linear ciruit is the alg