SYLLABUS

Course Title:	**Elements of Electrical Engineering**		
Course Code:	**22EEE13/23**	CIE Marks	50
Course Type (Theory/Practical /Integrated)	Theory	SEE Marks	50
		Total Marks	100
Teaching Hours/Week (L:T:P: S)	2:2:0:0	Exam Hours	03
Total Hours of Pedagogy	40 hours	Credits	03

Course objectives

- To explain the basic laws used in the analysis of DC circuits, electromagnetism.
- To explain the behavior of circuit elements in single-phase circuits.
- To explain three phase circuits, balanced loads and measurement of three phase power.
- To explain the measuring techniques, measuring instruments and domestic wiring.
- To explain electricity billing, equipment and personal safety measures.

Teaching-Learning Process

These are sample Strategies, which teacher can use to accelerate the attainment of the various course outcomes and make Teaching –Learning more effective

1. Chalk and talk 2. Animated/NPTEL videos 3. Cut sections 4. PPTs

Module-1 (08 Hrs)

DC circuits: Ohm's law and Kirchhoff's laws, analysis of series, parallel and series-parallel circuits. Power and energy.

Electromagnetism: Faraday's Laws of Electromagnetic Induction, Lenz's Law, Flemings rules, statically and dynamically induced EMF; concepts of self and mutual inductance. Coefficient of Coupling. Energy stored in magnetic field. Simple Numerical.

Module-2 (08hrs)

Single-phase AC circuits: Generation of sinusoidal voltage, frequency of generated voltage, average value, RMS value, form factor and peak factor of sinusoidal voltage and currents.

Phasor representation of alternating quantities. Analysis of R, L, C, R-L, R-C and R-L-C circuits with phasor diagrams, Real power, reactive power, apparent power, and Power factor. Series, Parallel and Series-Parallel circuits. Simple Numerical.

Module-3(08 Hrs)

Three-phase AC circuits: Necessity and advantage of 3-phase system. Generation of 3-phase power. Definition of phase sequence. Balanced supply and balanced load. Relationship between line and phase values of balanced star and delta connections. Power in balanced 3-phase circuits. Measurement of 3-phase power by 2-wattmeter method. Simple Numerical.

Module-4(08 Hrs)

Measuring instruments: construction and working principle of whetstone's bridge, Kelvin's double bridge, Megger, Maxwel's bridge for inductance, Schering's bridge for capacitance, concepts of current transformer and potential transformer.

Domestic Wiring: Requirements, Types of wiring: casing, capping. Two way and three way control of load.

Module-5 (08 Hrs)
Electricity bill: Power rating of household appliances including air conditioners, PCs, laptops, printers, etc. Definition of "unit" used for consumption of electrical energy, two-part electricity tariff, calculation of electricity bill for domestic consumers. **Equipment Safety measures:** Working principle of Fuse and Miniature circuit breaker (MCB), merits and demerits. **Personal safety measures:** Electric Shock, Earthing and its types, Safety Precautions to avoid shock, and Residual Current Circuit Breaker (RCCB) and Earth Leakage Circuit Breaker (ELCB).

Course outcome (Course Skill Set)

At the end of the course the student will be able to:

CO1	Understand the concepts of DC circuits and Electromagnetism.
CO2	Understand the concepts of single phase and Three phase AC circuits.
CO3	Apply the basic Electrical laws to solve circuits.
CO4	Understand the concepts of measurements and measuring Instruments
CO5	Explain the concepts of domestic wiring, electricity billing, circuit protective devices and personal safety measures.

Assessment Details (both CIE and SEE)

The weightage of Continuous Internal Evaluation (CIE) is 50% and for Semester End Exam (SEE) is 50%. The minimum passing mark for the CIE is 40% of the maximum marks (20 marks out of 50). The minimum passing mark for the SEE is 35% of the maximum marks (18 marks out of 50). A student shall be deemed to have satisfied the academic requirements and earned the credits allotted to each subject/ course if the student secures not less than 35% (18 Marks out of 50) in the semester-end examination(SEE), and a minimum of 40% (40 marks out of 100) in the sum total of the CIE (Continuous Internal Evaluation) and SEE (Semester End Examination) taken together.

Continuous Internal Evaluation(CIE):

Two Unit Tests each of30 Marks (duration 01 hour)

- First test after the completion of 30-40 % of the syllabus
- Second test after completion of 80-90% of the syllabus

One Improvement test before the closing of the academic term may be conducted if necessary. However best two tests out of three shall be taken into consideration

Two assignments each of 20 Marks

The teacher has to plan the assignments and get them completed by the students well before the closing of the term so that marks entry in the examination portal shall be done in time.Formative (Successive) Assessments include Assignments/Quizzes/Seminars/ Course projects/Field surveys/ Case studies/ Hands-on practice (experiments)/Group Discussions/ others.. The Teachers shall choose the types of assignments depending on the requirement of the course and plan to attain the Cos and POs. (to have a less stressed CIE, the portion of the syllabus should not be common /repeated for any of the methods of the CIE. Each method of CIE should have a different syllabus portion of the course). CIE methods /test question paper is designed to attain the different levels of Bloom's taxonomy as per the outcome defined for the course.

