UNIT-3.

ELECTRICAL SAFETY, WIRING & INTRODUCTION TO POWER SYSTEM

ELECTRICAL WIRING

HOUSE WIRING

House wiring deals with the distribution system arranged within the domestic premises. Wiring requirement varies with customer to customer. House wiring generally done on either 230 V single phase or 400 V three phase supply. In the latter case, total load is divided among the three phases. An earth wire is also run connecting all the power plugs from where large quantity of electrical energy is tapped by using electrical appliances like heater, electric iron, hot plate, air conditioner etc.

Wiring materials and accessories

The following are the wiring material used for house wiring:

Switches Lamp holders Ceiling roses

Socket out-lets Switch boards Wires

Miniature circuit breaker Fuse unit

The accessories used for house wiring are:

Screw driver Cutting pliers Nose pliers Wire stripper Knife

Hammer Drilling machine Test lamp Wood saw Hack saw

TYPES OF WIRING

The type of wiring depends on environment, durability, safety, appearance and cost.

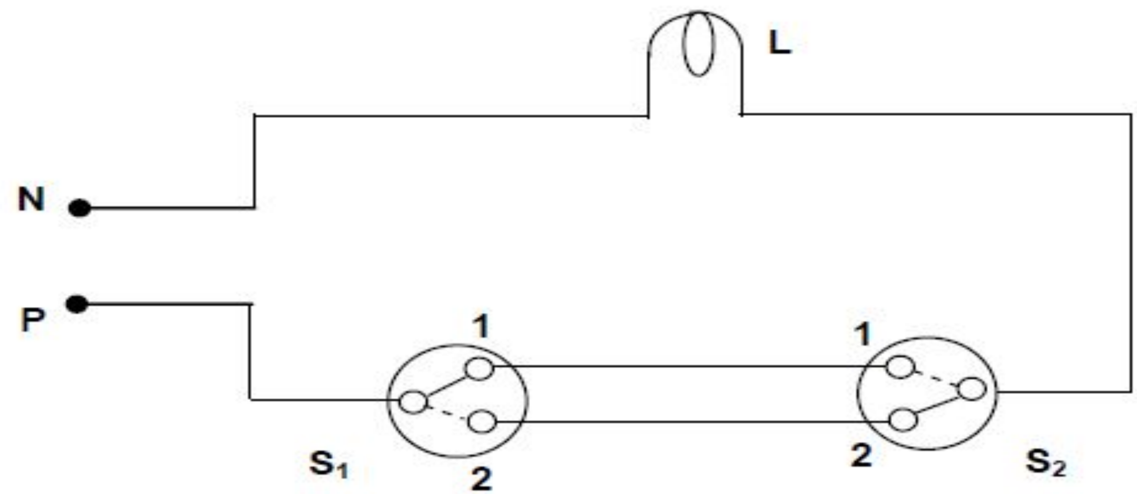
Cleat Wiring: In this system, V I R (Vulcanised India Rubber) conductor are supported in porcelain cleats. It is much cheaper; but will not provide good appearance.

Wooden Casing Capping: This system is more commonly used. It consists of rectangular wooden blocks, called casing. It has two grooves into which the wires are laid. Two or three wires of same polarity may be run in one groove. Wires of opposite polarity are not run in the same groove. The wooden casing at the top is covered by means of capping and is screwed on it. Nowadays the wooden casing and cappings are replaced by plastic to give good appearance and long life.

Conduit Wiring: In this system of wiring, V I R conductors are run inside metallic pipes called conduit. The conduits are buried into the walls. This system of wiring provides mechanical protection and good appearance. Nowadays instead of metal, PVC pipes are used.

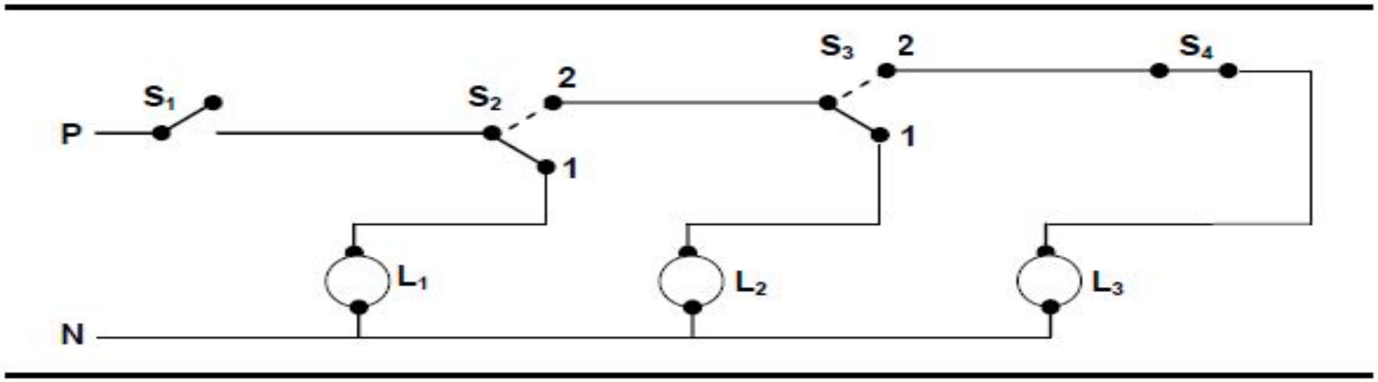
STAIRCASE WIRING

In staircase wiring a single lamp, placed at the middle of the staircase, is controlled by switches at two places, one at the beginning of the staircase and the other at the end of the staircase. For this purpose two-way switches are required. The wiring circuit is shown below.



Position of switch S_1	Position of switch S_2	Condition of lamp
1	1	ON
1	2	OFF
2	1	OFF
2	2	ON

CORRIDOR WIRING



Moving from left to right:

Enters	Closes S_1	L_1 ON
Reaches S_2	Put S_2 to 2	L_1 OFF and L_2 ON
Reaches S_3	Put S_3 to 2	L_2 OFF and L_3 ON
Reaches S_4	Opens S_4	L_3 OFF

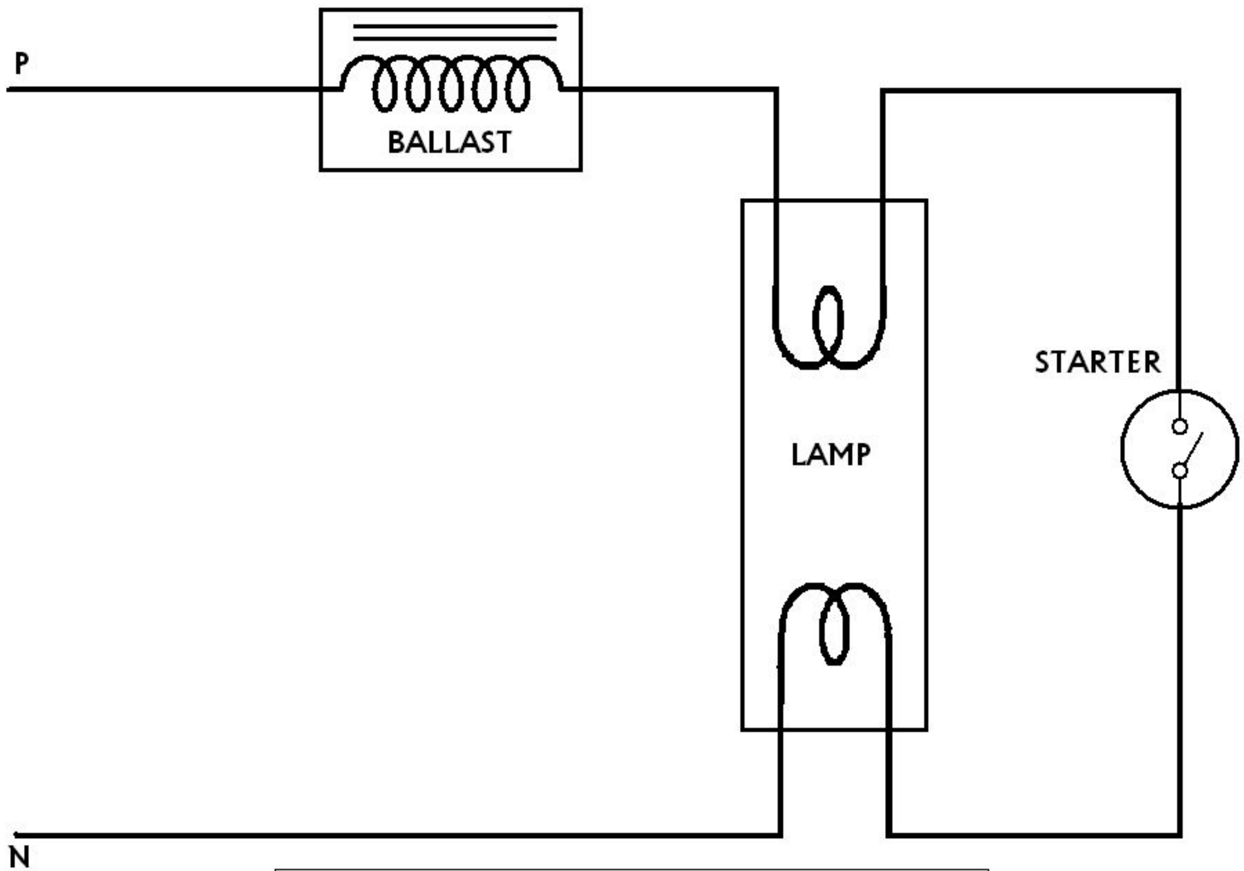
Moving from right to left:

Enters	Closes S_4	L_3 ON
Reaches S_3	Put S_3 to 1	L_2 ON and L_3 OFF
Reaches S_2	Put S_2 to 1	L_1 ON and L_2 OFF
Leaves	Opens S_1	L_1 OFF

FLUORESCENT LAMP

A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp is more costly because it requires a ballast to regulate the flow of current through the lamp.

While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes and is used as an energy-saving alternative in homes.



CIRCUIT DIAGRAM FOR FLUORESCENT LAMP WIRING

Safety Precautions when Working with Electricity

1. Never touch or try repairing any electrical equipment or circuits with **wet hands**. It increases the conductivity of electric current.

2. Never use equipment with **damaged insulation** or **broken plugs**.

3. If you are working on any electrical socket at your home then always **turn off the mains**.

4. Always **use insulated tools while working**.(never_use aluminium or steel ladder)

5. Electrical hazards include exposed **energized parts** and unguarded electrical equipment which may become **energized unexpectedly** -carries warning signs like "**Shock Risk**". Always be observant such electrical signs.

6. when working electrical circuit always use appropriate insulated rubber gloves and goggles.

7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire.

8. Know the wire code of your country.

9. Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential.

EARTHING

EARTHING

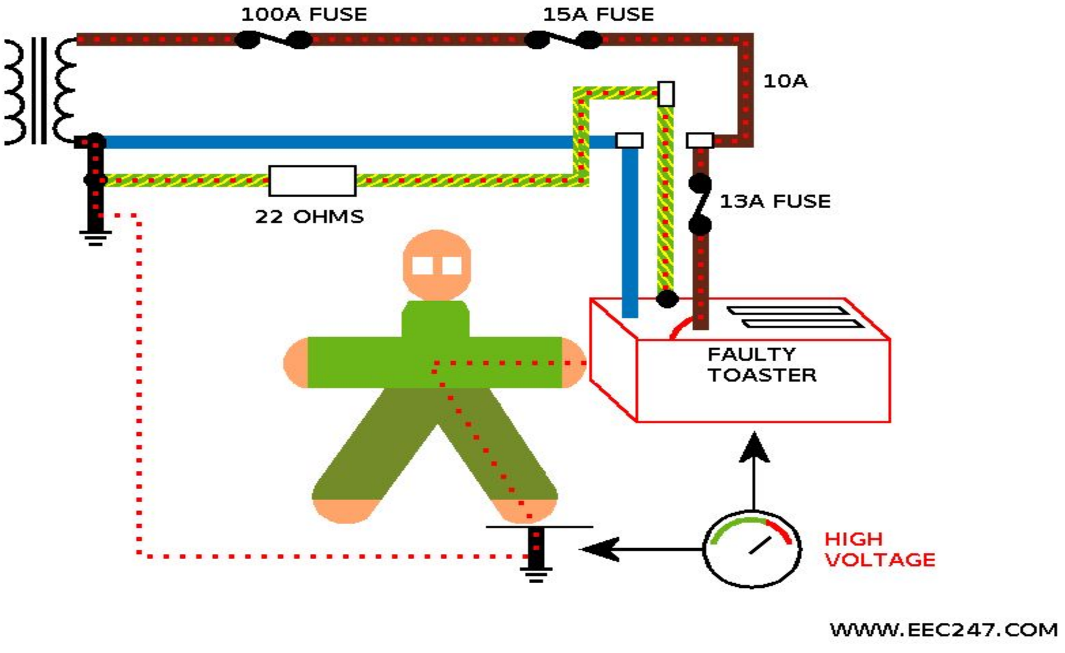
Earthing provides safe discharge of electric current due to leakages and faults to ground.

All metallic parts of electrical appliances shall be connected by earth wire made of very good conductor and finally the earth wire is connected to ground.

Earthing can be done through G.I. pipe or G.I. plate buried in the ground and surrounded by charcoal and common salt to provide good conductivity. To ensure safety earth resistance should be checked now and then and it is kept at a very low value.

What Is Earthing

The process of connecting metallic bodies of all the electrical apparatus and equipment to huge mass of earth by a wire having negligible resistance is called Earthing.



Objectives of the earthing

- Provide an alternative path for the fault current to flow so that it will not endanger the user
- Ensure that all exposed conductive parts do not reach a dangerous potential
- Maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.

Qualities Of Good Earthing

- Must be of low electrical resistance
- Must be of good corrosion resistance
- Must be able to dissipate high fault current repeatedly

Purpose of Earthing

- To save human life from danger of electrical shock or death by blowing a fuse i.e. To provide an alternative path for the fault current to flow so that it will not endanger the user
- To protect buildings, machinery & appliances under fault conditions ie. To ensure that all exposed conductive parts do not reach a dangerous potential.
- To provide safe path to dissipate lightning and short circuit currents.
- To provide stable platform for operation of sensitive electronic equipments i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment .
- To provide protection against static electricity from friction

Electric shock

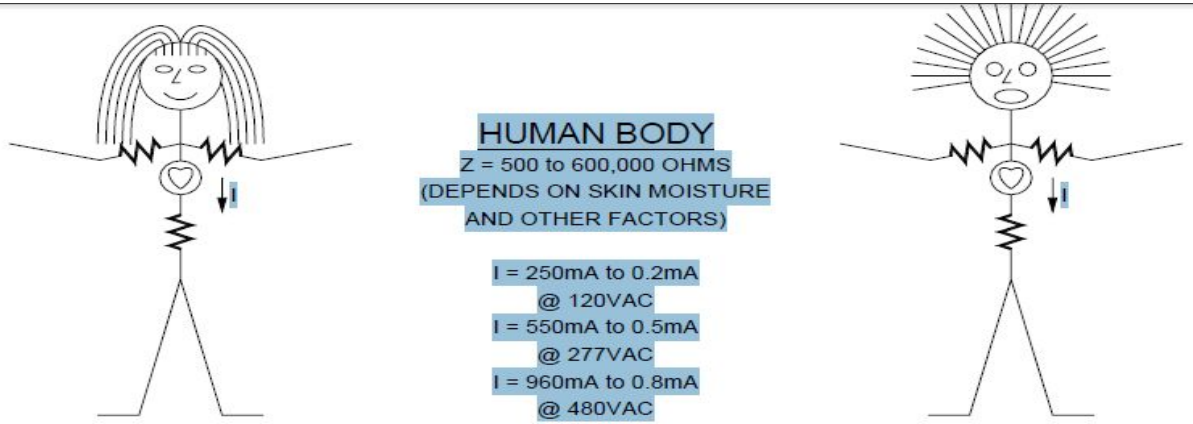
- An electric shock (electrocution)occurs when two portion of a person’s body come in contact with electrical conductors of a circuit which is at different potentials, thus producing a potential difference across the body.
- The human body does have resistance and when the body is connected between two conductors at different potential a circuit is formed through the body and current will flow
- When the human body comes in contact with only one conductor, a circuit is not formed and nothing happens. When the human body comes in contact with circuit conductors, no matter what the voltage is there is potential for harm.

Electric shock

- The higher the potential difference the more the damage. The effect of an electric shock is a function of what parts of body come in contact with each conductor, the resistance of each contact point the surface resistance of the body at the contact as well as other factor.
- When the electrical contact is such that the circuit path through the body is across the heart, you have the greatest potential for death.

Electric shock

- When a high voltage such as 13,800V is involved the body is literally cooked and at times explodes



ELECTRIC SHOCK

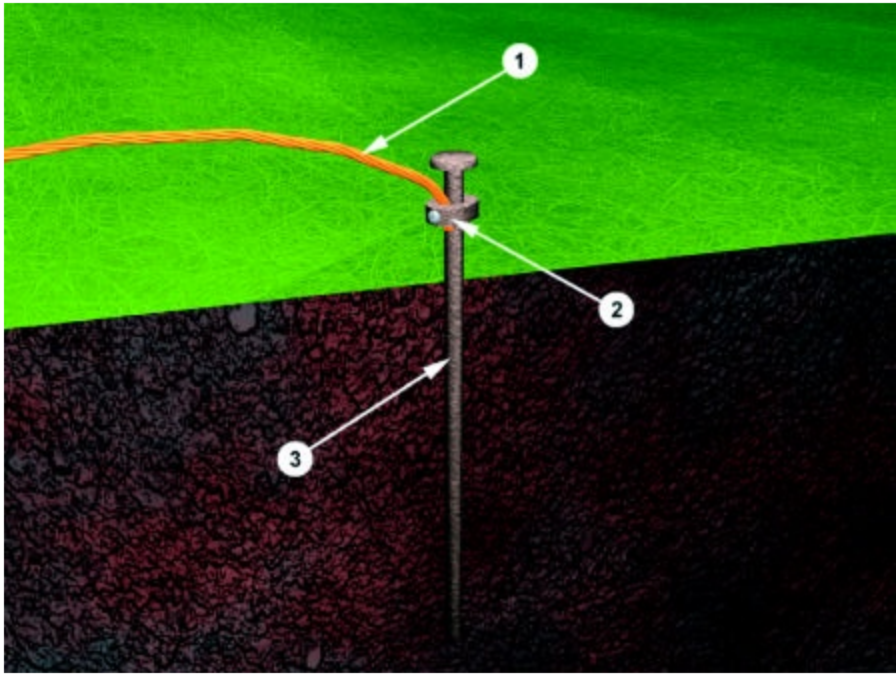
	AC @ 60Hz	DC
PERCEPTION LEVEL	1mA	2mA
NO-LET-GO LEVEL	15mA	300mA
FIBRILLATION LEVEL @ 0.2 SECONDS	500mA	500mA
FIBRILLATION LEVEL @ 0.5 SECONDS	75mA	400mA

Types of Earthing

1. Plate Earthing
2. Pipe Earthing

Earthing Electrode

The resistance of a ground electrode has 3 basic components:



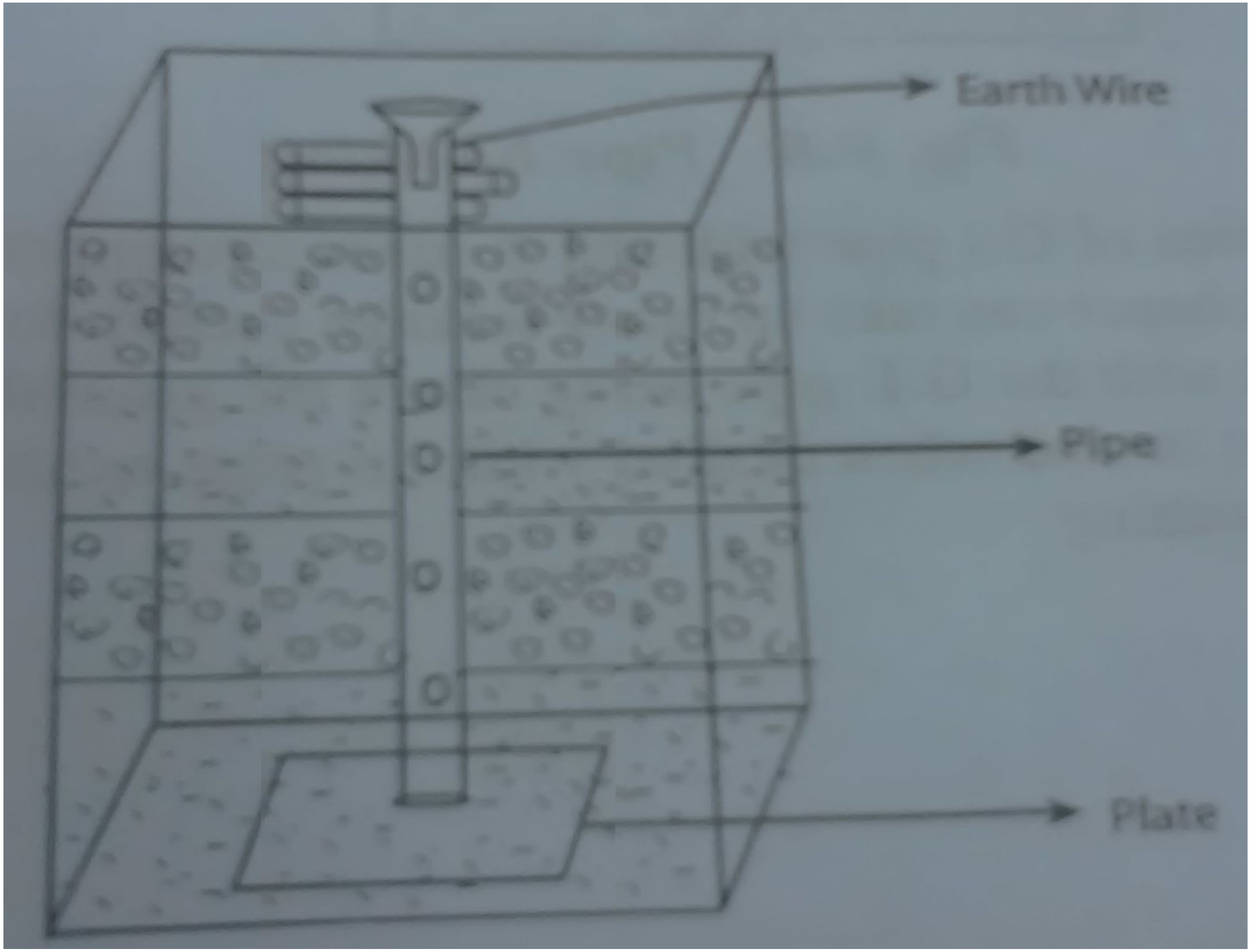
A) The resistance of the ground electrode itself and the connections to the electrode.
B) The contact resistance of the surrounding earth to the electrode.
C) The resistance of the surrounding body of earth around the ground Electrode. It consist of three basic components:

1. Earth Wire
2. Connector
3. Electrode

Plate Earthing

- In this type of earthing plate either of copper or of G.I. is buried into the ground at a depth of not less than 3 meter from the ground level.
- The earth plate is embedded in alternative layer of coke and salts for a minimum thickness of about 15cm.
- The earth wire(copper wire for copper plate earthing and G.I. wire for G.I. plate earthing) is securely bolted to an earth plate with the help of bolt nut and washer made of copper, in case of copper plate earthing and of G.I. in case of G.I. plate earthing.

