Department of Electrical & Electronics Engineering

Course File

Basic Electrical and Electronics Engineering

(Course Code: EE401ES)

II B.Tech II Semester

2023-24

K.RAJANI

Assistant Professor

ANURAG Anurag ENGINEERING COLLEGE (An Autonomous Institution)

Ananthagiri, Kodad, Telangana 508 206, India.

Department of Electrical & Electronics Engineering

Basic Electrical and Electronics Engineering

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Int. Marks:40 Ext. Marks:60 Total Marks:100

II Year B.Tech. II Semester

L	T	P	C
3	0	0	3

(EE401ES) Basic Electrical and Electronics Engineering

UNIT-I:

D.C.Circuits: Electrical circuit elements (R, L and C), voltage and current sources, KVL&KCL, analysis of simple circuits with dc excitation.

A.C. Circuits: Representation of sinusoidal wave forms, peak and RMS values, phasor representation, real power, reactive power, apparent power, power factor, Analysis of single-phase ac circuits.

UNIT-II:

Electrical Installations: Components of LT Switch gear: Switch Fuse Unit (SFU), MCB, ELCB, MCCB, Types of Wires and Cables, Earthing. Types of Batteries, Important characteristics for Batteries. Elementary calculations for energy consumption, power factor improvement and battery backup.

UNIT-III:

Electrical Machines: Working principle of Single-phase transformer, equivalent circuit, losses in transformers, efficiency.Construction and working principle of DC generators, EMF equation,working principle of DC motors,Torque equations and Speed control of DC motors, Construction and working principle of Three-phase Induction motor, Torques equations.

UNIT-IV:

P-N Junction and Zener Diode: Principle of Operation Diode equation, Volt-Ampere characteristics,Temperature dependence, Ideal versus practical, Static and dynamic resistances, Equivalent circuit, Zener diode characteristics and applications.

Rectifiers and Filters: P-N junction as a rectifier - Half Wave Rectifier, Ripple Factor - Full Wave Rectifier

,Bridge Rectifier,Harmonic components in Rectifier Circuits.

UNIT-V:

Bipolar Junction Transistor (BJT): Construction, Principle of Operation, Amplifying Action Common Emitter,Common Base and Common Collector configurations,Comparison of CE,CB and CC configurations.

Field Effect Transistor (FET): Construction, Principle of Operation, Comparison of BJT and FET, Biasing FET.

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Text Books:

1. Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar Oxford University.
2. Basic Electrical and electronics Engineering - DP Kothari. IJ Nazareth, McGraw Hill Education.

Reference Books:

1. Electronic Devices and Circuits – R.L.Boyle stad and Louis Nashelsky, PEI/PHI, 9^{th} Ed,2006.
2. Electronic Devices and Circuits – J. Millman and C.C. Halkias, SatyabrataJit, TMH,2/e,1998.
3. Engineering circuit analysis – by William Hayt and Jack E. Kemmerly, McGraw Hill Company, $6^{th\ edition}$.
4 Linear circuit analysis (time domain phasor and Laplace transform approaches) - 2^{nd} Edition by Raymond A. De Carlo and Pen-Min-Lin, Oxford UniversityPress-2004
5 Network Theory by N.C.Jagan & C. Lakshminarayana, B.S. Publications.
6 Network Theory by Sudhakar, Shyam Mohan Palli, TMH.

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Timetable

II B.Tech. II Semester – BEEE

Day/Hour	9.30-10.20	10.20-11.10	11.20-12.10	12.10-01.00	1.40-2.25	2.25-3.10	3.15-4.00
Monday						BEEE	
Tuesday	BEEE	BEEE					
Wednesday						BEEE	
Thursday			BEEE				
Friday							
Saturday	BEEE						

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Vision of the Institute

Vision of the Institute

To be a premier Institute in the country and region for the study of Engineering, Technology and Management by maintaining high academic standards which promotes the analytical thinking and independent judgment among the prime stakeholders, enabling them to function responsibly in the globalized society.

Mission of the Institute

To be a world-class Institute, achieving excellence in teaching, research and consultancy in cutting-edge Technologies and be in the service of society in promoting continued education in Engineering, Technology and Management.

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Quality Policy

To ensure high standards in imparting professional education by providing world-class infrastructure, top-quality-faculty and decent work culture to sculpt the students into Socially Responsible Professionals through creative team-work, innovation and research

Vision of the Department

Impart futuristic technical education and instil high patterns of discipline through our dedicated staff, which shall set global standards, making our students technologically superior and ethically strong, who in turn shall improve the quality of life of the human race.

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Mission of the Department

To Impart Quality higher education and to undertake research and extension with emphasis on application and innovation that cater to the emerging societal needs of students of all sections enabling them to be globally competitive and socially responsible citizens with intrinsic values.

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Program Educational Objectives (B.Tech. – EEE)

Graduates will be able to

PEO 1: To prepare students to excel in technical profession/industry and/or higher education by acquiring knowledge in mathematics, science and engineering principles.

PEO 2: Able to formulate, analyze, design and create novel products and solutions to electrical and electronics engineering problems those are economically feasible and socially acceptable.

PEO 3: Able to adopt multi-disciplinary environments, leadership qualities, effective communication, professional ethics and lifelong learning process.

Program Outcomes (B.Tech. – EEE)

At the end of the Program, a graduate will have the ability to

PO 1: An ability to apply the knowledge of mathematics, science and engineering fundamentals.

PO 2: An ability to conduct Investigations using design of experiments, analysis and interpretation of data to arrive at valid conclusions.

PO 3: An ability to design Electrical and Electronics Engineering components and processes within economic, environmental, ethical and manufacturability constraints.

PO 4: An ability to function effectively in multidisciplinary teams.

PO 5: An ability to identify, formulate, analyze and solve Electrical and Electronics Engineering problems.

PO 6: An ability to understand professional, ethical and social responsibility.

PO 7: An ability to communicate effectively through written reports or oral presentations.

PO 8: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

PO 9: An ability to recognize the need and to engage in independent and life-long learning.

PO 10: Knowledge on contemporary issues.

PO 11: An ability to use the appropriate techniques and modern engineering tools necessary for engineering practice.

PO 12: An ability to demonstrate knowledge and understanding of engineering and management principles and apply these to manage projects.

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COURSE OBJECTIVES

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	To introduce the concepts of electrical circuits, its components and AC single phase Circuits.
2	To import the knowledge of various electrical installations.
3	To study and understand the different types of DC/AC machines and transformers
4	To introduce the concepts of diodes & transistors.
5	To impart the knowledge of various configurations, characteristics and applications.

COURSE OUTCOMES

The expected outcomes of the Course/Subject are:

S.No	Outcomes
1.	To analyze and solve electrical circuits using network laws.
2.	To introduce components of Low Voltage Electrical Installations.
3.	To understand and analyze basic Electric and Magnetic circuits.
4.	To study the working principles of Electrical Machines.
5.	To identify and characterize diodes and various types of transistors.

Signature of faculty

Note: Please refer to Bloom’s Taxonomy, to know the illustrative verbs that can be used to state the outcomes.

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GUIDELINES TO STUDY THE COURSE / SUBJECT

Course Design and Delivery System (CDD):

- The Course syllabus is written into number of learning objectives and outcomes.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

Signature of HOD　　　　　　　　　　Signature of faculty

Date:　　　　　　　　　　Date:

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COURSE SCHEDULE

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. of Periods
		From	To	
1.	UNIT-I: D.C.Circuits: Electrical circuit elements (R, L and C), voltage and current sources, KVL&KCL, analysis of simple circuits with dc excitation. **A.C. Circuits:** Representation of sinusoidal wave forms, peak and RMS values, Phasor representation, real power, reactive power, apparent power, power factor, Analysis of single-phase ac circuits.	05.02.2024	24.02.2024	17
2.	UNIT-II: Electrical Installations: Components of LT Switch gear: Switch Fuse Unit (SFU), MCB, ELCB, MCCB, Types of Wires and Cables, Earthing. Types of Batteries, Important characteristics for Batteries. Elementary calculations for energy consumption, power factor improvement and battery backup.	26.02.2024	16.03.2024	16
3.	UNIT-III: Electrical Machines: Working principle of Single-phase transformer, equivalent circuit, losses in transformers, efficiency. Construction and working principle of DC generators, EMF equation, working principle of DC motors, Torque equations and Speed control of DC motors, Construction and working principle of Three-phase Induction motor, Torques equations.	18.03.2024	20.04.2024	15
4.	UNIT-IV:P-N Junction and Zener Diode: Principle of Operation Diode equation, Volt-Ampere characteristics, Temperature dependence, Ideal versus practical, Static and dynamic resistances, Equivalent circuit, Zener diode characteristics and applications. Rectifiers and Filters: P-N junction as a rectifier - Half Wave Rectifier, Ripple Factor - Full Wave Rectifier, Bridge Rectifier, Harmonic components in Rectifier Circuits.	24.04.2024	09.05.2024	17
5.	UNIT-V: Bipolar Junction Transistor (BJT): Construction, Principle of Operation, Amplifying Action Common Emitter, Common Base and Common Collector configurations, Comparison of CE,CB and CC configurations. Field Effect Transistor (FET): Construction, Principle of Operation, Comparison of BJT and FET, Biasing FET.	03.06.2024	15.06.2024	12

Total No. of Instructional periods available for the course: 77 Hours

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SCHEDULE OF INSTRUCTIONS - COURSE PLAN

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1	1	05-Feb-24	1	**UNIT-I Introduction to BEEE**	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	2	06-Feb-24	2	Basic Definitions	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	3	07-Feb-24	1	Types of elements	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	4	08-Feb-24	1	Types of Sources	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	5	12-Feb-24	1	Ohm,s law,kirchhoff's Laws.	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	6	13-Feb-24	2	Resistive networks	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	7	14-Feb-24	1	Seriescircuits	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	8	15-Feb-24	1	Numerical Problems	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	9	17-Feb-24	1	Analysis of circuits with DC excitation	1 1	Basic Electrical and electronics Engineering – MS Sukija

						TK Nagasarkar
	10	19-Feb-24	1	Representation of sinusoidal waveforms	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	11	20-Feb-24	2	Peak,rms and Average values	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	12	21-Feb-24	1	Single phase R-L,R-C,R-L-C circuit	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	13	22-Feb-24	1	Phasor Representation	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	14	24-Feb-24	1	powers in ac circuits	1 1	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
2	1	26-Feb-24	1	**UNIT-II** Electrical installation	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	2	27-Feb-24	2	Components of LT switch gear	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	3	28-Feb-24	1	Switch fuse unit	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	4	29-Feb-24	1	MCB	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	5	02-Mar-24	1	ELCB,MCCB	2 2	Basic Electrical and electronics Engineering

						– MS Sukija TK Nagasarkar
	6	04-Mar-24	1	Types of wires	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	7	05-Mar-24	2	Types of cables	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	8	06-Mar-24	1	Earthing	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	9	07-Mar-24	1	Types of earthing	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	10	11-Mar-24	1	types of batteries	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	11	12-Mar-24	2	Characteristics of batteries	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	12	13-Mar-24	1	Elementary calculation or energy consumption	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	13	14-Mar-24	1	Power factor improvement	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	14	16-Mar-24	1	Battery backup	2 2	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar

3	1	18-Mar-24	1	**UNIT-II**Transformers-Introduction	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	2	19-Mar-24	2	Construction details	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	3	20-Mar-24	1	Types of transformers , emf equation of transformer	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	4	21-Mar-24	1	Equivalent circuit	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	5	23-Mar-24	1	losses and efficiency	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	6	26-Mar-24	1	Construction of DC generator and motor	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	7	27-Mar-24	2	Speed control of Dcmotors	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	8	28-Mar-24	1	Numerical problems	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	9	04-Apr-24	1	Numerical problems	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	10	06-Apr-24	1	Numerical problems	3 3	Basic Electrical and electronics Engineering – MS Sukija

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						TK Nagasarkar
	11	08-Apr-24	1	Geneartion of rotating magnetic field	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	12	15-Apr-24	1	Principle & Construction of Three phase IM	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	13	16-Apr-24	1	Torque slip characteristics of IM	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	14	18-Apr-24	1	Numerical problems	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	15	20-Apr-24	1	Numerical problems	3 3	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
4	1	22-Apr-24	1	**UNIT-IV** P-N junction diode principle of operation	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	2	23-Apr-24	2	Diode equation	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	3	24-Apr-24	1	V-I charecteristics of Diode	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	4	25-Apr-24	1	ideal versus practical diodes	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar

	5	27-Apr-24	1	Equivalent circuit	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	6	29-Apr-24	1	static and dynamic resistance	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	7	30-Apr-24	2	Numerical problems	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	8	01-May-24	1	Zener diode characteristics	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	9	02-May-24	1	Applications of Zener diode	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	10	04-May-24	1	Applications of diodes	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	11	06-May-24	1	Half wave rectifier	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	12	07-May-24	2	Full Wave Rectifier	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	13	08-May-24	1	Bridge Rectifier	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	14	09-May-24	1	Harmonics in filter circuits	4 4	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar

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5	1	03-Jun-24	1	**Unit-V BJT Construction**	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	2	04-Jun-24	2	principle of operation	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	3	05-Jun-24	1	amplifing action	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	4	06-Jun-24	1	Configurations of Transistor	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	5	08-Jun-24	1	Configurations of Transistor	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	6	10-Jun-24	1	Comparision of Configurations	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	7	11-Jun-24	2	FET construction	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	8	12-Jun-24	1	Principle of operation	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	9	13-Jun-24	1	Comparison of BJT,FET	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar
	10	15-Jun-24	1	Revision	5 5	Basic Electrical and electronics Engineering – MS Sukija TK Nagasarkar

Signature of HOD Signature of faculty

Date: Date:

Note:

1. Ensure that all topics specified in the course are mentioned.
2. Additional topics covered, if any, may also be specified in bold.
3. Mention the corresponding course objective and outcome numbers against each topic.

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LESSON PLAN

DATE	DAY OF THE WEEK	WEEK NO.	DAYS PER WEEK	TOPICS TO BE COVERED
05-Feb-24	MON	1	1	**UNIT-I Introduction to BEEE**
06-Feb-24	TUE		2	Basic Definations
07-Feb-24	WED		1	Types of elements
08-Feb-24	THU		1	Types of Sources
09-Feb-24	FRI		0	No class
10-Feb-24	SAT	SECOND SATURDAY		
11-Feb-24	**SUN**	SUNDAY		
12-Feb-24	MON	2	1	Ohm,s law,kirchhoff's Laws.
13-Feb-24	TUE		2	Resistive networks
14-Feb-24	WED		1	Seriescircuits
15-Feb-24	THU		1	Numerical Problems
16-Feb-24	FRI		0	No class
17-Feb-24	SAT		1	Analysis of circuits with DC excitation
18-Feb-24	**SUN**	SUNDAY		
19-Feb-24	MON	3	1	Representation of sinusoidal waveforms
20-Feb-24	TUE		2	Peak,rms and Average values
21-Feb-24	WED		1	Single phase R-L,R-C,R-L-C circuit
22-Feb-24	THU		1	Phasor Representation
23-Feb-24	FRI		0	No class
24-Feb-24	SAT		1	powers in ac circuits
25-Feb-24	**SUN**	SUNDAY		
26-Feb-24	MON	4	1	**UNIT-II** Electrical installation
27-Feb-24	TUE		2	Components of LT switch gear
28-Feb-24	WED		1	Switch fuse unit
29-Feb-24	THU		1	MCB
01-Mar-24	FRI		0	No class
02-Mar-24	SAT		1	ELCB,MCCB
03-Mar-24	**SUN**	SUNDAY		
04-Mar-24	MON	5	1	Types of wires
05-Mar-24	TUE		2	Types of cables

06-Mar-24	WED		1	Earthing
07-Mar-24	THU		1	Types of earthing
08-Mar-24	FRI	MAHASHIVARATHRI		
09-Mar-24	SAT	SECOND SATURDAY		
10-Mar-24	**SUN**	SUNDAY		
11-Mar-24	MON	6	1	types of batteries
12-Mar-24	TUE		2	Characteristics of batteries
13-Mar-24	WED		1	Elementary calculation or energy consumption
14-Mar-24	THU		1	Power factor improvement
15-Mar-24	FRI		0	No class
16-Mar-24	SAT		1	Battery backup
17-Mar-24	**SUN**	SUNDAY		
18-Mar-24	MON	7	1	**UNIT-III** Transformers-Introduction
19-Mar-24	TUE		2	Construction details
20-Mar-24	WED		1	Types of transformers , emf equation of transformer
21-Mar-24	THU		1	Equivalent circuit
22-Mar-24	FRI		0	
23-Mar-24	SAT		1	losses and efficiency
24-Mar-24	**SUN**	SUNDAY		
25-Mar-24	MON	8		**HOLI**
26-Mar-24	TUE		1	Construction of DC generator and motor
27-Mar-24	WED		2	Speed control of Dcmotors
28-Mar-24	THU		1	Numerical problems
29-Mar-24	FRI		0	**GOOD FRIDAY**
30-Mar-24	SAT		1	
31-Mar-24	**SUN**	SUNDAY		
01-Apr-24	MON	9		MID-I
02-Apr-24	TUE			
03-Apr-24	WED			
04-Apr-24	THU		1	Numerical problems
05-Apr-24	FRI		0	No class
06-Apr-24	SAT		1	Numerical problems

07-Apr-24	**SUN**	SUNDAY		
08-Apr-24	MON	10	1	Geneartion of rotating magnetic field
09-Apr-24	TUE			**UGADI**
10-Apr-24	WED			**RAMDAN**
11-Apr-24	THU			
12-Apr-24	FRI			No Class
13-Apr-24	SAT	SECOND SATURDAY		
14-Apr-24	**SUN**	SUNDAY		
15-Apr-24	MON	11	1	Principle & Construction of Three phase IM
16-Apr-24	TUE		1	Torque slip characteristics of IM
17-Apr-24	WED			SRIRAMANAVAMI
18-Apr-24	THU		1	Numerical problems
19-Apr-24	FRI		0	No class
20-Apr-24	SAT		1	Numerical problems
21-Apr-24	**SUN**	SUNDAY		
22-Apr-24	MON	12	1	**UNIT-IV** P-N junction diode principle of operation
23-Apr-24	TUE		2	Diode equation
24-Apr-24	WED		1	V-I charecteristics of Diode
25-Apr-24	THU		1	ideal versus practical diodes
26-Apr-24	FRI		0	No class
27-Apr-24	SAT		1	Equivalent circuit
28-Apr-24	**SUN**	SUNDAY		
29-Apr-24	MON	13	1	static and dynamic resistance
30-Apr-24	TUE		2	Numerical problems
01-May-24	WED		1	Zener diode characteristics
02-May-24	THU		1	Applications of Zener diode
03-May-24	FRI		0	No class
04-May-24	SAT		1	Applications of diodes
05-May-24	**SUN**	SUNDAY		
06-May-24	MON	14	1	Half wave rectifier
07-May-24	TUE		2	Full Wave Rectifier
08-May-24	WED		1	Bridge Rectifier
09-May-24	THU		1	Harmonics in filter circuits

10-May-24	FRI		0	No class
11-May-24	SAT	SECOND SATURDAY		
12-May-24	**SUN**	SUNDAY		
13-May-24	MON	15		SUMMER VACATION
14-May-24	TUE			
15-May-24	WED			
16-May-24	THU			
17-May-24	FRI			
18-May-24	SAT			
19-May-24	**SUN**			
20-May-24	MON	16		
21-May-24	TUE			
22-May-24	WED			
23-May-24	THU			
24-May-24	FRI			
25-May-24	SAT			
26-May-24	**SUN**			
27-May-24	MON	17		
28-May-24	TUE			
29-May-24	WED			
30-May-24	THU			
31-May-24	FRI			
01-Jun-24	SAT			
02-Jun-24	**SUN**	SUNDAY		
03-Jun-24	MON	18	1	**Unit-V BJT Construction**
04-Jun-24	TUE		2	principle of operation
05-Jun-24	WED		1	amplifing action
06-Jun-24	THU		1	Configurations of Transistor
07-Jun-24	FRI		0	No class
08-Jun-24	SAT		1	Configurations of Transistor
09-Jun-24	**SUN**	SUNDAY		
10-Jun-24	MON	19	1	Comparision of Configurations

11-Jun-24	TUE		2	FET construction
12-Jun-24	WED		1	Principle of operation
13-Jun-24	THU		1	Comparison of BJT,FET
14-Jun-24	FRI		0	No class
15-Jun-24	SAT		1	Revision
16-Jun-24	**SUN**	SUNDAY		
17-Jun-24	MON	19	**BAKRID**	
18-Jun-24	TUE		**II-MID**	
19-Jun-24	WED			
20-Jun-24	THU			
21-Jun-24	FRI	**PREPEARATION HOLIDAYS**		
22-Jun-24	SAT			
23-Jun-24	**SUN**			
24-Jun-24	MON			
25-Jun-24	TUE			
26-Jun-24	WED	**END SEMESTER EXAMINATIONS**		
27-Jun-24	THU			
28-Jun-24	FRI			
29-Jun-24	SAT			
30-Jun-24	**SUN**			
01-Jul-24	MON			
02-Jul-24	TUE			
03-Jul-24	WED			
04-Jul-24	THU			
05-Jul-24	FRI			

Department of Electrical & Electronics Engineering

ASSIGNMENT – 1

This Assignment corresponds to Unit No. 1

Question No.	Question	Objective No.	Outcome No.
1	State and explain KVL and KCL? And also derive the equivalent resistance when three resistors are connected in parallel in a circuit?	1	1
2	Derive the average value, RMS value of an alternating Quantity?	1	1
3	What are the different types of batteries and their characteristics?	2	2
4	Explain about the importance of power factor improvement?	2	2
5	Explain the constructional details and working of transformers?	3	3

Signature of HOD

Date:

Signature of faculty

Date:

Department of Electrical & Electronics Engineering

ASSIGNMENT – 2

This Assignment corresponds to Unit No. 2

Question No.	Question	Objective No.	Outcome No.
1	Explain the constructional details and working of D.C generator?	3	3
2	Illustrate the operation of full wave rectifier?	4	4
3	Draw and explain the V-I Characteristics of P-N junction Diode?	4	4
4	Explain the principle of operation of FET?	5	5
5	2. Explain about different configurations of BJT?	5	5

Signature of HOD

Date:

Signature of faculty

Date:

Department of Electrical & Electronics Engineering

TUTORIAL – 1

This tutorial corresponds to Unit No. 1 (Objective Nos.: 1, Outcome Nos.: 1)

Q1. KCL is applied at _________
a) Neither loop nor node b) Both loop and node c) Node d) Loop

Q2. KVL is applied at _________
a) Neither loop nor node b) Both loop and node c) Node d) Loop

Q3. The Frequency Of An Alternating Current Is
a) cycles/sec b) cycles c) cycles-sec d) None of the above

Signature of HOD

Date:

Signature of faculty

Date:

Department of Electrical & Electronics Engineering

TUTORIAL – 2

This tutorial corresponds to Unit No. 2 (Objective Nos.: 2, Outcome Nos.: 2)

Q1. The fuse blows off by______
a) Arcing b) Melting c) Burning d) All of the above

Q2. The maximum value of power factor can be
a) 0 b) 0.1 c) 1 d) 2

Q3.The neutral wire is colored_______
a) Yellow b)Black c) Red d) Green

Signature of HOD

Date:

Signature of faculty

Date:

Department of Electrical & Electronics Engineering

TUTORIAL SHEET – 3

This tutorial corresponds to Unit No. 3 (Objective Nos.: 3, Outcome Nos.: 3)

Q1.A transformer

a) Steps up or down dc voltages   b) Changes ac to dc

c) Steps up or down ac voltages   d) Changes dc to ac

Q2 Transformer core are laminated in order to

a) Reduce copper loss   b) Minimize eddy current loss
c) Reduce eddy current and hysteresis loss   d) Reduce hysteresis loss

Q3.The purpose of a breather in a transformer to

a) To filter transformer oil   b) provide cold air in the transformer

c) Absorb moisture of air during breathing   d) None of the above

Signature of HOD   Signature of faculty

Date: Date:

Department of Electrical & Electronics Engineering

TUTORIAL – 4

This tutorial corresponds to Unit No. 4 (Objective Nos.: 3, Outcome Nos.: 3)

Q1. What can you do with a p-n junction diode?
a) Condenser b) Regulator
c) Amplifier d) Rectifier

Q2. What does a crystal diode have?
a) one pn junction b) two pn junctions c) three pn junctions d) four pn junctions

Q3. A diode's reverse current is of the order of……………….
a) kA b) mA c) µA d) A

Signature of HOD Signature of faculty

Date: Date:

Department of Electrical & Electronics Engineering

TUTORIAL SHEET – 5

This tutorial corresponds to Unit No. 5 (Objective Nos.: 5, Outcome Nos.: 5)

Q1. JFET has three terminals namely
a) Cathode, anode,grid b) Emitter,collector,base c) Source,drain,gate d) None of the above

Q2. JFET is similar in operation to -------- value.
a) Diode b) Pentode c) Triode d) Tetrode

Q3. JFET is a ______ driven device
a) Voltage b) Current c) Both d) None of the above

Signature of HOD | Signature of faculty

Date: | Date:

Department of Electrical & Electronics Engineering

EVALUATION STRATEGY

Target (s)

a. Percentage of Pass : 95%

Assessment Method (s) (Maximum Marks for evaluation are defined in the Academic Regulations)

a. Daily Attendance
b. Assignments
c. Online Quiz (or) Seminars
d. Continuous Internal Assessment
e. Semester / End Examination

List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this semester

Case Study of any one existing application

Signature of HOD | Signature of faculty

Date: | Date:

Department of Electrical & Electronics Engineering

COURSE COMPLETION STATUS

Actual Date of Completion & Remarks if any

Units	Remarks	Objective No. Achieved	Outcome No. Achieved
Unit 1	completed on 24.02.2024	1	1
Unit 2	completed on 16.03.2024	2	2
Unit 3	completed on 20.04.2024	3	3
Unit 4	completed on 09.05.2024	4	4
Unit 5	completed on 15.06.2024	5	5

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Date:

Signature of faculty

Date:

Department of Electrical & Electronics Engineering

Mappings

1. Course Objectives-Course Outcomes Relationship Matrix
(Indicate the relationships by mark "X")

Course-Outcomes / Course-Objectives	1	2	3	4	5
1	H	M	M		
2		H		M	
3			M		
4				H	

2. Course Outcomes-Program Outcomes (POs) & PSOs Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes / C-Outcomes	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	PSO 1	PSO 2
1	M	H	M		M	M	L	H	M	L		L	H	
2			M		L	L		M	H	L		M	H	H
3			L	M	L				H	L	M	L		M
4			L	M			H			L			M	
5	M	L	M	L			M	L		L	H	L		

Department of Electrical & Electronics Engineering

Rubric for Evaluation

Performance Criteria	Unsatisfactory	Developing	Satisfactory	Exemplary
	1	2	3	4
Research & Gather Information	Does not collect any information that relates to the topic	Collects very little information some relates to the topic	Collects some basic Information most relates to the topic	Collects a great deal of Information all relates to the topic
Fulfill team role's duty	Does not perform any duties of assigned team role.	Performs very little duties.	Performs nearly all duties.	Performs all duties of assigned team role.
Share Equally	Always relies on others to do the work.	Rarely does the assigned work - often needs reminding.	Usually does the assigned work - rarely needs reminding.	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking—never allows anyone else to speak.	Usually doing most of the talking-- rarely allows others to speak.	Listens, but sometimes talks too much.	Listens and speaks a fair amount.

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II B.TECH IV SEMESTER I MID EXAMINATIONS - APRIL 2024

Branch : B.Tech. (CE) **Subject : Basic Electrical and Electronics Engineering,EE401ES** **Max. Marks : ~~40~~ 20M**

Date : 01.04.2024 **Time :** 120 Min

PART - A

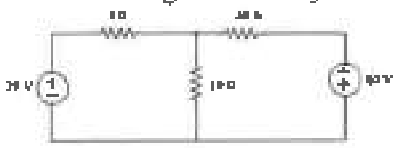
ANSWER ALL QUESTIONS **10 X 1M = 10M**

Q.No	Question		CO	BTL
1.	Mesh analysis mainly depends on (A). KVL (B). KCL (C). KVL&KCL (D). None	( )	CO1	L1
2.	An inductor stores energy in (A). magnetic field (B). electric field (C). eletro magnetic field (D). all	( )	CO1	L1
3.	A powerfactor of '1' indicates (A). purely resistive circuit (B). purely reactive circuit (C). both a&b (D). None	( )	CO1	L1
4.	Power factor is defined as (A). Cosine of phase angle between voltage and current (B). Ratio powerof active power to apparent (C). Ratio of resistance to impedance (D). all	( )	CO1	L1
5.	In Equipment grounding,the enclosure is connected to_____ wire (A). ground (B). neutral (C). both (D). Nnone	( )	CO2	L1
6.	The full form of MCCB (A). Main Current Circuit Breaker (B). Major Current Circuit Breaker (C). Moulded Case Circuit Breaker (D). Main Case Circuit Breaker	( )	CO2	L1
7.	The fuse blows off by ___ (A). Arcing (B). Burning (C). melting (D). Any one of the above	( )	CO2	L1
8.	A battery is a device which converts (A). Electrical Energy in to chemical Energy (B). Chemical Energy into Electrical Energy (C). Chemical Energy into Mechnical energy (D). Electrical Energy into mechanical Energy	( )	CO2	L1
9.	In a transformer energy is conveyed from primary to secondary through_____ (A). Air (B). Flux (C). Colling coil (D). All of the above	( )	CO3	L1
10.	Transformer transfers_____ (A). Power (B). Voltage (C). Current (D). Current and Voltage	( )	CO3	L1

PART - B

ANSWER ANY FOUR 4 X 5 = 20 M

Q.No	Question	CO	BTL
11.	A series has R=5 , L=0.15mH ,and C=100F and is supplied with 230V,50Hz single phase. Find impedance. current, power. power factor of the circuit.	CO1	L3
12.	Find the voltage across 30 resistor using Mesh analysis.	CO1	L3



Q.No	Question	CO	BTL
13.	Discuss about the important characteristics of batteries?	CO2	L2
14.	Explain any two methods of Earthing?	CO2	L2
15.	Obtain the equivalent circuit of transformer?	CO3	L3

16.	Explain the working principle of transformer with a neat sketch?	CO3	L2

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NAAC A+ GRADE
Venkatapur (V), Ghatkesar (M), Medchal-Malkajgiri (Dt.), Telangana

II B.TECH IV SEMESTER II MID EXAMINATIONS - JUNE 2024

Branch : B.Tech. (CE) | **Max. Marks : 30M**
Date : 18-Jun-2024 **Session : Morning** | **Time : 120 Min**
Subject : Basic Electrical and Electronics Engineering,EE401ES

PART - A

ANSWER ALL THE QUESTIONS **10 X 1M = 10M**

Q.No	Question		CO	BTL
1.	Yoke is made up of (A). Cast Steel (B). Cast iron (C). Mild Steel (D). Silicon Steel	( )	CO3	L1
2.	The back emf of Dc motor depends on (A). Speed (B). Flux (C). No of armature conductors (D). All of the above	( )	CO3	L1
3.	Efficiency of half wave rectier is (A). 50% (B). 60% (C). 40.60% (D). 46%	( )	CO4	L1
4.	Zener diode is used primarly as a (A). Amplifiers (B). Voltage regulators (C). Oscillators (D). Rectifiers	( )	CO4	L1
5.	A PN junction acts as a (A). Controlled switch (B). Bidirectional Switch (C). Unidirectional Switch (D). None of the above	( )	CO4	L1
6.	A diode has ________ (A). One PN junction (B). Two PN junctions (C). Three PN junctions (D). None of the above	( )	CO4	L1
7.	A JFET is also called as ______ Transistor (A). Unipolar (B). Bipolar (C). Uni junction (D). None of the above	( )	CO5	L1
8.	The base of a transistor is ______ doped (A). Heavily (B). Moderately (C). Lightly (D). None of the above	( )	CO5	L1
9.	The element that has Biggest size in transistor is (A). Emitter (B). Collector (C). Base (D). Collector- Base junction	( )	CO5	L1
10.	The gate of A JFET is ______________ biased (A). Forward (B). Reverse (C). Reverse as well as forward (D). None of the above	( )	CO5	L1

PART - B

ANSWER ANY FOUR **4 X 5M = 20M**

Q.No	Question	CO	BTL
11.	Describe the different speed control methods of DC motors?	CO3	L2
12.	Explain about principle of operation of three phase induction motor?	CO3	L3
13.	Draw and explain Zener diode charcteristics? And also mention its applications?	CO4	L2
14.	Draw and explain Volt-Ampere characteristics of P-N juction diode?	CO4	L3
15.	Explain about Common- Base Configuration of BJT?	CO5	L2
16.	Explain the construction and Working of a JFET?	CO5	L3

Continuous Internal Assessment (R-22)

Programme**: BTech** Year: **II** Course: **Theory** **A.Y: 2023-24**

Course: Basic Electrical & Electronis Engineering Faculty Name: K.Rajani

S. No	Roll No	MID-I (35M)	MID-II (35M)	Avg. of MID I & II	Viva-Voce/Poster Presentation (5M)	Total Marks (40)
1	21C11A0113	0	16	8	5	13
2	22C11A0101	18	19	19	5	24
3	22C11A0102	32	26	29	5	34
4	22C11A0103	18	21	20	5	25
5	22C11A0104	20	14	17	5	22
6	22C11A0105	27	30	29	5	34
7	22C11A0106	20	20	20	5	25
8	22C11A0107	25	21	23	5	28
9	23C15A0101	23	19	21	5	26
10	23C15A0102	24	19	22	5	27
11	23C15A0103	28	28	28	5	33
12	23C15A0104	20	15	18	5	23
13	23C15A0105	32	31	32	5	37

Total Strength: **13**

Signature of Faculty **Signature of HoD**

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Ananthagiri (V & M), Kodad, Suryapet (Dist), Telangana.

Program			YEAR	SEMESTER	MID EXAMINATION
B.Tech. ✓	M.Tech.	M.B.A.	II	II	II

HALL TICKET NO.

2	2	C	1	1	A	0	1	0	5

Regulation: R-22 Branch or Specialization: Civil

Course: BEEE

Signature of Student: A. Sangeetha

Signature of invigilator with date: [signature] 18/06/24

Signature of the Evaluator: [signature]

Q.No. and Marks Awarded

1	2	3	4	5	6	7	8	9	10	11

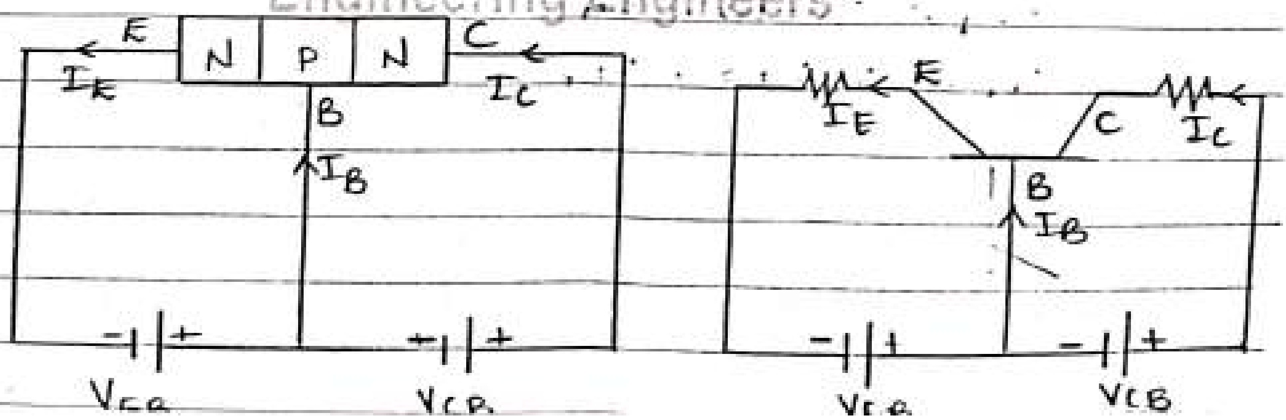
Maximum Marks: 30

Marks Obtained: 25

(Start Writing From Here)

1) → B
2) → A
3) → C
4) → B
5) → B
6) → B
7) → A
8) → ~~B~~ C
9) → B.
10) → B.

15) Common-Base Configuration of BJT :-



* current amplification factor :-

It is the ratio of output current to input current.

$$\alpha = \frac{\text{output current}}{\text{input current}}$$

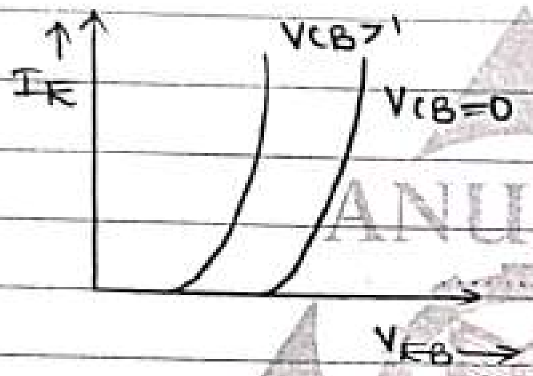
$$I_C = \alpha I_E + I_{CEO}$$

* input characteristics :-

input current $= I_E$

input voltage $= V_{EB}$

output voltage $= V_{CB}$



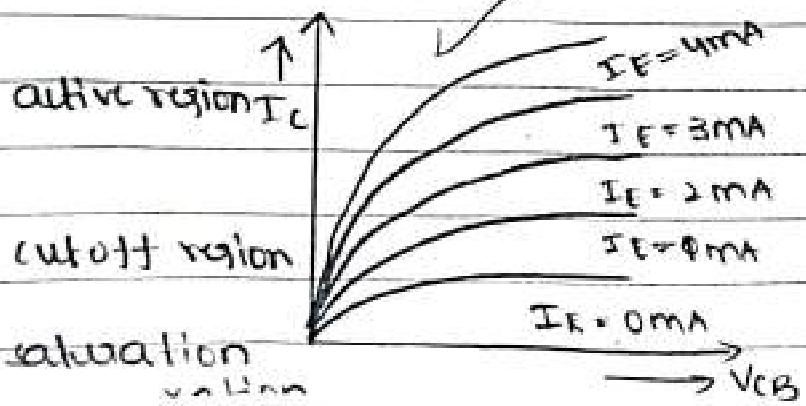
when $V_{CB}=0$ then the input current I_E increases rapidly by V_{EB}. at the same time V_{CB} increases then the break down region is small, so the curve is shifted to left side.

* output characteristics :-

output current $= I_C$

output voltage $= V_{CB}$

input voltage $= V_{EB}$.



⇒ In active region emitter base junctions are in forward bias and collector base region are reverse bias.

⇒ In cutoff region both the terminals of emitter base and collector base are reverse bias

⇒ In saturation region both the terminals of emitter base and collector base are forward bias

(16) Construction and working of a JFET.

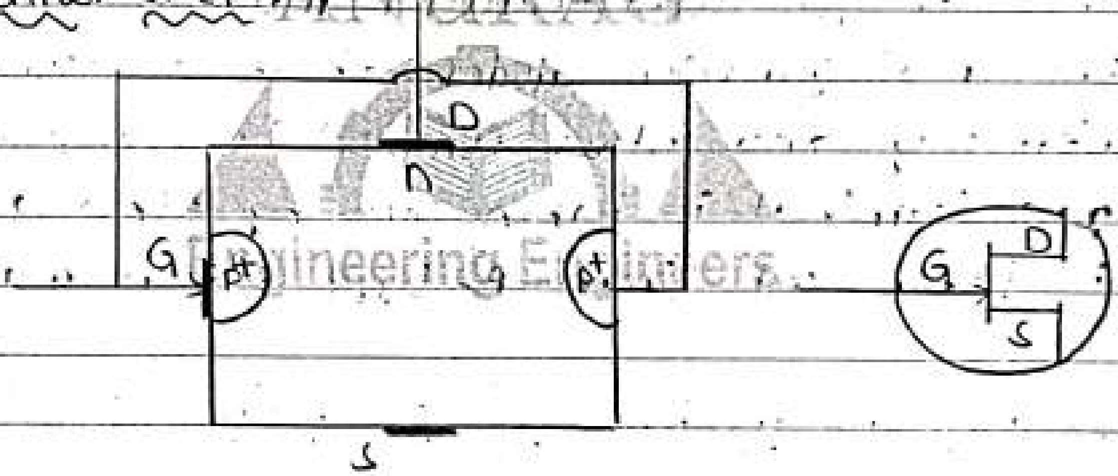
JFET is divided into two Parts.

(i) N-channel JFET / n-channel JFET

(ii) P-channel JFET.

