

COURSE TITLE: APPLIED ELECTRICITY I

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LECTURE I

1.0 INTRODUCTION

1.1 Units and Dimension

The SI system is the approved abbreviation for international system of unit (Systeme Internationale d'unités). The size physical or fundamental quantities selected as the basic unit of SI system are:

- Length (meter, m)
- Time (second, s)
- Mass (kilogramme, kg)
- Electric current (Ampere, A)
- Temperature (Kelvin, K)
- Luminous intensity (Candela, cd)

Other derived units from the basic physical quantities are derived physical quantities, some which include:

- Area (meter sqquare)
- Volume (meter cube)
- Velocity (meter per sec)
- Acceleration (meter per sec sq)
- Angular velocity (rad per sec)

1.2 Dimensions

All other mechanical quantities may be expressed in terms of the three basic quantities (mass, length and time) raise to the appropriate powers, which may be either positive or negative and which are termed the dimensions of the derived quantities.

For example, the dimension of the velocity is $[LT^{-1}]$, that of acceleration is $[LT^{-2}]$ and so on.

Solve Problem 1

Obtain the dimension of the following quantities:

- Force
- Momentum
- Charge
- Power
- Potential difference

- Resistance
- Magnetic flux density
- Permeability
- Electric flux density
- Inductance

1.3 Electrical Quantities

The basic electrical quantities include:

- Current
- Electric charge
- Potential difference

Current: The electric current is the flow of electrons. The intensity of constant current which when maintained in two parallel straight conductor of infinite length and negligible cross section placed one metre apart a vacuum produces between them a force $2 \times 10^{-7} \text{N/m}^2$.

Electric charge: The unit of charge is the Coulomb. This is defined as the charge transferred by a current of one ampere in one second. It can also be defined as the flow of one Coulomb of charge through a cross section in one second i.e. $i = \frac{dq}{dt}$

Potential difference: The unit of p.d is the volt, which is defined in terms of energy. The volt is that electric p.d existing between two points if a charge of one Coulomb receives or delivers one joule in moving between them.

LECTURE II

2.0 CIRCUIT ELEMENTS AND SOURCES

2.1 Linear Circuit: The figure 2.1 below shows a general electric network, circuit or system having two terminals A and B.

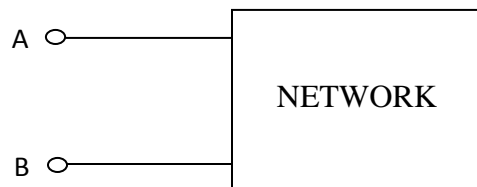


Figure 2.1

Suppose a battery is connected between A and B and the current flowing into the network at A is measured. If the battery voltage is varied, the current will also vary. If the resulting voltage/current characteristic is a straight line as shown in figure 2.2, the circuit is said to be linear.

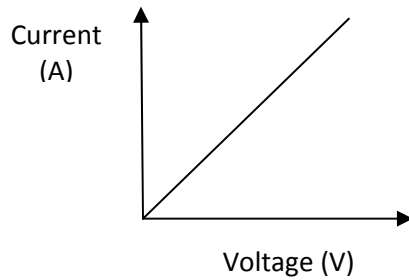


Figure 2.2

The linear circuit also obeys the principle of superposition.

2.2 Sign Convention

- The battery is represented by means of arrow with the arrow head pointing towards the positive terminal of the battery.
- The current flows from the positive terminal of the battery, the arrow head indicating the direction of flow.

2.3 Circuit Elements

The circuit elements include:

- The resistor
- The capacitor
- The inductor

2.4 Sources and their properties

The sources (generators) of energy to an electrical network include:

- The voltage source (independent or dependent)
- The current source (independent or dependent)

The ideal voltage source has zero source resistance

2.5 Sources Conversion

The conversion between voltage and current sources

Solve Problem 2

A current $I=10\cos 100\pi t$ mA is passed through a 10H inductor, obtain an expression for the voltage across the terminals of the inductor. Sketch the voltage and current waveforms and comment on their relationship.

LECTURE III

3.0 SOME CIRCUIT THEOREMS AND THEIR APPLICATIONS TO DC CIRCUITS

3.1 Ohm's law: the voltage across a linear resistor is proportional to the current flowing through it.

3.2 Kirchoff's Current Law (KCL): The algebraic sum of the current entering a junction in an electrical circuit is zero.

3.3 Kirchoff's Voltage Law (KVL): In any closed loop of an electric circuit, the algebraic sum of all the voltages in that loop is zero

LECTURE IV

4.0 ANALYSIS OF A SIMPLE CIRCUIT

In this section, the following basic principles shall be studied. These principles include:

- Kirchoff's Current Law (KCL)
- Kirchoff's Voltage Law (KVL)
- Thevenin's theorem
- Norton's theorem
- Star-Delta transformation
- Methods Network Analysis which includes:
 - Branch Current Analysis
 - Loop or Mesh Analysis
 - Nodal Analysis

SECTION: B

This section is divided into four (4) lectures

Lecture 1:

ELEMENTARY DISCUSSION OF SEMICONDUCTORS: PN JUNCTION DIODE, NPN AND PNP TRANSISTOR

1.1 Introduction: Review of Solid State Electronics

- Solid state electronics are those circuits or devices built entirely from solid materials
- Building materials are from crystalline semi-conductors
- Common solid state devices include transistors, microprocessor chips, etc.