The sum of two tests, two assignments, will be out of 100 marks and will be scaled down to 50 marks

Semester End Examination(SEE):

Theory SEE will be conducted by University as per the scheduled timetable, with common question papers for the subject (**duration 03 hours)**

- The question paper shall be set for 100 marks. The medium of the question paper shall be English/Kannada). The duration of SEE is 03 hours.
- The question paper will have 10 questions. Two questions per module. Each question is set for 20 marks.The students have to answer 5 full questions, selecting one full question from each module. The student has to answer for 100 marks and **marks scored out of 100 shall be proportionally reduced to 50 marks**.
- There will be 2 questions from each module. Each of the two questions under a module (with a maximum of 3 sub-questions), **should have a mix of topics** under that module.

Suggested Learning Resources:

Books (Title of the Book/Name of the author/Name of the publisher/Edition and Year)

Text Books:

1. Basic Electrical Engineering by D C Kulshreshtha, Tata McGraw Hill, First Edition 2019.
2. A text book of Electrical Technology by B.L. Theraja, S Chand and Company, reprint edition 2014.

Module - 1

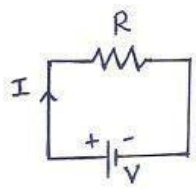
D.C Circuits

1.1 Ohm's Law

States that "At constant temperature potential difference across a passive element isdirectly proportional to current flowing through it".$V=IR$

Where, the constant of proportionality R is called the resistance, measured in ohms (Ω).

Illustration: consider a passive element (resistor R) connected to a DC voltage (V) source,the current (I) flowing through R is given by,



According to ohm's law,

$I=$ —

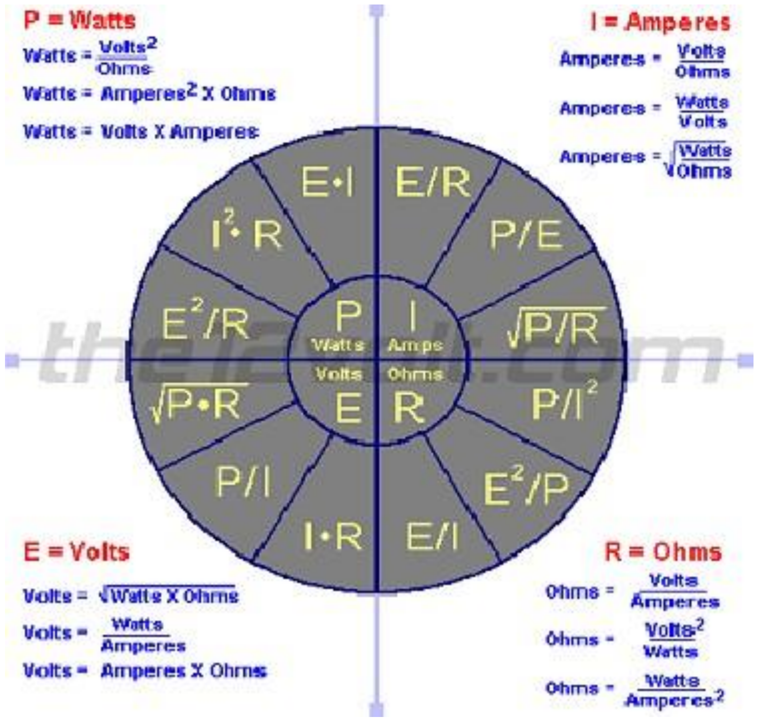
Limitations of ohm's law:

- It is not applicable to the nonlinear devices such as diodes, Zener diodes, voltageregulators etc.
- It does not hold good for non-metallic conductors such as silicon carbide.
- Not applicable where the temperature rise is rapid insome metals.

(I) Current is what flows on a wire or conductor like water flowing down a river. Current flows from negative to positive on the surface of a conductor. Current is measured in (A) amperes or amps.

(E) Voltage Ohm's Law defines the relationships between (P) power, (E) voltage, (I) current, and (R) resistance. One ohm is the resistance value through which one volt will maintain a current of one ampere is the difference in electrical potential between two points in a circuit. It's the push or pressure behind current flow through a circuit, and is measured in (V) volts.

(R) Resistance determines how much current will flow through a component. Resistors are used to control voltage and current levels. A very high resistance allows a small amount of current to flow. A very low resistance allows a large amount of current to flow. Resistance is measured in ohms Ω.



