CHANDIGARH UNIVERSITY

Discover. Learn. Empower.

UNIVERSITY INSTITUTE ENGINEERING

DEPARTMENT ACADEMIC UNIT-1

Bachelor of Engineering (Computer Science Engineering)

SUBJECT NAME: BASIC ELECTRICAL & ELECTRONICS ENGINEERING

SUBJECT CODE : 21ELH-101

By

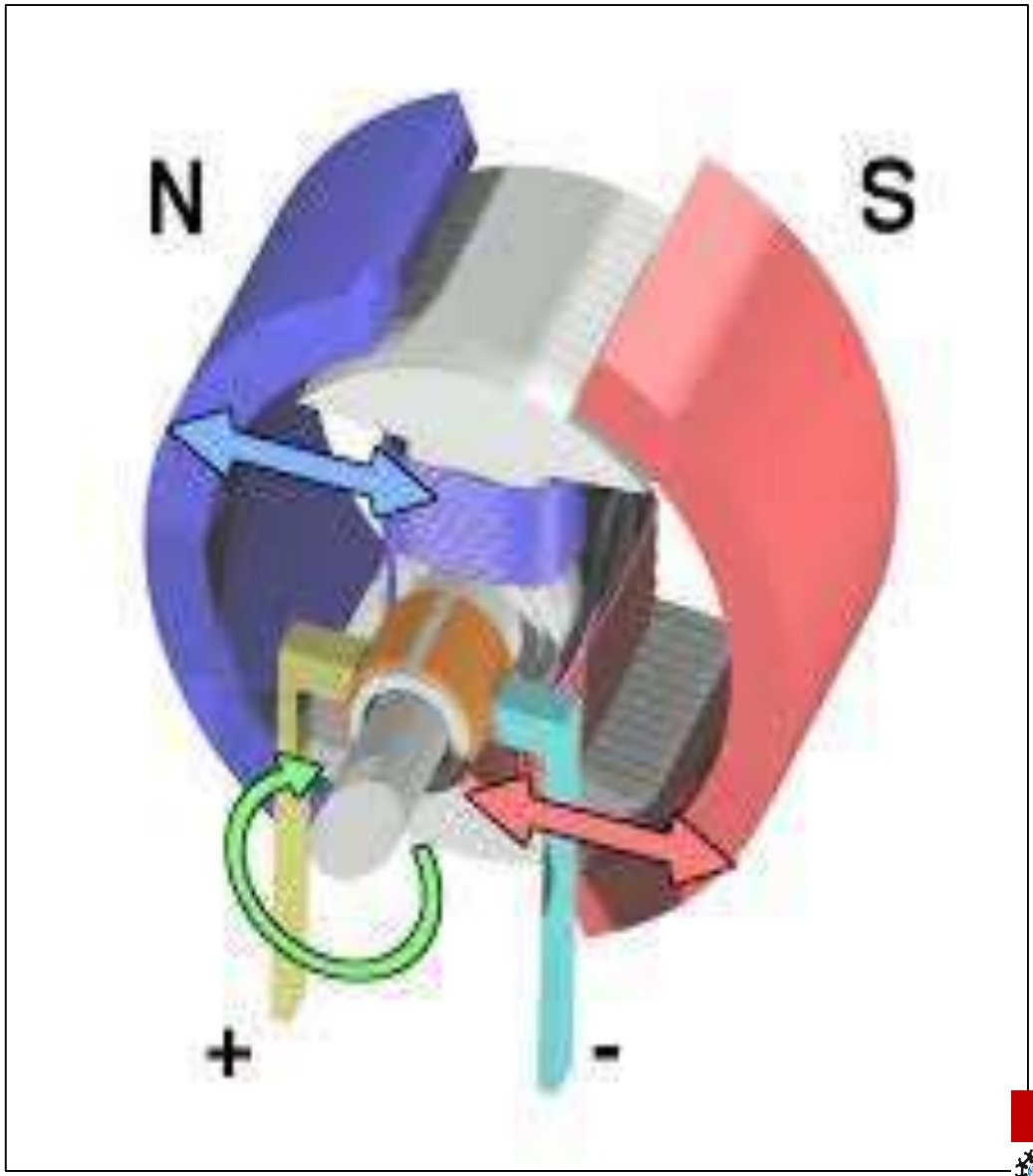
AKHIL NIGAM

Unit-2

DC MACHINES

LECTURE OBJECTIVES

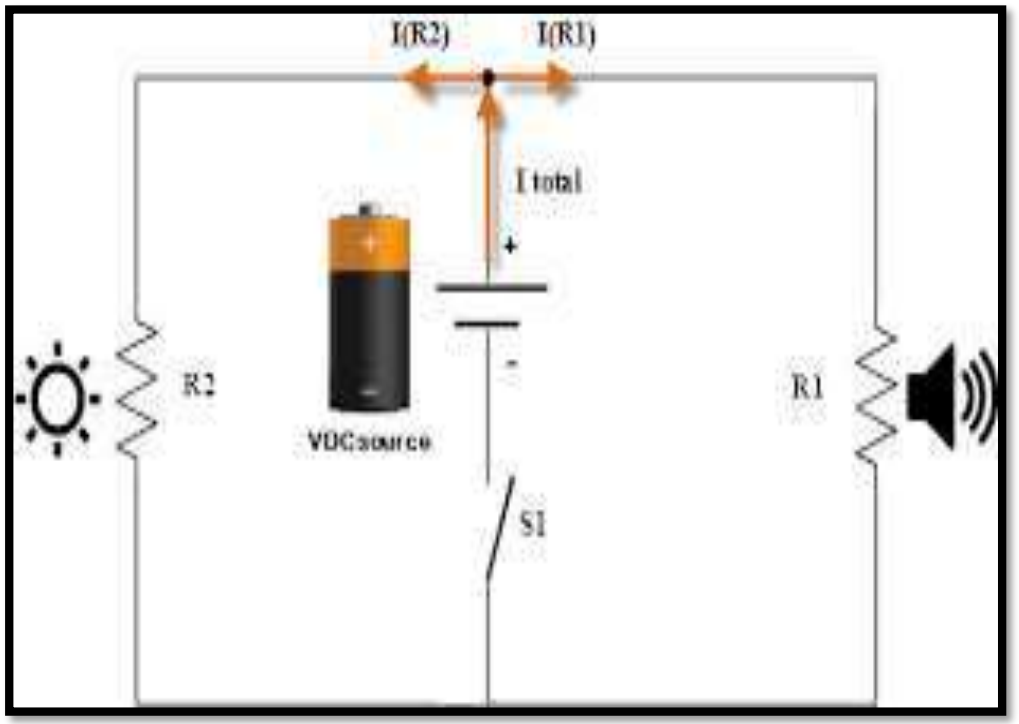
S. No.	Objectives
1	To make student aware about the basic construction of DC Machine.
2	To aware about the working principal of DC Machine.
3	To provide knowledge about the load characteristics of DC machines.
4	To make familiar with speed control of DC Machines.
5	To give knowledge about EMF equation of DC Machine.



https://en.wikipedia.org/wiki/DC_motor

Course Objectives

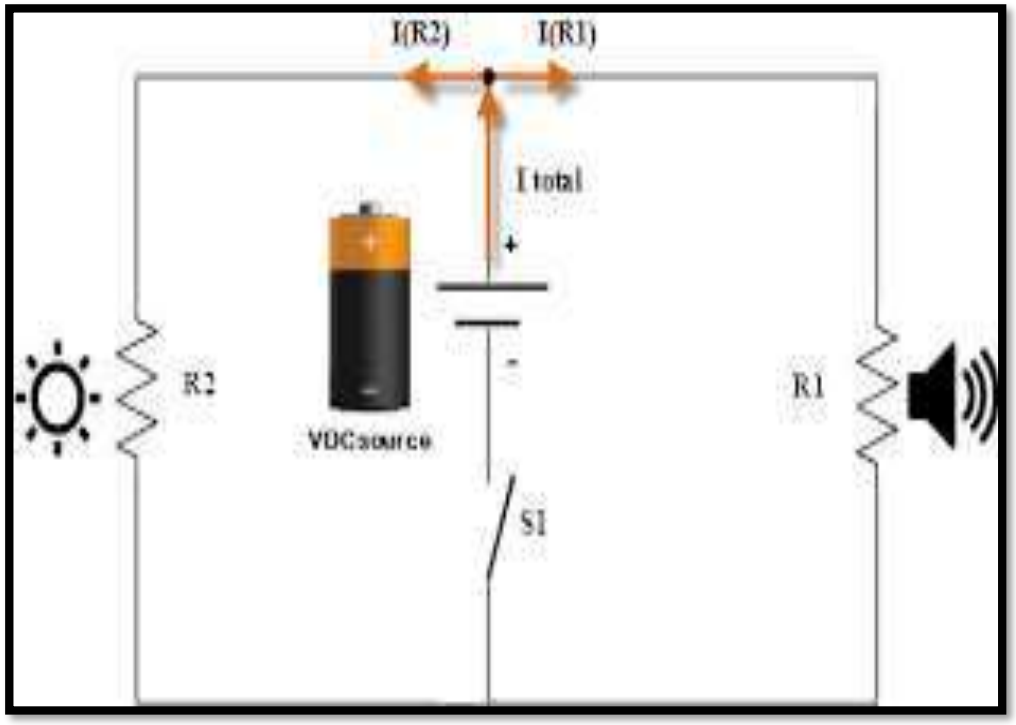
S. No.	Objectives
1	To meet students with basic knowledge of dc circuits, electromagnetism and ac fundamentals.
2	To aware about introduction to single and three phase ac circuit with their construction and working principles.
3	To provide knowledge about electrical and electronics engineering fundamentals.
4	To acquire specific knowledge skills so as to comprehend how electric, magnetic and electronic circuits are applied in practice.



https://library.automationdirect.com/basic-electrical-theory/

Course Outcomes

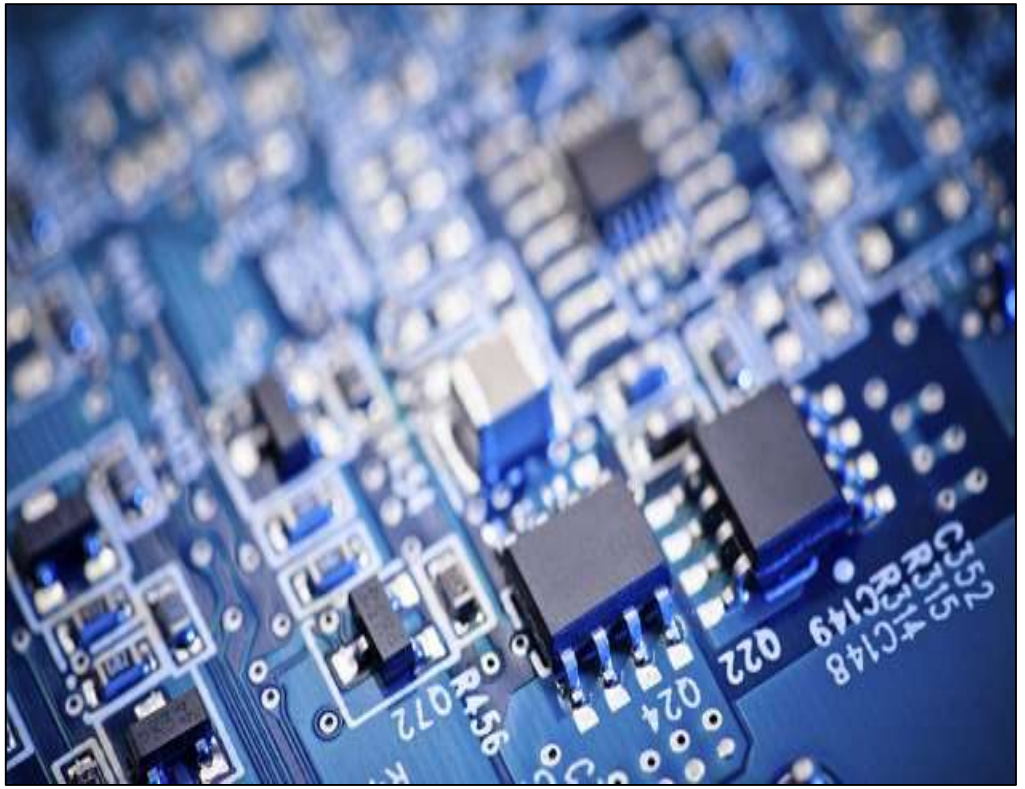
CO Number	Title	Level
CO1	Identify the different types of electrical elements and the basic op-amp circuit elements and to illustrate the various types of motors, transducers and batteries.	Remember
CO2	Understand basic principles of transformers, transducers, op-amps, DC and AC motors and to compare the different methods for analyzing electrical and magnetic circuits.	Understand
CO3	Derive the relationships between parameters in electric and magnetic circuits and motors and to determine specifications of op-amps.	Analyze
CO4	Solve the basic problems related to electric circuits, magnetic circuits and motors and to assess the characteristics of different configurations of op-amps.	Evaluate
CO5	Design the different applications of transducers, motors as well as the op-amps like adders, subtractor and comparators.	Create



https://library.automationdirect.com/basic-electrical-theory/

IMPORTANCE OF COURSE [BEEE]

- Use in communication and satellite navigation system.
- Handles in electronics equipment and computers.
- Deals with the problem of power transmission and motor control.
- Handles with robotics applications.



https://www.eletimes.com/electronics-manufacturing-cluster-ap-remains-distant-dream

CONTENTS

- Introduction of DC Motor
- Constructional Parts of DC Motor.
- Function of Commutator in DC Motor
- Function of Armature Winding.
- Types of Armature Windings
- Function of Brushes in DC Motor.
- Working of DC Motor.

UNIT-2
DC MOTOR

Fig: 1. Pictorial View of DC Motor
https://www.electrical4u.com/dc-motor-or-direct-current-motor/

DC MOTOR

- A DC Motor or Direct Current Motor converts electrical energy in to mechanical energy.
- A Direct Current (DC) motor is fairly simple electric motor that uses electricity and a magnetic field to produce torque, which turns the rotor and hence give mechanical work.

Fig: 2. Small Size DC Motor

Fig: 3. Large Size DC Motor

https://en.wikipedia.org/wiki/DC_motor

CONSTRUCTIONAL PARTS OF DC MACHINE

1) Magnetic Frame or yoke
2) Pole core & Pole shoes.
3) Magnetic field or Exciting coils
4) Armature core
5) Armature winding
   a) Lap Winding
   b) Wave Winding
6) Commutator
7) Brushes.
8) Bearing
9) End ring
10) Shaft.

CONSTRUCTIONAL VIEW OF DC MACHINE

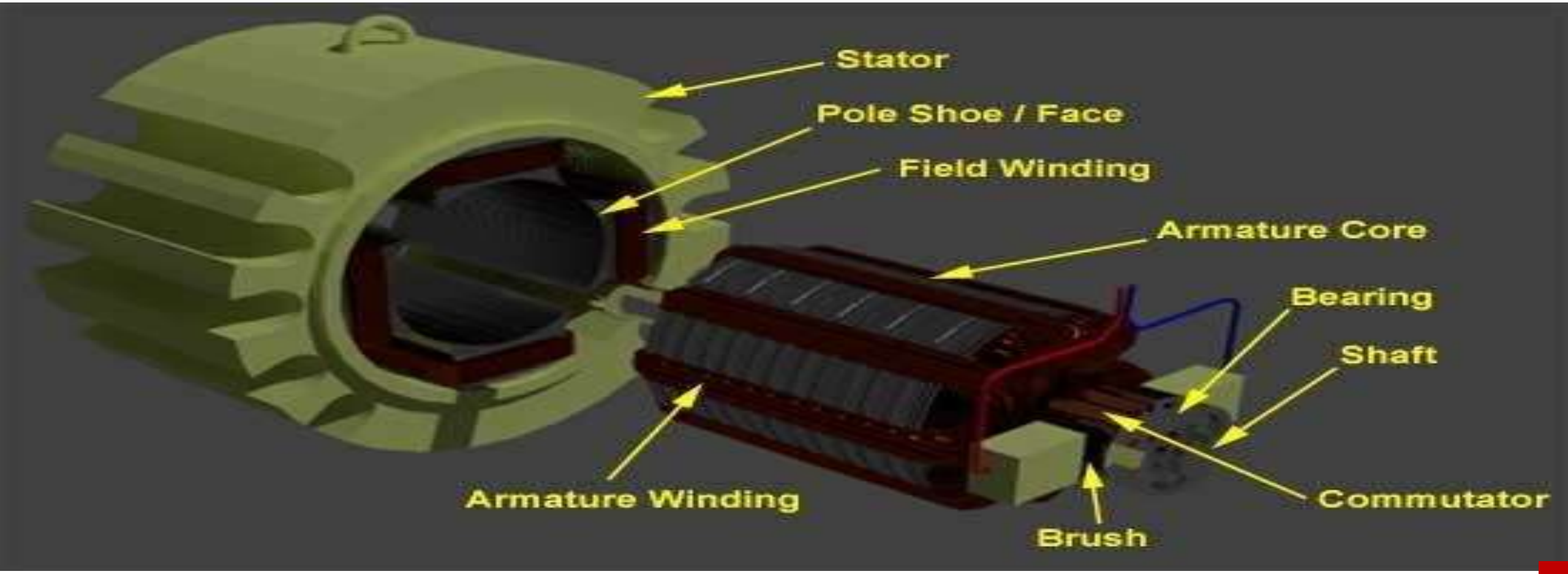


Fig: 4. Constructional View of DC Machine

https://www.electrical4u.com/construction-of-dc-motor-yoke-poles-armature-field-winding-commutator-brushes-of-dc-motor/

OVERVIEW OF DC MACHINE

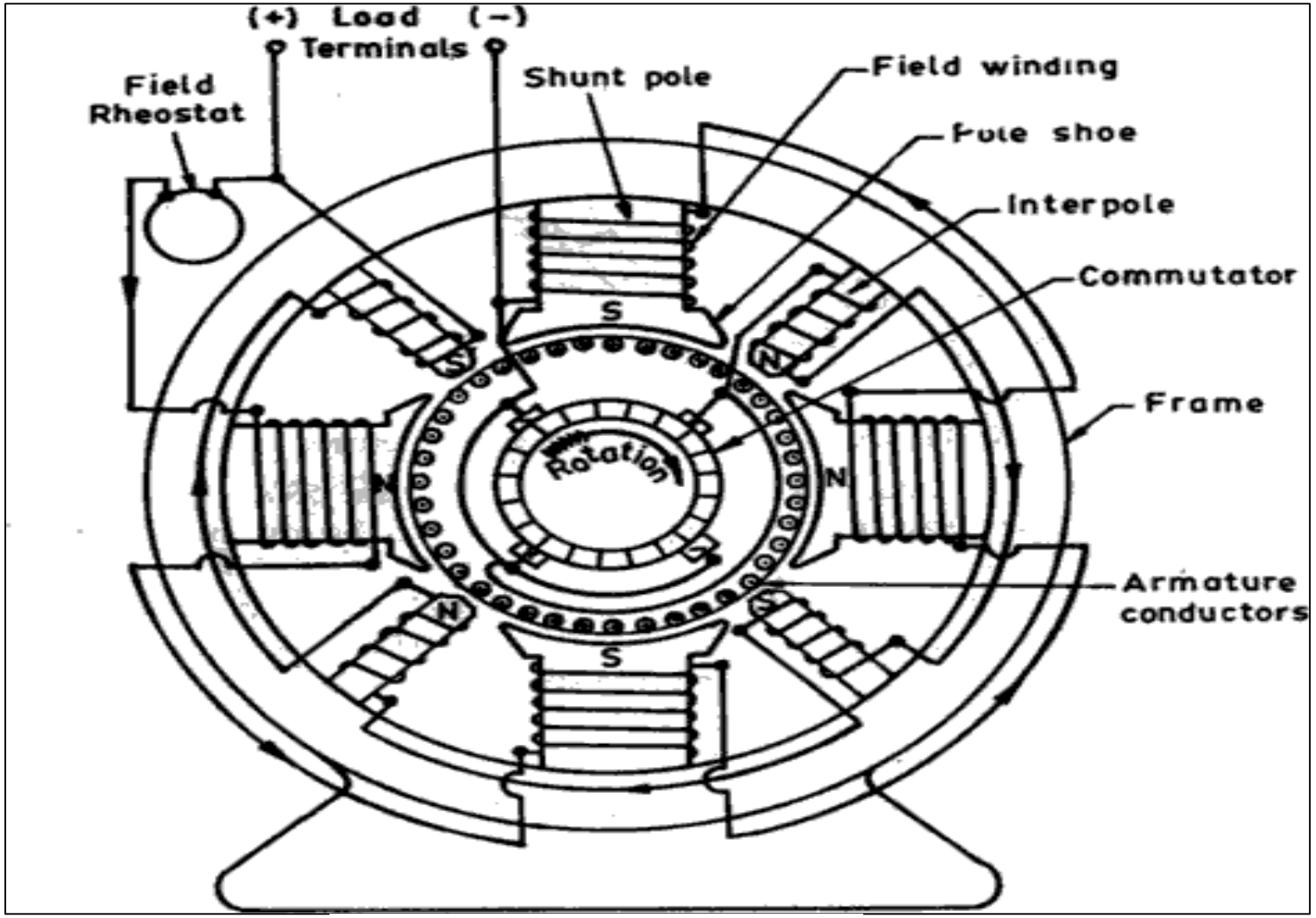
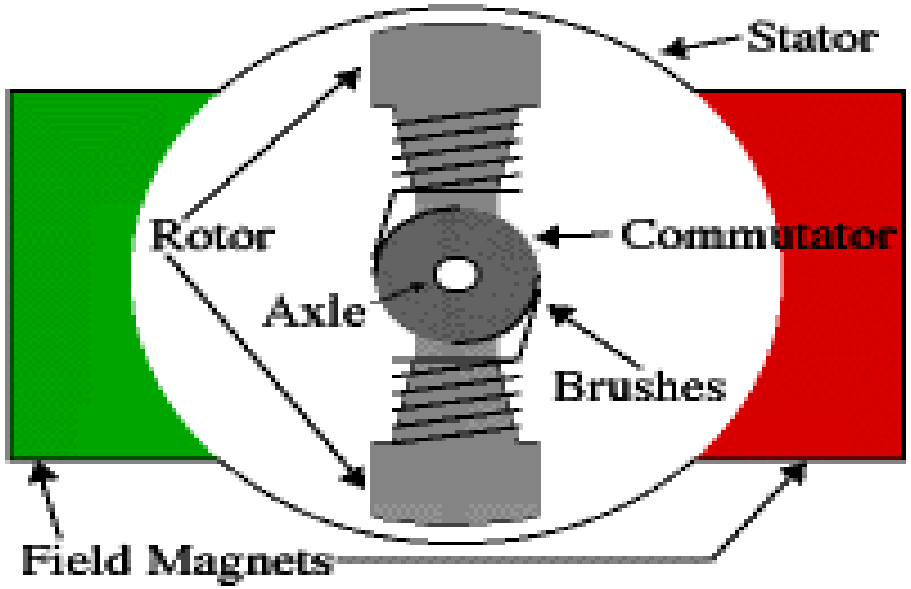
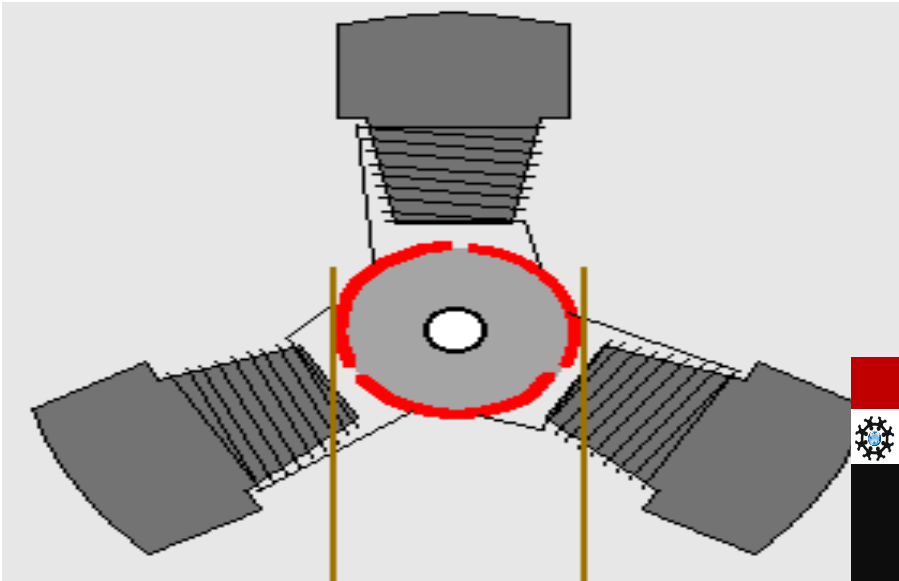


Fig:5. Overview of DC Machine

https://blog.oureducation.in/construction-of-dc-motor/





MAGNETIC FRAME OR YOKE

- The outer hollow cylindrical frame to which main poles and inter-poles are fixed and by means of which the machine is fixed to the foundation is known as Yoke.
- The two main purposes of the yoke are as follows:-
- It supports the pole cores and provides mechanical protection to the inner parts of the machines.
- It provides a low reluctance path for the magnetic flux.

POLE CORE & POLE SHOES

- The Pole Core and Pole Shoes are fixed to the magnetic frame or yoke by bolts.
- The pole core and shoes are made of thin cast steel or wrought iron laminations.
- It supports the field or exciting coils.
- They spread out the magnetic flux over the armature periphery more uniformly.
- It increases the cross-sectional area of the magnetic circuit, as a result, the reluctance of the magnetic path is reduced.

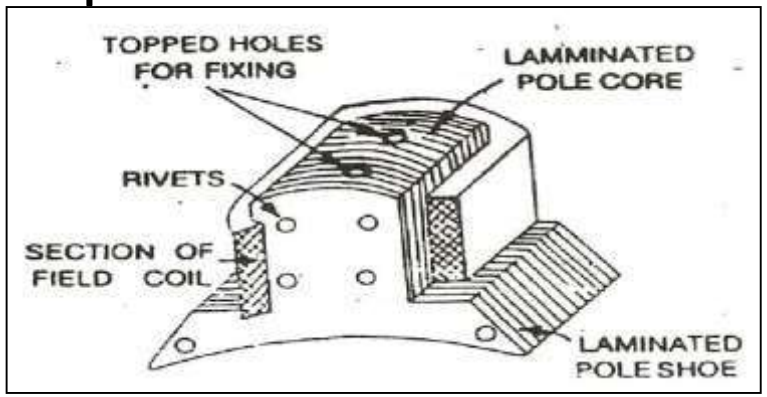


Fig:6. Pole Core & Pole Shoes

https://circuitglobe.com/construction-of-dc-generator.html

FIELD or EXCITING COILS

- The enameled copper wire is used for the construction of field or exciting coils.
- The field coils of all the poles are connected in series in such a way that when current flows through them, the adjacent poles attain opposite polarity.