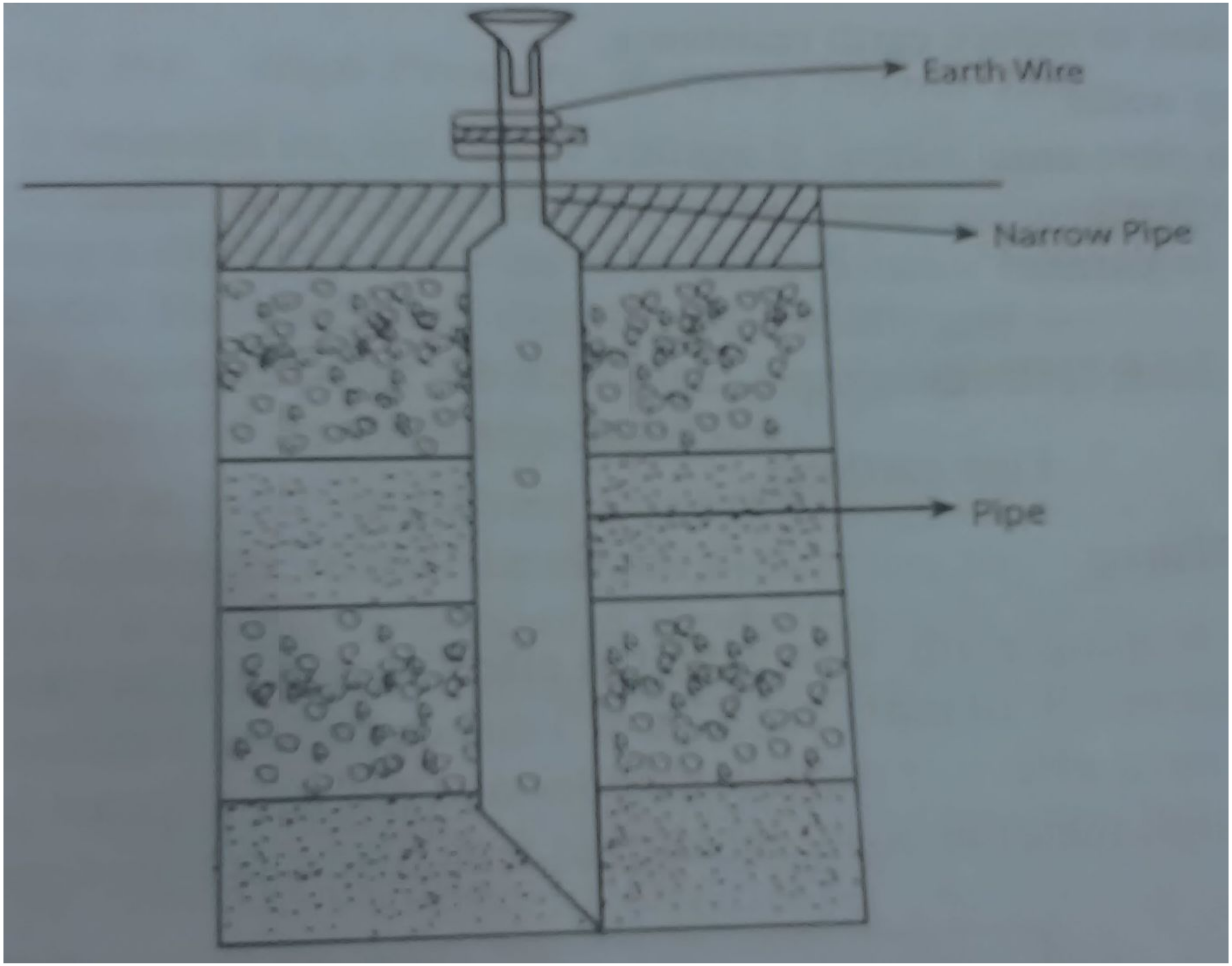
PLATE EARTHING



Pipe earthing

- Pipe earthing is best form of earthing and it is cheap also in this system of earthing a GI pipe of 38 mm dia and 2meters length is embedded vertically in ground to work as earth electrode but the depth depend upon the soil conditions, there is no hard and fast rule for this.
- But the wire is embedded up to the wet soil.
- The earth wire are fastened to the top section of the pipe with nut and bolts.
- The pit area around the GI pipe filled with salt and coal mixture for improving the soil conditions and efficiency of the earthing system.
- It can take heavy leakage current for the same electrode size in comparison to plate earthing.
- The earth wire connection with GI pipes being above the ground level can be checked for carrying out continuity test as and when desired, while in plate earthing it is difficult.
- In summer season to have an effective earthing three or four bucket of water is put through the funnel for better continuity of earthing.

PIPE EARTHING



Unit-3 **MEASURING INSTRUMENTS**

- PMMC
- PMMI
- Dynamometer
- Induction
- Thermal
- Rectifier

Measurement of voltage and current

Permanent Magnet Moving Coil (PMMC) Instrument

- The **PMMC type instrument** uses two permanent magnets in order to create stationary magnetic field.
- These types of instruments are only used for measuring the dc quantities.
- If we apply ac current to these type of instruments the direction of electric current will be reversed during negative half cycle and hence the direction of torque will also be reversed which gives average value of torque zero.
- The pointer will not deflect due to high frequency from its mean position showing zero reading. However it can measure the direct current very accurately.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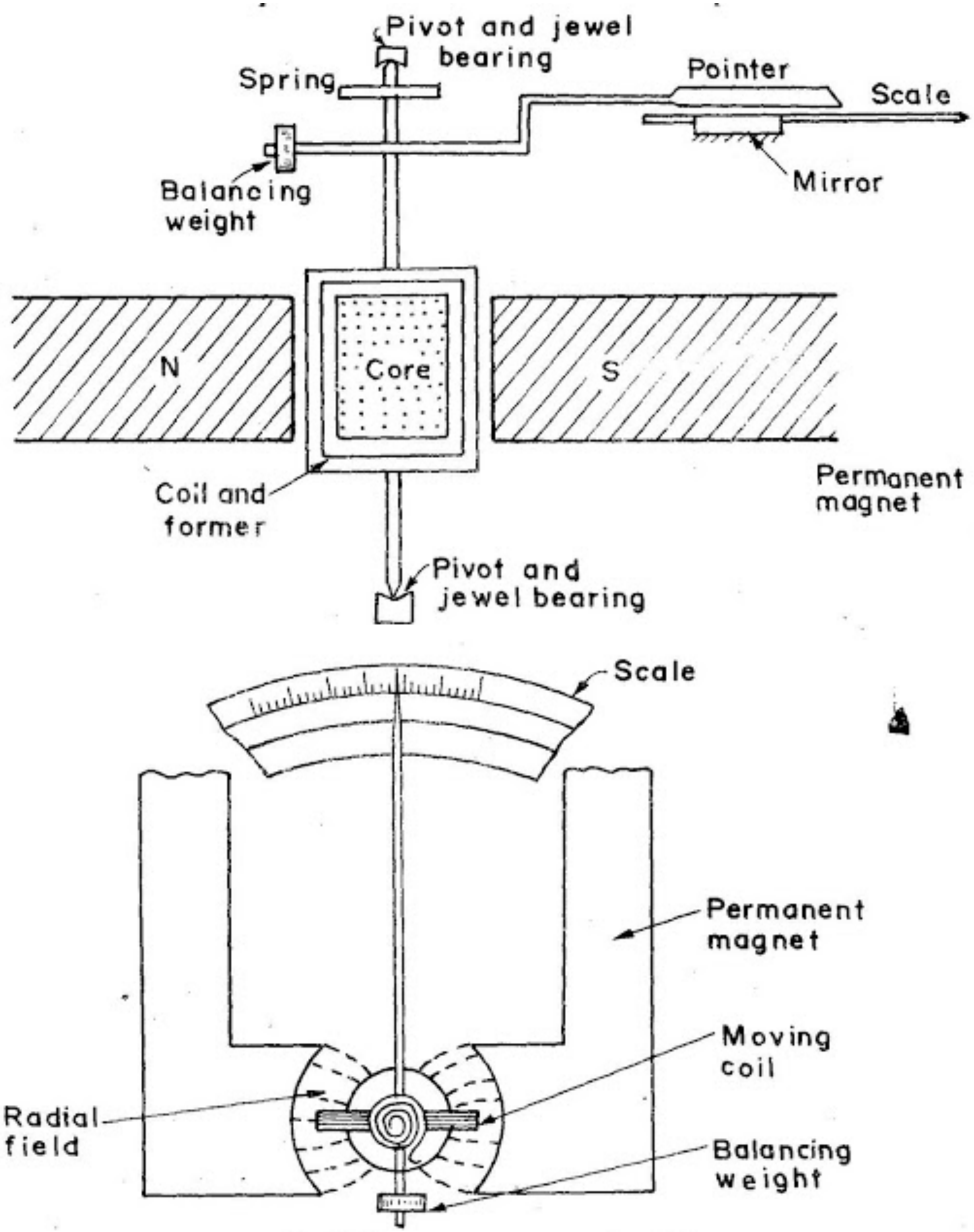

Pivot and jewel bearing
Spring
Pointer
Scale
Mirror
Balancing weight
N
Core
S
Coil and former
Permanent magnet
Pivot and jewel bearing
Scale
Permanent magnet
Moving coil
Radial field
Balancing weight

(a) **Stationary part or magnet system:** In the present time we use magnets of high field intensities, high coercive force instead of using U shaped permanent magnet having soft iron pole pieces. The magnets which we are using nowadays are made up of materials like alcomax and alnico which provide high field strength.

(b) **Moving coil:** The moving coil can freely moves between the two permanent magnets as shown in the figure given below. The coil is wound with many turns of copper wire and is placed on rectangular aluminium which is pivoted on jeweled bearings.

(c) **Control system:** The spring generally acts as control system for PMMC instruments. The spring also serves another important function by providing the path to lead current in and out of the coil.

(d) **Damping system:** The damping force hence torque is provided by movement of aluminium former in the magnetic field created by the permanent magnets.

(e) **Meter:** Meter of these instruments consists of light weight pointer to have free movement and scale which is linear or uniform and varies with angle.

- In PMMC meter or (D’Arsonval) meter or galvanometer all are the same instrument, a coil of fine wire is suspended in a magnetic field produced by permanent magnet.
- According to the fundamental law of electromagnetic force, the coil will rotate in the magnetic field when it carries an electric current by electromagnetic (EM) torque effect.
- A pointer which attached the movable coil will deflect according to the amount of current to be measured which applied to the coil.
- The (EM) torque is counterbalance by the mechanical torque of control springs attached to the movable coil also.
- When the torques are balanced the moving coil will stopped and its angular deflection represent the amount of electrical current to be measured against a fixed reference, called a scale.
- If the permanent magnet field is uniform and the spring linear, then the pointer deflection is also linear.

Advantages

The various advantages of PMMC instruments are,

1) It has uniform scale.
2) With a powerful magnet, its torque to weight ratio is very high. So operating current is small.
3) The sensitivity is high.
4) The eddy currents induced in the metallic former over which coil is wound, provide effective damping.
5) It consumes low power, of the order of 25 W to 200 μW.
6) It has high accuracy.
7) Instrument is free from hysteresis error.
8) Extension of instrument range is possible.
9) Not affected by external magnetic fields called stray magnetic fields.

Disadvantages

The various disadvantages of PMMC instruments are,

1) Suitable for d.c. measurements only.
2) Ageing of permanent magnet and the control springs introduces the errors.
3) The cost is high due to delicate construction and accurate machining.
4) The friction due to jewel-pivot suspension.

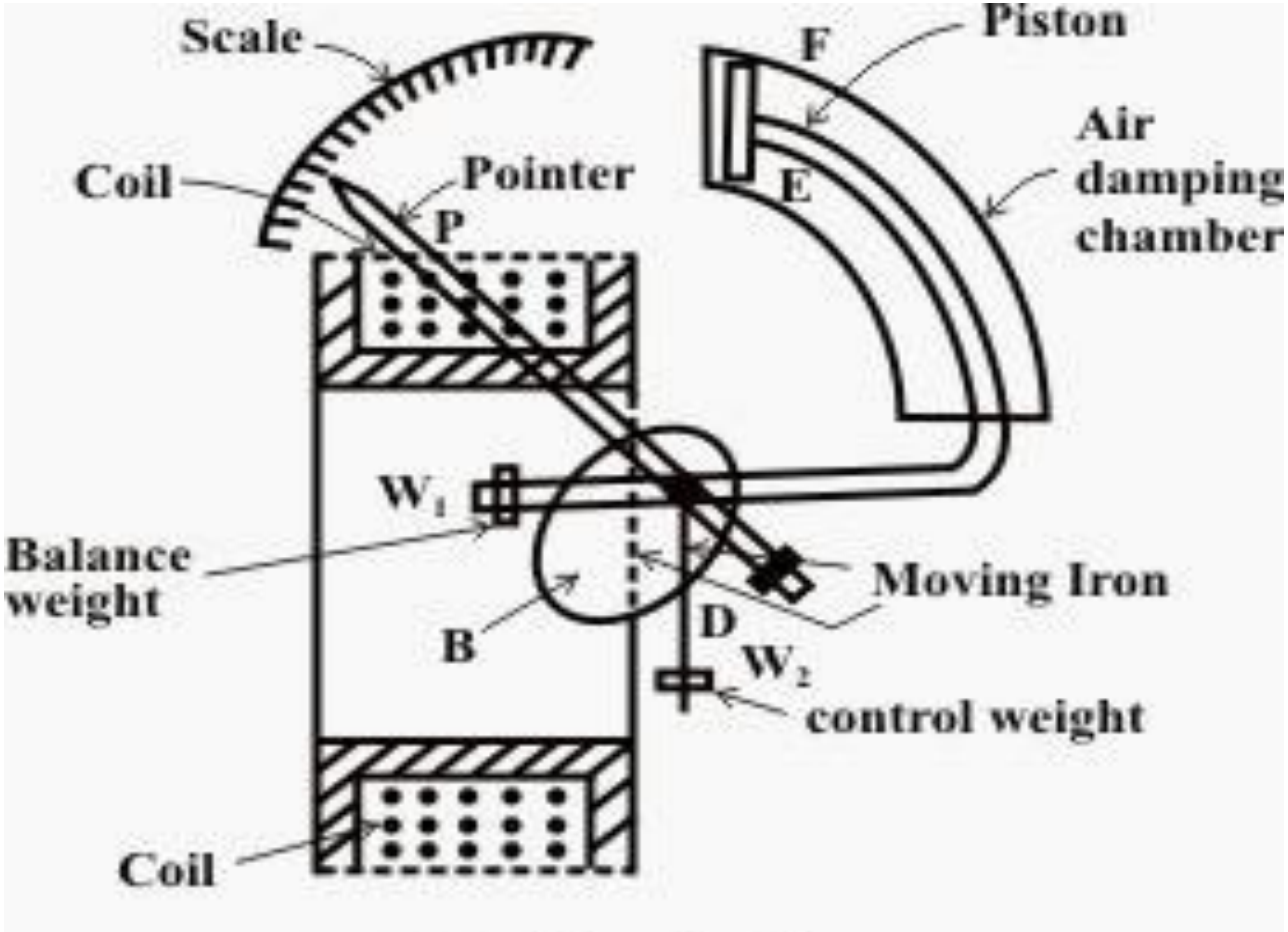
Permanent Magnet Moving Iron (PMMI) Instrument

- M.I instruments are mainly used for the measurement of alternating currents and voltages, though it can also be used for D.C measurements.
- Moving iron type instruments are of mainly two types. Attraction type and repulsion type instrument.

Attraction type Moving Iron Instrument

- Whenever a plate or vane of soft iron or of high permeability steel forms the moving element is placed nearer to a magnet it would be attracted by the magnet.
- The force of this attraction depends upon the strength said magnetic field.
- If the magnet is electromagnet then the magnetic field strength can easily be increased or decreased by increasing or decreasing electric current through its coil.
- Accordingly the attraction force acting on the piece of iron would also be increased and decreased.
- Depending upon this simple phenomenon attraction type **moving iron instrument** was developed.

In this type of instrument, a single soft iron vane (moving iron) is mounted on the spindle, and is attracted towards the coil when operating current flows through it.



Attraction type

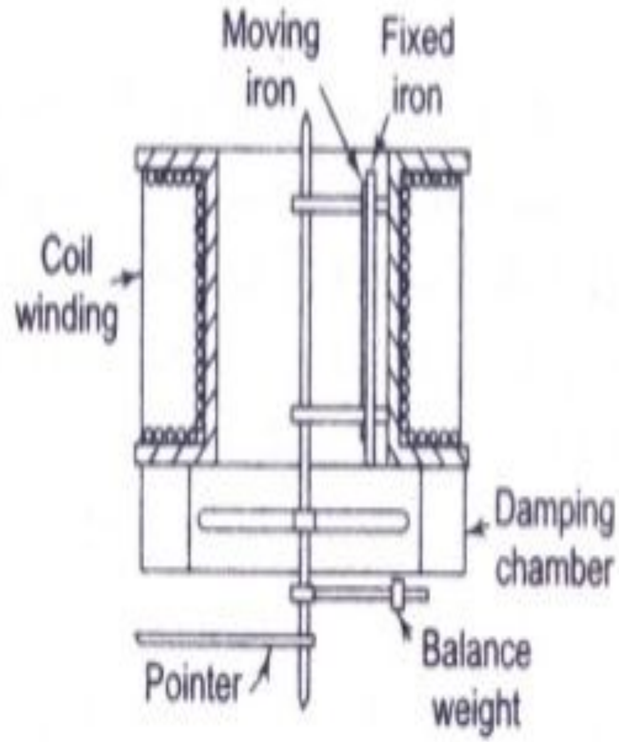
- This iron tends to move inward that is from weaker magnetic field to stronger magnetic field when current flowing through the coil.
- In attraction moving instrument gravity control was used previously but now gravity control method is replaced by spring control in relatively modern instrument.
- By adjusting balance weight null deflection of the pointer is achieved.
- The required damping force is provided in this instrument by air friction.
- The figure shows a typical type of damping system provided in the instrument, where damping is achieved by a moving piston in an air syringe.

Repulsion type Moving Iron Instrument

- In this two soft iron vanes are used
  - one fixed and attached the stationary coil,
  - other is movable (moving iron), and mounted on the spindle of the instrument.
- When operating current flows through the coil, the two vanes are magnetized, developing similar polarity at the same ends.
- Consequently, repulsion takes place between the vanes and the movable vane causes the pointer to move over the scale.

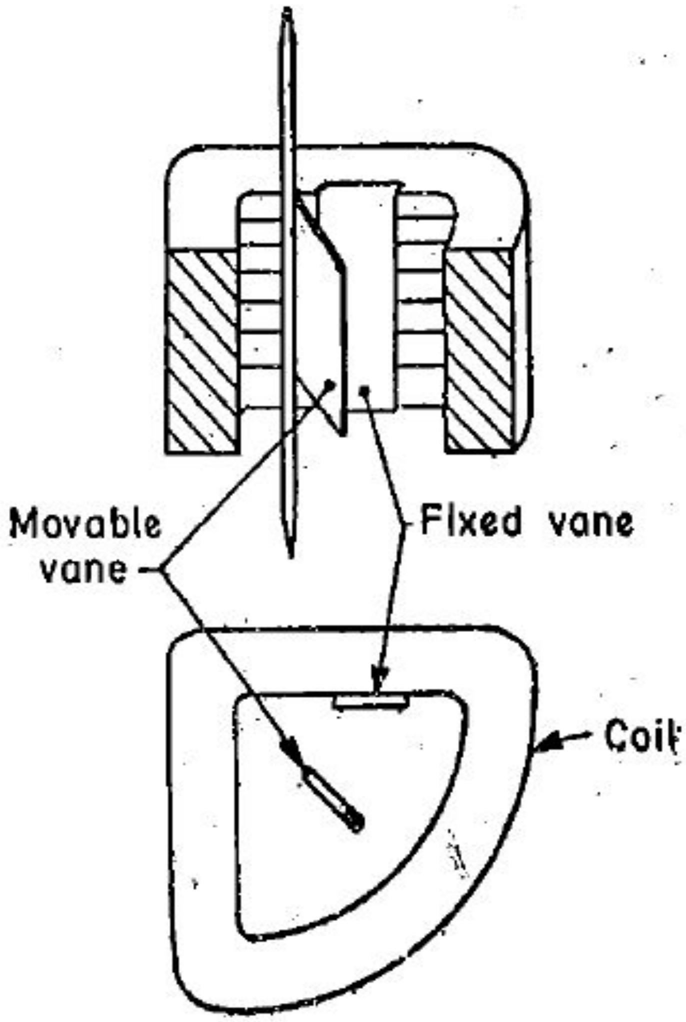
Moving Iron type instruments: ***Repulsion type***

When current flows through the coil, Two soft iron rods get magnetized similarly, causing them to repel each other.

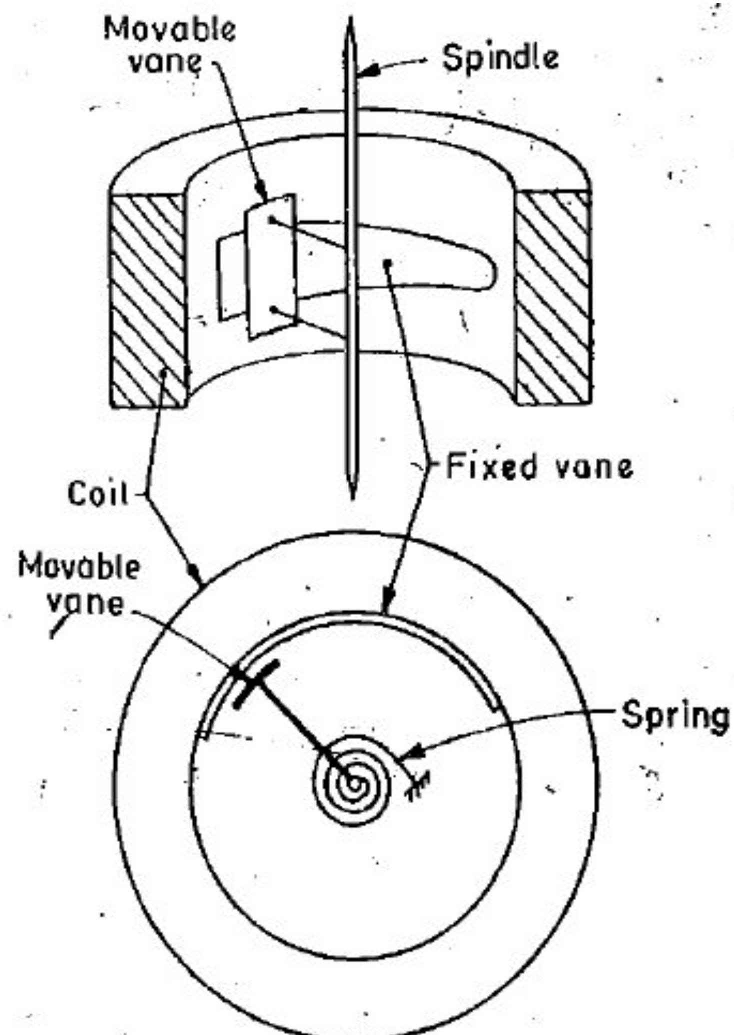


a. Radial Vane Type: - vanes are radial strips of iron.

b. Co-axial Vane Type:- vanes are sections of coaxial cylinders.



(*a*) Radial vane type.



(*b*) Co-axial vane type.

- This repulsion force is due to same magnetic poles induced in same sides the iron pieces due external magnetic field.
- This repulsion force increases if field strength of the magnet is increased. Like case if the magnet is electromagnet, then magnetic field strength can easily be controlled by controlling input current to the magnet.
- Hence if the electric current increases the repulsion force between the pieces of iron is increased and it the current decreases the repulsion force between them is decreased.
- Depending upon this phenomenon repulsion type **moving iron instrument** was constructed

Advantages

The various advantages of moving iron instruments are,

1) The instruments can be used for both a.c. and d.c. measurements.
2) As the torque to weight ratio is high, errors due to the friction are very less.
3) A single type of moving element can cover the wide range hence these instruments are cheaper than other types of instruments.
4) There are no current carrying parts in the moving system hence these meters are extremely rugged and reliable.
5) These are capable of giving good accuracy. Modern moving iron instruments have a d.c. error of 2% or less.
6) These can withstand large loads and are not damaged even under severe overload conditions.
7) The range of instruments can be extended.

Disadvantages

The various disadvantages of moving iron instruments are,

1) The scale of the moving iron instruments is not uniform and is cramped at the lower end. Hence accurate readings are not possible at this end.

2) There are serious errors due to hysteresis, frequency changes and stray magnetic fields.

3) The increase in temperature increases the resistance of coil, decreases stiffness of the springs, decreases the permeability and hence affect the reading severely.

4) Due to the non linearity of B-H curve, the deflecting torque is not exactly proportional to the square of the current.

5) There is a difference between a.c. and d.c. calibrations on account of the effect of inductance of the meter. Hence these meters must always be calibrated at the frequency at which they are to be used. The usual commercial moving iron instrument may be used within its specified accuracy from 25 to 125 Hz frequency range.

6) Power consumption is on higher side.

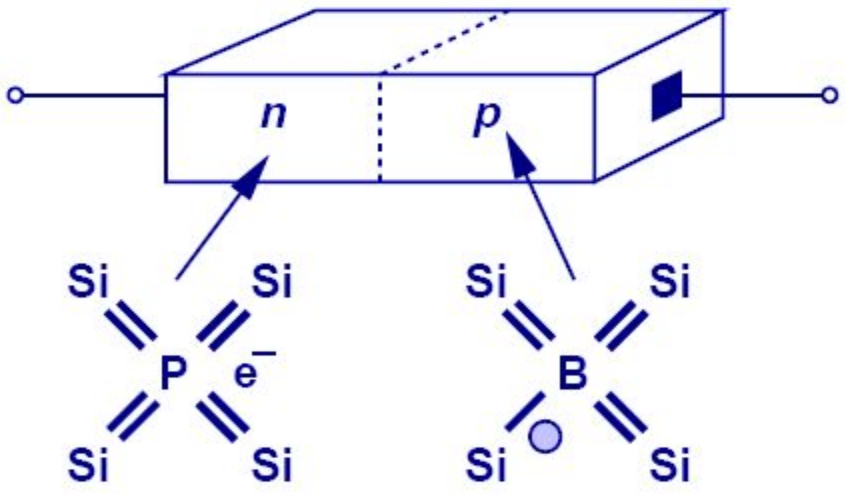
Meter Type	Control	Damping	Suitability	Application
PMMC	Spring	Eddy current	D.C.	Widely used for d.c. current and voltage measurements in low and medium impedance circuits.
Moving Iron	Spring or Gravity	Air friction	D.C. and A.C.	Used for rough indication of currents and voltages. Widely used for the indicator type instruments on panels.