(i) N-channel JFET :-

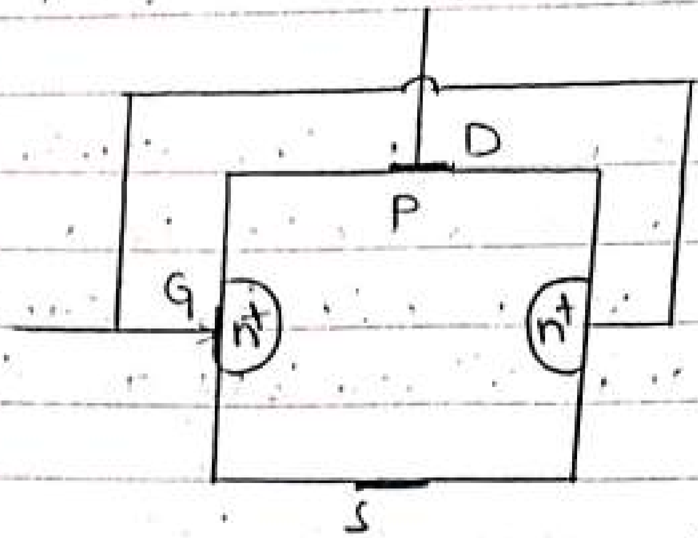
n-channel JFET :-

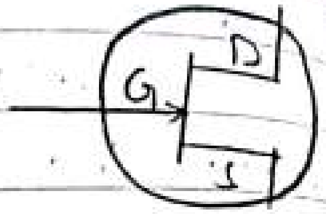


In this n-channel JFET, n-type silicon materials act as channel and it consists of two heavily doped two P-type semiconductor materials.

These P-type semiconductor materials are formed as two P-type P-N Junction diodes. these are connected internally and another common is known as gate gate terminal is taken out by other are source terminal is taken out from n-type silicon materials.

P-channel JFET :-



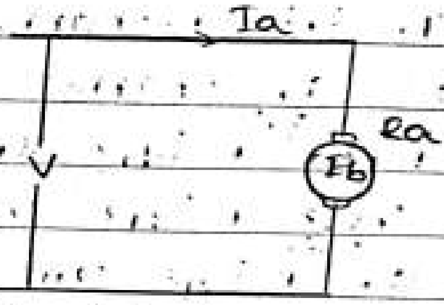


In this P-channel J-FET, P-type silicon material is aits as a common and it consist of two heavily N-type semiconductor materials.

These N-type semiconductor material is forms two P-N Junction diodes. these are connected internally and other common it known as gate gate terminal is taken out by other are source is taken out from P-type silicon material.

⑪ Speed control methods of DC motor :-

$E_b = \frac{\phi Z N}{60} \times \frac{P}{A}$



$N = \frac{E_b 60 A}{\phi Z P}$

[∵ 60, A, Z and P are constant]

$N = \frac{E_b}{\phi}$

$N \propto \frac{E_b}{\phi} \propto \frac{(V - I_a R_a)}{\phi}$

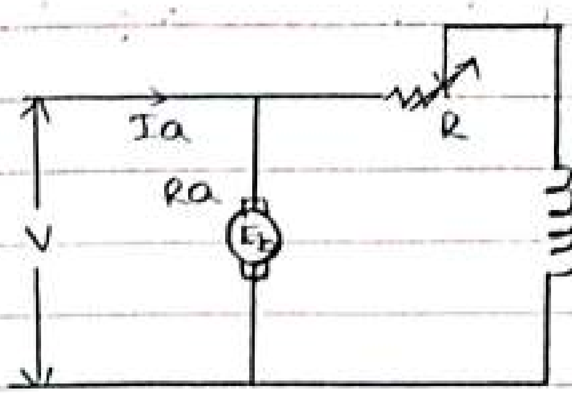
$V = E_b + I_a R_a$

$E_b = V - I_a R_a$.

speed control method is divided into two types.

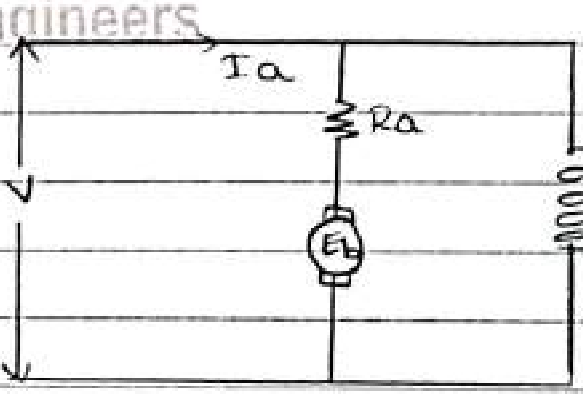
1. field flux control method
2. Armature control method.

1. field flux control method :-



This method is acceptable for speed above to rated rated speed. In this add a resistance in series through magnetic field get reduces and flux is introduced. This formation of flux can increases the speed.

2. Armature control method :-



The speed of the motor is directly proportional to back emf. E_b then E_b is $E_b = V - I_a R_a$. In this the the voltage drop and armature resistance are constant.

The speed of the motor is directly proportional to armature current. then add the armature resistance in series. then Ia decreases then automatically speed is also decreases.

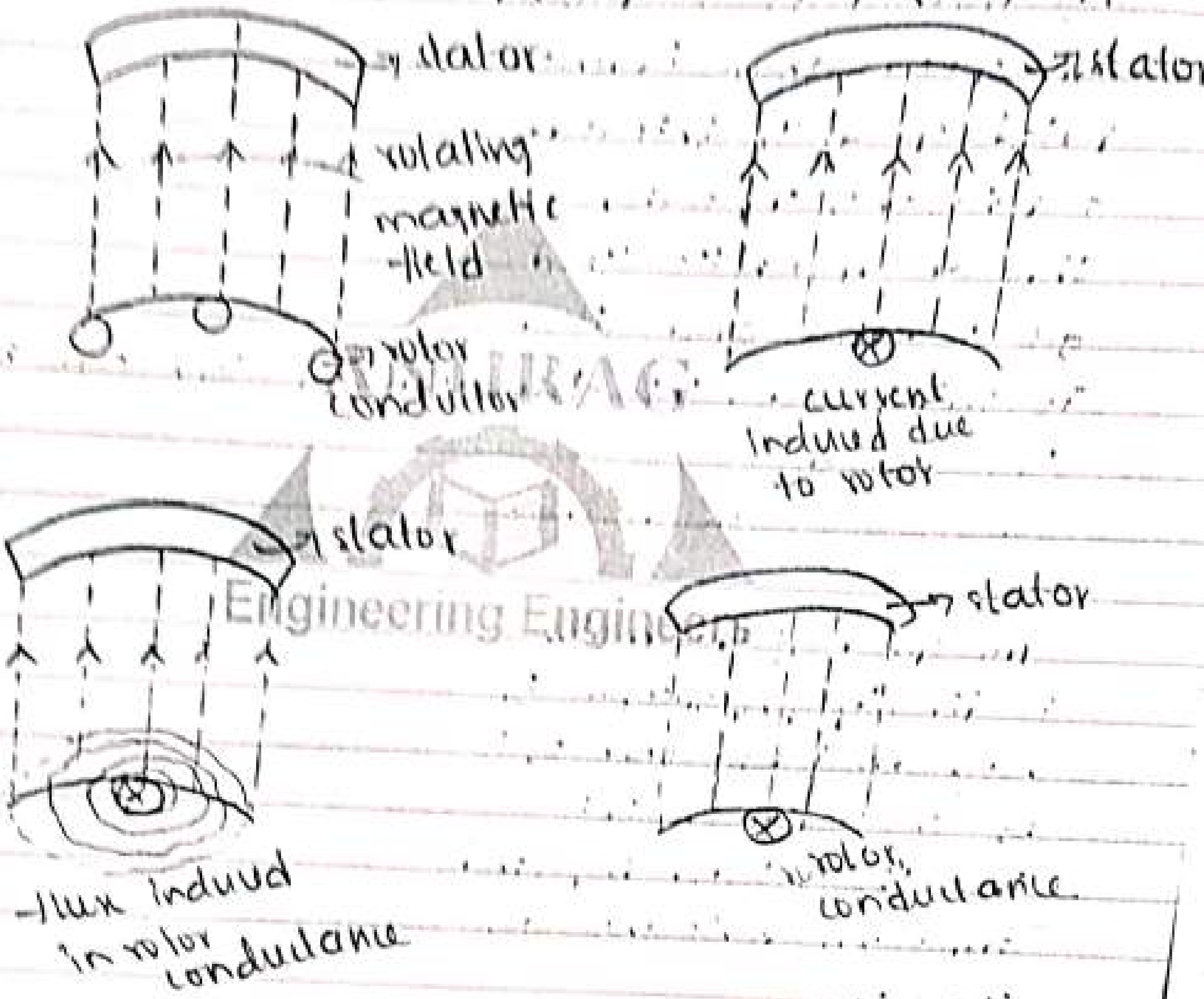
Principle of operation of three phase induction motor :-

→ A three phase induction motor is consists of stator and rotor.

→ A stator is providing three phase winding

→ A rotor is providing rotor winding

Principle of operation :-



* In a three phase induction motor energised a supply of 3-φ by the rotation of motor rotating magnetic field is developed in the field.
* The stator flux is rotating around the stator with a synchronous speed of Ns.

* Then after current is induced in the motor. and constant stationary yet. the speed of the motor is in between stationary and magnetic field.
* Flux is induced in the motor due to short circuit of current.

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Mid-I - Assignment

Name : A. Sangeetha

HT. NO. : 22C11A0105

Branch : Civil

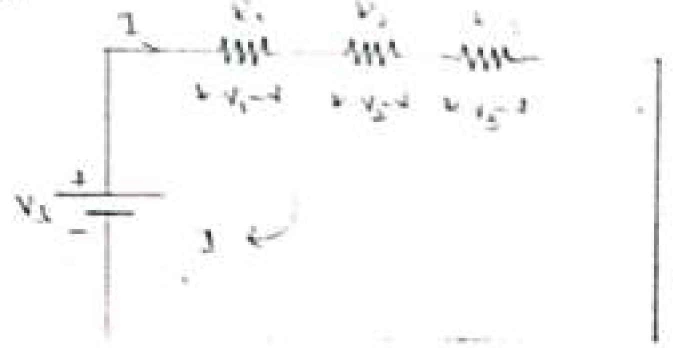
Subject : Basic Electrical and Electronics Engineering.

Submission date : 08-04-2024

25/5 = 5

Q) State and explain KVL and KCL? And also derive the equivalent resistance when three resistors are connected in parallel in a circuit.

* KVL (Kirchoff's voltage law) :- It states that algebraic sum of potential differences around a closed circuit is equal to zero.



$$\boxed{\Sigma V_D = 0}$$

$V_1 = IR_1$

$V_2 = IR_2$

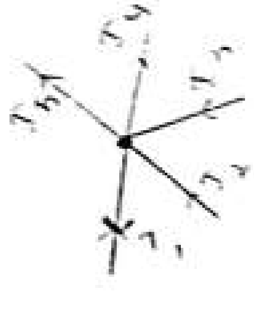
$V_3 = IR_3$

$$-V_1 - V_2 - V_3 + V_s = 0$$

$$\boxed{V_s = V_1 + V_2 + V_3}$$

* KCL (Kirchoff's current law) :- It states that algebraic sum of the currents meeting at a node is equal to zero. (or) sum of the current entering is equal to the sum of the currents leaving at the node.

$$\boxed{\Sigma I = 0}$$



entering currents $= I_2, I_3$

leaving currents $= I_1, I_4, I_5$

$$I_2 + I_3 = I_1 + I_4 + I_5.$$

* Resistors in parallel :- consider three resistors R_1, R_2 and R_3 are connected in parallel as shown in figure.

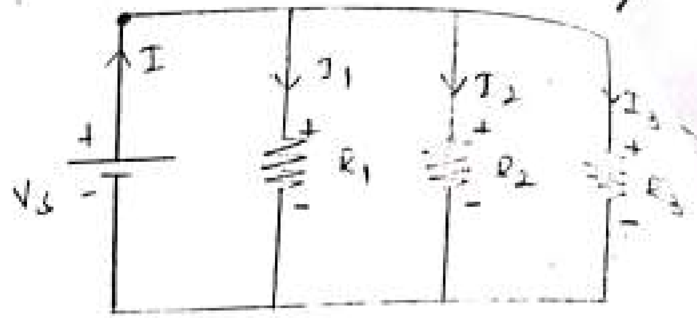
Apply KCL

$I = I_1 + I_2 + I_3$

$\frac{V_L}{R_{eq}} = \frac{V_L}{R_1} + \frac{V_L}{R_2} + \frac{V_L}{R_3}$

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$\therefore \boxed{R_{eq} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_3 R_1}}$



② Desive the average value. Rms value of an alternating quantity.?

* Average value :- It is the ratio of area of half cycle to the time period. It is represented by "Vavg".

$$\text{Average value} = \frac{\text{Area under half cycle}}{\text{Time period}}$$

$$V_{avg} = \frac{1}{T}\int_0^T f(t)\,dt$$

$$V_{avg} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t\, d(\omega t)$$

$$V_{avg} = \frac{1}{\pi} V_m \cdot \int_0^{\pi} \sin\omega t\, d(\omega t)$$

$$= \frac{1}{\pi} V_m \left[-\cos\omega t\right]_0^{\pi}$$

$$= \frac{V_m}{\pi}\left[-(-1-1)\right]$$

$$\therefore \boxed{V_{avg} = \frac{2V_m}{\pi}}$$

* Root mean square (RMS) value :- It is the ratio of square of area under half cycle to time period.

$$\text{RMS value} = \sqrt{\frac{(\text{Area of half cycle})^2}{T}}$$

$$F_{RMS} = \sqrt{\frac{1}{T}\int_0^T f(t)^2 dt}$$

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^{\pi}(V_m \sin\omega t)^2 d\omega t}$$

$$V_{RMS} = \sqrt{\frac{1}{\pi} V_m^2 \int_0^{\pi} \sin^2\omega t \, d(\omega t)}$$

$$= \sqrt{\frac{1}{\pi} V_m^2 \int_0^{\pi}\left[\frac{1-\cos 2\omega t}{2}\right]_0^{\pi} d\omega t}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\left[\left(\pi - \frac{\sin 2\pi}{2}\right) - \left(0 - \frac{\sin(0)}{2}\right)\right]}$$

$$= \sqrt{\frac{V_m^2}{2\pi}[\pi - 0]}$$

$$= \sqrt{\frac{V_m^2}{2\pi} \cdot \pi}$$

$$= \frac{V_m}{\sqrt{2}}$$

5

What are the different types of batteries and their characteristics?

A cell is a single unit that converts chemical energy into electrical energy, and a battery is a collection of cells.

Types of Batteries :-

* Primary Batteries :- Primary batteries are that cannot be recharged once depleted. Primary batteries are made of electrochemical cells whose electrochemical reaction cannot be reversed.

* Secondary Batteries :- Secondary batteries are batteries with electrochemical cells whose chemical reactions can be reversed by applying a certain voltage to the battery in the reversed direction. Also referred to as rechargeable batteries. Secondary cells unlike primary cells can be recharged after the energy on the battery has been used up.

Characteristics of Batteries :-

1. Chemistry : The main battery chemistries are lead, nickel and lithium. They all need a specific designated charger. This is why charging these batteries on a different charger from their own might cause an incorrect charge, despite it seeming to work at first. This happens because of the different regulatory requirement of each chemistry.

2. Battery capacity : Battery capacity is a measure of the charge stored by the battery, and is determined by the mass of active material contained in the battery.

The battery capacity represent the maximum amount of energy that can be extracted from the battery under certain specified conditions.

3. Voltage: A battery feature a nominal voltage. Along with the amount of cells connected in series, chemistry provides the open circuits voltage (OCV). which is about 5-7% higher on a fully charged battery. it is important to check the correct nominal voltage of a battery before connecting it.

4. Cold cranking Amps (CCA): Every starter battery is marked with cold cranking amps also abbreviated CCA. The number denotes the amount of amps that the battery is able to provide at -18oC.

② Explain about the importance of power factor improvement.

Importance of Power factor improvement :-

→ * Increase in efficiency of system and devices.
→ * Low voltage drop.
→ * Reduction in size of a conductor and cable which reduces cost of the cooper.
→ * An increase in available power line losses size is reduced.
→ * Appropriate size of electrical machines (Transformer)..
→ * Low kwh (kilo watt per hour)
→ * saving in power bill
→ * Better usage of power system, lines and generators etc.
→ * Eliminate the penalty of low power factor from the electric supply company.
→ * saving in energy as well as rating and the cost of the electrical devices and equipment is reduced,

Explain the constructional details and working of transformer.

of

* constructional details of transformer :—

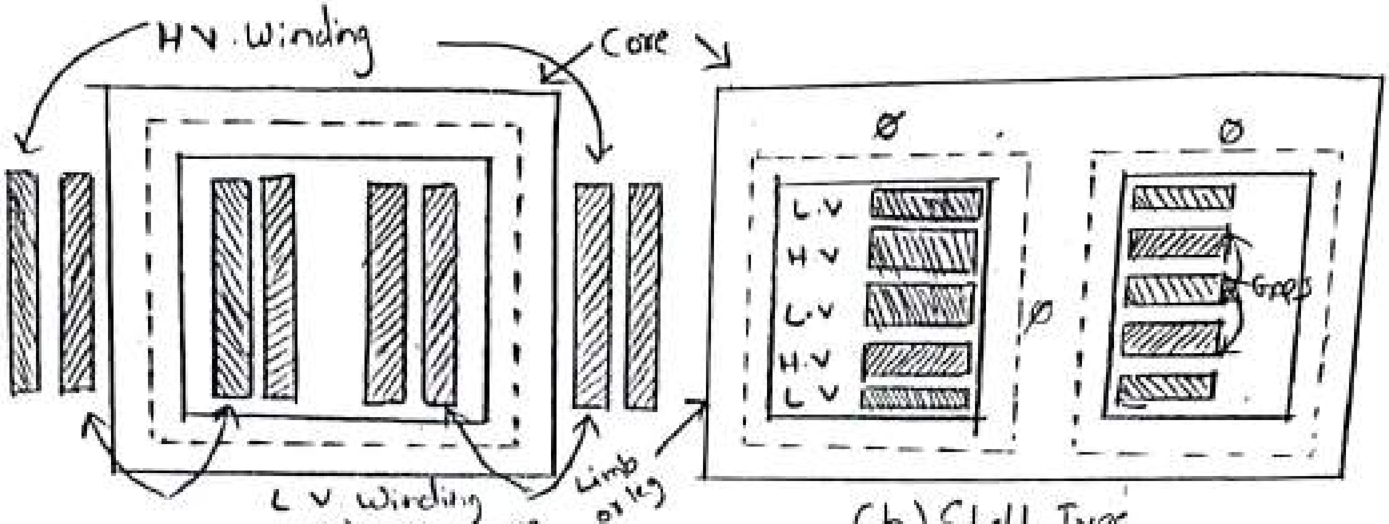
Depending upon the manner in which the primary and secondary windings are replaced on the core, and the shape of the core, there are two types of transformers, called.

(a) core type

(b) shell type.

Core type and shell-type construction :—

In core type transformers, the windings are replaced in the form of concentric cylindrical coils placed around the vertical limbs of the core. The low voltage (LV) as well as the high-voltage (HV) winding are made in two halves, and placed on the two limbs of core. The LV winding is placed next to the core for economy in insulation cost. figure 2.1(a) shows the cross-section of the arrangement. In the shell type transformer, the primary and secondary windings are wound over the central limb of a a three-limb core as shown in figure 2.1(b). The HV and LV windings are split into a number of sections, and the sections are interleaved or sandwiched i.e. the sections of the HV and LV windings are placed alternately.



(a) Core type (b) Shell Type

Core :- The core is built-up of thin steel laminations insulated from each other. This helps in reducing the eddy current losses in the core, and also helps in construction of the transformer. The steel used for core is of high silicon content, sometimes heat treated to produce a high permeability and low hysteresis loss. The material commonly used for core is CRGO conductor material used for windings is mostly copper. however, for small distribution transformer aluminum is also sometimes used. The conductors, core and whole windings are insulated using various insulating materials depending upon the voltage.

Insulating oil :- In oil-immersed transformer, the iron core together with windings is immersed in insulating oil. The insulating oil provides better insulation, protects insulation from moisture and transfers the heat produced in core and windings to the atmosphere.

The transformer oil should posses the following qualities.

(a) High dielectric strength,
(b) Low viscosity and high purity.
(c) high flash point
(d) free from sludge

Tank and conservator :— The transformer tank contains core wound with windings and the insulating oil. In large transformers small expansion tank is also connected with main tank is as conservator. Conservator provides space when insulating oil expands due to heating. The transformer tank is provided with tubes on the outside, to permits circulation of oil, which aids in cooling. Some additional devices like breather and Buchholz relay are connected with main tank. Buchholz relay is placed between main tank and conservator.

* **Principle of operation** :—

When an alternating voltage V_1 is applied to the primary an alternating flux ϕ is set up in the core. This alternating flux links both the windings and induces e.m.fs E_1 and E_2 in them according to faraday's law of electromagnetic induction. The e.m.f E_1 is termed as primary e.m.f and E_2 termed as secondary e.m.f.

clearly, $E_1 = -N_1 \frac{d\phi}{dt}$

and $E_2 = -N_2 \frac{d\phi}{dt}$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

Note that magnitudes of E_2 and E_1 depend upon the number of turns of on the secondary and primary respectively

If $N_2 > N_1$, then $E_2 > E_1$ and we get a step up transformer.

If $N_2 < N_1$, then $E_2 < E_1$ and we get a step down transformer.

If load is connected across the secondary winding the secondary e.m.f will cause a current to flow through the load. Thus, a transformer enables us to transfer a.c power from one circuit to another with a change in voltage level.

The following points may be noted carefully.

(a) The transformer action is based on the laws of electromagnetic induction.

(b) There is no electrical connection between the primary and secondary.

(c) The a.c power is transferred from primary to secondary through magnetic flux.

(d) There is no change in frequency, i.e. output power has the same frequency as the input power.

(e) The losses that occur in a transformer are:

(a) core losses - eddy current and hysteresis losses

(b) copper losses - in the resistance of the windings

In practice, these losses are very small so that output is nearly equal to the input primary power. In other words, a transformer has very high efficiency

S

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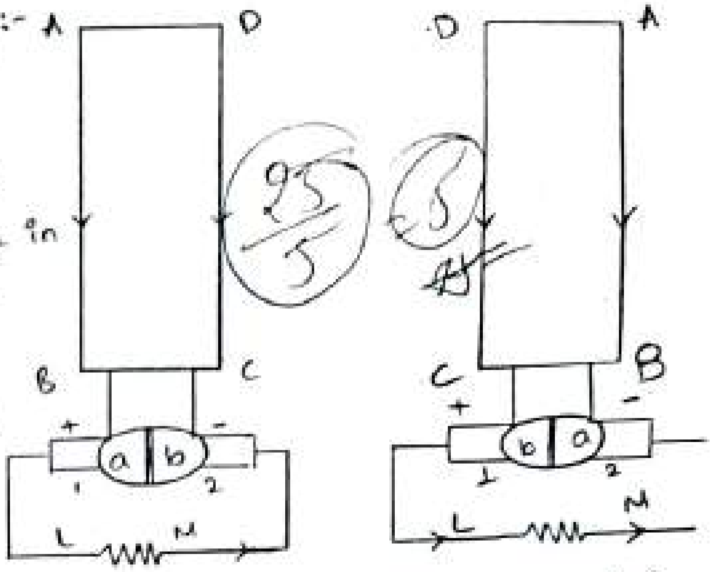
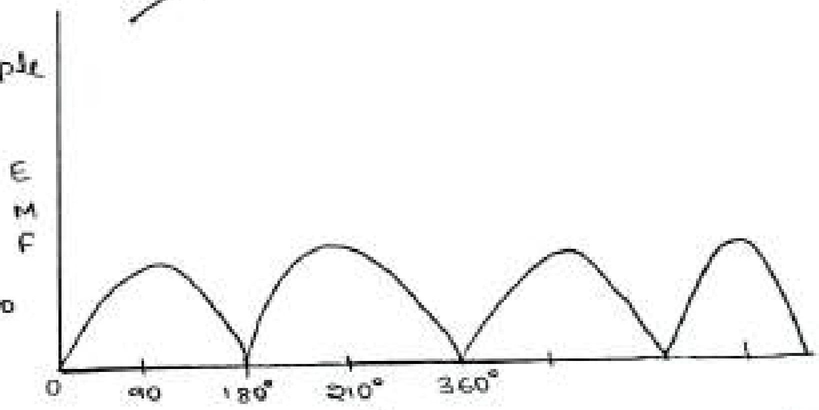
1. Explain the constructional details and working of generator.

Working principle of DC Generator:-



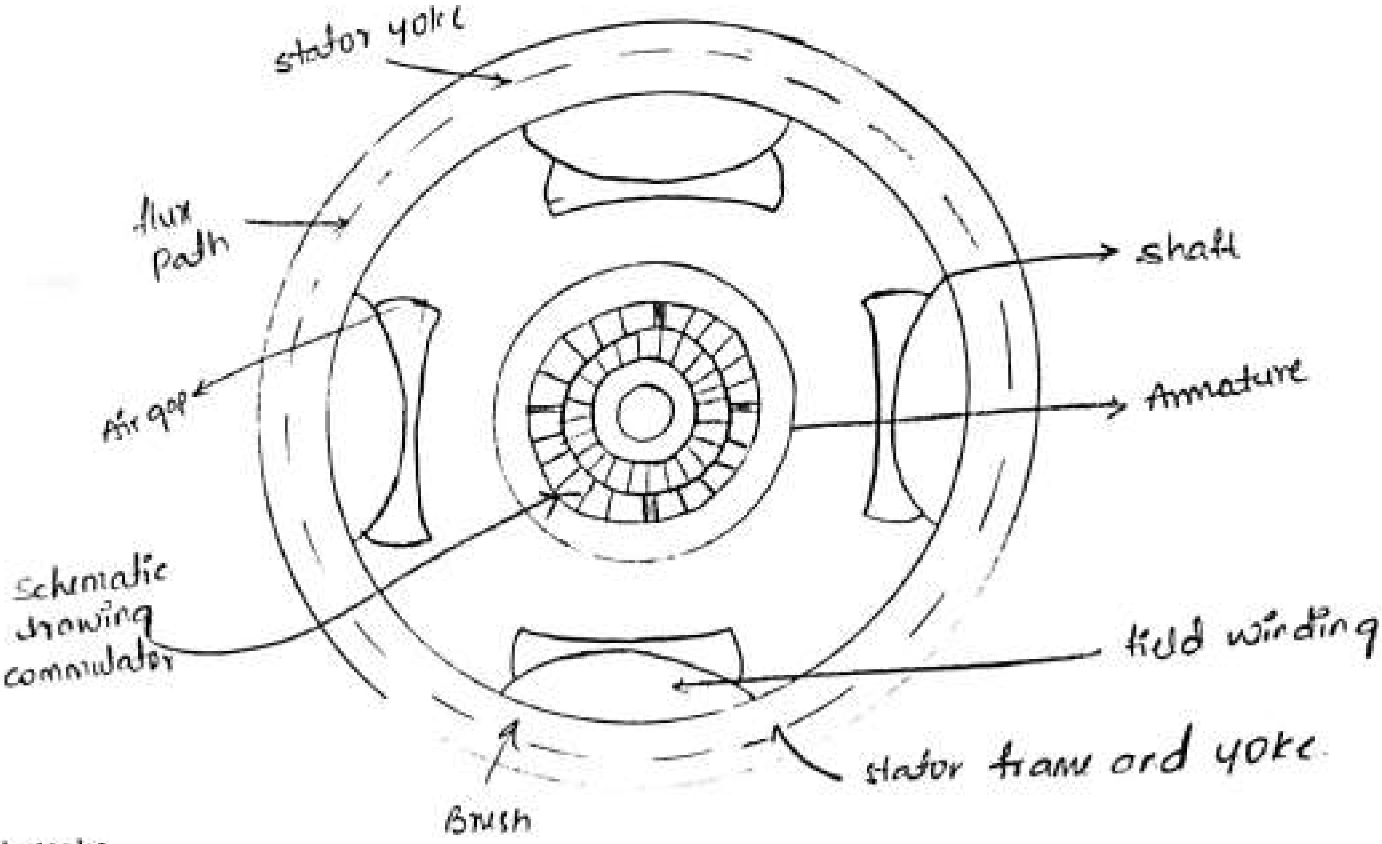
It is seen that in the first half of the revolution current flows always along ABCMCD i.e., brush no. 1 in contact with segment a. In the next half revolution, in the figure the direction of the current in the coils is reversed. But at same time the position of the segments a and b are also reversed which results the brush no. 1 comes in touch with the segment b. Hence, the current in the load resistance again flows from L to M. The wave from the current through the load circuit is as shown in the figure. This current is unidirectional.



This is basic working principle of DC generator, explained by single loop generator model. The position of the brushes of DC generator is so arranged that the change of the segment a and b from one brush to other takes place when the plate of rotating coil is at right angle to the plane of the lines of force it is so become in that position the induced emf in coil is zero.

Construction of DC Generator:-

*. DC machine whether a generator or motor with faces poles is shown in figure in construction the DC machine consists of the following parts.



1) yoke
2) poles
3) field winding
4) Armature
5) Commutator
6) Brushes and brush gear
7) Bearings.

① Yoke :-

→ It serves the purpose of outermost cover of dc m/c.
→ It provides mechanical support to poles.
→ It provides a path of low reluctance for magnetic flux.
→ For small rating m/c's cast iron material is used.
→ For large rating m/c's cast steel is used as it gives low reluctance and good mechanical strength.

② Poles :-

→ Each pole is divided into (i) Pole core (ii) Pole shoe
→ pole core carries field winding

It directs the flux produced through air gap to armature core to the next gap.

Pole shoe enlarge the area of armature core of come a/c the flux which is necessary to produce larger induced emf.

→ Cast Iron (or) cast steel used as manufacturing material.

③ Field winding :-

→ It is wound on the pole core with a definite direction.

→ It is used to carry current due to which pole core, on which field winding is placed behaves as an electromagnet producing necessary flux.

④ Armature : It is divided into 2 types.

① Armature core ⓘⓘ Armature winding

i) Armature core :- It is cylindrical in shape mounted on the shaft. it consist of slots on its periphery and air ducts to permit the air flow through armature which serves cooling purpose.

→ It provides house for armature winding

→ It provides a path of low reluctance to the magnetic flux produced by the field winding

→ Manufactured by cast iron (or) cast steel.

ii) Armature winding :- It is inter connection of armature conductors, placed in the slots provided on the armature periphery

→ when the armature is rotated, in case of generation flux gets out by armature conductors and emf gets induced in them.

⑤ Commutator :-

→ It is used to convert AC to DC.

→ It collects current from armature conductors.

→ To produce unidirectional torque in case of motors.

→ It is manufactured by copper.

⑥ Brushes :-

→ To collect current from commutator and make it available to the stationary external circuit.

→ These are manufactured with soft material like carbon.

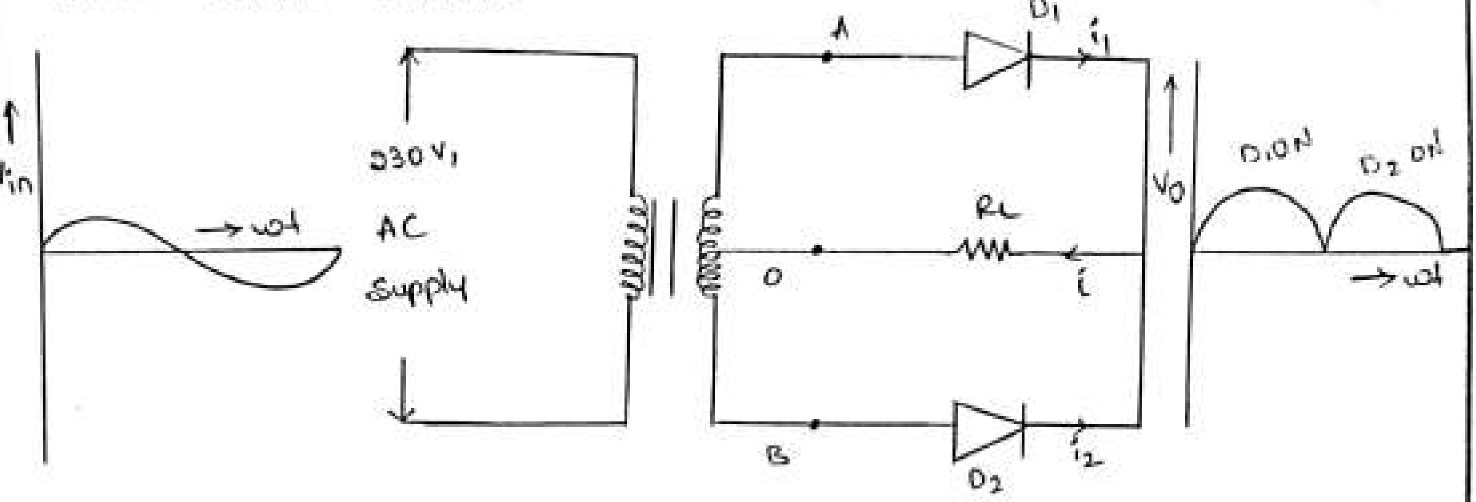
⑦ Bearings: For smooth running of machines, ball bearing is used and for heavy duty DC generator, roller bearing is used. The bearing must always be lubricated properly for smooth operation and long life of generator.

Illustrate the operation of full wave rectifier?

Full wave rectifier :-

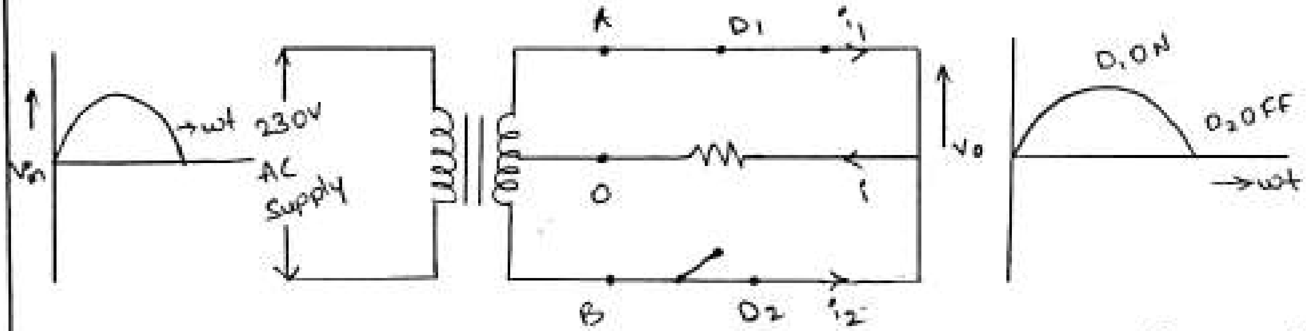
These are two types

i) **centre tapped rectifier :-**

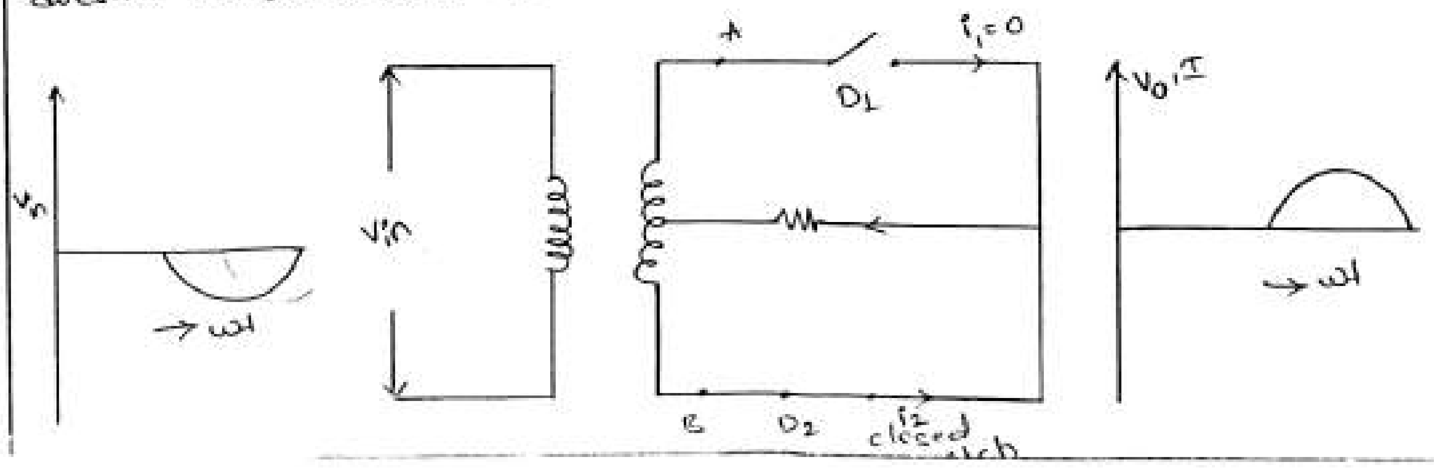


During +ve half cycle A is +ve and B is -ve then D_1 is forward bias and D_2 is reverse bias the I_1 current flows through the R_L and $I_2 = 0$.

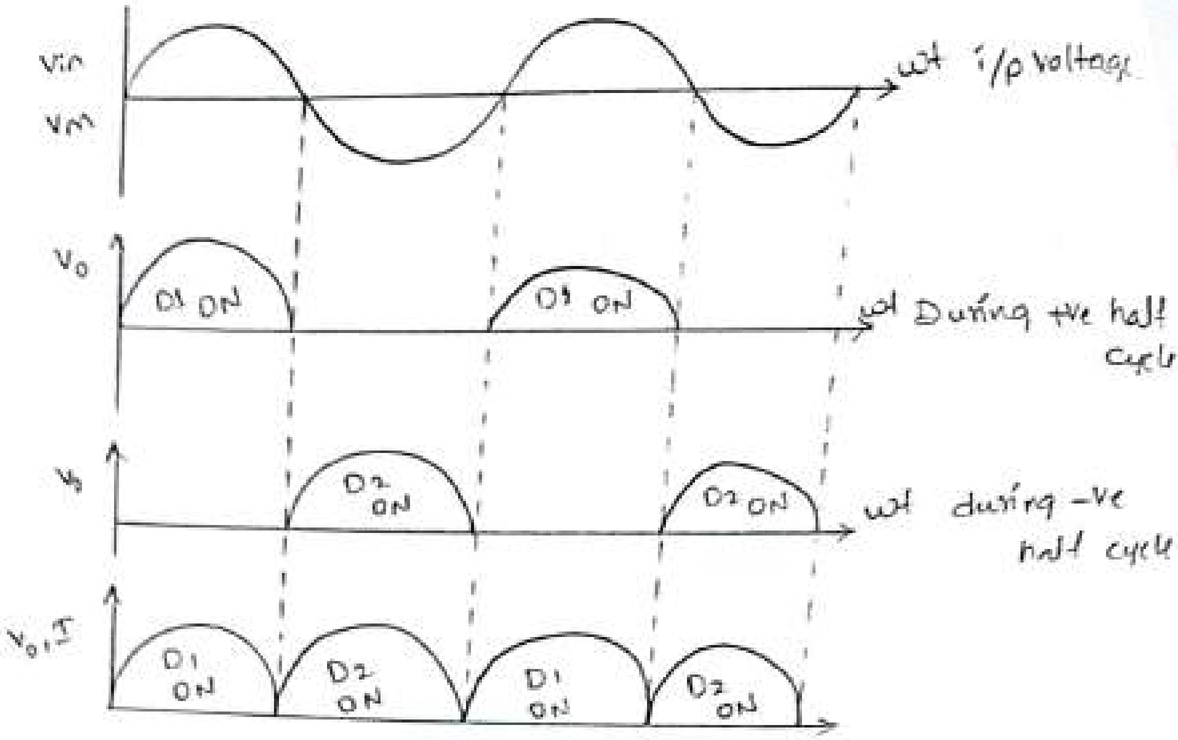
+ve half cycle :-



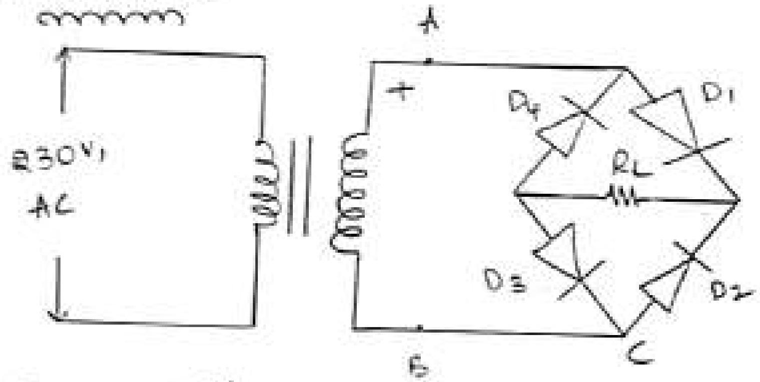
-ve half cycle :- During -ve half cycle A is -ve and B is +ve then D_1 doesn't conducts and D_2 conducts I_2 flows through the load resistor(R)



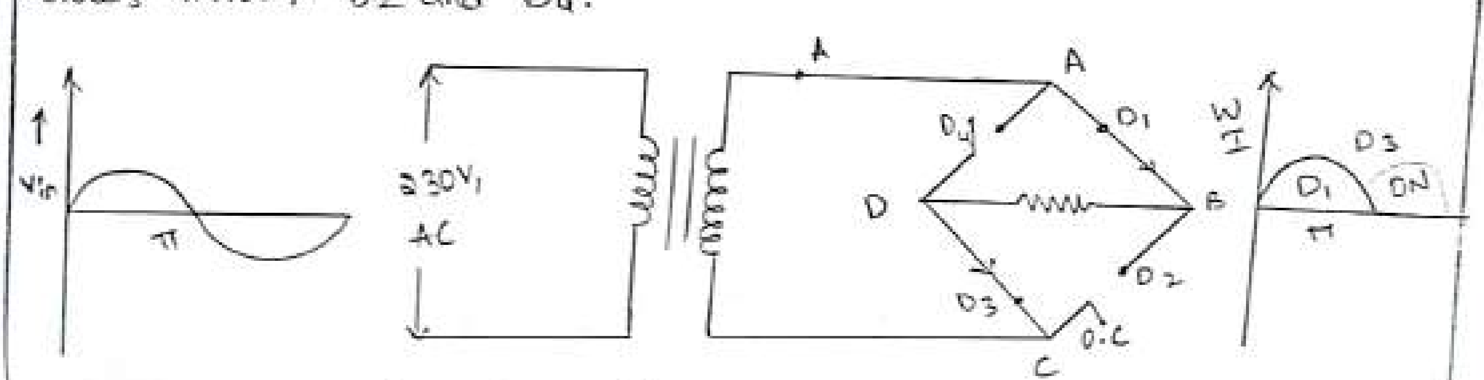
i/p & o/p w/f :-



ii) Bridge rectifier :-

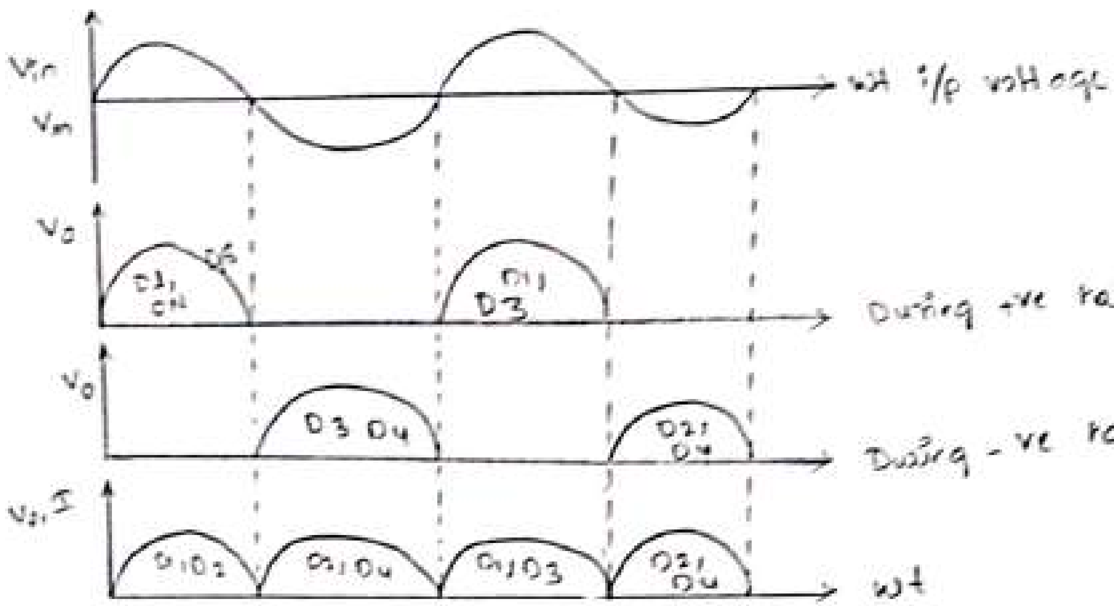


During +ve half cycle terminal A is +ve and B is -ve and diodes D1 and D3 are f.b then current flows through armature AB enter load resistance and return backs through arm CD and no current flows through D2 and D4.