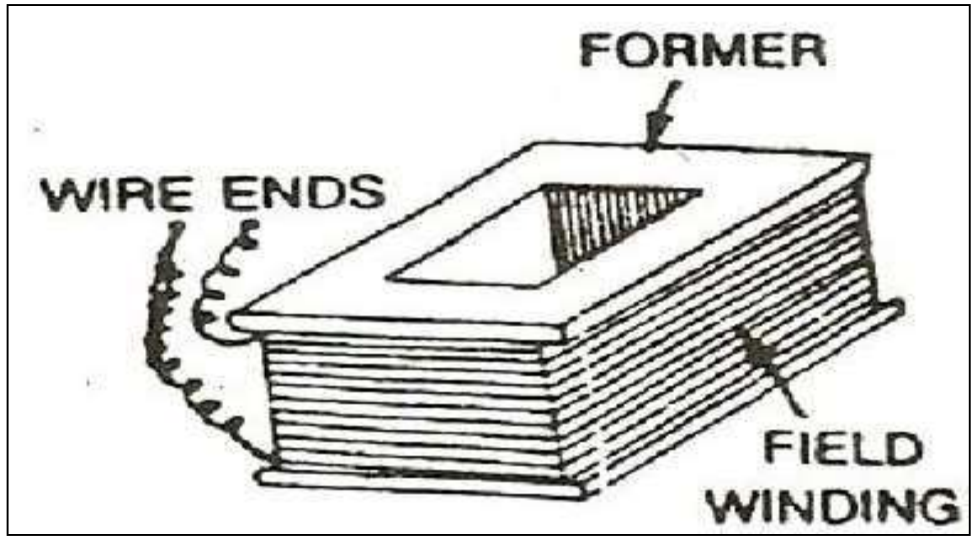


Fig:7. Field or Exciting Coils

https://circuitglobe.com/construction-of-dc-generator.html

ARMATURE WINDING

- The insulated conductors are placed in the slots of the armature core.
- **The armature winding is the heart of the DC Machine.**
- Armature winding is a place where conversion of power takes place.
- windings are classified into two types named as Lap Winding and Wave Winding.
- **Lap Winding**
- In lap winding, the conductors are connected in such a way that the number of parallel paths are equal to the number of poles.
- **Wave Winding**
- In wave winding, the conductors are so connected that they are divided into two parallel paths irrespective of the number of poles of the machine.

COMMUTATOR

- The commutator which rotates with the armature, is cylindrical in shape.
- It connects the rotating armature conductors to the stationary external circuit through brushes.
- It converts the induced alternating current in the armature conductor into unidirectional current in the external load circuit in DC Generator action, whereas it converts the alternating torque into unidirectional (continuous) torque produced in the armature in motor action.

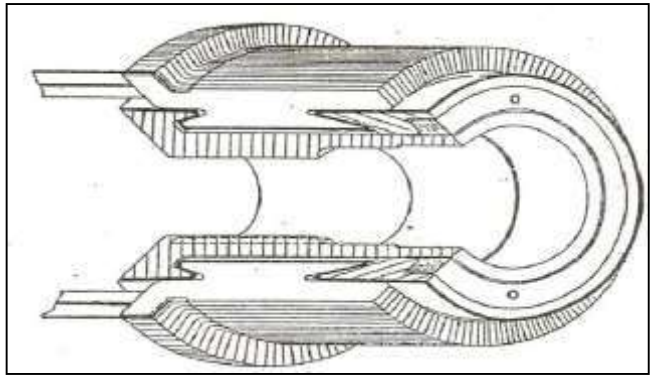


Fig:8. Commutator

https://circuitglobe.com/construction-of-dc-generator.html

BRUSHES

- The brushes are pressed upon the Commutator and form the connecting link between the armature winding and the external circuit.
- The pressure exerted by the brushes on the Commutator can be adjusted and is maintained at a constant value by means of springs.
- It can be used to provide a lubricating effect on Commutator surface.

END HOUSINGS

•End housings are attached to the ends of the Mainframe and provide support to the bearings.

BEARINGS

•The ball or roller bearings are fitted in the end housings. The function of the bearings is to reduce friction between the rotating and stationary parts of the machine

SHAFT

- The shaft is made of mild steel with a maximum breaking strength. The shaft is used to transfer mechanical power from or to the machine.

WORKING PRINCIPLE OF DC MOTOR

- A machine that converts DC electrical power into mechanical power is known as a Direct Current motor.
- **DC motor working is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.**
- The direction of this force is given by **Fleming's left-hand rule** and magnitude is given by;

F = BIL Newton's

- According to Fleming's left-hand rule when an electric current passes through a coil in a magnetic field, the magnetic force produces a torque that turns the DC motor. The direction of this force is perpendicular to both the wire and the magnetic field.

SUMMARY

- ✓ Introduction to DC Motor & its constructions.
- ✓ Working Principle of DC Motor
- ✓ Function of Commutator in DC motor
- ✓ Types of Armature Windings.

FREQUENTLY ASKED QUESTIONS

- What is the principle operation of DC Motors?
- What is the function of Commutator in DC Motor.
- What is the function of Brushes in DC Motor.
- What is Lap Winding & Wave Winding.

LEARNING OUTCOMES

To Guide the students about basic knowledge of DC motor & it's working principle.

- To aware about constructional part of DC motor.
- To make the students aware about concept of type of armature windings.
- To make the students about function of Commutator in DC Motor.

CONTENTS

- Various types of characteristics of DC motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC shunt motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC series motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC compound motor.
- Applications of DC motors.

TYPES OF CHARACTERISTICS OF DC MOTOR

- Three characteristic curves are there for DC Motors given below

➢ Torque-armature current

➢ Speed- armature current

➢ Speed- torque

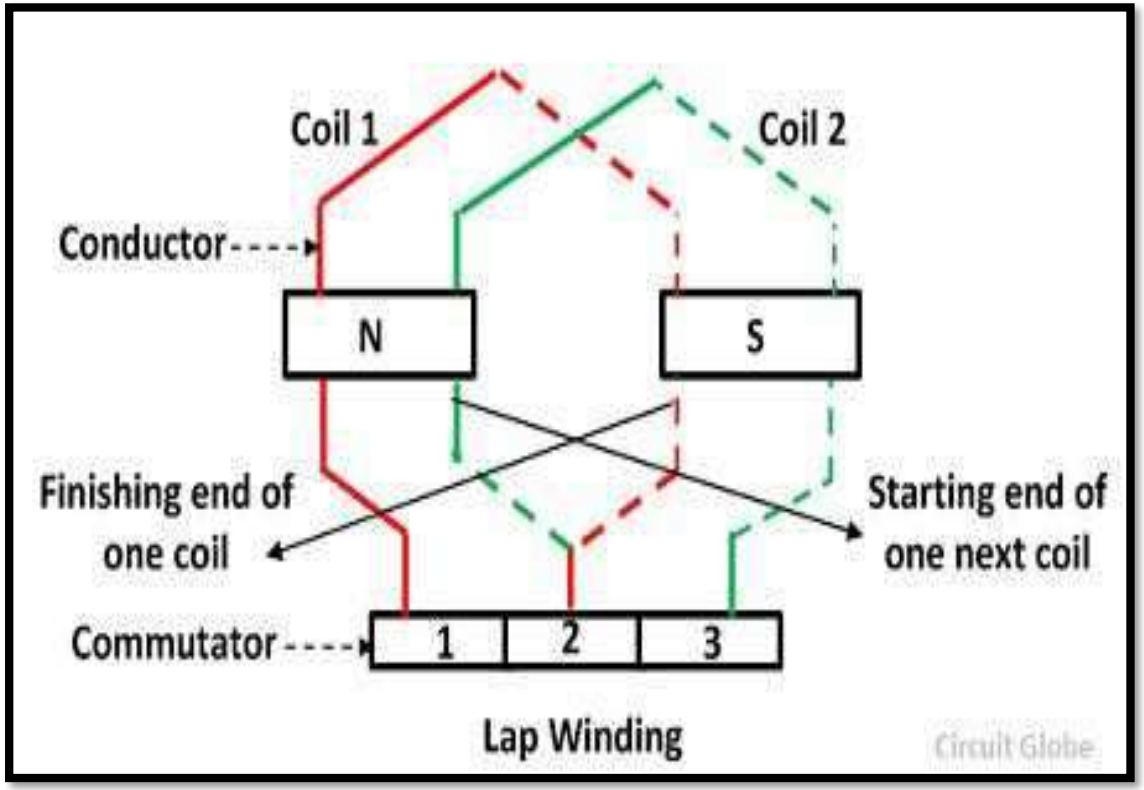
TORQUE- SPEED EQUATION OF DC MOTOR

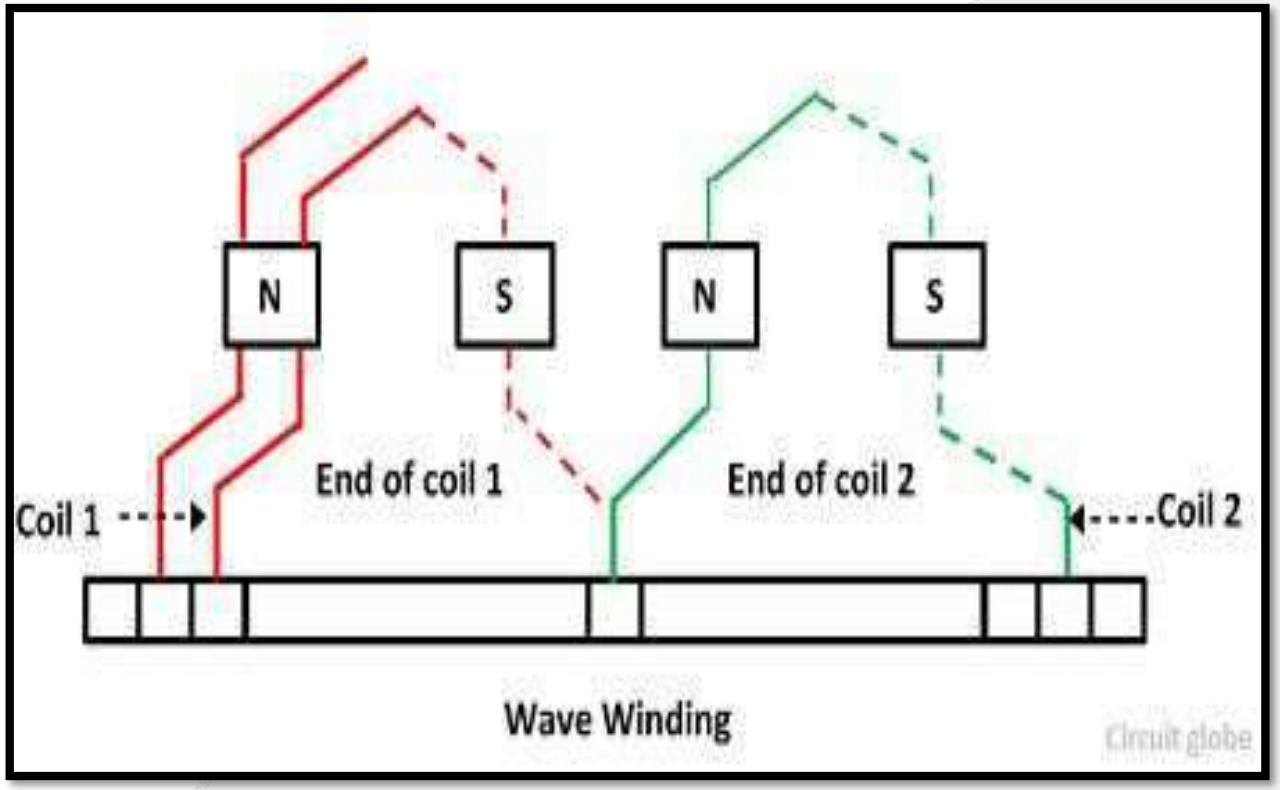
- For a d.c. motor, Torque is directly proportional to the product of **Armature current** and M**ain flux**.

$$T_a = \phi I_a \left(\frac{PZ}{2\pi A} \right)$$

$$T \propto \phi I_a$$

- Now is the flux produced by the field winding and is proportional to the current passing through the field winding.


Coil 1
Coil 2
Conductor
N
S
Finishing end of one coil
Starting end of one next coil
Commutator
1
2
3
Lap Winding
Circuit Globe


N
S
N
S
Coil 1
End of coil 1
End of coil 2
Coil 2
Wave Winding
Circuit globe

TORQUE- SPEED EQUATION OF DC MOTOR

- For a d.c. motor, Torque is directly proportional to the product of armature current and main flux.

$$\phi \propto qI_f$$

- Similarly the back emf produced in the armature is given by

$$E_b = \phi N \left(\frac{ZP}{60A}\right)$$

$$E_b \propto \phi N$$

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

TORQUE- SPEED EQUATION OF DC MOTOR

$$V = E_b + I_a R_a$$

$$\Rightarrow E_b = V - I_a R_a$$

Speed equation becomes :

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

- These relations play an important role in understanding the various characteristics of different types of motors.

TORQUE- ARMATURE CURRENT CHARACTERISTICS OF DC SHUNT MOTOR

$$T \propto \phi I_a$$

- For a constant values of and supply voltage **is also constant and hence flux is also constant.**

$$\phi \propto I_f$$

$$T_a \propto I_a$$

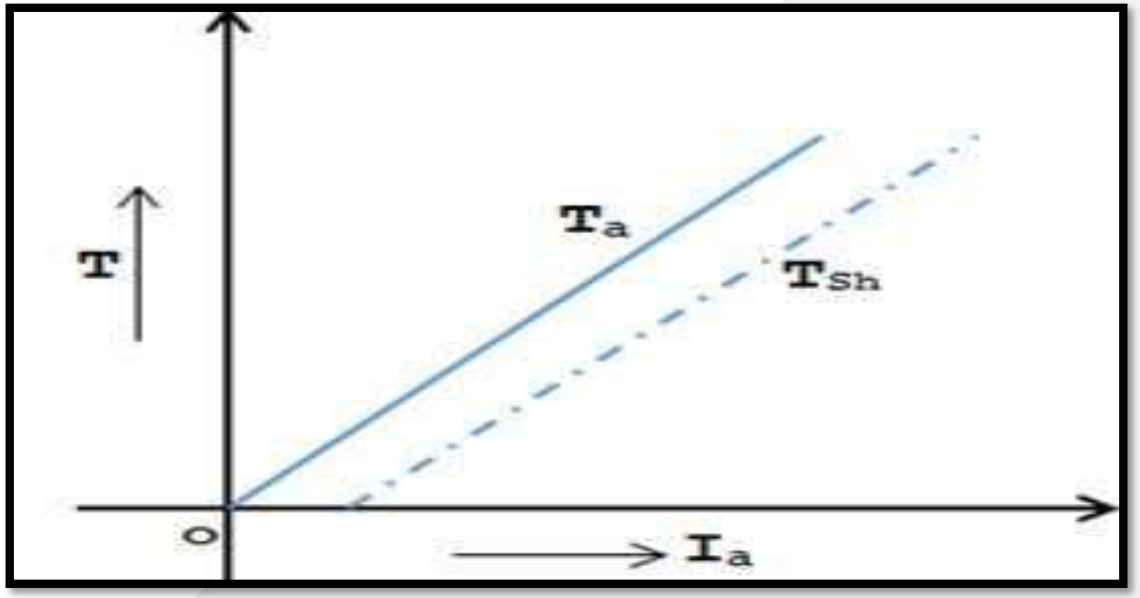


Fig.1 torque-armature current curve for DC shunt motor

http://www.mytech-info.com/2014/12/characteristics-of-dc-shunt-motor.html

SPEED- ARMATURE CURRENT CHARACTERISTICS OF DC SHUNT MOTOR

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

$$\phi \rightarrow \text{Constant}$$

$$N \propto V - I_a R_a$$

- So as load increases >> The armature current increases and hence drop also increases.

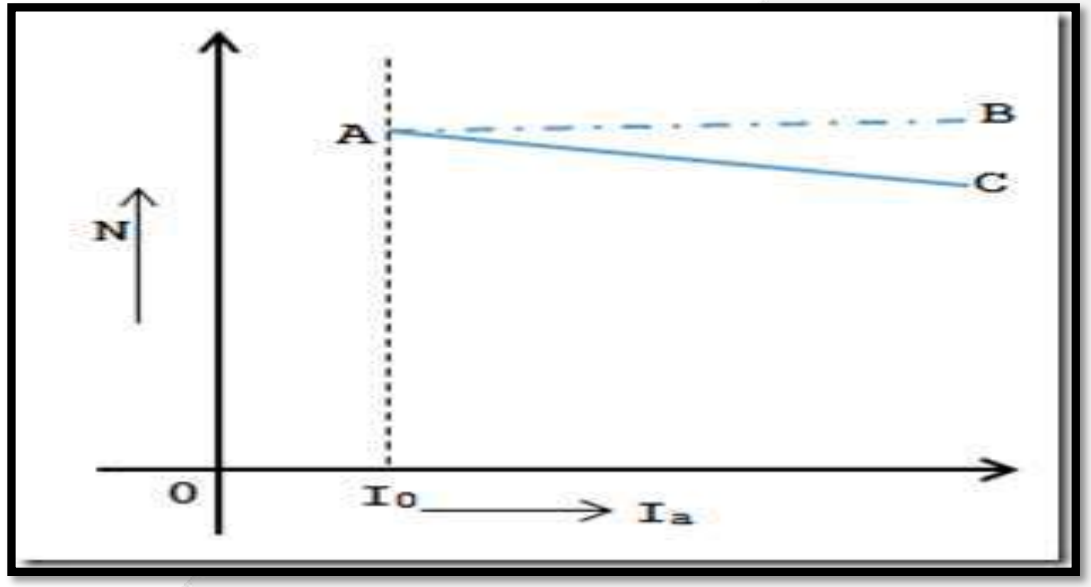


Fig.2 speed-armature current curve for DC shunt motor

http://www.mytech-info.com/2014/12/characteristics-of-dc-shunt-motor.html

SPEED- TORQUE CHARACTERISTICS OF DC SHUNT MOTOR

$$T \propto \phi I_a$$

$$T_a \propto I_a$$

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

$$\phi \rightarrow \text{Constant}$$

$$N \propto V - I_a R_a$$

- So from these 2 equations, we can conclude that Speed and Torque both has a **linear relationship.**

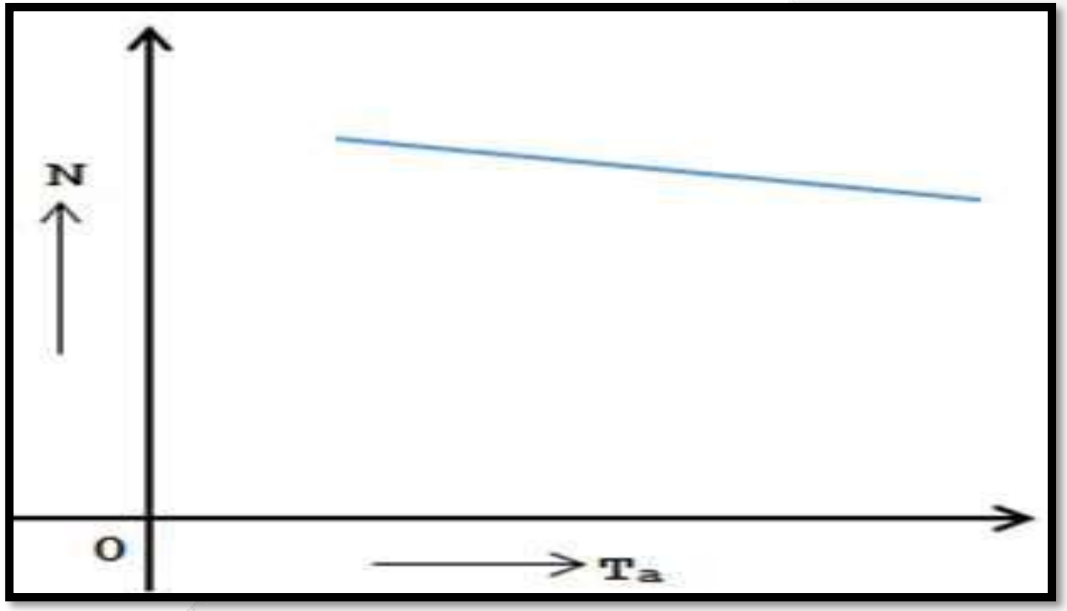


Fig.3 speed-torque curve for DC shunt motor

http://www.mytech-info.com/2014/12/characteristics-of-dc-shunt-motor.html

TORQUE- ARMATURE CURRENT CHARACTERISTICS OF DC SERIES MOTOR

- In the case of a series motor, the series field winding is carrying the entire armature current. So flux produced is proportional to the armature current.

$$T \propto \phi I_a$$

$$\phi \propto I_a$$

$$T_a \propto \phi I_a \propto I_a^2$$

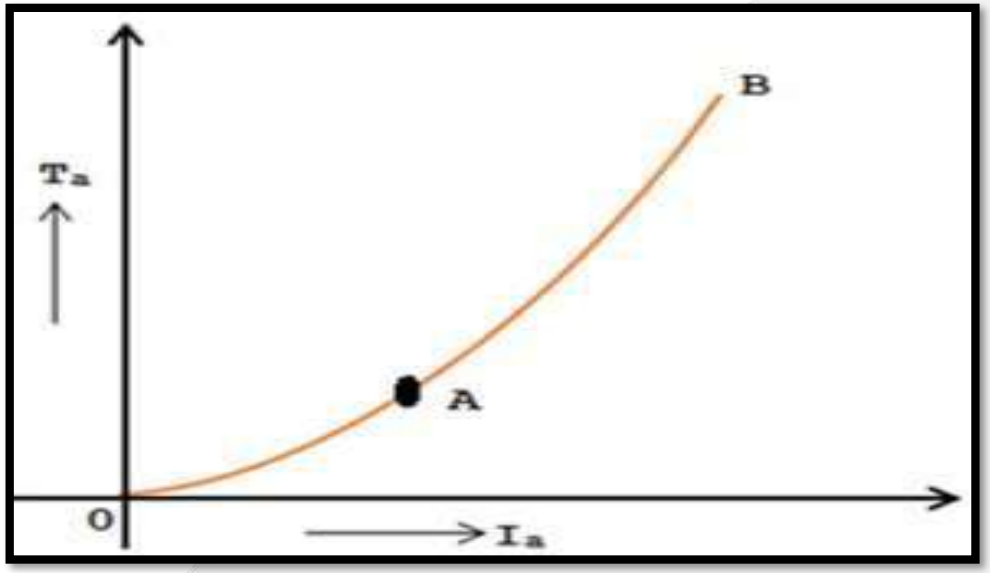


Fig.4 torque-armature current curve for DC series motor

http://www.mytech-info.com/2014/12/characteristic-of-dc-series-motor.html

SPEED- ARMATURE CURRENT CHARACTERISTICS OF DC SERIES MOTOR

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

$$N \propto \left(\frac{V - I_a R_a - I_a R_{se}}{I_a}\right) \qquad N \propto \frac{1}{I_a}$$

- Hence in the speed equation, $E_b \approx V$ and can be assumed constant. So speed equation reduces

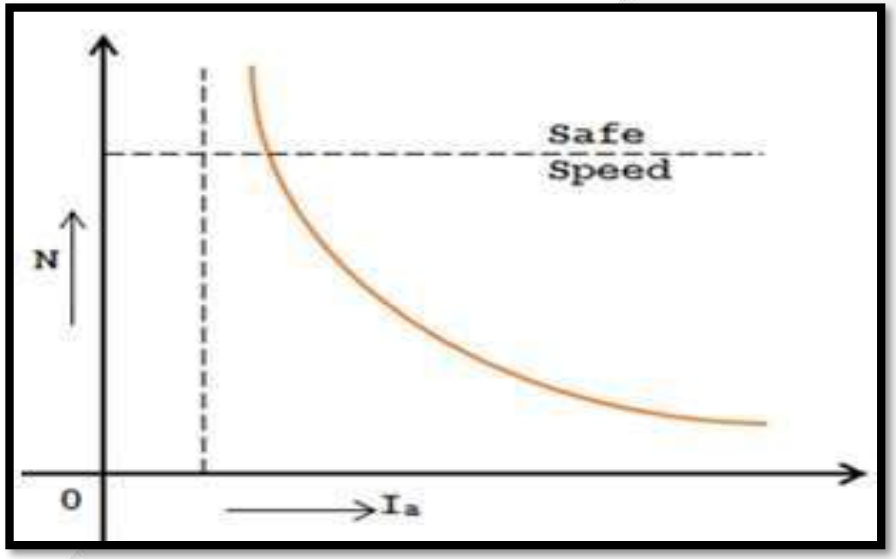


Fig.5 speed-armature current curve for DC series motor

http://www.mytech-info.com/2014/12/characteristic-of-dc-series-motor.html

SPEED- TORQUE CHARACTERISTICS OF DC SERIES MOTOR

In case of series motors

$$T \propto I_a^2$$

$$N \propto \frac{1}{I_a}$$

Hence we can write

$$N \propto \frac{1}{\sqrt{T}}$$

- Thus as torque increases when load increases, the speed decreases.

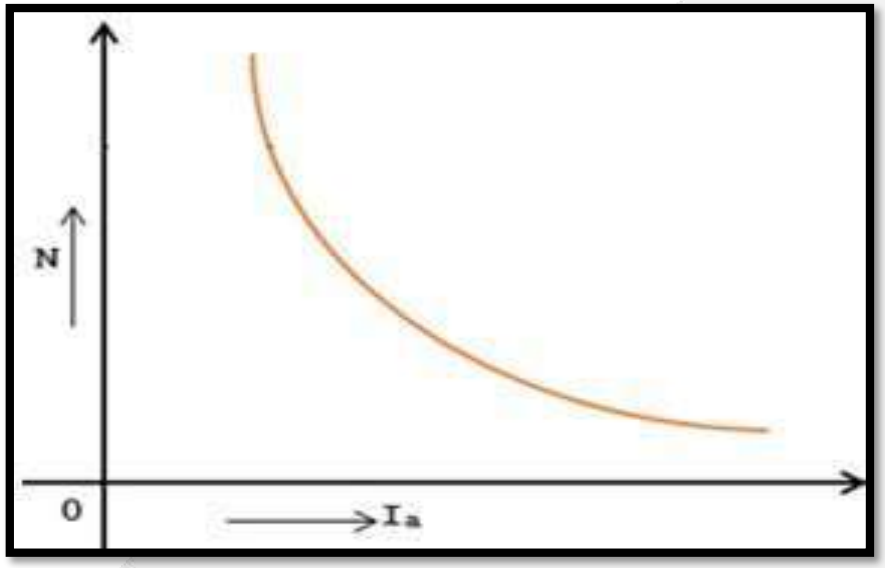


Fig.6 speed-torque curve for DC series motor

http://www.mytech-info.com/2014/12/characteristic-of-dc-series-motor.html

CHARACTERISTICS OF DC COMPOUND MOTOR

- A compound motor has both shunt and series field winding .The shunt field winding always stronger then series field winding.