To make a current flow through a resistance there must be a voltage across that resistance. Ohm's Law shows the relationship between the voltage (V), current (I) and resistance (R). It can be written in three ways:

or or

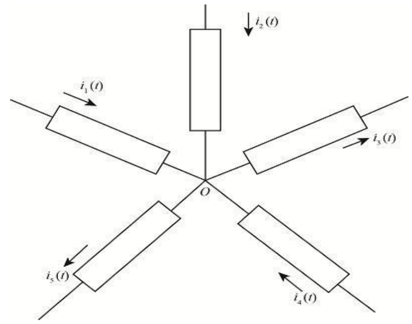
$$V = I \times R \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

where:	V = voltage in volts (V)	or:	V = voltage in volts (V)
	I = current in amps (A)		I = current in milliamps (mA)
	R = resistance in ohms (Ω)		R = resistance in kilohms (kΩ)

Kirchhoff's Current law

The law can be stated as,

The total current flowing towards a junction point is equal to the total current flowing y from that junction point.



The word algebraic means considering the signs of various currents.

$\sum I$ at junction point = 0

Sign convention: Currents flowing towards a junction point are assumed to be positive while currents flowing away from a junction point assumed to be negative.

e.g., Refer to Fig, currents I_1 and I_2 are positive while I_3 and I_4 are negative.

Applying KCL,

$\sum I$ at junction **0** = 0

$I_1 + I_2 - I_3 - I_4 = 0$ i.e. $I_1 + I_2 = I_3 + I_4$

The law is very helpful in network simplification.

1.2 Kirchhoff's voltage law:

Law can be defined as

"In any network, the algebraic sum of the voltage drops across the circuit elements of any closed path (or loop or mesh) is equal to the algebraic sum of the e.m.f s in the path"

In other words, "the algebraic sum of all the branch voltages, around any closed path or closed loop is always zero."

Around a closed path $\sum V$ = 0

- The law states that if one starts at a certain point of a closed path and goes on tracing and noting all the potential changes (either drops or rises), in any one direction, till the starting point reached again, he must be at the same potential with which he started tracing a closed path.

• Sum of all the potential rises must be equal to sum of all the potential drops while tracing any closed path of the circuit. The total change in potential along a closed path is always zero.

- This law is very useful in loop analysis of the network.

1.3 Resistance

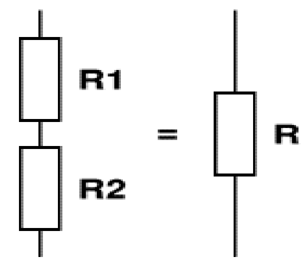
Resistance is the property of a component which **restricts the flow of electric current**. Energy is used up as the voltage across the component drives the current through it and this energy appears as heat in the component.

(i) <u>Resistance connected in Series</u>

When resistors are connected in series their combined resistance is equal to the individual resistances added together. For example, if resistors R1 and R2 are connected in series their combined resistance, R, is given by: Combined resistance in **series**:

R = R1 + R2

This can be extended for more resistors: **R = R1 + R2 + R3 + R4 + ...**

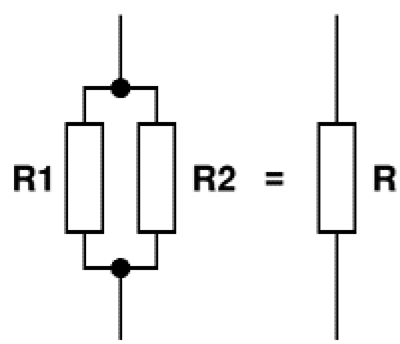


Note that the **combined resistance in series** will always be **greater** than any of the individual resistances.

(ii) <u>Resistors connected in Parallel</u>

When resistors are connected in parallel their combined resistance is less than any of the individual resistances. There is a special equation for the combined resistance of **two** resistors R1 and R2:

Combined resistance of **two resistors in parallel**: $R = \dfrac{R1 \times R2}{R1 + R2}$



For more than two resistors connected in parallel a more difficult equation must be used. This adds up the **reciprocal** ("one over") of each resistance to give the **reciprocal** of the combined resistance, R Note that the **combined resistance in parallel** will always be **less** than any of the individual resistances.

1.5. Electrical Power and Electrical Energy:

Electrical Power: The rate at which electrical work is done in an electric circuit is calledas electrical power.

Electrical work done is nothing but moving charges by applying voltage, therefore

*W=V*q and q=It,*

Electrical Energy: It is the total amount of electrical work done in an electrical circuit.

*Electrical Energy=W= Power * Time=VI*t Watt-Sec*

Watt-sec is a small unit to measure the energy consumed in a circuit so, normally Kilowatt-hour (Kwh) unit is used. 1Kwh=1 Unit of energy, which is the commercial unitof energy based on which we pay our electricity bill.