During -ve half cycle A is -ve and C is +ve and diodes D2 and D4 are forward bias and current flows through armature AD and enter load resistance and then return backs to BD.

i) o/p w/f :-



iii) Peak current and peak voltage :-

→ The total current flowing through the circuit

$i = I_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$

$V_o = V_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$

where, $I_m \rightarrow$ peak current ; $V_m \rightarrow$ peak voltage.

→ For +ve half cycle, the rectifier circuit can be drawn as Apply KVL

$+V_m - V_o = 0$

$V_o = V_m$ $\quad (\because V_o = I_m R_L)$

$I_m R_L = V_m$

$$\boxed{V_m = I_m R_L} \quad \text{(1)}$$

$$\boxed{I_m = \frac{V_m}{R_L}} \quad \text{(2)}$$

iv) Average current (or) DC current (I_{dc}) :-

$$I_{avg} \text{ (or) } I_{dc} = \frac{\int_0^T \text{Area}}{\text{period}} = \frac{1}{T}\int_0^T i \, d(\omega t)$$

$$I_{dc} = \frac{1}{\pi}\int_0^\pi I_m \sin\omega t \, d(\omega t)$$

$$I_{dc} = \frac{I_m}{\pi}\int_0^\pi \sin\omega t \, d(\omega t) = \frac{I_m}{\pi}\left(-\cos\omega t\right)_0^\pi$$

$$I_{dc} = -\frac{I_m}{\pi}\left(\cos\pi - \cos(0)\right) = -\frac{I_m}{\pi}(-1-1)$$

$$\boxed{I_{avg} \text{ (or) } I_{dc} = \frac{2I_m}{\pi}} \longrightarrow (3)$$

Average DC voltage :-

$$V_{dc} = \left(\frac{2I_m}{\pi}\right) \times R_L \quad (\because \text{from eqn } (3))$$

$$V_{dc} = \frac{2V_m}{\pi R_L} \times R_L \quad (\because \text{from eqn } (2))$$

$$\therefore \boxed{V_{avg} \text{ (or) } V_{dc} = \frac{2V_m}{\pi}} \longrightarrow (4)$$

(V) **RMS current :-**

We know that : $I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2 d(\omega t)}$

$i = I_m \sin\omega t \;;\; 0 \le \omega t \le \pi$

So, $I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I^2_m \sin^2\omega t \, d(\omega t)}$

$$I_{rms} = \left[\frac{I^2_m}{\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I^2_m}{\pi}\left[\int_0^{\pi} \left(\frac{1-\cos 2\omega t}{2}\right) d\omega t\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{I^2_m}{2\pi}\left[\int_0^{\pi} 1\, d(\omega t) - \int_0^{\pi} \cos 2\omega t \, d(\omega t)\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{I^2_m}{2\pi}\left[(\omega t)_0^{\pi} - \frac{1}{2}(\sin 2\omega t)_0^{\pi}\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{I^2_m}{2\pi}\left(\pi - 0 - \frac{1}{2}(\sin 2\pi - \sin 0)\right)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I^2_m}{2\pi} \times \pi\right]^{1/2}$$

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \longrightarrow (5)$$

RMS voltage (V_{rms}) :-

$$V_{rms} = I_{rms} \cdot R_L \Rightarrow V_{rms} = \frac{I_m}{\sqrt{2}} \cdot R_L = \frac{V_m}{\sqrt{2} R_L} \times R_L$$

$$\therefore \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}} \longrightarrow (6)$$

Form factor and peak factor :-

$$\text{Form factor } (K_f) = \frac{\text{RMS value}}{\text{Average value}} = \frac{I_{rms}}{I_{dc}}$$

$$K_f = \frac{I_m/\sqrt{2}}{2I_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

$$\boxed{F.F \text{ (or) } K_f = 1.11}$$

$$\text{Peak factor } (K_p) = \frac{I_m}{I_{rms}} = \frac{\text{Peak value}}{\text{RMS value}}$$

$$P.F \text{ (or) } K_p = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2}$$

$$\boxed{P.F \text{ (or) } K_p = \sqrt{2}}$$

(vii) Ripple factor (γ) :-

$$R.F \text{ (or) } \gamma = \frac{\text{RMS value of ac component of output current}}{\text{Average (or) dc value of output current}}$$

$$\gamma = \frac{I_{ac\,rms}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}} = \sqrt{\frac{I^2_{rms} - I^2_{dc}}{I^2_{dc}}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{1/\sqrt{2}}{2/\pi}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} = \sqrt{(1.11)^2 - 1}$$

$$\boxed{\gamma = 0.482}$$

(viii) Rectification efficiency (η) :-

$$\eta = \frac{\text{DC power delivered to load}}{\text{AC input power}} = \frac{P_{dc}}{P_{ac}} = \frac{I^2_{dc} R_L}{I^2_{rms} R_L}$$

$$= \frac{(2I_m/\pi)^2}{(I_m/\sqrt{2})^2} = \frac{4}{\pi^2} \times 2 = \frac{8}{\pi^2}$$

$$\boxed{\%\,\eta = 81.2\%}$$

(iv) Transformer utilization factor (T.U.F) :-

$$TUF = \frac{\text{DC power delivered to load}}{\text{AC rating of the transformer primary}}$$

$$TUF = \frac{P_{dc}}{P_{ac}} = \frac{I^2_{dc} \times R_L}{V_{rms} \text{ rated} \times I_{rms}}$$

$\therefore$ $\boxed{(TUF)P = 0.812}$

(v) Peak Inverse voltage (PIV) :- It is the maximum voltage that the rectifying diode can with stand when it is operated in reverse bias

$\therefore$ $\boxed{PIV = 2V_m}$

Advantages :-

i) High efficiency.

ii) Low ripple factor, so simple filter circuit is required.

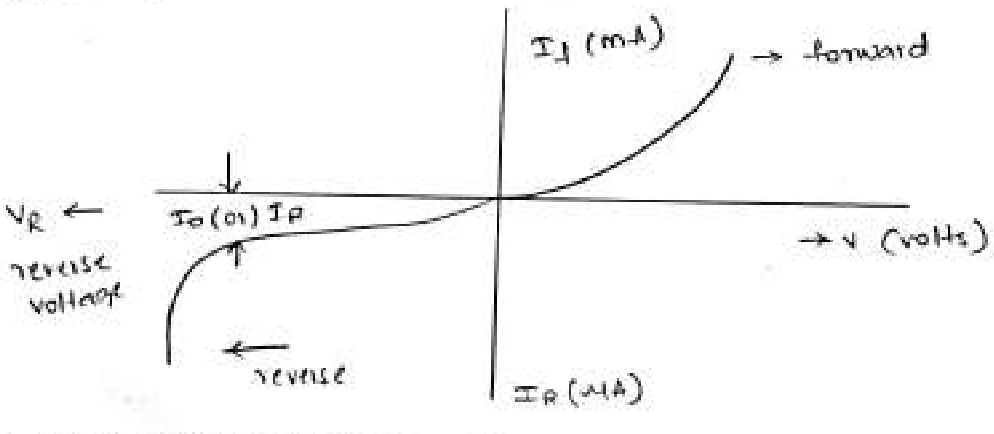
iii) TUF is high, so high O/P voltage & there by high O/P power.

Disadvantages :-

i) More circuit elements and is costlier.

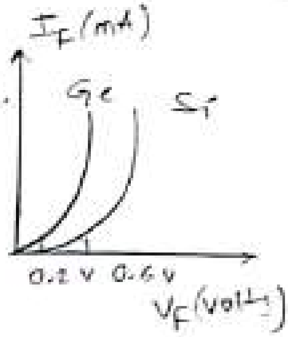
ii) PIV is high.

2) Draw and explain the V-I characteristics of P-N Junction diode.



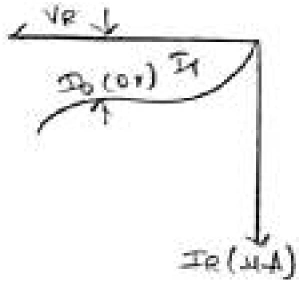
Cutting voltage (or) Breakdown voltage :- It is the forward voltage applied across P-N junction diode at which current through junction starts increasing rapidly.

Case I under forward bias condition:-



- when $V_F < V_\gamma$, very little current flows always negligible.
- when $V_F > V_\gamma$, current flows through diode rapidly increases.

Case II under reverse bias condition:-



Under this cond'n very small current due to minority called reverse saturation current called through the junction.

- In this condition width of depletion region increases and cutting voltage also increases so only minority charge carriers flows.

Note:- Resistance offered by the junction during forward bias condition is very small.

- In reverse bias cond'n is very high.

Diode current eqn:-

$$I = I_0 \left[e^{V/\eta V_T} - 1 \right]$$

where; I = Diode current.

I_0 = Diode reverse saturation current.

V = external voltage

η = constant 1 for Ge; 2 for Si

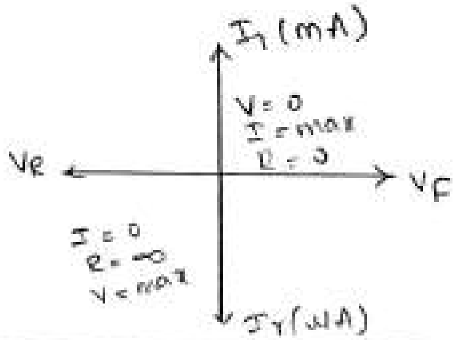
$V_T = \frac{KT}{q}$

K = Boltzmann's constant $(1.38 \times 10^{-23}\ J/K)$

q = charge $(1.602 \times 10^{-19} C)$

T = temp. of diode

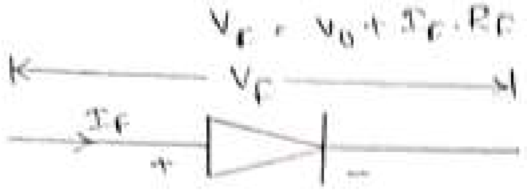
***. Ideal diode:-**

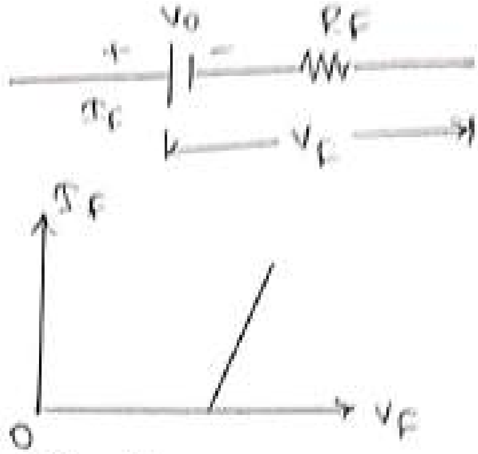


In the forward bias cond'n it offers zero resistance in forward bias cond'n and infinite resistance in reverse bias condition.

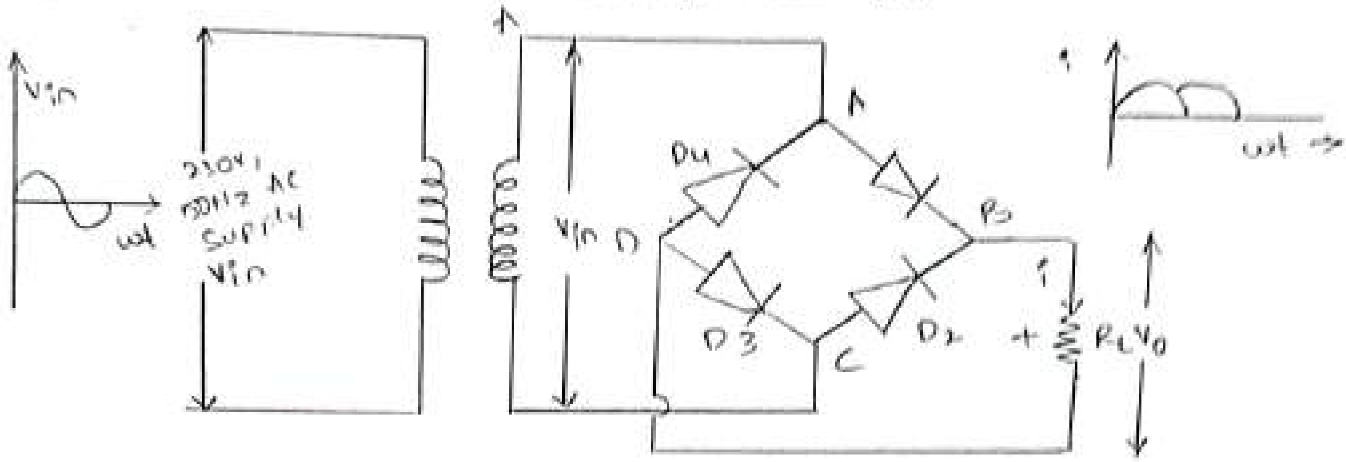
Diode equivalent circuit:-

when forward voltage is applied across the diode it will not ... till cutting voltage (V_0) at it the junction is overcome. when it exce... diode starts conducting then I_F flows through the diode causes vol... drop in the resistance R.F.





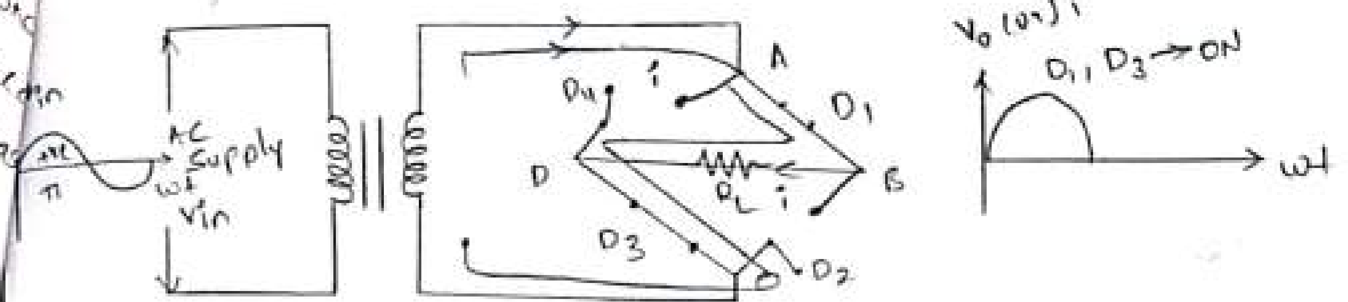
① Explain the operation of bridge rectifier?



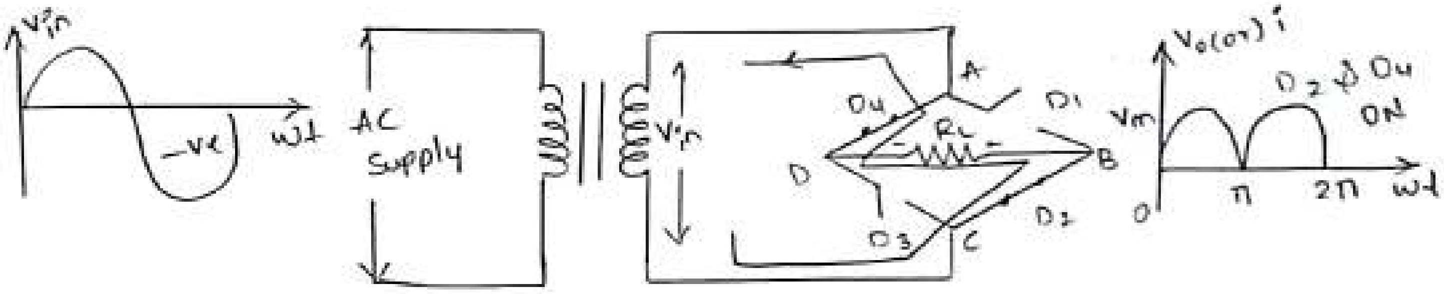
* The need for a centre tap transformer in FWR is eliminated in the bridge rectifier. So, in bridge rectifier circuit, four diodes are connected in the form of bridge, where two diametrically opposite terminals A & C are connected to secondary of transformer and other two terminals B & D are connected to load resistor R_L.

Working:-

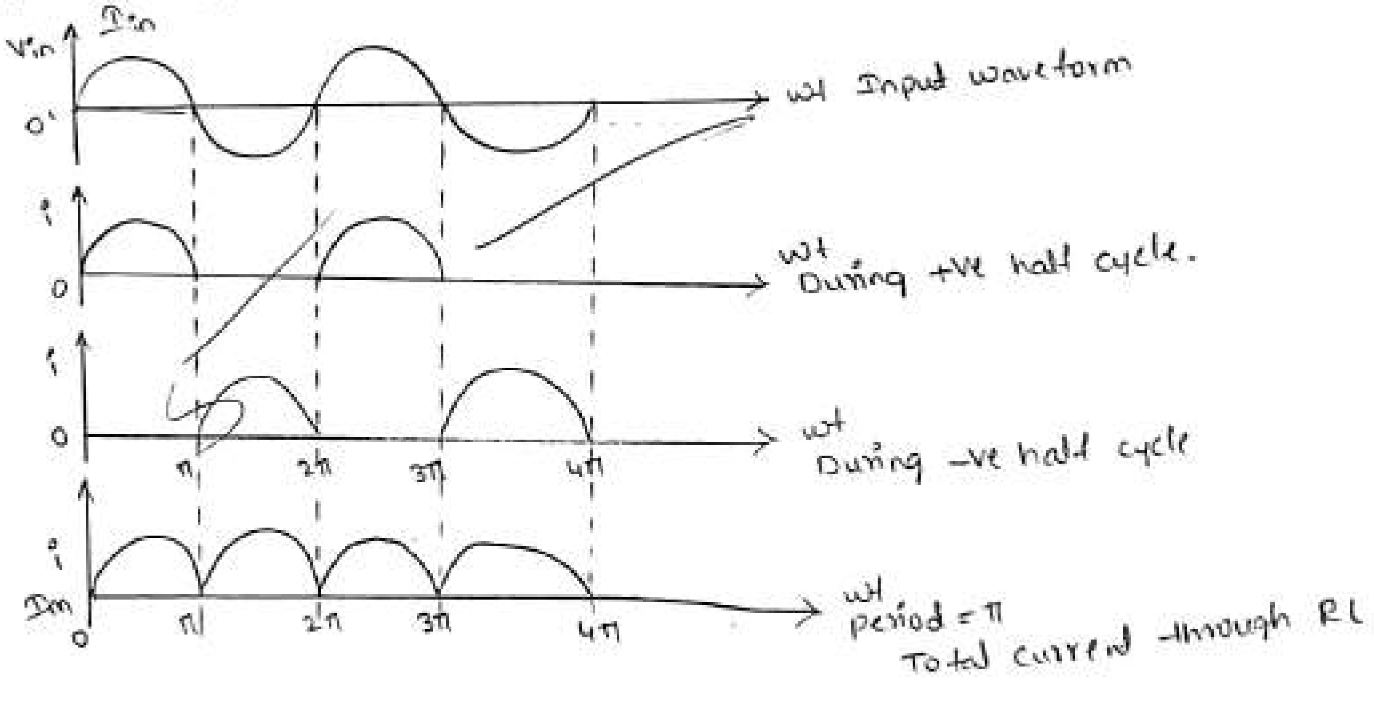
(i) For positive half cycle of input voltage, the point "A", becomes +ve and point 'C' is -ve so diodes D_1 and D_3 are forward biased. current flows through arm AB, enters load R_L and returns back flowing through arm DC as shown in figure while no current flows through D_2 and D_4 as they are reverse biased.



ii) For negative (-ve) half cycle of input voltage, the point A becomes -ve and point "C" is +ve, so diodes D_2 and D_4 are forward biased. So current "i" flows through arm CB, enters load R_L and return back flowing through arm BA. While no current flows through D_1 and D_3 as they are reverse biased.



Input and output waveforms :-



Mathematical Analysis of bridge rectifier :-

$$I_{in} = I_m \sin\omega t \;;\; 0 \le \omega t \le 2\pi.$$

$$V_{in} = V_m \sin\omega t \;;\; 0 \le \omega t \le 2\pi$$

and $v_0 = V_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$

$i = I_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$ } period $= \pi$.

i) Peak current and voltage :-

$$V_m = I_m R_L$$

$$I_m = V_m / R_L$$

ii) DC output current & voltage :-

$$I_{dc} = \frac{2 I_m}{\pi}$$

$$V_{dc} = \frac{2 V_m}{\pi}$$

iii) RMS output current and voltage :-

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$V_{rms} = V_m / \sqrt{2}$$

iv) Form factor and peak factor :-

$$K_f = 1.11$$

$$K_p = \sqrt{2}$$

v) Ripple factor :-

$$\gamma = 0.482.$$

vi) Efficiency (η) :- $\% \eta = 81.2\%$.

vii) Transformer utilization factor :-

As no centre tap transformer used, the primary and secondary winding TUF are same.

$$T.U.F = \frac{P_{dc}}{P_{ac\,rated}} = \frac{(TUF)_p + (TUF)_s}{2}$$

$$T.U.F = \frac{(0.812) + (0.812)}{2} = 0.812$$

viii) Peak inverse voltage :- It is the max reverse bias voltage that can applied to the diode.

KVL at loop ① $PIV - V_0 = 0$; $\boxed{V_0 = PIV}$

KVL at loop ② $+V_m - PIV + V_0 - PIV = 0$

$$\boxed{PIV = V_m}$$

Advantages of bridge rectifier :-

(i) No centre-tap transformer is required.

(ii) PIV across each diode is less than (i.e. half) the centre tap rectifier i.e. V_m.

(iii) TUF is higher than that of centre tap rectifier.

Disadvantages of Bridge rectifier :-

→ It requires 4 diodes and the efficiency (η) is reduced due to voltage drop across the diodes

⑨ Explain about different configurations of BJT?

Construction & operation of BJT :-

① NPN transistor :-

→ Si (or) Ge materials are used for the construction of BJT.

→ when a P-type material is sandwitched b/w two N-type materials called as NPN transistor.

→ NPN transistor consists of two PN-Junctions forming 3 regions giving rise to 3 terminals called as emitter, base and collector.

Emitter (E) :- It is the left hand section of transistor and its main function is to supply the majority charge carriers.

→ It is more heavily doped than of the other regions because its main function is to supply majority charge carriers to the base.

→ Emitter is always forward based with respect to base.

→ The size of emitter terminal is medium.

1. Base (B) :-

→ The middle section which forms two PN junctions between the emitter and collector is called the base.

→ It is very thin as compared to either the emitter (or) collector.

→ Base is lightly doped region.

→ The size of the base terminal is small. so that it may pass most of the injected charge carriers to the collector.

4. collector (C):-

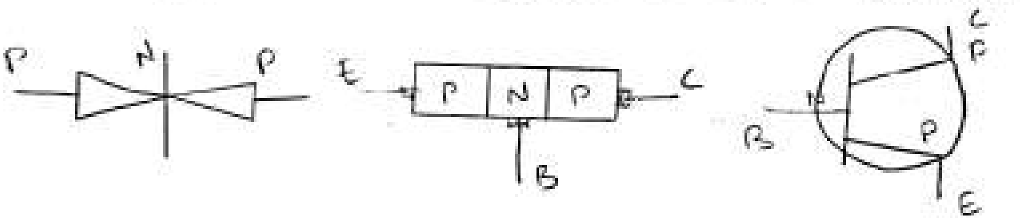
→ The section on the other side collects the majority charge carriers is called the collector.

→ It is always reverse biased with respect to base.

→ The collector region is made physically larger than the emitter and base region because it has to dissipate more power at the collector function.

② PNP Transistor:-

→ when a N-type semi conductor material is sandwiched between two P-type materials called as PNP transistor.



Symbol of PNP

→ The In PNP transistor symbol, arrow indicates the direction of emitter current when emitter-base junction is forward biased.

→ In PNP transistor the majority charge carriers are holes.

UNIT-I

D.C.CIRCUITS

Definitions of Various Terms

Charge: Charge (q) is an electrical property of the atomic particles of which matter consists, measured in coulombs(C).

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

(or)

Electric current is defined as the rate of flow of electrons in a conductive or semi conductive material. Expressed mathematically

$$I=Q/t$$

Where I is the current, Q is the charge of electrons, and t is the time.

Voltage: Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V). The voltage V_{ab} between two points aand b in an electric circuit is the energy (or work) needed to move a unit charge from a to b; mathematically

$$V_{ab} = dw/dq$$

Where w is energy in joules (J) and q is charge in coulombs(C).

Power and Energy: Energy is the capacity to do work, measured in joules (J). Energy may exist in many forms such as mechanical, electrical, chemical and so on. Power is the rate of change of energy, and is denoted by either P or p.

$$\text{Power (p)}=\text{Energy/time}=W/t \text{(or)} p=dw/dt$$

Where dw is the change in time and dt is the change in time.We can also write

$$P=dw/dt=(dw/dq)*(dq/dt)=v*I \text{ watts.}$$

Network and Circuit: An electrical network is an interconnection of electrical components (e.g. voltage sources, current sources, resistances, inductances, capacitances). An electrical circuit is a network consisting of a closed loop, giving a return path for the current.

Ohm's law: Ohm's law states that at constant temperature, in an electrical circuit, the current passing through conductor, from one point on the conductor to another terminal point on the conductor, is directly proportional to the potential difference the two terminal points.. That is

$$V \propto I$$

$$V = IR$$

Where R=Resistance of the conductor

Limitations of Ohm's law:

i) It is applicable for metallic conductors such as copper, silver, nichrome.

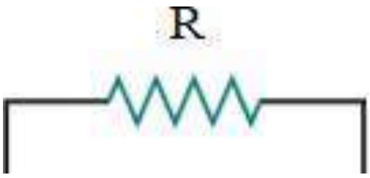
ii) It is not applicable for all electric circuits such as vacuum tubes, semiconductor devices.

ELECTRICAL CIRCUIT ELEMENTS (R, L AND C)esistor

A resistor is a passive two terminal electrical element that is used (or) regulate the flow of electric current.

Resistance:

The resistance R of an element denotes its ability to resist the flow of electric current. It is measured in ohms (Ω).

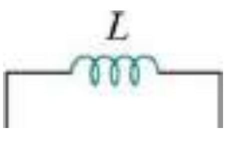


$$R = v/i$$

Power dissipated by the resistor is $p = v*i = i^2R = v^2/R$

Inductor:

An inductor is a passive element designed to store energy in its magnetic field. An inductor consists of a coil of conducting wire. If current is made to pass through an inductor, an electromagnetic field is formed. A change in current, produces change in the electromagnetic field, which induces a voltage across the coil according to faraday's law of electromagnetic induction.



$$v = L\frac{di}{dt}$$

Where V= voltage across inductor in volts

I = current flowing through inductor in amps

Inductance:

It is the property of a material, by which it opposes any sudden change of current passing through it, measured in henry (H).

Power absorbed by inductor is p=v*i=L(di/dt)*I

Energy stored by the inductor is $W=(1/2)Li^2$

Note: The induced voltage across an inductor is zero, if the current through it is constant i.e. inductor acts as short circuit to DC.

Capacitor: A capacitor is a passive element designed to store energy in its electric field. Capacitors are used extensively in electronics, communications, computers, and power systems.

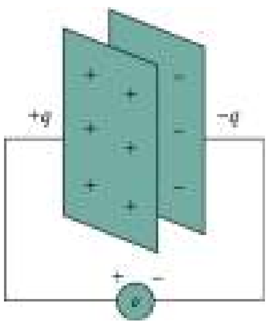
A capacitor consists of two conducting plates separated by an insulator.

When a voltage source v is connected to the capacitor, as in Fig., the source deposits a positive charge +q on one plate and a negative charge −q on the other. The capacitor is said to store the electric charge. The amount of charge stored, represented by q, is directly proportional to the applied voltage v so that

q=C*v

C=q/v

Where C, the constant of proportionality, is known as the capacitance of the capacitor.



Although the capacitance C of a capacitor is the ratio of the charge q per plate to the applied voltage v, it does not depend on q or v. It depends on the physical dimensions of the capacitor.

$$C = \frac{\epsilon A}{d}$$

Where A is the surface area of each plate, d is the distance between the plates, and € is the permittivity of the dielectric material between the plates.

Capacitance: It is a measure of the amount of electric charge stored for a given electric potential and is given by the ratio of the charge on one plate of a capacitor to the voltage difference between the two plates, measured in farads(F).

i=dq/dt=d(Cv)/dt=Cdv/dt.

Where v= voltage across the capacitor,

i=current through the capacitor.

Power absorbed by capacitor is p=v*i=vC(dv/dt)

Energy stored by the capacitor is $W=(1/2)Cv^2$

Note: The current in a capacitor is zero, if the voltage across it is constant, i.e. capacitor acts as an open circuit to DC.

KIRCHHOFF'SLAWS:

Kirchhoff's Current Law (KCL)

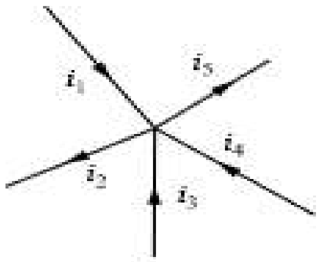
Kirchhoff's first law is based on the law of conservation of charge, which requires that the algebraic sum of charges within a system cannot change.

Kirchhoff's current law (KCL) states that the algebraic sum of currents entering anode is zero. Mathematically, KCL implies that

$$\sum_{n=1}^{N} i_n = 0$$

Where N is the number of branchesconnected to the node and in is then the current entering (or leaving) the node.

Consider the node in Fig.a. Applying KCL gives



Since currents i_1,i_3, and i_4 are entering the node, While currents $i_2$and i_5 are leaving it. By rearranging the terms, we get

$$i_1+(-i_2)+i_3+i_4+(-i_5)=0$$

$$i_1+i_3+i_4 = i_2 + i_5$$

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

Kirchhoff's Voltage Law (KVL)

Kirchhoff's second law is based on the principle of conservation of energy.

Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop)is zero. Expressed mathematically,

$$\sum_{m=1}^{M} v_m = 0$$

Where M is the number of voltages in the loop (or the number of branches in the loop) and V_m is the m^{th} voltage.

Consider the circuit in Fig.b, the sign on each voltage is the polarity of the terminal encountered first as we travel around the loop. We can start with any branch and go around the loop either clockwise or counter clockwise. Suppose we start with the voltage source and go clockwise around the loop as shown, then voltages would be $+V_1$,$-V_2$, $-V_3$, $+V_4$ and$-V_5$, in that order.

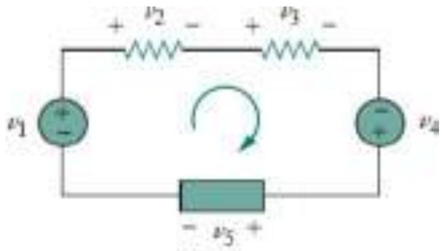


Fig.b

$$V_1-V_2-V_3+V_4-V_5=0$$

Rearranging terms gives, $V_1+V_4= V_2+ V_3+ V_5$ Which may be interpreted as the sum of the voltage drops around a loop=the sum of the voltage rises around the loop.

Mesh Analysis: Mesh analysis provides general procedure for analyzing circuits using mesh currents as the circuit variables. Mesh Analysis is applicable only for planar networks. It is preferably useful for the circuits that have many loops .This analysis is done by using KVL and Ohm's law.

In Mesh analysis, we will consider the currents flowing through each mesh. Hence, Mesh analysis is also called as **Mesh-current method**.

A branch is a path that joins two nodes and it contains a circuit element. If a branch belongs to only one mesh, then the branch current will be equal to mesh current.

If a branch is common to two meshes, then the branch current will be equal to the sum (or difference) of two mesh currents, when they are in same (or opposite) direction.

Procedure of Mesh Analysis:

Follow these steps while solving any electrical network or circuit using Mesh analysis.

Step 1 − Identify the meshes and label the mesh currents in either clockwise or anti-clockwise direction.

Step2− Observe the amount of current that flows through each element in terms of mesh currents.

Step 3− Write mesh equations to all meshes. Mesh equation is obtained by applying KVL first and then Ohm’s law.

Step4− Solve the mesh equations obtained in Step 3 in order to get the mesh currents.

Now, we can find the current flowing through any element and the voltage across any element that is present in the given network by using mesh currents.

Nodal analysis:

Nodal analysis is a method that provides a general procedure for analyzing circuits using node voltages as the circuit variables. It is also called the Node-Voltage Method. Nodal Analysis is based on the application of the Kirchhoff’s Current Law (KCL).

Having ‘n’ nodes there will be ‘n-1’ simultaneous equations to solve.

Solving ‘n-1’ equations all the nodes voltages can be obtained.

The number of non reference nodes is equal to the number of Nodal equations that can be obtained.

sic Steps Used in Nodal Analysis

1. Select a node as the reference node. Assign voltages V_1, V_2… V_{n-1} to the remaining nodes. The voltages are referenced with respect to the reference node.
2. Apply KCL to each of the non reference nodes.
3. Use Ohm's law to express the branch currents in terms of node voltages.
4. After the application of Ohm's Law get the 'n-1' node equations in terms of node voltages and resistances.
5. Solve 'n-1' node equations for the values of node voltages and get the required node Voltages.

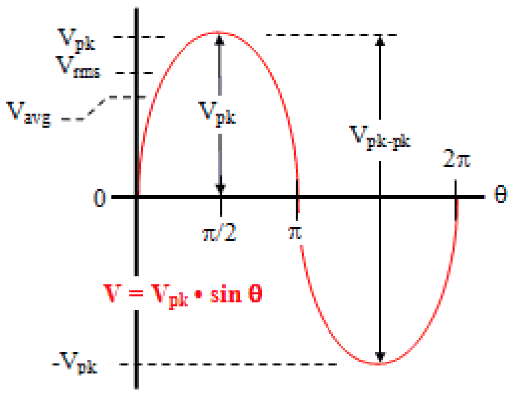
A.C.CIRCUITS

REPRESENTATION OF SINUSOIDAL WAVEFORMS

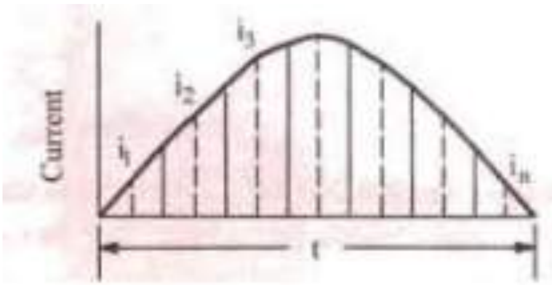
A sine wave is defined by the trigonometric sine function. When plotted as voltage (V) as a function of phase (θ),it looks similar to the figure to the below.Thewaveformrepeatsevery2pradians(360°),andissymmetricalaboutthevoltageaxis(when no DC offset is present). Voltage and current exhibiting cyclic behavior is referred to as alternating; i.e., alternating current (AC). One full cycle is shown here. The basic equation for a sine wave is as follows:

$$V(t)= V_{pk} \sin \theta$$

There are a number of ways in which the amplitude of a sine wave is referenced, usually as peak voltage (Vpkor Vp), peak-to-peak voltage (Vpp or Vp-p or Vpkpk or Vpk-pk), average voltage (Vav or Vavg),and root-mean-square voltage (Vrms). Peak voltage and peak-to peak voltage are apparent by looking at the above plot. Root mean-square and average voltage are not so apparent.



Root mean square (rms) or Effective value of a.c:



$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + \ldots\ldots + i_n^2}{n}} = \text{Square root of the mean of square of the instantaneous currents}$$

- It is the square root of the average values of square of the alternating quantity over a time period.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(\omega t)\,d(\omega t)}$$

Average Value:

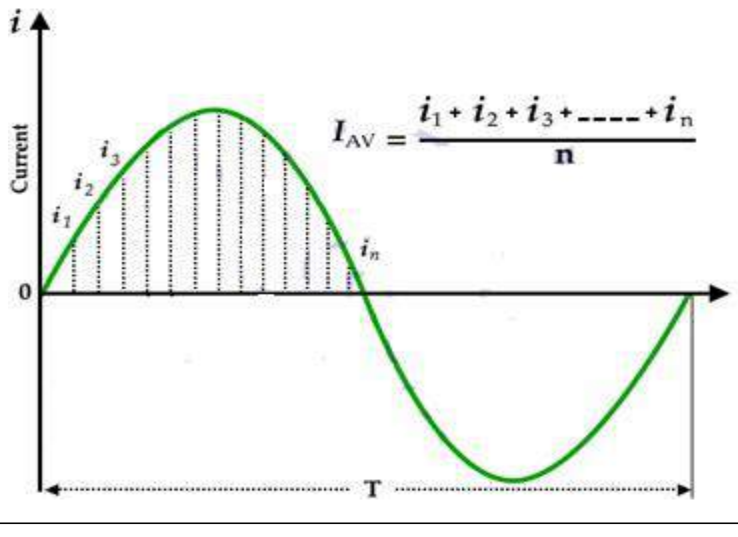
If we convert the alternating current (AC) sine wave into direct current (DC) sine wave through rectifiers,then the converted value to the DC is known as the average value of that alternating current sine wave.

If the maximum value of alternating current is "I_{MAX}", then the value of converted DC current through rectifier would be "0.637 I_M" which is known as average value of the AC Sine wave (I_{AV}).