Two types of the compound motor

(1) Cumulative compound motor
(current direction is same in series and shunt)

(2) Differentially compound motor
(current is in opposite direction in series and shunt winding)

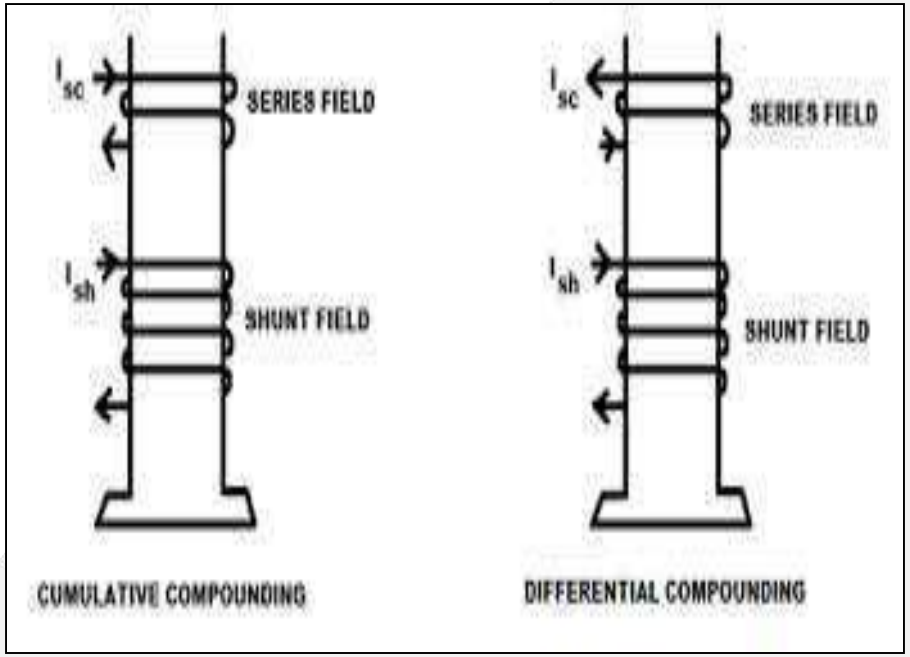


Fig:7 DC Compound Motor (Cumulative & Differential Compound)

https://top-ee.com/dc-compound-motor/

CUMULATIVE COMPOUND MOTOR

- In this series and shunt both characteristics are required
- The load is likely to be removed completely.
- Series winding takes care of the heavy load.
- The shunt winding prevents the motor from running at dangerously high speed.
- These motors have generally employed a flywheel, where sudden and temporary loads are applied like in rolling mills.

DIFFERENTIALLY COMPOUND MOTOR

- Series flux opposes shunt flux, the total flux decreases with increase in load.
- Thus the machine runs at a higher speed with increase in the load.
- This property is dangerous as on full load, the motor may try to run with dangerously high speed.
- So differential compound motor is generally not used in practice.

CHARACTERISTICS OF DC COMPOUND MOTOR

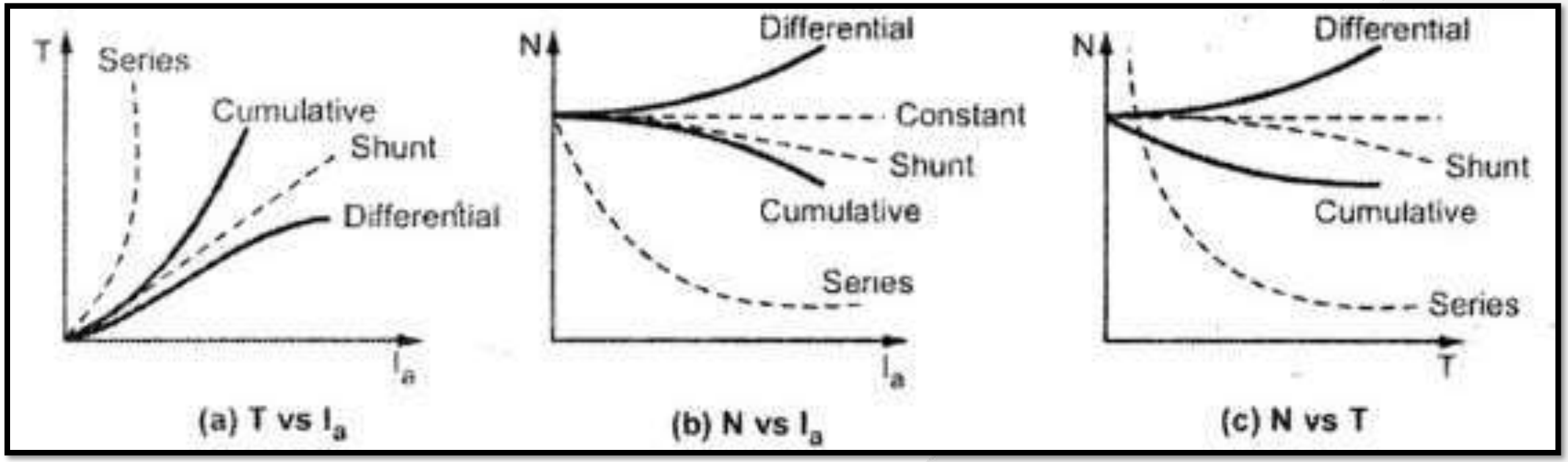


Fig:8 T-Ia Characteristics

Fig: 9 N-Ia Characteristics

Fig:10 N-T Characteristics

https://eeebooks4u.wordpress.com/2017/05/23/characteristics-of-dc-motors/

APPLICATIONS OF DC MOTORS

- Blower
- Fans
- Lathe machine
- Machine tool
- Drilling machines
- Punches
- Elevators

SUMMARY

- Types of characteristics of DC motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC shunt motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC series motor.
- Torque- armature current, speed - armature current and speed-torque characteristics of DC compound motor.
- Applications of DC motors.

FREQUENTLY ASKED QUESTIONS

- Give the classification of characteristics of DC motors
- Draw the torque speed curve for DC series motor.
- Design the torque armature current curve for DC shunt motor.
- Write the applications of DC motors.

BRUSHLESS DC MOTOR

- Permanent magnet (PM) brushless DC motors (BLDCM) are generated by virtually inverting the stator and rotor of PM DC motors.
- These motors are actually fed by rectangular AC waveform.
- The advantage is the removal of brushes, leading to eliminate many problems associated with brushes.

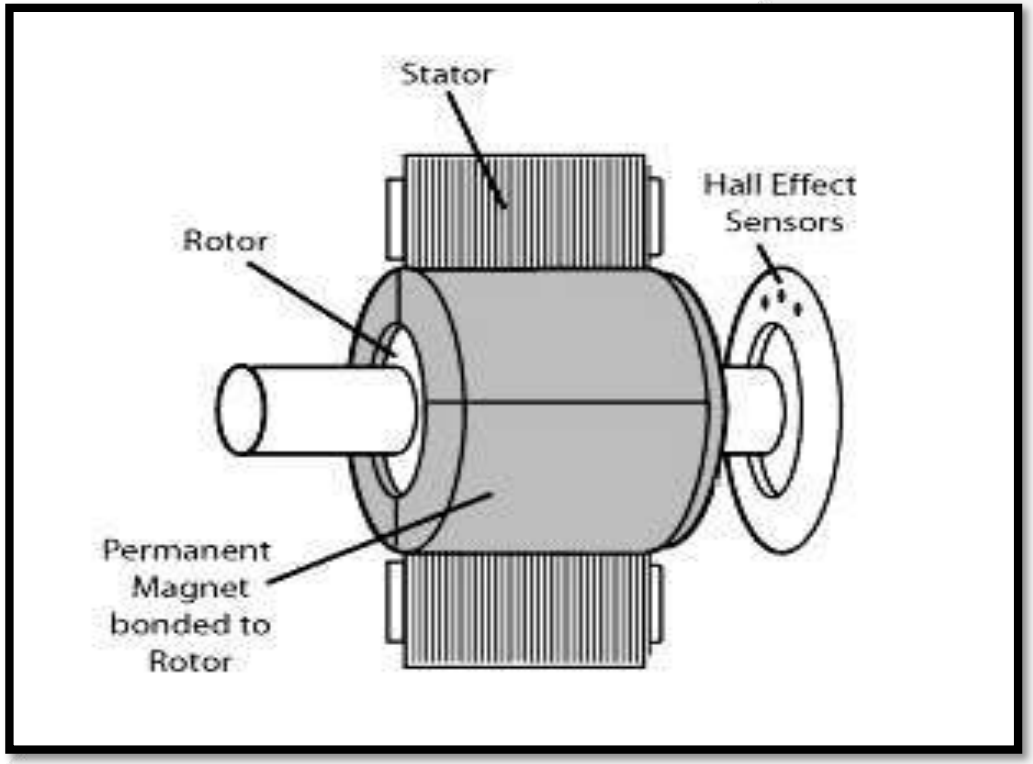


Fig.2 BLDC motor

https://www.elprocus.com/brushless-dc-motor-advantages-applications-and-control/

BRUSHLESS DC MOTOR

- Classical DC motors are no doubt good and simple but inefficient in some ways.
- Although dc motors possess good control characteristics and ruggedness, their performance and applications are inhibited due to sparking and commutation problems.
- The Permanent Magnet Brushless DC (PMBLDC) motor is able to overcome the limitations mentioned above and satisfy the requirements of a variable speed drive.

MAIN PARTS OF BRUSHED MOTOR

- ✓ Commutator -Facilitate collection of current from the armature conductors . Facilitate collection of current from the armature conductors.
- ✓ Brush -Collects current from the commutator.

BLDC MOTOR

- ✓ Has no brushes and commutators.
- ✓ Rotation of the rotor depends on the accurate position with stator.
- ✓ Detected by Hall Sensor, mounted on rotor, shifted at 60º or 120º phase shift.
- ✓ Electronic commutation used to vary the PWM duty-cycle for speed control, using software..

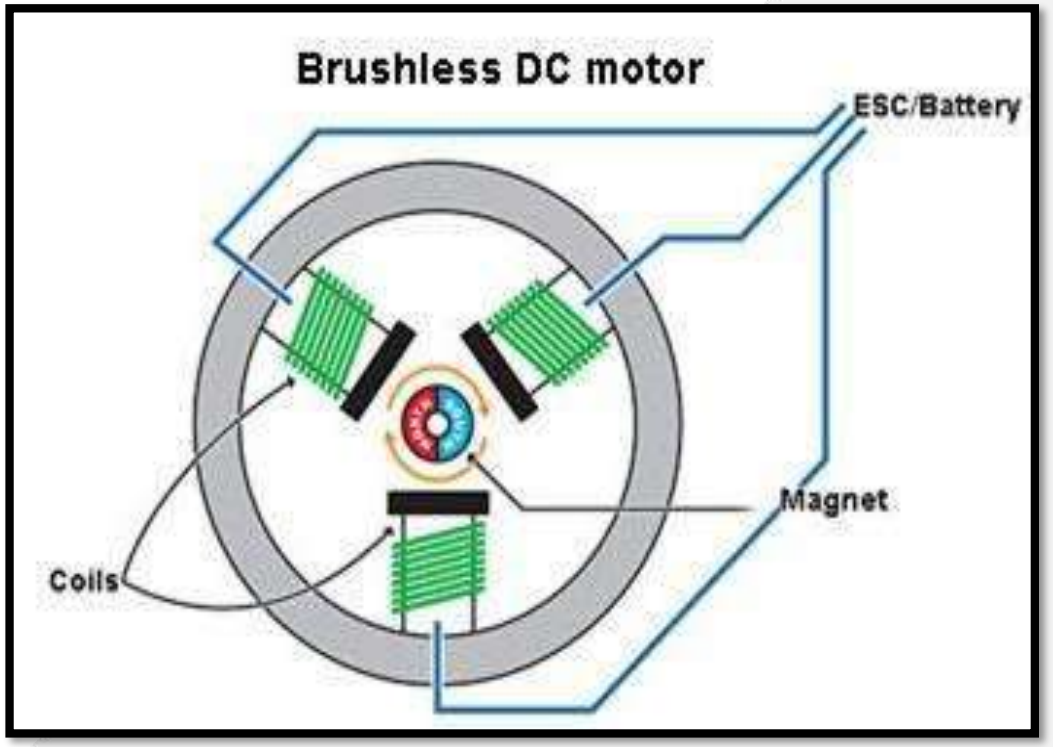


Fig-3(BLDCM)
https://images.app.goo.gl/2nFyQSrPrgkfo7FL8

WORKING OF BLDCM

- As there is no commutator ,the current direction of the conductor on the stator controlled electronically.
- Rotor consists the permanent magnet where as stator consist a no. of windings. Current through winding produces magnetic field and force.
- Hall sensor used to determine the position during commutation. Brushless DC motor requires external commutation circuit to rotate rotor.
- Rotor position is very important.
- HALL SENSOR senses the position of the coil accurately..

APPLICATIONS

PMBLDC motors are increasingly being used in a wide spectrum of applications:

- domestic equipments
- automobiles information technology equipment
- industries
- public life appliances
- transportation
- aerospace, defence equipments, power tools, toys, vision and sound equipments
- medical and health care equipment ranging from microwatts to megawatts

PRACTICE QUESTIONS

1. Explain the operation of geared motor.
2. Explain the operation of brushless motor.
3. What are the different types of brushless motor?

CONTENTS

- Introduction to single phase induction motor
- Basic construction of single phase induction motor
- Advantages and disadvantages of squirrel cage and slip ring rotor
- Working principle of single phase induction motor
- Applications of single phase induction motor
- Introduction to three phase induction motor with construction and working principle
- Advantages and disadvantages of three phase induction motor
- Applications of three phase induction motor

SINGLE PHASE INDUCTION MOTOR

TOPIC NAME: INTRODUCTION TO SINGLE PHASE INDUCTION MOTOR

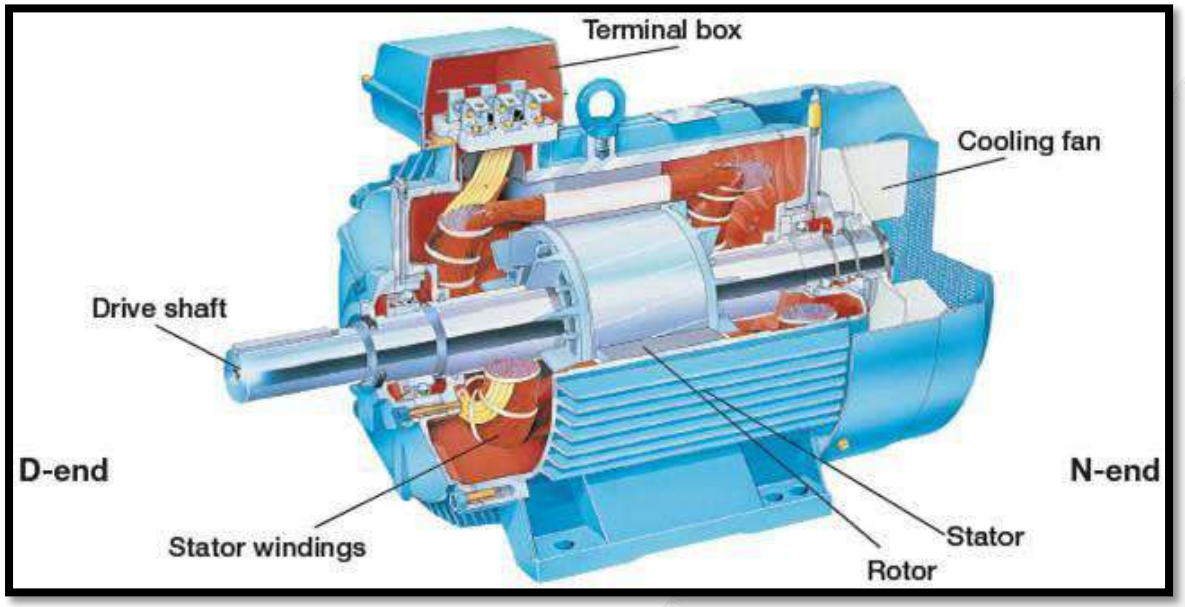


Fig.1

https://university.listenlights.com/2017/08/03/induction-motors/

SINGLE PHASE INDUCTION MOTOR

- Single-phase a.c supply is commonly used for lighting purpose in shops, offices, houses, schools etc.
- Hence instead of d.c motors, the motors which work on single-phase a.c. supply are popularly used. These a.c motors are called **single-phase induction motors**.
- Used in applications like small toys, small fans, hairdryers etc.

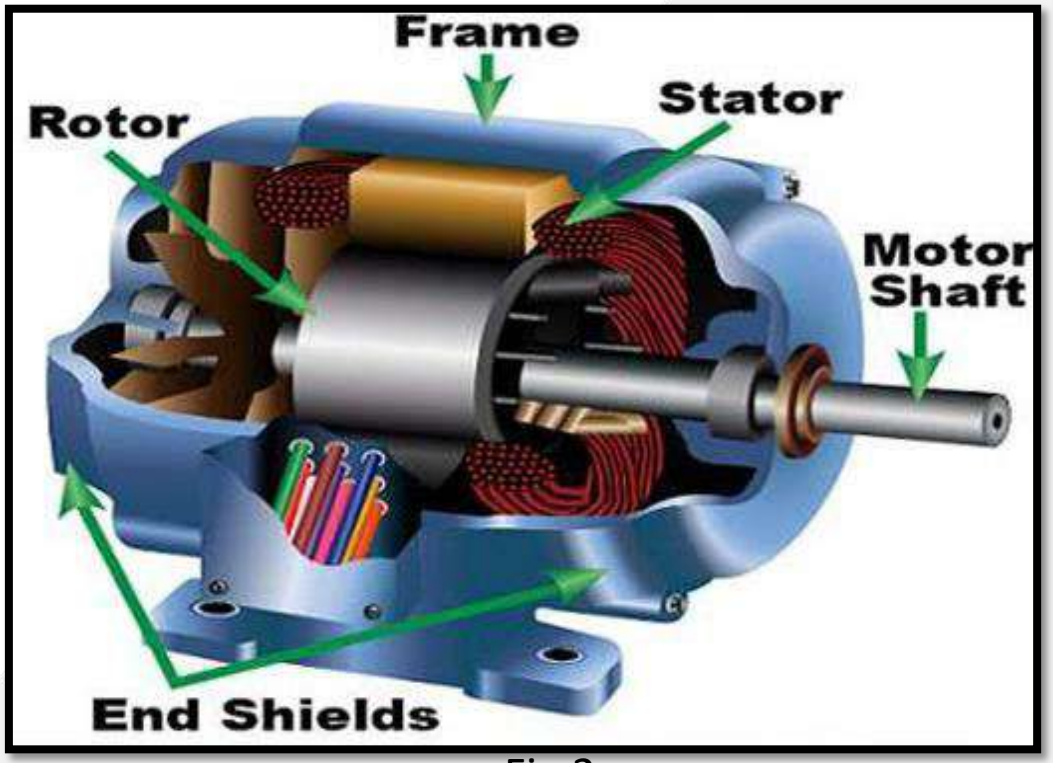


Fig.2

https://www.polytechnichub.com/construction-3-phase-induction-motor/

CONSTRUCTION OF SINGLE PHASE INDUCTION MOTOR

- **Single-phase induction motor** also has two main parts, one rotating and other stationary.
- The stationary part in single-phase induction motors is **Stator** and the rotating part is **Rotor**. The stator has laminated construction, made up of stampings.
- The number of poles for which stator winding is wound decides the synchronous speed of the motor.

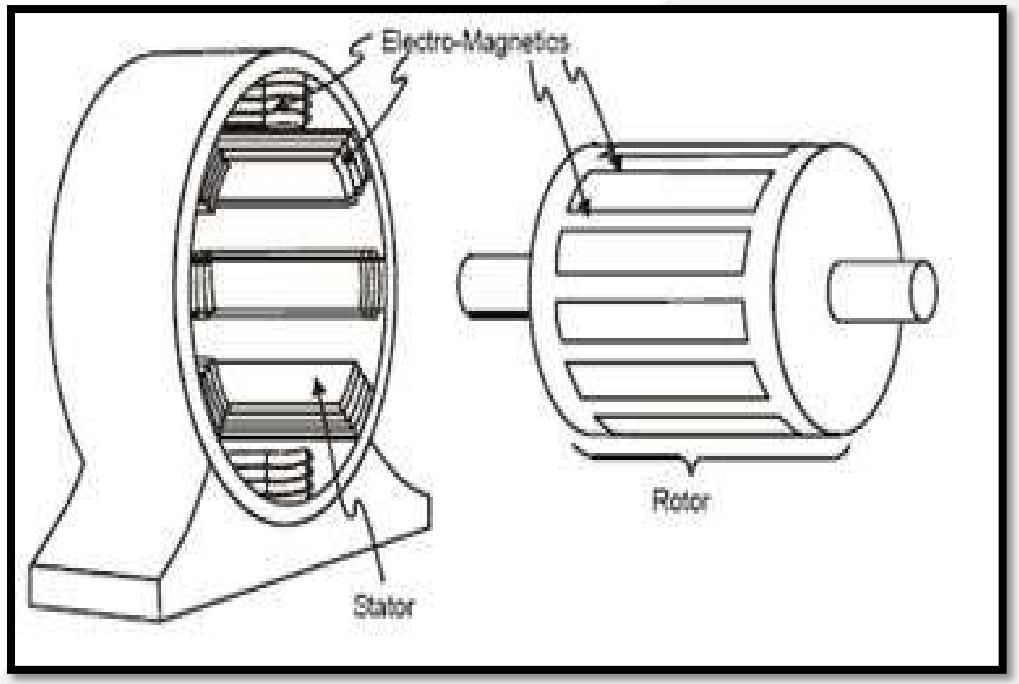


Fig.3

https://www.polytechnichub.com/construction-3-phase-induction-motor/

TYPES OF ROTOR

There are two types of rotor such as:

1. Squirrel cage rotor
2. Slip ring rotor

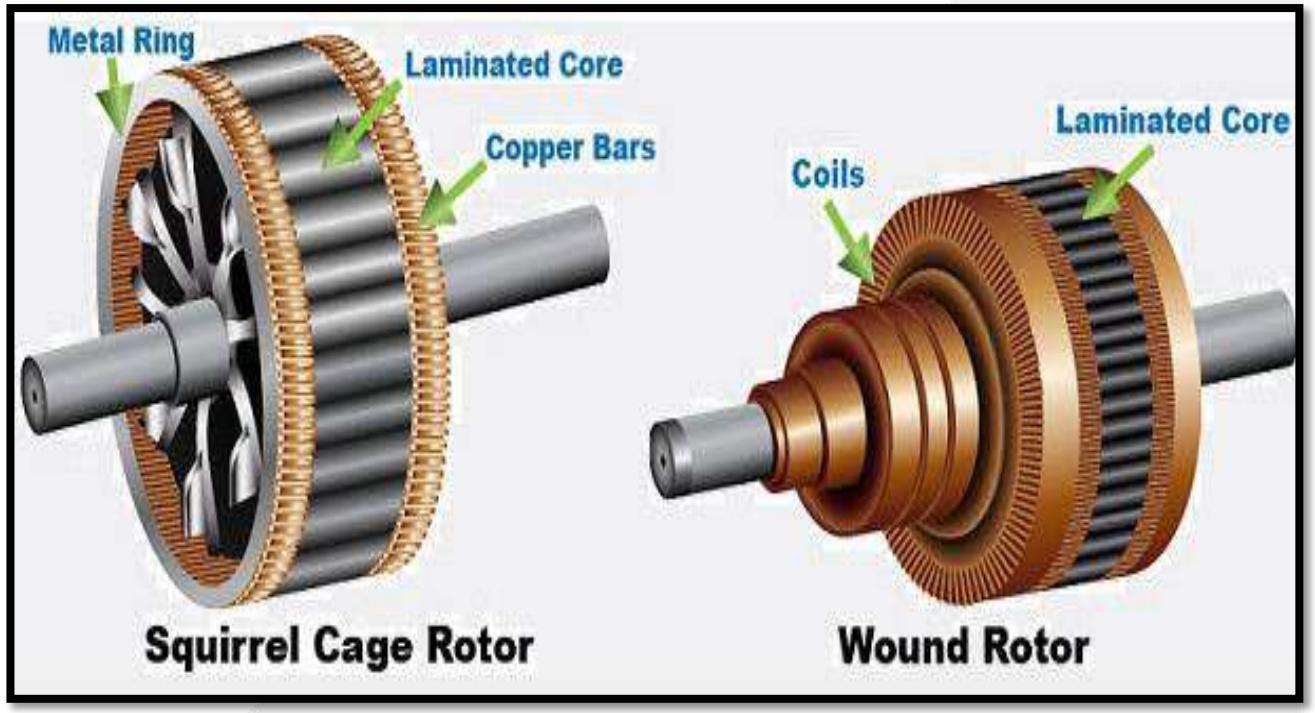


Fig.5

https://www.electricaledition.com/2017/06/squirrel-cage-slip-ring-induction-motor-differences.html

SQUIRREL CAGE ROTOR

- Squirrel cage motor is one of the types of induction motors. In order to generate motion, it hardens electromagnetism.
- As the output shaft is connected to the rotor inner component which is looking like a cage. Hence it is called squirrel cage.
- In order to avoid hysteresis and eddy currents that are leading to power loss, the rotor is laminated.

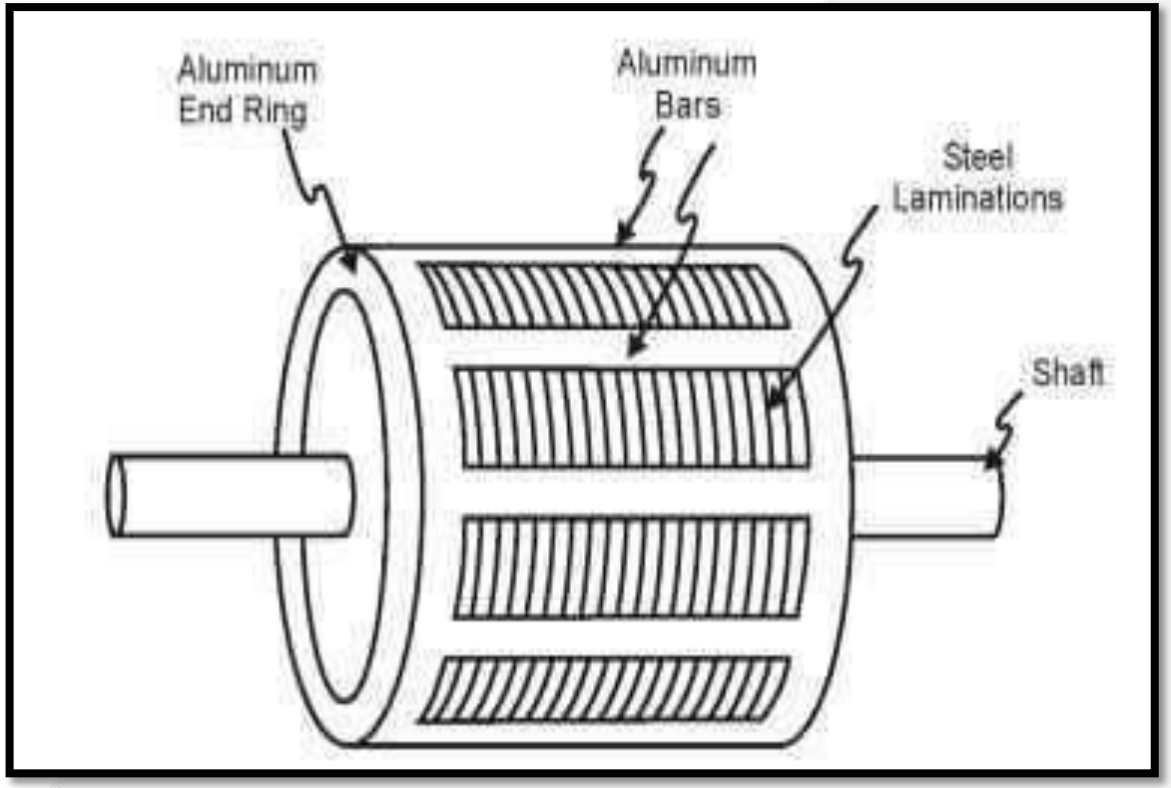


Fig.6

https://www.electrical4u.com/squirrel-cage-induction-motor/

ADVANATGES & DISADVANTAGES OF SQUIRREL CAGE ROTOR

Advantages:

- Simple and rugged construction.
- The low initial as well as maintenance cost.
- Maintains constant speed.