ELECTROMAGNETISM

Laws of Magnetism:

Law-1: It states that "*Like magnetic poles repel and unlike poles attract each other*"

Law-2: "*the force of attraction or repulsion between two magnetic poles is directly proportional to their strengths and inversely proportional to the square of the distance between them*"

$F \propto \frac{m1\,m2}{d^2}$; $F = force\ of\ attraction\ or\ repulsion$

$F = \frac{K\,m1\,m2}{d^2}$ $m1, m2 = Pole\ Strength\ of\ the\ poles$

$K = \frac{1}{4\,\pi\mu_0\mu_r}$ $d = distance\ between\ the\ poles$

μ_0= Absolute Permeability of vacuum or air $=4\pi\times 10^{-7}$

μ_r= Relative Permeability of medium surrounding the poles.

Some Important Definitions:

(i) Magnetic Field:

The region or space around a magnet in which the magnetic effects are felt is known as the ***magnetic field.***

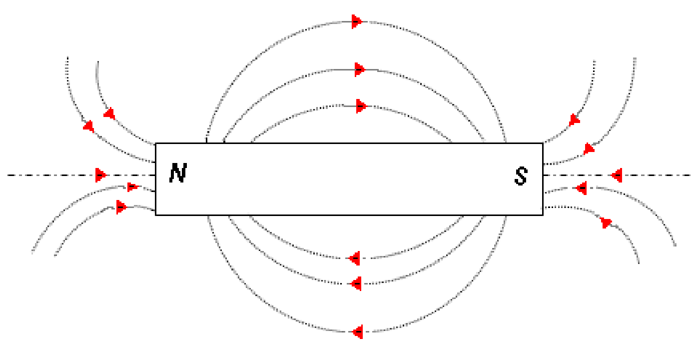


Fig. 1

Fig. 1 represents a bar magnet and the magnetic field around it. The magnetic field is represented by magnetic lines of force, which start from the North Pole & go into the South Pole, completing their path in the surrounding medium and the material of the magnet. Hence magnetic lines of force are always closed lines.

(ii) Magnetic Flux:

The total number of magnetic lines of force in a magnetic field is called magnetic flux. It is represented by φ. The S. I unit of it is weber.

1 weber = 10^8 lines or Maxwell.

(iii) Magnetic Flux Density (B):

The magnetic flux per unit area, the area being normal to the lines of flux is known as **magnetic flux density**.

Or

The number of lines per unit area through any substance in a place at right angles to the lines of force

Therefore, $B = \frac{\varphi}{A}$

Where, B=flux density

Φ= Flux

A= Cross sectional area i.e. area perpendicular to flux.

The unit is wb/m^2 or T (Tesla).

(iv) Magnetic Field Strength

It is defined as the force of acting on a unit N- pole placed at that point. It is also called as *Magnetising Force* or *Magnetic Field Intensity*. Its unit is Newton per Weber or Ampere turn per Weber.

(v) Permeability:

The ability of a material to conduct magnetic flux through it is called permeability of that material.

(a) Absolute Permeability:

It is defined as the flux density induced in the magnetic material per unit magnetising force.

$\mu = \frac{B}{H}$ where, H is the magnetising force.

(b) Relative Permeability:

The ratio of the permeability of material (μ) to the permeability of air or vacuum (μ_0) is called relative permeability of the material.

$$Relative\ Permeability = \frac{Permeability\ of\ Material}{Permeability\ of\ air\ or\ vaccum}$$

i.e. $$\mu_r = \frac{\mu}{\mu_0}$$

Therefore, $\mu = \mu_0 \mu_r$

Where, $\mu_0 = 4\pi \times 10^{-7}$.

(vi) Reluctance (S):

It is the property of the magnetic circuit which opposes the flow of the magnetic flux through it. Its unit is Ampere turn per weber (AT/wb).

Also, the reluctance of a magnetic material is directly proportional to the length of the magnetic material and inversely proportional to its area of cross section.

$R \propto \frac{l}{a} = \frac{1}{\mu}\frac{l}{a} = \frac{l}{\mu_0 \mu_r a}$

Where, $l \equiv length\ of\ magnetic\ material$

$a \equiv area\ of\ cross\ section$

$\mu = \mu_0 \mu_r \equiv Absolute\ permeability\ of\ the\ magnetic\ material.$

The reluctance of a magnetic circuit can also be defined as,

Reluctance, $S = \frac{mmf}{flux}, ampere\ turns/weber$

(vii) Magnetomotive Force (mmf):

mmf is defined as the magnetic force, which creates magnetic flux in a magnetic material. The unit is ampere turns (AT).

mmf = N I

where, N= number of turns in the coil.

I= Current through the coil

Or, mmf= Flux X Reluctance= $\varphi \times S$.

Faradays Laws of Electromagnetic Induction:

First Law: *Whenever the flux linking an electric circuit changes, an emf is induced in the electric circuit.*

Second Law: *the magnitude of the induced emf is equal to the rate of change of flux linkages.*

The direction of the induced emf was given by Heinrich Friedrich Emil Lenz (1804-1865), a Russian geologist and Physicist.

Lenz's Law:

The direction of induced emf and hence current is such that it opposes the cause producing it.