Electronic devices

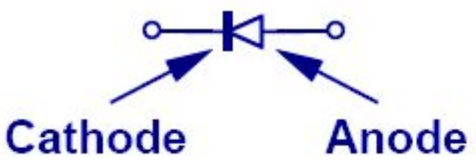
PN- DIODE

SEMICONDUCTOR DIODE

- **Theory of p-n junction**
- **p-n junction as diode**
- **p-n diode currents**
- **Volt-amp characteristics**
- **Diode resistance**
- **Temperature effect of p-n junction**
- **Transition and diffusion capacitance of p-n diode**
- **Diode switching times**



(a)

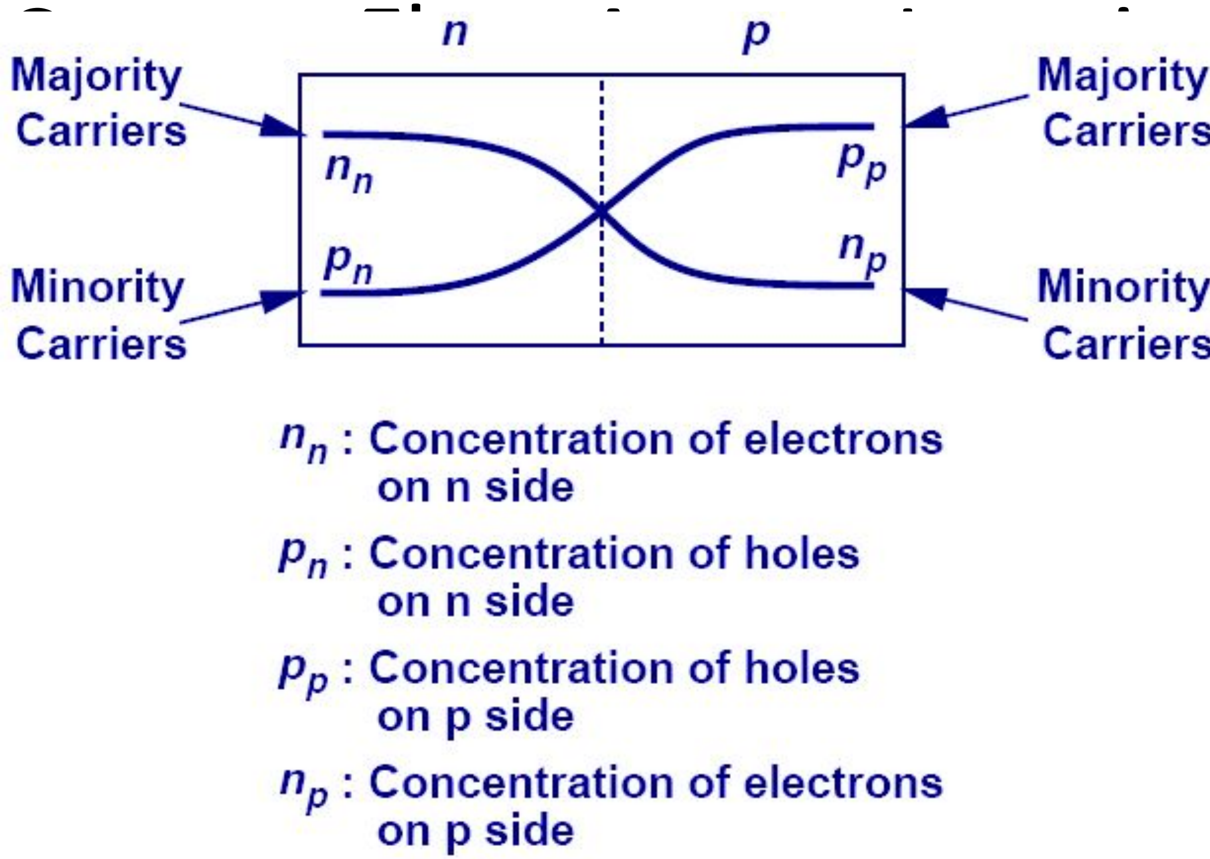


(b)

- When N-type and P-type dopants are introduced side-by-side in a semiconductor, a PN junction or a diode is formed.
- The p-n junction is also called as semiconductor diode .
- The left side material is a p-type semiconductor having –ve acceptor ions and +vely charged holes. The right side material is n-type semiconductor having +ve donor ions and free electrons

p-n junction as diode

- Suppose the two pieces are suitably treated to form pn junction, then there is a tendency for the free electrons from n-type to diffuse over to the p-side and holes from p-type to the n-side . This process is called **diffusion**
- The left side material is a p-type semiconductor having –ve acceptor ions and +vely charged holes. The right side material is n-type semiconductor having +ve donor ions and free electrons.

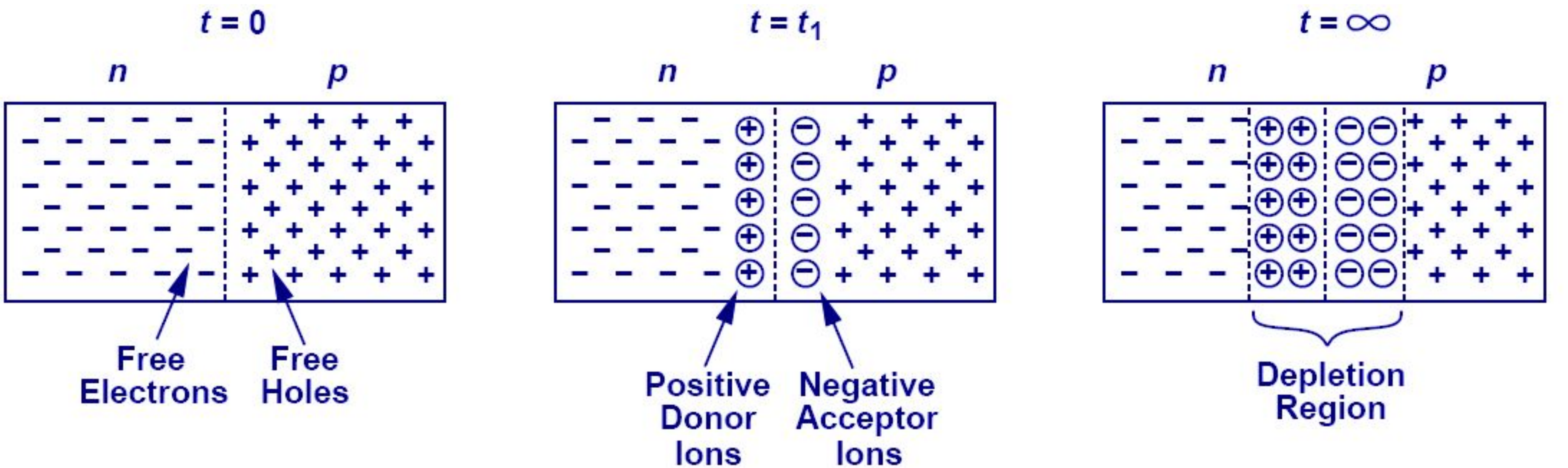


- Because each side of the junction contains an excess of holes or electrons compared to the other side, there exists a large concentration gradient. Therefore, a diffusion current flows across the junction from each side.

p-n junction as diode

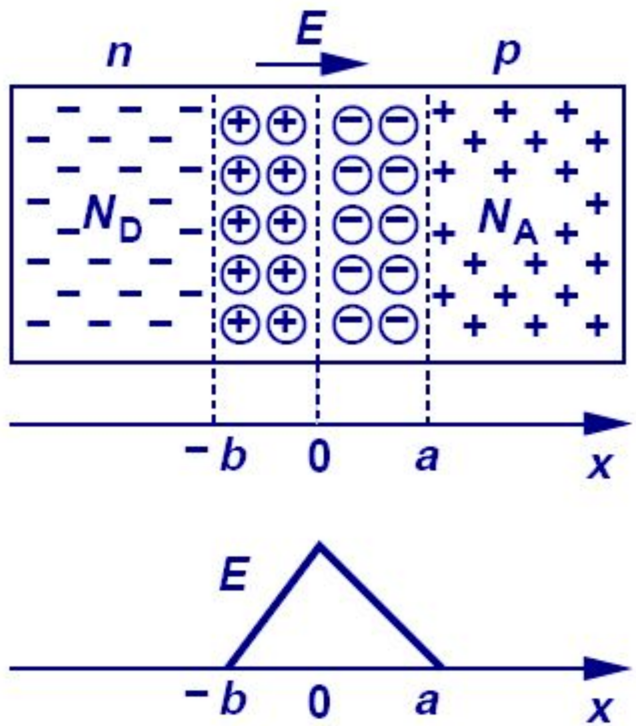
- As the free electrons move across the junction from n-type to p-type, +ve donor ions are uncovered. Hence a +ve charge is built on the n-side of the junction. At the same time, the free electrons cross the junction and uncover the –ve acceptor ions by filling in the holes. Therefore a net –ve charge is established on p-side of the junction.

Depletion Region



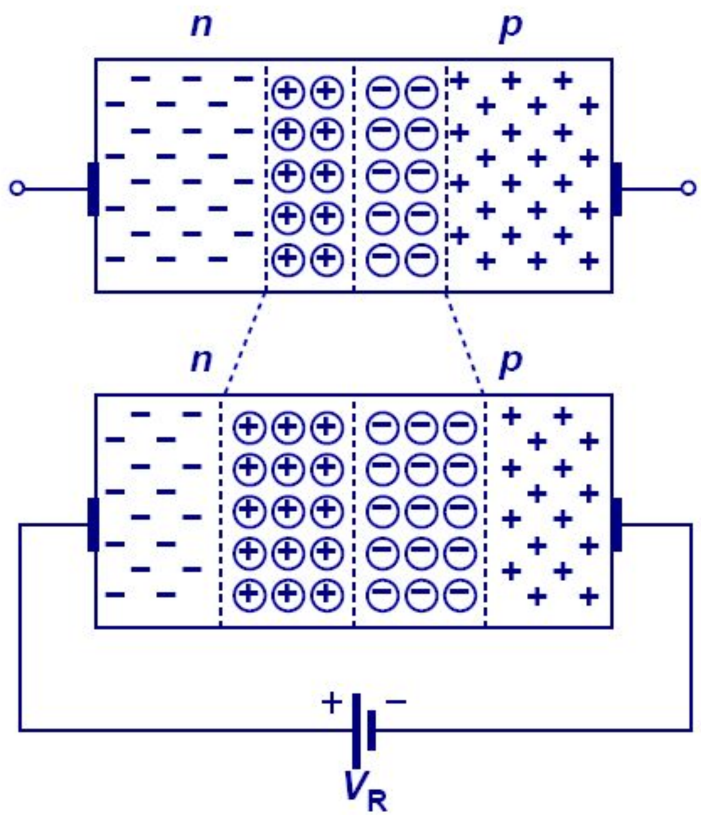
- As free electrons and holes diffuse across the junction, a region of fixed ions is left behind. This region is known as the "depletion region."

Current Flow Across Junction: Drift

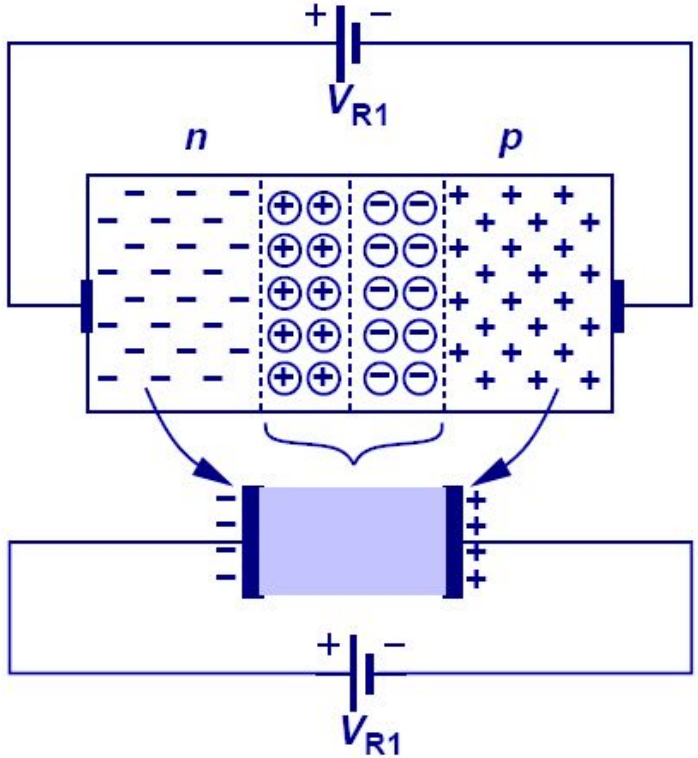


- The fixed ions in depletion region create an electric field that results in a drift current.

D e Bias



- When the N-type region of a diode is connected to a higher potential than the P-type region, the diode is under reverse bias, which results in wider depletion region and larger built-in electric field across the junction.



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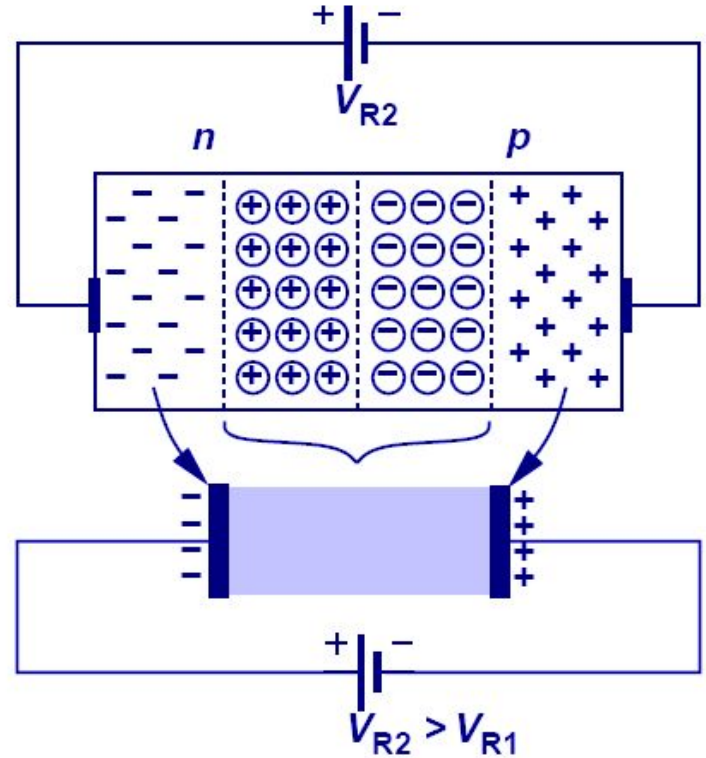


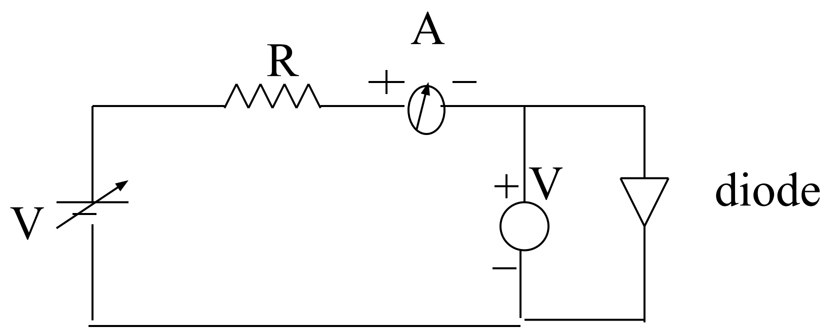
(b)

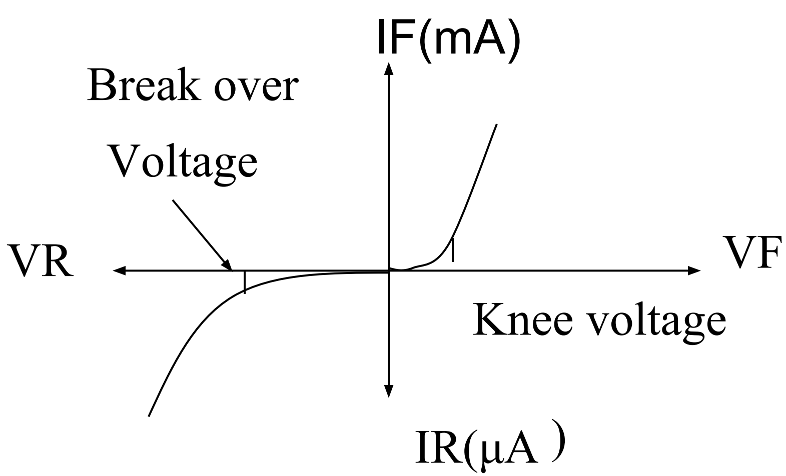
- The PN junction can be viewed as a capacitor. By varying V_R, the depletion width changes, changing its capacitance value; therefore, the PN junction is actually a voltage-dependent capacitor.

p-n junction as diode

- When a sufficient number of donor and acceptor ions is uncovered further diffusion is prevented.
- Thus a barrier is set up against further movement of charge carriers. This is called potential barrier or junction barrier Vo. The potential barrier is of the order of 0.1 to 0.3V.
- **Note:** outside this barrier on each side of the junction, the material is still neutral. Only inside the barrier, there is a +ve charge on n-side and –ve charge on p-side. This region is called depletion layer.

Volt-amp characteristics

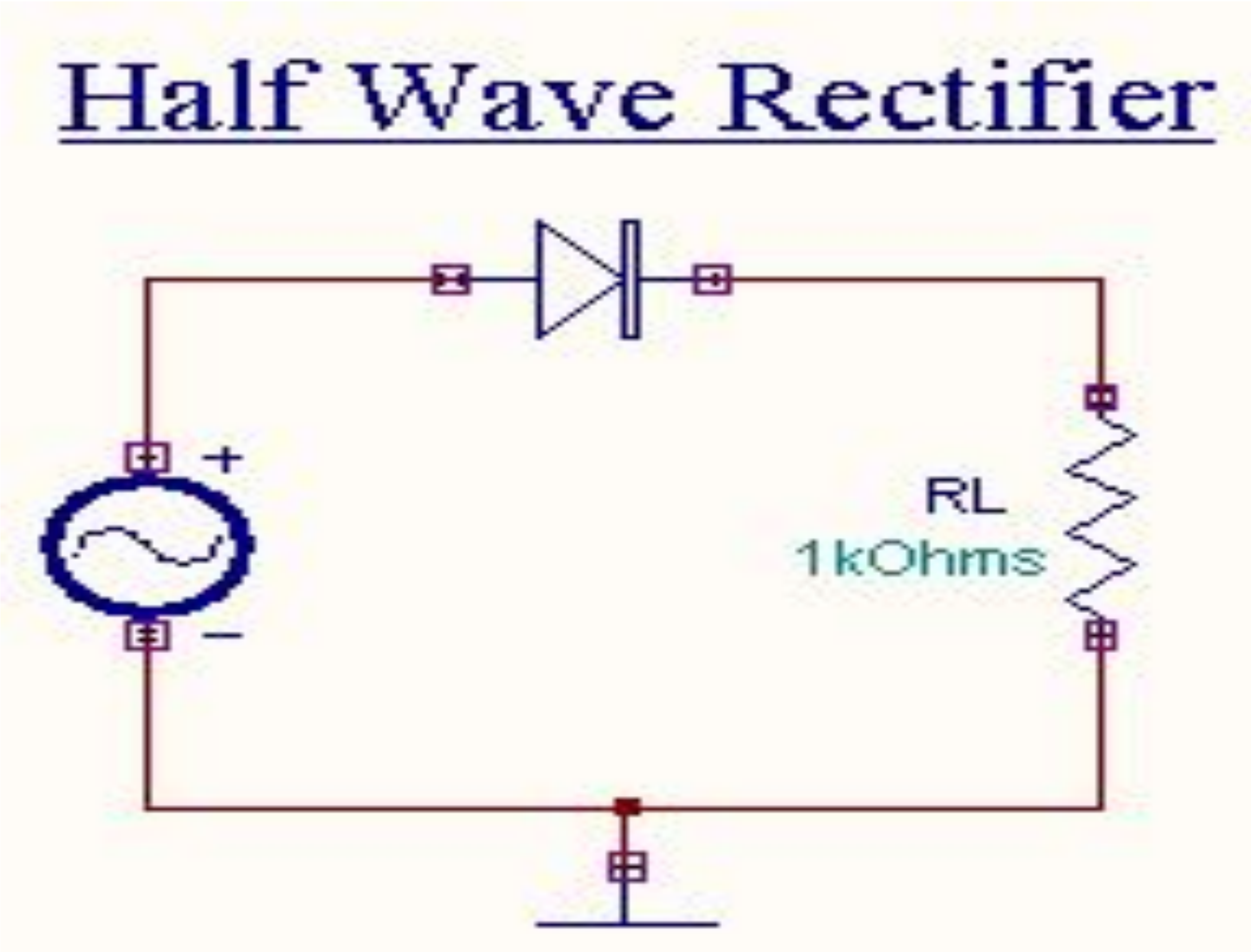




Volt-amp characteristics

- The supply voltage V is a regulated power supply, the diode is forward biased in the circuit shown. The resistor R is a current limiting resistor. The voltage across the diode is measured with the help of voltmeter and the current is recorded using an ammeter.
- By varying the supply voltage different sets of voltage and currents are obtained. By plotting these values on a graph, the forward characteristics can be obtained. It can be noted from the graph the current remains zero till the diode voltage attains the barrier potential.
- For silicon diode, the barrier potential is 0.7 V and for Germanium diode, it is 0.3 V. The barrier potential is also called as knee voltage or cut-in voltage.

HALFWAVE RECTIFIER



HALFWAVE RECTIFIER

- The primary of the transformer is connected to ac supply. This induces an ac voltage across the secondary of the transformer.
- During the positive half cycle of the input voltage the polarity of the voltage across the secondary forward biases the diode. As a result a current IL flows through the load resistor, RL. The forward biased diode offers a very low resistance and hence the voltage

HALFWAVE RECTIFIER

- Drop across it is very small. Thus the voltage appearing across the load is practically the same as the input voltage at every instant.
- During the negative half cycle of the input voltage the polarity of the secondary voltage gets reversed. As a result, the diode is reverse biased.
- Practically no current flows through the circuit and almost no voltage is developed across the resistor. All input voltage appears across the diode itself.

HALFWAVE RECTIFIER

- Hence we conclude that when the input voltage is going through its positive half cycle, output voltage is almost the same as the input voltage and during the negative half cycle no voltage is available across the load.
- This explains the unidirectional pulsating dc waveform obtained as output. The process of removing one half the input signal to establish a dc level is aptly called half wave rectification.