Disadvantages:

- High starting current.
- Very sensitive to fluctuations in supply voltage.
- Low power factor at light loads.

APPLICATIONS OF SQUIRREL CAGE ROTOR

The applications of squirrel cage induction motor include the following.

- Suitable for industrial drives of small power where speed control is not required such as for printing machinery, flour mills, and other shaft drives of small power.
- Centrifugal pumps, fans, blowers, etc

SLIP RING ROTOR

- A slip ring induction motor is referred to as an asynchronous motor as the speed at which it operates is not equal to the synchronous speed of a rotor.
- The rotor of this type of motor is wound type. It comprises of a cylindrical laminated steel core and a semi-closed groove at the outer boundary

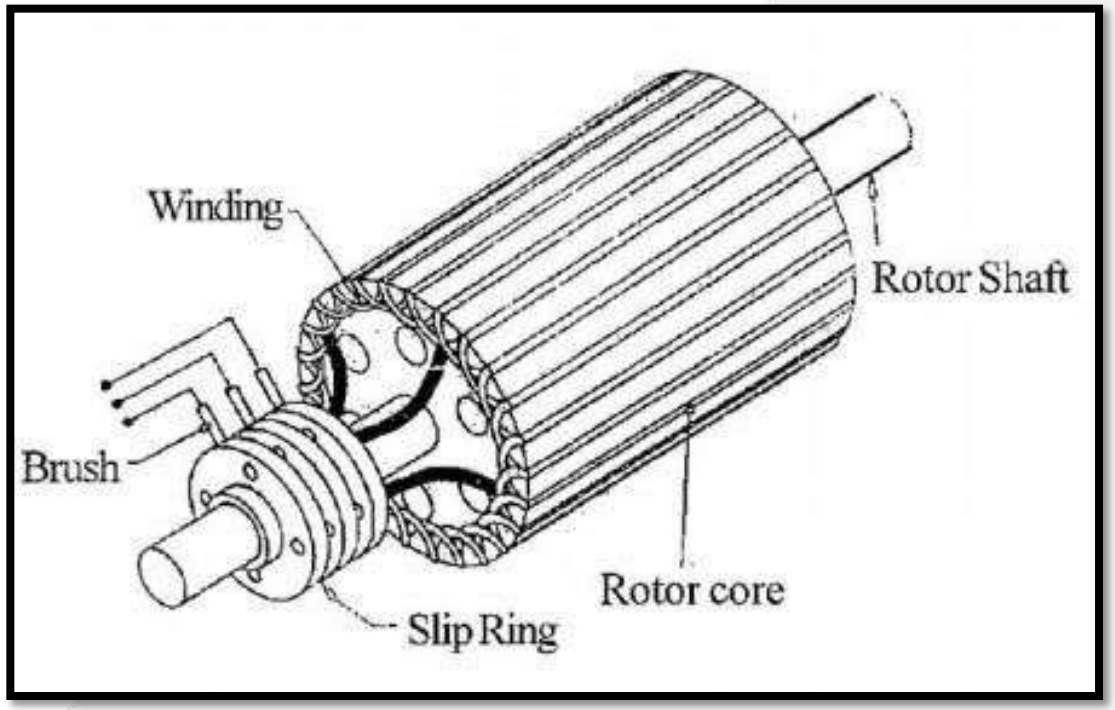


Fig.7

https://www.elprocus.com/what-is-slip-ring-induction-motor-and-its-working/

ADVANATGES & DISADVANTAGES OF SLIP RING ROTOR

Advantages:

- High and excellent starting torque to support high inertia loads.
- It has a low starting current due to external resistance.
- Can take full load current that is 6 to 7 times higher.

Disadvantages:

- Includes higher maintenance costs due to brushes and slip rings compared to squirrel cage motor.
- Intricate construction.

APPLICATIONS OF SLIP RING ROTOR

The applications of slip ring induction motor include the following.

- These motors are used where higher torque and low starting current are required.
- Used in applications like elevators, compressors, cranes, conveyors, hoists, and many more.

DIFFERENCE BETWEEN SQUIRREL CAGE & SLIP RING INDUCTION MOTOR

Parameters	Slip ring	Squirrel cage
Rotor	It has a rotor of wound type	Its rotor is of squirrel cage type.
Rotor slots	Rotor has cylindrical core has parallel slots, in which each slot has a bar	Slots are not parallel to each other
Construction	Construction is complicated because of slip rings and brushes	Simple construction

Table.1

DIFFERENCE BETWEEN SQUIRREL CAGE & SLIP RING ROTOR

Parameter	Slip ring	Squirrel cage
External resistance	External resistance circuit is connected with a motor	No external resistance circuit as bars of the rotor is completely slotted
Starting torque	High	Low
Efficiency	Low	High

Contd. Table.1

WORKING PRINCIPLE OF SINGLE PHASE INDUCTION MOTOR

- In the **single-phase induction motor**, single-phase a.c supply is given to the stator winding. The stator winding carries an alternating current which produces the flux which is also alternating in nature. This flux is called the main flux.
- This flux links with the rotor conductors and due to transformer action e.m.f gets induced in the rotor.
- The induced emf drives current through the rotor as the rotor circuit is the closed circuit.

WORKING PRINCIPLE OF SINGLE PHASE INDUCTION MOTOR

- This rotor current produces another flux called rotor flux required for the motoring action. Thus second flux is produced according to the induction principle due to induced e.m.f hence the motor is called **induction motor**.
- As against this in d.c motor a separate supply is required to the armature to produce armature flux. This is an important difference between d.c motor and an induction motor.

APPLICATIONS OF SINGLE PHASE INDUCTION MOTOR

- Fans
- Refrigerators
- Air-conditioners
- Vacuum cleaners
- Washing machines
- Centrifugal pumps
- Small farming appliances

INTRODUCTION TO THREE PHASE INDUCTION MOTOR

- The three phase induction motor is a preferable type of motor. It is mostly used in industrial drives because it is very reasonable and vigorous, economical and reliable.
- It is also called asynchronous motor because it does not run at a synchronous speed.
- The induction motor requires very little maintenance and also it has high overloading capacity.

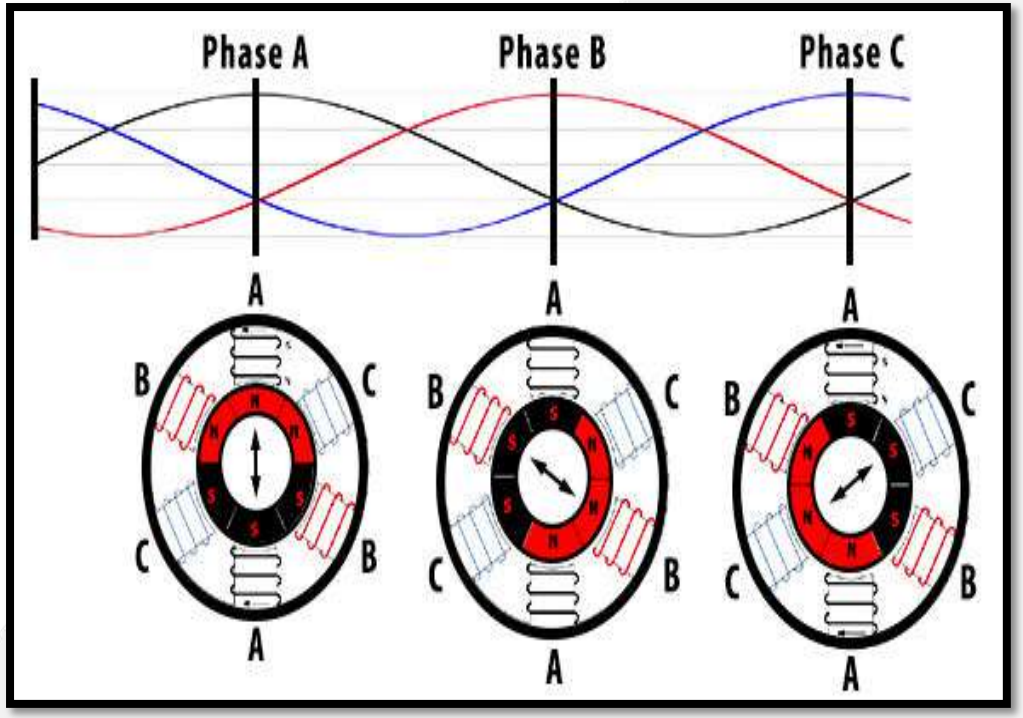


Fig. 8

https://www.kebamerica.com/blog/how-a-3-phase-ac-induction-motor-works/

INTRODUCTION TO THREE PHASE INDUCTION MOTOR

- In the case of three phase AC (alternating current) operation, the most widely used motor is a **3 phase induction motor**, as this type of motor does not require an additional starting device.
- These types of motors are known as self-starting induction motors.

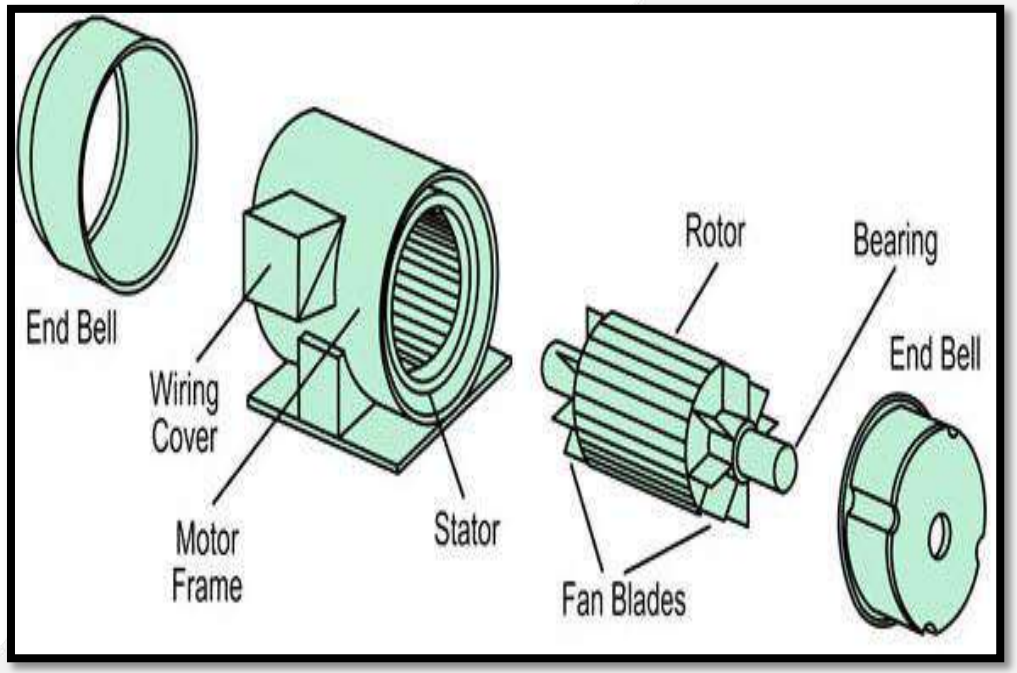


Fig. 9

https://www.elprocus.com/three-phase-ac-induction-motor-control-using-svpwm/

CONSTRUCTION OF THREE PHASE INDUCTION MOTOR

•A three phase **Induction motor** mainly consists of two parts called as the **Stator** and the **Rotor**.

•The stator is the stationary part of the induction motor, and the rotor is the rotating part.

There are two types of rotor such as:

1. Squirrel cage
2. Slip ring

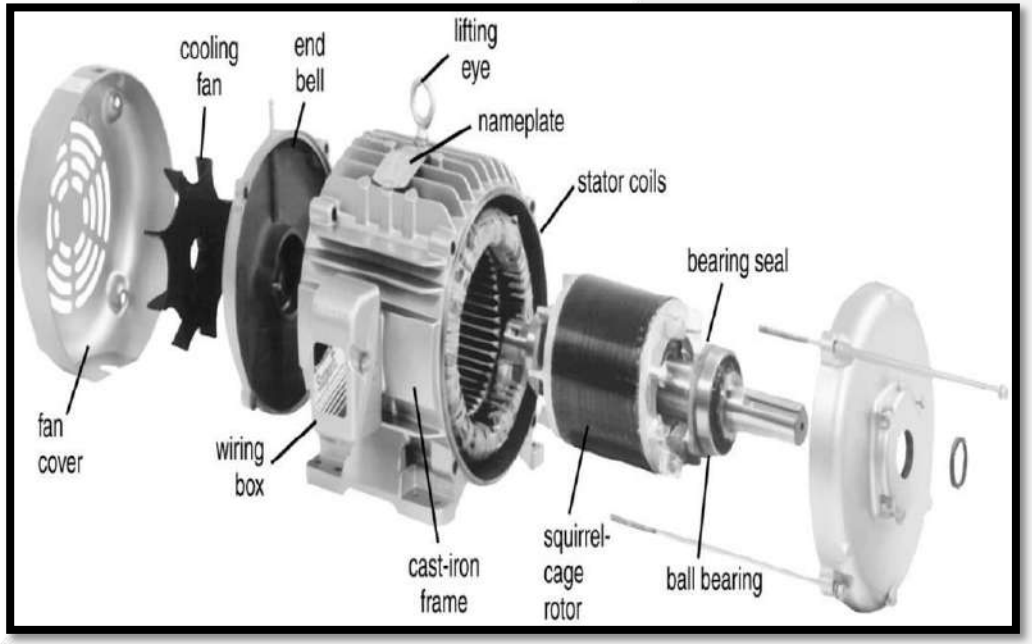


Fig. 10

https://electricalacademia.com/induction-motor/three-phase-induction-motor-construction/

STATOR OF THREE PHASE INDUCTION MOTOR

- The stator is built up of high-grade alloy steel laminations to reduce eddy current losses.
- It has three main parts, namely outer frame, the stator core and a stator winding.

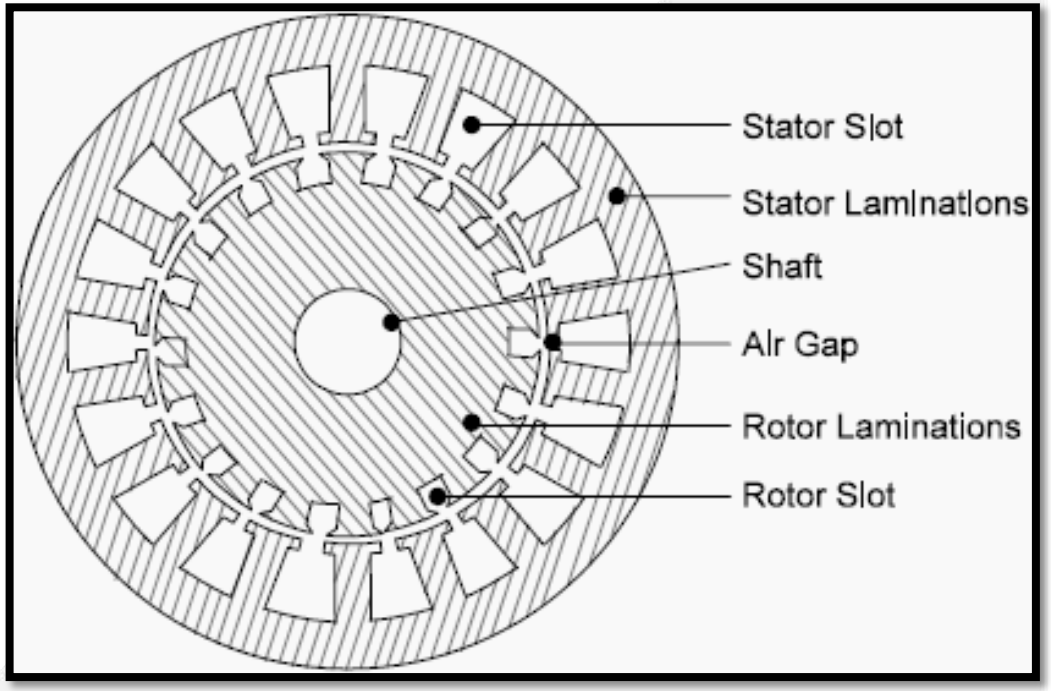


Fig. 11

https://electrical-engineering-portal.com/construction-of-3-phase-ac-induction-motors

SQUIRREL CAGE ROTOR

- A squirrel cage rotor consists of a laminated cylindrical core.
- The circular slots at the outer periphery are semi-closed.
- Each slot contains uninsulated bar conductor of aluminium or copper.

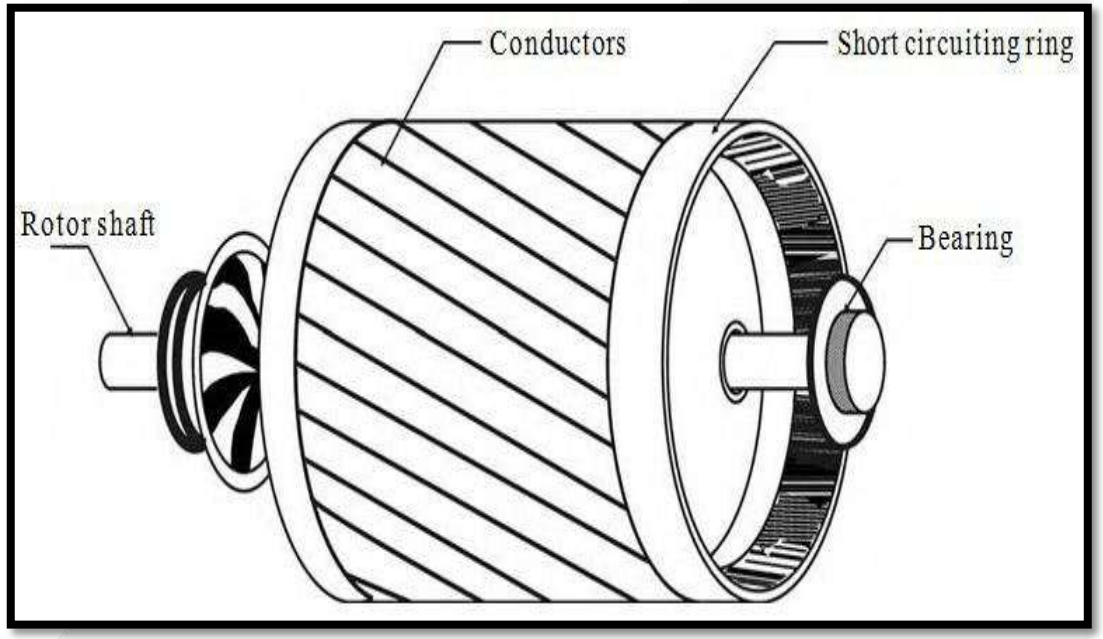


Fig. 12

https://www.theengineeringprojects.com/2016/10/squirrel-cage-induction-motor.html

SLIP RING ROTOR OR PHASE WOUND ROTOR

- The Phase wound rotor is also called as Slip Ring Rotor.
- It consists of a cylindrical core which is laminated.
- The outer periphery of the rotor has a semi-closed slot which carries a 3 phase insulated windings. The rotor windings are connected in star.

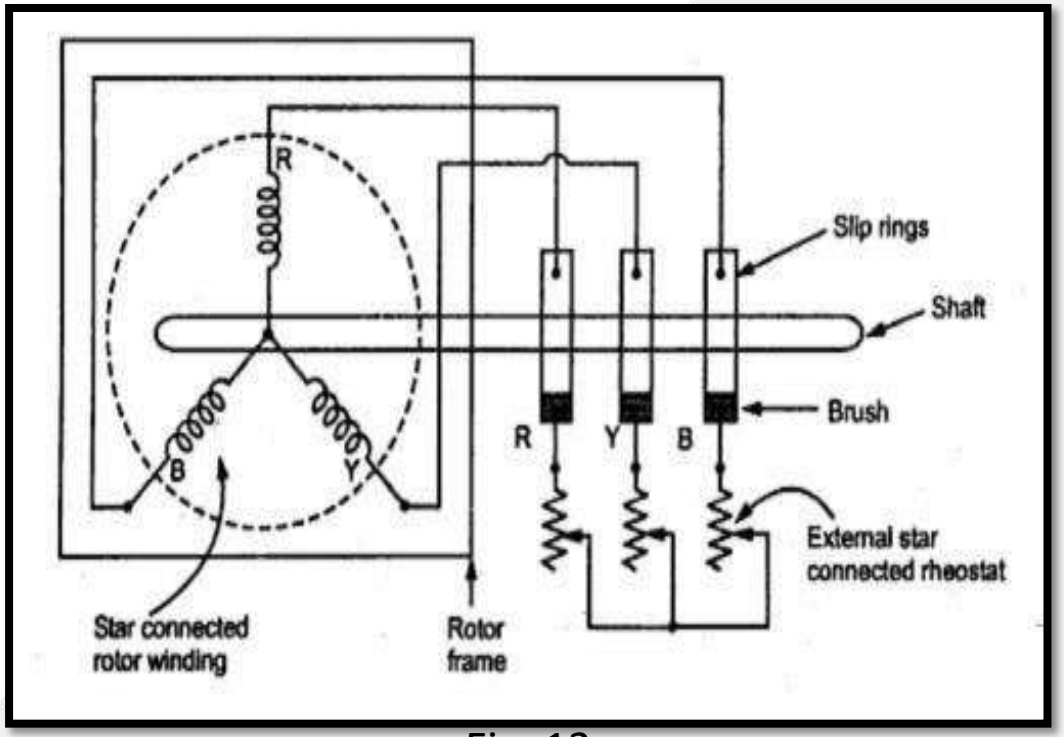


Fig. 13

https://electricallive.com/2015/03/slip-ring-rotor-or-wound-rotor-in-three.html

WORKING OF THREE PHASE INDUCTION MOTOR

- When 3 phase supply is given to the motor, the resulting current generates a magnetic flux "Ø".
- Due to the switching sequence of 3 phase current in R, Y, and B, the generated flux rotates around the rotor conductor.
- According to Faraday's law, which states that –"an emf induced in any closed circuit is due to the rate of change of magnetic flux through the circuit", Emf is induced in the copper bar and due to this, current flows in the rotor.

WORKING OF THREE PHASE INDUCTION MOTOR

- The direction of the rotor can be given by Lenz law which states that – "the direction of induced current will be in the opposite of the motion causing it."
- Here the relative velocity between the rotating flux and static rotor conductor is the cause of current generation; hence the rotor will rotate in the same direction to reduce the cause i.e. the relative velocity, thus rotating the rotor of the induction motor.

SPEED OF THREE PHASE INDUCTION MOTOR

- The speed of three phase induction motor is given by:

$$Ns = 120f/P$$

Where

Ns = synchronous speed

f = supply frequency

P = number of poles

SLIP OF SINGLE PHASE INDUCTION MOTOR

- The slip in an induction motor is the difference between the main flux speed and their rotor speed.
- The symbol S represents the slip. It is expressed by the percentage of synchronous speed. Mathematically, it is written as

$$\%S = \frac{N_s - N}{N_s} \times 100$$

Where Ns is synchronous speed and Nr is rotor speed.

ROTOR SPEED OF SINGLE PHASE INDUCTION MOTOR

- The rotor speed is given by the equation shown below.

$$N_r = N_S (1 - S)$$

Alternatively, if

- Ns is the synchronous speed in revolution per second
- Nr is the actual rotor speed in revolution per second.
- S is slip.

FREQUENCY OF ROTOR

The rotor frequency is given by the equation shown below.

$$fr = s.\ fs$$

Where fr is rotor frequency

- s is slip
- fs is supply frequency

At standstill condition

Slip s = 1, then rotor frequency

$$fr = 1.\ fs$$

ADVANTAGES OF THREE PHASE INDUCTION MOTOR

Advantages:

- They are robust and simple in construction with very few moving parts
- They can efficiently operate in a rugged and harsh environment such as in seagoing vessels
- The maintenance cost of 3 phase induction motor is less and unlike that of DC or synchro motor, they do not have parts like brushes, commuters or slip rings etc.

DISADVANTAGES OF THREE PHASE INDUCTION MOTOR

Disadvantages:

- During starting, it draws high initial starting current when attached to a heavy load.
- Induction motor operates at lagging power factor which results in increased I2R losses and efficiency reduction, especially at low load.
- Speed control of 3 phase induction motor is difficult as compared to DC motors.

APPLICATIONS OF THREE PHASE INDUCTION MOTOR

- Lifts
- Cranes
- Large capacity exhaust fans
- Engine Auxiliary pumps
- Engine blower fan motor

DIFFERENCE BETWEEN SINGLE PHASE & THREE PHASE INDUCTION MOTOR

Parameters	Single phase induction motor	Three phase induction motor
Supply	Single Phase induction motor uses single phase supply, for its operation.	Three Phase induction motor uses three phase supply, for its operation
Maintenance	They are easy to repair and maintain.	Difficult to repair and maintain.
Efficiency	Efficiency is less	Efficiency is high

Table.1

DIFFERENCE BETWEEN SINGLE PHASE & THREE PHASE INDUCTION MOTOR

Parameters	Single phase induction motor	Three phase induction motor
Power Factor	Power factor is low	Power factor is high
Applications	They are mostly used in domestic appliances such as mixer grinder, fans, compressors etc	Three phase induction motors are mostly used in industries.
Cost	Cheaper	Quiet expensive

Table.1

SUMMARY

- ✓Introduction to single phase induction motor.
- ✓Construction of single phase induction motor.
- ✓Working principle of single phase induction motor.
- ✓Difference between squirrel cage and slip ring rotor.
- ✓Introduction to three phase induction motor.
- ✓Construction and working of three phase induction motor.
- ✓Difference between single phase and three phase induction motor.

FREQUENTLY ASKED QUESTIONS

- What do you understand by single phase induction motor?
- What is the difference between squirrel cage and slip ring rotor?
- What is meant by slip in induction motor?
- Give the brief description of three phase induction motor.
- Differentiate between single phase and three phase induction motor.

CONTENTS

- Introduction to Gear motor with its construction and working.
- Introduction of servo motor.
- Construction of servo motor.
- Working principle of DC servomotor.
- Advantages disadvantages and applications of servo motor.
- Stepper Motor with its working and types.
- Advantages ,disadvantages and applications of stepper motor.
- Linear motor with its construction and working.

WHAT IS A GEAR MOTOR?

- Gear motors are complete motive force systems consisting of an electric motor and a reduction gear train integrated into one easy-to-mount and –configure package.
- This greatly reduces the complexity and cost of designing and constructing power tools, machines and appliances calling for high torque at relatively low shaft speed or RPM.