Average Value of Current = I_{AV} = 0.637 I_M

Average Value of Voltage = E_{AV} = 0.637 E_M

The Average Value (also known as Mean Value) of an Alternating Current (AC) is expressed by that Direct Current (DC) which transfers across any circuit the same amount of charge as is transferred by that Alternating Current (AC) during the same time.



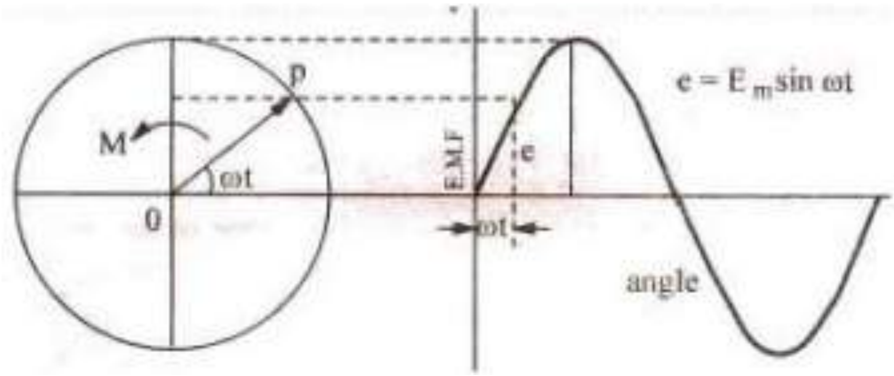
Peak Factor: Peak Factor is also known as Crest Factor or Amplitude Factor. It is the ratio between maximum value and RMS value of an alternating wave.

For a sinusoidal alternating voltage its value is 1.414

Form Factor: The ratio between RMS value and Average value of an alternating quantity (Current or Voltage) is known as Form Factor.

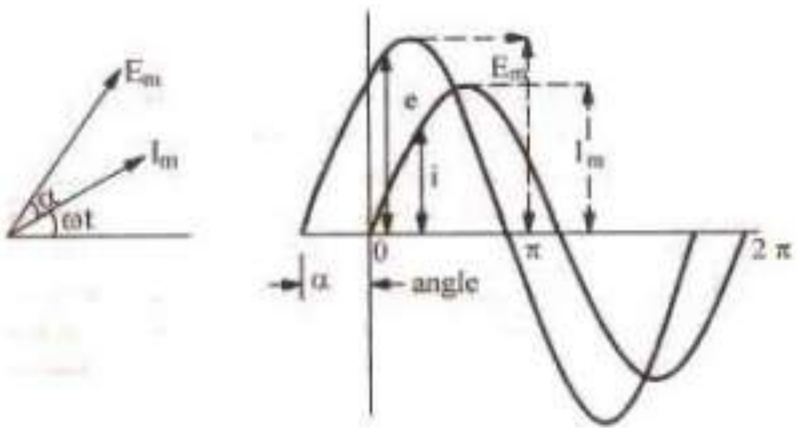
For a sinusoidal alternating voltage its value is 1.11

PHASOR & PHASOR DIAGRAM



Phasor: Alternating quantities are vector (i.e having both magnitude and direction). Their instantaneous values are continuously changing so that they are represented by a rotating vector. A phasor is a vector rotating at a constant angular velocity.

Phasor diagram: Phasor diagram is one in which different alternating quantities of the same frequency are represented by phasors with their correct phase relationship.



Points to remember

- The angle between two phasors is the phase difference.
- Reference phasor is drawn horizontally.
- Phasors are drawn to represent rms values.

- Phasors are assumed to rotate in anti clock wise direction.
- Phasor diagram represents a "still position" of the phasors in one particular Point.

POWER FACTOR:

The phase angle of the load impedance plays a very important role in the absorption of power impedance. The average power dissipated by an AC dependent on the cosine of the angle of the impedance. To recognize the importance of this factor in AC power computations, the term cos(θ) is referred to as the power factor(pf). Note that the power factor is equal to 0 for a purely inductive or capacitive load and equal to1 for a purely resistive load; in every othercase,$0<pf<1$.If the load has an inductive reactance, then θ is positive and the current lags (or follows) the voltage. Thus, when θ and Q are positive, the corresponding power factor is termed lagging. Conversely, a capacitive load will have a negative Q, and hence a negative θ. This corresponds to a leading power factor, meaning that the load current leads the load voltage.

A power factor close to unity signifies an efficient transfer of energy from the AC source to the load, while a small power factor corresponds to inefficient use of energy. Two equivalent expressions for the power factor are given in the following:

$$pf = \cos(\theta) = \frac{P_{av}}{\tilde{V}\tilde{I}} \qquad \text{Power factor}$$

where $\tilde{V}$ and $\tilde{I}$ are the rms values of the load voltage and current.

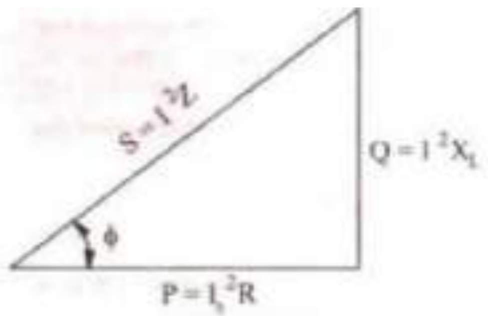


Fig. Power Triangle

ACTIVE, REACTIVE AND APPARENT POWER:

$$S^2=P^2+Q^2$$

$$S=P+jQ$$

Apparent power(S): It is the product of rms values of the applied voltage and circuit current. It is also known as watt less (idle) component.

$$S=VI=IZxI=I^2Z \text{ volt-amp}$$

Active power or true power (P): It is the power which actually dissipated in the circuit resistance. It is also known as watt full component of power.

$$P=I^2R=I^2Z\cos\phi=VI\cos\phi \text{ watt}$$

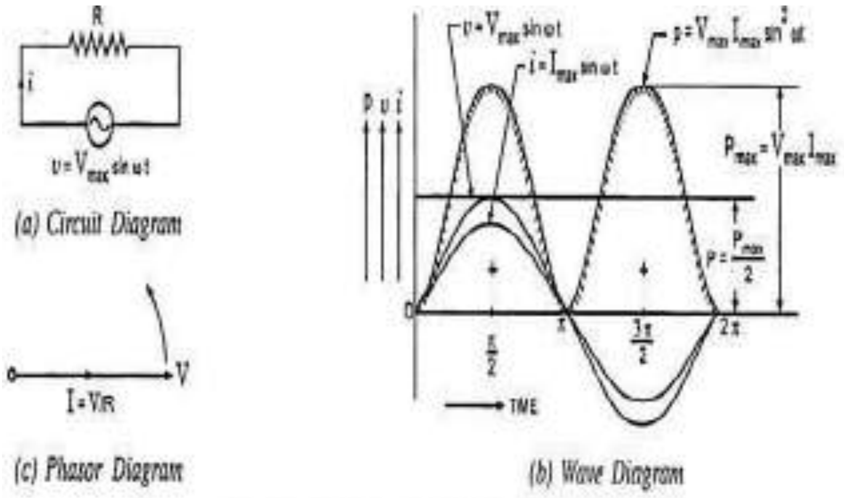
Reactive power(Q): It is the power developed in the reactance of the circuit.

$$Q=I^2X=I^2Z\sin\phi=VI\sin\phi \text{ VAR}$$

ANALYSIS OF SINGLE PHASE AC CIRCUITS:

Purely Resistive Circuit:

Consider an ac circuit containing a non-inductive resistance of R ohms connected across a sinusoidal voltage represented by $v = V_m \sin wt$, as shown in Fig.



When the current flowing through a pure resistance changes, no back emf is set up,therefore, applied voltage has to overcome the ohmic drop of i R only:

$$i.e. \quad iR = v$$

$$\text{or} \quad i = \frac{v}{R} = \frac{V_{max}}{R} \sin \omega t$$

Current will be maximum when $\omega t = \frac{\pi}{2}$ or $\sin \omega t = 1$

$$\therefore \quad I_{max} = \frac{V_{max}}{R}$$

And instantaneous current may be expressed as:

$i = I_{max} \sin \omega t$

From the expressions of instantaneous applied voltage and instantaneous current, it is evident that in a pureresistive circuit, the applied voltage and current are in phase with each other, as shown by wave and phasor diagrams in Figs.

Power in Purely Resistive Circuit: The instantaneous power delivered to the circuit is the product of the instantaneous values ofapplied voltage and current.

$$i.e.\quad p = v\,i = V_{max}\sin\omega t\; I_{max}\sin\omega t = V_{max}\; I_{max}\sin^2\omega t$$

$$\text{or}\quad p = \frac{V_{max}\, I_{max}}{2}(1-\cos 2\,\omega\, t) \qquad \text{Since } \sin^2\omega\, t = \frac{1-\cos 2\,\omega\, t}{2}$$

$$= \frac{V_{max}\, I_{max}}{2} - \frac{V_{max}\, I_{max}}{2}\cos 2\,\omega\, t$$

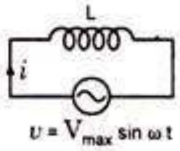
$$\text{Average power, } P = \text{Average of } \frac{V_{max}\, I_{max}}{2} - \textit{average of } \frac{V_{max}\, I_{max}}{2}\cos 2\,\omega\, t$$

Since average of $\frac{V_{max}\, I_{max}}{2}\cos 2\,\omega\, t$ over a complete cycle is zero,

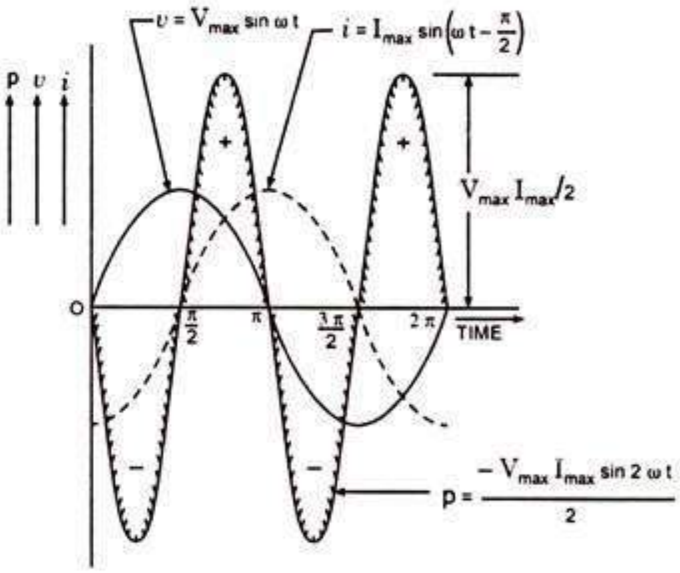
$$P = \frac{V_{max}\, I_{max}}{2} = \frac{V_{max}}{\sqrt{2}} \cdot \frac{I_{max}}{\sqrt{2}} = V\, I \text{ watts}$$

Purely Inductive Circuit: An inductive circuit is a coil with or without an iron core having negligible resistance. Practically pureinductance can never be had as the inductive coil has always small resistance. However, a coil of thickcopper wire wound on a laminated iron core has negligible resistance arid is known as a choke coil.

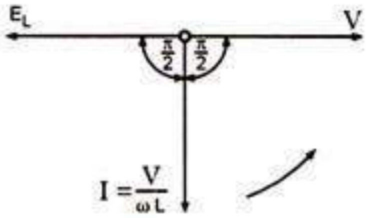
When an alternating voltage is applied to a purely inductive coil, an emf, known as self-induced emf, is induced in the coil which opposes the applied voltage. Since coil has no resistance, at every instant



(a) Circuit Diagram



(b) Wave Diagram



(c) Phasor Diagram

appliedvoltage has to overcome this self-induced emf only.

Let the applied voltage $v = V_{max} \sin \omega t$

and self inductance of coil = L henry

Self induced emf in the coil, $e_L = -L \dfrac{di}{dt}$

Since applied voltage at every instant is equal and opposite to the self induced emf *i.e.* $v = -e_L$

$$\therefore \quad V_{max} \sin \omega t = -\left(-L\frac{di}{dt}\right)$$

$$\text{or} \quad di = \frac{V_{max}}{L} \sin \omega t\, dt$$

Integrating both sides we get

$$i = \frac{V_{max}}{L} \int \sin \omega t\, dt = \frac{V_{max}}{\omega L} (-\cos \omega t) + A$$

where A is a constant of integration, which is found to be zero from initial conditions

$$i.e. \quad i = \frac{-V_{max}}{\omega L} \cos \omega t = \frac{V_{max}}{\omega L} \sin\left(\omega t - \frac{\pi}{2}\right)$$

Current will be maximum when $\sin\left(\omega t - \dfrac{\pi}{2}\right) = 1$, hence, maximum value of current,

$$I_{max} = \frac{V_{max}}{\omega L}$$

and instantaneous current may be expressed as $i = I_{max} \sin\left(\omega t - \dfrac{\pi}{2}\right)$

From the expressions of instantaneous applied voltage and instantaneous current flowing through a purelyinductive coil it is observed that the current lags behind the applied voltage by π/2 as shown in Fig.(b)by wave diagram and in Fig(c) by phasor diagram.

Inductive Reactance:

ωL in the expression Imax = V_{max}/ωL is known as inductive reactance and is denoted by X_L i.e., X_L = ω LIf L is in henry and co is in radians per second then X_L will be in ohms.

Power in Purely Inductive Circuit:

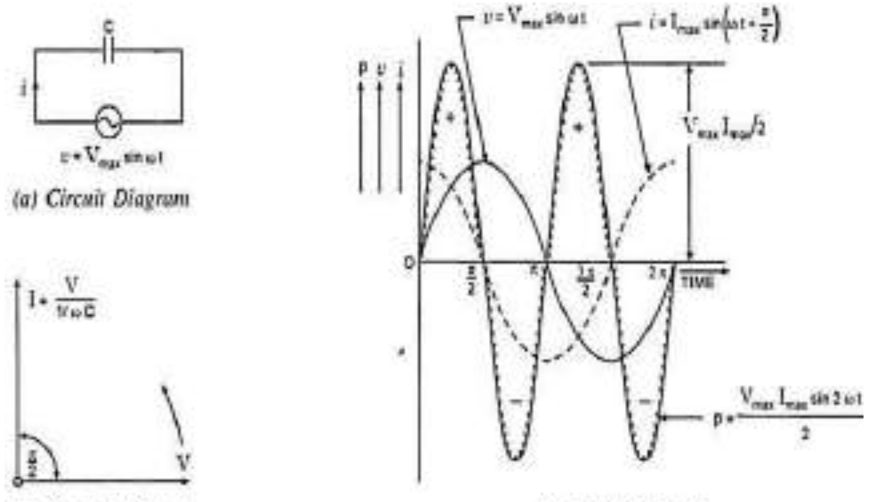
Instantaneous power, p = v × i = Vmax sin ω t Imax sin (ωt – π/2)Or p = – Vmax Imax sin ω t cos ω t = Vmax Imax/2 sin 2 ωt

The power measured by wattmeter is the average value of p which is zero since average of a sinusoidalquantity of double frequency over a complete cycle is zero. Hence in a purely inductive circuit power absorbed is zero.

Purely Capacitive Circuit: When a dc voltage is impressed across the plates of a perfect condenser, it will become charged to full voltage almost instantaneously. The charging current will flow only during the period of "build up" and willcease to flow as soon as the capacitor has attained the steady voltage of the source. This implies that for a direct current, a capacitor is a break in the circuit or an infinitely high resistance.

In Fig.(a) sinusoidal voltage is applied to a capacitor. During the first quarter-cycle, the applied voltageincreases to the peak value, and the capacitor is charged to that value. The current is maximum in the

Let an alternating voltage represented by v = V_{max} sin ω t be applied across a capacitor of capacitance C farads.



(a) Circuit Diagram

(c) Phasor Diagram

(b) Wave Diagram

The expression for instantaneous charge is given as:

$$q = C\,V_{max}\,\sin\omega t$$

Since the capacitor current is equal to the rate of change of charge, the capacitor current may be obtained by differentiating the above equation:

From the equations of instantaneous applied voltage and instantaneous current flowing through capacitance,it is observed that the current leads the applied voltage by π/2, as shown in Figs. (b) and (c) by wave and phasor diagrams respectively.

$$i = \frac{dq}{dt} = [C\,V_{max} \sin \omega t] = \omega C\,V_{max} \cos \omega t = \frac{V_{max}}{1/\omega C} \sin\left(\omega t + \frac{\pi}{2}\right)$$

Current is maximum when $t = 0$

$$\therefore \quad I_{max} = \frac{V_{max}}{1/\omega C}$$

Substituting $\frac{V_{max}}{1/\omega C} = I_{max}$ in the above equation for instantaneous current, we get

$$i = I_{max} \sin\left(\omega t + \frac{\pi}{2}\right)$$

Capacitive Reactance: $1/\omega C$ in the expression $I_{max} = V_{max}/1/\omega C$ is known as capacitive reactance and is denoted by X_C i.e.,$X_C = 1/\omega C$

If C is in farads and ω is in radians/s, then X_C will be in ohms.

Power in Purely Capacitive Circuit:

$$p = v\,i = V_{max} \sin \omega t .\ I_{max} \sin\left(\omega t + \frac{\pi}{2}\right) = V_{max}\,I_{max} \sin \omega t \cos \omega t$$

$$= \frac{V_{max}\,I_{max}}{2} \sin 2\omega t$$

Average power, $P = \frac{V_{max}\,I_{max}}{2} \times$ average of $\sin 2\,\omega t$ over a complete cycle $= 0$.

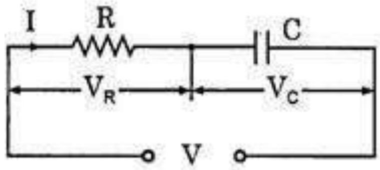
Hence power absorbed in a purely capacitive circuit is zero. The same is shown graphically in Fig. (b).

Resistance — Capacitance (R-C) Series Circuit:

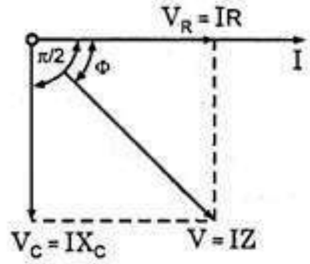
Consider an ac circuit consisting of resistance of R ohms and capacitance of C farads connected in series, asshown in Fig(a)

Let the supply frequency be of *f* Hz and current flowing through the circuit be of I amperes (rms value).Voltage drop across resistance, $V_R = I\,R$ in phase with the current.

Voltage drop across capacitance, $V_C = I\,X_C$ lagging behind I by π/2 radians or 90°, as shown in Fig. (b).



(a) Circuit Diagram



(b) Phasor Diagram

The applied voltage, being equal to phasor sum of V_R and V_C, is given in magnitude by-

$$V = \sqrt{(V_R)^2 + (V_C)^2} = \sqrt{(IR)^2 + (IX_C)^2} = I\sqrt{R^2 + X_C^2} = IZ$$

where $Z^2 = R^2 + X_C^2$

The applied voltage lags behind the current by an angle ϕ:

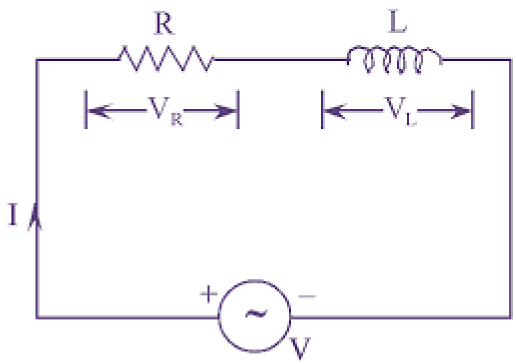
where $$\tan\Phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R} = \frac{1}{\omega RC} \quad \text{or} \quad \Phi = \text{Tan}^{-1}\frac{1}{R\omega C}$$

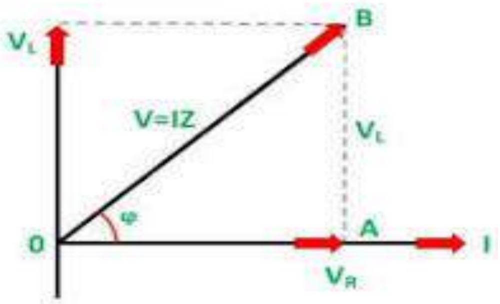
Power factor, $$\cos\Phi = \frac{R}{Z}$$

Resistance — Inductor (R-L) Series Circuit: Consider an ac circuit consisting of resistance of R ohms and inductance of L henry connected in series, asshown in Fig(a)

Let the supply frequency be of *f* Hz and current flowing through the circuit be of I amperes (rms value).Voltage drop across resistance, V_R = I R in phase with the current.

Voltage drop across inductance, $V_L = I X_L$ leading behind I by π/2 radians or 90°, as shown in Fig.(b).





From the Circuit Diagram

$V_R = IR$ and $V_L = IX_L$ where $X_L = 2\pi fL$

$$V = \sqrt{(V_R)^2 + (V_L)^2}$$

$$= \sqrt{(IR)^2 + (IX_L)^2}$$

$$= I\sqrt{R^2 + (X_L)^2}$$

$$= IZ$$

Where $Z = \sqrt{R^2 + X_L^2}$

Phase angle $\theta = \tan^{-1}(X_L / R)$.

Analysis of series RLC circuit: Consider an ac circuit consisting of resistance of R ohms, inductance of L Henry, and capacitance of C farads connected in series, asshown in Fig.(a)

Let the supply frequency be of *f* Hz and current flowing through the circuit be of I amperes (rms value).Voltage drop across resistance, $V_R = I R$ in phase with the current.

Voltage drop across inductance, $V_L = I X_L$ leading behind I by π/2 radians or 90°, as shown in Fig.(b). Voltage drop across capacitance, $V_C = I X_C$ lagging behind I by π/2 radians or 90°, as shown in

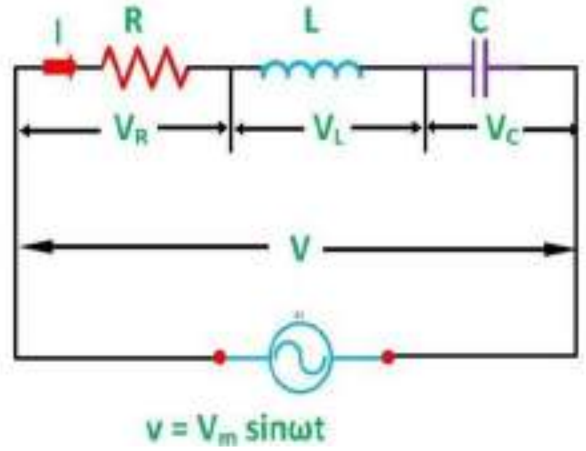
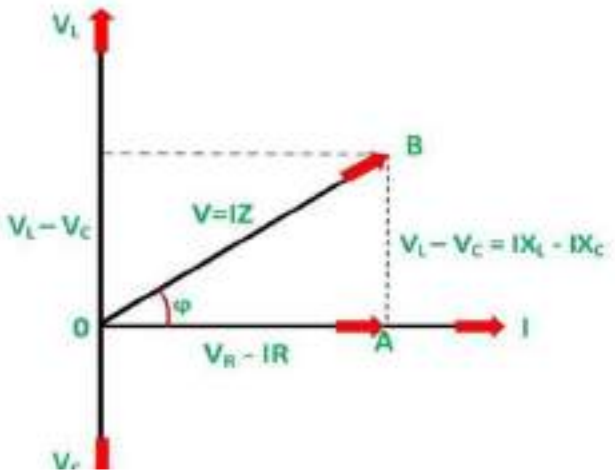


Fig.(b)



$$V_R = I.R \qquad V_L = I.X_L \qquad V_C = I.X_C$$

$$V_S = \sqrt{(I.R)^2 + (I.X_L - I.X_C)^2}$$

$$V_S = I.\sqrt{R^2 + (X_L - X_C)^2}$$

$\therefore V_S = I \times Z$ where: $Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$

UNIT-II

Components of LT Switchgear

Switchgear: The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchgear.

Switch gear Equipment:

Switches (air break type).

Fuses.

Circuit breakers.

Relays.

Isolators.

All these required to protect the LV system

Protection for electrical installation must be provided in the event of faults such as

Short Circuit

Overload

Earth faults

Fuse:

The electrical equipment are designed to carry a particular rated value of current under normal conditions.Under abnormal conditions such as short circuits, overload, or any fault; the current rises above this value,damaging the equipment and sometimes resulting in fire hazard. Fuses come into operation under fault conditions.

A fuse is short piece of metal, inserted in the circuit, which melts when excessive current flows through it and thus breaks the circuits. Under normal operating conditions it designed to carry the full load current. If the current increases beyond this designed value due to any of the reasons mentioned above, the fuse melts, isolating the power supply from the load.

(a) Desirable characteristics of a Fuse Element:

The material used foe fuse wires must have the following characteristics:

i. Low melting point e.g., tin, lead.

ii. High conductivity e.g., copper.

iii. Free from deterioration due oxidation e.g., silver.

iv. Low cost e.g., tin, copper.

(b) Materials:

Material used are tin lead or silver having low melting points. Use of copper or iron is dangerous, though tinned copper may be used.

(c) Types of Fuses:

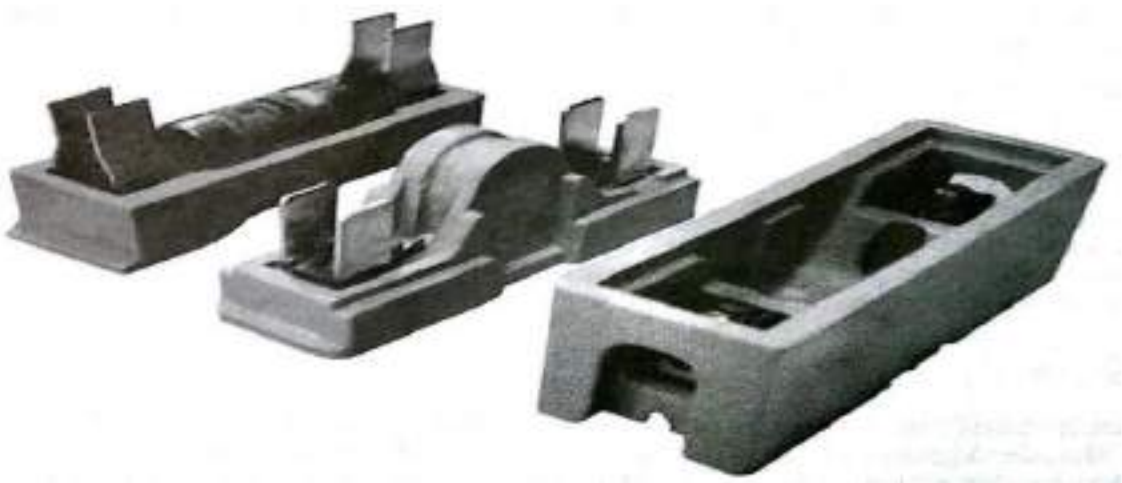
Fuses are classified into following types

(i) Re-wireable or kit-Kat fuse and

(ii) High rupturing capacity (H.R.C) cartridge fuse

Re-wireable or Kit-Kat Fuse:

Re-wireable fuse is used where low values of fault current are to be interrupted. These fuses are

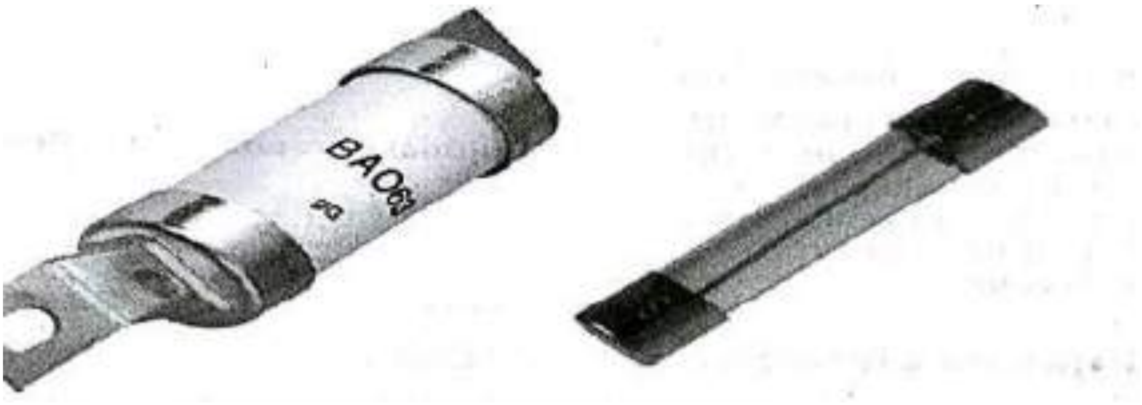


simple in construction, cheap and available up to a current rating of 200A.They are erratic in operation and their performance deteriorates with time. An image of re-wireable fuse is as shown in figure.

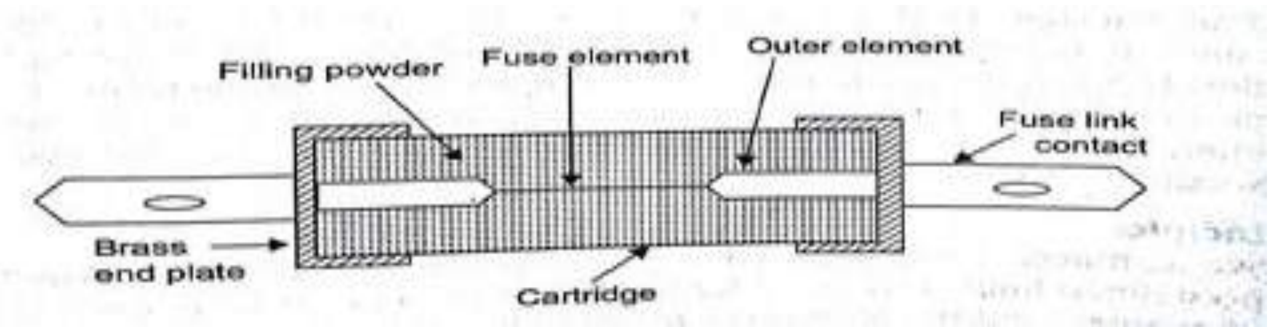
High Rupturing Capacity (HRC) Cartridge Fuse:

Fig(a) shown an image of HRC cartridge fuse and fig(b) the essential parts of a typical HRC cartridge fuse. It consists of a heat resisting ceramic body having metal end-caps to which a silver current-carrying element is welded. The space within the body surrounding the elements is completely packed with a filling powder. The filling material may be chalk, plaster of Paris, quartz or marble dust and acts as an arc quenching and cooling medium. Therefore, it carries the normal current without overheating

Under normal loading conditions, the fuse element is at a temperature below its melting point. When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak. The heat produced in the process vaporizes the melted silver element. The chemical reaction between the silver vapors and the filling powder results in the formation of a high resistance substance which helps in quenching the arc.



Fig(A):HRC Catridge Fuse



Fig(b) Cross section view of HRC fuse

Circuit Breaker:

Electrical circuit breaker is a switching device which can be operated manually and automatically for the controlling and protection of electrical power system, respectively. The modern power system deals with a huge power network and huge numbers of associated electrical equipment. During shirt circuits fault or any other type of electrical fault, this equipment, as well as the power network, suffer a high stress of fault current, which in turn damage the equipment and networks permanently. For saving this equipment and the power networks, the fault current should be cleared from the system as quickly as possible. Again, after the cleared, the system must come to its normal working condition as soon is possible for supplying reliable quality power to the receiving ends. The circuits breaker is the special device all the required switching operations during current carrying condition.

A circuits breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. The contacts can be opened manually or by remote control whenever desired. When a fault occurs in any part of the system, the trip coils of the breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuits.

The main types of circuits breakers are

i. Miniature circuits breakers (MCB)

ii. Earth leakage circuits breakers (ELCB) or Residual Current Breaker (RCCB)

iii. Air blast Circuits Breaker (ACB)

iv. Molded Case Circuits Breakers (MCCB)

v. Vacuum Circuits Breaker (VCB)

vi. SF_6 Circuits Breaker

Miniature Circuit Breaker (MCB):

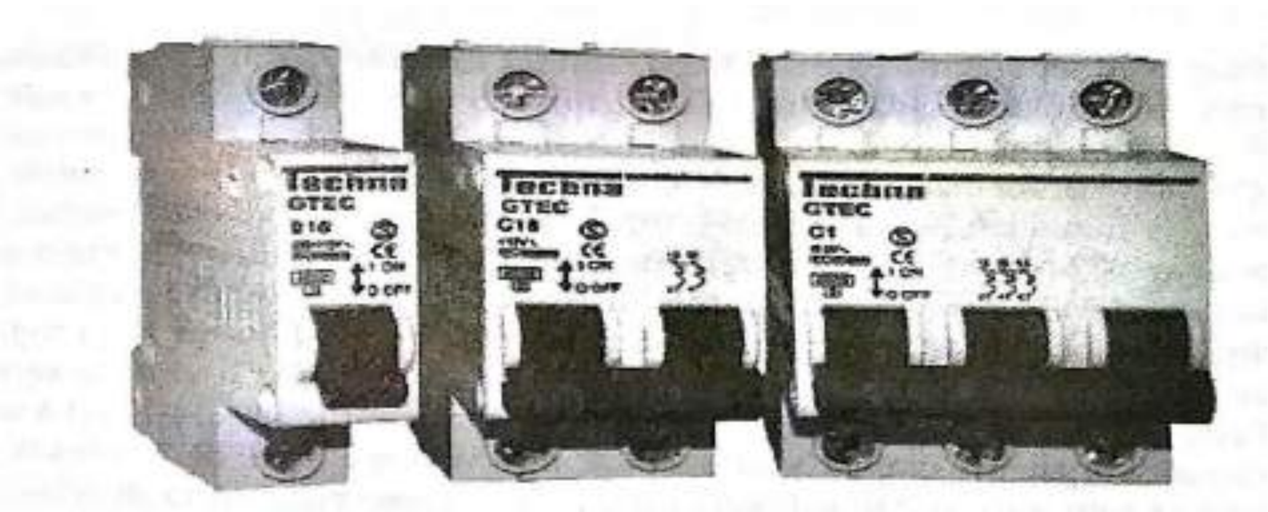
Minimum circuits breakers are electromechanical devices which protect an electrical circuit from over currents. Over currents in an electrical circuit may results from short circuits overload, or faulty design. An MCB is better alternative than fuse, since it does not require replacement once an overload is detected. An MCB functions by interrupting the continuity of electrical flow through the circuits once a fault is detected. In simple terms, MCB is a switch which automatically turns off when the current flowing through it passesthe maximum allowable limit. Generally, MCB is designed to protect against over current and over temperature faults (over heating).

Working Principle:

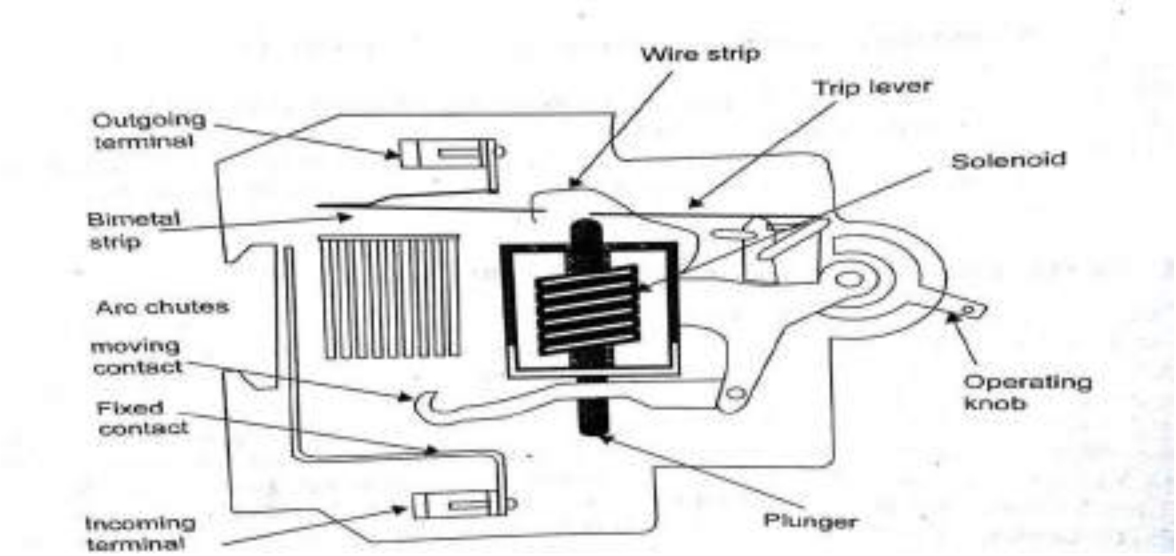
There are two contact - one is fixed and the other is moveable. When the current exceeds the predefined limit, a solenoid forces the moveable contact to open (i.e., disconnect from the fixed contact) and the MCB turns off, thereby stopping the current from flowing in the circuits.

Operation:

An image of MCB is shown in fig(a) and internal parts of an MCB are shown in fig(b). It mainly consists of one bi- metallic strip, one trip coil and one hand operated on-off lever. Electric current carrying path of a MCB is as follows - first left hand side power terminal- then bimetallic strip - then current coil - then moving contact - then fixed contact and - lastlyright hand side power terminal, and all are arranged in series.



Fig(a) Miniature Circuit Breaker



Fig(b) Cross section of MCB

if circuits is overload for a long time, the bi -metallic strip becomes over heated and deformed. This deformation of bi-metallic strip causes displacement of latch point. The moving contact of the MCB is so arranged by means of spring, with this latch point, that a little displacement of latch causes releases of spring and makes the moving contact to move for opening the MCB. The current coil or trip coil placed in such a manner that during SC faults, the MMF of that coil causes its plunger to hit the same latch point andforce the latch to be displaced. Hence, the MCB will open in the same manner. Again when operating leverof the MCB is operated by hand, that means when we make the MCB at off position manually, the same latch point is displaced as a result moving contact separated from fixed contact in same manner. So, whatever may be the operating mechanism, i.e., may be due to deformation of bi-metallic strip or may be due to increased MMF of trip coil or may be due to manual operation - actually the same latch point is displaced and the deformed spring is released, which is ultimately responsible for movement of the moving contact. When the moving contacts is separated from fixed contact, there may be a high chance of arc. Thisare then goes up thorough the arc runner and enters into arc splitters and is finally quenched. When we switch on the MCB, we actually reset the displaced operating latch to its previous on position and make theMCB ready for another switch off or trip operation.

These are available in single pole, double pole, triple pole, and four pole versions with neutral poles, if required. The normal current ratings are available from 0.5-63 A with a symmetrical short circuit rupturing capacity of 3-10kA, at a voltage level of 230/440v. MCBs are generally designed to trip within 2.5 millisecond when an over current fault arises. In case of temperature rise or over heating it may take 2 seconds to 2 min. For the MCB to trip.

Advantages:

i. MCBs are replacing the re-wireable switch i.e., fuse units for low power domestic and industrialapplications.

ii. The disadvantages of fuses, like low SC interrupting capacity (say 3kA), Etc. Are overcome with highSC breaking capacity of 10kA.

iii. MCB is combination of all three functions in a wiring system like switching, overload and short circuitsprotection. Overload protection can be obtained by using bi-metallic strips whereas shorts circuits protection can be obtained by using solenoid

Earth Leakage Circuits Breaker (ELCB):

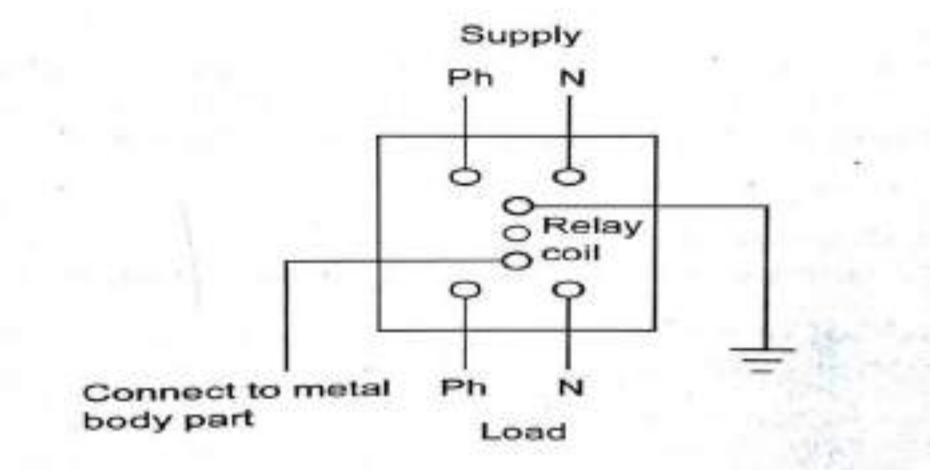
None of the protection devices like MCB, MCCB, etc. Can protect the human life against electric shocks oravoid fire due to leakage current. The human resistance noticeably drops with an increase in voltage. It alsodepends upon the duration of impressed voltage and drops with increase in time. As per IS code, a contact potential of 65V is within tolerable limit of human body for 10 seconds, whereas 250V can be withstood by human body for 100 milliseconds. The actual effect of current thorough human body varies from person to person with reference to magnitude and duration. The body resistance at 10V is assessed to be 19 kΩ for 1 second and 8kΩ for 15 min. At 240V, 3 to 3.6 kΩ for dry skin and 1-1.2 kΩ for wet skin.