HALFWAVE RECTIFIER

Peak Inverse Voltage

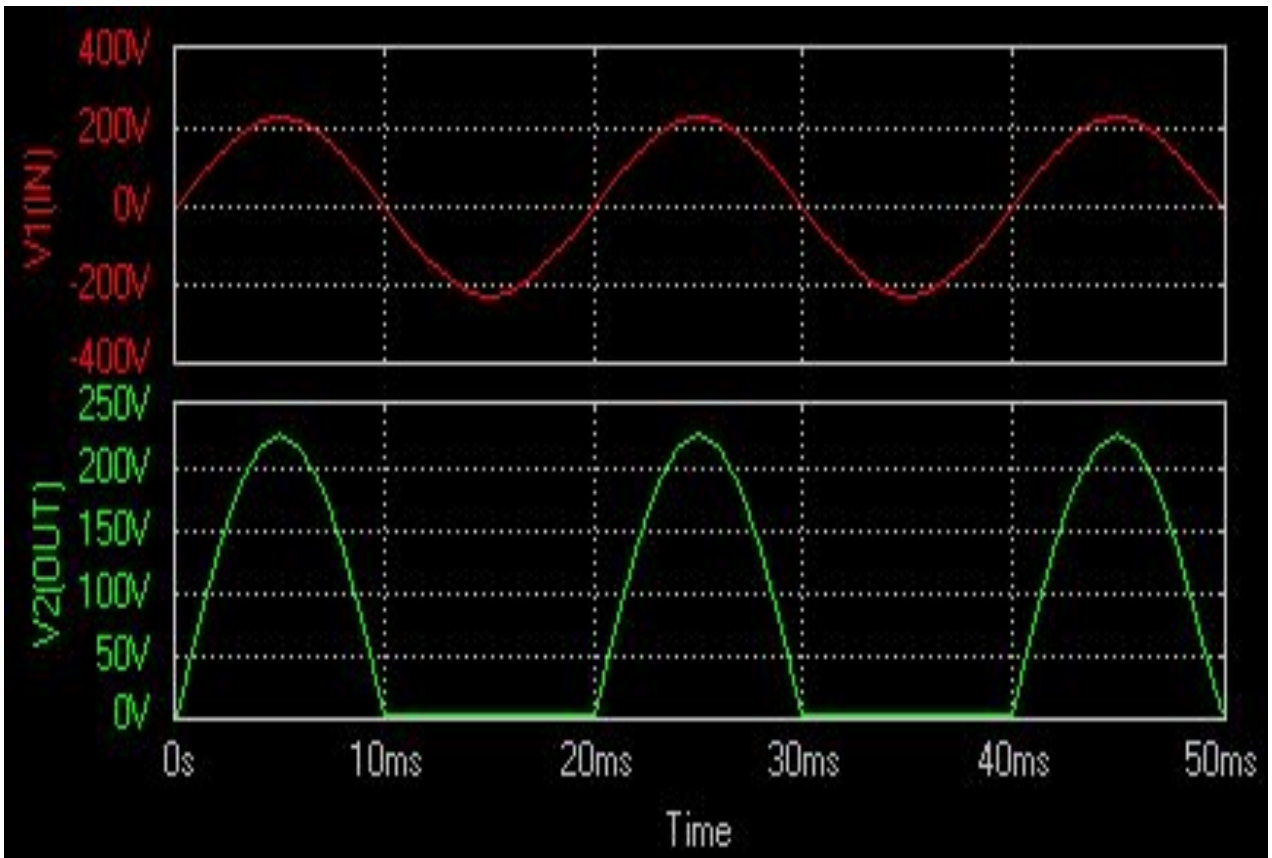
- When the input voltage reaches its maximum value *Vm* during the negative half cycle the voltage across the diode is also maximum. This maximum voltage is known as the peak inverse voltage.

Thus for a half wave rectifier

Let *Vi* be the voltage to the primary of the transformer. *Vi* is given by

where *Vr* is the cut-in voltage of the diode.

Half wave waveform



HALFWAVE RECTIFIER

Ripple Factor

- Ripple factor is defined as the ratio of rms value of ac component to the dc component in the output.

Ripple factor

$$r = \frac{RMS\ value\ of\ the\ ac\ componen.}{dc\ value\ of\ the\ component}$$

HALFWAVE RECTIFIER

The ripple is

$$\gamma = \frac{Vr_{rms}}{V_{dc}} \rightarrow (2)$$

$$V\gamma_{rms} = \sqrt{V_{rms}^{2} - V_{dc}^{2}} \rightarrow (3)$$

$$r = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^{2} - 1} \rightarrow (4)$$

HALFWAVE RECTIFIER

Vav the average or the dc content of the voltage across the load is given by

$$V_{av} = V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 . d(\omega t)\right] \rightarrow (5)$$

HALFWAVE RECTIFIER

RMS voltage at the load resistance can be calculated as

$$V_{rms} = \left[\frac{1}{2\pi}\int_0^{\pi} V_m^{\,2} \sin^2 \omega t \, d(\omega t)\right]^{1/2} \rightarrow (8)$$

$$= V_m \left[\frac{1}{4\pi}\int_0^{\pi} (1 - \cos 2\,\omega t)\, d(\omega t)\right]^{1/2} = \frac{V_m}{2} \rightarrow (9)$$

HALFWAVE RECTIFIER

Ripple Factor

$$r = \sqrt{\left(\frac{V_m/2}{V_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2} = \underline{\underline{1.21}} \rightarrow (10)$$

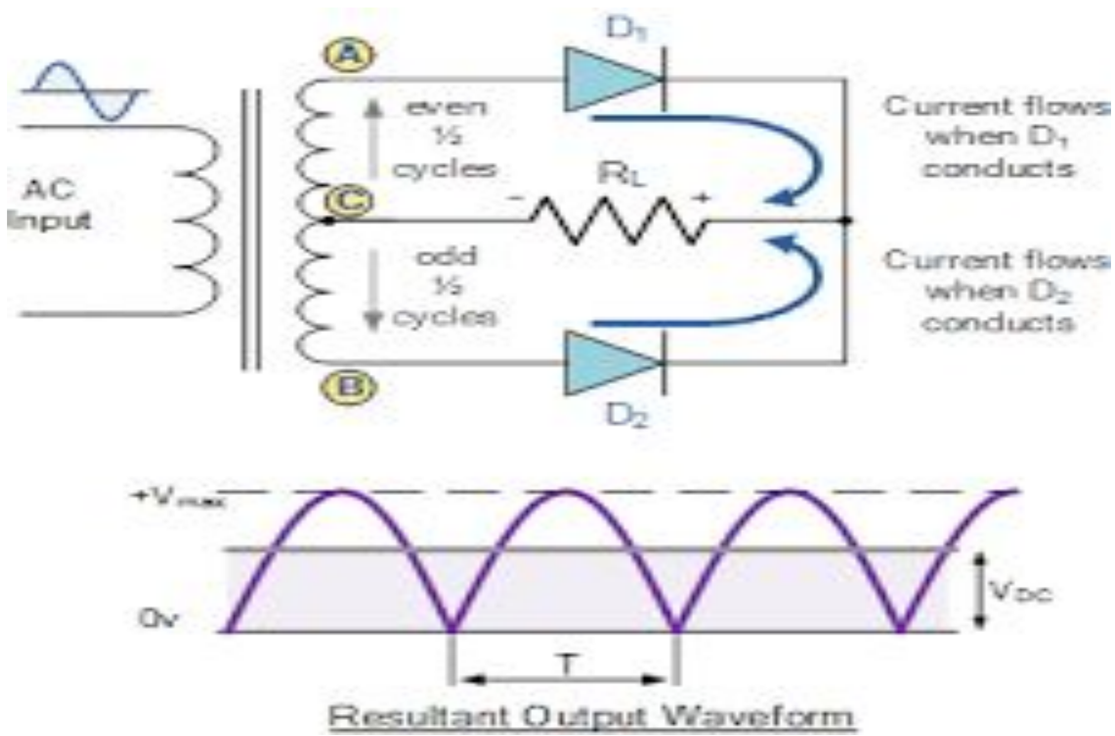
HALFWAVE RECTIFIER

<u>Efficiency</u> Efficiency, is the ratio of the dc output power to ac input power

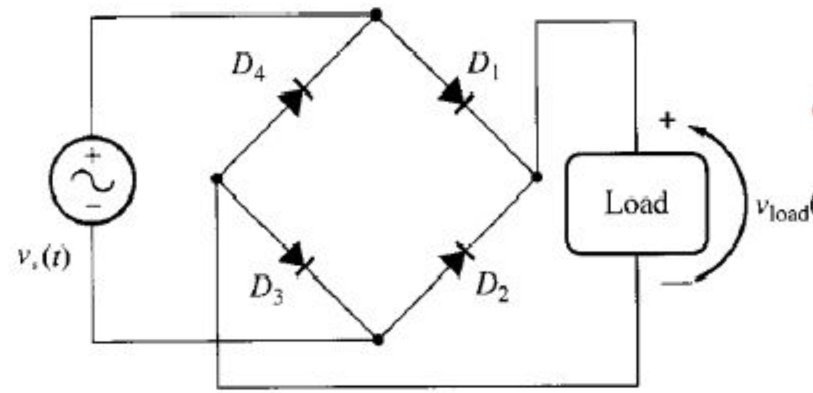
$$\eta = \frac{dc\,output\,power}{ac\,input\,power} = \frac{P_{dc}}{P_{ac}} \rightarrow (11)$$

Full Wave Rectifier

The waveform of fullwave rectifier is
Ripple factor=0.48; efficiency=81.2%; PIV=2Vm



Full Wave Bridge Rectifier

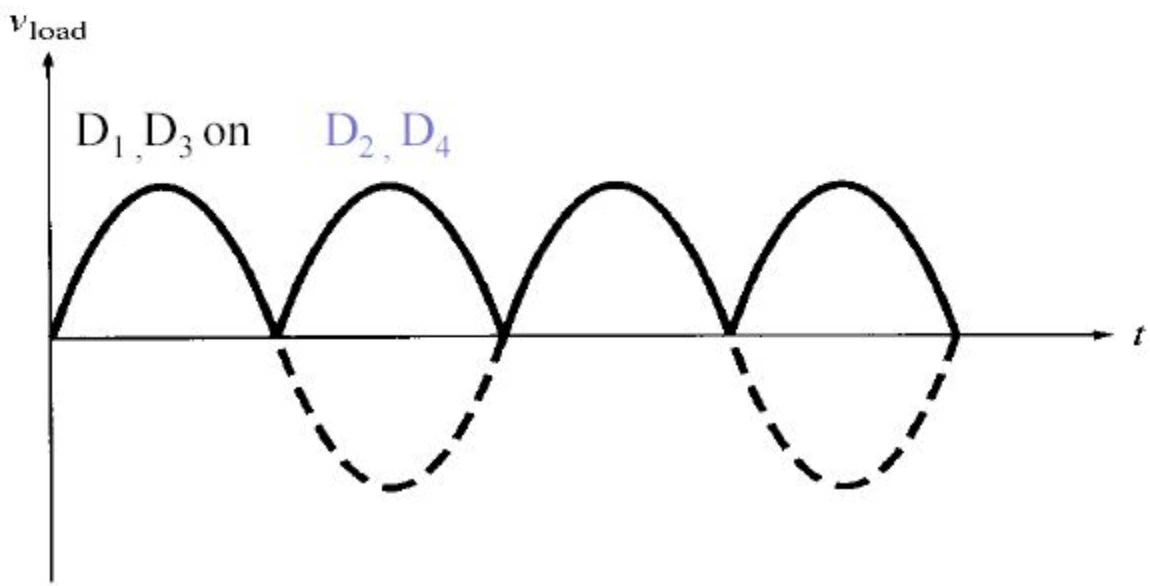


The waveform of fullwave bridge rectifier is

Ripple factor=0.48; efficiency=81.2%; PIV=Vm

The waveform of fullwave rectifier is

Ripple ... 2Vm

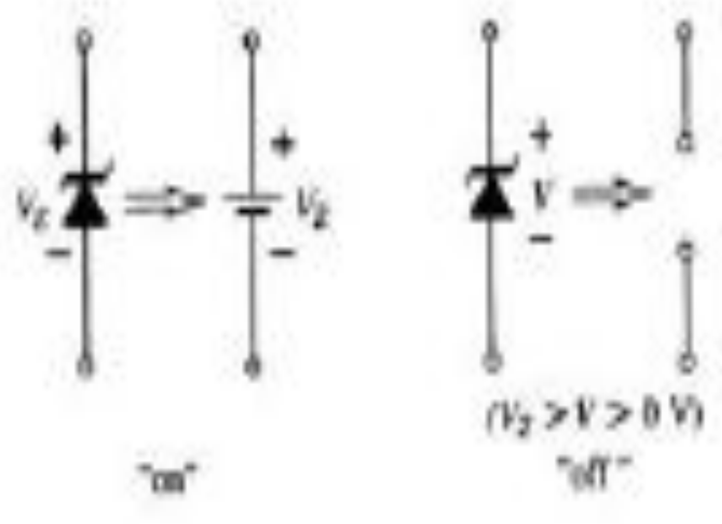


Zener Diode

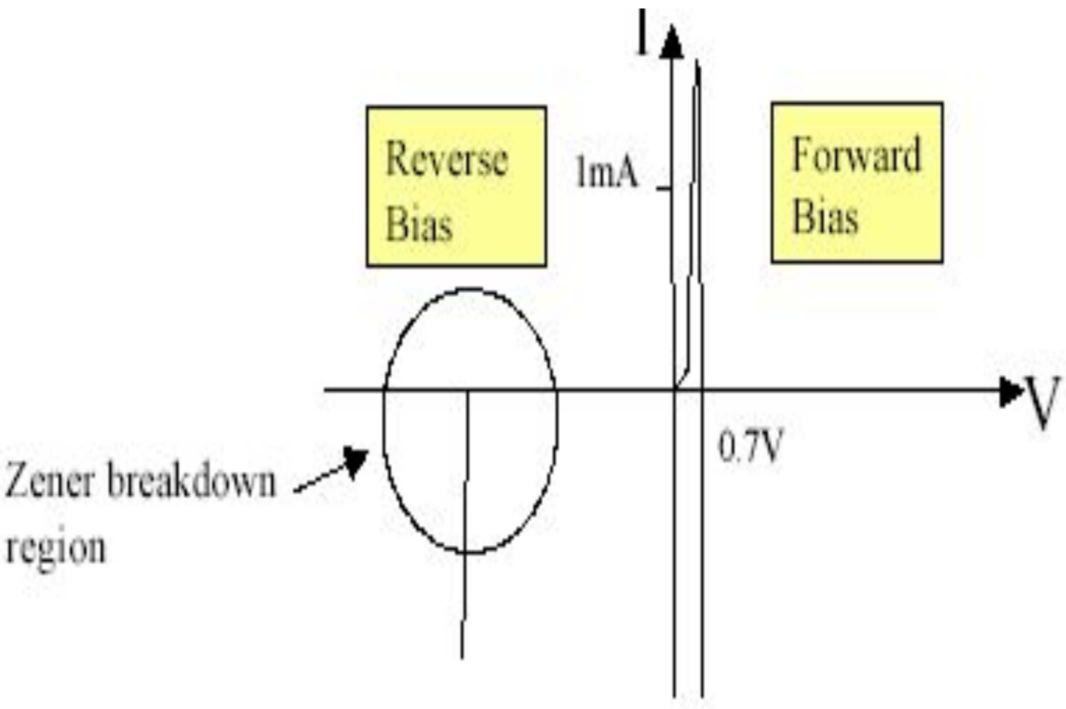
- Zener Diode : Works in the break down region when subjected to reverse bias.
- Large variation in current. Voltage almost constant.
- Used for voltage regulation. Upper limit of current depends on the power dissipation rating of the device.

Zener Diode

Zener diode



V-I Characteristics of Zener Diode



V-I Characteristics of Zener Diode

- Zener diodes are manufactured to have a very low reverse bias breakdown voltage
- Since the breakdown at the zener voltage is so sharp, these devices are often used in voltage regulators to provide precise voltage references. The actual zener voltage is device dependent. For example, you can buy a 6V zener diode.

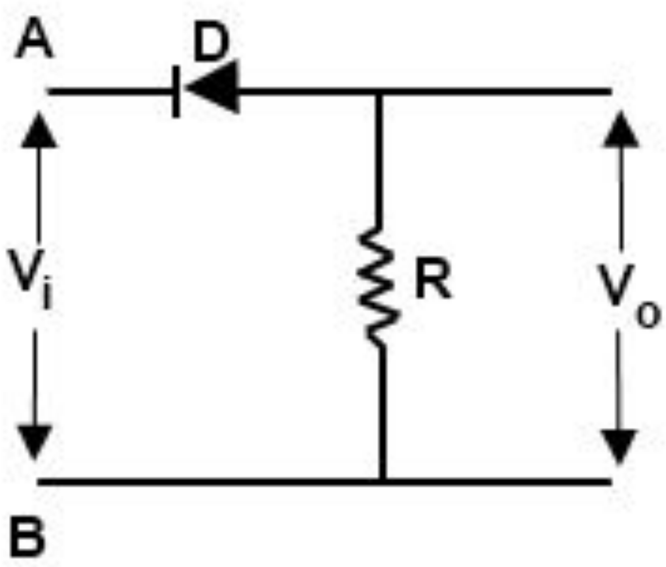
Clipper circuits

- Clipping circuits
  - “A clipper is a device which limits, remove or prevents some portion of the wave form (input signal voltage) above or below a certain level.”
- In other words
  - “the circuit which limits positive or negative amplitude ,or both is called clipping circuit.”

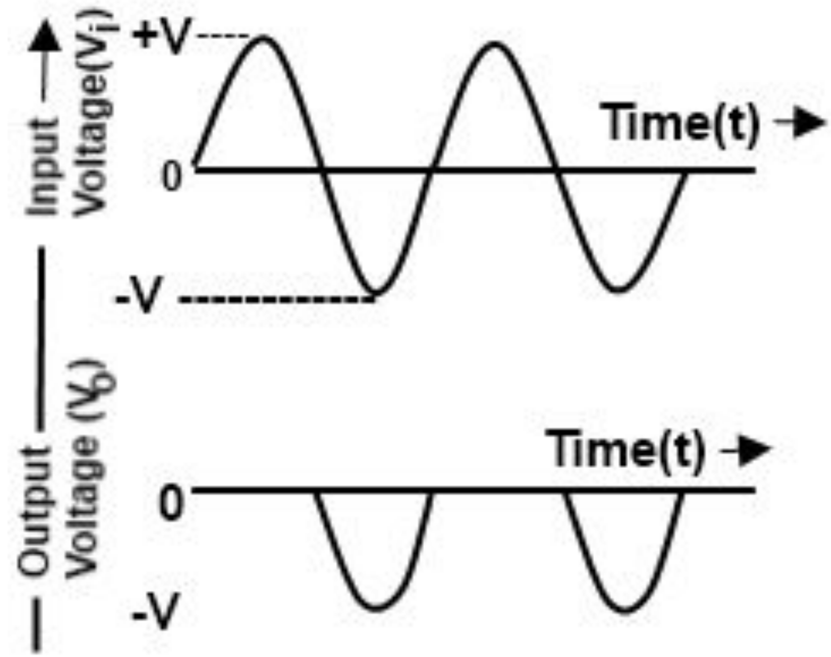
Types of clippers

- **The clipper circuits are of the following types.**
- Series positive clipper
- Series negative clipper
- Shunt or parallel clipper
- Shunt or parallel positive negative
- Clipper Dual (combination)Diode clipper