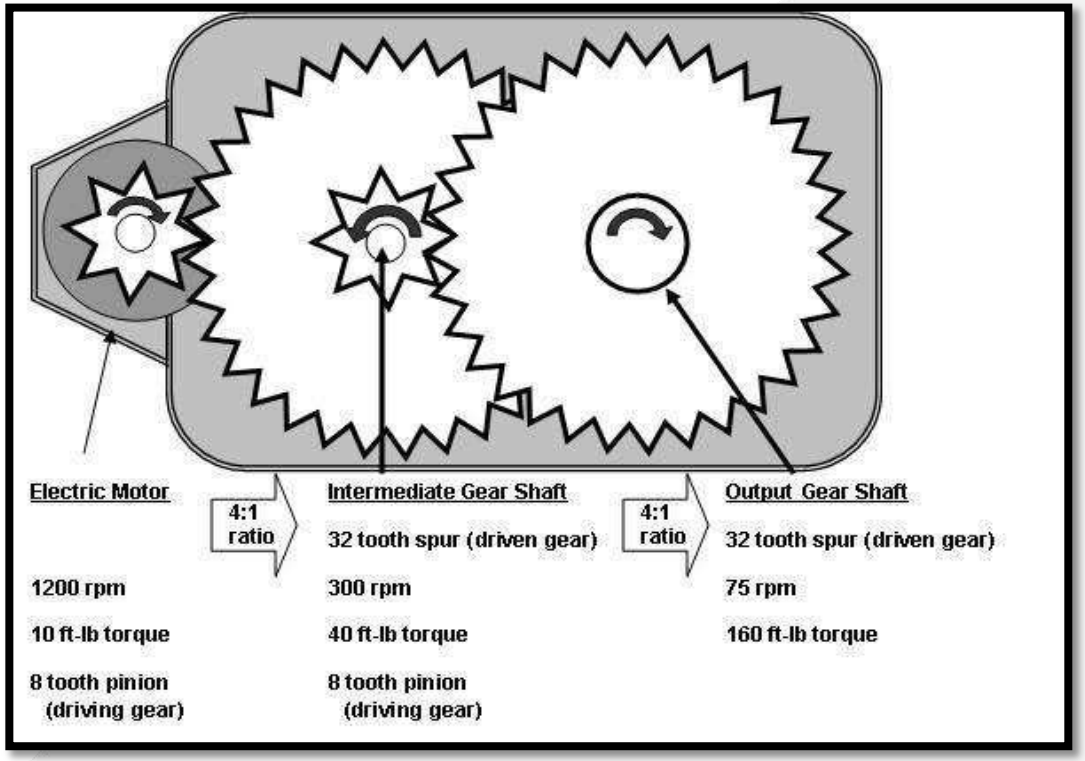


Fig-1-(geared motor)

https://in.pinterest.com/pin/422845852485215270/

OPERATING PRINCIPLE OF GEAR MOTOR

- Most synchronous AC electric motors have output ranges of from 1,200 to 3,600 revolutions per minute. They also have both normal speed and stall-speed torque specifications.
- The reduction gear trains used in gear motors are designed to reduce the output speed while increasing the torque. The increase in torque is inversely proportional to the reduction in speed. Reduction gearing allows small electric motors to move large driven loads, although more slowly than larger electric motors.
- Reduction gears consist of a small gear driving a larger gear. There may be several sets of these reduction gear sets in a reduction gear box.

TYPES OF GEAR MOTORS

- Helical gear motor
- Shaft mounted gear motor
- Bevel-geared motor
- Worm geared motor.

FEATURES OF GEAR MOTORS

Some of the salient features that geared motors possess are:

- Available in standard gear mechanism
- Available in non lubricated metal bearing gear mechanism Also, available in planetary gear mechanism
- Provides speed reduction by the means of a gear box Increases the torque ratio

FEATURES OF GEAR MOTORS

- Provides protection against overload and locked rotor
- Used as precautions for instantaneous reversing and dynamic braking
- Used in speed detection and control

MAIN AIM OF USING GEAR MOTORS

The main aim of using gear motors are:

- Everything in one box
- Easy to Control
- Wide range of sizes, speeds and options
- Mounting
- Durability

APPLICATIONS OF GEAR MOTOR

- Garage door openers
- Stair lifts
- Timer cycle knobs on washing machines
- Power drills
- Cake mixers
- Electromechanical clocks

WHAT IS THE MEANING OF SERVO?

- In modern usage the term servo or servo-mechanism is restricted to a feedback control system in which the controlled variable is mechanical position or time derivatives of position such as velocity and acceleration.
- A servo is a device, electrical, mechanical or electro mechanical, that upon receipt of a input will employ feedback for velocity and/or position control, creating a closed loop.

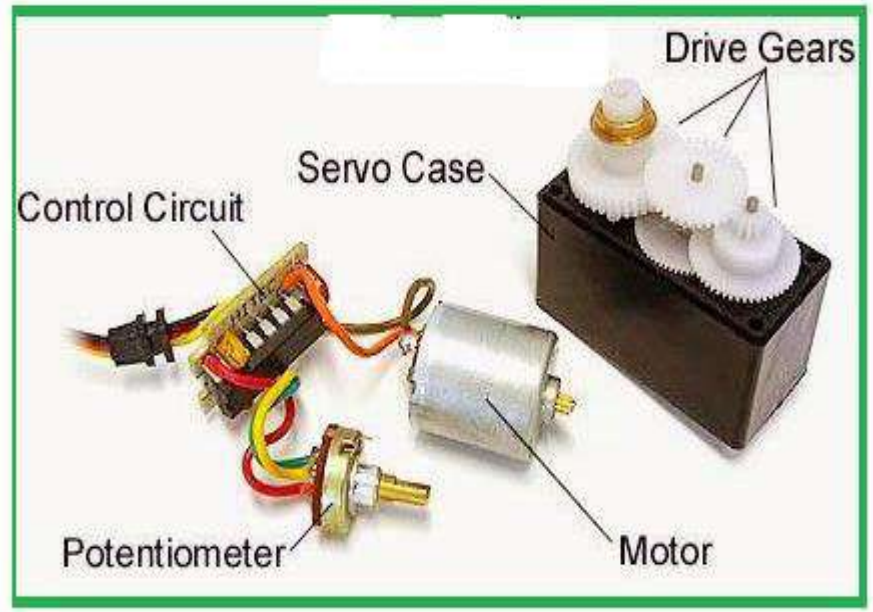


Fig-1 (Servo Motor)

http://eee-resetsg.blogspot.com/2016/01/construction-of-simple-servo-motor.html

CONSTRUCTION OF SERVO MOTOR

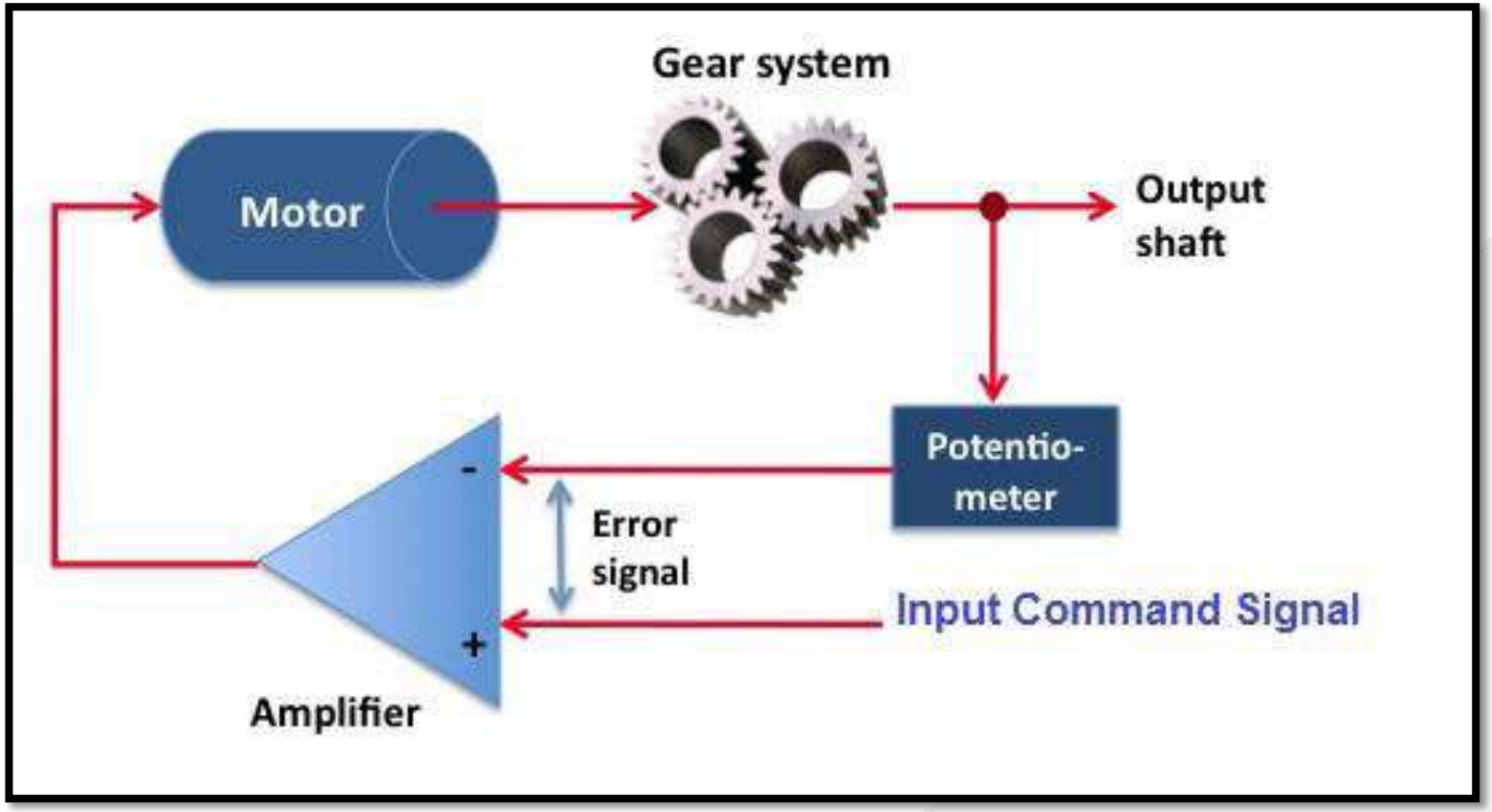


Fig-2(construction of servo motor)

https://electricalbaba.com/basics-of-servomechanism-and-servo-motor/

Working principle of Servomotor

It is having three major parts:

1. Controlled device
2. Feedback system
3. Output sensor

- The servo motor works on the phenomenon of the automatic closed-loop system. The controller is required for this closed-loop system.
- This controller is composed of a comparator and a feedback path. It has one output and two inputs.
- In this, for producing an output signal, the comparator is used to compare the required reference signal and this output signal is sensed by the sensor. The input signal for the motor is termed as a feedback signal.
- On the basis of the feedback signal, the motor starts working. Comparator signal is called a logic signal of the motor.
- The motor would be ON for the desired time when the logical difference is higher and the motor would be OFF for the desired time when the logical difference is lower.
- Basically, a comparator is used to decide that motor would be ON or OFF. Proper functioning of the motor can be done with the help of a good controller.

ADVANTAGES

- ✓ High output power relative to motor size and weight.
- ✓ Encoder determines accuracy and resolution.
- ✓ High efficiency. It can approach 90% at light loads.
- ✓ High torque to inertia ratio. It can rapidly accelerate loads.
- ✓ Has "reserve" power. 2-3 times continuous power for short periods.
- ✓ Has "reserve" torque. 5-10 times rated torque for short periods.
- ✓ Motor stays cool. Current draw proportional to load.

DISADVANTAGES

- ✓ Requires "tuning" to stabilize feedback loop.
- ✓ Motor "runs away" when something breaks. Safety circuits are required.
- ✓ Brush wear out limits life to 2,000 hrs. Service is then required.
- ✓ Peak torque is limited to a 1% duty cycle.
- ✓ Motor can be damaged by sustained overload.
- ✓ Bewildering choice of motors, encoders, and servo-drives.
- ✓ Power supply current 10 times average to use peak torque.
- ✓ Motor develops peak power at higher speeds. Gearing often required.
- ✓ Poor motor cooling. Ventilated motors are easily contaminated.

APPLICATIONS

- They play an important role in robotics information of robot because of their smooth switching on or off and accurate positioning.
- They are used in hydraulic systems to maintain hydraulic fluid in the aerospace industry.
- In radio controlled toys these are also used.
- They are used to extend or replay the disc trays in electronic devices such as DVDs or Blue-ray Disc players.
- They are used to maintain the speed of vehicles in the automobile industries.

STEPPER MOTOR

- A stepper motor is an electromechanical device which converts train of pulses into discrete mechanical movements.
- The shaft of motor rotates through a fixed angle for each discrete pulse. This rotation can be linear or angular.
- When a train of pulses is applied, it gets turned through a certain angle.
- The angle through which the stepper motor shaft turns for each pulse is referred as step angle.

WORKING OF STEPPER MOTOR

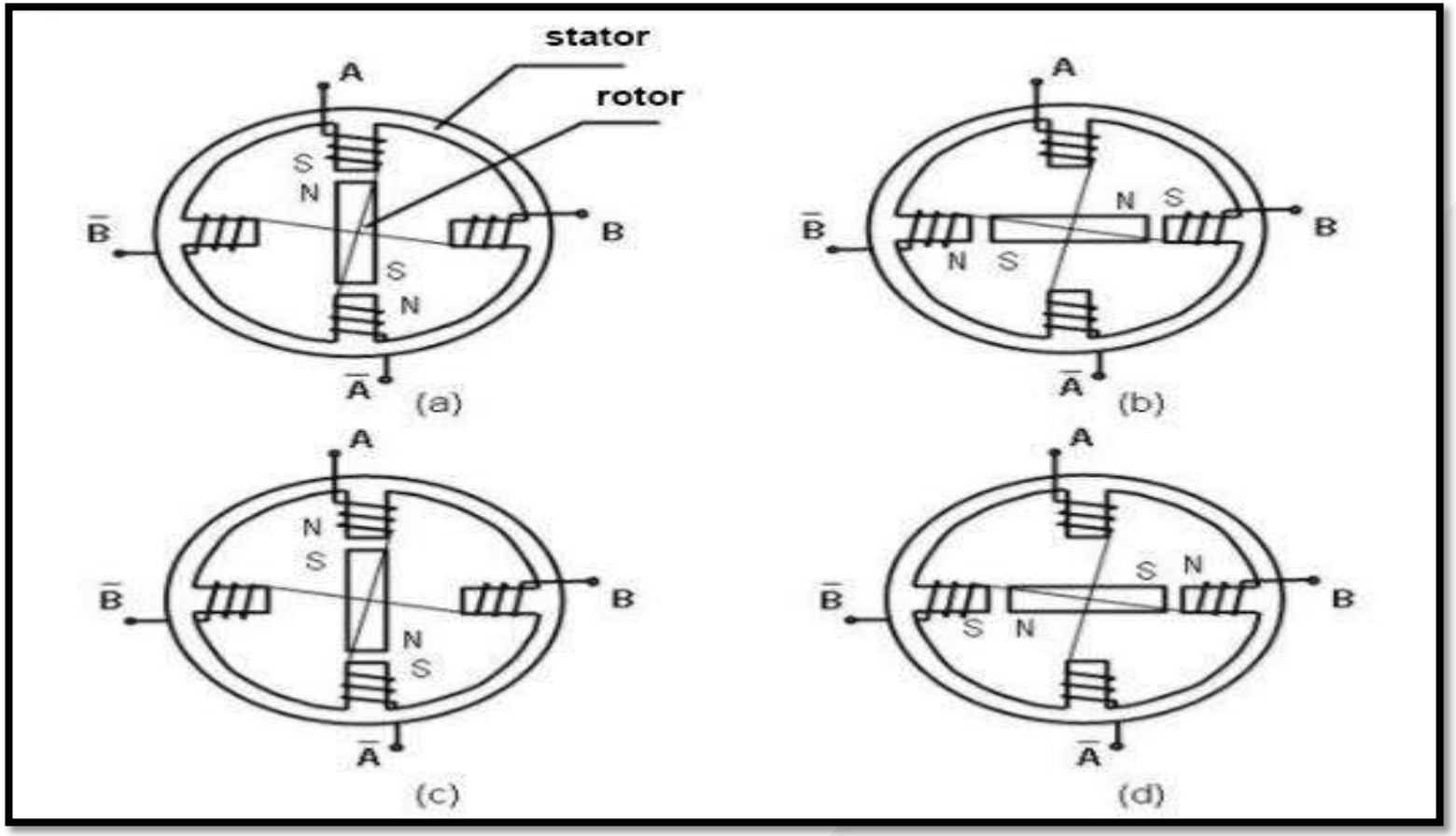


Fig-3(stepper motor)
https://images.app.goo.gl/PsZMXpQW5ZgWaqZi6

OPERATION OF STEPPER MOTOR

- Each of those slight rotations is called a step, with an integer number of steps making a full rotation.
- In that way, the motor can be turned by a precise.
- Stepper motor doesn’t rotate continuously, they rotate in steps.
- There are 4 coils with 90 deg angle between each other fixed on the stator.
- The stepper motor connections are determined by the way the coils are interconnected.
- In stepper motor, the coils are not connected together.
- The motor has 90deg rotation step with the coils being energized in a cyclic order.

WORKING OF STEPPER MOTOR

- The stepper motor rotor is a permanent magnet, when the current flows through the stator winding, the stator winding to produce a vector magnetic field.
- The magnetic field drives the rotor to rotate by an angle so that the pair of magnetic fields of the rotor and the magnetic field direction of the stator are consistent.
- When the stator's vector magnetic field is rotated by an angle, the rotor also rotates with the magnetic field at an angle.
- Each time an electrical pulse is input, the motor rotates one degree further. The angular displacement it outputs is proportional to the number of pulses input and the speed is proportional to the pulse frequency.
- it can control the rotation of the stepping motor by controlling the number of pulses, the frequency and the electrical sequence of each phase winding of the motor.

TYPES OF STEPPER MOTOR

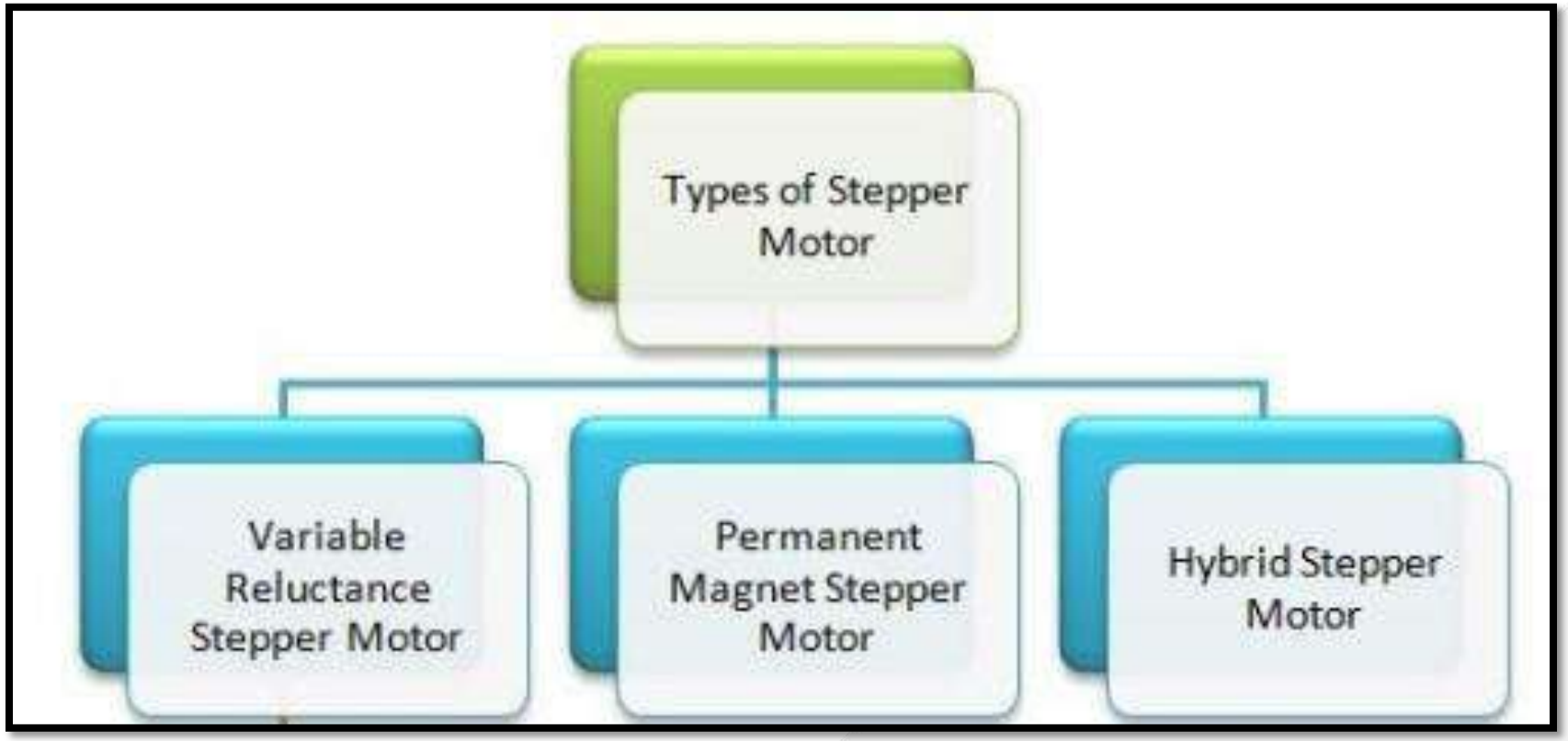


Fig-4(types of stepper motor)
https://circuitglobe.com/stepper-motor.html

PERMANENT MAGNET STEPPER MOTOR

- Permanent magnet motors use a permanent magnet (PM) in the rotor.
- It operate on the attraction or repulsion between the rotor PM and the stator electromagnets.
- When the stator windings are excited with DC supply, it produces magnetic flux and establishes north poles and south poles.
- Due to force of attraction and repulsion between PM rotor poles and stator poles, the rotor starts moving upto the position for which pulses are given to the stator.

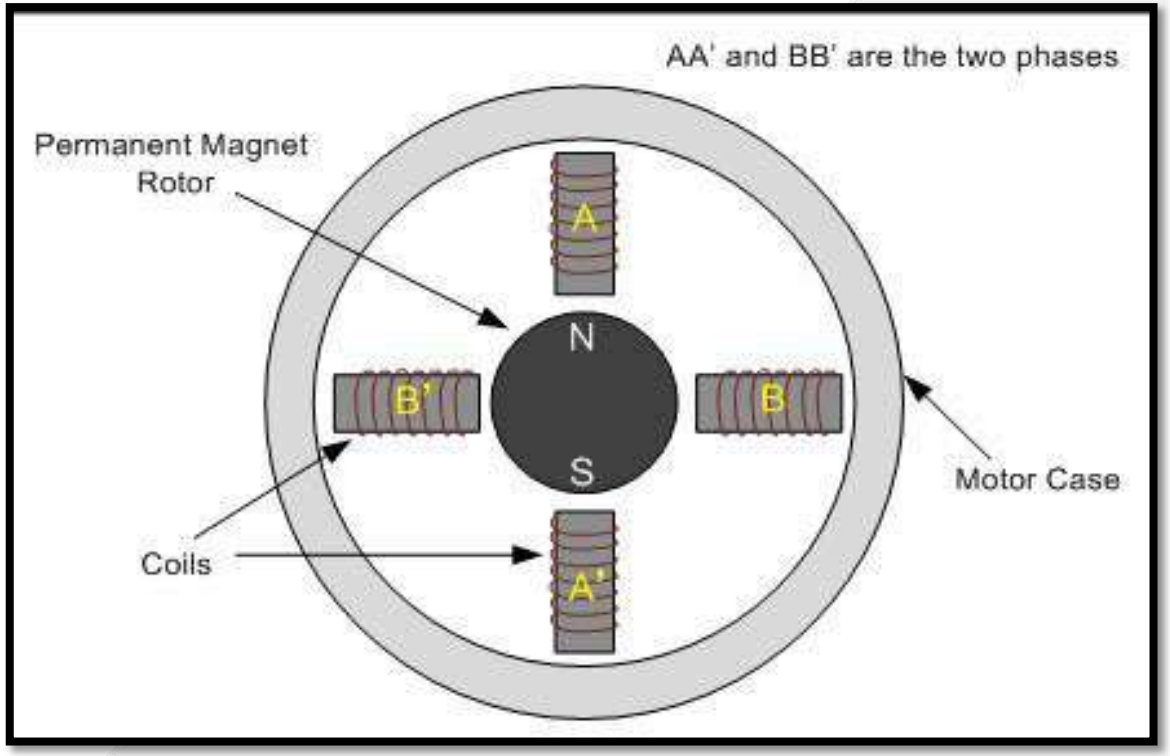


Fig.5 Permanent magnet stepper motor

https://www.engineersgarage.com/article_page/stepper-motor-basics-types-and-working/

VARIABLE RELUCTANCE STEPPER MOTOR

•Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

•All the stator poles are aligned in a Multi-Stack motor. But the rotor poles are displaced by 1/m of the pole pitch angle from each other.

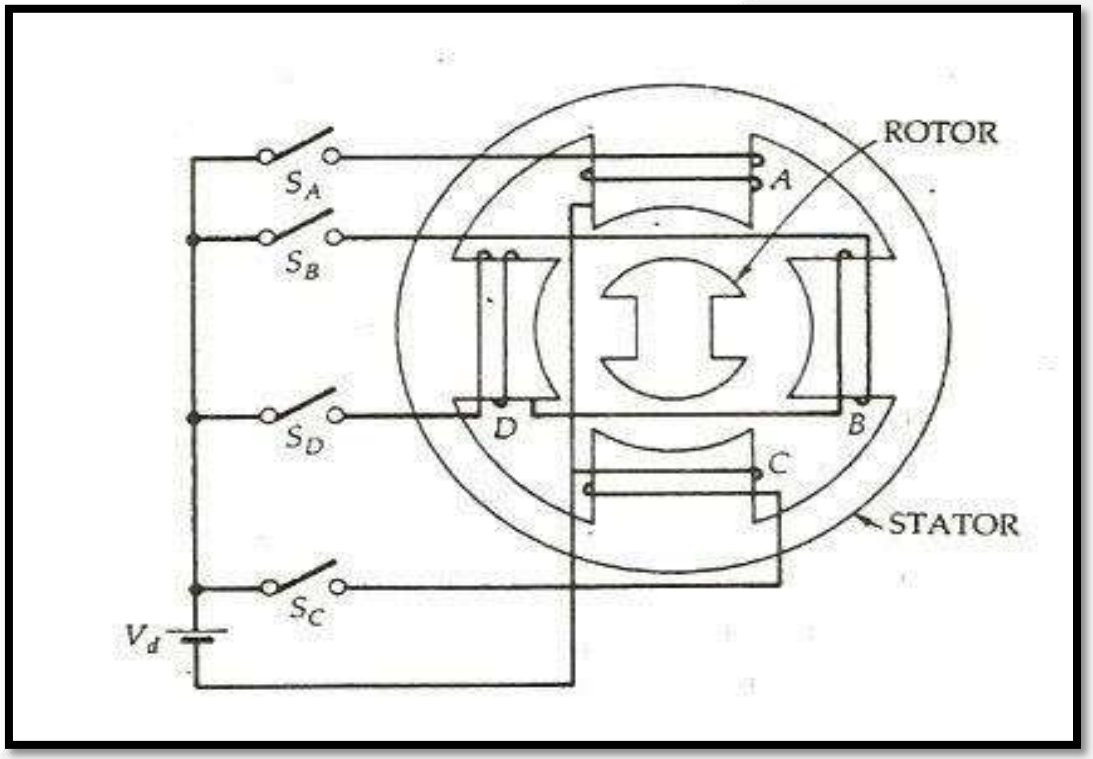


Fig.6 variable stepper motor

https://circuitglobe.com/variable-reluctance-stepper-motor.html

HYBRID STEPPER MOTOR

- Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in a small package size.
- The **Hybrid Stepper Motor** is a combination of the features of the variable reluctance motor and permanent magnet stepper motor.