1.2 Semiconductors

- Their specific electrical conductivity are somewhere between that of good conductors and good insulators
- Common semiconductor materials are silicon (Si), Germanium (Ge) (Group iv element)
- Silicon is considered for this lectures

1.2.1 Doping: Addition of impurities to a semiconductor material to increase conductivity

1.2.2 N-type semiconductors:

- Addition of pentavalent atom (e.g antimony) to silicon and
- Characteristics of N-type semiconductors

1.2.3 P-type semiconductors:

- Addition of trivalent atom (e.g Boron) to silicon and
- Characteristics of P-type semiconductors

1.3 PN-Junction

- Doping of silicon in such a way that half is N-type and other half is P-type
- Discussion on potential distribution

1.3.1 PN-Junction Diode

- Introduction
- PN-junction diode allow current to flow in one direction. Why?
- Circuit symbol
- Schematic representation of PN-junction diode
- PN-junction under forward and reversed biases
- Schematic diagram of PN-junction under forward & reversed bias
- The energy diagram
- Graphical representation of diode currents and voltage characteristics
- Mathematical expression of leakage current
- Application of PN-junction diode

1.4 Bipolar Junction Transistor

- Introduction
- Transistor structure
- Schematic representation
- Formation of depletion regions
- Biasing transistor
- Application of BJ Transistor: Amplification, Switching

1.4.1 PNP Transistor

- Biasing arrangement and energy diagram
- Circuit configuration
- Common base, common emitter, and common collector, configuration

1.4.2 Worked examples and Tutorial Questions

Lecture II

RECTIFIERS

2.1 Brief introduction to rectifiers

2.2 Half-wave rectification

- Brief discussion on half-wave rectification
- Circuit diagram and wave form representation
- Mathematical expression for mean value of current (I_{dc}) rms value of current (I_{rms}), mean value of load voltage (V_{dc}), rms value of the load voltage (V_{rms})
- Efficiency of the rectifiers circuit

2.3 Full wave rectification (as above)

2.4 Bridge rectifier network

- Current diagram and wave form representation
- Discussion on operation details
- Efficiency of bridge rectification circuit
- Examples

2.5 Smoothing

- Discussion on smoothing circuits
- Other smoothing circuits

Tutorials Questions

Lecture III: Illumination

3.1 Introduction

3.2 Definition of terms

3.3 Laws of Illumination

- First Law: Illumination E is directly proportional to the luminous intensity (I) of the source i.e $E \propto I$
- Inverse Square Law: The illumination of a surface inversely proportional to the square of the distance of the surface from the source

$$E \propto \frac{1}{r^2}$$

$$E = \frac{I}{r^2}$$

- Lambert's cosine law of Illumination: Illumination E , is directly proportional to the cosine of the angle made by normal to the illuminated surface with direction of the incident flux

- Mathematical expression of Lambert's cosine law

3.4 Electric Lamps

- The most important electric light sources are
 - (i) the incandescent lamp
 - (ii) the fluorescent lamp
 - (iii) the High-intensity Discharge (HD) lamps

3.5 Illumination required for different purposes

Various tasks require different levels of illumination depending on

- (i) size of detail that must be seen
- (ii) degree of contrast of the object
- (iii) for how long the job lasts

Examples

A 0.4m diameter diffusing sphere of opal glass (20% absorption) encloses an incandescent lamp with a luminous flux of 4850lumens. Calculate the average luminance of the sphere.

Solution

Since absorption is 20%, flux emitted by the globe

$$80\% \text{ of } 4850 = 3880 \text{ lumens}$$

Surface area of the globe

$$= 4 \pi r^2 = \pi d^2 \text{ (m}^2\text{)}$$

$$\begin{aligned} \text{Luminance} &= \frac{\text{flux emitted}}{\text{surface area}} \\ &= \frac{3880}{\pi \times 0.4^2} \\ &= \underline{7720\text{lm/m}^2} \end{aligned}$$

Lecture IV

INTRODUCTION TO ELECTROSTATIC AND CAPACITANCE

4.1 Static Electricity

Electrostatic is the branch of science which deals with the phenomena associated with electricity at rest.

The total deficiency or excess of electrons in a body is known as its charge.

4.1.1 Absolute and Relative permittivity of a medium

A certain property of the medium called its permittivity plays an important role while discussing electrostatic phenomenon. Every medium is supposed to possess two permittivities:

- (i) Absolute permittivity (ϵ)
- (ii) Relative permittivity (ϵ_r)

$$\epsilon = \epsilon_0 \epsilon_r \text{ F/m}$$

4.1.2 Laws of Electrostatics

First Law: Like charges of electricity repel each other, whereas unlike charges attract each other

Second Law: According to this law, the force exerted between two point charges

(i) is directly proportional to the product of their strength

(ii) is inversely proportional to the square of the distance between them. This law is known as Coulomb's law and can be expressed mathematically as

$$F \propto \frac{Q_1 Q_2}{d^2} \text{ or } F = K \frac{Q_1 Q_2}{d^2}$$

4.1.3 Electrostatic Induction

It is found that when an uncharged body is brought near a charged body, it acquires some charge. This phenomenon of an uncharged body getting charged merely by the nearness of a charged body is known as induction.

4.2 Introduction to Capacitance

A capacitor consists of two conductors separated by a layer of an insulating medium called dielectric

Capacitance C is defined as

$$C = \frac{Q}{V_{ab}}$$

Where V_{ab} is the potential difference between the two conductors and Q is the magnitude of the charge

4.2.1 Capacitance of an isolated conducting sphere

$$V = \frac{Q}{4\pi\epsilon_0\epsilon_r r}$$

$$\frac{Q}{V} = 4\pi\epsilon_0\epsilon_r r = C$$

$$C = 4\pi\epsilon_0\epsilon_r r \text{ (F) in a medium}$$

$$= 4\pi\epsilon_0 r \text{ (F) in air}$$

4.2.2 Parallel plate capacitor

$$C = \frac{Q}{V_{ab}} = \frac{\epsilon_0 A Q}{Qd}$$

$$= \frac{\epsilon_0 A}{d} \text{ (F) - in air}$$