Series positive clipper

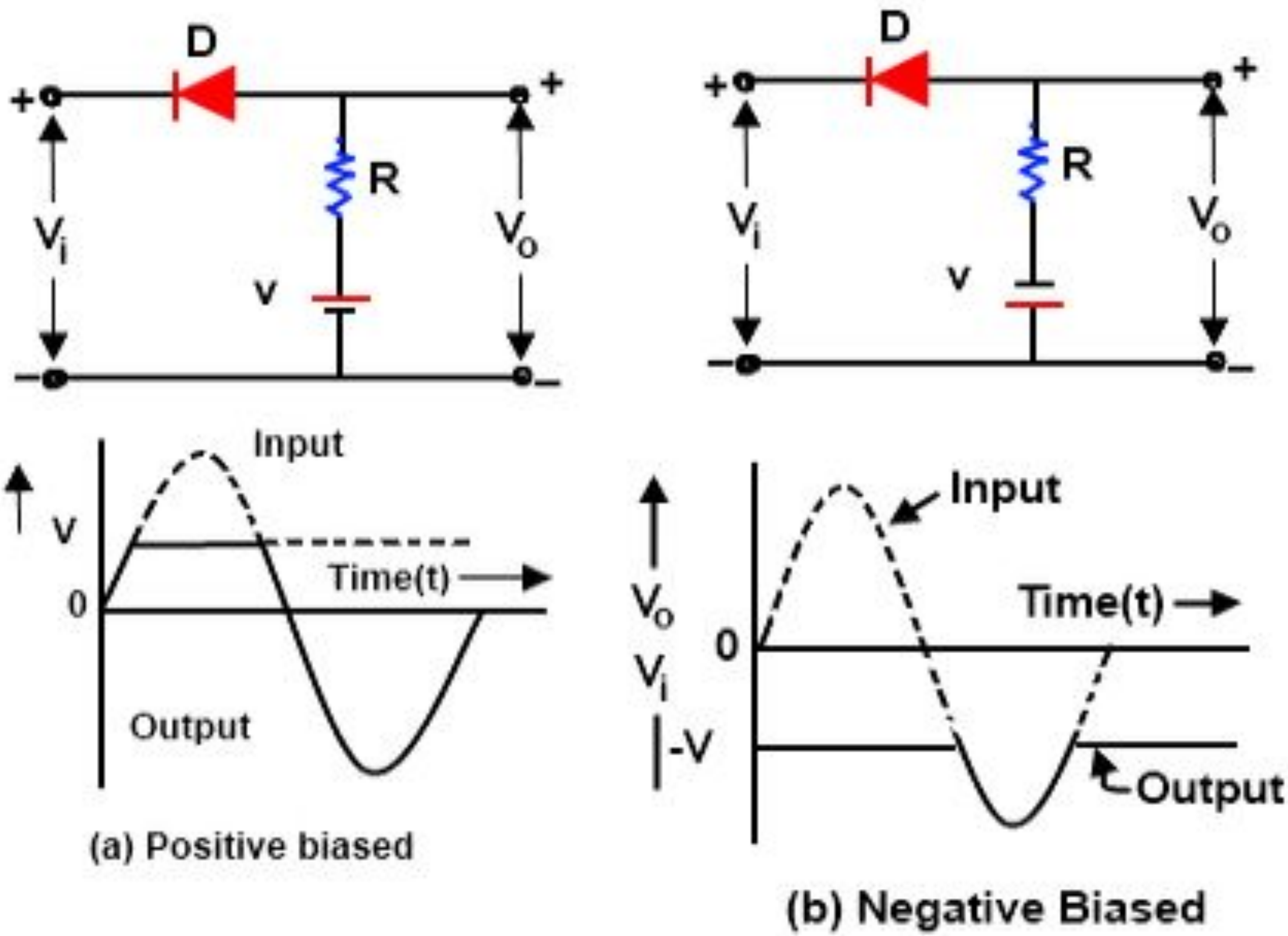


Positive clipper

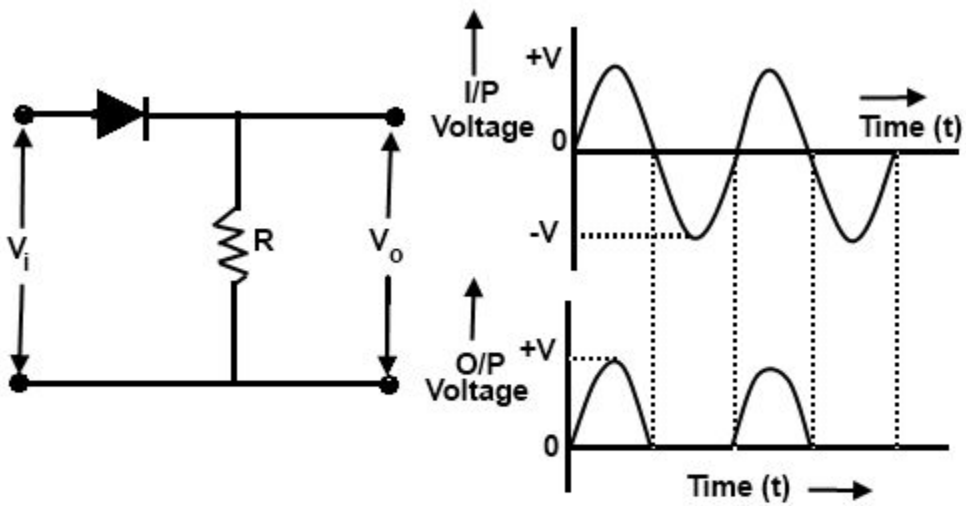


Output voltage

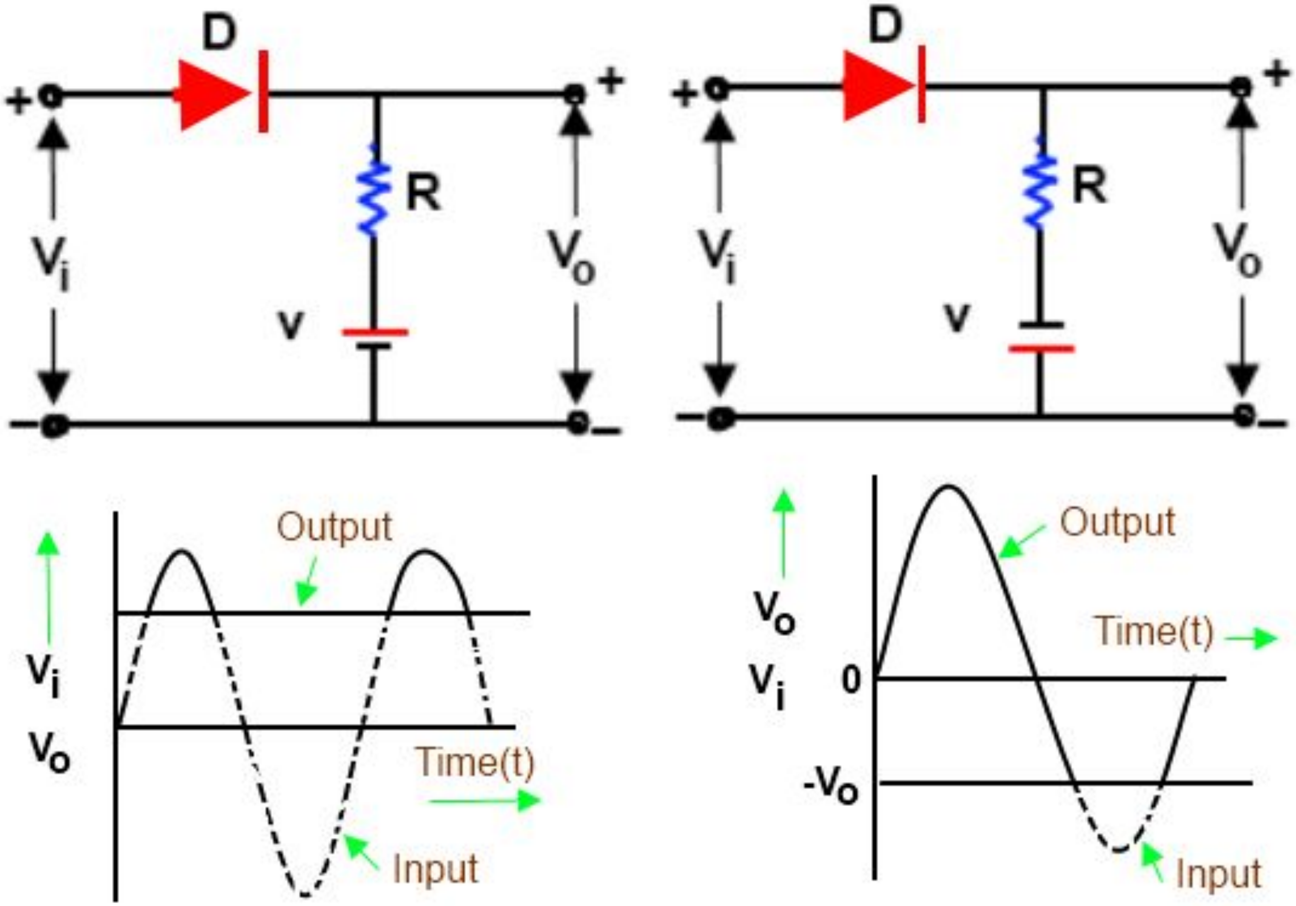
SERIES-POSITIVE CLIPPER WITH BIAS



SERIES NEGATIVE CLIPPER



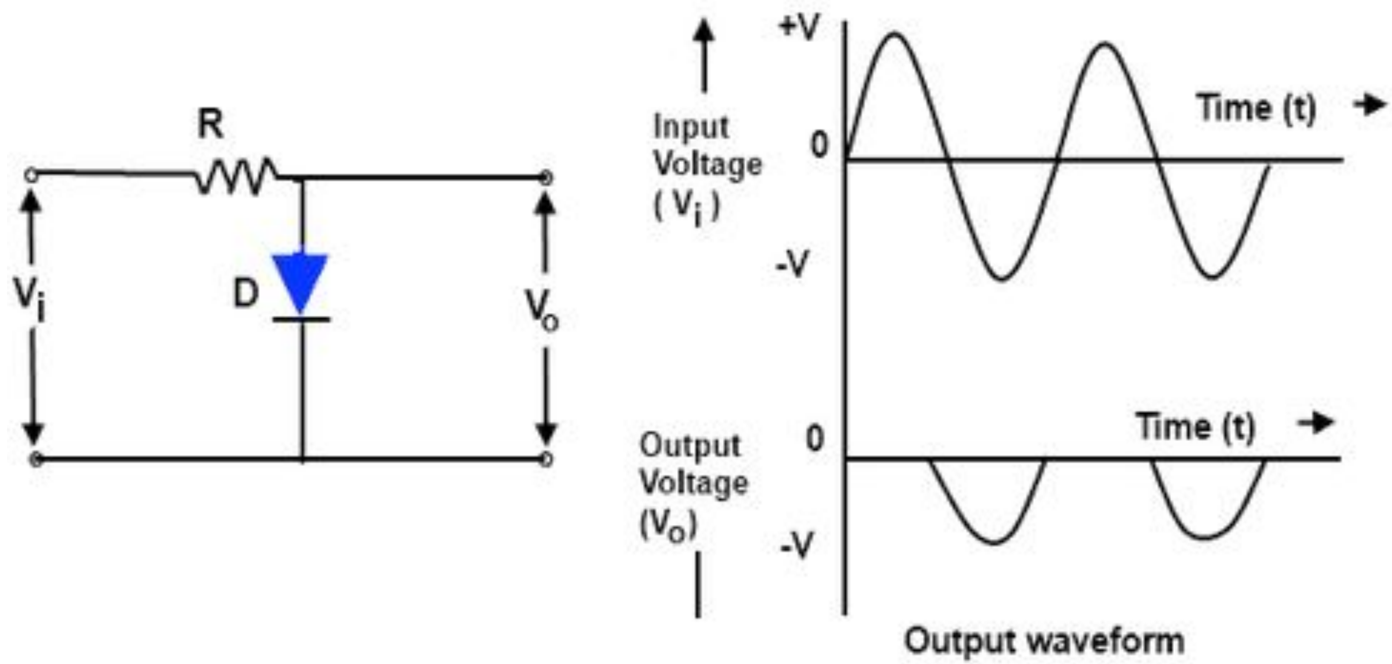
SERIES-NEGATIVE CLIPPER WITH BIAS



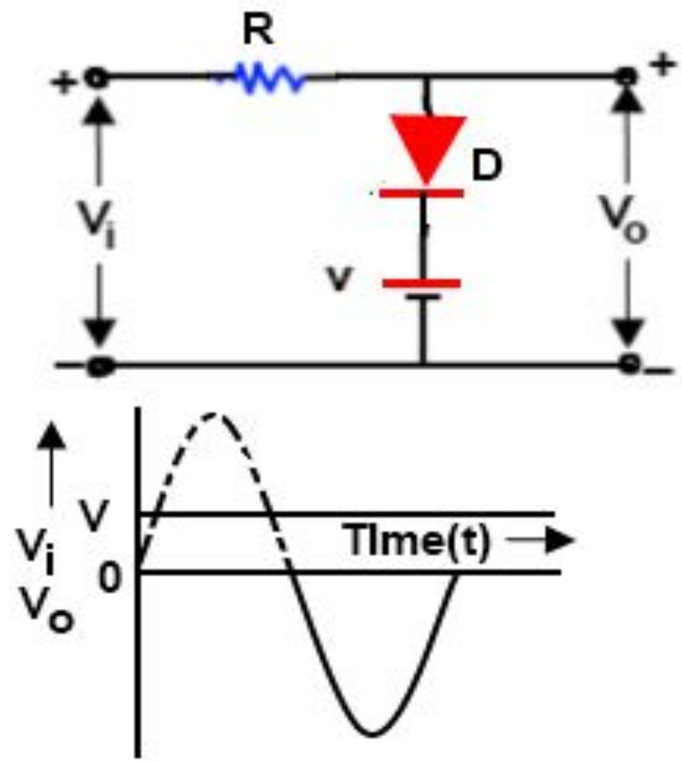
(a) Positive biased

(b) Negative biased

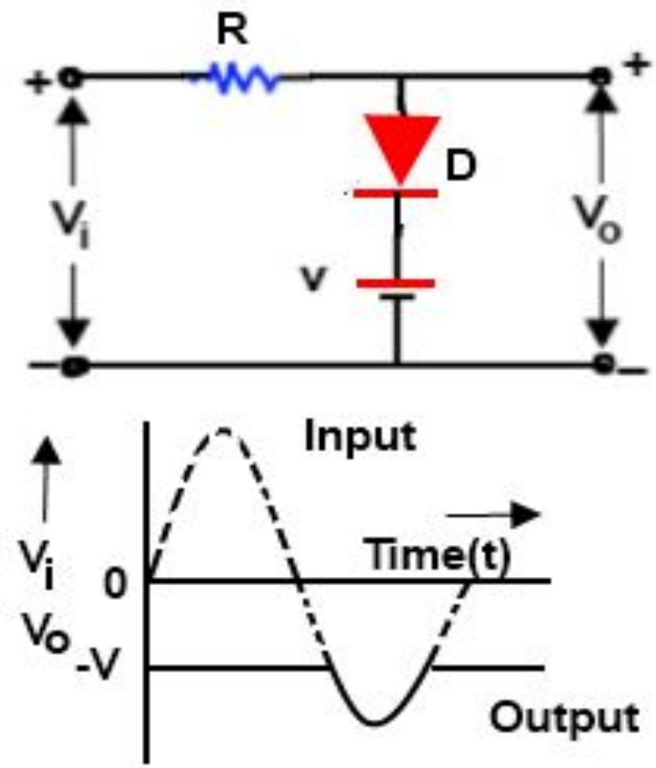
SHUNT OR PARALLEL POSITIVE CLIPPER



SHUNT OR PARALLEL POSITIVE CLIPPER WITH BIAS

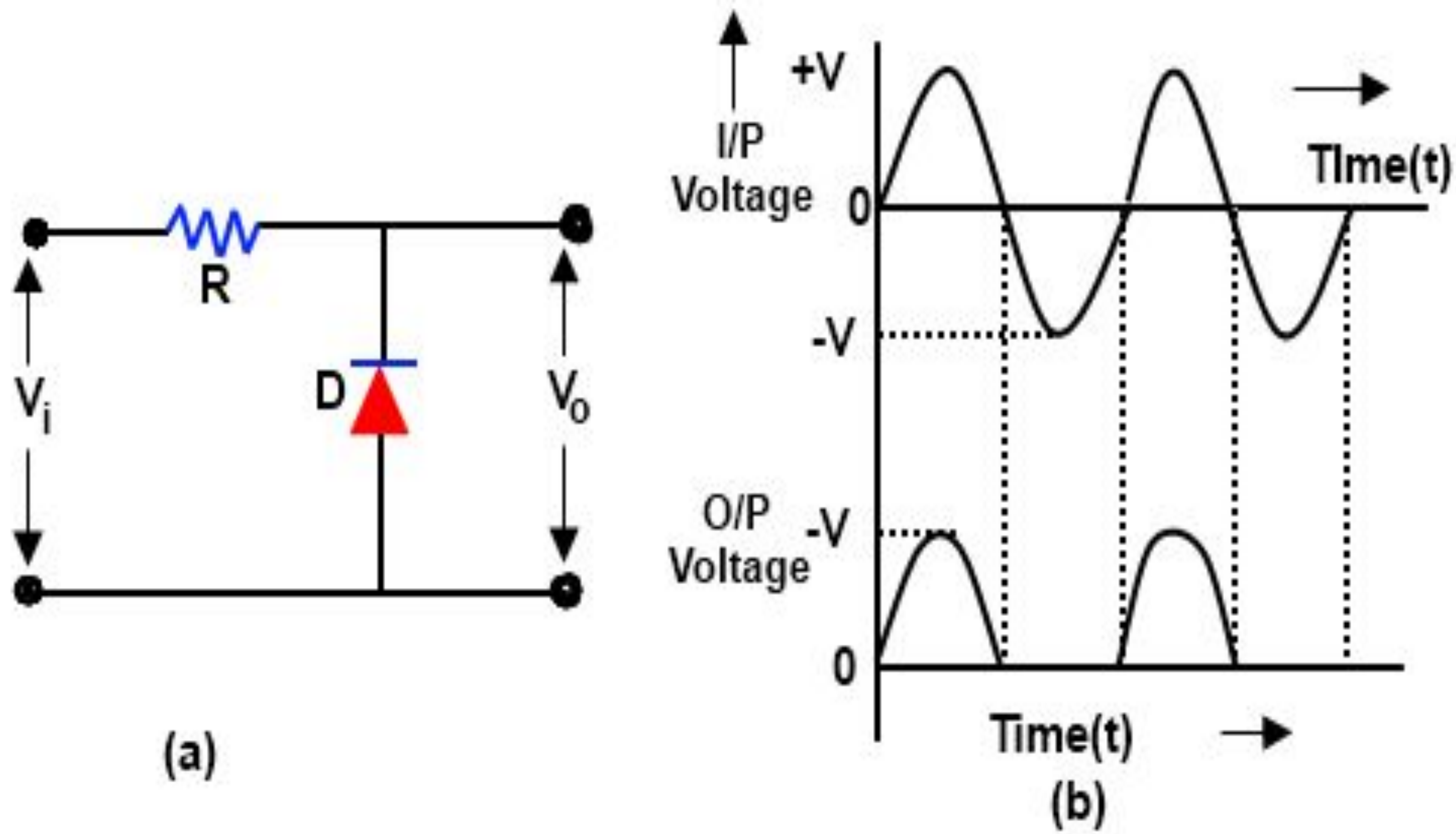


(a) Positive biased

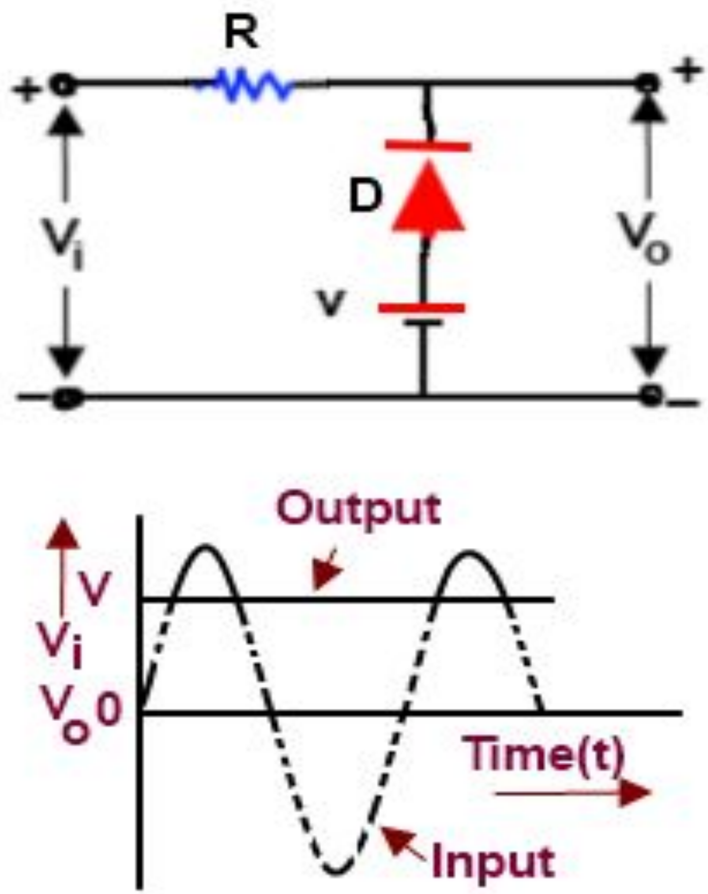


(b) Negative biased

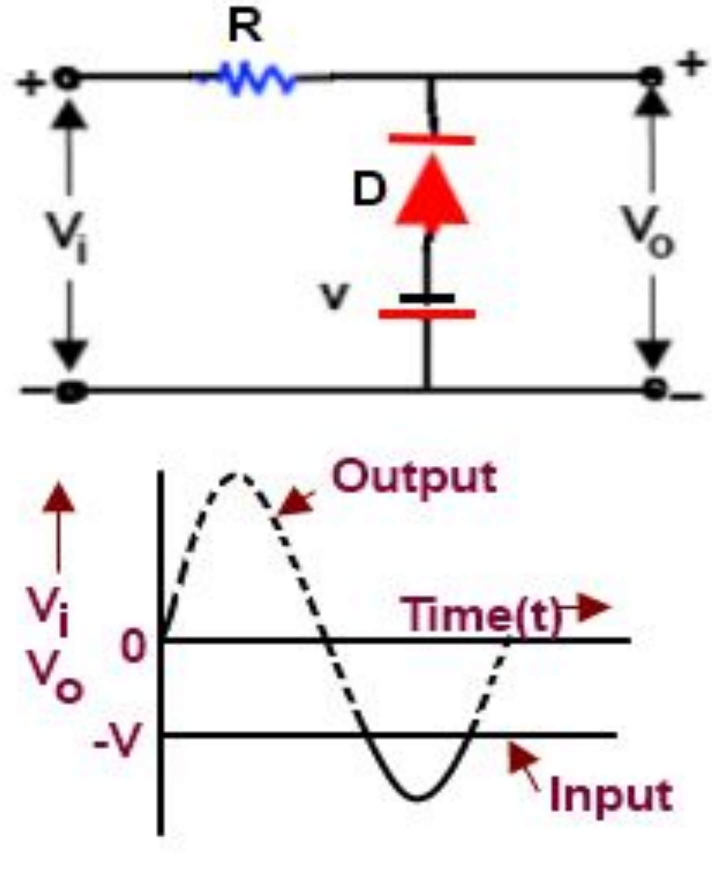
SHUNT OR PARALLEL NEGATIVE CLIPPER



SHUNT OR PARALLEL NEGATIVE CLIPPER WITH BIAS

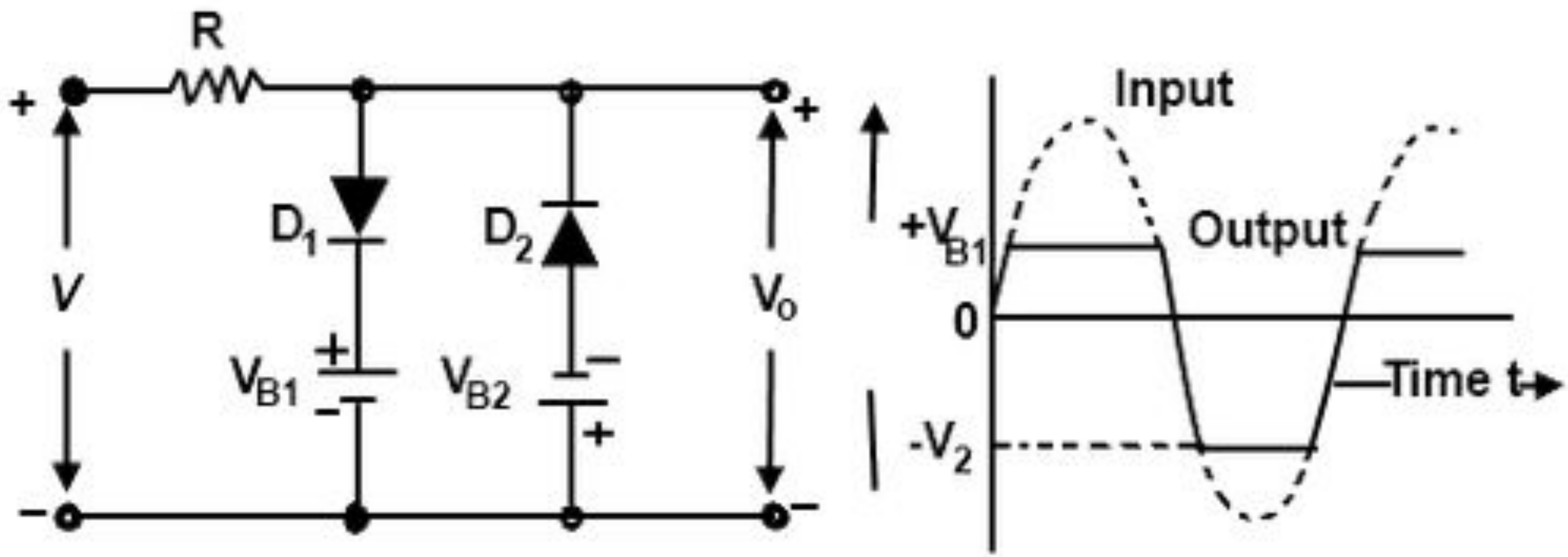


(a) Positive bias



(b) negative bias

DUAL (COMBINATION) DIODE CLIPPER



Clipper applications

- Clippers can be used as voltage limiters and amplitude selectors.
- half wave rectifier
- protection of transistor from transients
- excessive noise spikes above a certain level can be limited or clipped in FM transmitters

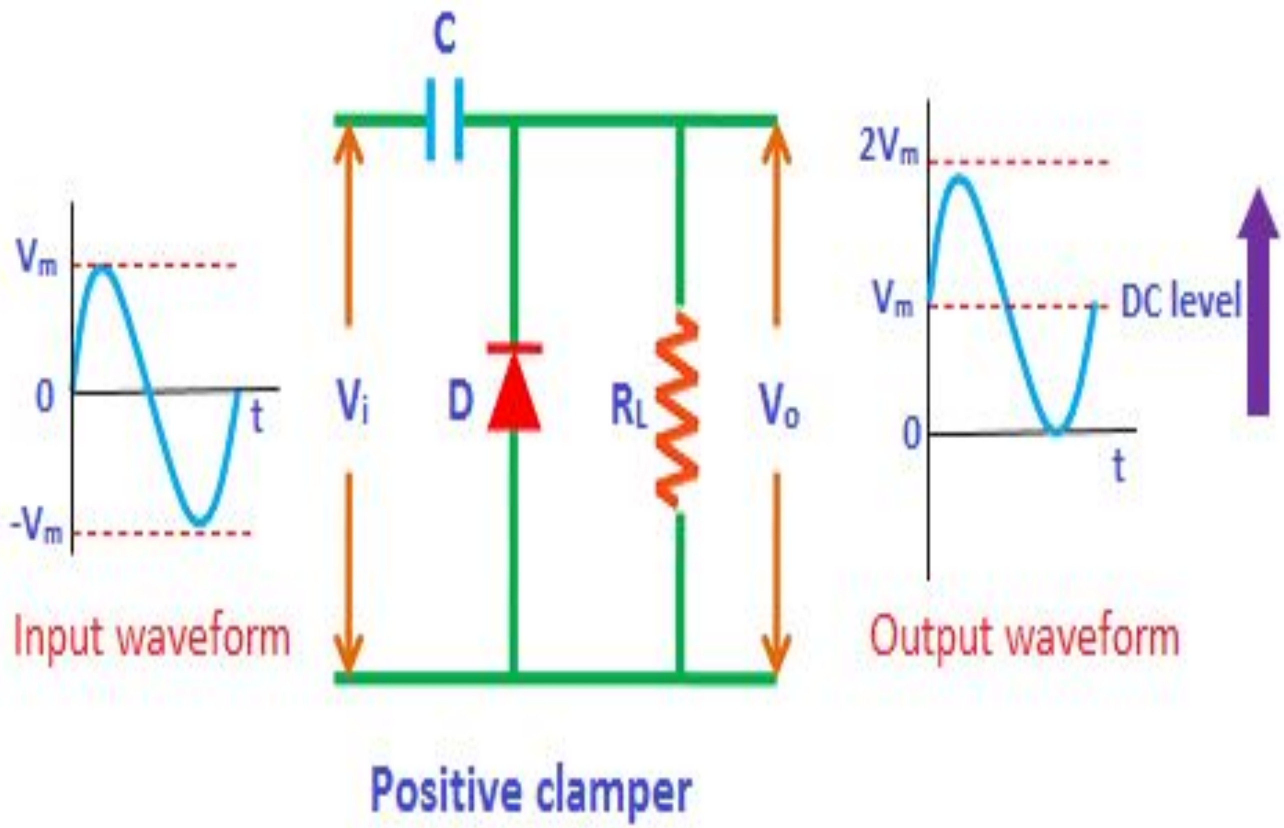
Clamper circuits

- A circuit that places either the positive or negative peak of a signal at a desired D.C level is known as a clamping circuit.
- A clamping circuit introduces (or restores) a D.C level to an A.C signal.
- Thus a clamping circuit is also known as D.C restorer.
- the original signal will not get changed, only there is vertical shift in the signal.

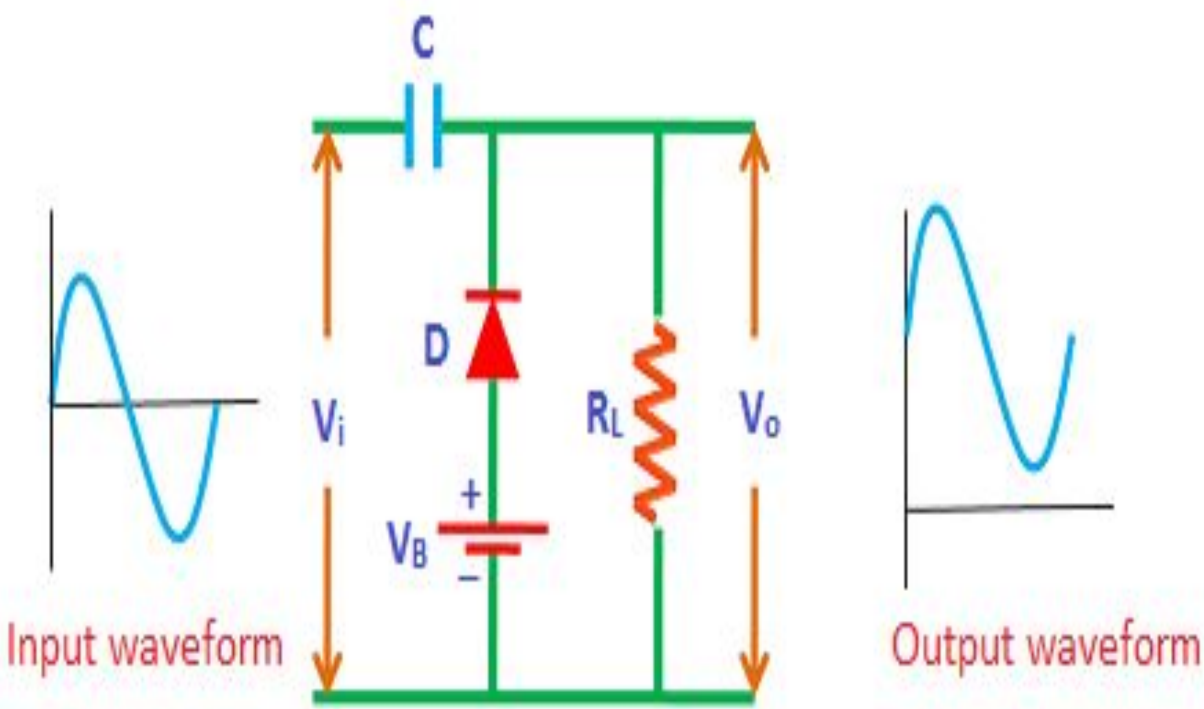
Types of clampers

- Positive clamper - Positive clamping
- occurs when negative peaks raised or clamped to ground or on the zero level
- In other words, it pushes the signal upwards so that negative peaks fall on the zero level.
- Negative clamper - Negative clamping
- occurs when positive peaks raised or clamped to ground or on the zero level
- In other words, it pushes the signal downwards so that the positive peaks fall on the zero level.