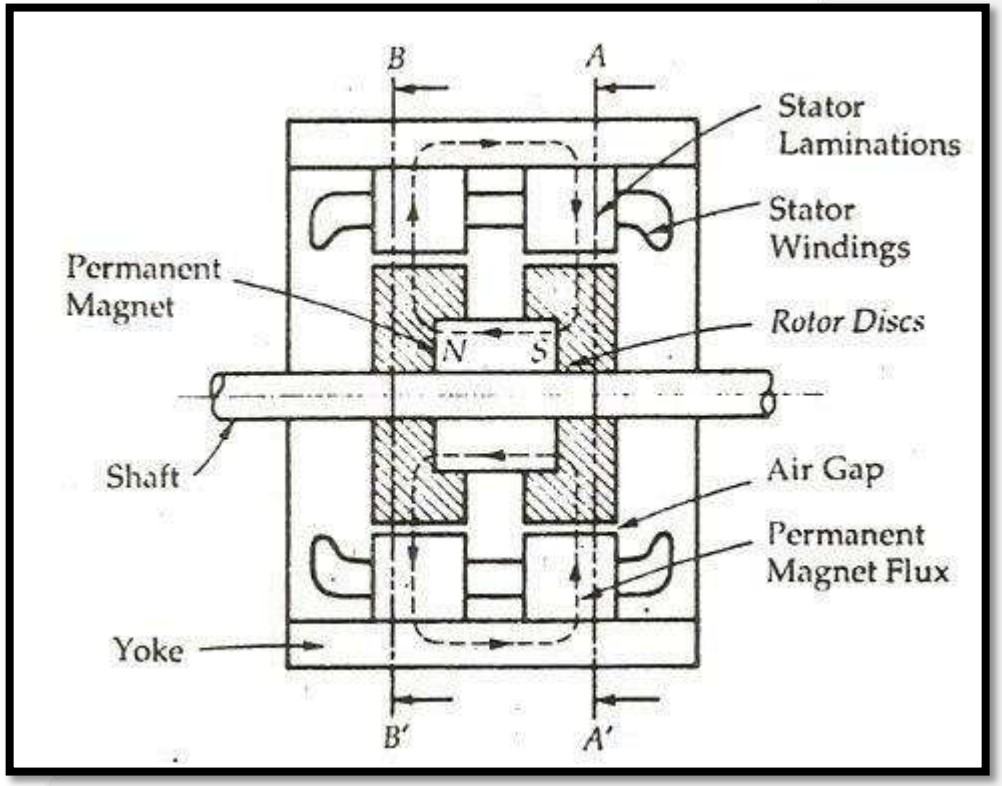


Fig.7 hybrid stepper motor

https://circuitglobe.com/hybrid-stepper-motor.html

STEPPER MOTOR ADVANTAGES

- ✓ The rotation angle of the motor is proportional to the input pulse.
- ✓ The motor has full torque at standstill.
- ✓ Excellent response to starting, stopping and reversing.
- ✓ Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.
- ✓ The motors response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
- ✓ It is possible to achieve very low speed synchronous rotation with a load that is directly coupled to the shaft.

STEPPER MOTOR DISADVANTAGES

- ✓ Resonances can occur if not properly controlled.
- ✓ Not easy to operate at extremely high speeds

STEPPER MOTOR APPLICATIONS

- Industrial Machines – Stepper motors are used in automotive gauges and machine tooling automated production equipment's.
- Security – new surveillance products for the security industry.
- Medical – Stepper motors are used inside medical scanners, samplers, and also found inside digital dental photography, fluid pumps, respirators and blood analysis machinery.
- Consumer Electronics – Stepper motors in cameras for automatic digital camera focus and zoom functions.

LINEAR INDUCTION MOTOR

- A Linear Induction Motor (or **LIM**) is a special type of induction motor used to achieve rectilinear motion rather than rotational motion as in the case of conventional motors.
- Linear induction motors are quite an engineering marvel, to convert a general motor for a special purpose with more or less similar working principle, thus enhancing its versatility of operation.

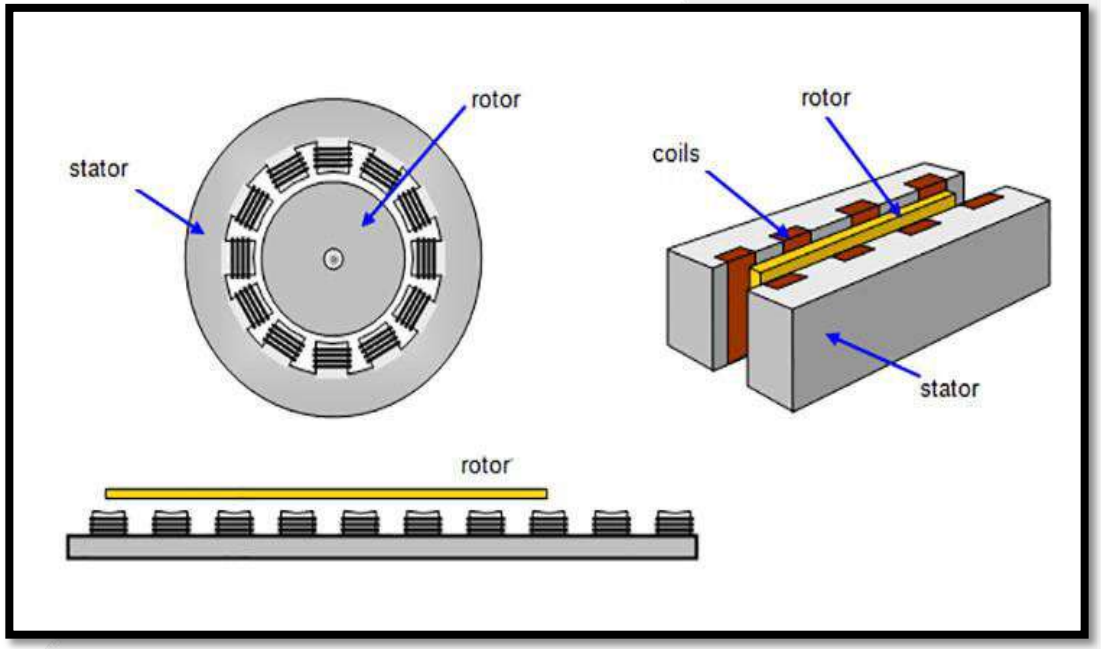


Fig.1 linear induction motor

https://www.linearmotiontips.com/what-are-linear-induction-motors/

CONSTRUCTION OF LINEAR INDUCTION MOTOR

- The basic design and construction of a linear induction motor is similar to a three phase induction motor, although it does not look like a conventional induction motor. If we cut the stator of a polyphase induction motor and lay on a flat surface, it forms the primary of the linear induction motor system.
- Similarly, after cutting the rotor of the induction motor and making it flat, we get the secondary of the system.
- There is another variant of LIM also being used for increasing efficiency known as the **Double Sided Linear Induction Motor** or **DLIM**, as shown in the figure below. It has primary on either side of the secondary, for more effective utilization of the flux from both sides.

WORKING PRINCIPLE OF LINEAR INDUCTION MOTOR

- When the primary of a LIM gets excited by a balanced three-phase power supply, a flux starts traveling along the entire length of the primary.
- This linearly traveling magnetic field is equivalent to the rotating magnetic field in the stator of a three phase induction motor or a synchronous motor. Electric current gets induced in the conductors of the secondary due to the relative motion between the traveling flux and the conductors.
- Then the induced current interacts with the traveling flux wave to produce linear force or thrust.

WORKING PRINCIPLE OF LINEAR INDUCTION MOTOR

- If the primary is fixed and the secondary is free to move, the force will pull the secondary in the direction of the force and will result in the required rectilinear motion.
- When we give supply to the system the developed field will result in a linear travelling field, the velocity of which is given by the equation,
- Where f_s is the supply frequency in Hz, V_s is the velocity of the linear traveling field in meter per second, and t is the linear pole pitch i.e. pole to pole linear distance in meter.

$$V = (1 - s)V_s$$

APPLICATION OF LINEAR INDUCTION MOTOR

- Automatic sliding doors in electric trains.
- Mechanical handling equipment, such as propulsion of a train of tubs along a certain route.
- Metallic conveyor belts.
- Pumping of liquid metal, material handling in cranes, etc.

FREQUENTLY ASKED QUESTIONS

1. Why servo motor is used for feedback system?
2. What are the different types of dc servo motor?
3. Discuss applications of servo motor.
4. What are the difference between variable and hybrid type stepper motor?
5. Discuss applications of stepper motor.

PRACTICE QUESTIONS

1. Explain the operation of servo motor.
2. Explain the operation of stepper motor.
3. What are the different types of servo motor?

Content

- What is transducer?
- Characteristics of transducer
- Basic requirements of transducer
- Classification of transducer

TRANSDUCERS

- A transducer is a device that converts one type of energy to another.
- The conversion can be to/from electrical, electro-mechanical, electromagnetic, photonic, photovoltaic, or any other form of energy.

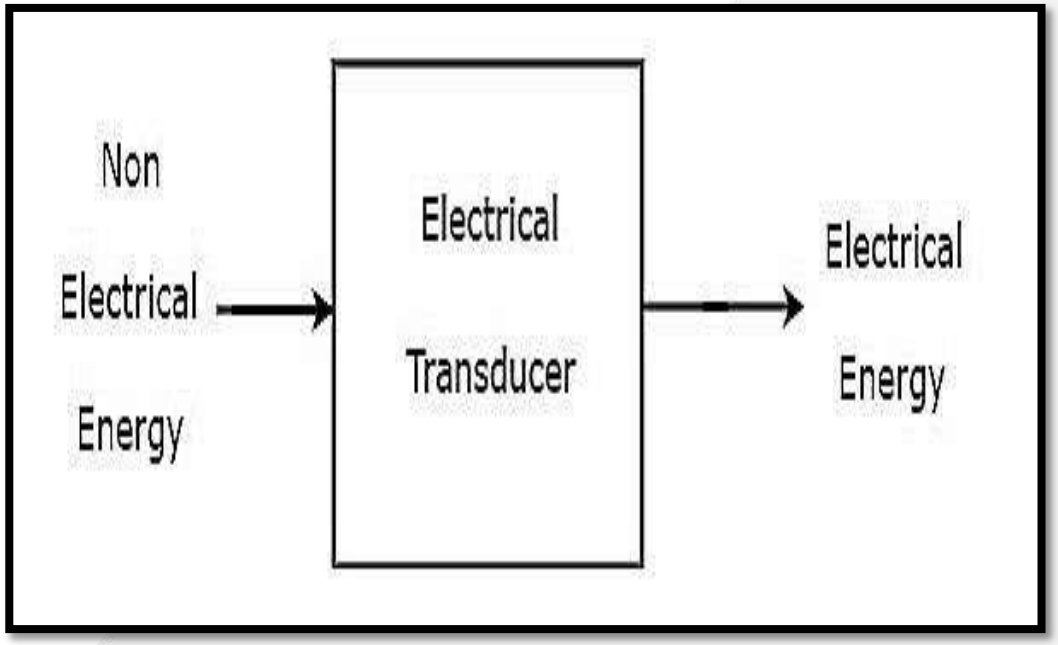


Fig.1 transducer

https://www.electronics-tutorials.ws/io/io_1.html

TRANSDUCERS

The word “Transducer” is the collective term used for both **Sensors** which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc,

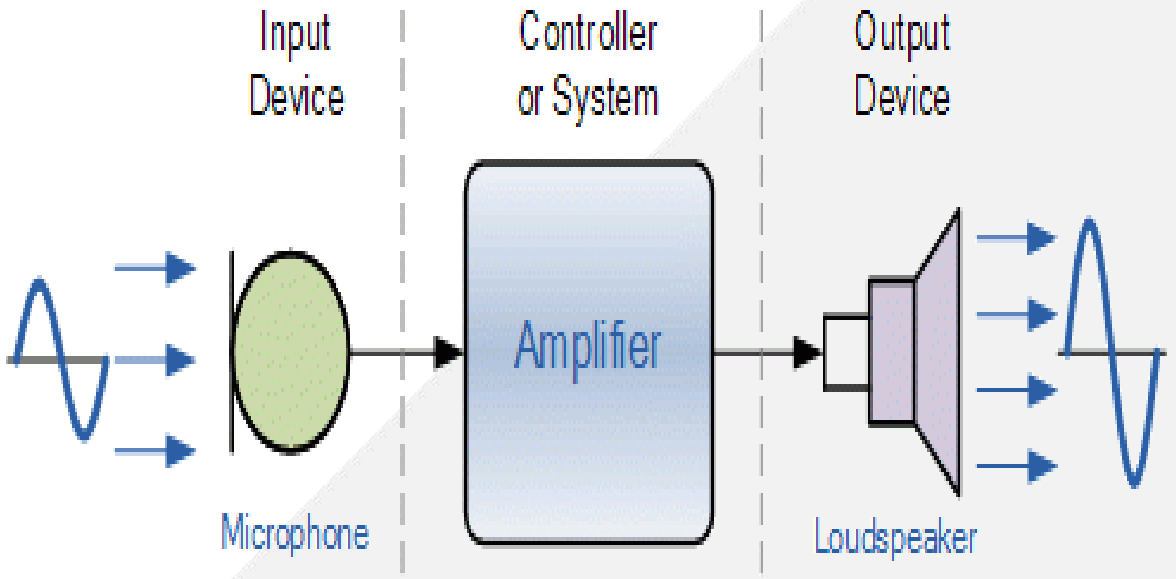


Fig.2 Transducer

https://www.electronics-tutorials.ws/io/io_1.html

CHARACTERISTICS OF TRANSDUCERS

- Ruggedness
- Linearity
- Repeatability
- Accuracy
- High stability and reliability
- Speed of response
- Sensitivity
- Small size

BASIC REQUIREMENTS OF TRANSDUCER

- **Ruggedness**. It should be capable of withstanding overload and some safety arrangement should be provided for overload protection.
- **Linearity.** Its input-output characteristics should be linear and it should produce these characteristics in symmetrical way.
- **Repeatability.** It should reproduce same output signal when the same input signal is applied again and again under fixed environmental conditions e.g. temperature, pressure, humidity etc.
- **High Output Signal Quality.** The quality of output signal should be good i.e. the ratio of the signal to the noise should be high and the amplitude of the output signal should be enough.

BASIC REQUIREMENTS OF TRANSDUCER

- **High Reliability and Stability**. It should give minimum error in measurement for temperature variations, vibrations and other various changes in surroundings.
- **Good Dynamic Response**. Its output should be faithful to input when taken as a function of time. The effect is analyzed as the frequency response.
- **No Hysteretic.** It should not give any hysteretic during measurement while input signal is varied from its low value to high value and vice-versa.
- **Residual Deformation.** There should be no deformation on removal of local after long period of application.

CLASSIFICATION OF TRANSDUCER

There are different types of transducers such as follows:

1. Primary and secondary
2. Active and passive
3. Analog and digital
4. Transducer and inverse transducer

PRIMARY & SECONDARY TRANSDUCER

- **Primary transducer:** When the input signal is directly sensed by transducer and the physical phenomenon is converted into electrical form directly then such a transducer is called primary transducer.

  Examples: bourdon tube

- **Secondary transducer:** When the input signal is sensed first by some detector or sensor then its output being of some other form than the input signal given as input to transducer for conversion into electrical form then such a transducer is called secondary transducer.

  Examples: LVDT

ACTIVE & PASSIVE TRANSDUCER

- **Active transducer:** No extra power is required to produce I/p. They are Self generating. Draws power from input applied.

Examples: piezoelectric

- **Passive transducer:** These transducer require external source of energy.

Examples: resistive, inductive and capacitive transducer

ANALOG & DIGITAL TRANSDUCER

- **Analog transducer:** These transducer use analog signals to convert input quantity to output quantity.

Example: strain gauge, thermocouple

Digital transducer: These transducers use digital signals to convert input quantity into form of pulses.

Examples: converters

CLASSIFICATION OF TRANSDUCER

Transducer: A transducer is a device which converts non electrical quantity into electrical quantity.

Examples: bourdon tube

Inverse transducer: An inverse transducer is a device which converts electrical quantity into non electrical quantity.

Examples: piezo-electric

APPLICATIONS OF TRANSDUCER

- The transducers measure the pressure of the gas and liquid by converting it into an electrical signal.
- It converts the temperature of the devices into an electrical signal or mechanical work.
- The transducer is used in the ultrasound machine. It receives the sound waves of the patient by emitting their sound waves and pass the signal to the CPU.
- The transducer is used in the speaker for converting the electrical signal into acoustic sound.

SUMMARY

- ✓Introduction to transducer
- ✓Various types of transducer
- ✓Primary and secondary transducer
- ✓Active and passive transducer
- ✓Analog and digital transducer
- ✓Transducer and inverse transducer
- ✓Applications of transducer

FREQUENTLY ASKED QUESTIONS

- What is transducer?
- What is primary transducers?
- Difference between active and passive transducers?
- How inverse transducers different from transducers?

CONTENTS

- Introduction to capacitive transducer
- Construction and working of capacitive transducer
- Advantages and disadvantages of capacitive transducer
- Applications of capacitive transducer
- Introduction to inductive transducer
- Construction and working of inductive transducer
- Advantages and disadvantages of inductive transducer
- Applications of inductive transducer
- Linear variable differential transformer with its construction and working

CAPACTIVE TRANSDUCER

- The capacitive transducer is used for measuring the displacement, pressure and other physical quantities.
- It is a passive transducer that means it requires external power for operation. The capacitive transducer works on the principle of variable capacitances.
- The capacitive transducer contains two parallel metal plates. These plates are separated by the dielectric medium which is either air, material, gas or liquid.

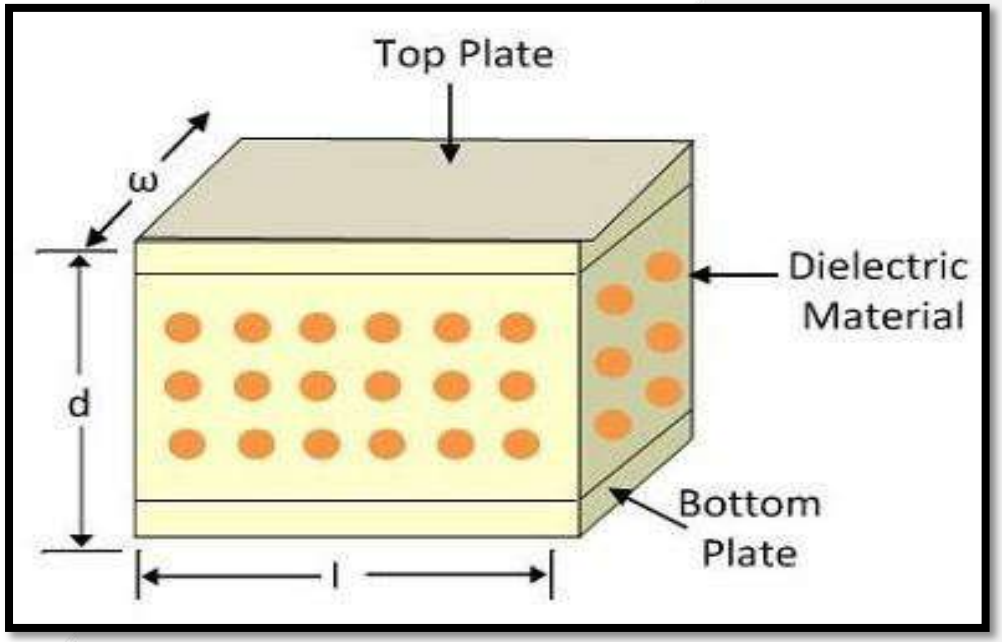


Fig.1 capacitive transducer

https://circuitglobe.com/capacitive-transducer.html

WORKING OF CAPACTIVE TRANSDUCER

- In capacitive transducer, the above changes are caused by physical variables like linear displacement, angular displacement, force, pressure and level of liquid.
- Notice that when the liquid level changes through the capacitor, the dielectric medium is changed and hence the capacitance will change.
- The change in capacitance may be measured by bridge circuit. The output impedance of capacitive transducer is given as $X_c = (1/2\pi fC)$ where f is supply frequency and C is capacitance.

APPLICATIONS OF CAPACTIVE TRANSDUCER

- The capacitive transducer uses for measurement of both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.
- It is used for the measurement of the force and pressures. The force or pressure, which is to be measured is first converted into a displacement, and then the displacement changes the capacitances of the transducer.
- It is used as a pressure transducer in some cases, where the dielectric constant of the transducer changes with the pressure.

INDUCTIVE TRANSDUCER

Let us further understand the principle of induction, whenever there is a rate of change current and a conductor sees it, it produces a voltage which opposes it. In a mathematical way we can say:

V= L.di/dt

Where 'L' is the inductance, 'V' is the voltage and 'di/dt' is the rate of change of current.

Further, 'L' depends on the number of turns in a coil, magnetic flux, and the area.

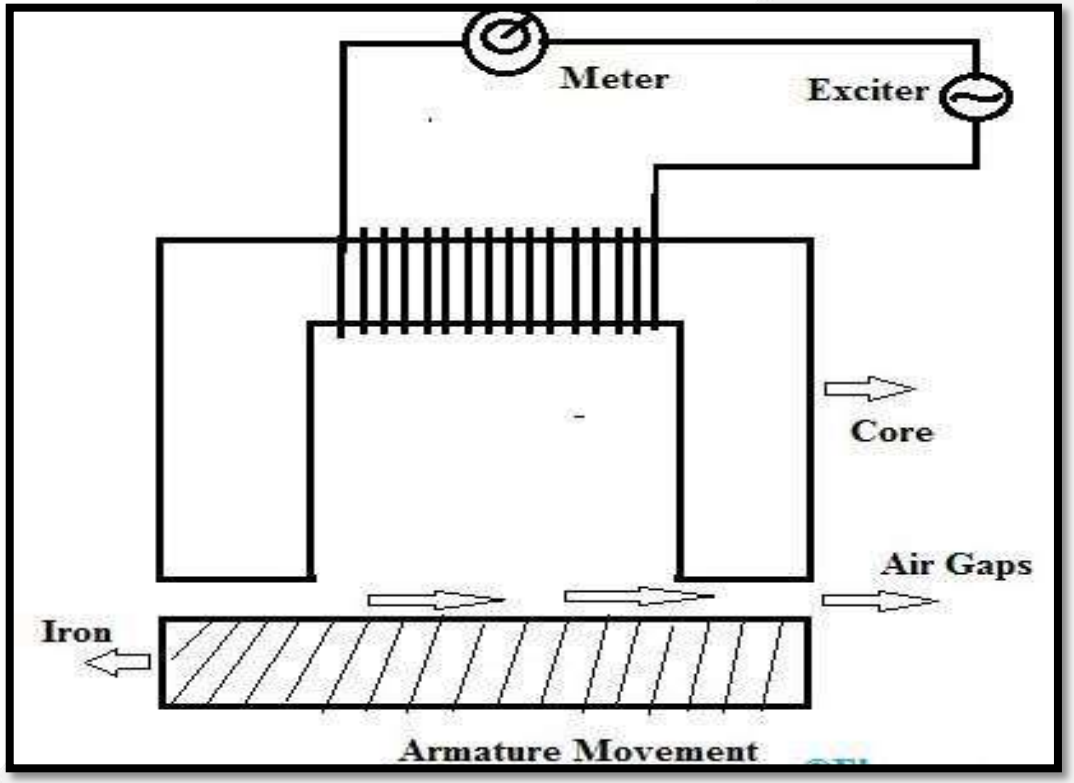


Fig.2 inductive transducer

https://www.elprocus.com/inductive-transducer-working-its-applications/

WORKING OF INDUCTIVE TRANSDUCER

- The inductive transducer uses three working principles which include the following.

- ❑ Self Inductance Change
- ❑ Mutual Inductance Change
- ❑ Eddy Current Production

WORKING OF INDUCTIVE TRANSDUCER

Self Inductance Change:

We know that the coil's self-inductance can be derived by

$$L = N^2/R$$

Where 'N' is the number of twists of coil

'R' is the magnetic circuit's reluctance

The reluctance 'R' can be derived by the following equation

$$R = l/\mu A$$

WORKING OF INDUCTIVE TRANSDUCER

Mutual Inductance Change:

•Here transducers work on the principle of change in mutual inductance. It uses several coils for the purpose of knowing.

•These coils include their self-inductance which are indicated by L1 & L2. The common inductance among these two twists can be derived by the following equation.

M = √ L1. L2

WORKING OF INDUCTIVE TRANSDUCER

Eddy Current Production:

- Whenever a conducting shield is located close to a coil carrying alternating current then the current flow can be induced within the shield which is known as “EDDY CURRENT”. This kind of principle is used in inductive transducers.
- When a conducting plate is arranged near to a coil carrying AC then eddy currents will be generated within the plate.
- The plate which carries eddy current will generates their own magnetic field which works against plate magnetic field. So the magnetic flux will be reduced.

APPLICATIONS OF INDUCTIVE TRANSDUCER

- The application of these transducers finds in proximity sensors to measure position, touchpads, dynamic motion, etc.
- Mostly these transducers are used for detecting the kind of metal, to find miss lost parts otherwise counts the objects.
- These transducers are also applicable for detecting the movement of the apparatus which include belt conveyor and bucket elevator etc.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

- The LVDT full form is “Linear Variable Differential Transformer” is LVDT. Generally, LVDT is a normal type of transducer.
- The main function of this is to convert the rectangular movement of an object to the equivalent electrical signal.
- LVDT is used to calculate displacement and works on the transformer principle.