An Earth Leakage Circuits Breakers (ELCB) is a device used to directly detect currents leaking to earthfrom an installation and cut the power. There are two types of ELCBs:

(i) Voltage Earth Leakage Circuits Breaker (voltage -ELCB)

(ii) Current Earth Leakage Circuits Breaker (Current -ELCB)

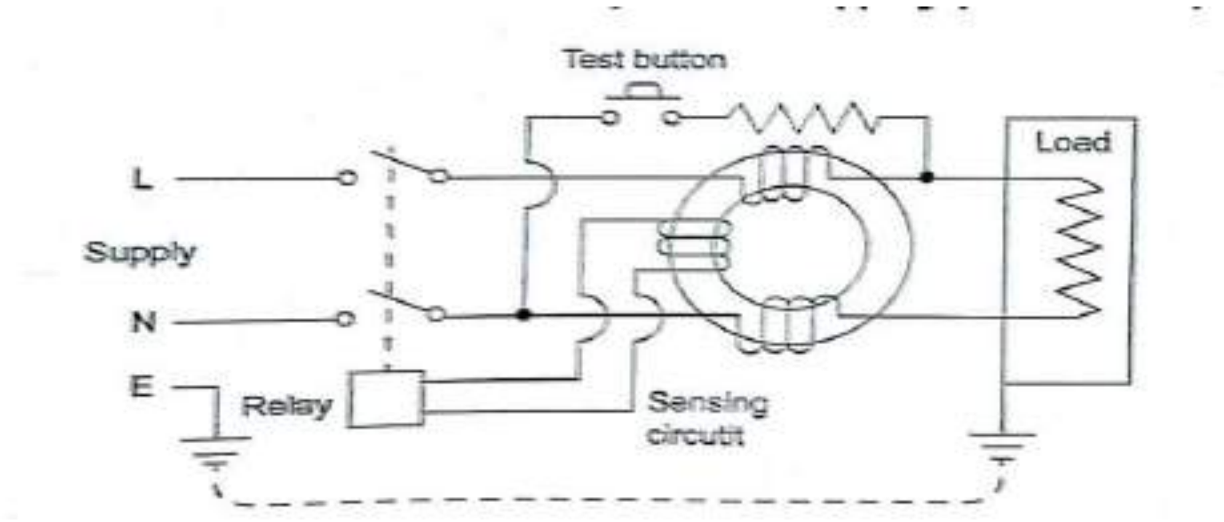
(i) Voltage Earth Leakage Circuits Breaker (voltage -ELCB):



Voltage –ELCB is a voltage operated circuits breaker. The device will function when the current passes thorough the ELCB. Voltage-ELCB contains relay coil and one end of the coil is connected to metallic load body and the other end is connected to ground wire as shown in figure (12.12). If the voltage of the equipment body rises (by touching phase to metal part or insulation failure of equipment), which could cause the difference between earth and load body voltage and the danger of electric shock will occur. This voltage difference will produce an electric current from the load metallic body and phase through the loop to the Earth. When voltage on the equipment metallic body rises to danger level i.e., whichexceed to 50V, the flowing current through relay loop could move the relay contact by disconnecting the supply current avoid from any danger electric shock. The ELCB detects fault currents from line to the earth (ground) wire within the installation it protects. If sufficient voltage appears across the ELCB's sensing coil, it will switch off the power, and remain off until manually reset. A voltage –sensing ELCB does not sense fault current from line to any other earthed body.

(ii) Current Earth Leakage Circuits Breaker (Current -ELCB):

Current –ELCB is a current operated circuits breaker which is a commonly used ELCB. Current-ELCB consists of a 3- winding transformer, which has two primary windings and 1 secondary winding as shown in figure (12.13). Neutral and line wires act as the two primary windings. A wire wound coil is the secondary winding. The current thorough the secondary winding is zero at the balanced condition. In the balanced condition, the flux due to current through the phase wire will be neutralized by the current through the neutral wire, since the current which flows from the phase will be returned back to the neutral. When a fault occurs, a small current will flow to the ground also. This makes an unbalanced between line and neutral currents and creates an unbalanced magnetic field. This induces a current through the secondary winding, which is connected to the sensing circuits. This will sense the leakage and send a signal to the tripping system and trips the contact.



MCCB (MOULDED CASE CIRCUIT BREAKER):

A moulded case circuit breaker (MCCB) is a type of electrical protection device that is used to protect the electrical circuit from excessive current, which can cause overload or short circuit. With a current rating of up to 2500A, MCCBs can be used for a wide range of voltages and frequencies with adjustable trip settings. These breakers are used instead of miniature circuit breakers (MCBs) in large scale PV systems for system isolation and protection purposes. The MCCB uses a temperature sensitive device (the thermal element) with a current sensitive electromagnetic device (the magnetic element) to provide the trip mechanism for protection and isolation purposes. This enables the MCCB to provide:

Overload Protection, Electrical Fault Protection against short circuit currents, and Electrical

Switch for disconnection.

Overload Protection

Overload protection is provided by the MCCB via the temperature sensitive component. This component is essentially a bimetallic contact: a contact which consists of two metals that expand at different rates when exposed to high temperature. During the normal operating conditions, the bimetallic contact will allow the electric current to flow through the MCCB. When the current exceeds the trip value, the bimetallic contact will start to heat and bend away due to the different thermal rate of heat expansion within the contact. Eventually, the contact will bend to the point of physically pushing the trip bar and unlatching the contacts, causing the circuit to be interrupted.

Electrical Fault Protection against short circuit currents:

MCCBs provide an instantaneous response to a short circuit fault, based on the principle of electromagnetism. The MCCB contains a solenoid coil which generates a small electromagnetic field when current passes through the MCCB. During normal operation, the electromagnetic field generated by the solenoid coil is negligible. However, when a short circuit fault occurs in the circuit, a large current begins to flow through the solenoid and, as a result, a strong electromagnetic field is established which attracts the trip bar and opens the contacts.

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Wire and cable:

The use of Conductors and their insulation is regulated by Indian Electricity (IE) regulation and Indian Standard (IS) Code of Practice. Wires and cables are the most common forms of conductors. They carry electric current through all types of circuits and systems. A conductor is a wire or cable or anyother form of mental, suitable for carrying current from generating station the point where it is used.

Difference Between Wire and Cable:

According to Bureau of Indian Standards (BIS), wire and cable can be defined as follows:

Bare Conductors: They have no covering. The best example is overhead transmission and distributionlines.

Wire: If bare conductors are provided with Insulation, then it is known as a wire. The insulation separatesthe conductor electrically from other conductors.

Cable: It consists of two or more conductors covered with suitable insulation and surrounded by a protecting cover. The necessary requirements of a cable are that it should conduct electricity efficiently, cheaply, and safely. This should neither be so small that it has a large internal voltage drop nor be too largeso that it costs too much. Its insulation should be such that it prevents leakage of current in unwanted direction to minimize risk of fire and shock.

The cable essentially consists of three parts :

(i) Conductor or core- the metal wire, or strand of wires, carrying the current

(II) insulation of dielectric- a covering of insulating material to avoid leakage of current fromthe conductor and

(iii) protective covering for protection of insulation from mechanical damage

Basically, there is no difference between a cable and a wire. It is a relative term. The term cable is used forall heavy section insulated conductors, whereas a wire means a thin (i.e., smaller) section insulated conductor used for carrying current from one point to another point.

Classifications of Wire / Cables:

The wires/ cables used for domestic or industrial wiring are classified into different groups as follows :

(i) According to the conductor material used

(a) Copper conductor cables

(b) Aluminum conductor cable

(ii) According to number of cores

(a) Singles core cable (SCC)

(b) Double core or twin core cables (DCC)

(c) Three core cables

(d) four core cables

(e) Two core with earth continuity conductor cables

(iii) According to type of insulation

(a) Vulcanized Indian rubber (VIR) insulated wires/cables

(b) Tough rubber sheathed (TRS) or cable tyre sheathed (CTS) cables

(c) Polyvinyl chloride (PVC) cables

(b) Lead sheathed cables

(e) Weather proof cables

(f) Flexible cords and cables

(g) XLPE cables

(IV) According to the voltage at which they are manufactured

(a) Low tension (LT) cables – up to 1000V

(b) High tension (HT) cables – up to 11kV

(c) Super tension (ST) cables – from 22-33kV

(d) Extra high tension (EHT) cables – from 33-66kV

(e) Extra super voltage cables – beyond 132 kV

Specifications of Cables:

Cables are specified by providing

(i) Size of the cable in metric system (e.g., 19/2.24, 7/1.70, 7/2.24, 7/2.50 etc) giving the Number of strands used and diameter of each strand, or giving the area of cross- sectionof conductor used.

(ii) Type of conductor used in cables (copper or aluminium)

(iii) Number of cores that cable consists of e.g. single core, twin core, three core, four coreetc.

(iv) Voltage grade (240/415V or 650/1100V grade)

(v) Type of cable with clear description regarding insulation, shielding, armouring, beddingetc.

A few specifications of a cable are given below:

(i) 7/20, VIR, aluminum conductor, twin core,650/1100 grade.

in this case, the numerator 7 indicates the number of stands in cable and denominator 20 represents the gauge number of each strand. The cable has two cores made with Aluminum, With VIR insulation and is used for 650/1100 voltage

(ii) 19/1.12, aluminium conductor,3 ½ core, 1100V, PVC cable, PVC sheathed.

in this case, the cable consists of 19 strands, each strand has a diameter of 1.12mm. The conductor is made with aluminium, insulation is made with PVC, is covered with PVC sheathing, and is used for 1100Vsupply system.

Earthing of Grounding:

The process of connecting the metallic frame (i.e., non- current carrying part) of electrical equipment or some electrical part of the system (e.g., neutral point in a star-connected system, one conductor of the secondary of a transformer, etc.) to the earth (i.e., soil) is called grounding or Earthing. The potential of the earth is to be considered zero for all practical purposes. Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential, This ensures safe discharge of electrical energy due to failure of the insulation line coming in contact with the casing, etc. Earthing brings the potential of the body of the equipment to zero i.e., to the earth's potential, thus ptotecting the operating personnel against electrical shock.

The earth resistance is affected by the following factors :

(a) Material properties of the earth, wire and the electrode

(b) Temperature and moisture content of the soil

(c) Depth of the pit

(d) Quantity of the charcoal used

Necessity of Earthing:

The requirement for provision of earthing can be listed as follows :

(1) To protect the operating personnel from the danger of shock.

(2) To maintain the line voltage constant, under unbalanced load condition.

(3) To avoid risk of fire due to earth leakage current through unwanted path.

(4) Protection of the equipments.

(5) Protection of large buildings and all machines fed from overhead lines against lighting.

Methods of Earthing:

The various methods of earthing in common use are

(i) Plate earthing

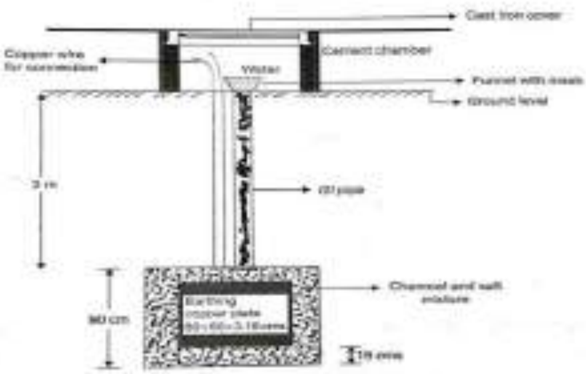
(ii) Pipe earthing

(iii) Rod earthing

(iv) Strip or wire earthing

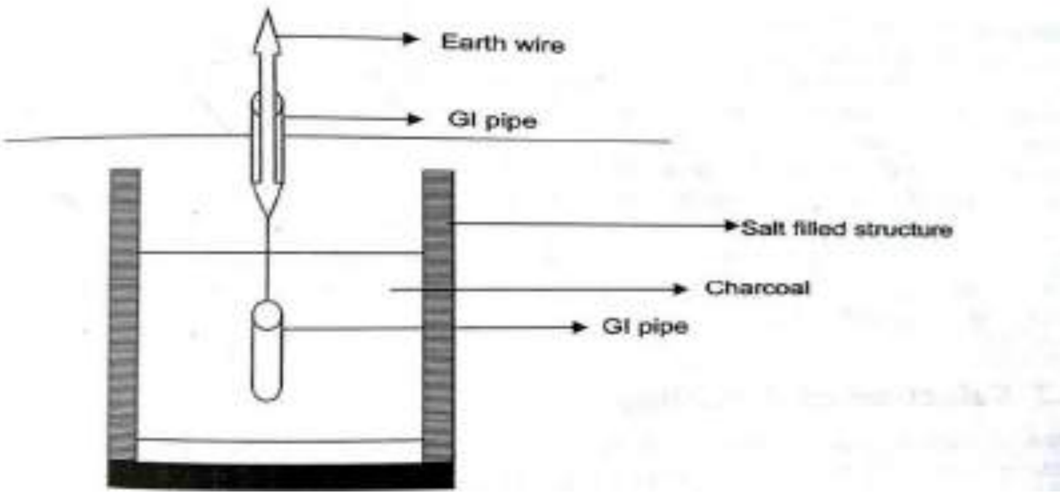
(i) Plate earthing:

In this method either a copper plate of 60cm × 60cm ×3.18 or GI plate of 60cm × 60cm × 6.35 is used for earthing. The plate is buried into the ground not less than 3m from the ground level. The earth plate is embedded in alternate layers of coal and salt for a thickness of 15cm as shown in figure. In addition, water is poured for keeping the earth's electrode resistance value below a maximum of 5Ω. The earth wire issecurely bolted to the earth plate.A cement masonry chamber is built with a cast iron cover for easy regular maintenance



(ii) Pipe earthing:

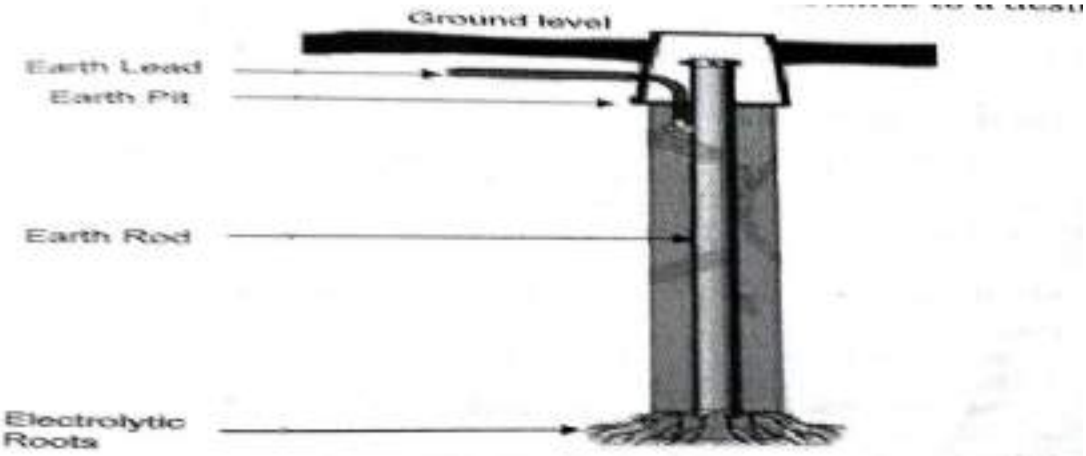
Earth electrode made of a GI (galvanized iron) pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75cm in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15 cm) surrounding the GI pipe is filled with a mixture of salt and coal. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross-sectional area are run through a12.7mm diameter pipe (at 60cm below) from the 19mm diameter pipe and secured tightly at the top as shown in figure.



When compared to the plate earth system the pipe earth system can carry larger leakage currents due tolarger surface area is in contact with the soil for given electrode size. This system also enables easy maintenance as the earth wire connection is housed at the ground levels.

(iii) Rod earthing:

It is the same method as pipe earthing, A copper rod of 12.5cm (1/2 inch) diameter or 16mm (0.6in) diameter of galvanized steel or hollow section 25mm (1 inch) of GI pipe of length above 2.5m (8.2 ft) are buried upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.



(iv) Strip or wire earthing:

In this method of earthing strip electrodes of cross- section not less than 25mm × 1.6mm (1 in × 0.06in) isburied in a horizontal trench of a minimum depth of 0.5m. If copper with a cross-section of 25mm × 4mm(1in × 0.15in) is used and a dimension of 3.0 mm^2 if it's a galvanized iron or steel.

If at all round conductors are used, their cross-section area should not be too small, say less than 6.0 mm^2 if it's a galvanized iron or steel. The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m. The electrodes shall be as widely distributed as possible in a single straight or circular trench radiating from a point. This type of earthing isused where the earth bed has a rocky soil and excavation work is difficult.

Selection of Earthing:

The type of earthing to be provided depends on many factors such as type of soil, type of installation, etc..The following table helps in selecting a type of earthing for a particular application

S.No	Type of Earthing	Application
01	Plate earthing	Large installations such as transmission towers, all sub- stations generating stations

02	Pipe earthing	• For domestic installations such as heaters, coolers, refrigerators, geysers, electric iron, etc. • For 11kV/400V distribution transformers • For induction motors rating upto 100HP • For conduit pipe in a wall, all wall brackets
03	Rod earthing	In areas where the soil is loose or sandy
04	Strip of wire earthing	In rocky ares

Earth Resistance:

The earth resistance should be kept as low as possible so that the neutral of any electrical system, which isearthed, is maintained almost at the earth potential. The earth resistance for copper wire is 1Ω and that of GI wire less than 3Ω. The typical value of the earth resistance at large power stations is 0.5Ω , major sub-stations is 1Ω, small sub-stations is 2 Ω and in all other cases 5 Ω.

The resistance of the earth depends on the following factors

Condition of soil.

ii. Moisture content of soil.

iii. Temperature of soil.

iv. Depth of electrode at which it is embedded.

v. Size, material and spacing of earth electrode.

vi. Quality and quantity of coal and salt in the earth pit.

Difference Between Earth Wire and Neutral Wire:

Neutral Wire :

(i) In a 3-phase 4-wire system, the fourth wire is a neutral wire.

(ii) IT acts a return path for 3-phase currents when the load is not balanced.

(iii) IN domestic single phase AC circuit, the neutral wire acts as return path for the linecurrent.

Earth Wire :

(i) Earth wire is actually connected to the general mass of the earth and metallic body of the equipment

(ii) It is provided to transfer any leakage current from the metallic body to the earth.

Energy Consumption Calculation:

Energy and power are closely related. Electrical energy can be measured only when electrical power is known. So first we understand the electrical power. Electrical power it the amount of electrical current thatresults from a certain amount of voltage or we can say that power is the rate which energy is delivered. It ismeasured in watts. Mathematically it is written as

Power = Voltage × Current

The measurement of electrical energy is completely dependent on power which is measured in watt,kilowatts, megawatts, gigawatts, and time which is measured in an hour. Joule is the smallest unit of energy. But for some bigger calculation, some better unit it required. So, the unit used for electrical energy is watt- hour.

Electrical energy is the product of electrical power and time, and it measured in joules. It is defined as “1joule of energy is equal to 1 watt of power is consumed for 1 second”. I.e.,

Energy = Power × Time

1 Joule = 1 watt × 1 second

Watts are the basic unit of power in which electrical power is measured or we can say that rate at whichelectrical current is being used at a particular moment.

Watt-hour is the standard unit used for measurement of energy, describing the amount of watts used over atime. It shows how fast the power is consumed in the period of time.

Energy in watt hours = Power in watts × Time in hours

Kilowatt-hour is simply a bigger unit of energy when large appliance drawn power in kilowatts. It can be described as one kilowatt hour is the amount of energy drawn by the 1000 watts appliance when used for anhour.

Where, One kilowatt = 1000 watts

Energy in kilowatt hours = Power in kilowatts × Time in hours

The electrical supply companies take electric energy charges from their consumer per kilowatt hour unitbasis.

This kilowatt hour is board of trade (BOT) unit.

Illustration for Energy Consumption:

A consumer uses a 10 kW geezer, a 6 kW electric furnace and five 100 W bulbs for 15 hours. How manyunits (kWh) of electrical energy have been used?

Explanation : Given that

Load – 1 = 10 kW geezer

Load – 2 = 6 kW electric furnace

Load – 3 = 500 watt (five 100 watt bulbs)

Total load = 10kW + 6kW + 0.5kW = 16.5kW

Time taken = 155 hours

Energy consumed = Power in kW × Time in hours

= 16.5 × 15 = 247.5 kWh

For above electrical energy consumption, the tariff can be calculated as follows :1 unit = 1kWh

So, the total energy consumption = 247.5 units

If the cost per unit is 2.5, then the total cost of energy consumption

247.5 × 2.5 = 618.75/-

UNIT-III

TRANSFORMER

Introduction

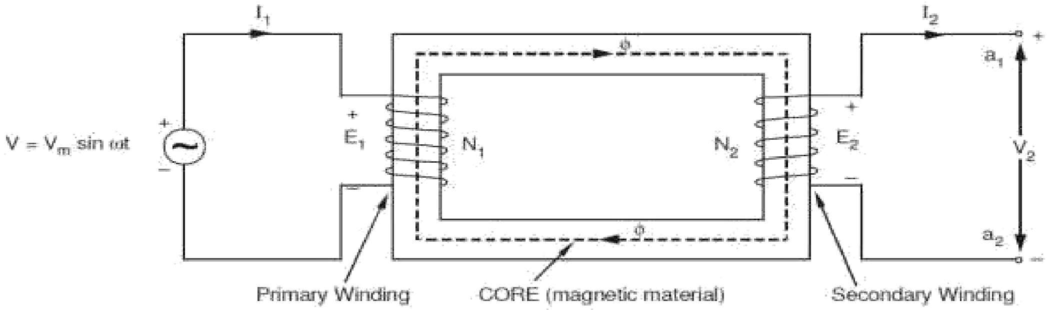
The transformer is a device that transfers electrical energy from one electrical circuit to another electrical circuit. The two circuits may be operating at different voltage levels but always work at the same frequency. Basically transformer is an electro-magnetic energy conversion device. It is commonly used in electrical power system and distribution systems. It can change the magnitude of alternating voltage or current from one value to another. This useful property of transformer is mainly responsible for the widespread use of alternating currents rather than direct currents i.e., electric power is generated, transmitted and distributed in the form of alternating current. Transformers have no moving parts, rugged and durable in construction, thus requiring very little attention. They also have a very high efficiency as high as 99%.

Single Phase Transformer

A transformer is a static device of equipment used either for raising or lowering the voltage of an a.c. supply with a corresponding decrease or increase in current. It essentially consists of two windings, the primary and secondary, wound on a common laminated magnetic core as shown in Fig 1. The winding connected to the a.c. source is called primary winding (or primary) and the one connected to load is called secondary winding (or secondary). The alternating voltage V_1 whose magnitude is to be changed is applied to the primary.

Depending upon the number of turns of the primary (N_1) and secondary (N_2), an alternating e.m.f. E_2 is induced in the secondary. This induced e.m.f. E_2 in the secondary causes a secondary current I_2. Consequently, terminal voltage V_2 will appear across the load. If $V_2 > V_1$, it is called a step up-transformer.

If V2 < V1, it is called a step-down transformer.



Constructional Details

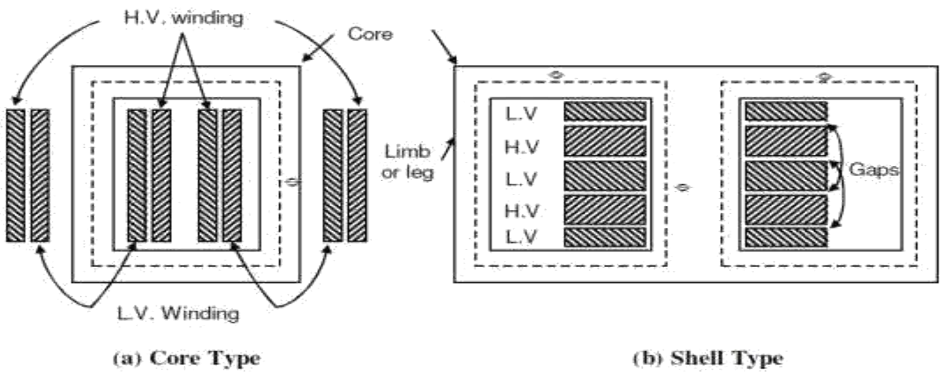
Depending upon the manner in which the primary and secondary windings are placed on the core, and the shape of the core, there are two types of transformers, called

(a) Core type

(b) Shell type.

Core-type and Shell-type Construction

In core type transformers, the windings are placed in the form of concentric cylindrical coils placed around the vertical limbs of the core. The low-voltage (LV) as well as the high- voltage (HV) winding are made in two halves, and placed on the two limbs of core. The LV winding is placed next to the core for economy in insulation cost. Figure 2.1(a) shows the cross-section of the arrangement. In the shell type transformer, the primary and secondary windings are wound over the central limb of a three-limb core as shown in Figure 2.1(b). The HV and LV windings are split into a number of sections, and the sections are interleaved or sandwiched i.e. the sections of the HV and LV windings are placed alternately.



Core

The core is built-up of thin steel laminations insulated from each other. This helps in reducing the eddy current losses in the core, and also helps in construction of the transformer. The steel used for core is of high silicon content, sometimes heat treated to produce a high permeability and low hysteresis loss. The material commonly used for core is CRGO (Cold Rolled Grain Oriented) steel. Conductor material used for windings is mostly copper. However, for small distribution transformer aluminum is also sometimes used. The conductors, core and whole windings are insulated using various insulating materials depending upon the voltage.

Insulating Oil

In oil-immersed transformer, the iron core together with windings is immersed in insulating oil. The insulating oil provides better insulation, protects insulation from moisture and transfers the heat produced in core and windings to the atmosphere.

The transformer oil should possess the following qualities:

(a) High dielectric strength,

(b) Low viscosity and high purity,

(c) High flash point,

(d) Free from sludge.

Transformer oil is generally a mineral oil obtained by fractional distillation of crude oil.

Tank and Conservator

The transformer tank contains core wound with windings and the insulating oil. In large transformers small expansion tank is also connected with main tank is known as conservator. Conservator provides space when insulating oil expands due to heating. The transformer tank is provided with tubes on the outside, to permits circulation of oil, which aides in cooling. Some additional devices like breather and Buchholz relay are connected with main tank. Buchholz relay is placed between main tank and conservator. It protect the transformer under extreme heating of transformer winding. Breather protects the insulating oil from moisture when the cool transformer sucks air inside. The silica gel filled breather absorbs moisture when air enters the tank. Some other necessary parts are connected with main tank like, Bushings, Cable Boxes, Temperature gauge, Oil gauge, Tapings, etc.

Principle of Operation

When an alternating voltage V1 is applied to the primary, an alternating flux ϕ is set up in the core. This alternating flux links both the windings and induces e.m.f.s E1 and E2 in them according to Faraday’s laws of electromagnetic induction. The e.m.f. E1 is termed as primary e.m.f. and E2 is termed as secondary e.m.f.

$$\text{Clearly,} \quad E_1 = -N_1 \frac{d\phi}{dt}$$

$$\text{and} \quad E_2 = -N_2 \frac{d\phi}{dt}$$

$$\therefore \quad \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

Note that magnitudes of E2 and E1 depend upon the number of turns on the secondary and primary respectively.

If $N2 > N1$, then $E2 > E1$ (or $V2 > V1$) and we get a step-up transformer.

If $N2 < N1$, then $E2 < E1$ (or $V2 < V1$) and we get a step-down transformer.

If load is connected across the secondary winding, the secondary e.m.f. E2 will cause a current I2 to flow through the load. Thus, a transformer enables us to transfer a.c. power from one circuit to another with a change in voltage level.

The following points may be noted carefully

(a)The transformer action is based on the laws of electromagnetic induction.

(b)There is no electrical connection between the primary and secondary.

(c) The a.c. power is transferred from primary to secondary through magnetic flux.

(d) There is no change in frequency i.e., output power has the same frequency as the input power.

(e)The losses that occur in a transformer are:

(a) core losses—eddy current and hysteresis losses

(b) copper losses—in the resistance of the windings

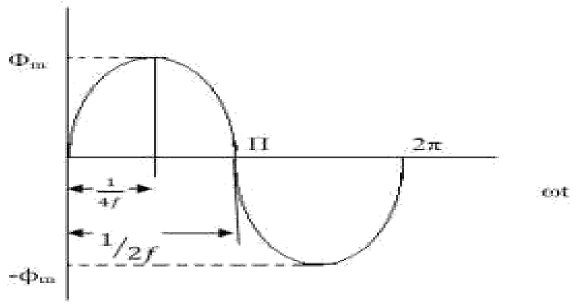
In practice, these losses are very small so that output power is nearly equal to the input primary power. Inother words, a transformer has very high efficiency

E.M.F. Equation of a Transformer

Consider that an alternating voltage V1 of frequency f is applied to the primary as shown in Fig.2.3. Thesinusoidal flux ϕ produced by the primary can be represented as:

$$\phi=\phi m \sin\omega t$$

When the primary winding is excited by an alternating voltage V1, it is circulating alternating current,producing an alternating flux ϕ.



Let ϕ - Flux

ϕm - maximum value of flux ,

N1 - Number of primary turns ,

N2 - Number of secondary turns

f - Frequency of the supply voltage

E1 - R.M.S. value of the primary induced e.m.f ,

E2 - R.M.S. value of the secondary induced e.m.fThe instantaneous e.m.f. e1 induced in the primary is –

The flux increases from zero value to maximum value ϕm in 1/4f of the time period that is in 1/4f seconds.The change of flux that takes place in 1/4f seconds = ϕm - 0 = ϕm webers

$$\frac{d\phi}{dt} = \frac{dt}{1/4f} = 4f\phi_m \ w_b/\text{sec}.$$

Since flux ϕ varies sinusoidally, the R.m.s value of the induced e.m.f is obtained by multiplying the average value with the form factor

$$\text{Form factor of a sinwave} = \frac{\text{R.m.s value}}{\text{Average value}} = 1.11$$

R.M.S Value of e.m.f induced in one turns = $4\phi_m f \times 1.11$ Volts.

= $4.44\phi_m f$ Volts.

R.M.S Value of e.m.f induced in primary winding = $4.44\phi_m f N1$ Volts.

R.M.S Value of e.m.f induced in secondary winding = $4.44\phi_m f N2$ Volts.

The expression of E_1 and E_2 are called e.m.f equation of a transformer

$V_1 = E_1 = 4.44\phi_m f N_1$ Volts.
$V_2 = E_2 = 4.44\phi_m f N_2$ Volts.

Voltage Ratio: Voltage transformation ratio is the ratio of e.m.f induced in the secondary

$$\frac{E2}{E1} = \frac{4.44\phi m f\ N2}{4.44\phi m f\ N1}$$

$$\frac{E2}{E1} = \frac{N2}{N1} = K$$

winding to the

e.m.f induced in the primary winding.

This ratio of secondary induced e.m.f to primary induced e.m.f is known as voltage transformation ratio

1. If N2>N1 i.e. K>1 we get E2>E1 then the transformer is called step up transformer.
2. If N2< N1 i.e. K<1 we get E2< E2 then the transformer is called step down transformer.
3. If N2= N1 i.e. K=1 we get E2= E2 then the transformer is called isolation transformer or 1:1 Transformer.

$$E_2 = KE_1 \qquad \text{where } K = \frac{N2}{N1}$$

Current Ratio

Current ratio is the ratio of current flow through the primary winding (I1) to the currentflowing through the secondary winding (I2). In an ideal transformer -

Apparent input power = Apparent output power. $V_1I_1 = V_2I_2$

$$\frac{I1}{I2} = \frac{V2}{V1} = \frac{N2}{N1} = K$$

Volt-Ampere Rating:

i)The transformer rating is specified as the products of voltage and current (VA rating).

i)On both sides, primary and secondary VA rating remains same. This rating is generally expressed in KVA(Kilo Volts Amperes rating)

$$\frac{V1}{V2} = \frac{I2}{I1} = K$$

$$V_1I_1 = V_2I_2$$

$$\text{KVA Rating of a transformer} = \frac{V1I1}{1000} = \frac{V2I2}{1000} \quad \text{(1000 is to convert KVA to VA)}$$

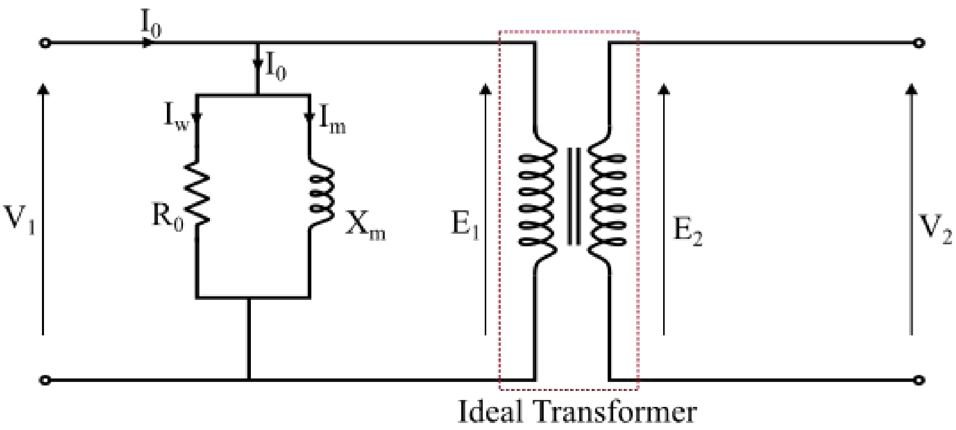
V_1 and V_2 are the V_t of primary and secondary by using KVA rating we can calculate I_1 and I_2 Full load current and it is safe maximum current.

$$I_1 \text{ Full load current} = \frac{KVA\ Rating\ X\ 1000}{V1}$$

No-Load Equivalent Circuit of Transformer

$$I_1 \text{ Full load current} = \frac{KVA\ Rating\ X\ 1000}{V2}$$

The figure shows the no-load equivalent circuit of a practical transformer. In this, the practical transformer is replaced by an ideal transformer with a resistance R_0 and an inductive reactance X_m in parallel with its primary winding. The resistance R_0 represents the iron losses so the current I_W passes it and supplies the iron losses. The inductive reactance X_m draws the magnetising current I_m which produces the magnetic flux in the core.



Therefore,

Iron losses of practical transformer=$I_2^2R_o$

Also, from the equivalent circuit,

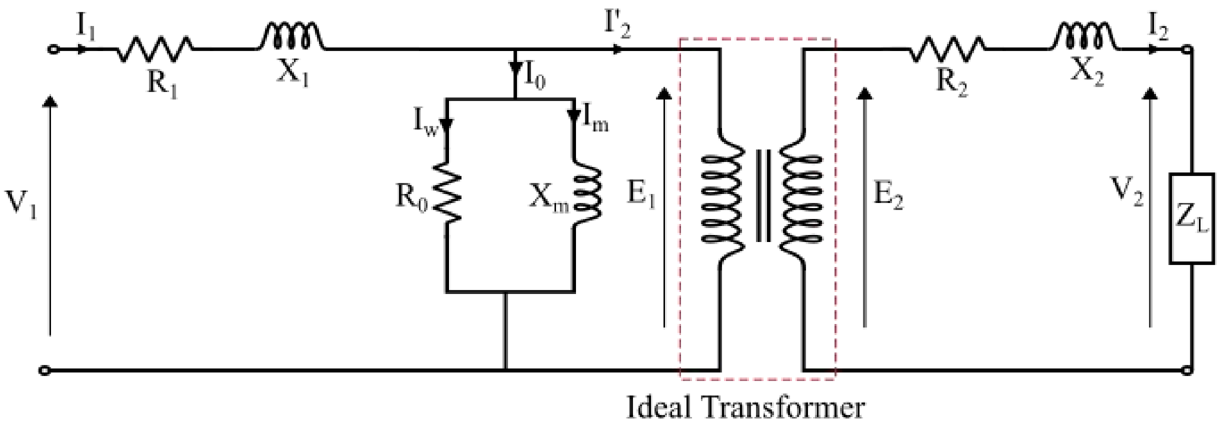
$V_1 = I_W R_0 = I_m X_m$

The no-load current is given by phasor sum of current I_W and the magnetising current I_m i.e.

$I_0 = I_W + Im$

Exact Equivalent Circuit of Transformer

The exact equivalent circuit of the transformer is shown in the figure. In which, the resistance R_1 is the primary winding resistance and resistance R_2 is the resistance of secondary winding. Likewise, the inductive reactance X_1 is the primary winding leakage reactance and the reactance X_2 is the secondary winding leakage reactance. The parallel circuit $R_0 – X_m$ is the no-load equivalent circuit of the transformer.



As in the exact equivalent circuit of the transformer, all the $I_m$perfections are represented by various circuit elements. Therefore, the transformer is now an ideal one. From the exact equivalent circuit, it can be seen that there are two electrical circuit which are separated by an ideal transformer that changes the voltage and current as per the equation given below.

$$K=E_2/E_1=N2/N1$$

Now, consider a load of Impedance Z_L is connected across the secondary winding of the transformer, thus, the induced emf E_2 causes a secondary current I_2. Due to this I_2 voltage drops occur in I_2R_2 and I_2X_2 so that the load voltage V_2 will be less than E_2 and is given by,

$$V_2=E_2-I_2(R_2+jX_2)=E_2-I_2Z_2$$

Also, the total primary current (I_1) drawn from the supply is equal to the phasor sum of no-load current (I_0) and the current I'_2 which is required to supply the load current through the secondary winding. Thus,

$$I_1=I_0+I'_2$$

The primary voltage V_1 is given by adding drops I_1R_1 and I_1X_1 to the emf E_1 i.e.

$$V_1=-E_1+I_1(R_1+jX_1)=-E_1+I_1Z_1$$

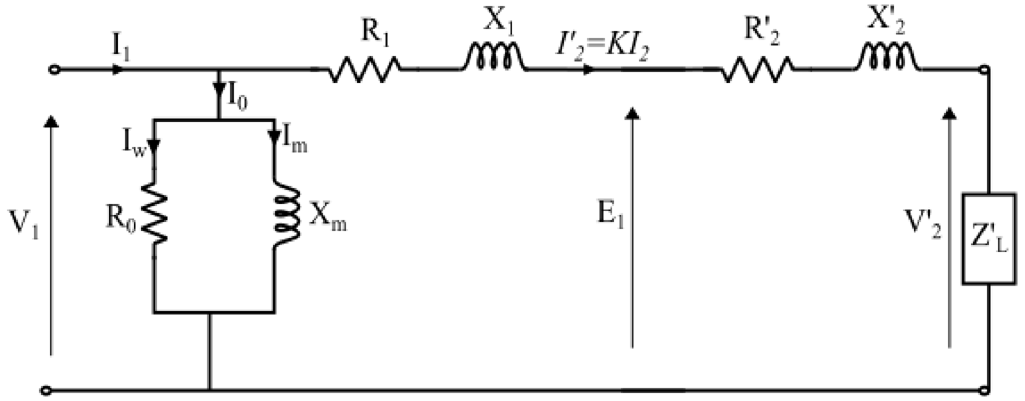
Here, the negative sign of E1 denotes that the E1 is 180° out of phase with V_1

As in a practical transformer, the no-load current I_0 is very small as compared to rated primary current, thus the drops in R_1 and X1 due to the I_0 can be neglected. Therefore, the parallel circuit $R_0 – X_m$ can be transferred to the input terminals. The figure shows the simplified equivalent circuit of the transformer.

The simplified equivalent circuit can be referred to primary side or secondary as discussed below (*here, the assumed transformer is step-up transformer*).