Positive clamper

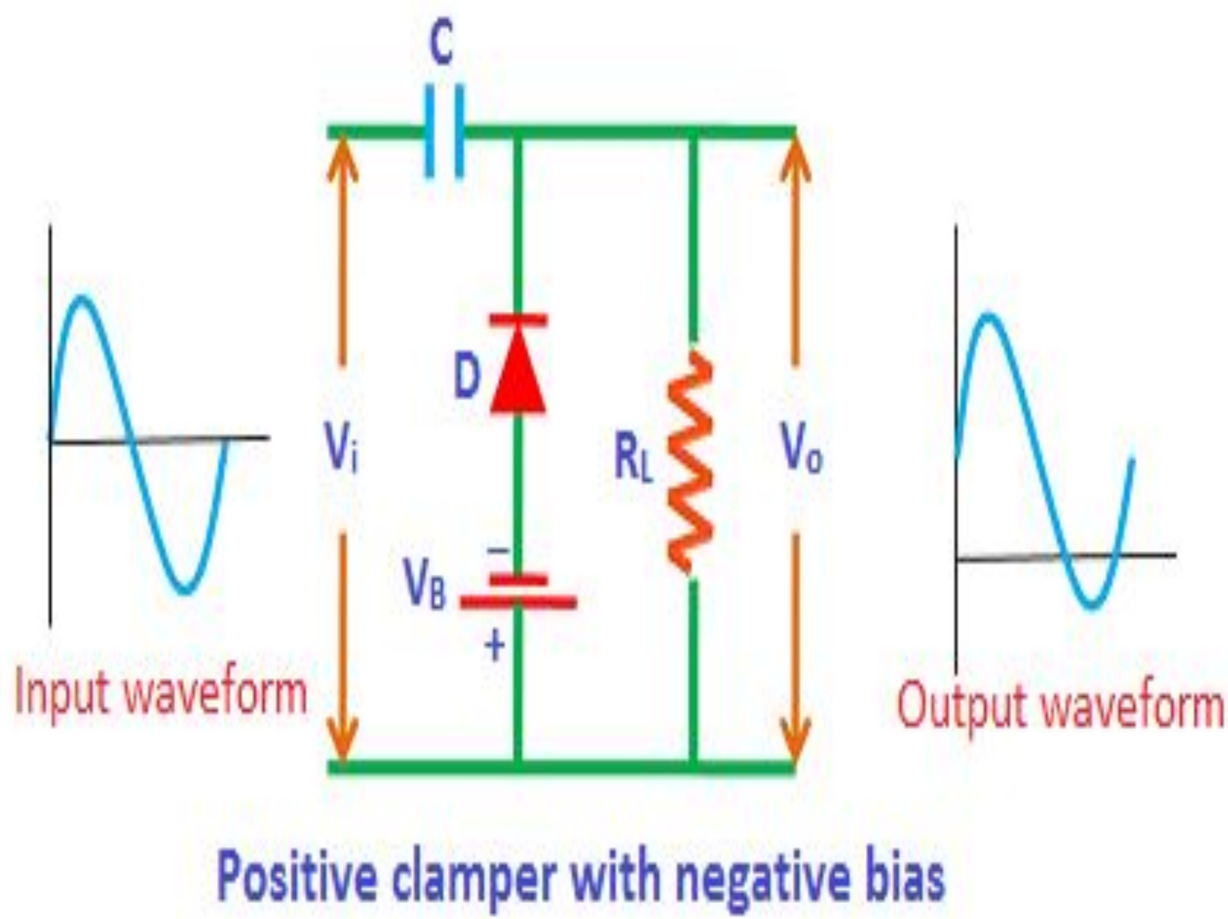


Positive clamper with positive bias

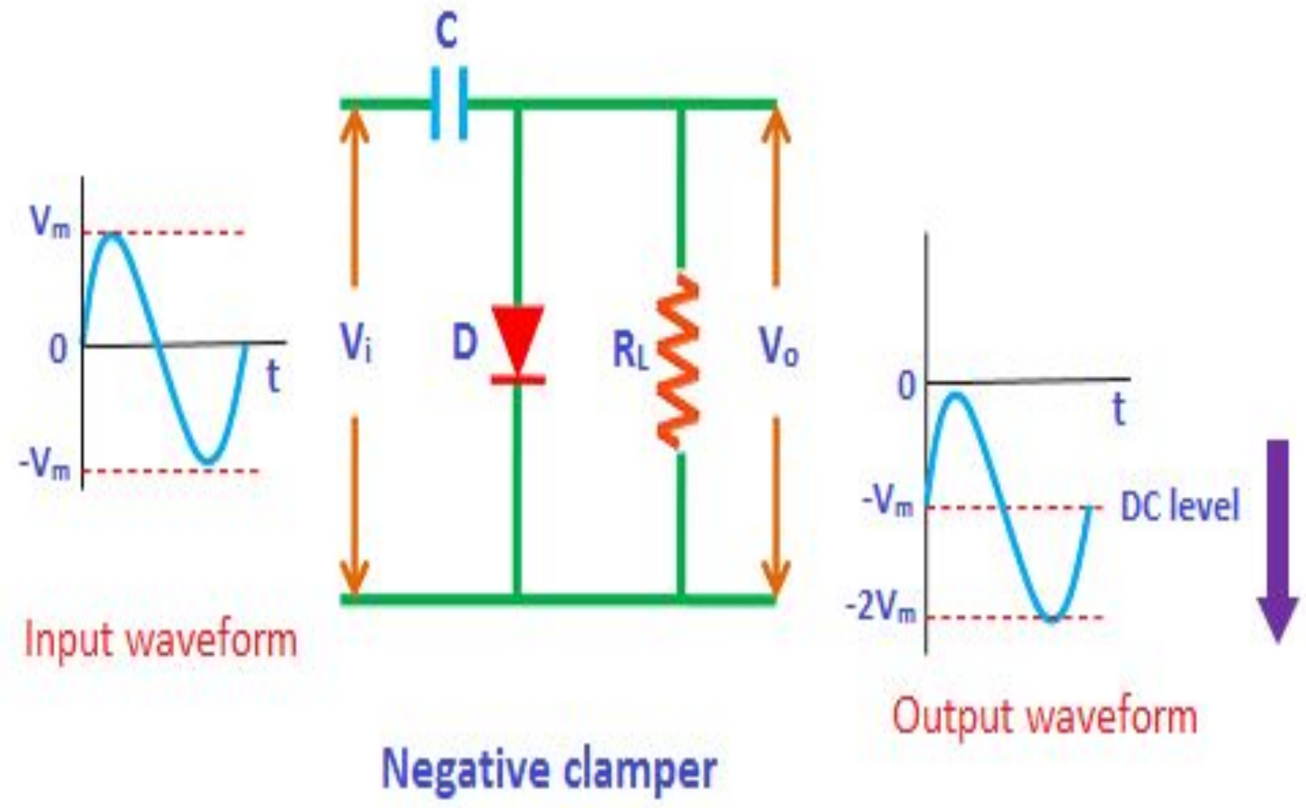


Positive clamper with positive bias

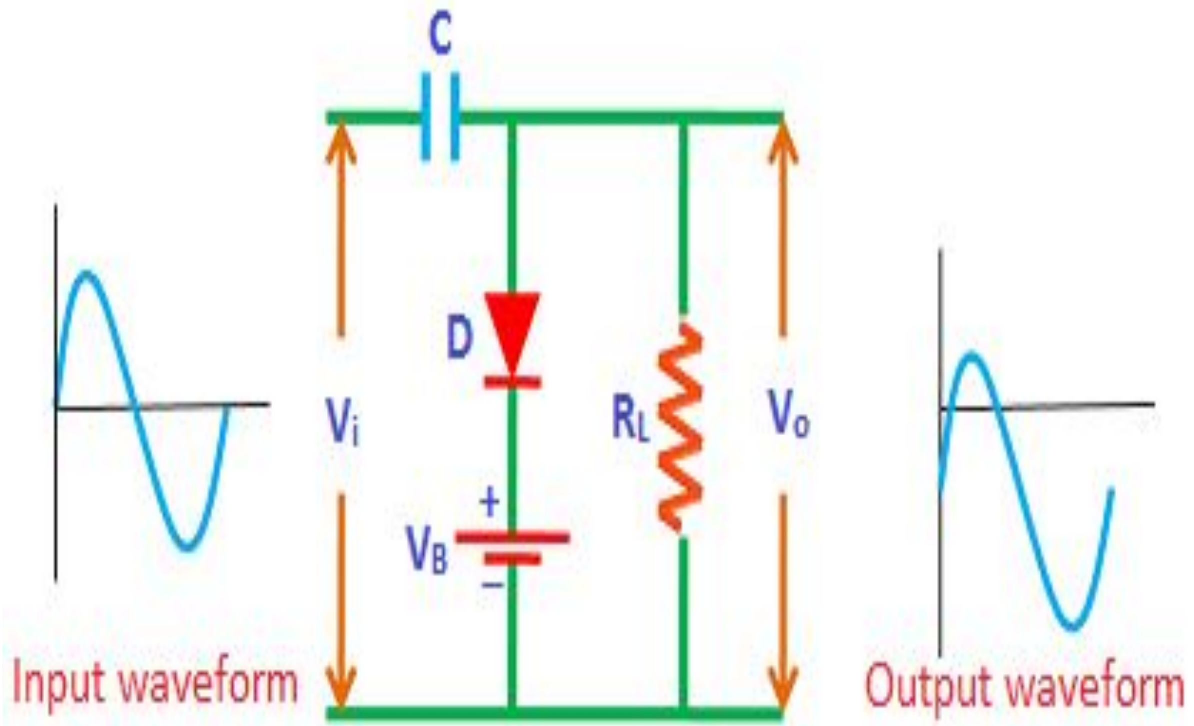
Positive clamper with negative bias



Negative clamper

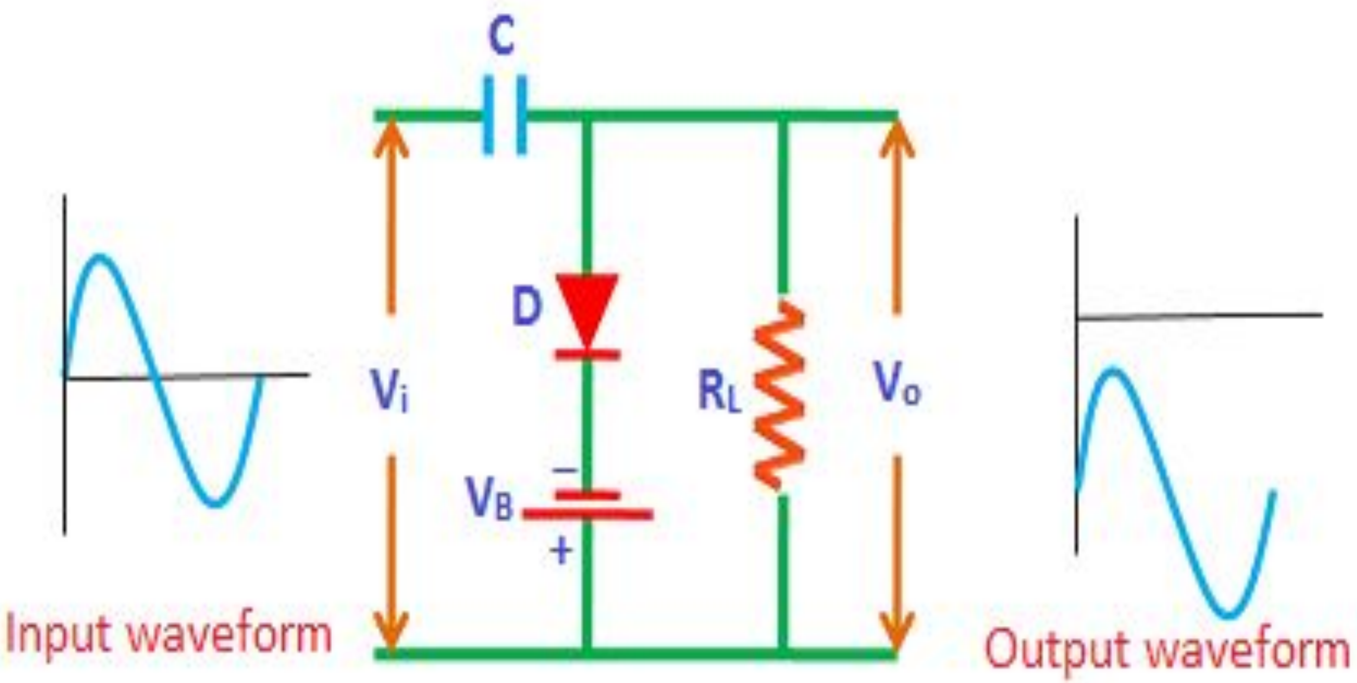


Negative clamper with positive bias



Negative clamper with positive bias

Negative clamper with negative bias



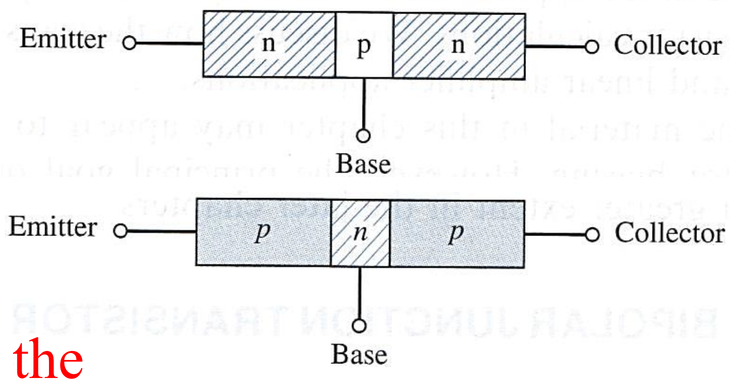
Negative clamper with negative bias

applications

- **Applications of clamping circuits**
- They find some applications in sonar and radar testing
- Used as voltage doublers
- They are used to remove distortions in a circuit
- Used in video processing equipment like TV
- base line stabilizer

Transistor Structures

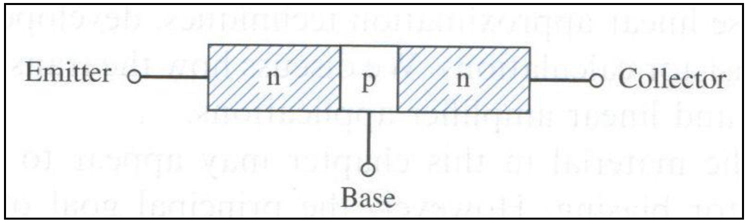
- The **bipolar junction transistor (BJT)** has three separately doped regions and contains two pn junctions.
- Bipolar transistor is a 3-terminal device.
  - Emitter (E)
  - Base (B)
  - Collector (C)

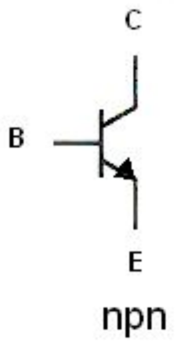


- The basic transistor principle is that the voltage between two terminals controls the current through the third terminal.
- Current in the transistor is due to the flow of both electrons and holes, hence the name **bipolar**.

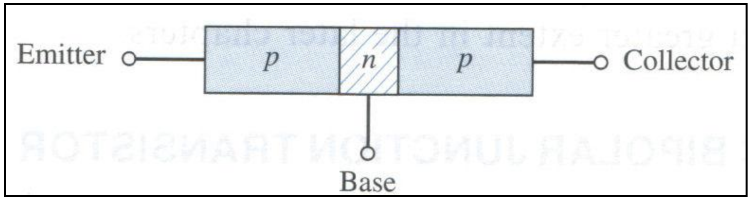
Transistor Structures

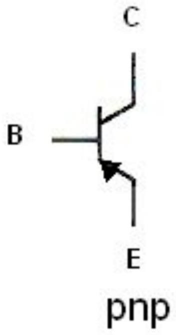
- There are two types of bipolar junction transistor: **npn** and **pnp**.
- The **npn bipolar transistor** contains a thin p-region between two n-regions.





- The **pnp bipolar transistor** contains a thin n-region sandwiched between two p-regions.

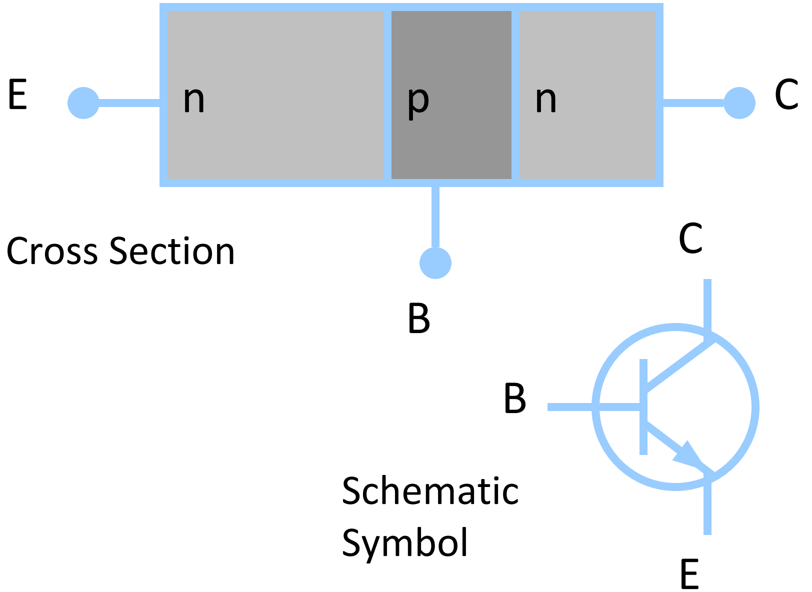




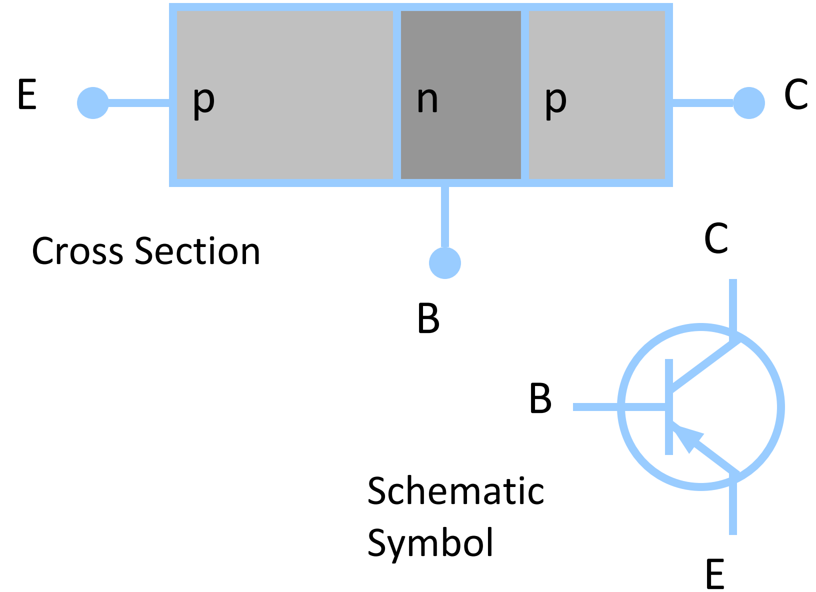
Note: It will be very helpful to go through the Analog Electronics Diodes Tutorial to get information on doping, n-type and p-type materials.

The Two Types of BJT Transistors:

npn



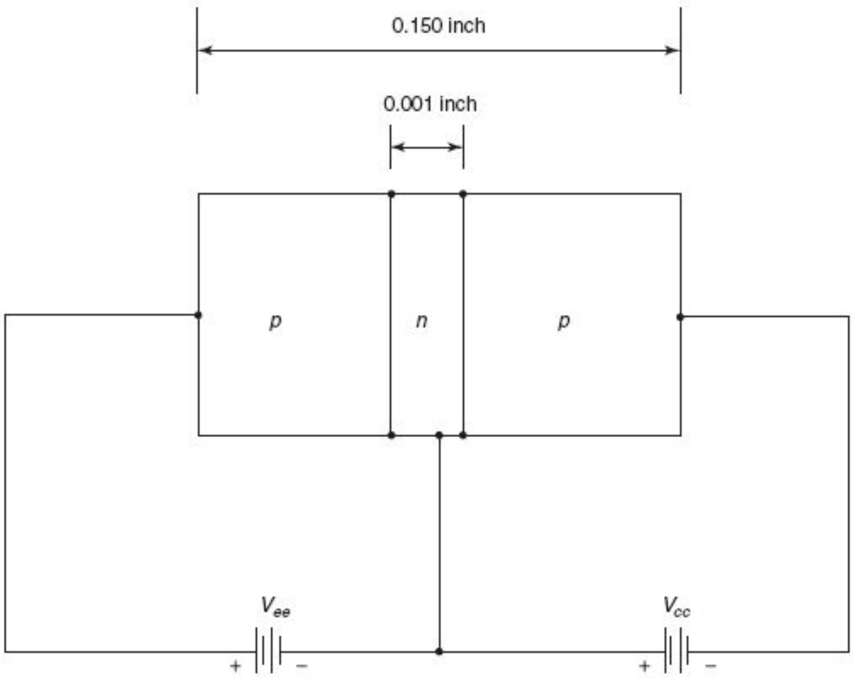
pnp



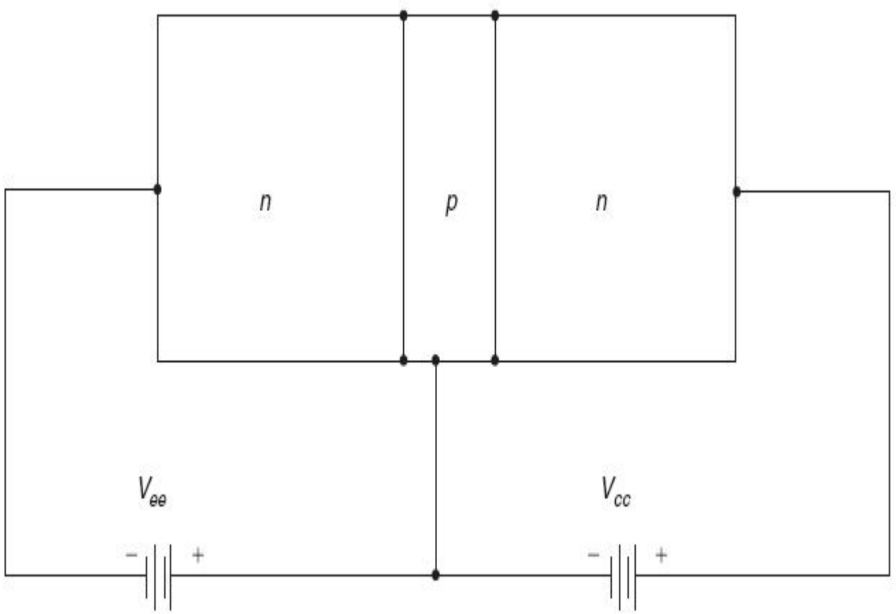
- Collector doping is usually ~ 10^6
- Base doping is slightly higher ~ 10^7 – 10^8
- Emitter doping is much higher ~ 10^{15}

FORMATION OF p–n–p AND n–p–n JUNCTIONS

- When an *n-type thin semiconductor layer is placed between two p-type semiconductors, the resulting* structure is known as the *p–n–p transistor.*
- *The fabrication steps are complicated, and demand stringent* conditions and measurements.
- When a *p-type semiconductor is placed between two n-type semiconductors,* the device is known as the *n–p–n transistor.*