All the above laws can be represented by the following equation: $e = -N\frac{d\varphi}{dt}$

– ve sign indicates that the induced emf opposes the very cause of it i.e. applied voltage.

e = induced emf in volts.

$\frac{d\varphi}{dt}$ = Rate of Change of Flux.

Explanation of Lenz's Law:

Consider a coil of 'n' turns as shown in fig. 2, to which an alternating voltage V is applied, due to which an alternating current 'i' flows through the coil.

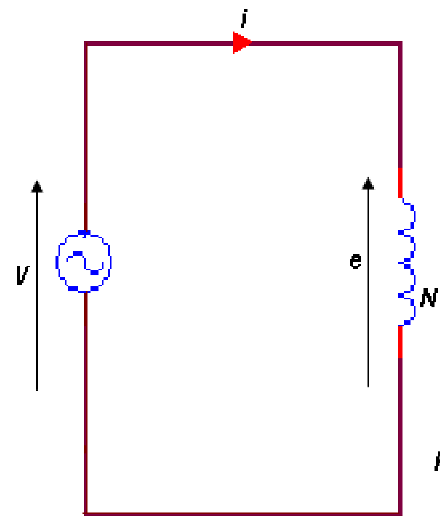


Fig. 2

This alternating current produces an alternating flux φ, which links the coil. Hence an emf is induced in the coil, coil, which is given by the equation,

$$e = -N\frac{d\varphi}{dt}$$

This induced emf opposes its own cause. The cause of the induced emf is the changing flux, which is due to the changing current, which inturn is due to the alternating voltage applied. Hence, we say that the induced emf opposes the applied voltage which is the very cause of it.

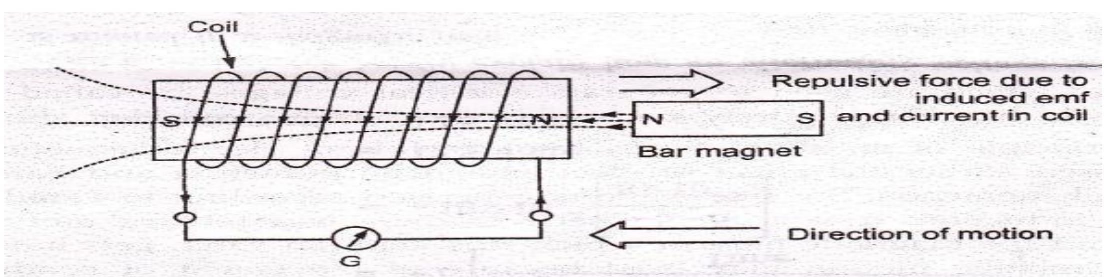


Fig. 1

Fleming's Left Hand Rule:

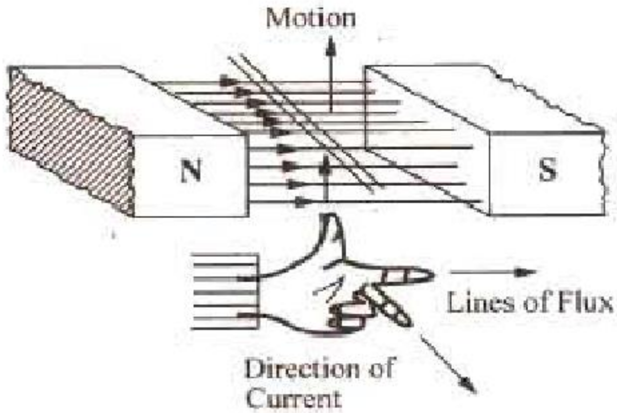


fig. 3

This rule gives the direction of current. When the thumb, the forefinger and the middle finger of the left hand are held mutually perpendicular to each other, the thumb in the direction of force or motion, the fore finger in the direction of magnetic field and the direction of the middle finger gives the direction of current. This is best illustrated from the fig. 3 shown above.

Fleming's Right Hand Rule:

This rule gives the direction of the induced emf. When the thumb, the fore finger and the middle finger of the right hand are held mutually perpendicular to each other, the thumb in the direction of the motion of conductor, the fore finger in the direction of the magnetic field, then the direction of the middle finger gives the direction of the induced emf. This is best illustrated from the fig.4 below.

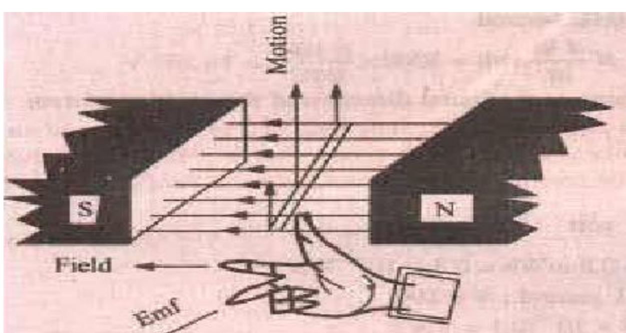


fig. 4

Dynamically Induced E.M.F:

In this case, an E.M.F is induced in the conductor when the conductor cuts across magnetic flux lines. This can be achieved either by moving magnetic poles with respect to stationary conductors or by moving conductors with respect to stationary magnetic poles.