Simplified Equivalent Circuit Referred to primary Side

This can be obtained by referring all the secondary side quantities to the primary side as shown in the figure. The values of secondary side quantities referred to primary side being given by,



Secondary resistance referred to primary, $R'_2=R_2/K^2$

Secondary reactance referred to primary, $X'_2=X_2/K^2$

Load Impedance referred to primary, $Z'_L=Z_L/K^2$

Secondary voltage referred to primary, $V'_2=V_2/K$

Secondary current referred to primary, $I'_2=KI_2$

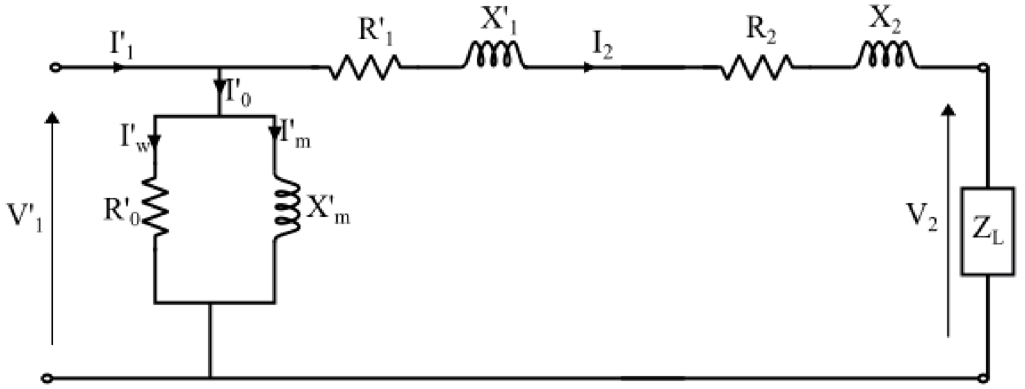
Therefore, the total Impedance of the transformer becomes,

$$\therefore Z_{01}=R_{01}+jX_{01}$$

Where, $R_{01}=R_1+R'_2$ $X_{01}=X_1+X'_2$

simplified Equivalent Circuit Referred to Secondary side

If all the primary side quantities are referred to secondary side, then we obtain the simplified equivalent circuit of transformer referred to secondary side as shown in the figure. The values of primary side quantities referred to secondary side being given by,



Primary resistance referred to secondary, $R'_1 = K^2 R_1$

Primary reactance referred to secondary, $X'_1 = K^2 X_1$

Primary voltage referred to secondary, $V'_1 = KV_1$

Primary current referred to secondary, $I_1' = I1/K$

Thus, the total Impedance of the transformer becomes,

$$\therefore Z_{02} = R_{02} + jX_{02}$$

Where,

$$R_{02} = R_2 + R_1'$$

$$X_{02} = X_2 + X_1'$$

LOSSES IN TRANSFORMERS:

The following power losses may occur in a practical transformer −

- Iron Loss or Core Loss
- Copper Loss or I^2R Loss
- Stray Loss
- Dielectric Loss

In a transformer, these power losses appear in the form of heat and cause two major problems

- Increases the temperature of the transformer.
- Reduces the efficiency of the transformer.

Iron Loss or Core Loss

Iron loss occurs in the magnetic core of the transformer due to flow of alternating magnetic flux through it. For this reason, the iron loss is also called **core loss**. We generally use the symbol (Pi) to represent the iron loss. The iron loss consists of hysteresis loss (Ph) and eddy current loss (Pe). Thus, the iron loss is given by the sum of the hysteresis loss and eddy current loss, i.e.

Ironloss,Pi=Hysteresiesloss(Ph)+Eddycurrentloss(Pe)

The hysteresis loss and eddy current loss (or iron loss) are determined by performing the **open-circuit test** on the transformer.

The empirical formulae for the hysteresis loss and eddy current loss are given by,

$$P_h=k_h f B_{max}\cdots(1)$$

$$P_e=k_e f^2 t^2 B_{max}^2 \ldots..(2)$$

Where,

- The exponent of B_m, i.e. "*x*" is called the **Steinmetz's constant**. Depending on the properties of the core material, its value is ranging from 1.5 to 2.5.
- k_h is a proportionality constant whose value depends upon the volume and quality of the material of core.
- k_e is a proportionality constant which depend on the volume and resistivity of material of the core.
- ***f*** is the frequency of the alternating flux in the core.
- B_m is the maximum flux density in the core.
- ***t*** is the thickness of each core lamination.

Therefore, the total iron loss or core loss can also be written as,

$$P_i= k_h f B_{max}+ k_e f^2 t^2 B_{max}^2 \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Since the input voltage to the transformer is approximately equal to the induced voltage in the primary winding, i.e.

$$V_1=E_1=4.44 f \phi_m N_1$$

Where, *A* is the cross-sectional area of the transformer core, N_1 is the number of turns in the primary winding and *f* is the supply frequency.

$$\therefore B_m=V_1 4.44 f A N_1$$

Hence, from above equations, we get,

$P_h= k_h f(V_1 4.44 f A N_1)$

Thus, Equation shows that *the hysteresis loss depends upon both input voltage and supply frequency*.

Again, from above equations we get,

$Pe= k_e f^2 t^2 (V_1 4.44fAN_1)$

Hence, from equation we can conclude that *the eddy current loss in the transformer is proportional to the square of the input voltage and is independent of the supply frequency*.

Therefore, the total core loss can also be written as,

$Pi= k_h f(V_1 4.44fAN_1)+ k_e f^2 t^2 (V_1 4.44fAN_1)$

In practice, transformers are connected to an electric supply of constant frequency and constant voltage, thus, both ***f*** and B_m are constant. Therefore, the core or iron loss is practically remains constant at all loads.

We can reduce the hysteresis loss by using steel of high silicon content to construct the core of transformer while the eddy current loss can be minimized by using core of thin laminations instead of solid core. The **open-circuit test** is performed on a transformer to determine the iron or core loss.

Copper Loss or I^2R Loss

Power loss in a transformer that occurs in both the primary and secondary windings due to their Ohmic resistance is called **copper loss or I^2R loss.** We usually represent the copper loss by PC. Therefore, the total copper loss in a transformer is the sum of power loss in the primary winding and power loss in the secondary winding, i.e.,

Pc=Copper loss in primary+ Copper loss in secondary

From Equation ,it is clear that the *copper loss in a transformer varies as the square of the load current*. For this reason, the copper loss is also referred as "variable loss" because in practice a transformer is subjected to variable load and hence has variable load current.

We conduct the "short-circuit test" on the transformer to determine the value of its copper loss. In a practical transformer, the copper loss accounts for about 90% of the total power loss in the transformer.

Stray Loss

In practical transformer, a fraction of the total flux follows a path through air and this flux is called **leakage flux**. This leakage flux produces eddy currents in the conducting or metallic parts like tank of the transformer. These eddy currents cause power loss, which is known as **stray loss**.

Dielectric Loss

The power loss occurs in insulating materials like oil, solid insulation of the transformer, etc. is known as **dielectric loss**. The dielectric loss is significant only in transformers working on high voltages.

Although, in practice, the stray loss and dielectric loss are very small, constant and may be neglected.

From the above discussion, we found that a transformer has some losses which are constant and some other are variable. Thus, we may categorize losses in a transformer in two types namely **constant losses** and **variable losses**.

Therefore, the total losses in a transformer are the sum of constant losses and variable losses, i.e.,

Total losses in transformer = Constant losses + Variable losses

Transformer Efficiency: The ratio of the output power to the input power in a transformer is known as **efficiency of transformer**. The transformer efficiency is represented by Greek letter Eta (η).

Efficiency,η= Output Power/InputPower

From this definition, it appears that we can determined the efficiency of a transformer by directly loading the transformer and measuring the input power and output power. Although, this method of efficiency determination has the following disadvantages −

- In practice, the efficiency of a transformer is very high, and a very small error (let say 1%) in input and output wattmeters may give ridiculous results. Consequently, this method may give efficiency more than 100%.
- In this method, the transformer is loaded, hence a considerable amount of power is wasted. Therefore, this method becomes uneconomical for large transformers.
- It is very difficult to find a load which is capable of absorbing all of the output power.
- This method does not provide any information about losses in the transformer.

Thus, due to these limitations, the direct-loading method is rarely used to determine the efficiency of a transformer. In practice, we use open-circuit and short-circuit tests to find out the transformer efficiency.

For a practical transformer, the input power is given by,

$$\text{Input power} = \text{Output power} + \text{Losses}$$

Therefore, the transformer efficiency can also be calculated using the following expression −

$$\eta = \text{Output power}/(\text{Output power} + \text{Losses})$$

$$\Rightarrow \eta = \text{VA} \times \text{Power Factor}/(\text{VA} \times \text{Power Factor}) + \text{Losses}$$

Where, Output power=VA× Power factor

And, losses can be determined by transformer tests.

Efficiency from Transformer Tests

When we perform transformer tests, the following results are obtained −

- From open-circuit test −
  Full load iron loss=P_i

- From short-circuit test −
  Full load copper loss=P_c

Therefore, the total losses at full load in a transformer are

$$\text{Total FL losses} = P_i + P_c$$

Now, we are able to determine the full-load efficiency of the transformer at any power factor without actual loading the transformer.

$$n_{FL} = (VA)_{FL} \times \text{Powerfactor} / [(VA)_{FL} \times \text{Powerfactor}] + P_i + P_c$$

Also, the transformer efficiency at any load equal to *x × full load*. Where, x is the fraction of loading. In this case, the total losses corresponding to the given load are,

$$(\text{Total losses}) = P_i + x^2 P_c$$

It is because, the iron loss (Pi) is the constant loss and hence remains the same at all loads, while the copper loss is proportional to the square of the load current.

$$\therefore \eta_x = x \times (VA)FL \times \text{Power factor} / [x \times (VA)FL \times \text{Power factor}] + P_i + x^2 P_c$$

Condition for Maximum Efficiency

For a given transformer, we have,

$$\text{Outputpower} = V_2 I_2 \cos\phi_2$$

Let the transformer referred to secondary side, then R_{o2} is the total resistance of the transformer. The total copper loss is given by,

$$P_c = I_2^2 R_{o2}$$

Therefore, the transformer efficiency is given by,

$$\eta = V_2 \cos\phi_2 / (V_2 \cos\phi_2 + P_i + I^2 R_{o2})$$

In practice, the secondary voltage V_2 is approximately constant. Hence, for a load of given power factor, the transformer efficiency depends upon the load current (I_2). From the equation (1), we can see that the numerator is constant and for the efficiency to be maximum, the denominator ($_D$) should be minimum, i.e.

$$d(D)/dI_2 = 0$$

$$\Rightarrow d/dI_2[V2\cos\phi_2+(P_iI_2)+I_2R_{02}]=0$$

$$\Rightarrow 0-(P_iI_2)+R_{o2}=0$$

$$\Rightarrow P_i=I^2{}_2R_{o2}$$

$$\Rightarrow Ironloss=Copperloss$$

Therefore, *the transformer efficiency for a given power factor will be maximum when the constant iron loss is equal to the variable copper loss*.

The maximum efficiency at any load is given by,

$$\eta_{max}=x\times(VA)FL\times Powerfactor/[x\times(VA)FL\times Powerfctor]+2P_i$$

Also, the load current (I_2) corresponding to the maximum efficiency of transformer is,

$$I_2=\sqrt{\frac{Pi}{Ro2}}$$

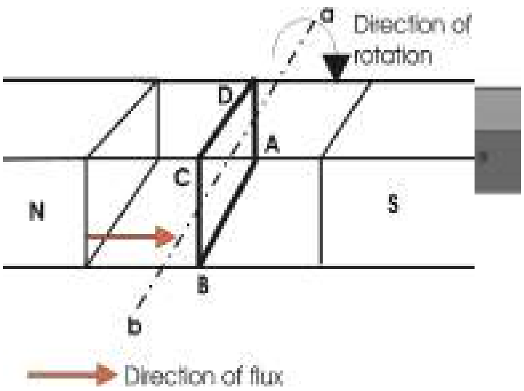
DC GENERATOR

Principle of DC Generator

There are two types of generators, one is ac generator and other is DC generator. Whatever may be the types of generators, it always converts mechanical power to electrical power. An AC generator produces alternating power. A DC generator produces direct power. Both of these generators produce electrical power, based on same fundamental principle of Faraday's law of electromagnetic induction. According to this law, when a conductor moves in a magnetic field it cuts magnetic lines of force, due to which an emf is induced in the conductor. The magnitude of this induced emf depends upon the rate of change of flux (magnetic line force) linkage with the conductor. This emf will cause a current to flow if the conductor circu

1. a magnetic field
2. conductors which move inside that magnetic field.

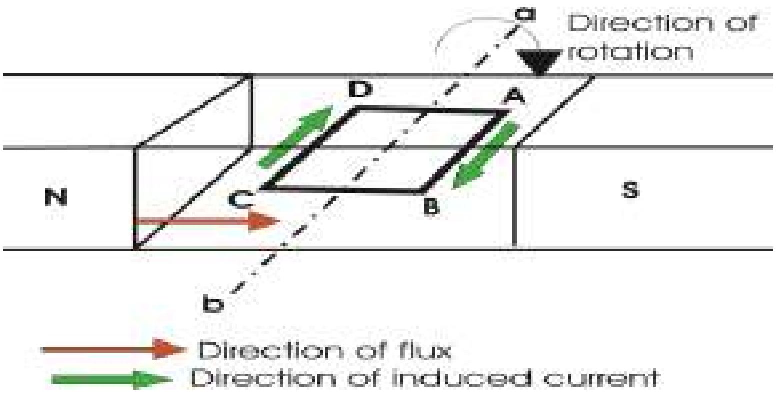
Now we will go through working principle of DC generator. As, the working principle of ac generator is not in scope of our discussion in this section.



Single Loop DC Generator

In the figure above, a single loop of conductor of rectangular shape is placed between two opposite poles of magnet.

Let's us consider, the rectangular loop of conductor is ABCD which rotates inside the magnetic field about its own axis ab. When the loop rotates from its vertical position to its horizontal position, it cuts the flux lines of the field. As during this movement two sides, i.e. AB and CD of the loop cut the flux lines there will be an emf induced in these both of the sides (AB

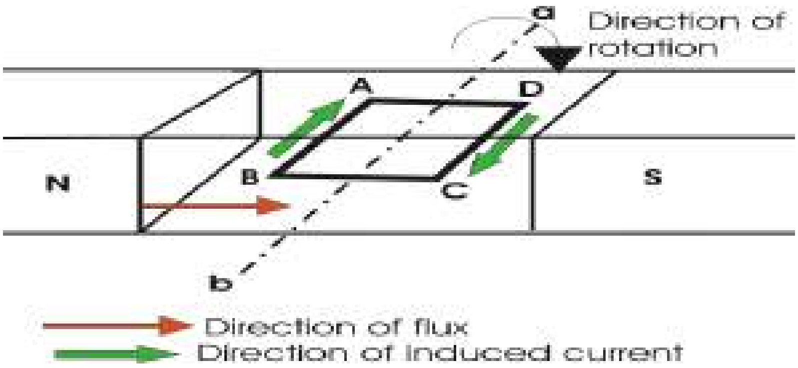


and BC) of the loop.

As the loop is closed there will be a current circulating through the loop. The direction of the current can bedetermined by Fleming's right hand Rule. This rule says that if you stretch thumb, index finger and middle finger of your right hand perpendicular to each other, then thumbs indicates the direction of motion of the conductor, index finger indicates the direction of magnetic field i.e. N - pole to S - pole, and middle finger indicates the direction of flow of current through the conductor. Now if we apply this right-hand rule, we will see at this horizontal position of the loop, current will flow from point A to B and on the other side of the loop current will flow from point C to D.

Now if we allow the loop to move further, it will come again to its vertical position, but now upper side of the loop will be CD and lower side will be AB (just opposite of the previous vertical position). At this position the tangential motion of the sides of the loop is parallel to the flux lines of the field. Hence there will be no question of flux cutting and consequently there will be no current in the loop. If the loop rotates further, it comes to again in horizontal position. But now, said AB side of the loop comesin front of N pole and CD comes in front of S pole, i.e. just opposite to the previous horizontal position as shown in the figure beside.

Here the tangential motion of the side of the loop is perpendicular to the flux lines, hence rate of flux cuttingis maximum here and according to Fleming's right hand rule, at this position current flows from B to A and on other side from D to C.Now if

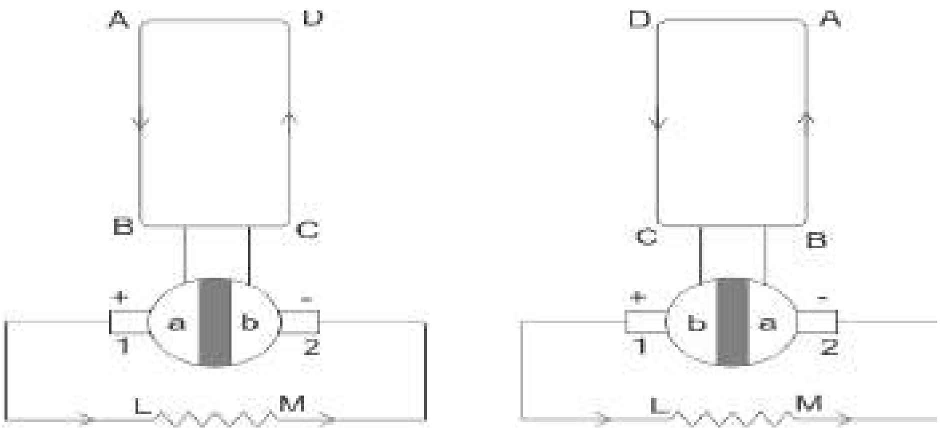


the loop is continued to rotate about its axis, every time the side AB comesin front of S pole, the current flows from A to B and when it comes in front of N pole, the current flows from B to A. Similarly, every time the side CD comes in front of S pole the current flows from C to D and when it comes in front of N pole the current flows from D to C.

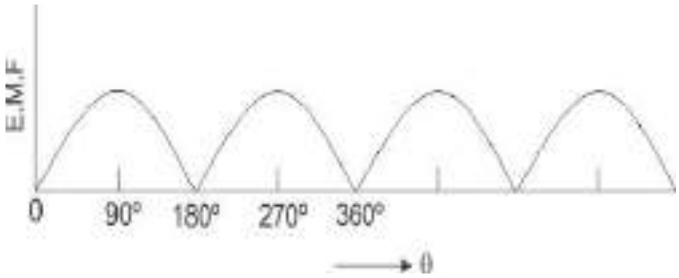
If we observe this phenomena in different way, it can be concluded, that each side of the loop comes in frontof N pole, the current will flow through that side in same direction i.e. downward to the reference plane and similarly each side of the loop comes in front of S pole, current through it flows in same direction i.e. upwards from reference plane. From this, we will come to the topic of principle of DC generator.

Now the loop is opened and connected it with a split ring as shown in the figure below. Split ring are made out of a conducting cylinder which cuts into two halves or segments insulated from each other. The external load terminals are connected with two carbon brushes which are rest on these split slip ring segments.

Working Principle of DC Generator



It is seen that in the first half of the revolution current flows always along ABLMCD i.e. brush no 1 in contact with segment a. In the next half revolution, in the figure the direction of the induced current in the coil is reversed. But at the same time the position of the segments a and b are also reversed which results that brush no 1 comes in touch with the segment b. Hence, the current in the load resistance again flows from L to M. The wave from of the current through the load circuit is as shown in the figure. This current is unidirectional.



This is basic working principle of DC generator, explained by single loop generator model. The position of the brushes of DC generator is so arranged that the change over of the segments a and b from one brush to other takes place when the plane of rotating coil is at right angle to the plane of the lines of force. It is so become in that position, the induced emf in the coil is zero.

Construction of DC Generator

During explaining working principle of DC Generator, we have used a single loop DC generator. But now we will discuss about practical construction of DC Generator.A DC generator has the following parts

1. Yoke
2. Pole of generator
3. Field winding
4. Armature of DC generator
5. Brushes of generator and Commentator
6. Bearing

Yoke of DC Generator

Yoke or the outer frame of DC generator serves two purposes,

1. It holds the magnetic pole cores of the generator and acts as cover of the generator.
2. It carries the magnetic field flux.

In small generator, yoke are made of cast iron. Cast iron is cheaper in cost but heavier than steel. But forlarge construction of DC generator, where weight of the machine is concerned, lighter cast steel or rolled steel is preferable for constructing yoke of DC generator. Normally larger yokes are formed by rounding a rectangular steel slab and the edges are welded together at the bottom. Then feet, terminal box and hangers are welded to the outer periphery of the yoke frame.

Pole Cores and Pole Shoes

Let's first discuss about pole core of DC generator. There are mainly two types of construction available.One: Solid pole core, where it is made of a solid single piece of cast iron or cast steel. Two: Laminated pole core, where it made of numbers of thin, limitations of annealed steel which are riveted together. The thickness of the lamination is in the range of 0.04" to 0.01". The pole core is fixed to the inner periphery of the yoke by means of bolts through the yoke and into the pole body. Since the poles project inwards they are called salient poles. The pole shoes are so typically shaped, that, they spread out the magnetic flux in the air gap and reduce the reluctance of the magnetic path. Due to their larger cross-sectionthey hold the pole coil at its position.

Pole Coils: The field coils or pole coils are wound around the pole core. These are a simple coil of insulated copper wire or strip, which placed on the pole which placed between yoke and pole shoes as shown.

Armature Core

The purpose of armature core is to hold the armature winding and provide low reluctance path for the flux through the armature from N pole to S pole. Although a DC generator provides direct current but induced current in the armature is alternating in nature. That is why, cylindrical or drum shaped armature core is build up of circular laminated sheet. In every circular lamination, slots are either die - cut orpunched on the outer periphery and the key way is located on the inner periphery as shown. Air ducts are also punched of cut on each lamination for circulation of air through the core for providing better cooling. Up to diameter of 40", the circular stampings are cut out in one piece of lamination sheet. But above 40", diameter, number of suitable sections of a circle is cut. A complete circle of lamination is formed by four or six or even eight such segment.

Armature Winding

Armature winding are generally formed wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots, which are lined with tough insulating material. This slot insulation is folded over above the armature conductors placed in it and secured in place by special hard wooden or fiber wedges. Two types of armature windings are used – Lap winding and Wave winding.

Commutator

The commentator plays a vital role in DC generator. It collects current from armature and sends it t o the load as direct current. It actually takes alternating current from armature and converts it to direct current and then send it to external load. It is cylindrical structured and is build up of wedge-shaped segments of high conductivity, hard drawn or drop forged copper. Each segment is insulated from the shaft by means of insulated commutator segment shown below. Each commentator segment is connected with corresponding armature conductor through segment riser or lug.

Brushes:

The brushes are made of carbon. These are rectangular block shaped. The only function of these carbon brushes of DC generator is to collect current from commutator segments. The brushes are housed in the rectangular box shaped brush holder or brush box. As shown in figure, the brush face is placedon the commutator segment which is attached to the brush holder.

Bearing

For small machine, ball bearing is used and for heavy duty DC generator, roller bearing is used. The bearing must always be lubricated properly for smooth operation and long life of generator.

Armature winding

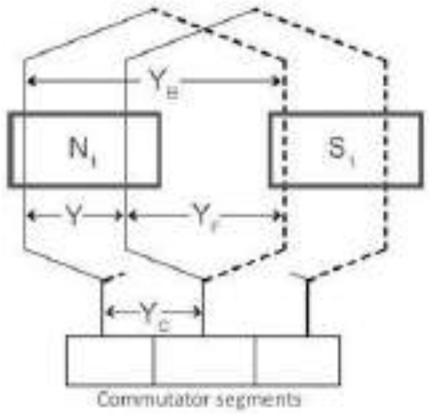
Basically armature winding of a DC machine is wound by one of the two methods, lap winding or wave winding.

Armature winding can be done as single layer or double layer. It may be simplex, duplex or multiplex, and this multiplicity increases the number of parallel paths.

Lap Winding and Wave Winding

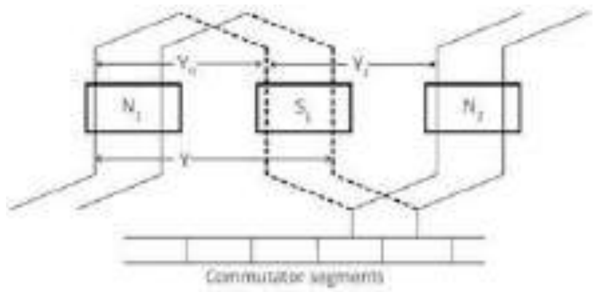
In lap winding, the successive coils overlap each other. In a simplex lap winding, the two ends of a coil are connected to adjacent commutator segments. The winding may be progressive or retrogressive. A progressive winding progresses in the direction in which the coil is wound. The opposite way is retrogressive. The following image shows progressive simplex lap winding.

Now,



Lap Winding

In wave winding, a conductor under one pole is connected at the back to a conductor which occupies an almost corresponding position under the next pole which is of opposite polarity. In other words, all the coils which carry e.m.f in the same direction are connected in series. The following diagram shows a part of simplex wave winding.



Wave winding

EMF Equation of a DC Generator

Consider a DC generator with the following parameters,

P = number of field poles

Ø = flux produced per pole in Wb (weber)

Z = total no. of armature conductors

A = no. of parallel paths in armature

N = rotational speed of armature in revolutions per min. (rpm)

Now,

- Average emf generated per conductor is given by dΦ/dt (Volts) ... eq. 1
- Flux cut by one conductor in one revolution = dΦ = PΦ ….(Weber),
- Number of revolutions per second (speed in RPS) = N/60

- Therefore, time for one revolution = dt = 60/N (Seconds)
- From eq. 1, emf generated per conductor = dΦ/dt = PΦN/60 (Volts) …..(eq. 2)

Above equation-2 gives the emf generated in one conductor of the generator. The conductors are connected in series per parallel path, and the emf across the generator terminals is equal to the generated emf across any parallel path.

Therefore, Eg = PΦNZ / 60A

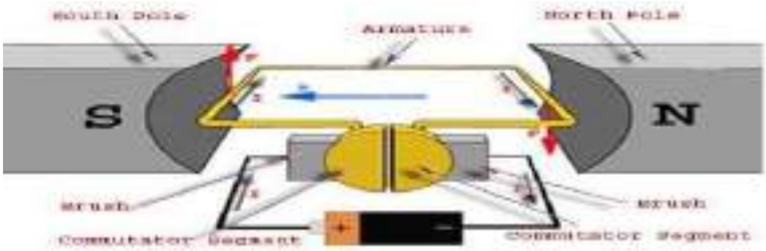
For simplex lap winding, number of parallel paths is equal to the number of poles (i.e. A=P), Therefore, for simplex lap wound dc generator, Eg = PΦNZ / 60P

For simplex wave winding, number of parallel paths is equal to 2 (i.e P=2), Therefore, for simplex wave wound dc generator, Eg = PΦNZ / 120

DC MOTOR

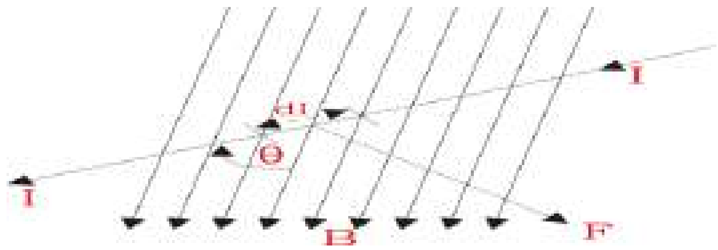
Working or Operating Principle of DC Motor

A DC motor in simple words is a device that converts electrical energy (direct current system) into mechanical energy. It is of vital importance for the industry today, and is equally important forengineers to look into the working principle of DC motor in details that has been discussed in this article. Inorder to understand the operating principle of DC motor we need to first look into its constructional feature. The very basic construction of a DC motor contains a current carrying armature which is connected to the supply end through commutator segments and brushes. The armature is placed in between north south poles of a permanent or an electromagnet as shown in the diagram above.



As soon as we supply direct current in the armature, a mechanical force acts on it due to electromagnetic effect of the magnet. Now to go into the details of the operating principle of DC motor its important that we have a clear understanding of Fleming's left hand rule to determine the direction of force acting on the armature conductors of DC motor.

If a current carrying conductor is placed in a magnetic field perpendicularly, then the conductor experiences a force in the direction mutually perpendicular to both the direction of field and the current carrying conductor. Fleming's left hand rule says that if we extend the index finger, middle finger and thumb of our left hand perpendicular to each other, in such a way that the middle finger is along the direction of current in the conductor, and index finger is along the direction of magnetic field i.e. north to south pole, then thumb indicates the direction of created mechanical force. For clear understanding the principle of DC motor we have to determine the magnitude of the force, by considering the diagram below.



We know that when an infinitely small charge dq is made to flow at a velocity 'v' under the influence of anelectric field E, and a magnetic field B, then the Lorentz Force dF experienced by the charge is given by:-

$$dF = dq(E + vB)$$

For the **operation of DC motor**, considering E = 0

$$dF = dq \times v \times B$$

i.e. it's the cross product of dq v and magnetic field B.

$$dF = dq\frac{dL}{dt} \times B \qquad \left[V = \frac{dL}{dt}\right]$$

Where, dL is the length of the conductor carrying charge q.

$$dF = dq\frac{dL}{dt} \times B$$

$$or,\ dF = IdL \times B \qquad \left[Since,\ current\ I = \frac{dq}{dt}\right]$$

$$or,\ F = IL \times B = ILB\sin\theta$$

$$or,\ F = BIL\sin\theta$$

From the 1st diagram we can see that the construction of a DC motor is such that the direction of current through the armature conductor at all instance is perpendicular to the field. Hence the force acts on the armature conductor in the direction perpendicular to the both uniform field and current is constant.

$$i.e.\ \theta = 90^\circ$$

So if we take the current in the left hand side of the armature conductor to be I, and current at right hand side of the armature conductor to be -I, because they are flowing in the opposite direction with respect to each other.

Then the force on the left hand side armature conductor,

$$F_i = BIL\sin 90^\circ = BIL$$

Similarly force on the right hand side conductor

$$F_r = B(-I)L\sin 90^\circ = -BIL$$

Therefore, we can see that at that position the force on either side is equal in magnitude but opposite in direction. And since the two conductors are separated by some distance w = width of the armature turn, the two opposite forces produces a rotational force or a torque that results in the rotation of the armature conductor.

Now let's examine the expression of torque when the armature turn crate an angle of α (alpha) with its initialposition.

The torque produced is given by,

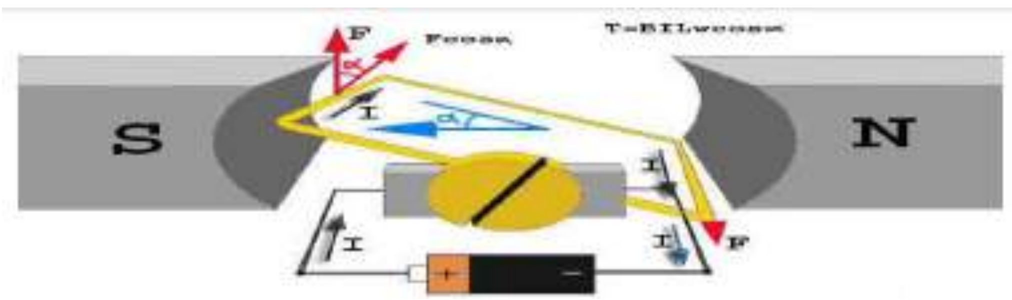
$$Torque = (force,\ tangential\ to\ the\ direction\ of\ armature\ rotation) \times (distance)$$

$$or,\ \tau = F\cos\alpha \times w$$

$$or,\ \tau = BILw\cos\alpha$$

Where, α (alpha) is the angle between the plane of the armature turn and the plane of reference or the initial position of the armature which is here along the direction of magnetic field.

The presence of the term cosα in the torque equation very well signifies that unlike force the torque at all position is not the same. It in fact varies with the variation of the angle α (alpha). To explain the variation oftorque and the principle behind rotation of the motor let us do a step wise analysis.



Step 1:

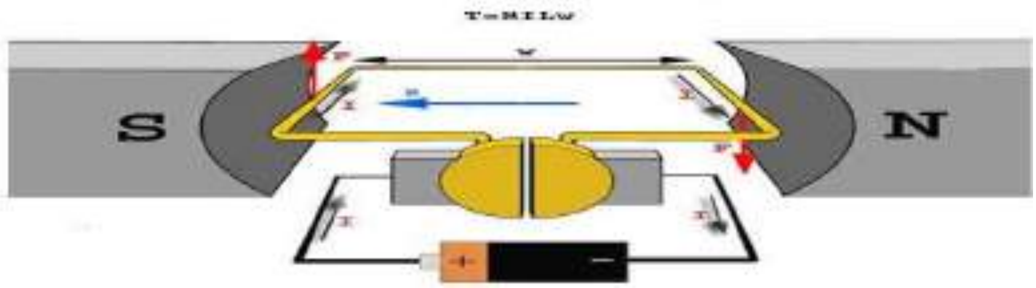
Initially considering the armature is in its starting point or reference position where the angle α = 0.

$$\therefore\ \tau = BILw \times \cos 0^\circ = BILw$$

Since, α = 0, the term cos α = 1, or the maximum value, hence torque at this position is maximum given by τ = BILw. This high starting torque helps in overcoming the initial inertia of rest of the armature and sets it into rotation.

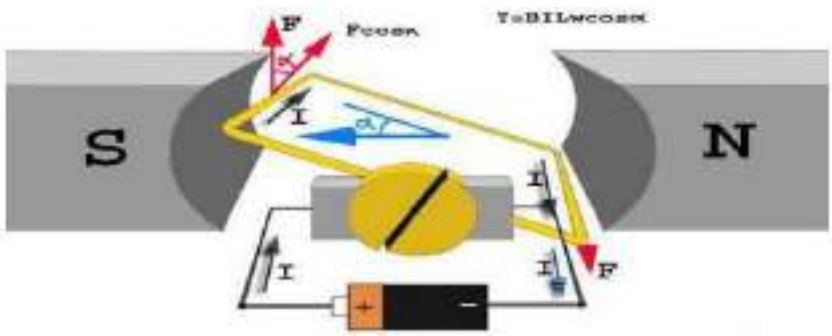
Step 2:

Once the armature is set in motion, the angle α between the actual position of the armature and its reference initial position goes on increasing in the path of its rotation until it becomes 90° from its initial position. Consequently the term cosα decreases and also the



value of torque.

The torque in this case is given by τ = BILwcosα which is less than BIL w when α is greater than 0°.



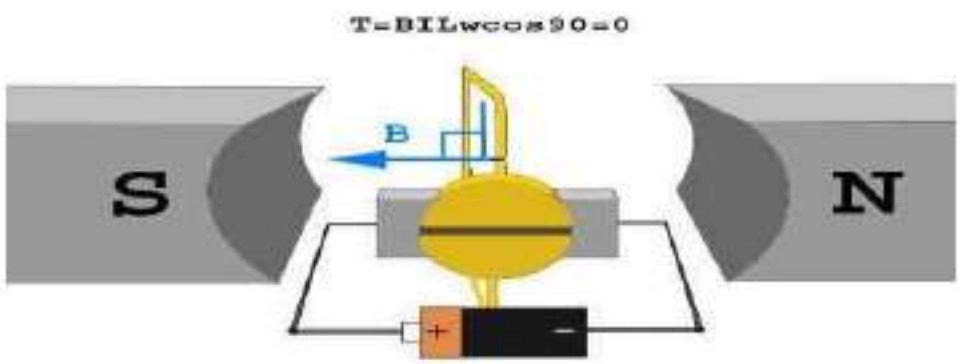
Step 3:

In the path of the rotation of the armature a point is reached where the actual position of the rotor is exactlyperpendicular to its initial position, i.e. α = 90°, and as a result the term cosα = 0.

The torque acting on the conductor at this position is given by,

i.e. virtually no rotating torque acts on the armature at this instance. But still the armature

$$\therefore \tau = BIL\omega \times \cos 90^\circ = 0$$



does not come to astandstill, this is because of the fact that the operation of DC motor has been engineered in such a way that the inertia of motion at this point is just enough to overcome this point of null torque. Once the rotor crosses over this position the angle between the actual position of the armature and the initial plane again decreases and torque starts acting on it again.

Torque Equation of DC Motor

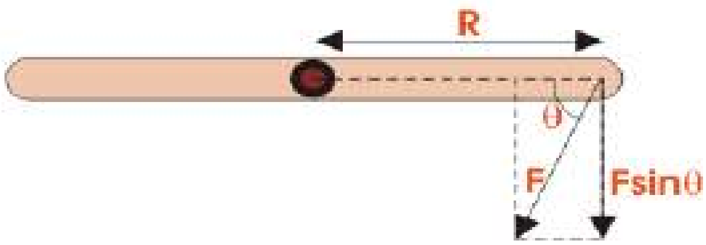
When a DC machine is loaded either as a motor or as a generator, the rotor conductors carry current. These conductors lie in the magnetic field of the air gap. Thus each conductor experiences a force. The conductors lie near the surface of the rotor at a common radius from its center. Hence torque is produced at the circumference of the rotor and rotor starts rotating. The term torque as best explained by Dr. Huge d Young is the quantitative measure of the tendency of a force to cause a rotational motion, or to bring about a change in rotational motion. It is in fact the moment of a force that produces or changes a rotational motion.

The equation of torque is given by,

The DC motor as we all know is a rotational machine, and torque of DC motor is a very

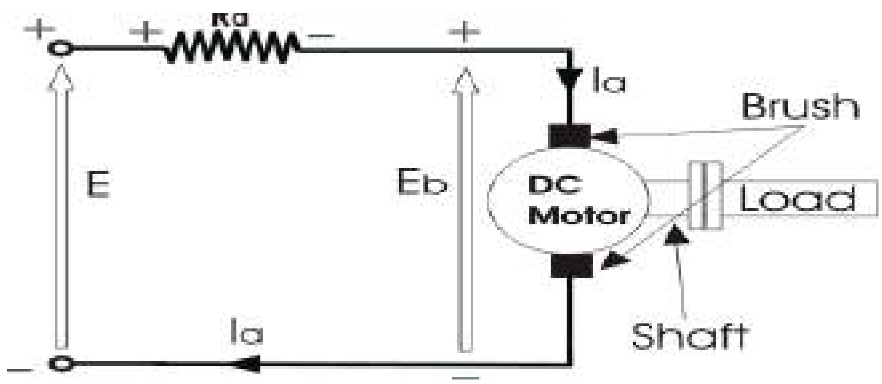
$$\tau = FR\sin\theta\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where, F is force in linear direction,
R is radius of the object being rotated,
and θ is the angle, the force F is making with R vector



important parameter in this concern, and it's of utmost importance to understand the torque equation of DC motor for establishing its running characteristics.

To establish the torque equation, let us first consider the basic circuit diagram of a DC motor, and its voltage equation.



Referring to the diagram beside, we can see, that if E is the supply voltage, E_b is the back emf produced and I_a, R_a are the armature current and armature resistance respectively then the voltage equation is given by,

$$E = E_b + I_a R_a \text{ .... } (2)$$

But keeping in mind that our purpose is to derive the torque equation of DC motor we multiply both sides of equation (2) by I_a.

$$Therefore,\ EI_a = E_b I_a + I_a^2 R_a \text{ .... } (3)$$

Now $I_a^2.R_a$ is the power loss due to heating of the armature coil, and the true effective mechanical power that is required to produce the desired torque of DC machine is given by,

The mechanical power P_m is related to the electromagnetic torque T_g as,

$$P_m = E_b I_a \text{ .... } (4)$$

$$P_m = T_g \omega \text{ .... } (5)$$

Where ω is speed in rad/sec.

Now equating equation (4) and (5) we get,

$$E_b I_a = T_g \omega$$

Now for simplifying the torque equation of DC motor we substitute.

$$E_b = \frac{P\varphi ZN}{60A} \text{ .... } (6)$$

Where, P is no of poles, φ is flux per pole,

Z is no. of conductors,

A is no. of parallel paths,

and N is the speed of the DC motor.

$$Hence,\ w = \frac{2\pi N}{60} \text{ .... } (7)$$

Substituting equation (6) and (7) in equation (4), we get:

$$T_g = \frac{P.Z.\varphi.I_a}{2\pi A}$$

The torque we so obtain, is known as the electromagnetic torque of DC motor, and subtracting the mechanical and rotational losses from it we get the mechanical torque. Therefore,

$$T_m = T_g - mechanical\ losses$$

\This is the torque equation of DC motor. It can be further simplified as:

$$T_g = k_a \phi I_A$$

$$Where,\ k_a = \frac{P.Z}{2\pi A}$$

Which is constant for a particular machine and therefore the torque of DC motor varies with only flux φ andarmature current Ia.ich is constant for a particular machine and therefore the torque of DC motor varies with only flux φ andarmature current Ia.

SPEED CONTROL METHODS OF DC MOTOR:

The speed of a DC shunt is given by,

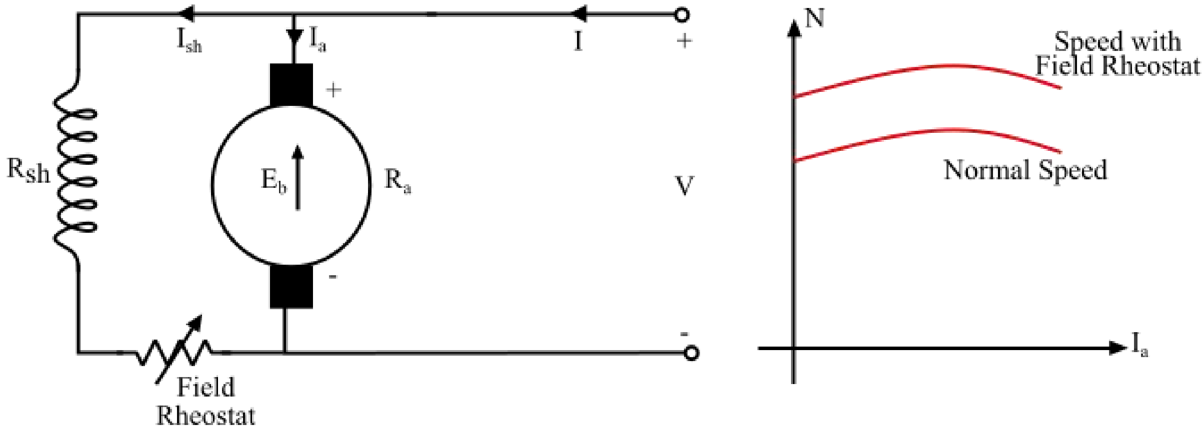
$$N \propto Eb/\varphi$$

$$\Rightarrow N = K(V - IaRa)/\varphi \ldots(1)$$

It is clear from the equation (1) that the speed of a DC shunt motor can be changed by two methods −**Flux Control Method**

Flux Control Method

The *flux control method* is based on the principle that by varying the field flux ϕ, the speed of DC shunt motor can be changed.



$$N \propto 1/\o$$

In this method, a variable resistance (called *field rheostat*) is connected in series with the shunt field winding. By increasing the resistance of the field rheostat, the shunt field current Ish can be reduced and hence the field flux. Thus, by the flux control method, the speed of a DC shunt can only be increased above the normal speed.