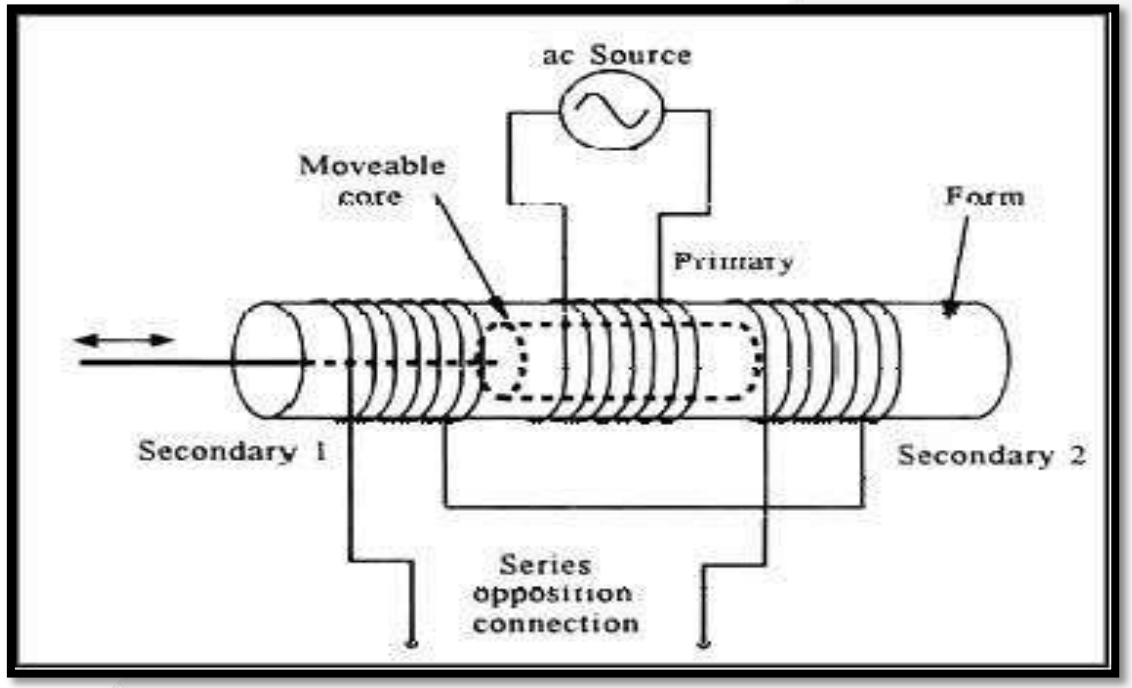


Fig.3 LVDT

https://www.ni.com/en-in/innovations/white-papers/06/measuring-position-and-displacement-with-lvdts.html

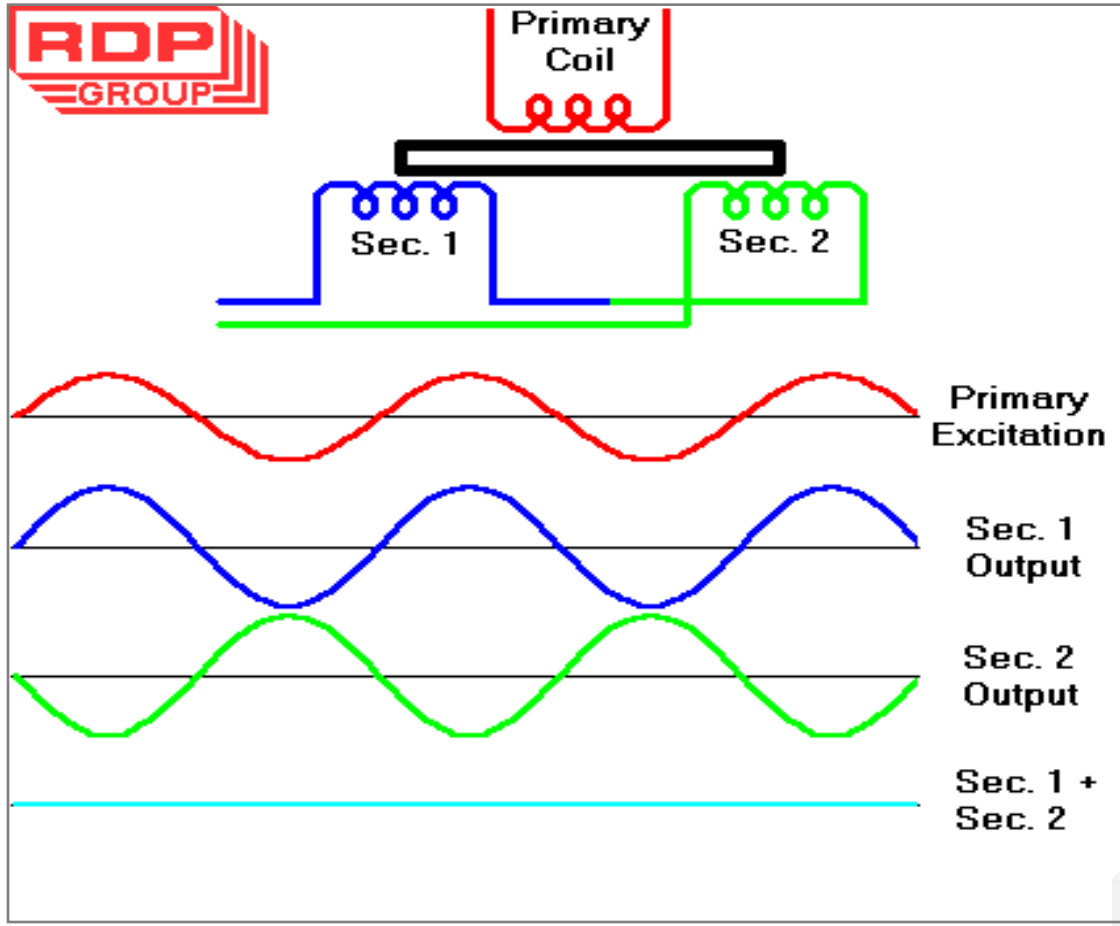
WORKING OF LVDT

- The linear variable differential transformer has three solenoid coils placed end-to-end around a tube.
- The center coil is the primary, and the two outer coils are the top and bottom secondary's.
- A cylindrical ferromagnetic core, attached to the object whose position is to be measured, slides along the axis of the tube.
- An alternating current drives the primary and causes a voltage to be induced in each secondary proportional to the length of the core linking to the secondary.

WORKING OF LVDT

- As the core moves, the primary's linkage to the two secondary coils changes and causes the induced voltages to change. The coils are connected so that the output voltage is the difference between the top secondary voltage and the bottom secondary voltage.
- Any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneously, reducing the voltage in the other secondary winding.
- The difference of the two voltages appears across the output terminals of the transducers and gives a measure of the physical position of the core and hence the displacement.

WORKING OF LVDT



- Displacement to be measure is applied to an arm attached to the soft iron core.
- Voltage waveforms of LVDT shown in figure with different colors.

Fig.4

http://staff.fit.ac.cy/eng.os

WORKING OF LVDT

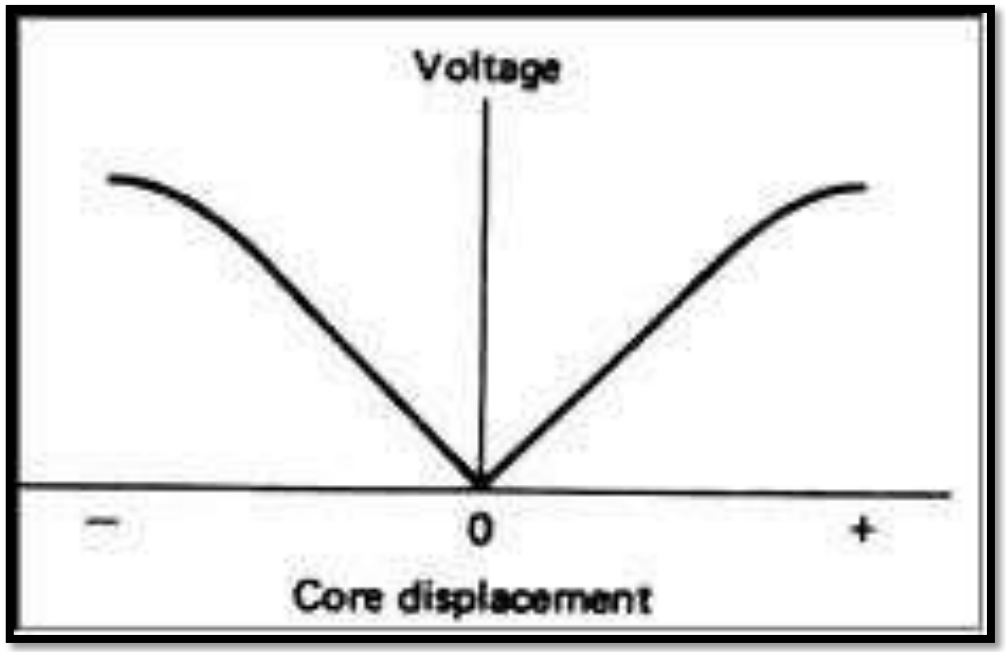


Fig.5

https://www.ni.com/en-in/innovations/white-papers/06/measuring-position-and-displacement-with-lvdts.html

- This figure showcase the graphical representation of LVDT shaft variations and their effect in terms of the magnitude of differential AC output from a null position .

WORKING OF LVDT

- When the core is in its central position, equidistant between the two secondary, equal voltages are induced in the two secondary coils, but the two signals cancel, so the output voltage is theoretically zero.
- When the core is displaced toward the top, the voltage in the top secondary coil increases as the voltage in the bottom decreases. The resulting output voltage increases from zero. This voltage is in phase with the primary voltage.
- When the core moves in the other direction, the output voltage also increases from zero, but its phase is opposite to that of the primary. The phase of the output voltage determines the direction of the displacement and amplitude indicates the amount of displacement. A synchronous detector can determine a signed output voltage that relates to the displacement.

ERRORS AND ADJUSTMENTS

- Nickel iron is used generally in place of soft iron to get low harmonics, low null voltage and high sensitivity.
- Core is slotted longitudinally in LVDT to reduce eddy current losses.
- Placed in stainless steel housing and end lids provides electrostatic and electromagnetic shielding.

APPLICATIONS OF LVDT

- The LVDT sensor works as the main transducer, and that changes dislocation to electrical signal straight.
- This transducer can also work as a secondary transducer.
- LVDT is used to measure the weight, force and also pressure.
- Some of these transducers are used to calculate the pressure and load.
- LVDT's are mostly used in industries as well as servomechanism.

ADVANTAGES

- Wide range of displacement from µm to cm.
- Frictionless and electrical isolation.
- High output.
- High sensitivity [sensitivity is expressed in mV (output voltage)/ mm (input core displacement)].
- Has almost linear characteristics.
- Consumes very less power.

DISADVANTAGES

- Sensitive to stray magnetic fields.
- Affected by vibrations.
- Dynamic response is limited mechanically by the mass of core and electrically by frequency of excitation voltage.

SUMMARY

- ✓Introduction to capacitive transducer with its construction.
- ✓Working of capacitive transducer.
- ✓Introduction to capacitive transducer with its construction.
- ✓Working of capacitive transducer.
- ✓Introduction to LVDT.
- ✓Difference between transducer and transformer.
- ✓Construction of LVDT.
- ✓Working of LVDT
- ✓Applications of LVDT.

FREQUENTLY ASKED QUESTIONS

1. What is capacitive and inductive transducer?
2. LVDT is primary or secondary transducer? Justify
3. Explain working principle of LVDT?

CONTENTS

- ✓Introduction to thermocouple
- ✓Working principle of thermocouple
- ✓Applications of thermocouple
- ✓Introduction to piezo-electric transducer
- ✓Working principle of piezo-electric transducer
- ✓Applications of piezo-electric transducer

THERMOCOUPLE

- A thermocouple is a temperature measuring device consisting of two dis similar conductors that contact each o ther at one or more spots.
- It produces a voltage when the temp erature of one of the spots differs from the reference temperature at other p arts of the circuit.

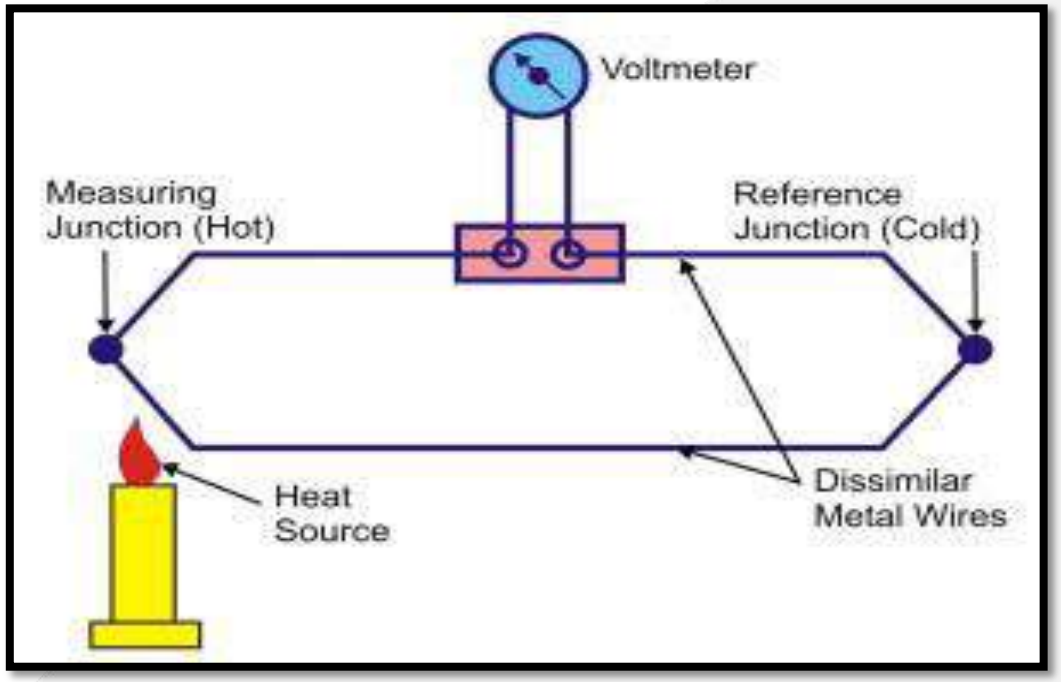


Fig.1

https://www.elprocus.com/what-is-a-thermocouple-definition-working-principle-diagram-applications/

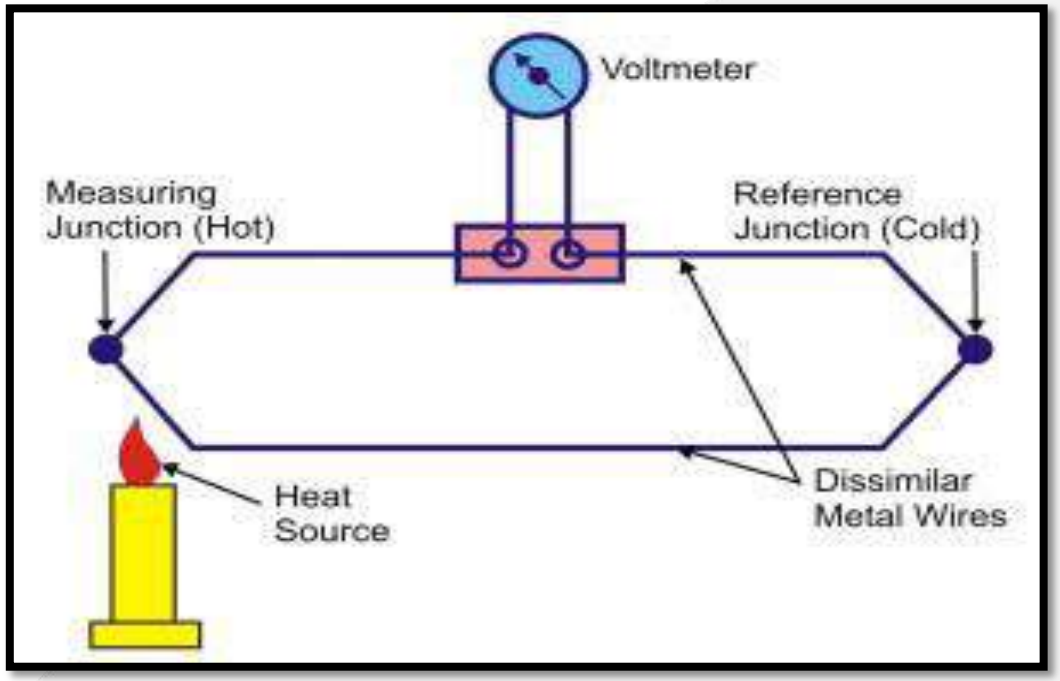
PRINCIPLE OF THERMOCOUPLE

- The **thermocouple principle** mainly depends on the three effects namely

➢Seebeck effect

➢Peltier effect

➢Thompson effect



Contd. Fig.1

https://www.elprocus.com/what-is-a-thermocouple-definition-working-principle-diagram-applications/

THERMOCOUPLES: SEEBECK EFFECT

- The Seebeck effect is the conversion of thermal energy/temperature differences directly into electrical energy or electricity.
- This effect measures the ease at which excess electrons will circulate in an electrical circuit under the influence of thermal difference.
- The change in the voltage is proportional to the temperature difference between the junctions when the ends are connected to form a loop.

THERMOCOUPLES: PELTIER EFFECT

- This Peltier effect is opposite to the Seebeck effect.
- This effect states that the difference of the temperature can be formed among any two dissimilar conductors by applying the potential variation among them.

THERMOCOUPLES: THOMSON EFFECT

- This effect states that as two disparate metals fix together & if they form two joints then the voltage induces the total conductor's length due to the gradient of temperature.
- This is a physical word that demonstrates the change in rate and direction of temperature at an exact position.

WORKING OF THERMOCOUPLE

- The thermocouple schematic diagram is shown in the below figure. This circuit can be built with two different metals, and that are coupled together by generating two junctions. The two metals are surrounded by the connection through welding.
- In the diagram, the junctions are denoted by P & Q, and the temperatures are denoted by T1, & T2. When the temperature of the junction is dissimilar from each other, then the electromagnetic force generates in the circuit.

WORKING OF THERMOCOUPLE

- This circuit can be built with two different metals, and that are coupled together by generating two junctions. The two metals are surrounded by the connection through welding.
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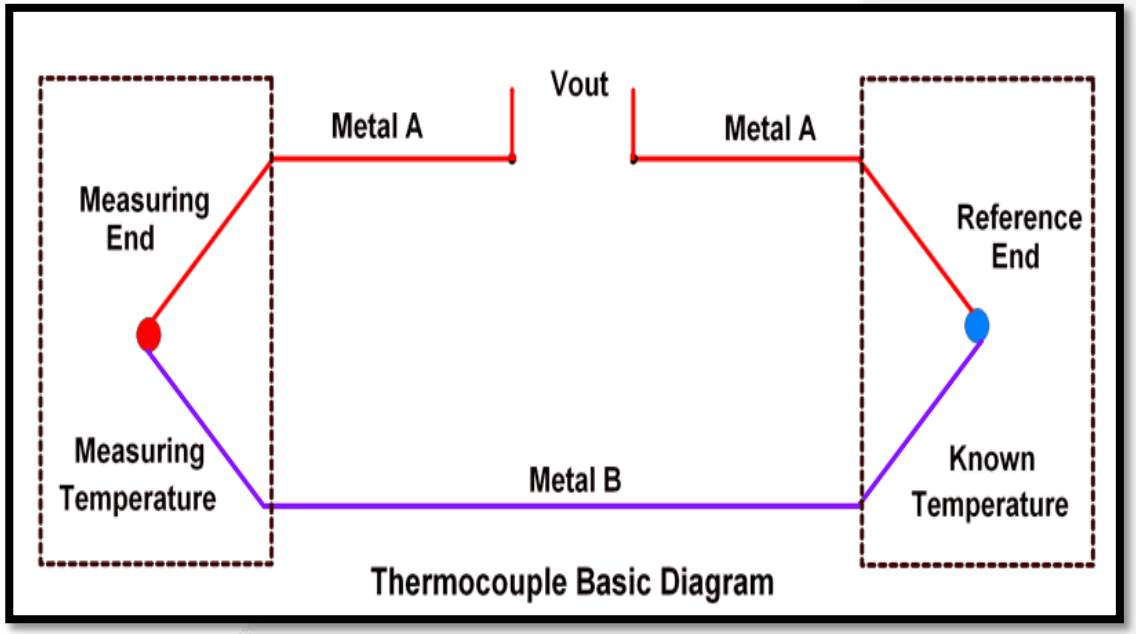

Fig.2

https://www.electronicwings.com/sensors-modules/thermocouple

APPLICATIONS OF THERMOCOUPLE

- These are used as the temperature sensors in thermostats in offices, homes, offices & businesses.
- These are used in industries for monitoring temperatures of metals in iron, aluminum, and metal.
- These are used in the food industry for cryogenic and Low-temperature applications. Thermocouples are used as a heat pump for performing thermoelectric cooling.
- These are used to test temperature in the chemical plants, petroleum plants.
- These are used in gas machines for detecting the pilot flame.

PIEZOELECTRIC TRANSDUCER

- The piezoelectric transducers work on the principle of piezoelectric effect. When mechanical stress or forces are applied to some materials along certain planes, they produce electric voltage.
- This electric voltage can be measured easily by the voltage measuring instruments, which can be used to measure the stress or force.
- Detect motion (high and low frequency)

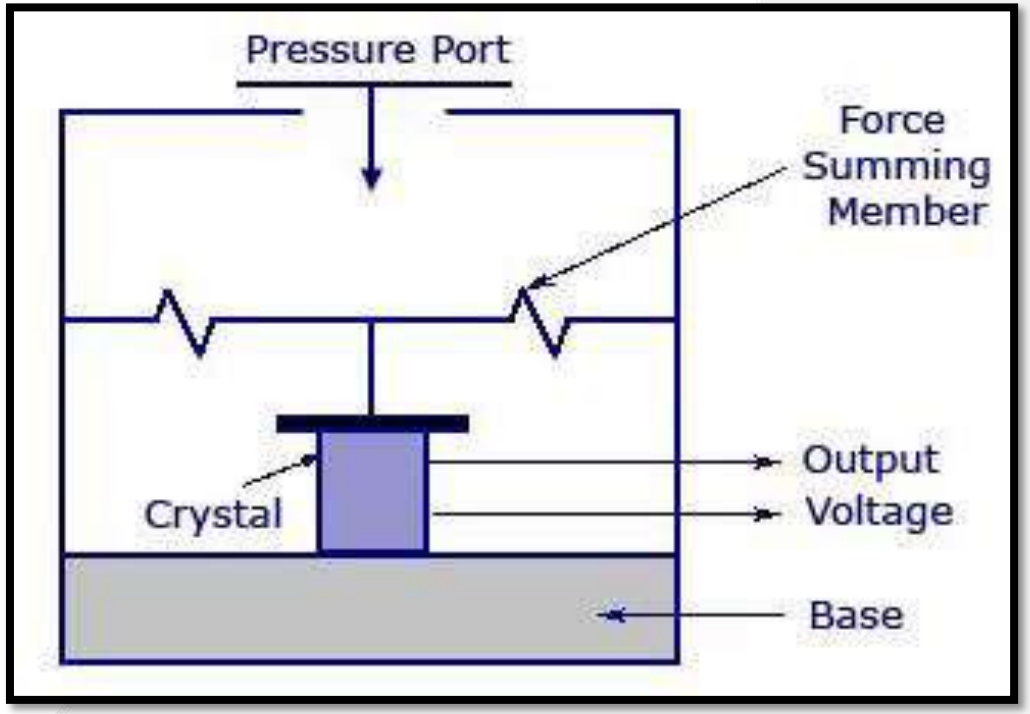

Fig.3

http://www.instrumentationtoday.com/piezoelectric-transducer/2011/07/

WORKING OF PIEZOELECTRIC TRANSDUCER

- The EMF develops because of the displacement of the charges. The effect is changeable, i.e. if the varying potential applies to a piezoelectric transducer, it will change the dimension of the material or deform it. This effect is known as the piezoelectric effect.
- The pressure is applied to the crystals with the help of the force summing devices for examples the stress is applied through mechanical pressure gauges and pressure sensors, etc.
- The deformation induces the EMF which determines the value of applied pressure.

PRINCIPLE OF APPLICATION

- **Energy Conversion Mechanism -** An externally applied electric field causes a change in the dielectric polarization in the material which in turn causes an elastic strain. The generating action takes place when an elastic strain causes a change in the polarization that induces a charge on the electrodes.

- **Transducer Operating Environment-**

The acoustic properties of the medium (air, water or ice) are very important in the design of transducers.

- Transducers must also withstand the severe effects of sea water, biological activity, hydrostatic pressure, and extreme temperature conditions.

PRINCIPLE OF APPLICATION

- **Conversion Criteria –** The following are the general performance criteria for the transducers.

❑**Linearity -** The output of the transducer is a linear function of the input.

❑**Reversibility -** The transducer must convert energy in either direction.

❑**Passivity -** All the output energy from the transducer is obtained from the input energy - electrical or acoustical.

APPLICATIONS OF PIEZOELECTRIC TRANSDUCER

- The piezoelectric material has high stability and hence it is used for stabilizing the electronic oscillator.
- The ultrasonic generators use the piezoelectric material. This generator is used in SONAR for underwater detection and in industrials apparatus for cleaning.
- It is used in microphones and speakers for converting the electric signal into sound.
- The piezoelectric material is used in electric lighter.

SUMMARY

- ✓Introduction to thermocouple
- ✓Working principle of thermocouple
- ✓Applications of thermocouple
- ✓Introduction to piezo-electric transducer
- ✓Working principle of thermocouple
- ✓Applications of thermocouple

FREQUENTLY ASKED QUESTIONS

- What is thermocouple ?
- Explain working of thermocouple?
- What is seebeck effect?
- Give the applications of peizo electric transducer?

LEARNING OUTCOMES

To make students understand

- Concepts of piezoelectric and thermocouple
- Working and piezoelectric and thermocouple
- Applications of piezoelectric and thermocouple

IMPORTANCE OF COURSE[BEEE]

- Use in communication and satellite navigation system.
- Handles in electronics equipment and computers.
- Deals with the problem of power transmission and motor control.
- Handles with robotics applications.

https://images.app.goo.gl/JY2jmAuASfpDUENZ8

STRAIN GAUGE

- If a strip of conductive metal is placed under compressive force (without buckling), it will broaden and shorten.
- If these stresses are kept within the elastic limit of the metal strip (so that the strip does not permanently deform), the strip can be used as a measuring element for physical force, the amount of applied force inferred from measuring its resistance.
- This is the principle of a Strain Gauge.

STRAIN GAUGE

- A **strain gauge** is a resistor used to measure strain on an object. When an external force is applied on an object, due to which there is a deformation occurs in the shape of the object.
- This deformation in the shape is both compressive or tensile is called strain, and it is measured by the strain gauge.

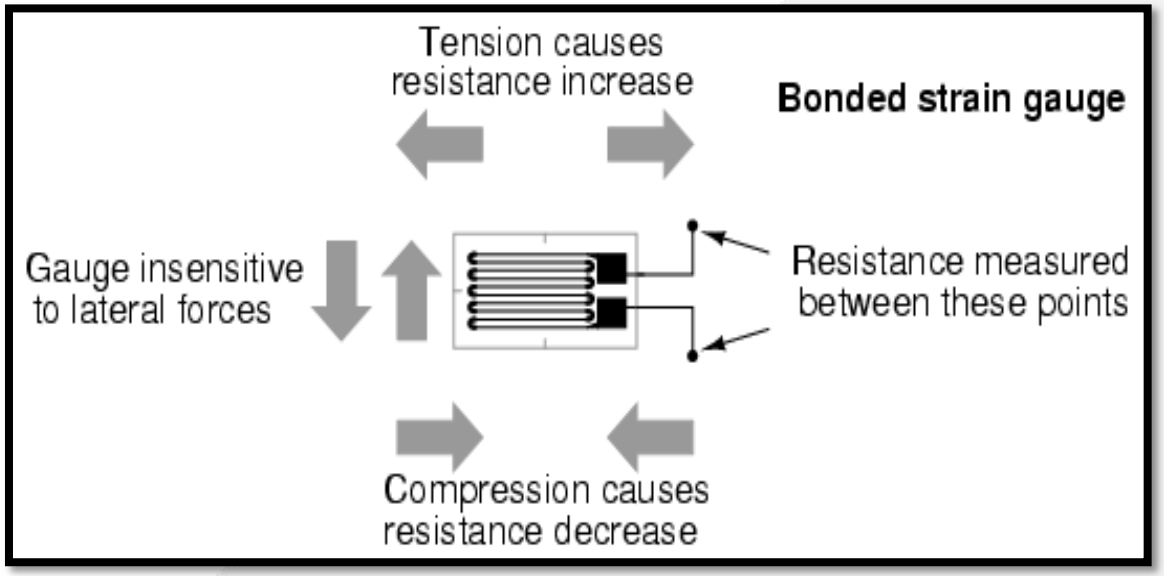

Fig.1 strain gauge

https://nptel.ac.in/content/storage2/courses/108105063/pdf/L-05(SS)(IA&C)%20((EE)NPTEL).pdf

WORKING OF STRAIN GAUGE

- The functioning of a strain gauge entirely depends on the electrical resistivity of an object/conductor.
- When an object gets stretched within its limits of elasticity and does not break or buckle permanently, it becomes thinner and longer, resulting in high electrical resistance.
- If an object is compressed and does not deform, but, broadens and shortens, results in decreased electrical resistance.
- The values obtained after measuring the electrical resistance of a gauge helps to understand the amount of stress-induced.