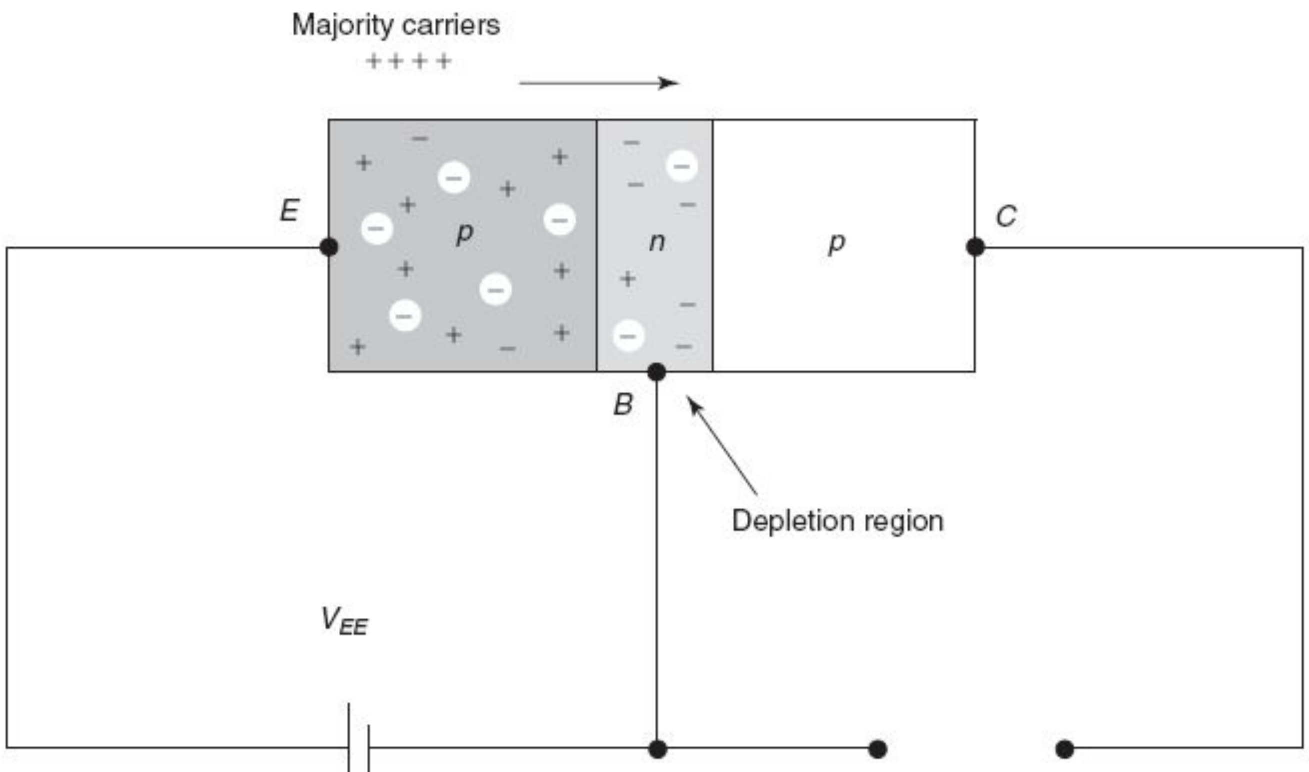
p–n–p transistor



n–p–n transistor

TRANSISTOR MECHANISM

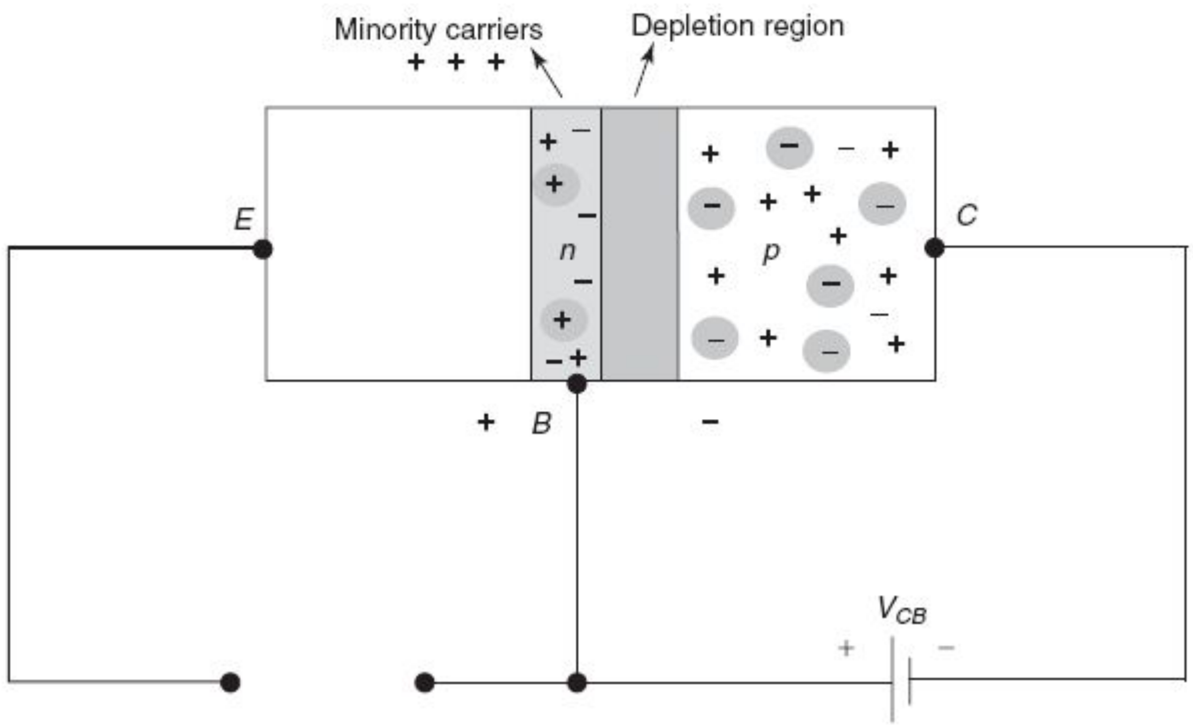
- The basic operation of the transistor is described using the *p–n–p transistor.*
- *The p–n junction of the transistor* is forward-biased whereas the base-to-collector is without a bias.
- The depletion region gets reduced in width due to the applied bias, resulting in a heavy flow of majority carriers from the *p-type to the n-type material gushing down the depletion region and reaching the base.*
- The forward-bias on the emitter–base junction will cause current to flow.



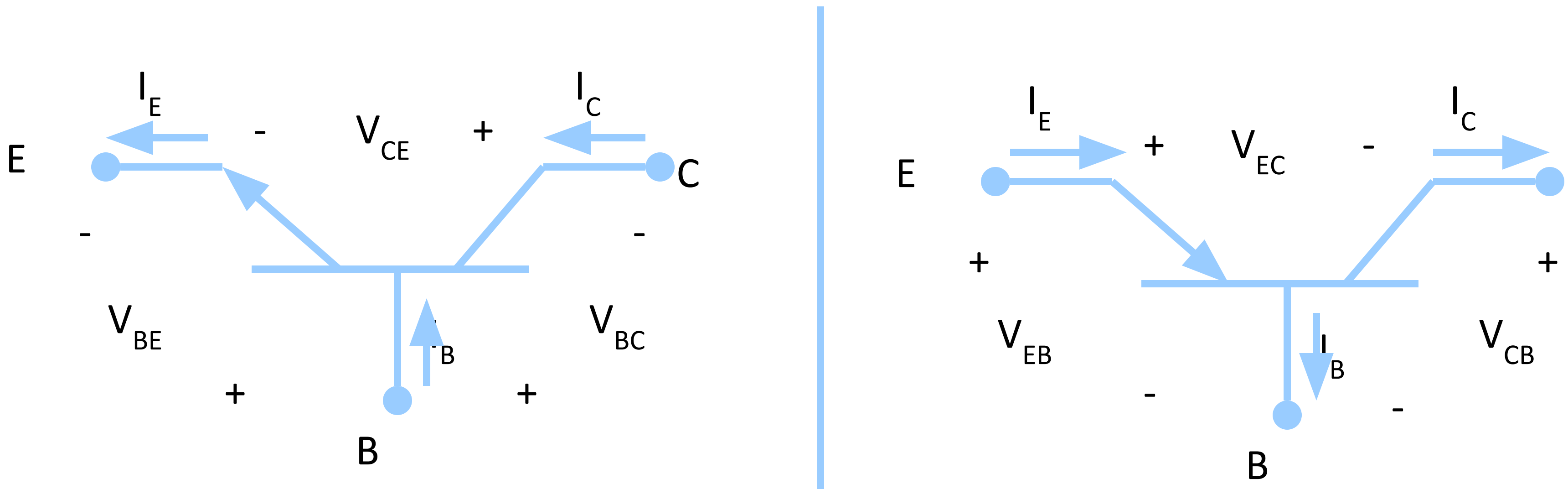
Forward-biased junction of a *p–n–p transistor*

TRANSISTOR MECHANISM

- For easy analysis, let us now remove the base-to-emitter bias of the *p–n–p transistor.*
- The flow of majority carriers is zero, resulting in a minority-carrier flow. Thus, one *p–n junction of a* transistor is reverse-biased, while the other is kept open.
- The operation of this device becomes much easier when they are considered as separate blocks. In this discussion, the drift currents due to thermally generated minority carriers have been neglected, since they are very small.



Reverse-biased junction of a *p–n–p transistor*



npn

$I_E = I_B + I_C$

$V_{CE} = -V_{BC} + V_{BE}$

pnp

$I_E = I_B + I_C$

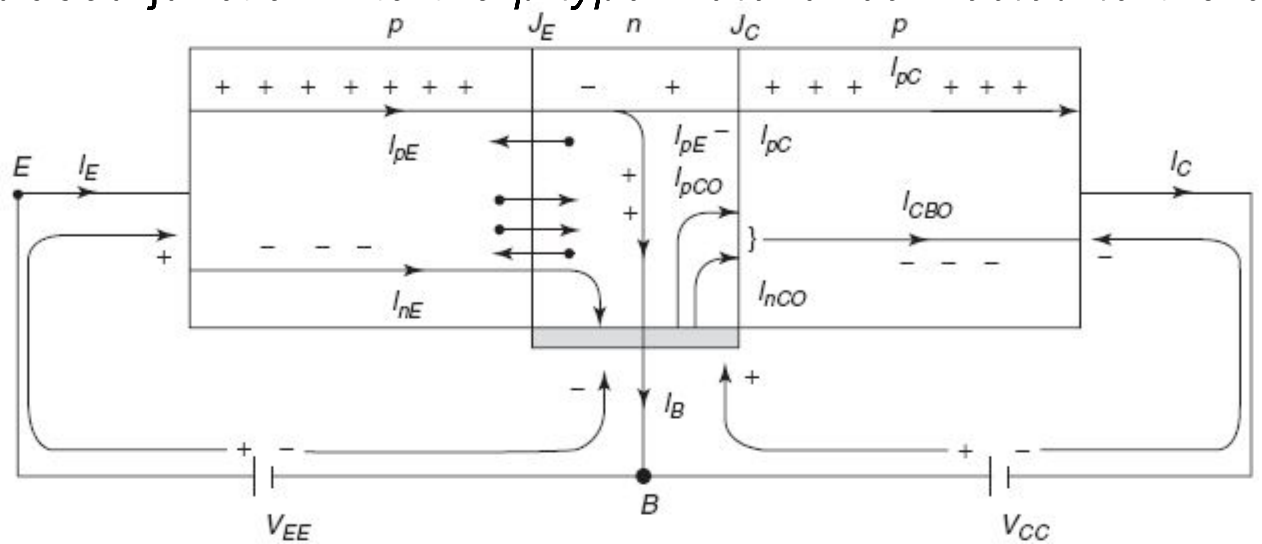
$V_{EC} = V_{EB} - V_{CB}$

Note: The equations seen above are for the transistor, not the circuit.

TRANSISTOR CURRENT COMPONENTS

❖ Current Components in *p–n–p Transistor*

- Both biasing potentials have been applied to a *p–n–p transistor,* with the resulting majority and minority carrier flow indicated.
- The width of the depletion region clearly indicates which junction is forward-biased and which is reverse-biased.
- The magnitude of the base current is typically in the order of microamperes as compared to mill amperes for the emitter and collector currents. The large number of these majority carriers will diffuse across the reverse-biased junction into the *p-type material connected to* the collector terminal

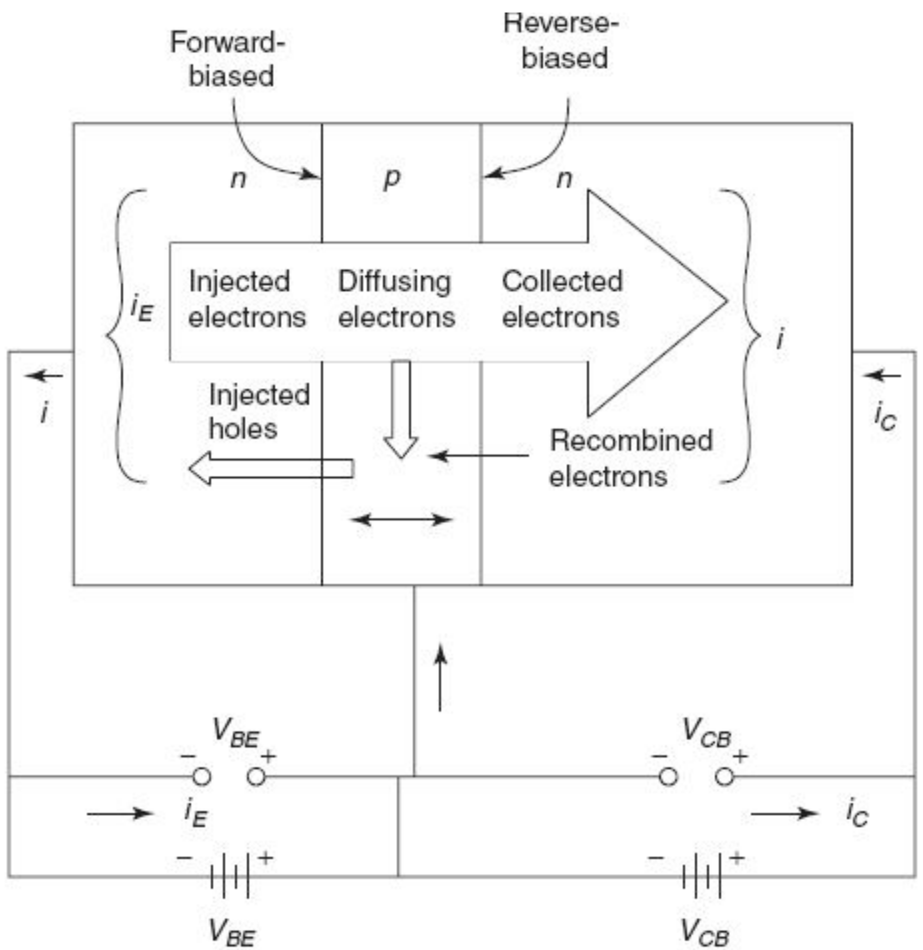


Direction of flow of current in *p–n–p transistor with the base–emitter junction forward-biased* and the collector–base junction reverse-biased

TRANSISTOR CURRENT COMPONENTS

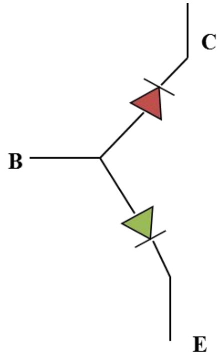
❖ Current Components in an *n–p–n Transistor*

- The operation of an *n–p–n transistor is the same as that of a p–n–p transistor, but with the roles played by* the electrons and holes interchanged.
- The polarities of the batteries and also the directions of various currents are to be reversed.
- Here the majority electrons from the emitter are injected into the base and the majority holes from the base are injected into the emitter region. These two constitute the emitter current.

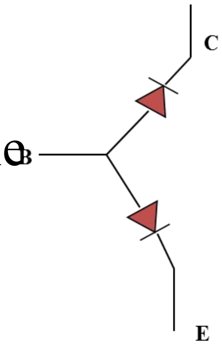


The majority and the minority carrier current flow in a forward-biased *n–p–n transistor*

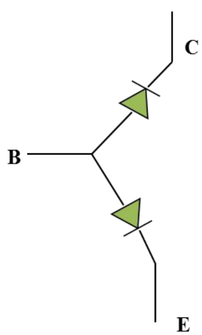
3 Regions of Operation



- **Active**
  Operating range of the amplifier.
  Base-Emitter Junction forward biased.
  Collector-Base Junction reverse biased



- **Cutoff**
  The amplifier is basically off. There is voltage but little current.
  Both junctions reverse biased



- **Saturation**
  The amplifier is full on. There is little voltage but lots of current.
  Both junctions forward biased

Biasing the transistor refers to applying voltage to get the transistor to achieve certain operating conditions.

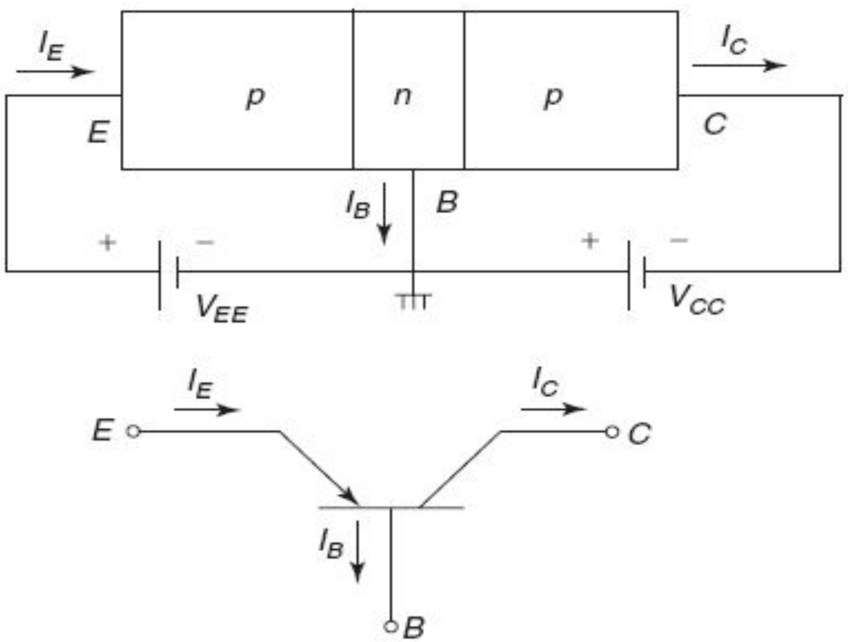
Common-Base Biasing (CB) : input $= V_{EB}$ & I_E
output $= V_{CB}$ & I_C

Common-Emitter Biasing (CE): input $= V_{BE}$ & I_B
output $= V_{CE}$ & I_C

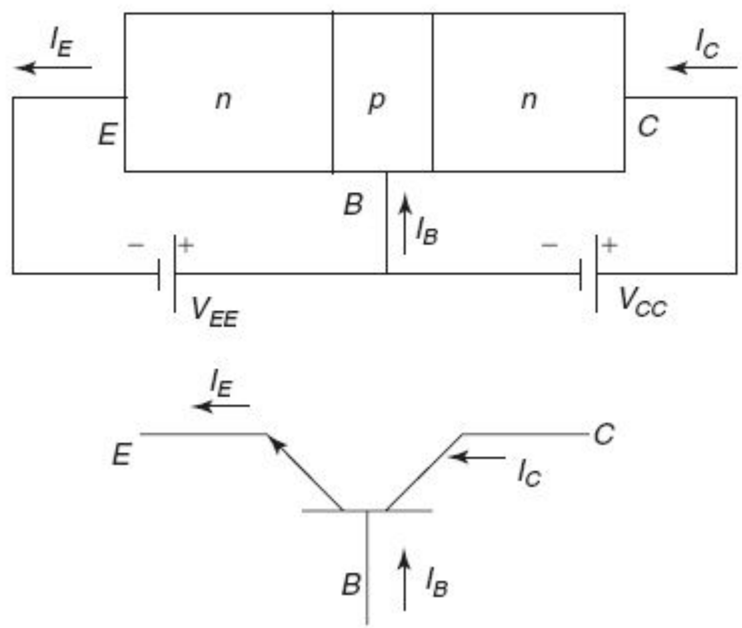
Common-Collector Biasing (CC): input $= V_{BC}$ & I_B
output $= V_{EC}$ & I_E

CB CONFIGURATIONS

- Depending on the common terminal between the input and the output circuits of a transistor, it may be operated in the common-base mode, or the common-emitter mode, or the common-collector mode.
- **Common-base (CB) Mode**
  - In this mode, the base terminal is common to both the input and the output circuits. This mode is also referred to as the ground–base configuration.



Notation and symbols used for the common-base configuration of a *p–n–p* transistor



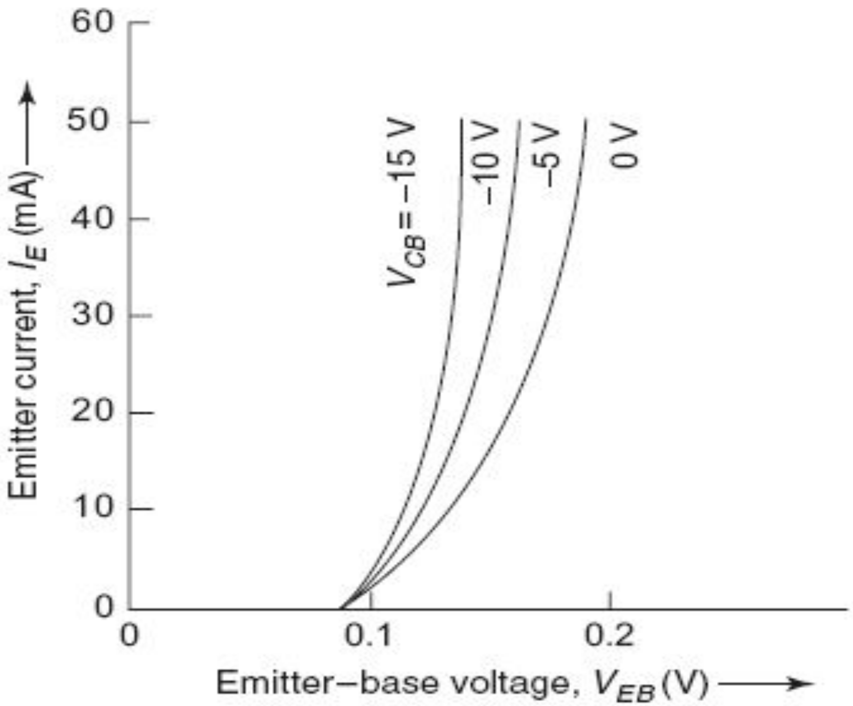
Common-base configuration of an *n–p–n* transistor

TRANSISTOR CHARACTERISTICS

❖The graphical forms of the relations between the various current and voltage variables (components) of a transistor are called *transistor static characteristics.*