The flux control method is frequently used for the speed control of DC shunt motors because it is simple and inexpensive method.

Advantages:

The flux control method for the speed control of DC shunt motor has following advantages −

It is a simple and convenient method.

It is an inexpensive method as the small power loss in the field rheostat due to the small value of I_{sh}.

The speed control using flux control method is independent of the load on the machine.

Disadvantages:

Following are the disadvantages of the flux control method −

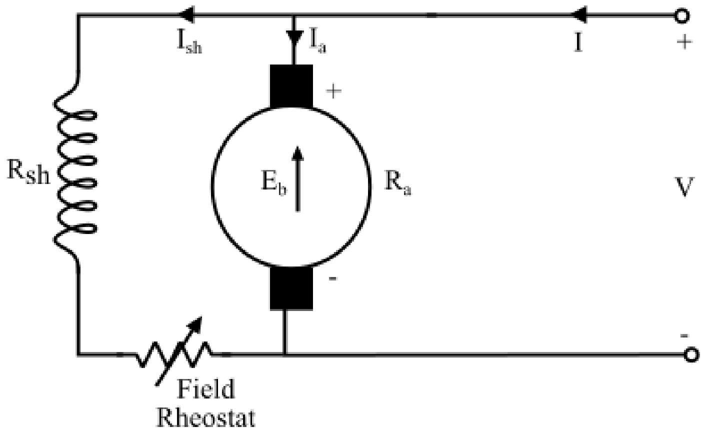
By this method, only speeds higher than the normal speed can be obtained because the total resistance of the field circuit cannot be decreased below shunt field winding resistance (R_{sh}).

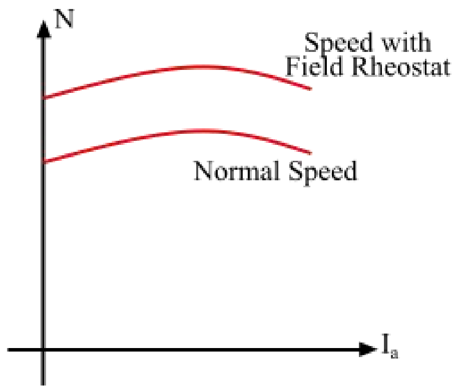
In flux control method, there is a limit to the maximum speed obtainable, because if the field flux is too much weakened, the commutation becomes poorer.

Armature Resistance Control Method:

The *armature resistance control method* is based on the principle that by varying the voltage available across the armature, the back EMF of the motor can be changed, which in turn changes the speed of the shunt motor.

In this method, a variable resistance RC (called *controller resistance*) is inserted in series with the armature.





The speed of DC shunt motor is given by,

$$N \propto E_b$$

Also,

$$E_b = V - Ia(R_a + R_C)$$

Thus, due to the voltage drop in the controller resistance, the back EMF is decreased and hence the speed of the motor. The maximum speed that can be obtained using armature resistance control method is the speed corresponding to $R_C = 0$, i.e., the normal speed. Therefore, by this method only speed below the normal speed can be obtained.

Disadvantages:

The armature resistance control method has following disadvantages −

A large amount of power being wasted in the controller resistance since it carries full armature current.

The output and efficiency of the motor being decreased.

This method of speed control results in the poor speed regulation.

The speed changes with the variation in the load because the speed depends upon the voltage drop across the controller resistance and hence on the armature current demanded by the load.

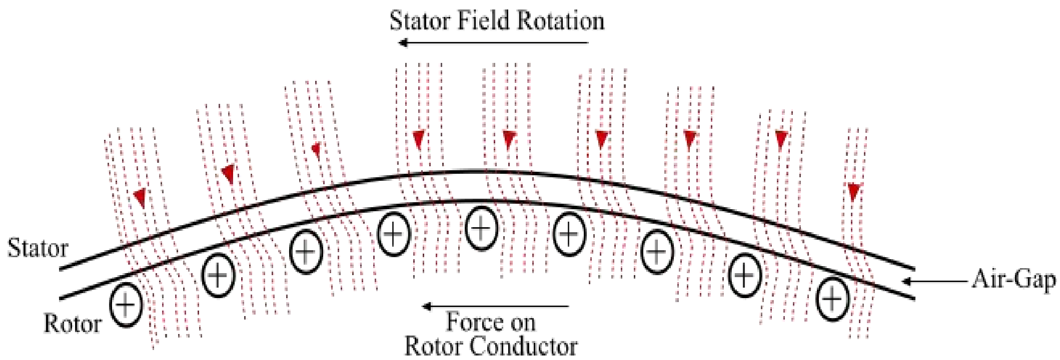
THREE PHASE INDUCTION MOTOR

A ***3-phase induction motor*** is an **electromechanical energy conversion** device which converts 3-phase input electrical power into output mechanical power.

A 3-phase induction motor consists of a stator and a rotor. The stator carries a *3-phase stator winding* while the rotor carries a short-circuited winding called *rotor winding*. The stator winding is supplied from a 3-phase supply. The rotor winding drives its voltage and power from the stator winding through *electromagnetic induction* and hence the name.

Working Principle of a 3-Phase Induction Motor

The working principle of a 3-phase induction motor can be explained by considering a portion of it as follows−



When the 3-phase stator winding is fed from a balanced 3-phase supply, a rotating magnetic field (RMF) is produced in the motor. This RMF rotates around the stator at *synchronous speed* which is given by,

SynchronousSpeed,NS=120fPSynchronousSpeed,$NS=120fP$

The RMF passes through the air gap and cuts the rotor conductors, which as yet are stationary. Due to the relative motion between the RMF and the stationary rotor conductors, EMFs are induced in the rotor conductors. As the rotor circuit is closed with short-circuit so currents start flowing in the rotor conductors.

Since the current carrying rotor conductors are placed in the magnetic field produced by the stator winding. As a result, the rotor conductors experience mechanical force. The sum of the mechanical forces on all the rotor conductors produce a torque which moves the rotor in the same direction as the rotating magnetic field. Hence, in such a way the three phase input electric power is converted into output mechanical power in a 3-phase induction motor.

Also, *according to Lenz's law*, the rotor should move in the direction of the stator field, i.e., the direction of rotor currents would be such that they tend to oppose the cause producing them. Here, the cause producing the rotor currents is the relative speed between the RMF and the rotor conductors. Thus to reduce this relative speed, the rotor starts running in the same direction as that of the RMF.

Advantages of Three Phase Induction Motor

Following are the chief advantages of a 3-phase induction motor −

It has simple and rugged construction.

It requires less maintenance.

It has high efficiency and good power factor.

It is less expensive.

It has self-starting torque.

Disadvantages of Three Phase Induction Motor

The disadvantages of a 3-phase induction motor are given as follows −

The 3-phase induction motors are constant speed motors; hence their speed control is very difficult.

3-phase induction motors have poor starting torque and high inrush currents (about 4 to 8 times of the rated current).

They always operate under lagging power factor and during light loads, they operate at very worst power factor (about 0.3 to 0.5 lagging).

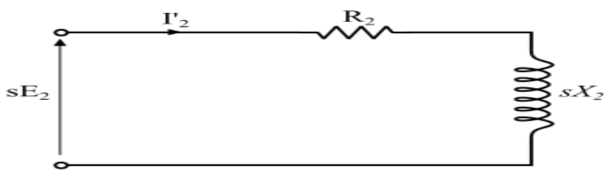
Torque of 3-Phase Induction Motor under Running Condition

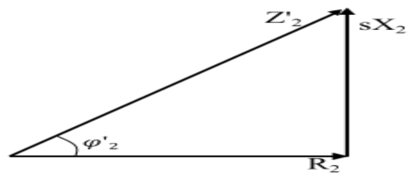
Let the rotor circuit of 3-phase induction motor at standstill has per phase resistance R_2, per phase reactance X_2 and per phase induced EMF E_2. If 's' is the slip under running condition of the motor, then,

Rotor reactance/phase, $X'_2 = sX_2$

Rotor EMF/phase, $E'_2 = sE_2$

Rotorimpedance/phase, $Z'_2 = \sqrt{R_2^2 + (sX_2)^2}$





$$Cos\ \phi_2 = \frac{R_2}{\sqrt{R_2^2 + (s\,X_2)^2}}$$

$$T \propto E_2 = \frac{sE_2}{\sqrt{R_2^2 + (s\,X_2)^2}} \times \frac{R_2}{\sqrt{R_2^2 + (s\,X_2)^2}}$$

$$T = K\,\frac{s\,E_2^2\,R_2}{R_2^2 + (s\,X_2)^2}$$

UNIT-IV

P-N JUNCTION DIODE AND ZENER DIODE

Introduction:

Semiconductor is a chemical Element in which the conductivity lies between conductor and insulator, Hence the movement of electrons (Current Conduction) can be controlled easily by means of an external voltage (Biasing).

Two types of Semiconductors

1. Intrinsic Semiconductor (Pure Semiconductor) and
2. Extrinsic Semiconductor (Impure semiconductor/Added impurity)

Extrinsic semiconductor is further classified into two types

a. P-Type Extrinsic Semiconductor (Doping Trivalent element) and
b. N-Type Extrinsic Semiconductor (Doping Pentavalent element).

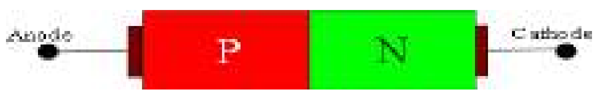
The holes are majority charge carriers and electrons are minority charge carriers in P-Type and electrons are majority and holes are minority charge carriers in case of N-Type Semiconductor.

P-N Junction(Semiconductor Diode/ Diode):

Construction: +

Starting with a piece of intrinsic semiconductor and divide it into two halves, one half is doped with any tri-valent element such as Boron, Aluminum etc., to form P-Type semiconductor, in which the holes are majority charge carriers and electrons are minority charge carriers. Other half is doped with any penta-valent element such as phosphorus, arsenic etc., to form N-Type Semiconductor, in which the electrons are majority charge carriers and holes are minority charge carriers.

The Junction or a line dividing the P-Type and N-Type is called P-N Junction. Metallic contact is connected to P-Type and N-Type material to get terminals for the device called Electrodes such as Anode and Cathode, this device is called P-N Junction Diode or Semiconductor diode or simply Diode as shown in figure(1).



Figure(1): P-N Junction Diode/Diode

Working:

The working principle can be studied in three different operations or Biasing arrangements as follows.

Case (1): Zero Biasing.

Without any external supply and at normal room temperature, at the time of contact with P-Type and N-Type material, it has aoccupies holes from the P side. Similarly holes in the P side attract electrons in the N side. This results forming a thin layer near the P-N Junction due to loosing electrons near the junction from the N side and holes near the junction from the P side. This layer or region is called depletion layer and it acts as an intrinsic semiconductor as shown in figure (2).

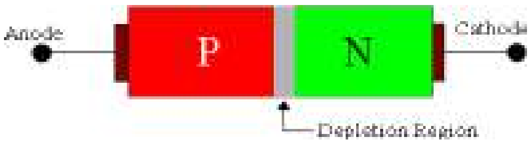


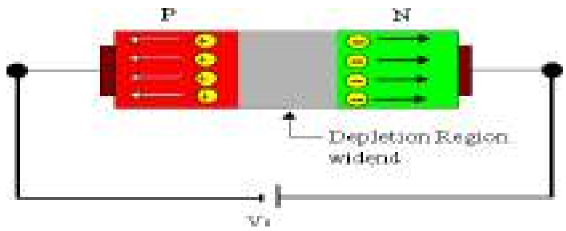
Figure (2): P-N Junction Diode/Diode with depletion layer/region.

Case (2): Reverse Biasing:

External supply with Positive terminal of the battery is connected to the cathode and negative terminal of the battery is connected to the anode is called Reverse biasing.

With this biasing the negative terminal of the battery sucks out or attracts the holes from P-Type material and positive terminal of the battery sucks out or attract electrons from N-Type material, this results wider depletion region and the resistance is very high, and the current that flows through the device only due to minority charge carriers as shown in figure (3).

The magnitude of current under reverse biasing is in terms of nano amperes for silicon diodes.

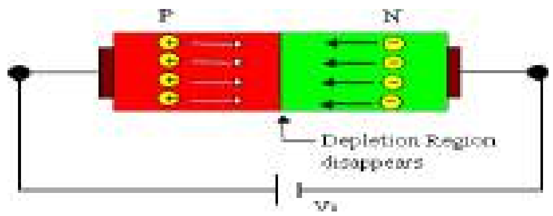


P-N Junction Diode is under Reverse Biasing.

Case (3): Forward Biasing.

External Supply with Positive terminal of the battery is connected to the anode and negative terminal of the battery is connected to the cathode is called forward biasing.

With this biasing the negative terminal of the battery pushes or pumps more electrons to the N-Type material and positive terminal of the battery pushes or pumps more holes to the P-Type material. By go on increasing the biasing voltage the width of the depletion region decreases, Resistance decreases and the current flowing through the device is increases(not proportional to voltage). If the Biasing voltage VS is greater than or equal to $V\gamma$ (Thresold Voltage) the depletion layer completely vanishes and easily current will flow as shown in figure (4).The cut in voltage or threshold voltage (Vγ) for silicon diodes is 0.7 V and for Germanium diodes is 0.3V.



P-N Junction Diode is under Forward Biasing

V-I Characteristics:

V-I Characteristics of P-N Junction Diode.

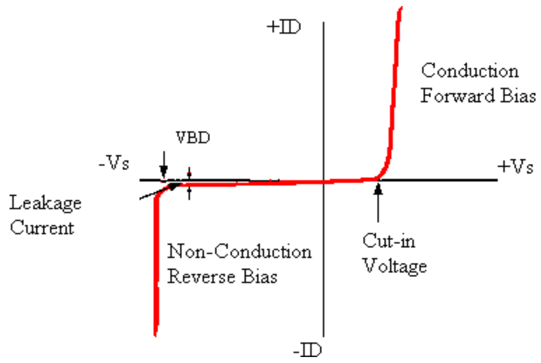


Figure shows the V-I Characteristics of P-N Junction diode, VS is the biasing voltage, ID is the Diode Current and VBD is the Break down voltage. The leakage current flows through the device under reverse biasing due to minority charge carriers. Under forward biasing and biasing voltage is greater than or equal to the threshold voltage, the device then acts as a conducting material.

Diode Characteristic Parameters:

1. Reverse Resistance (Rr):

The ratio of Reverse biasing voltage to the reverse current is called Reverse resistance of the PN Junction Diode.

i.e.,$=VRIo$; where, VR is the Biasing voltage under reverse biasing, called as reverse voltage and Io is the reverse leakage current.

2. Forward Resistance (Rf):

The ratio of Forward biasing voltage to the Forward current is called Forward resistance of the PN Junction Diode.

i.e.,$=VFIF$; where, VF is the Biasing voltage under Forward biasing, called as Forward voltage and ID is the Forward Current.

Diode Current Equation:

The diode current equation is given by,

ID=($eVF\eta VT$ -1)

Where,

ID is the diode current,

IO is the reverse saturation or leakage current,

VF is the applied forward voltage,

η is a constant 1 for Ge and 2 for Si and

VT is the volt equivalent temperature (Thermal Voltage) is given by, $\boldsymbol{VT=kTq}$;

Where,

k is the boltzmann's constant,

T is the temperature in Kelvin and

q is the charge of an electron. $\boldsymbol{k=1.38064852 \times 10-23\ J/K\ q=1.6x10-19 Coloumbs}$

At room Temperature, i.e., at 300oK, $\boldsymbol{VT=25.85mV\approx 26mV}$

Or $\boldsymbol{VT=\mathrm{T}11600}$

Equivalent Circuit of diode:

1. DC Equivalent Circuit.

The DC equivalent circuit of a diode under reverse biasing is an open circuit or Reverse Resistance Rr(typically in terms of MΩ) shown in figure (6a), and under forward biasing as shown in figure (6). Where Rf is the forward resistance of the diode, VON is the voltage drop across the diode under Conduction State (VON=0.7V for Silicon diodes and VON=0.3V for Germanium Diodes).

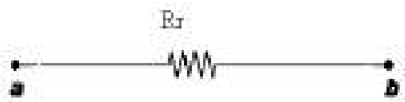


Figure (6a): Diode DC Equivalent Circuit under reverse biasing.

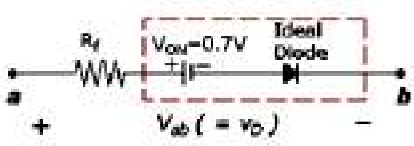


Figure (6b): Diode DC Equivalent Circuit under forward biasing.

2. AC Equivalent Circuit.

The AC equivalent circuit of a diode under reverse biasing and for forward biasing is the parallel connection of a Resistor and a Capacitor as shown in figure (7a) and figure (7b) respectively.

Under reverse biasing the depletion layer width increases and acts as a parallel plate capacitor with dielectric, hence the diode will be considered as a capacitor called Transition Capacitance/ Junction Capacitance/ Space charge Capacitance.

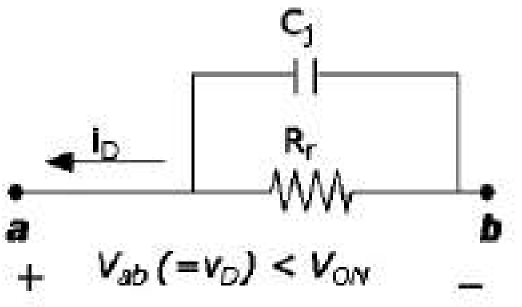


Figure (7a): AC Equivalent circuit under Reverse Biasing.

Effect of Temperature on Diodes:

The number of charge carriers will vary depending on the temperature. i.e., if temperature increases the number of charge carriers also increases and due to this the conduction current (ID) also increases. The relation between current, voltage and temperature is as follows.

 The reverse saturation current doubles for every 10°C rise in Temperature.

i.e., $\boldsymbol{IO}$'=$\boldsymbol{IO\ x}$ ($-\boldsymbol{t110}$) ;

where,

IO' is the reverse saturation current at temperature t2 and

IO is the reverse saturation current at temperature t1.

 The forward voltage drop across the diode reduces 2.56mV for every 1°C rise in temperature.

i.e., $\boldsymbol{VF'}$=VF$-\mathbf{2}$.($\boldsymbol{t2}-\boldsymbol{t1}$).

Where,

VF' is the voltage drop across the diode at t2 and

VF is the voltage drop across the diode at t1

Zener Diode:

The reverse current through the normal diode is in terms of microamperes and it is almost constant until the reverse voltage is less than break down voltage, if the reverse voltage is greater than or equal to the break down voltage the junction breaks and high current will flow through the device and more power will be dissipated then the device may be destroyed or damaged.

If we limit the current through the device by means of connecting a resistor in series with the device, the power dissipation reduces and the device may not be destroyed even under breakdown region. By using this principle the special type of diode is designed by Clearance Zener called as Zener diode.

There are two types of breakdown occurs in Zener diode depending on the break down voltage levels.

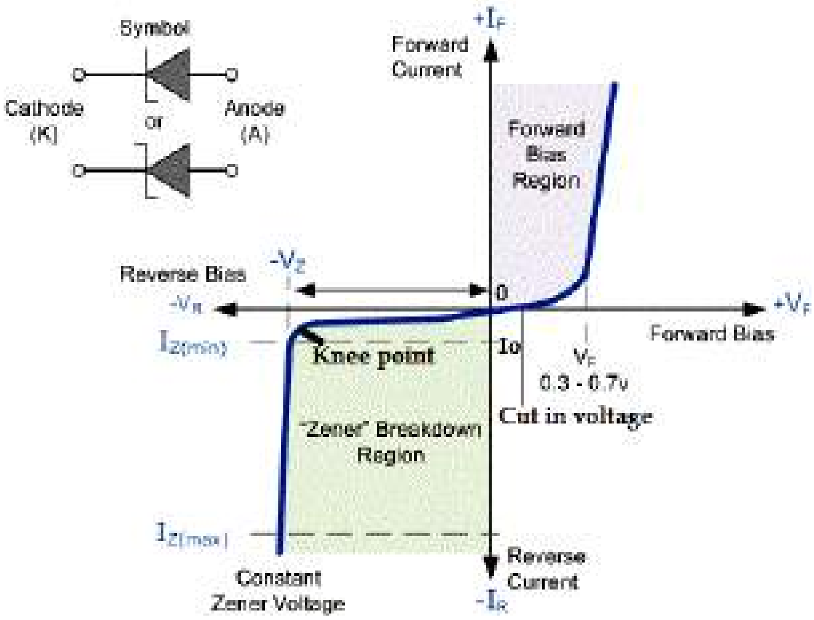
i) Zener Break down:

This type of breakdown occurs in the device if the breakdown voltage is less than or equal to 6V(typically), this strong electric field at the junction becomes very large and breaks the covalent bonds to release free electrons, due to this very high current will flow through the device. This mechanism or process is called ionization by Electric field.

ii) Avalanche Breakdown:

This type of breakdown occurs in the device if the breakdown voltage is greater than 6V (Typically), this high potential forces minority charge carriers to move quickly means kinetic energy increases, due to this the minority charge carriers collide with atoms to break covalent bonds which increase the free electrons and hence the current increases sharply. This process or mechanism is called, Impact Ionization or Ionization by collision. In this mechanism, the free electrons increase in multiples and hence called avalanche breakdown.

VI Characteristics of Zener Diode:



Rectifiers:

Rectifiers are the electronics circuits that convert AC quantity into to DC quantity. This can be achieved by using unidirectional conduction devices like diode.

Depending on the conduction angle the rectifier circuits are classified into two types, they are,

1. Half wave Rectifier and
2. Full wave Rectifier.

The Full wave Rectifiers are further classified (based on number of diodes using) into two types, they are,

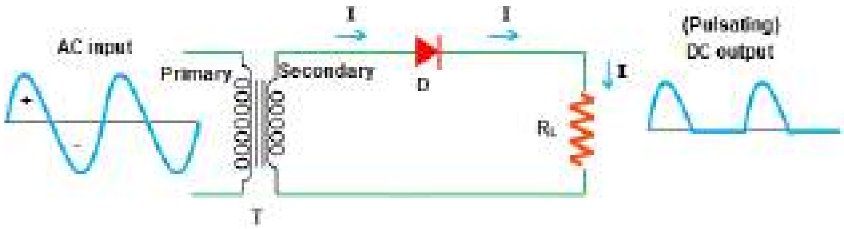
a. Center Tap Transformer (Two Diodes) full wave rectifier and

b. Bridge Type (Four Diodes) full wave rectifier.

1. Half wave Rectifier:

The half rectifier is an electronic circuit, which converts AC quantity into pulsating DC, by using a single diode with conduction angle only 180o that is only half cycle.

Circuit Diagram:



Half wave Rectifier circuit.

Figure shows the circuit diagram of a half wave rectifier, where D is a diode (Assume Diode is ideal), RL is the load resistor, input is an AC signal and output is the Pulsating DC Signal.

Explanation:

During every Positive half cycle diode D conducts and acts as a short circuit, hence the current flows through the Load resistor and is proportional to the input voltage according to Ohm's law, therefore the voltage across RL is same as input signal.

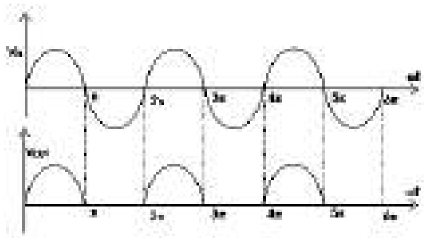
i.e., $\boldsymbol{Vo}=\boldsymbol{Vi}$

During every negative half cycle diode D does not conducts and acts as an open circuit and no current flows through the load element, hence the voltage across RL is zero.

i.e., $\boldsymbol{Vo}=\mathbf{0}$

Waveforms:

Figure shows the waveforms of an half wave rectifier circuit, and it can be observed that the output is only half cycle for every complete cycle input and also pulsating DC (Ripples/ some AC Components also present), i.e., not a pure DC.



Input and Output Waveforms of a Half wave Rectifier circuit.

Mathematical expressions:

The output of half wave rectifier circuit is irregular in nature and hence, need to analyze the circuit for average DC and AC voltage or current along with the efficiency and ripple factor.

Transformer voltage and current is given by,

$\boldsymbol{v(t)=vmsin\omega t}$. $\boldsymbol{i(t)=imsin\omega t}$

Therefore

1. Average DC Voltage.

$\boldsymbol{Vdc=1/T}\int_0^T v(t)\boldsymbol{d\omega t}$.

$\boldsymbol{Vdc=1/2\pi}\int_0^{2\pi}\int \boldsymbol{vmsin\omega t\ d\omega t}.= \boldsymbol{v_m} / \boldsymbol{\pi}$

2. Average DC Current.

$I_{dc}=\boldsymbol{1/T}\int_0^T i(t)\boldsymbol{d\omega t}.=\boldsymbol{i_m/\pi}$

i.e., $I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i \, d(\omega t)$

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} i \, d(\omega t) + \int_{\pi}^{2\pi} i \, d(\omega t)\right]$$

$$I_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t \; d(\omega t)\right]$$

where $i = \begin{cases} I_m \sin \\ 0 \end{cases}$

$$I_{dc} = \frac{I_m}{2\pi}\left[\left(-\cos\omega t\right)_0^{\pi} \right]$$

$$I_{dc} = -\frac{I_m}{2\pi}\left[\cos\pi - \cos 0\right]$$ [∵ c

$$I_{dc} = -\frac{I_m}{2\pi}\left[-1-1\right] = \frac{2 I_m}{2\pi}$$

∴ $\boxed{I_{dc} \text{ (or) } I_{avg} = \frac{I_m}{\pi}}$ — ③

(or) $I_{dc} = 0.318 I_m$.

lly, V_{dc} = Average (or) dc output voltage

where $V_{dc} = I_{dc} \times R_L$

$$V_{dc} = \frac{I_m}{\pi} \times R_L \quad (\because \text{from eqn ③})$$

$$V_{dc} = \frac{V_m}{R_L \pi} \times R_L \quad (\because \text{from eqn ②})$$

Or

Idc*=*VdcRL

3. Root Mean Square value of the output voltage.= $\boldsymbol{vm}/2$

(5)

RMS value of voltage : V_{rms}

V_{rms} is calculated across the load resistor R_L

so $V_{rms} = I_{rms} \times R_L$ (∵ from ohm's law)

$$V_{rms} = \frac{I_m}{2} \times R_L \quad (\because \text{from equ (5)})$$

$$V_{rms} = \frac{V_m}{2R_L} \times R_L \quad (\because \text{from equ (2)})$$

$$\therefore \boxed{V_{rms} = \frac{V_m}{2}} \text{ —— (6)}$$

(iii) RMS Current :-

→ RMS stands to Root mean square value of the output current flowing through the circuit and is denoted by I_{rms}.

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2\, d(\omega t)}$$

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{2\pi} i^2 d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{1}{2\pi}\left[\int_0^{\pi} i^2 d(\omega t) + \int_{\pi}^{2\pi} i^2 d(\omega t)\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2\omega t \; d(\omega t)\right]^{1/2}$$

$$i = \begin{cases} I_m \sin\omega t & ; 0 \text{ to } \pi \\ 0 & ; \pi \text{ to } 2\pi \end{cases}$$

$$I_{rms} = \left[\frac{I_m^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\omega t}{2}\right) d(\omega t)\right]^{1/2}$$

$$\left(\because \sin^2\theta = \frac{1-\cos 2\theta}{2}\right)$$

$$I_{rms} = \left[\frac{I_m^2}{4\pi}\left(\int_0^{\pi} 1\, d(\omega t) - \int_0^{\pi}\cos 2\omega t \; d(\omega t)\right)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{4\pi}\left((\omega t)_0^{\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{\pi}\right)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{4\pi}\left(\pi - \frac{1}{2}(\sin 2\pi - \sin 0)\right)\right]^{1/2}$$

$$(\because \sin 2\pi = \sin 0 = 0)$$

$$I_{rms} = \left[\frac{I_m^2}{4\pi} \times \pi\right]^{1/2} = \sqrt{\left(\frac{I_m}{2}\right)^2}$$

$$\therefore \boxed{I_{rms} = \frac{I_m}{2}} \text{ —— (5)}$$

Form factor and Peak factor :-

Form factor (K_f) :- It is defined as the ratio of RMS value to average value.

$$F.F = K_f = \frac{\text{RMS value}}{\text{Average value}}$$

$$K_f = \frac{I_{rms}}{I_{dc} \text{ (or) } I_{avg}} = \frac{I_m/2}{I_m/\pi} = \frac{\pi}{2}$$

$$\therefore \boxed{K_f = \frac{3.14}{2} = 1.57}$$

Peak factor (K_p) :- It is defined as the ratio of Peak value to the RMS value, and denoted by K_p.

$$P.F = K_p = \frac{\text{Peak value}}{\text{RMS value}} = \frac{I_m}{I_{rms}} = \frac{I_m}{I_m/2}$$

$$\therefore \boxed{K_p = 2}$$

(v) Ripple factor (γ) :-

→ The output of the rectifier is a pulsating dc signal which contains a dc component and ac component called as Ripples.

→ Ripple factor measures the percentage of ac component in the rectified output.

→ Ripples are undesirable and it's value should be small to make rectifier effective.

→ So Ripple factor can be defined as the ratio of RMS value of ac component of the output current to the average value of output current.

i.e., $RF = \gamma = \frac{\text{RMS value of ac component of output}}{\text{Average value of output}}$

$$RF = \gamma = \frac{I_{ac\,rms}}{I_{avg} \text{ (or) } I_{dc}} \qquad \left(\because I_{rms}^2 = I_{ac_{rms}}^2 + I_{dc}^2 \right.$$
$$I_{ac_{rms}} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\gamma = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$\gamma = \sqrt{\frac{I_{rms}^2 - I_{dc}^2}{I_{dc}^2}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1}$$

$$\therefore \boxed{\gamma = 1.21} \qquad \text{i.e., } \%\gamma = 121\%$$

Disadvantage of HWR

(vi) **Efficiency (η) :-** It is defined as the ratio of dc power delivered to the load to ac input power.

i.e., $\eta = \dfrac{\text{dc output power delivered to load}}{\text{Input ac power}}$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2 \times R_L}{I_{rms}^2 \times R_L} \qquad \left(\because \; P = V \times I, \; P = \frac{V^2}{R} \text{ (or) } I^2 R\right)$$

$$\eta = \frac{(I_m/\pi)^2}{(I_m/2)^2} = \frac{4}{\pi^2} = 0.405$$

$$\therefore \boxed{\% \eta = 40.5\%}$$

(vii) **Transformer utilization Factor (T.U.F) :-**

It is defined as the ratio of power delivered to load and ac rating of the transformer secondary.

i.e., $TUF = \dfrac{\text{dc power delivered to load}}{\text{ac rating of transformer secondary}}$

$$TUF = \frac{P_{dc}}{P_{ac\,(rated)}}$$

$$TUF = \frac{I_{dc}^2 R_L}{V_{rms\,(rated)} \times I_{rms}} = \frac{V_{dc} \times I_{dc}}{V_{rms\,(rated)} \times I_{rms}}$$

$$TUF = \frac{\frac{V_m}{\pi} \times \frac{I_m}{\pi}}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{2}} = \frac{2\sqrt{2}}{\pi^2} = 0.286$$

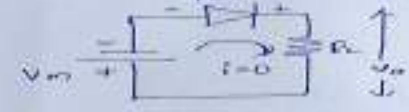
$$\therefore \boxed{TUF = 0.286}$$

(viii) **Peak Inverse voltage (PIV) :-**

It is the maximum voltage that the rectifying diode can withstand when it is operated in reverse bias.

(or)

Maximum reverse bias voltage that can be applied across a diode before it enter the breakdown region.



By applying KVL

$$-V_m + PIV + V_o = 0$$

$$-V_m + PIV + I R_L = 0 \qquad (\because I = 0)$$

$$\therefore \boxed{PIV = V_m}$$

(ix) **Regulation :-**

The variation of dc output voltage as a function of dc load current is called as regulation.

$$\boxed{\% \text{ of regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100}$$

For an ideal power supply, output voltage should be independent of load current and percentage regulation should be equal to zero.

* **Advantages of HWR :-** Simple circuit and Low cost.
* **Disadvantages of HWR :-** (i) Ripple factor (γ) is high
  (ii) Rectification efficiency is low
  (iii) Transformer utilization factor is low.

Advantages:

- Simple and easy to construct.
- PIV is only Vm.

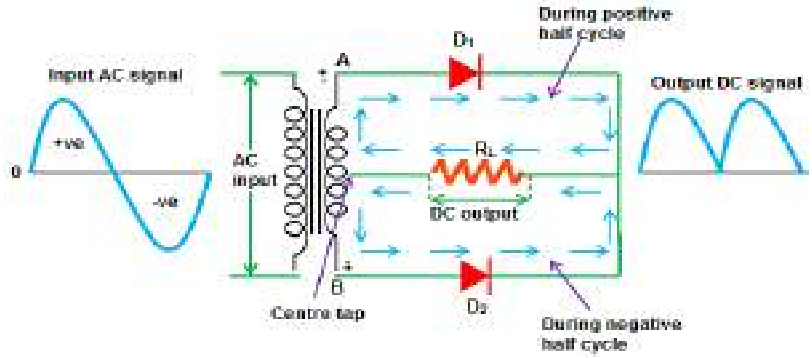
Disadvantages:

- Conducts only half cycle, due to this more power will be wasted.
- More ripples occur in the output.

2. Full wave Rectifier using Center tap transformer:

A full wave rectifier is a type of rectifier which converts both half cycles of the AC signal into pulsating DC signal.

Circuit Diagram:

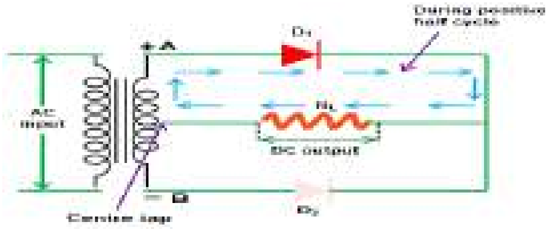


Explanation:

The center tapped full wave rectifier uses a center tapped transformer and two diodes to convert the input AC voltage into output DC voltage.

When input AC voltage is applied, the secondary winding of the center tapped transformer divides this input AC voltage into two parts: positive and negative.

During every positive half cycle of the input AC signal, terminal A become positive, terminal B become negative and center tap is grounded (zero volts). The positive terminal A is connected to the p-side of the diode D1 and the negative terminal B is connected to the n-side of the diode D1. So the diode D1 is forward biased during the positive half cycle and allows electric current through it.

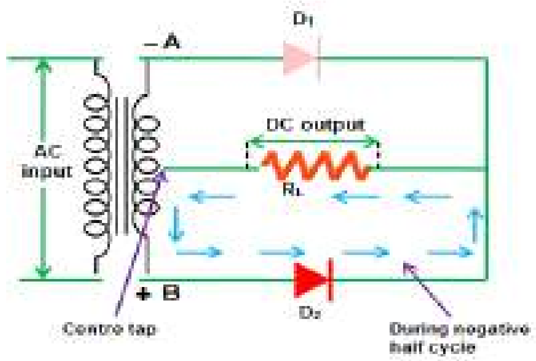


On the other hand, the negative terminal B is connected to the p-side of the diode D2 and the positive terminal A is connected to the n-side of the diode D2. So the diode D2 is reverse biased during every positive half cycle and does not allow electric current through it.

The diode D1 supplies DC current to the load RL. The DC current produced at the load RL will return to the secondary winding through a center tap.

During the positive half cycle, current flows only in the upper part of the circuit while the lower part of the circuit carry no current to the load because the diode D2 is reverse biased. Thus, during the positive half cycle of the input AC signal, only diode D1 allows electric current while diode D2 does not allow electric current as shown in figure .

During every negative half cycle of the input AC signal, terminal A become negative, terminal B become positive and center tap is grounded (zero volts). The negative terminal A is connected to the p-side of the diode D1 and the positive terminal B is connected to the n-side of the diode D1. So the diode D1 is reverse biased during the negative half cycle and does not allow electric current through it.

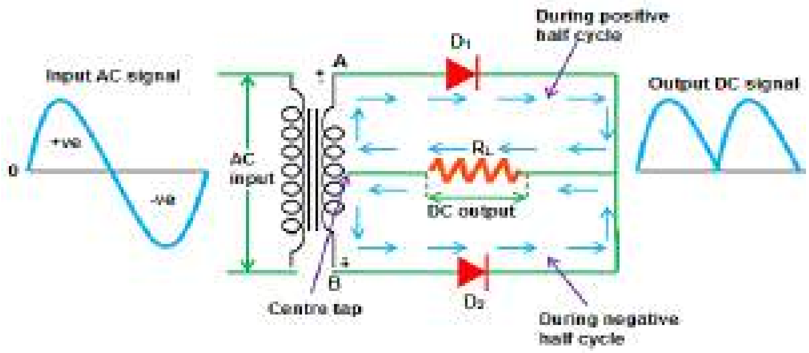


On the other hand, the positive terminal B is connected to the p-side of the diode D2 and the negative terminal A is connected to the n-side of the diode D2. So the diode D2 is forward biased during the negative half cycle and allows electric current through it.

The diode D2 supplies DC current to the load RL. The DC current produced at the load RL will return to the secondary winding through a center tap as shown in figure .

During the negative half cycle, current flows only in the lower part of the circuit while the upper part of the circuit carry no current to the load because the diode D1 is reverse biased. Thus, during the negative half cycle of the input AC signal, only diode D2 allows electric current while diode D1 does not allow electric current.

Thus, the diode D1 allows electric current during the positive half cycle and diode D2 allows electric current during the negative half cycle of the input AC signal. As a result, both half cycles (positive and negative) of the input AC signal are allowed. So the output DC voltage is almost equal to the input AC voltage as shown in figure (17).



The diodes D1 and D2 are commonly connected to the load RL. So the load current is the sum of individual diode currents.

We know that a diode allows electric current in only one direction. From the figure (17), we can see that both the diodes D1 and D2 are allowing current in the same direction.

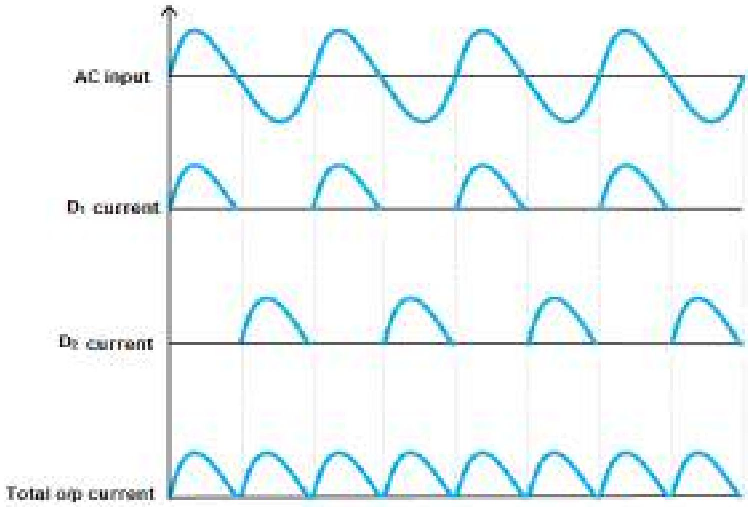
We know that a current that flows in only single direction is called a direct current. So the resultant current at the output (load) is a direct current (DC). However, the direct current appeared at the output is not a pure direct current but a pulsating direct current.

The value of the pulsating direct current changes with respect to time. This is due to the ripples in the output signal. These ripples can be reduced by using filters such as capacitor and inductor.

The average output DC voltage across the load resistor is double that of the single half wave rectifier circuit.

Waveforms:

The output waveforms of the full wave rectifier is shown in figure (18). ee



The first waveform represents an input AC signal. The second waveform and third waveform represents the DC signals or DC current produced by diode D1 and diode D2. The last waveform represents the total output DC current produced by diodes D1and D2. From the above waveforms, we can conclude that the output current produced at the load resistor is not a pure DC but a pulsating DC.