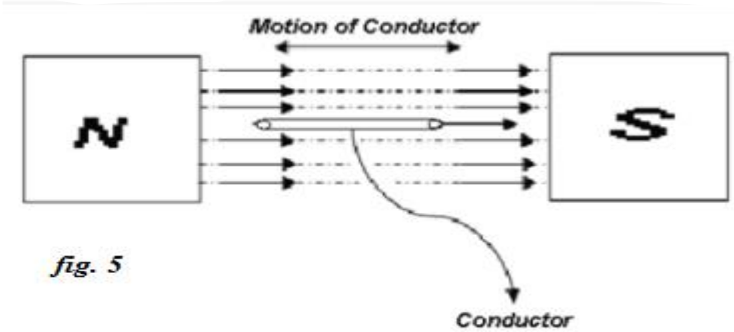


fig. 5

Consider a conductor of length "*l*" meters moving in the air gap between the poles of the magnet. If plane of the motion of the conductor is parallel to the plane of the magnetic field then there is no cutting of flux lines and there cannot be any induced E.M.F in the conductor such condition is shown in the fig. 5.

In second case as shown in fig. 6 the velocity direction i.e. motion of conductor is perpendicular to the flux. Hence whole length of conductor is cutting the flux line. Hence, there is maximum possible induced E.M.F in the conductor.

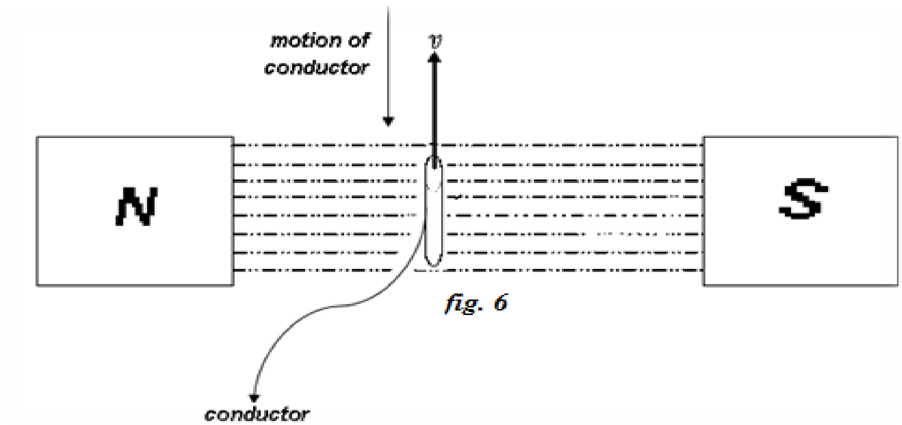


fig. 6

Let the conductor move through a small distance dx in dt seconds.

So, $area\ swept = l \times dx$

$$flux\ cut = flux\ density \times area\ swept$$

$$flux\ cut = B \times l \times dx$$

As per Faraday's Law of Electromagnetic Induction, the E.M.F 'e' induced in the conductor is given by:

$$e = \frac{flux\ cut}{time} = \frac{B \times l \times dx}{dt}$$

$$e = B\ l\ \frac{dx}{dt} \qquad e = B\ l\ v, \text{ volts} \quad \text{where, } v = \frac{dx}{dt}$$

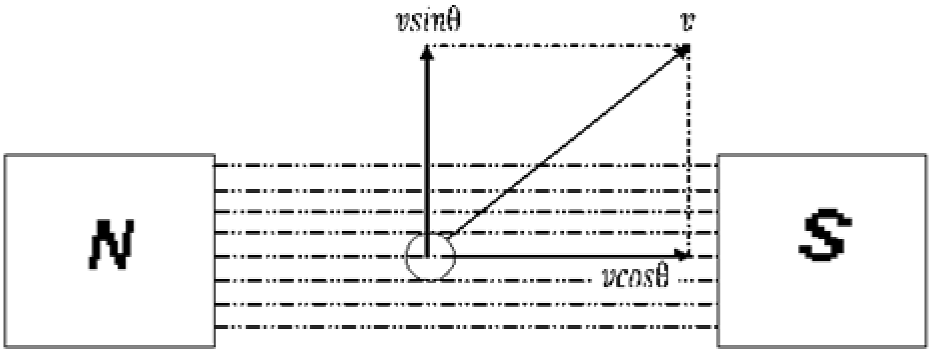


fig. 7

(i) $vcos\theta$, parallel to the field.

(ii) $vsin\theta$, perpendicular to the field.

The components $vcos\theta$, being parallel to the field, does not induce any voltage. But, component $vsin\theta$ produces emf and is given by: $e = Blvsin\theta \; volts$.