WORKING OF STRAIN GAUGE

- As we know that the resistance is directly dependent on the length and cross-sectional area of a conductor, which is given by **R = L/A**

Where,

- ‘R’= Resistance
- ‘L’ = Length
- ‘A’ = cross-sectional area

- Clearly, the length of a conductor is altered with the change in size and shape of a conductor, eventually, altering the cross-sectional area and resistance.

GAUGE FACTOR

- The gauge factor is defined as:

$$GF = (\Delta R / RG) / \epsilon$$

Where,

- ‘ΔR’ is the change in resistance due to strain
- ‘RG’ is the resistance of the undeformed gauge
- ‘ε’ is the strain

WORKING OF STRAIN GAUGE

- With no force applied to the test specimen, both strain gauges have equal resistance and the bridge circuit is balanced.
- However, when a downward force is applied to the free end of the specimen, it will bend downward, stretching gauge #1 and compressing gauge #2 at the same time.

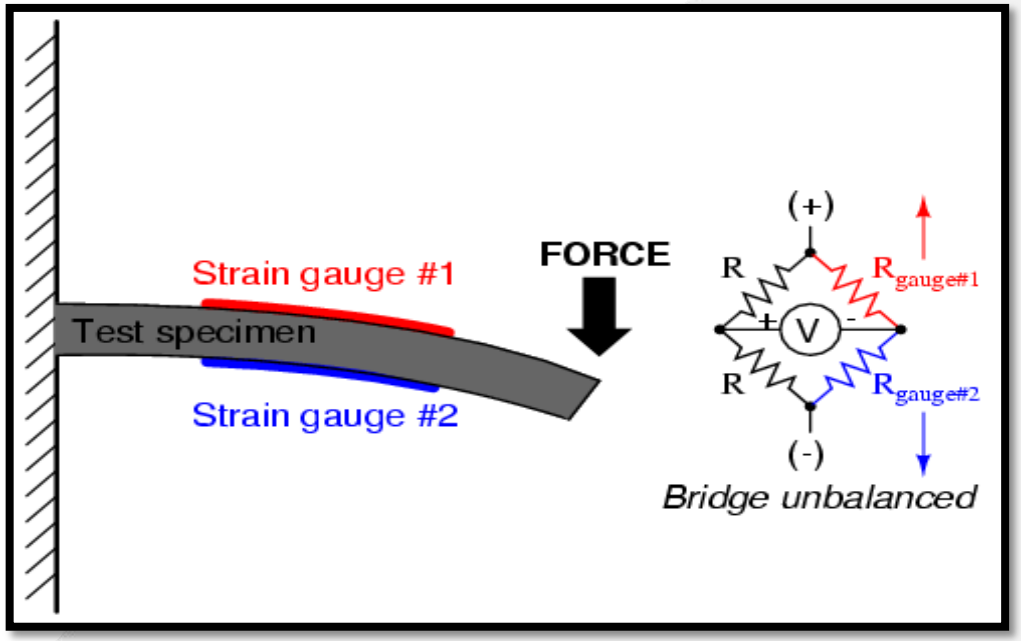

Fig.2 strain gauge

https://nptel.ac.in/content/storage2/courses/108105063/pdf/L-05(SS)(IA&C)%20((EE)NPTEL).pdf

TYPES OF STRAIN GAUGE

Based on principle of working :

- Mechanical
- Electrical
- Piezoelectric

Based on mounting :

- Bonded strain gauge
- Unbonded strain gauge

MECHANICAL STRAIN GAUGE

- MECHANICAL STRAIN GAUGE is made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer. One layer is glued to one side of the crack and one layer to the other.
- As the crack opens, the layers slide very slowly past one another and the pointer moves over the scale. The red crosshairs move on the scale as the crack widens.
- Piezoelectric generate electric voltage when strain is applied over it. Strain can be calculated from voltage. Piezoelectric strain gauges are the most sensitive and reliable devices.

MECHANICAL STRAIN GAUGE

Fig.3 mechanical strain gauge

https://www.surplustronics.co.nz/products/9335-piezo-disc-element-leads

ELECTRIC STRAIN GAUGE

- When an electrical wire is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer, changes that increase its electrical resistance end-to-end.
- Strain can be inferred by measuring change in resistance.

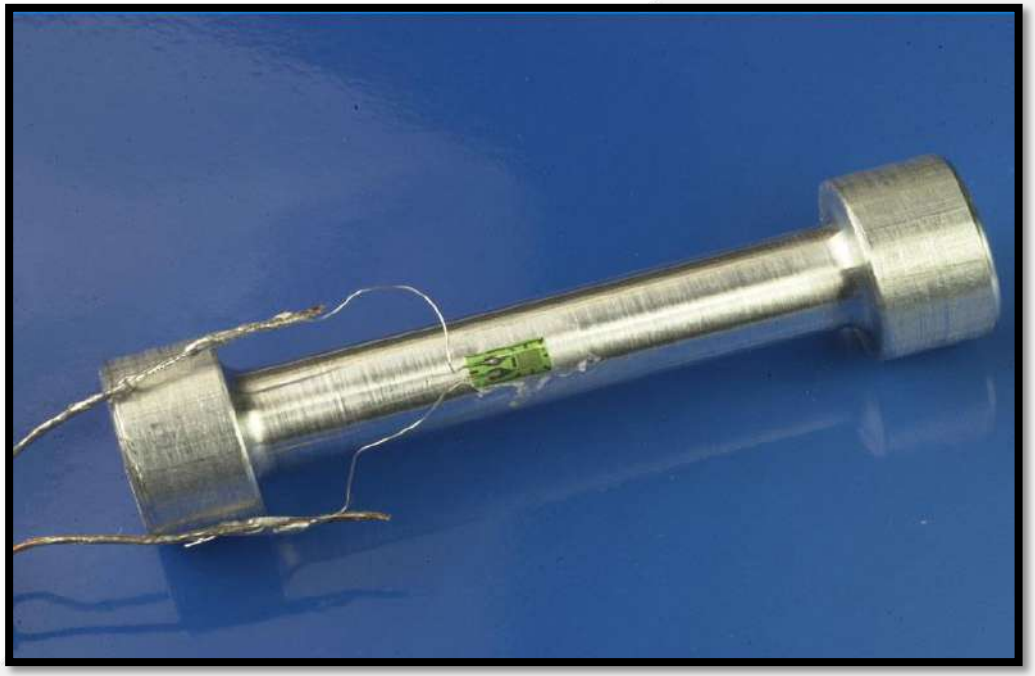

Fig.4 electric strain gauge

https://www.surplustronics.co.nz/products/9335-piezo-disc-element-leads

ADVANTAGE AND DISADVANTAGE OF STRAIN GAUGE

Advantage:

- There is no moving part.
- It is small and inexpensive.

Disadvantage:

- It is non-linear.
- It needs to be calibrated.

APPLICATIONS OF STRAIN GAUGE

- Residual stress
- Vibration measurement
- Torque measurement
- Bending and deflection measurement
- Compression and tension measurement
- Strain measurement

THERMISTOR

- Thermistor work on the principle that resistance of some materials changes with the change in their temperature.
- When the temperature of the material changes, its resistance changes and it can be measured easily and calibrated against the input quantity.
- The commonly used thermistors are made up of the ceramic like semiconducting materials such as oxides of manganese, nickel and cobalt.

THERMISTOR

- Thermistors can be used for the measurement of temperature, as electric power sensing devices and also as the controls for various processes.
- The most common type of thermistor that we use has a resistance that falls as the temperature rises.
- It is referred to as a negative temperature coefficient device(NTC).

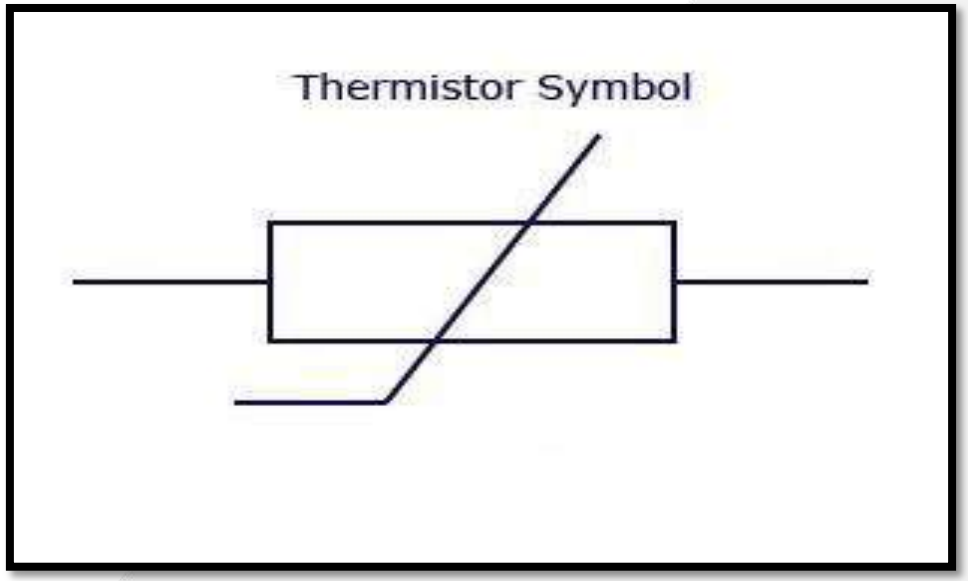

Fig.5 thermistor symbol

https://www.homemade-circuits.com/thermistors/

THERMISTOR

The thermistor resistance-temperature relationship can be approximated by,

$$R = R_{Ref}.e^{\beta(\frac{1}{T}-\frac{1}{T_{Ref}})}$$

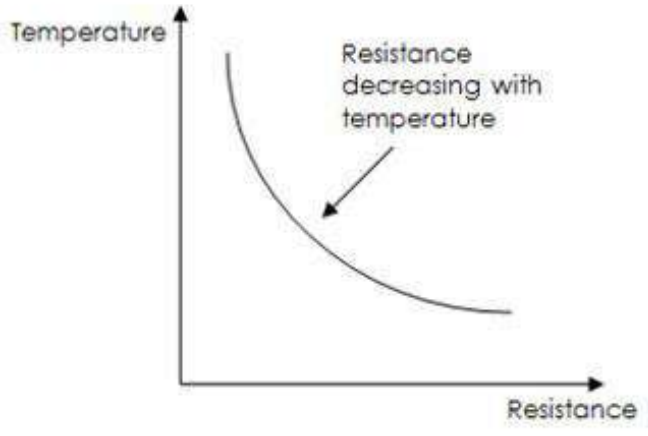

Fig.6 thermistor characteristics

https://www.homemade-circuits.com/thermistors/

APPLICATIONS OF THERMISTOR

- Measurement of temperature
- Measurement of difference of two temperatures
- Control of temperature
- Temperature compensation
- Thermal conductivity measurement
- Measurement of gas composition
- Measurement of flow
- Current-limiting devices for circuit protection as replacement for fuse (PTC).

SUMMARY

- ✓Introduction to strain gauge
- ✓Working of strain gauge
- ✓Applications of strain gauge
- ✓Introduction to thermistor
- ✓Working of thermistor
- ✓Applications of thermistor

FREQUENTLY ASKED QUESTIONS

- What is transducer ?
- What is strain gauge?
- Give the applications of strain gauge and thermistor.
- Define negative temperature coefficient.

LEARNING OUTCOMES

To make students understand

- Concept of strain gauge and thermistor
- Working and strain gauge and thermistor
- Applications of strain gauge and thermistor

CONTENTS

- Introduction to photoelectric transducer
- Types of photoelectric transducer
- Advantages and disadvantages of photo voltaic cell
- Types of photo emissive cell
- Advantages of photo emissive cell
- Concept of photoconductive cell
- Tri axial sensor
- Tri axial sensor applications

PHOTOELECTRIC TRANSDUCER

- Conversion of light energy into electrical energy.
- When light falls on photosensitive element electric current is generated that is measured directly or after amplification.
- PHOTOELECTRIC EFFECT is the ejection of electrons from a metal or semiconductor surface when illuminated by light or any radiation of suitable wavelength.

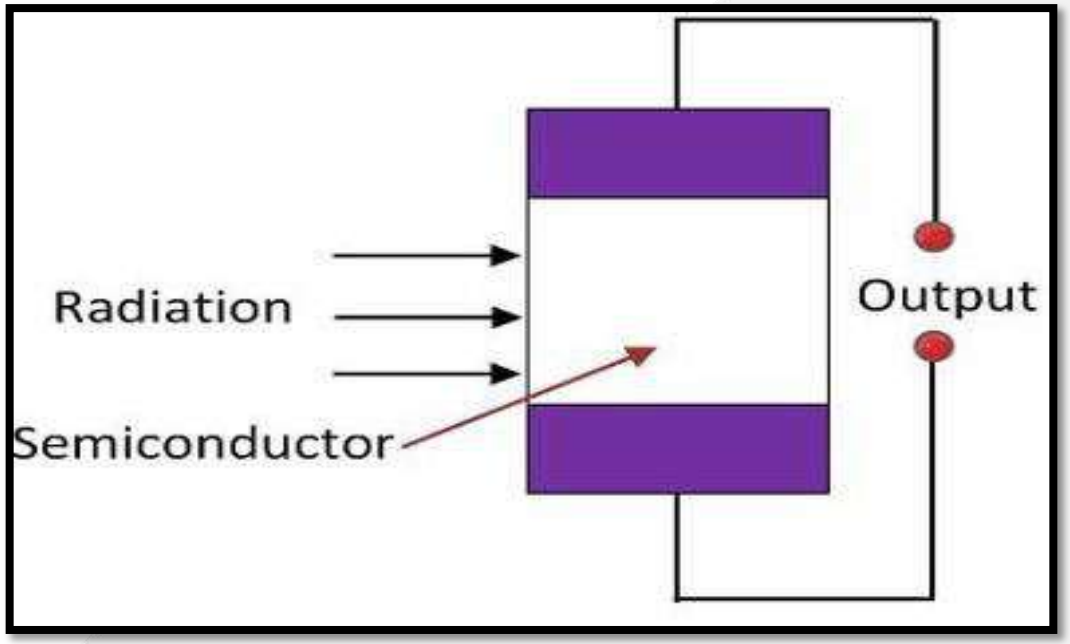

Fig.1 photoelectric transducer

https://circuitglobe.com/photoelectric-transducer.html

WORKING OF PHOTOELECTRIC TRANSDUCER

- The photoelectric transducer absorbs the radiation of light which falls on their semiconductor material.
- **The absorption of light energises the electrons of the material, and hence the electrons start moving**. The mobility of electrons produces one of the three effects.

➢The resistance of the material changes.

➢The output current of the semiconductor changes.

➢The output voltage of the semiconductor changes.

TYPES OF PHOTOELECTRIC TRANSDUCER

Photo emissive cell:

- The Photoemissive cell converts the photons into electric energy. It consists the anode rode and the cathode plate.
- The anode and cathode are coated with a photoemissive material called caesium antimony.

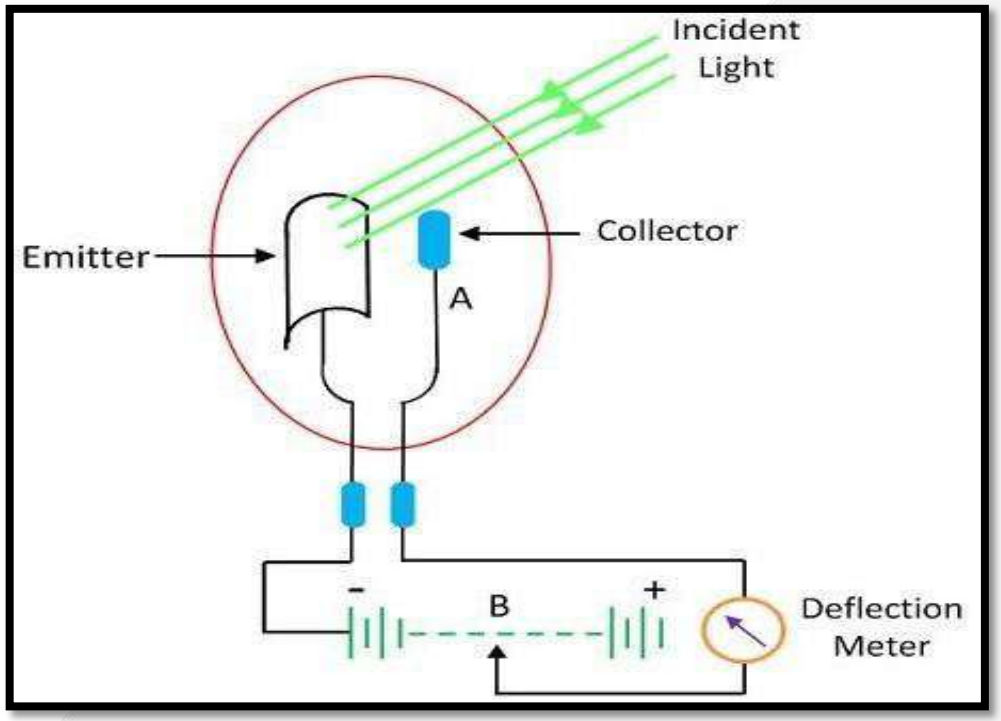

Fig.2 photo emissive cell

https://circuitglobe.com/photoelectric-transducer.html

PHOTO VOLTAIC CELL

- The photovoltaic cell is the type of active transducer. The current starts flowing into the photovoltaic cell when the load is connected to it.
- The silicon and selenium are used as a semiconductor material.
- When the semiconductor material absorbs heat, the free electrons of the material starts moving. This phenomenon is known as the photovoltaic effect.

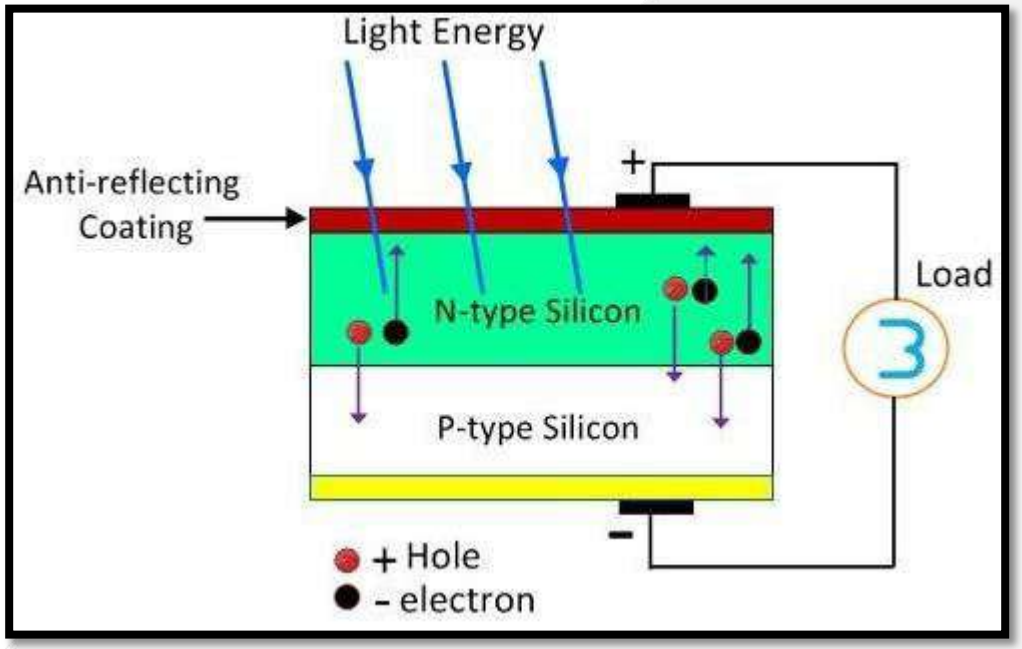

Fig.3 photovoltaic cell

https://circuitglobe.com/photoelectric-transducer.html

ADVANTAGES OF PHOTO VOLTAIC CELL

- Robust in construction.
- Need no external power supply.
- It produces photo current stronger than the photo sensitive elements.

DISADVANTAGES OF PHOTO VOLTAIC CELL

- Selenium has low internal resistance. Hence amplification is difficult.
- Very sensitive galvanometers has to be used for measurement purpose.

PHOTO EMISSIVE CELL

- It consists of a cathode and an anode mounted in a vacuum tube made of glass.
- The cathode consists of a curved metal plate made of photosensitive material such as cesium or oxidised silver .
- the anode is made of nickel or platinum.
- When radiation of frequency above the threshold frequency falls on the cathode, electrons are emitted and flow to the anode constituting an electric current.

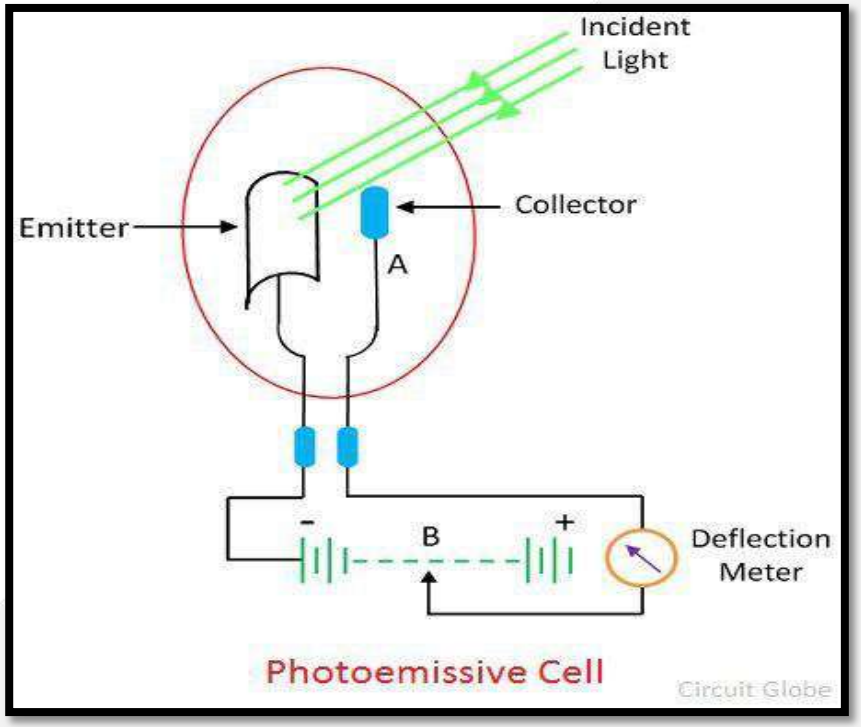

Fig.4 photo emissive cell

https://circuitglobe.com/photoelectric-transducer.html

ADVANTAGES OF PHOTO EMISSIVE CELL

- ✓ The emission is instantaneous.
- ✓ The maximum current is proportional to the intensity of radiation.
- ✓ Increased sensitivity.

DISADVANTAGES OF PHOTOEMISSIVE CELL

- ✓ Generates extremely small current.
- ✓ Direct power supply required for photomultiplier.
- ✓ More expensive. Can be replaced by silicon diode detectors.

PHOTOCONDUCTIVE CELL

- ✓ Also called LDRs-Light Dependent Resistors. Works on the principle that the resistance of a photosensitive semiconducting material decreases with the intensity of the incident light.
- ✓ The disadvantages are that the photoconductive cells are sluggish and show effect.
- ✓ When light of varying intensity falls on the film, a current flows through the circuit containing a galvanometer and a battery.
- ✓ The current directly varies with the intensity of light.

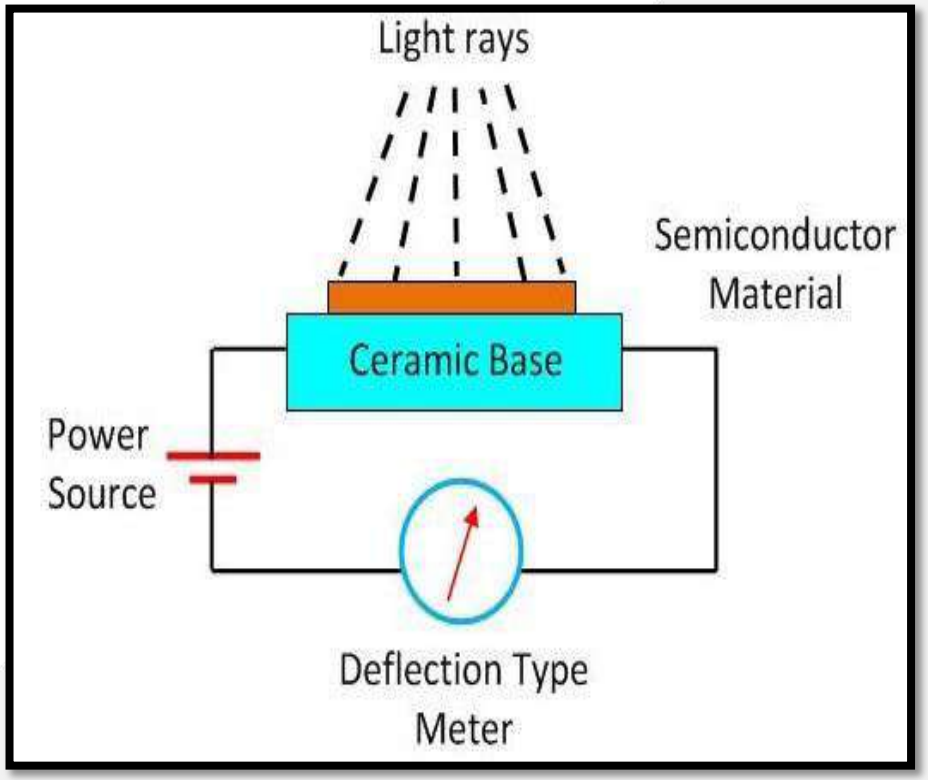

Fig.5 photoconductive cell

https://circuitglobe.com/photoelectric-transducer.html

TRIAXIAL SENSORS

Accelerometer: It is used to measure acceleration. Basically the sensors measures some electrical quantity like capacitance, current or voltage based on the acceleration it senses . The electrical quantity is then converted to its equivalent acceleration reading.

Gyroscopes: It measures angular velocity. Here also the sensors measure some change in capacitance proportional to the angular velocity the sensor is experiencing.

Magnetometer: It measures the heading based on earths magnetic field. But one has take care of the fact that there is no magnetic substances near by. Otherwise the reading will be seriously flawed.

TRIAXIAL SENSORS APPLICATIONS

- For inertial navigation systems, highly sensitive accelerometers are used.
- To detect and monitor vibrations in rotating machinery.
- To display images in an upright position on screens of digital cameras.
- For flight stabilization in drones.
- Accelerometers are used to sense orientation, coordinate acceleration, vibration, shock.
- Used to detect the position of the device in laptops and mobiles.

Practice Questions

1. Explain different types of photo electric transducer.
2. Explain tri axial sensor.
3. What are the advantages of photo emissive cell.