Mathematical Expressions:

(i) Peak Current and Peak voltage :-

→ The total current flowing through the circuit

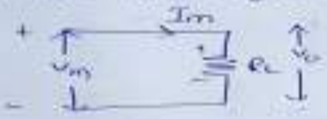
$$i = I_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$$

$$V_o = V_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$$

where I_m → Peak current

V_m → peak voltage

→ For +ve half cycle, the rectifier circuit can be drawn as



Apply KVL.

$$+V_m - V_o = 0$$

$$V_o = V_m \quad (\because V_o = I_m R_L)$$

$$I_m R_L = V_m$$

$$\boxed{V_m = I_m R_L} \quad \text{— (1)}$$

$$\boxed{I_m = \frac{V_m}{R_L}} \quad \text{— (2)}$$

(ii) Average current (or) DC current (I_{dc}) :-

We know that

$$I_{avg} \text{ (or) } I_{dc} = \frac{\int_0^T \text{Area}}{\text{Period}} = \frac{1}{T}\int_0^T i \, d(\omega t)$$

Here $i = I_m \sin\omega t$; $0 \le \omega t \le \pi$ and $T = \pi$

so

$$I_{dc} = \frac{1}{\pi}\int_0^\pi I_m \sin\omega t \, d(\omega t)$$

$$I_{dc} = \frac{I_m}{\pi}\int_0^\pi \sin\omega t \, d(\omega t) = \frac{I_m}{\pi}\left(-\cos\omega t\right)_0^\pi$$

$$I_{dc} = \frac{-I_m}{\pi}\left[\cos\pi - \cos 0\right] = \frac{-I_m}{\pi}\left[-1-1\right]$$

(4)

$$\boxed{I_{avg} \text{ (or) } I_{dc} = \frac{2I_m}{\pi}} \quad \text{— (3)}$$

Average (or) DC voltage:-

Similarly

$$V_{dc} = I_{dc} \times R_L$$

$$V_{dc} = \left(\frac{2I_m}{\pi}\right) \times R_L \quad (\because \text{from eqn (3)})$$

$$V_{dc} = \frac{2V_m}{\pi R_L} \times R_L \quad (\because \text{from eqn (2)})$$

$$\therefore \boxed{V_{avg} \text{ (or) } V_{dc} = \frac{2V_m}{\pi}} \quad \text{— (4)}$$

(iii) RMS Current :-

We know that

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^\pi i^2 \, d(\omega t)}$$

$$i = I_m \sin\omega t \; ; \; 0 \le \omega t \le \pi$$

So,

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^\pi I_m^2 \sin^2\omega t \, d(\omega t)}$$

$$I_{rms} = \left[\frac{I_m^2}{\pi}\int_0^\pi \sin^2\omega t \, d(\omega t)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{\pi}\left(\int_0^\pi \left(\frac{1-\cos 2\omega t}{2}\right) d(\omega t)\right)\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{2\pi}\left[\int_0^\pi 1 \, d(\omega t) - \int_0^\pi \cos 2\omega t \, d(\omega t)\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{2\pi}\left[\left(\omega t\right)_0^\pi - \frac{1}{2}\left(\sin 2\omega t\right)_0^\pi\right]\right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{2\pi} \left(\pi - 0 - \frac{1}{2} (\sin 2\pi - \sin 0) \right) \right]^{1/2}$$

$\because \sin 2\pi = \sin 0 = 0$

$$I_{rms} = \left[\frac{I_m^2}{2\pi} \times \pi \right]^{1/2}$$

$$\therefore \boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \quad \text{---} (5)$$

RMS voltage (V_{rms}) :-

'V_{rms}' → voltage across the load resistor 'R_L'.

$$V_{rms} = I_{rms} \cdot R_L$$

$$V_{rms} = \frac{I_m}{\sqrt{2}} \cdot R_L = \frac{V_m}{\sqrt{2} R_L} \times R_L$$

$$\therefore \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}} \quad \text{---} (6)$$

(iv) Form factor and Peak factor :-

$$\text{Form factor } (K_f) = \frac{\text{RMS value}}{\text{Average value}} = \frac{I_{rms}}{I_{dc}}$$

$$K_f = \frac{I_m/\sqrt{2}}{2I_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

$$\therefore \boxed{FF \text{ (or) } K_f = 1.11}$$

$$\text{Peak factor } (K_p) = \frac{\text{Peak value}}{\text{RMS value}} = \frac{I_m}{I_{rms}}$$

$$PF \text{ (or) } K_p = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2}$$

$$\therefore \boxed{PF \text{ (or) } K_p = \sqrt{2}}$$

(v) Ripple factor (γ) :-

$$R.F \text{ (or) } \gamma = \frac{\text{RMS value of ac component of output current}}{\text{Average (or) dc value of output current}}$$

$$\gamma = \frac{I_{ac\,rms}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$\left(\because i = i_{dc} + i_{ac}, \; I_{rms}^2 = I_{dc}^2 + I_{ac\,rms}^2 \right)$

$$\gamma = \sqrt{\frac{I_{rms}^2 - I_{dc}^2}{I_{dc}^2}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{1/\sqrt{2}}{2/\pi}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} = \sqrt{(1.11)^2 - 1} = 0.482$$

$$\boxed{\gamma = 0.482} \quad \text{(or)} \quad \% \gamma = 48.2\%$$

(vi) Rectification Efficiency (η) :-

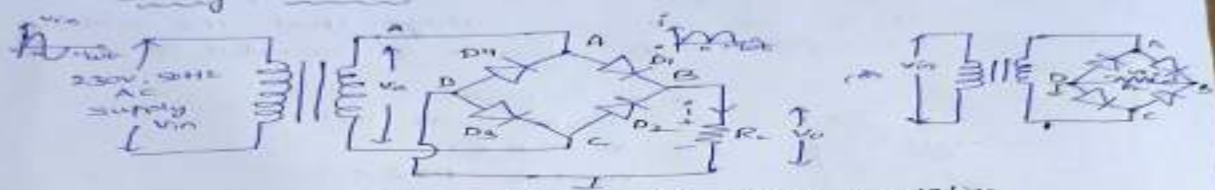
$$\eta = \frac{\text{DC power delivered to load}}{\text{AC input power}} = \frac{P_{dc}}{P_{ac}}$$

$$\eta = \frac{I_{dc}^2 R_L}{I_{rms}^2 R_L} = \frac{(2I_m/\pi)^2}{(I_m/\sqrt{2})^2} = \frac{4}{\pi^2} \times 2$$

$$\eta = \frac{8}{\pi^2} = 0.812$$

$$\therefore \boxed{\% \eta = 81.2\%}$$

(ii) Bridge Rectifier :-



Circuit diagram of Bridge rectifier

→ The need for a centre-tap transformer in FWR is eliminated in the bridge rectifier.
So. In bridge rectifier circuit, four diodes are connected in the form of bridge, where two diametrically opposite terminals A & C are connected to secondary of transformer and other two terminals B & D are connected to load resistor R_L.

Working :-

(i) For positive half cycle of input voltage, the point 'A' becomes +ve and point 'c' is −ve. So diodes D_1 and D_3 are forward biased, current flows through arm AB, enters load R_L and returns back flowing through arm DC as shown in fig. below. while no current flows through D_2 and D_4, as they are reverse biased.

(iii) Transformer utilization factor (T.U.F) :-

$$TUF = \frac{\text{DC power delivered to load}}{\text{AC rating of the transformer primary}}$$

$$TUF = \frac{P_{dc}}{P_{ac(rated)}} = \frac{I_{dc}^2 \times R_L}{V_{rms\ rated} \times I_{rms}}$$

$$TUF = \frac{(2I_m/\pi)^2 \times R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}} = \frac{4 I_m^2 R_L}{\pi^2} \times \frac{2}{V_m I_m}$$

$$(TUF)_p = \frac{8 I_m}{\pi^2} \times R_L \times \frac{1}{I_m R_L} = \frac{8}{\pi^2} = 0.812$$

$$\therefore \boxed{(TUF)_p = 0.812}$$

⇒ Overall transformer utilization factor of a Center-tap FWR is calculated as average T.U.F w.r.to primary and secondary winding.

$$(TUF)_{avg} = \frac{(TUF)_p + (TUF)_s}{2}$$

$$(T.U.F)_{avg} = \frac{(T.U.F)_p + 2 \times (T.U.F)_s}{2}$$

$$(T.U.F)_{avg} = \frac{0.812 + 2(0.286)}{2}$$

$$\therefore \boxed{(T.U.F)_{avg} = 0.692}$$

(viii) Peak Inverse voltage (PIV) :-

It is the maximum voltage that the rectifying diode can withstand, when it is operated in reverse bias.

KVL at loop-①

$V_m - V_D = 0 \Rightarrow V_D = V_m$

KVL at loop-②

$V_m + V_D - PIV = 0$

$PIV = V_m + V_D$

$PIV = V_m + V_m$

$\boxed{PIV = 2V_m}$

The peak inverse voltage of a centre-tap FWR is $2V_m$.

(ix) Voltage Regulation :-

It is the dc voltage that varies as a function of dc load current is called as regulation.

$$\boxed{\%\ Regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100}$$

* Advantages :- (i) High efficiency

(ii) Low ripple factor, so simple filter circuit is required.

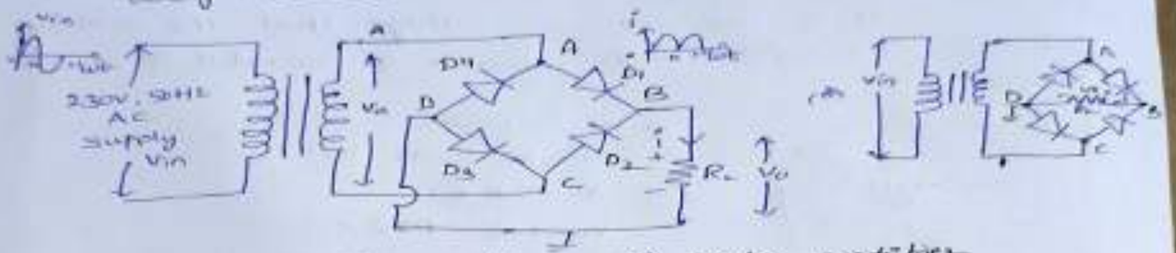
(iii) TUF is high, so high o/p voltage & thus by high o/p power.

(iv) Centre-tapped transformer removes the problem due to dc saturation.

* Disadvantages :- (i) More circuit elements and a costlier

(ii) High PIV.

(i) Bridge Rectifier :-



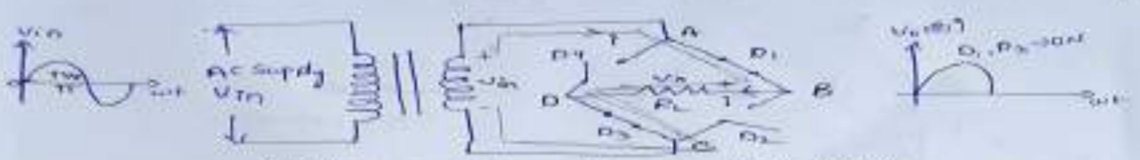
Circuit diagram of Bridge rectifier

→ The need for a centre-tap transformer in FWR is eliminated in the bridge rectifier.

So, In bridge rectifier circuit, four diodes are connected in the form of bridge, where two diametrically opposite terminals A & C are connected to secondary of transformer and other two terminals B & D are connected to load resistor R_L.

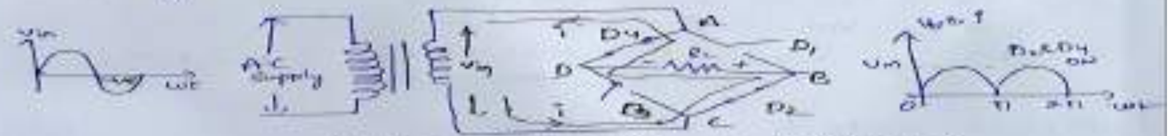
Working :-

(i) For positive half cycle of input voltage, the point 'A' becomes +ve and point 'C' is -ve. So diodes D_1 and D_3 are forward biased, current flows through arm AB, enters load R_L and returns back flowing through arm DC as shown in fig. below. while no current flows through D_2 and D_4, as they are reverse biased.



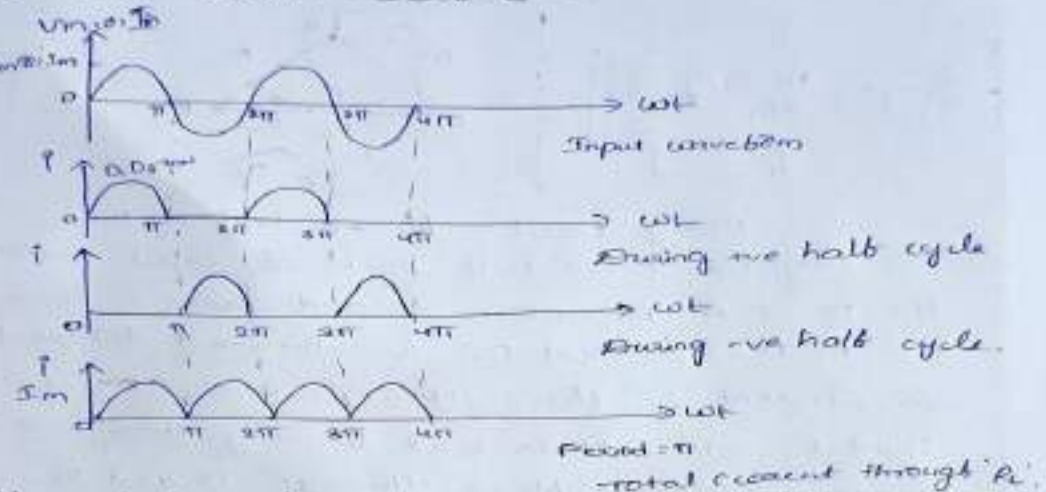
Bridge rectifier for +ve half cycle

(ii) For negative (-ve) half cycle of input voltage, the point 'A' becomes -ve and point 'C' is +ve, so diodes D_2 and D_4 are forward biased. So current 'i' flows through arm CB, enters load R_L and return back flowing through arm DA, while no current flows through D_1 and D_3, as they are reverse biased.



Bridge rectifier for -ve half cycle.

Input and output waveforms :-



Mathematical Analysis of Bridge Rectifier :-

$\Rightarrow$ $I_{in} = I_m \sin\omega t \quad ; \quad 0 \le \omega t \le 2\pi$

$V_{in} = V_m \sin\omega t \quad ; \quad 0 \le \omega t \le 2\pi$

and $V_o = V_m \sin\omega t \quad ; \quad 0 \le \omega t \le \pi$

$i = I_m \sin\omega t \quad ; \quad 0 \le \omega t \le \pi$ } period $= \pi$.

(i) Peak current and voltage :-

$$V_m = I_m R_L$$

$$I_m = V_m / R_L$$

(ii) DC output current & voltage :-

$$I_{dc} = \frac{2 I_m}{\pi}$$

$$V_{dc} = \frac{2 V_m}{\pi}$$

(iii) RMS output current and Voltage (I_{rms} & V_{rms}) :-

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

(iv) Form factor and peak factor :-

$$K_f = 1.11$$

$$K_p = \sqrt{2}$$

(v) Ripple factor :-

$$\gamma = 0.482$$

(vi) Efficiency (η) :- $\% \eta = 81.2\%$.

NOTE :- The above analysis are similar to that of center-tap F.W.R transformer. Only TUF and PIV are different in bridge rectifier.

(vii) Transformer utilization factor :-

→ As no center-tap transformer used, the primary and secondary winding TUF are same.

$$\therefore T.U.F = \frac{P_{dc}}{P_{ac\ rated}} = \frac{(TUF)_p + (TUF)_s}{2}$$

$$T.U.F = \frac{(0.812) + (0.812)}{2} = 0.812.$$

(viii) Peak Inverse voltage :- It is the maximum reverse bias voltage that can applied to the diode.

For +ve half cycle :-

KVL at loop ① $PIV - V_0 = 0$

$$V_0 = PIV$$

KVL at loop ②

$$\rightarrow V_m - PIV + V_0 - PIV = 0$$

$$\therefore PIV = V_m$$

* Advantages of Bridge Rectifier :-

(i) No centre-tap transformer is required
(ii) PIV across each diode is less than (i.e., half) the centre-tap rectifier i.e., Vm
(iii) TUF is higher than that of Centre-tap rectifier.

Disadvantages of Bridge Rectifier :-

→ It requires 4 diodes and the efficiency (η) is reduced due to voltage drop across the diodes.

* Comparision between Half-wave, Centre-tap & Bridge rectifiers :-

S.No.	Particulars	Half-wave rectifier	Full wave rectifier	
			Centre-tap	Bridge
1	Number of Diodes	1	2	4
2.	Transformer Requirement	yes Step down	yes Centre tap	yes Stepdown
3.	DC output (I_{dc}) current	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
4.	RMS current (I_{rms})	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
5.	Form factor	1.57	1.11	1.11
6.	Peak factor	2	$\sqrt{2}$	$\sqrt{2}$
7.	Ripple factor	1.21	0.48	0.48
8.	η. Efficiency	40.6%	81.2%	81.2%
9.	T.U.F	0.286	0.692	0.812
10.	PIV	Vm	2Vm	Vm

Zener Diode:

The reverse current through the normal diode is in terms of microamperes and it is almost constant until the reverse voltage is less than break down voltage, if the reverse voltage is greater than or equal to the break down voltage the junction breaks and high current will flow through the device and more power will be dissipated then the device may be destroyed or damaged.

If we limit the current through the device by means of connecting a resistor in series with the device, the power dissipation reduces and the device may not be destroyed even under breakdown region. By using this principle the special type of diode is designed by Clearance Zener called as Zener diode.

There are two types of breakdown occurs in Zener diode depending on the break down voltage levels.

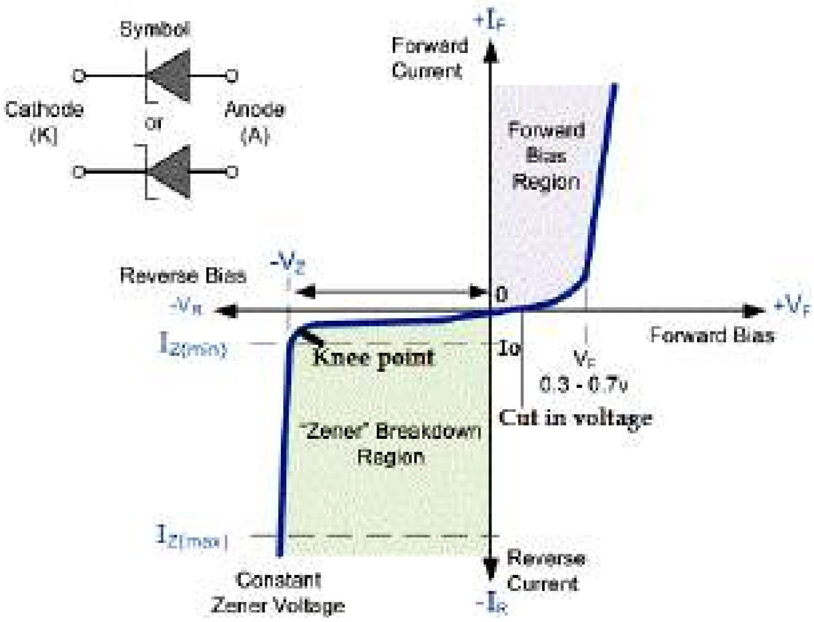
i) Zener Break down:

This type of breakdown occurs in the device if the breakdown voltage is less than or equal to 6V(typically), this strong electric field at the junction becomes very large and breaks the covalent bonds to release free electrons, due to this very high current will flow through the device. This mechanism or process is called ionization by Electric field.

ii) Avalanche Breakdown:

This type of breakdown occurs in the device if the breakdown voltage is greater than 6V (Typically), this high potential forces minority charge carriers to move quickly means kinetic energy increases, due to this the minority charge carriers collide with atoms to break covalent bonds which increase the free electrons and hence the current increases sharply. This process or mechanism is called, Impact Ionization or Ionization by collision. In this mechanism, the free electrons increase in multiples and hence called avalanche breakdown.

VI Characteristics of Zener Diode:



BJT

The transistor was developed by Dr.Shockley along with Bell Laboratories team in 1951

The transistor is a main building block of all modern electronic systems

It is a three terminal device whose output current, voltage and power are controlled by its input current.

In communication systems it is the primary component in the amplifier.

An amplifier is a circuit that is used to increase the strength of an ac signal

Basically there are two types of transistors

- Bipolar junction transistor
- Field effect transistor

The important property of the transistor is that it can raise the strength of a weak signal

This property is called amplification.

Transistors are used in digital computers, satellites, mobile phones and other communication systems, control systems etc.,

A transistor consists of two P-N junction

The junction are formed by sand witching either p-type or n-type semiconductor layers between a pair of opposite types which is shown below

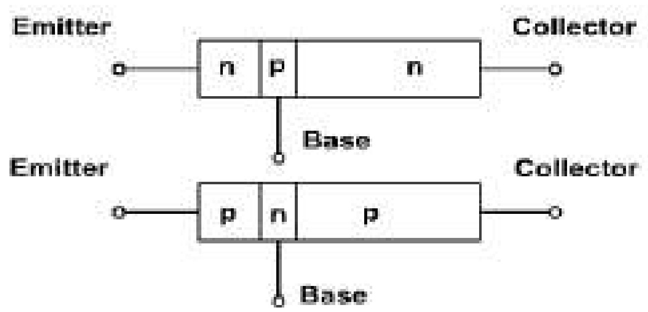


Fig: transistor

TRANSISTOR CONSTRUCTION

A transistor has three regions known as emitter, base and collector

Emitter: it is aregion situated in one side of a transistor, which supplies charge carriers (ie., electrons and holes) to the other two regions

Emitter is heavily doped region

Base: It is the middle region that forms two P-N junction in the transistor

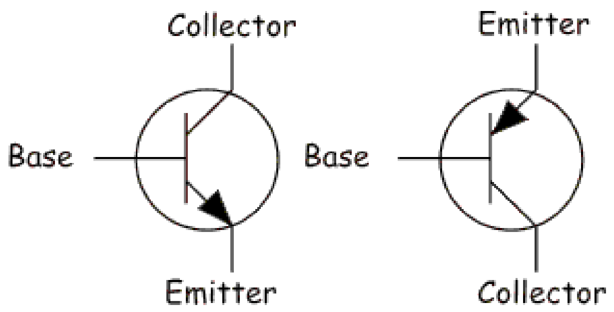
The base of the transistor is thin as compared to the emitter and is alightly doped region

Collector: It is aregion situated in the other side of a transistor (ie., side opposite to the emitter) which collects the charge carrirs

The collector of the transistor is always larger than the emitter and base of a transistor

The doping level of the collector is intermediate between the heavy doping of emitter and the light doping of the base.

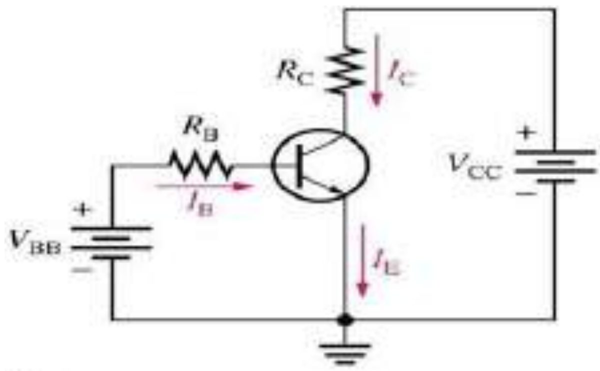
TRANSISTOR SYMBOLS



The transistor symbol carries an arrow head in the emitter pointing from the P- region towards the N- region. The arrow head indicates the direction of a conventional current flow in a transistor. The direction of arrow heads at the emitter in NPN and PNP transistor is opposite to each other. The PNP transistor is a complement of the NPN transistor.

In NPN transistor the majority carriers are free electrons, while in PNP transistor these are the holes.

OPERATION OF NPN TRANSISTOR

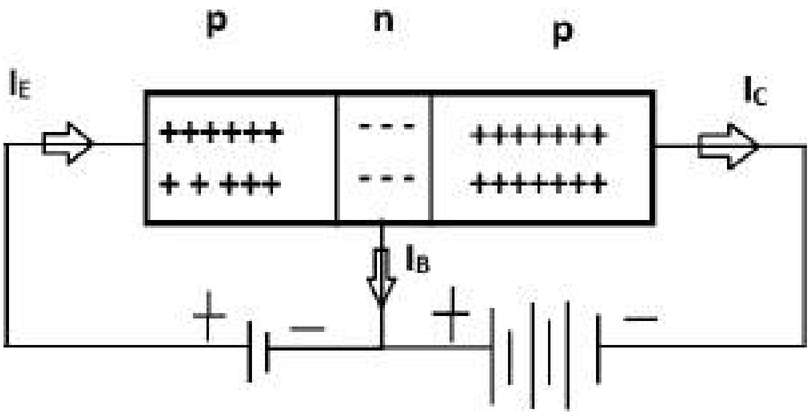


(a) *npn*

The NPN transistor is biased in forward active mode ie., emitter – base of transistor is forward biased and collector base junction is reverse biased. The emitter – base junction is forward biased only if V is greater than barrier potential which is 0.7v for silicon and 0.3v for germanium transistor. The forward bias on the emitter- base junction causes the free electrons in the N –type emitter to flow towards the base region. This constitutes the emitter current. Direction of conventional current is opposite to the flow of electrons. Electrons after reaching the base region tend to combine with the holes. If these free electrons combine with holes in the base, they constitute base current (I_B).

Most of the free electrons do not combine with the holes in the base. This is because of the fact that the base and the width is made extremely small and electrons do not get sufficient holes for recombination. Thus most of the electrons will diffuse to the collector region and constitutes collector current. This collector current is also called injected current, because of this current is produced due to electrons injected from the emitter region. There is another component of collector current due to the thermal generated carriers. This is called as reverse saturation current and is quite small.

OPERATION OF PNP TRANSISTOR



p-n-p transistor

Operation of a PNP transistor is similar to npn transistor. The current within the PNP transistor is due to the movement of holes where as, in an NPN transistor it is due to the movement of free electrons. In PNP transistor, its emitter – base junction is forward biased and collector base junction is reverse biased.The forward bias on the emitter – base junction causes the holes in the emitter region to flow towards the base region.

This constitutes the emitter current (I_E).

The holes after reaching the base region, combine with the electrons in the base and constitutes base current. Most of the holes do not combine with the electrons in the base region. This is due to the fact that base width is made extremely small, and holes does not get sufficient electrons for recombination. Thus most of the holes diffuse to the collector region and constitutes collector region. This current is called injected current, because it is produced due to the holes injected from the emitter region. There is small component of collector current due to the thermally generated carriers. This is called reverse saturation current.

TRANSISTOR CURRENTS

We know that direction of conventional current is always opposite to the electron current in any electronic device. However, the direction of a conventional current is same as that of a hole current in a PNP transistor Emitter current, Base current, Collector current. Since the base current is very small.

TRANSISTOR CONFIGURATIONS

A transistor is a three terminal device, but we require four terminals (two for input and two for output) for connecting it in a circuit. Hence one of the terminal is made common to the input and output circuits. The common terminal is grounded There are three types of configuration for the operation of a transistor.

Common base configuration (CB)

This is also called grounded base configuration

In this configuration emitter is the input terminal, collector is the output terminal and base is the common terminal.

Common emitter configuration (CE)

This is also called grounded emitter configuration

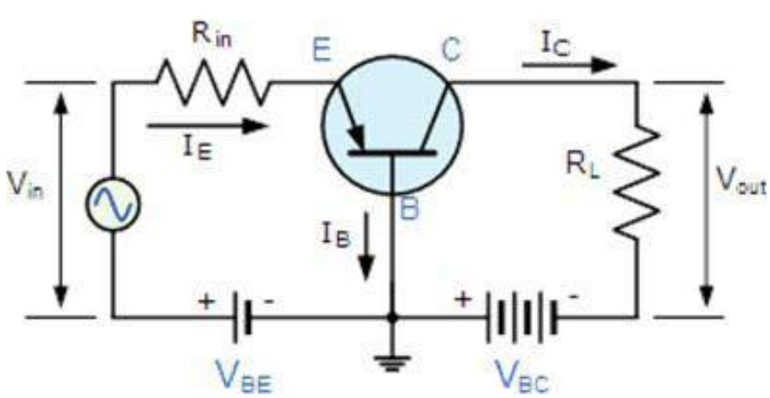
In this configuration base is the input terminal, collector is the output terminal and emitter is the common terminal

Common collector configuration (CC)

This is also called grounded collector configuration

In this configuration, base is the input terminal, emitter is the output terminal and collector is the common terminal.

Common base configuration (CB)



The input is connected between emitter and base and output is connected across collector and base The emitter – base junction is forward biased and collector – base junction is reverse biased. The emitter current, flows in the input circuit and the collector current flows in the output circuit. The ratio of the collector current to the emitter current is called current amplification factor. If there is no input ac signal, then the ratio of collector current to emitter current is called dc alpha. The ratio of change in the collector current to change in the emitter current is known as ac alpha.

The input characteristics look like the characteristics of a forward-biased diode. Note that V_{BE} varies only slightly, so we often ignore these characteristics and assume:

Common approximation: VBE = Vo = 0.65 to 0.7V

The higher the value of better the transistor. It can be increased by making the base thin and lightly doped. The collector current consists of two parts transistor action. Ie., component depending upon the emitter current , which is produced by majority carriers. The leakage current due to the movement of the minority carriers across base collector junction

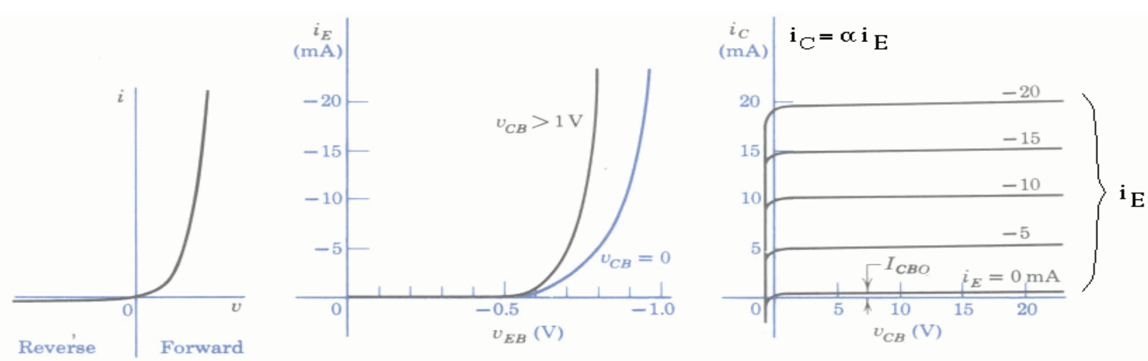
CHARACTERISTICS OF CB CONFIGURATION

The performance of transistors determined from their characteristic curves that relate different d.c currents and voltages of a transistor. Such curves are known as static characteristics curves

There are two important characteristics of a transistor

Input characteristics

Output characteristics



(a) Diode characteristic (b) Emitter characteristics (c) Collector characteristics

INPUT CHARACTERISTICS

The curve drawn between emitter current and emitter – base voltage for a given value of collector – base voltage is known as input characteristics

Base width modulation (or) Early effect

In a transistor, since the emitter – base junction is forward biased there is no effect on the width of the depletion region. However, since collector – base junction is reverse biased as the reverse bias voltage across the collector – base junction increase the width of the depletion region also increases. Since the base is lightly doped the depletion region penetrates deeper into the base region .This reduces the effective width of the base region.

This variation or modulation of the effective base width by the collector voltage is known as base width modulation or early effect. The decrease in base width by the collector voltage has the following three effects. It reduces the chances of recombination of electrons with the holes in the base region. Hence current gain increases with increase in collector – base voltage

The concentration gradient of minority carriers within the base increases. This increases the emitter current .For extremely collector voltage , the effective base width may be reduced to zero, resulting in voltage breakdown of a transistor This phenomenon is known as punch through The emitter current increases rapidly with small increase in which means low input resistance Because input resistance of a transistor is the reciprocal of the slope of the input characteristics

Output characteristics

The curve drawn between collector current and collector – base voltage, for a given value of emitter current is known as output characteristics

ACTIVE REGION

There is a very small increase in with increase in This is because the increase in expands the collector – base depletion region and shorten the distance between two depletion region.

Hence due to the early effect does not increase very much with increase in Although, the collector current is independent of if is increased beyond a certain value, eventually increases rapidly because of avalanche effects. This condition is called punch – through or reach – through When it occurs large current can flow destroying the device

CUT – OFF REGION

small collector currentflows even when emitter current

this is the collector leakage current

SATURATION REGION

collector current flows even when the external applied voltage is reduced to zero. There is a low barrier potential existing at the collector – base junction and this assists in the flow of collector current

COMMON – EMITTER CONFIGURATION

The input is connected between base and emitter, while output is connected between collector and emitter

Emitter us common to both input and output circuits.

The bias voltage applied are Vce and Vbe.

The emitter-base junction is forward biased and collector-emitter junction is reverse biased.

The base current Ib flows in the input circuit and collector current Ic flows sin the output circuit.

CE is commonly used because its current, Voltage, Power gain are quite high nd output to input impedance ratio is moderate

The rate of change in collector current to change in base current is called amplification factor B.

The current gain in the common-emitter circuit is called BETA (b). Beta is the relationship of collector current (output current) to base current (input current).

Two voltages are applied respectively to the base B and collector C with respect to the common emitter E.

Same as the CB configuration, here in the CE configuration, the BE junction is forward biased while the CB junction is reverse biased. The voltages of CB and CE configurations are related by:

$$V_{CE} = V_{CB} + V_{BE}, \quad \text{or} \quad V_{CB} = V_{CE} - V_{BE}$$

The base current is treated as the input current, and the collector current is treated as the output current:

$$I_C = \alpha I_E + I_{CB0} = \alpha(I_C + I_B) + I_{CB0} \approx \alpha(I_C + I_B)$$

Solving this equation for collector current, we get the relationship between the output collector current and the input base current:

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CB0} = \beta I_B + (\beta+1) I_{CB0} = \beta I_B + I_{ce0} \approx \beta I_B$$

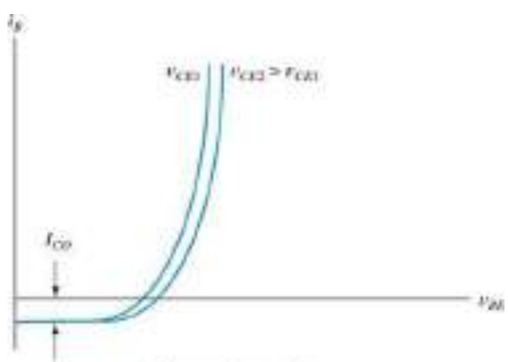
Here we have also defined the CE current gain or current transfer ratio

$$\beta = \frac{\alpha}{1-\alpha} \approx \frac{I_C}{I_B}$$

which is approximately the ratio of the output current and the input current . The two parameters α and β are related by:

$$\beta = \frac{\alpha}{1-\alpha}, \qquad \alpha = \frac{\beta}{1+\beta}, \qquad 1+\beta = \frac{1}{1-\alpha}, \qquad 1-\alpha = \frac{1}{1+\beta}$$

Characteristics of CE configuration


(a) Input characteristics

Input Characteristics

Same as in the case of common-base configuration, the junction of the common-emitter configuration can also be considered as a forward biased diode, the current-voltage characteristics is similar to that of a diode:

$$I_B = f(V_{BE}, V_{CE}) \approx f(V_{BE}) = I_0(e^{V_{BE}/V_T} - 1)$$

The Curve drawn between base current and base-emitter voltage for a given value of collector-emitter voltage is known as input characteristics.

The input characteristics of CE transistors are similar to those of a forward biased diode because the base-emitter region of the transistor is forward-biased.

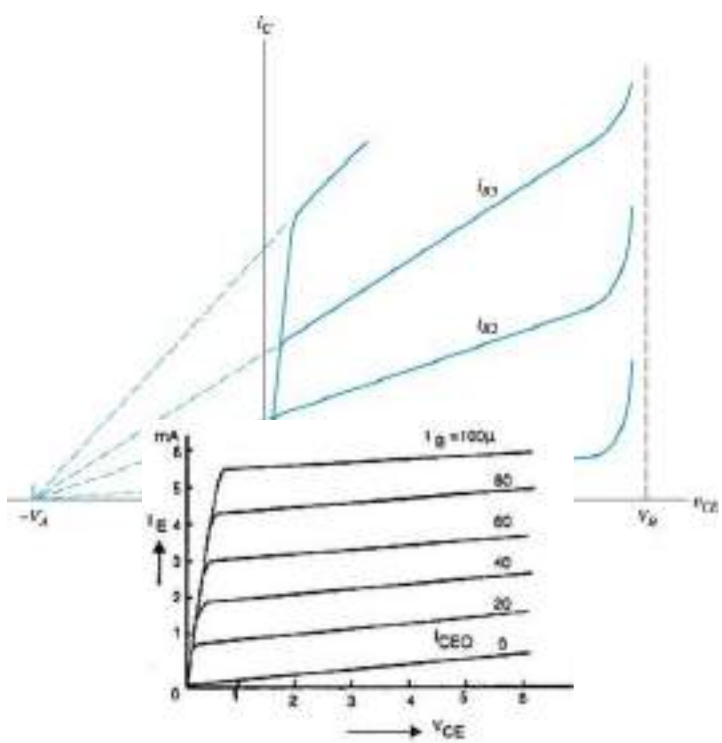
Input Resistance is larger in CE configuration than in CB configuration.

This is because the I/P current increases less rapidly with increase in Vbe.

An increment in value of Vce causes the input current to be lower for a given level of Vbe. This is explained on the basis of early effect.

As a result of early effect, more charge carriers from the emitter flows across the collector-base junction and flow out through the based lead.

Output Characteristics



$$I_C = f(I_B, V_{CE}) \approx f(I_B) = \beta I_B \qquad \text{(in linear region)}$$

It is the curve drawn between collector current Ic and collector-emitter voltage Vce for a given value of base current Ib.

The collector current Ic varies with Vce and becomes a constant.

Output characteristics in CE configuration has some slope while CB configuration has almost horizontal characteristics.

This indicates that output resistance incase of CE configuration is less than that in CB configuration.

Active Region

For small values of base current, the effect of collector voltage Vc over Ic is small but for large values of Ib, this effect increases.

The shape of the characteristic is same as CB configuration

The difference that Ic is larger than input current

Thus, the current gain is greater than unity.

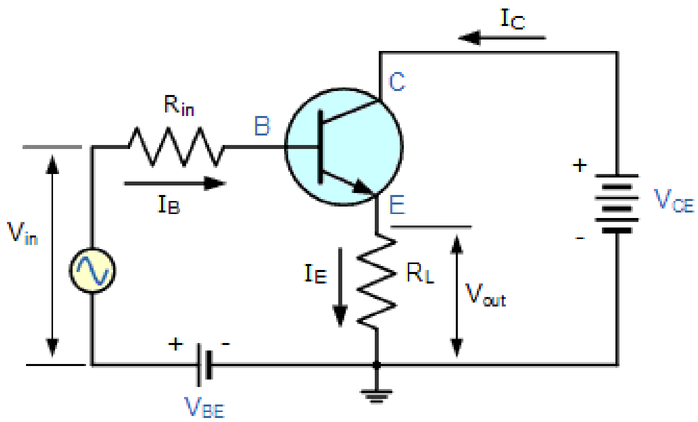
Saturation Region

With low values of Vce, the transistor is said to be operated in saturation region and in this region, base current Ib does not correspond to Ic,

Cut off Region

A small amount of collector current Ic flows even when Ib=0, This is called emitter leakage current.

Common Collector Configuration:



Input is applied between base and collector while output is applied between emitter and collector.

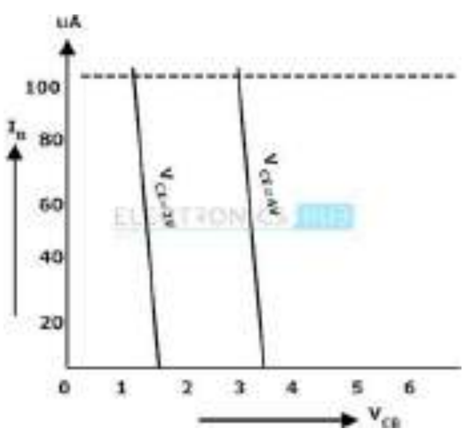
The collector forms the terminal common to both the input and output.

GAIN is a term used to describe the amplification capabilities of an amplifier. It is basically a ratio of output to input. The current gain for the three transistor configurations (CB, CE, and CC) are ALPHA(a), BETA (b), and GAMMA (g), respectively.

$$\alpha = \frac{\Delta I_C}{\Delta I_E}$$

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$



Input Characteristics

To determine the i/p characteristics Vce is kept at a suitable fixed value.

The base collector voltage Vbc is increased in equal steps and the corresponding increase in Ib is noted.

This is repeated for different fixed values of Vce.

Output Characteristics