The direction of the induced emf is found by the Flemings Right Hand Rule.

Example: dc generator works on the principle of dynamically induced emf in the conductors which are housed in a revolving armature lying within magnetic field

This type of induced e.m.f. is also available in the rotating machines such as alternators, generator etc.

Statically Induced EMF:

When a conductor is stationary and the magnetic field is moving or changing the emf induced is called statically induced emf.

Statically induced enf may be of following types:

i. self-induced emf
ii. mutually induced emf

i. Self-Induced EMF:

Consider a coil of N – turns which is connected to an alternating voltage 'V' due to which an alternating current 'I' flows through the coil. The alternating current produces an alternating flux 'φ', which links

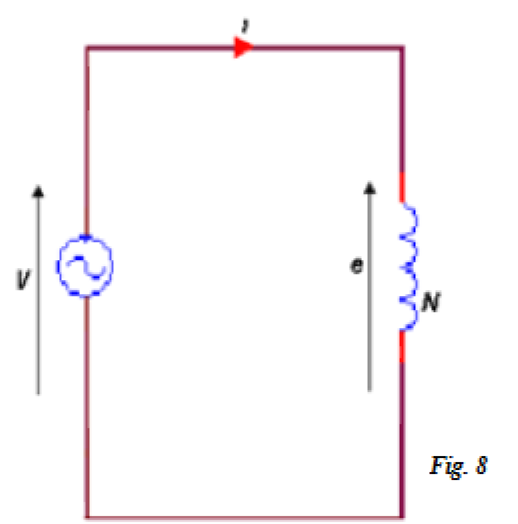


Fig. 8

the coil as shown in fig.8. Hence an emf is induced in the coil. This emf induced is known as self-induced emf and is given by:

$$e = -N\frac{d\varphi}{dt} = -N\frac{d\varphi}{dt} \times \frac{di}{di} = -N\frac{d\varphi}{di} \times \frac{di}{dt} = -L\frac{di}{dt}$$

Where,

$$L = N\frac{d\varphi}{di} = \frac{N\varphi}{I}, L \to Constant\ known\ as\ the\ self\ inductance\ of\ the\ coil$$

$$\frac{\mathrm{d}\varphi}{\mathrm{di}} \to \text{constant because; } \varphi\alpha i$$

Self-Inductance (L):

The self-inductance of a coil is its property by virtue of which, it always opposes any change in the value of the current flowing through it.

The self-inductance of a coil is also defined as the number of weber turns produced per ampere in the coil.

$$L = \frac{N\varphi}{I};\ \varphi = \frac{mmf}{reluctance} = \frac{NI}{S} = \frac{N}{I} \times \frac{NI}{S} = \frac{N^2}{S}, Henries$$

$$Now, S = \frac{l}{\mu a}$$

$$\therefore, L = \frac{N^2}{(^l/_{\mu a})} = \frac{N^2 \mu a}{l} = \frac{N^2 \mu_0 \mu_r a}{l}, Henries$$

$$where, l = length\ of\ magnetic\ circuit$$

$$a = area\ of\ cross\ section\ of\ magnetic\ circuit\ through\ which\ flux\ passes$$

Mutually Induced EMF:

Mutually inductance: Two coils, which are placed close to each other are said to be mutually compelled, when a part of alternating flux produced in one coil links the other coil. As the flux is of alternating type, emf is induced in both the coils. The emf induced in the first coil, where the flux is produced, is called as self induced emf and the emf induced in the second coil, which links a part of the flux produced in the fires coil, is known as mutually induced emf.

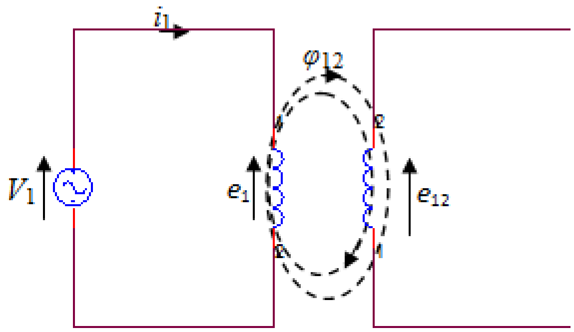


Fig. 9

Consider two coils of turns N_1 & N_2 , which are placed very close to each other as shown in fig 9, when an alternating voltage V_1, is applied to the first coil, an alternating current *i*, flows through it, producing an alternating flux φ_1 . This flux φ_1, links coil – 1 & hence an emf e_1, is induced in it, which is given by: $e_1 = -N_1 \frac{d\varphi_1}{dt} \dots\dots\dots (1)$

Where, $\varphi_1 = \varphi_{11} + \varphi_{12} \dots\dots\dots (a)(total\ flux\ due\ to\ coil - 1)$

The emf induced in coil – 2, is given by:

$$e_{12} = -N_2 \frac{d\varphi_{12}}{dt} \dots\dots\dots (2)$$

$$e_{12} = -N_2 \frac{d\varphi_{12}}{di_1} \times \frac{di_1}{dt}$$

$$\boldsymbol{e_{12} = -M_{12} \frac{di_1}{dt}}$$

Where, $M_{12} = N_2 \frac{d\varphi_{12}}{di_1}, is\ the\ mutual\ inductance\ between\ coil - 1\ \&\ coil - 2.$

Similar equation can b written, when coil -2 is energized by an alternating current i_2, producing a total flux φ_2 in it, as shown in fig. 9.

$$\varphi_2 = \varphi_{22} + \varphi_{21} \dots\dots\dots (b)$$

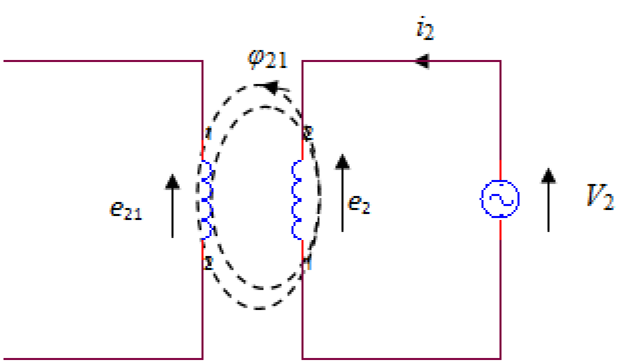


Fig. 10

Where, φ_2 = total flux produced in coil – 2.

φ_{22} = flux that links only coil – 2.

φ_{21} = flux that links both coil – 2 and coil – 1.

The self induced *emf* in coil – 2 is given by:

$$e_2 = -N_2 \frac{d\varphi_2}{dt} \dots\dots\dots (3)$$

The mutually induced between coil – 2 and coil – 1.

As the coupling between the two coils is bilateral, which means that the coupled circuit has the same characteristics in both directions. $M_{12} = M_{21} = M$ … … … (5)

Hence, the mutual inductance between any two coils, which are placed close to each other, may be defined as the ability of one coil to induce an emf in the other coil, when an alternating current flows through one of the coils.

$$M = N_2 \frac{d\varphi_{12}}{di_1} = N_1 \frac{d\varphi_{21}}{di_2} \ldots\ldots\ldots (6)$$

<u>Co-efficient of coupling (K):</u>

The co-efficient of coupling is the ratio of the mutual flux to the total flux.

Therefore, $K_{12} = \frac{\varphi_{12}}{\varphi_1}$ $and\ K_{21} = \frac{\varphi_{21}}{\varphi_2} \ldots\ldots\ldots (7)$

As the coupling is bilateral. $K_{12} = K_{21} = K$ ………(8)

$$\therefore \varphi_{12} = k\varphi_1 \ \&\ \ \varphi_{21} = k\varphi_2 \ldots\ldots\ldots (9)$$

$$we\ have, M_{12} = N_2 \frac{d\varphi_{12}}{di_1} \ \&\ M_{21} = N_1 \frac{d\varphi_{21}}{di_2}$$

Multiplying M_{12} and M_{21}.

$$M_{12} \times M_{21} = N_2 \frac{d\varphi_{12}}{di_1} \times N_1 \frac{d\varphi_{21}}{di_2}\ \ (from\ eqn\ 5)$$

$$M^2 = N_1 N_2 \frac{d\varphi_{12}}{di_1} \times \frac{d\varphi_{21}}{di_2}\ \ (using\ eqn\ 9)$$

$$M^2 = K^2 \times N_1 \frac{d\varphi_1}{di_1} \times N_2 \frac{d\varphi_2}{di_2}$$

$$M^2 = K^2 L_1 L_2$$

$$\therefore, K = \frac{M}{\sqrt{L_1 L_2}}.$$

Therefore, K is the co-efficient of coupling, which gives the relation between self and mutual inductance.

<u>Energy stored in the magnetic field of an inductor:</u>

The energy required to establish magnetic field is then gets stored into it as a potential energy. This energy can be recovered when magnetic field collapses.

Let the induced emf in a coil be: $e = -L\frac{dI}{dt}$

This opposes a supply voltage. So, $V = -e = -\left[-L\frac{dI}{dt}\right] = L\frac{dI}{dt}$

Therefore, power supplied, $P = VI = L\frac{dI}{dt} \times I$

Therefore, energy supplied in time dt is, $E = Power \times Time = LI\frac{dI}{dt}.dt = LI.dI$

This is energy supplied for change in current of dI but actually current changes from zero to I. Therefore, integrating above total energy stored.

$$E = \int_0^I LI.dI = L\int_0^I I.dI = L\left[\frac{I^2}{2} - 0\right] = \frac{1}{2}LI^2$$

$$E = \frac{1}{2}LI^2, Joules.$$