❖ **Input Characteristics**

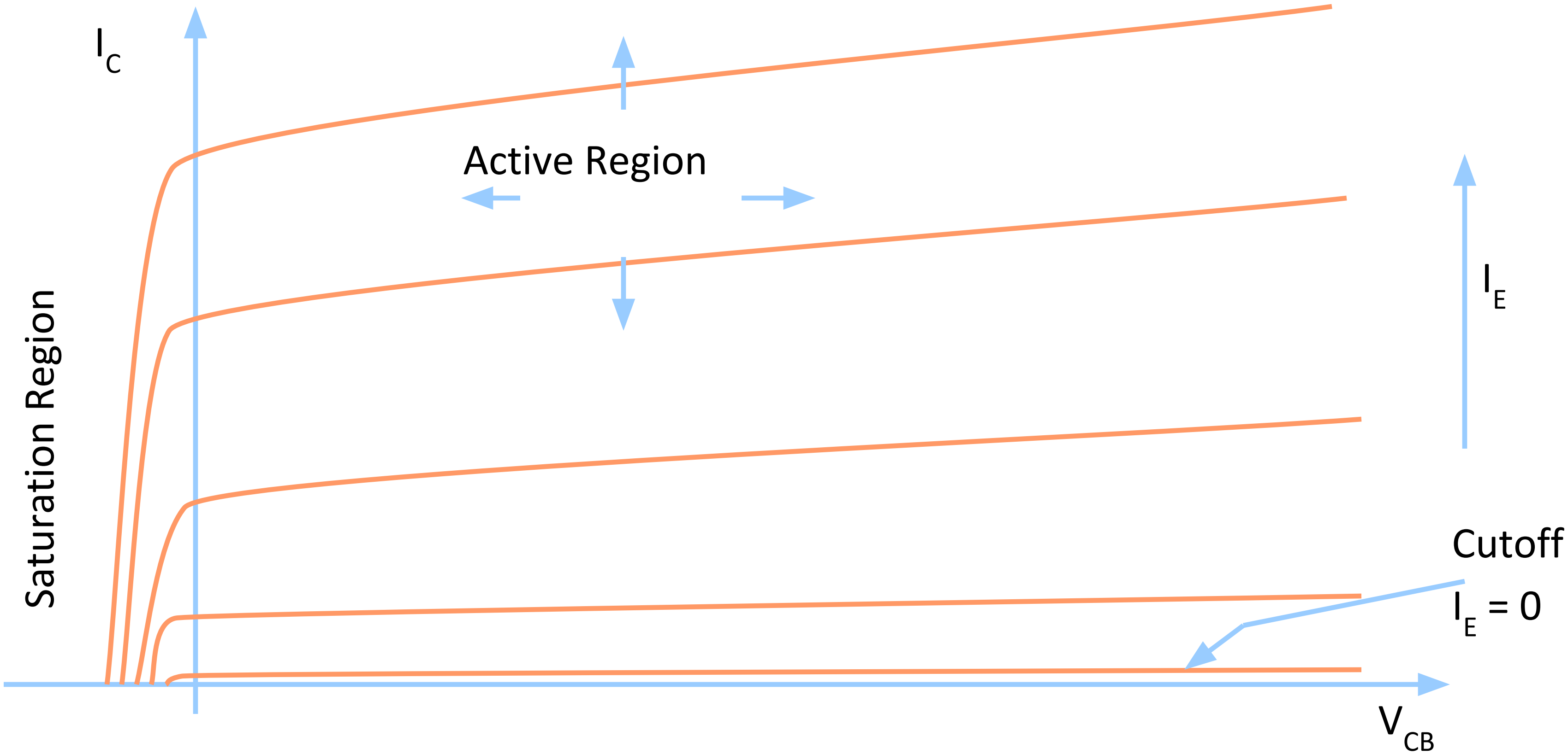
- The plot of the input current against the input voltage of the transistor in a particular configuration with the output voltage as a parameter for a particular mode of operation gives the input characteristics for that mode.
- **Common-base mode**



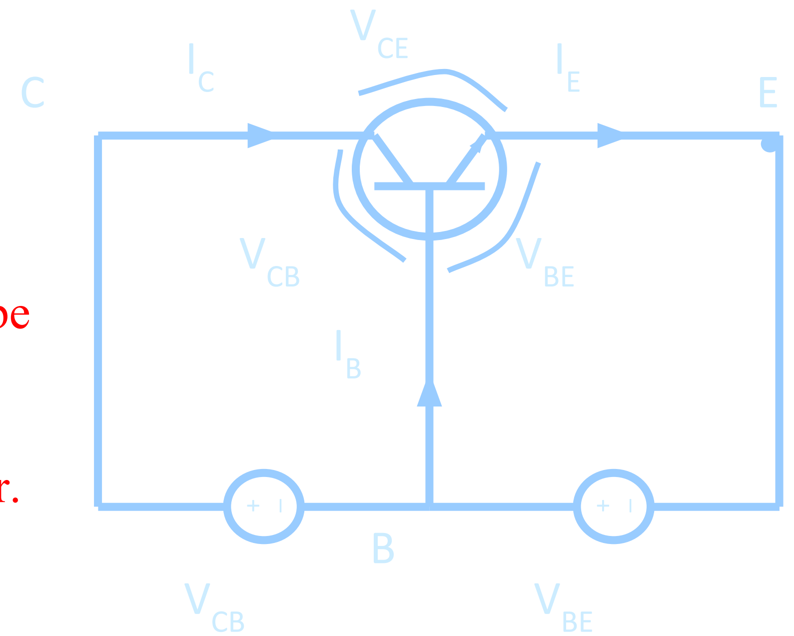
Input characteristics in the CB mode

Although the Common-Base configuration is not the most common biasing type, it is often helpful in the understanding of how the BJT works.

Emitter-Current Curves



Circuit Diagram: NPN Transistor



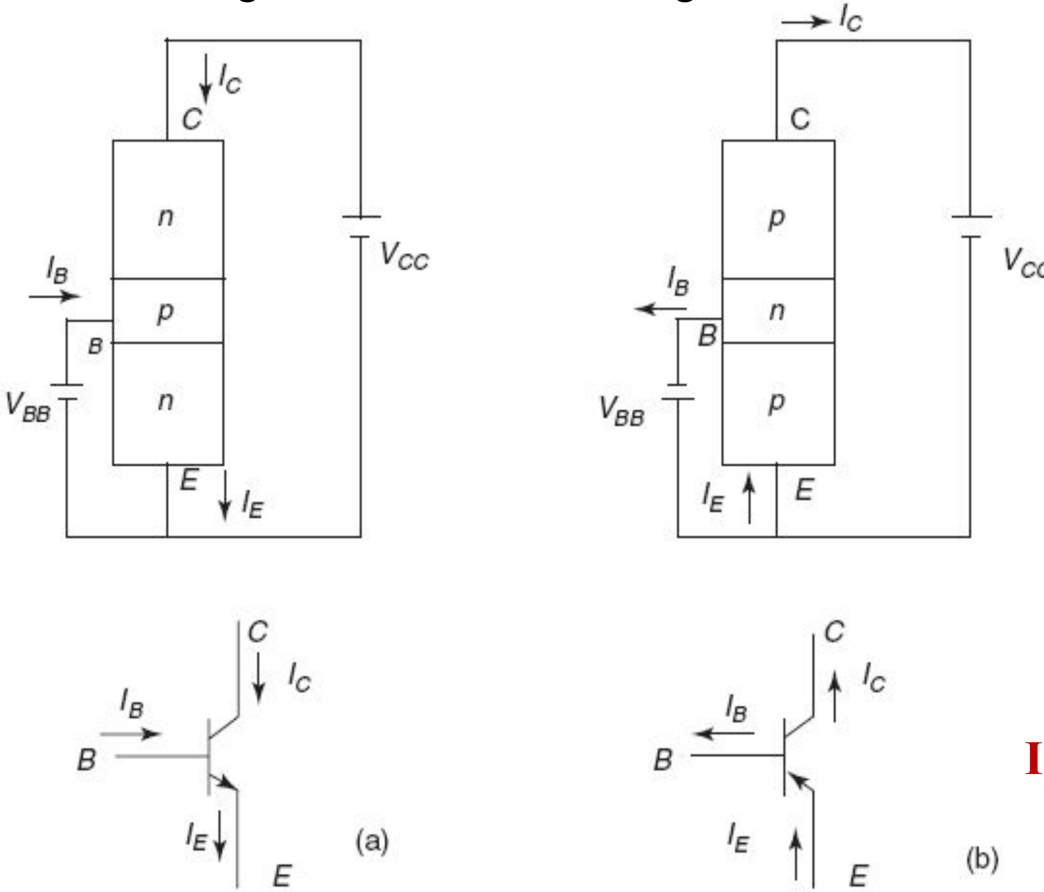
The Table Below lists assumptions that can be made for the attributes of the common-base biased circuit in the different regions of operation. Given for a Silicon NPN transistor.

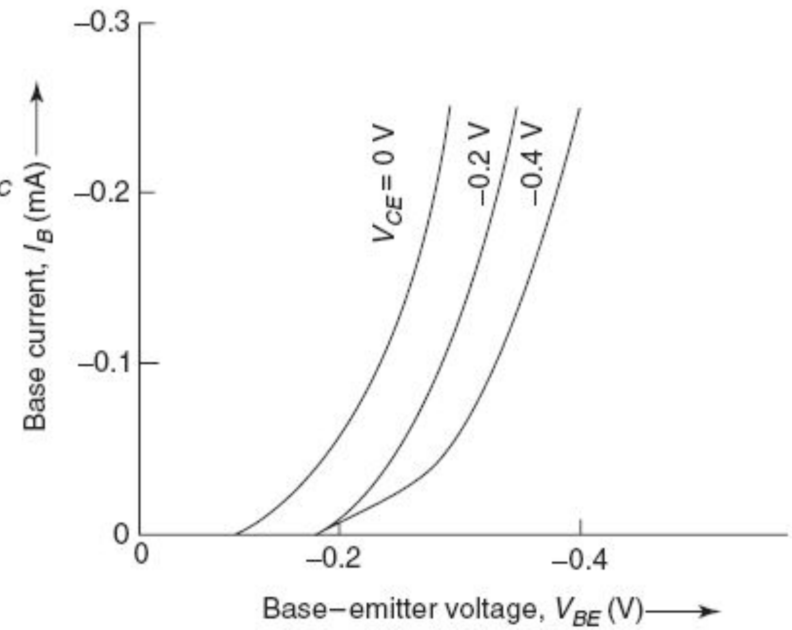
Region of Operation	I_C	V_{CE}	V_{BE}	V_{CB}	C-B Bias	E-B Bias
Active	□I_B	$=V_{BE}+V_{CE}$	~0.7V	□ 0V	Rev.	Fwd.
Saturation	Max	~0V	~0.7V	$-0.7V<V_{CE}<0$	Fwd.	Fwd.
Cutoff	~0	$=V_{BE}+V_{CE}$	□ 0V	□ 0V	Rev.	None /Rev.

CE CONFIGURATIONS

❖ Common-emitter (CE) Mode

- When the emitter terminal is common to both the input and the output circuits, the mode of operation is called the common-emitter (CE) mode or the ground–emitter configuration of the transistor.

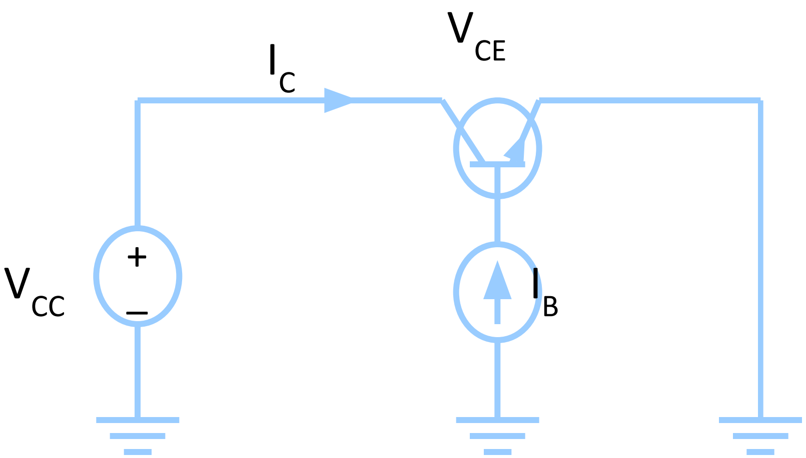




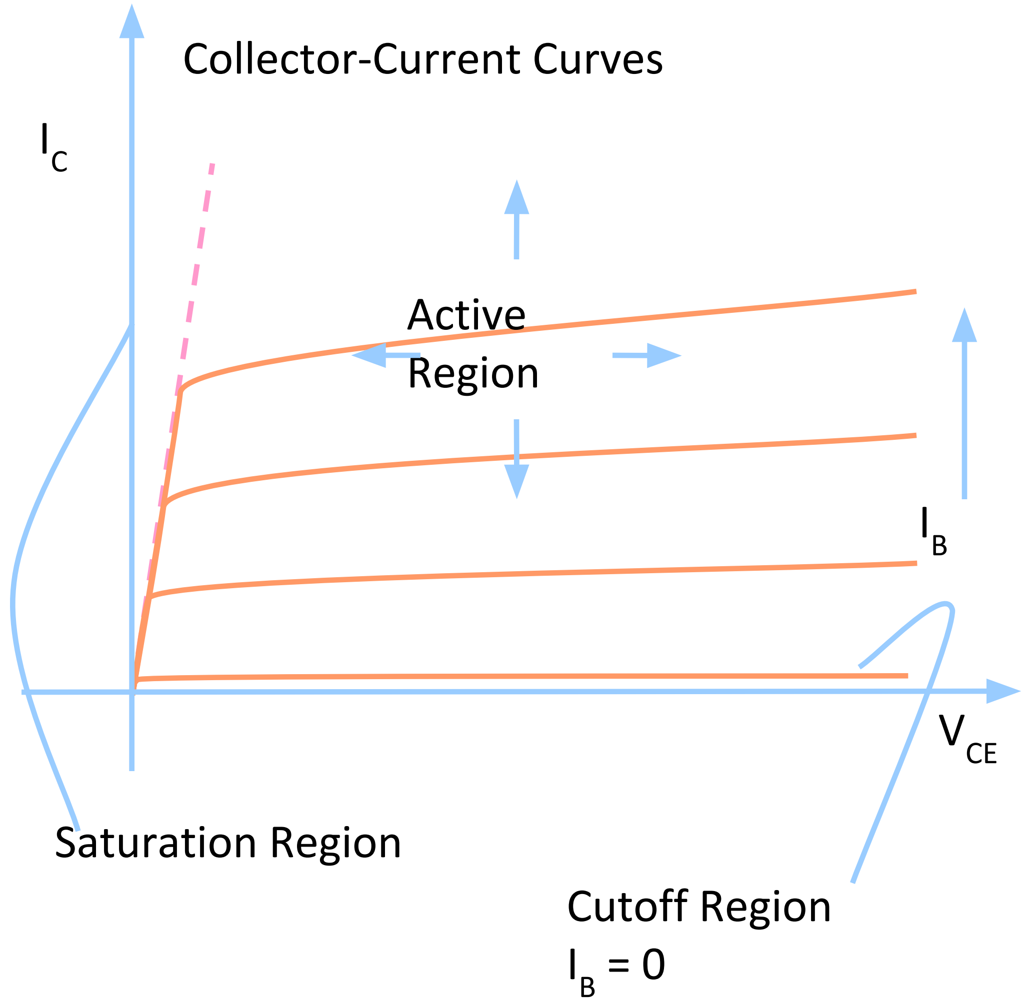
Input characteristics in the CE mode

Notation and symbols for common-emitter configuration (a) *n–p–n transistor* (b) *p–n–p transistor*

Circuit Diagram



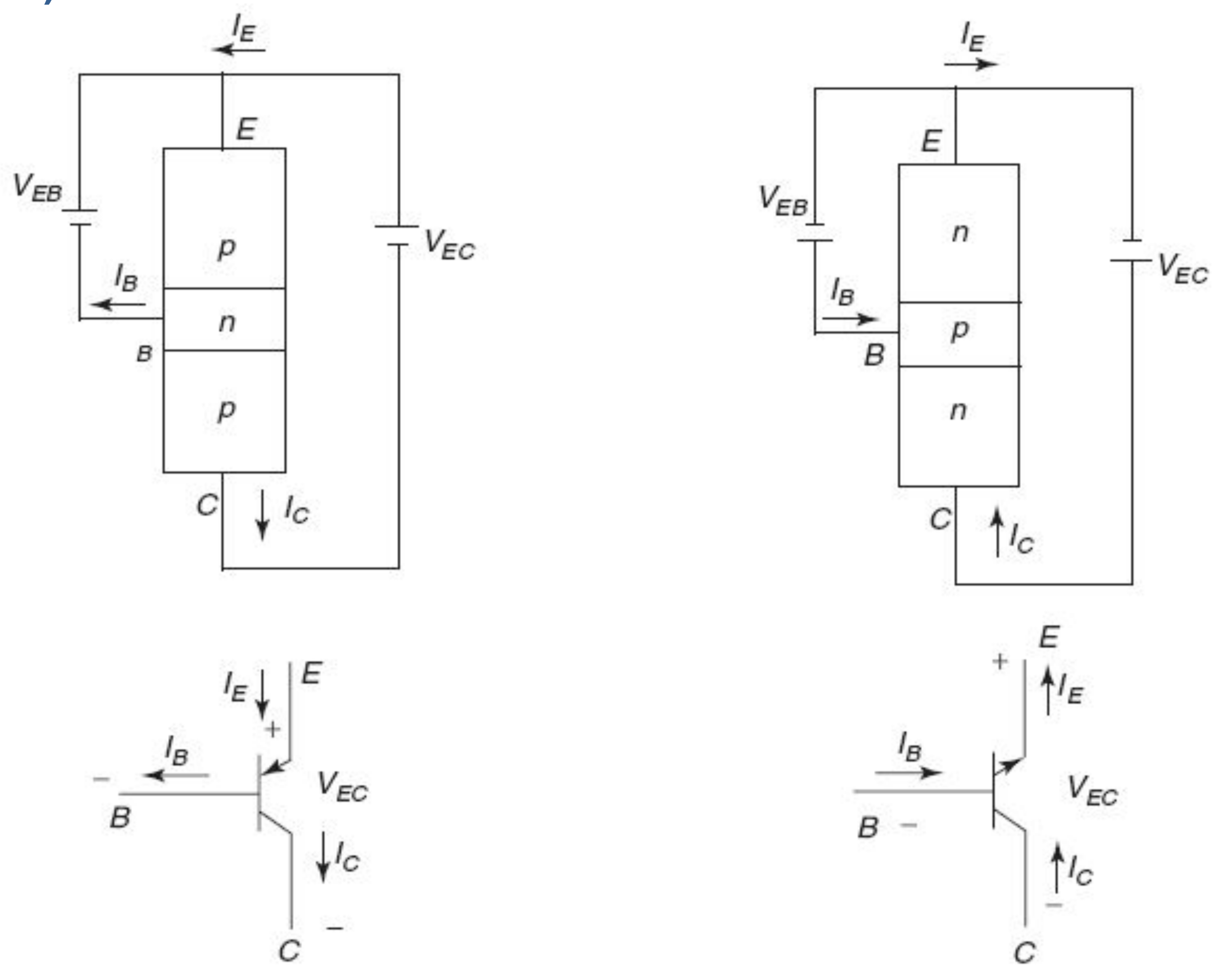
Region of Operation	Description
Active	**Small base current controls a large collector current**
Saturation	**$V_{CE(sat)}$ ~ 0.2V, V_{CE} increases with I_C**
Cutoff	**Achieved by reducing I_B to 0, Ideally, I_C will also equal 0.**



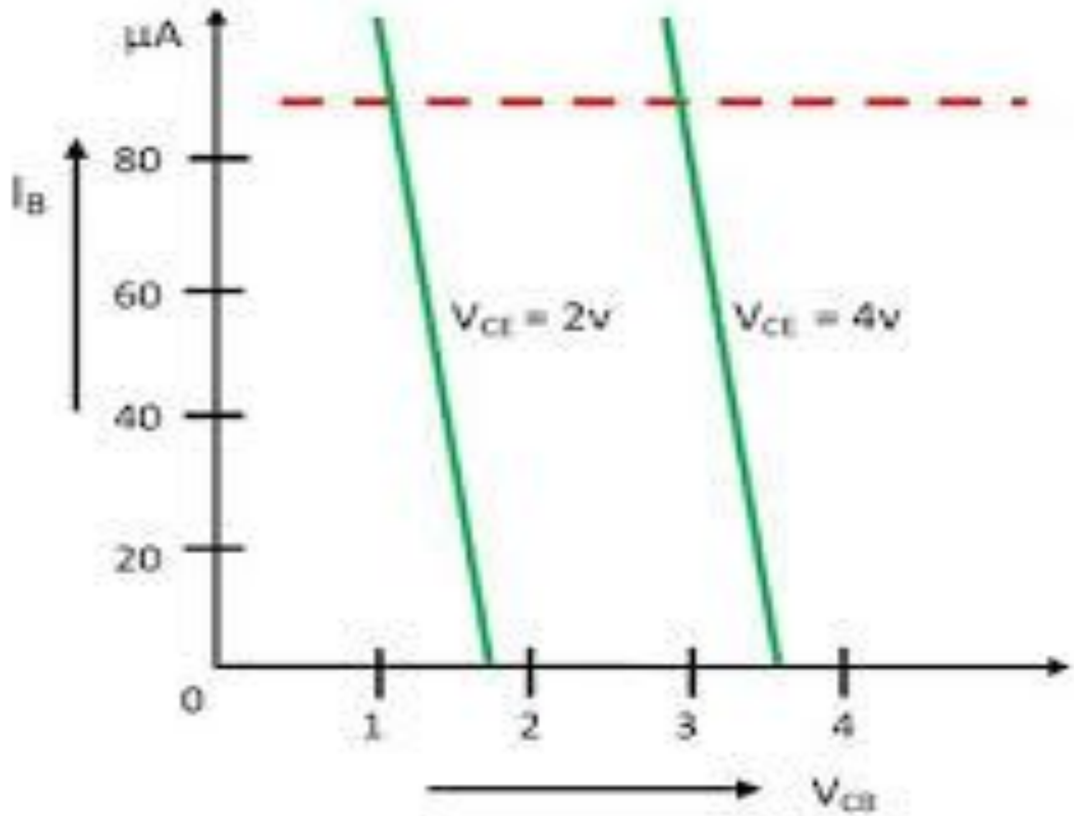
CC CONFIGURATIONS

❖ **Common-collector (CC) Mode**

- When the collector terminal of the transistor is common to both the input and the output terminals, the mode of operation is known as the common-collector (CC) mode or the ground–collector configuration.



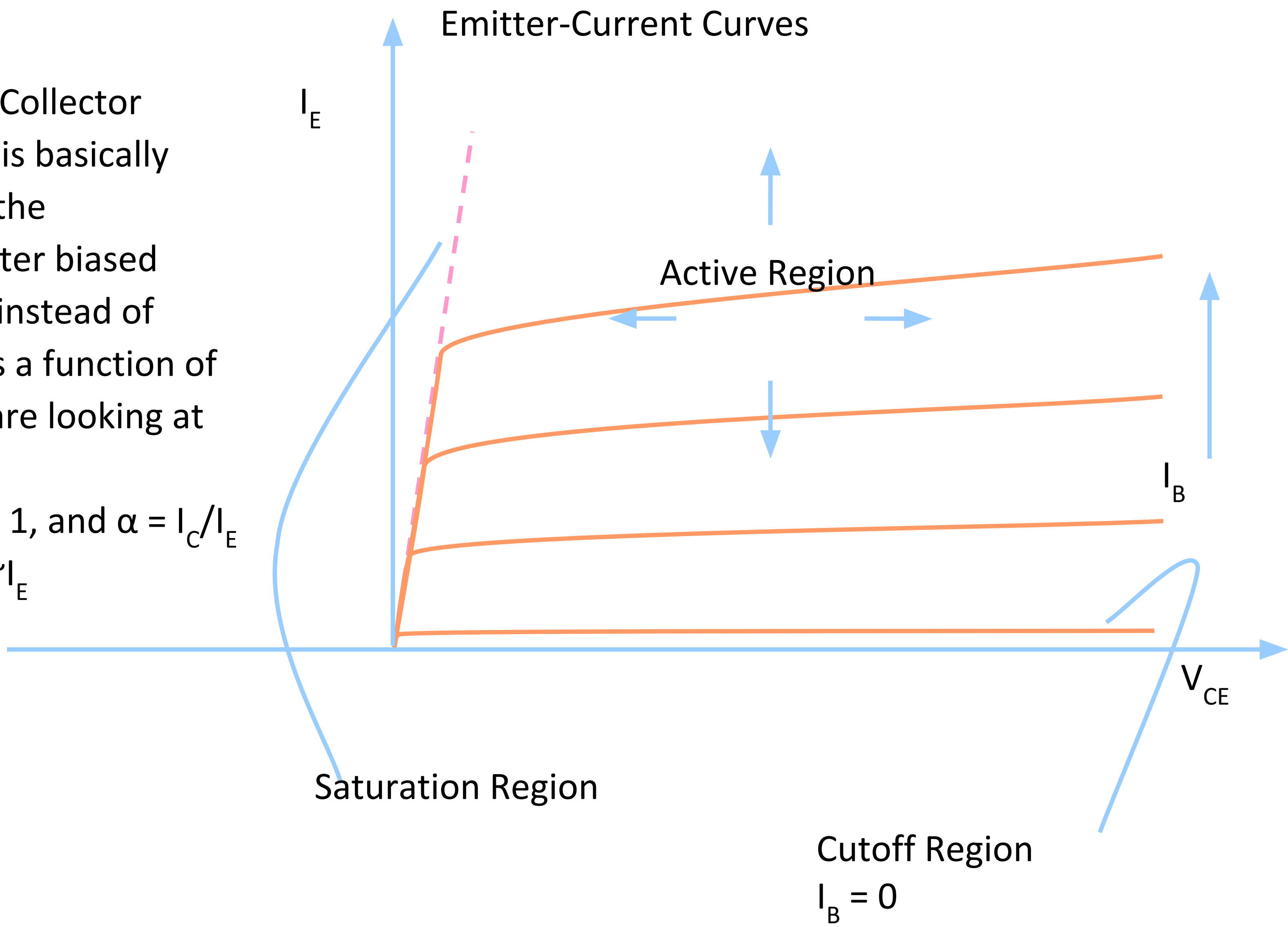
Common-collector configuration



Input Characteristic Curve

The Common-Collector biasing circuit is basically equivalent to the common-emitter biased circuit except instead of looking at I_C as a function of V_{CE} and I_B we are looking at I_E.

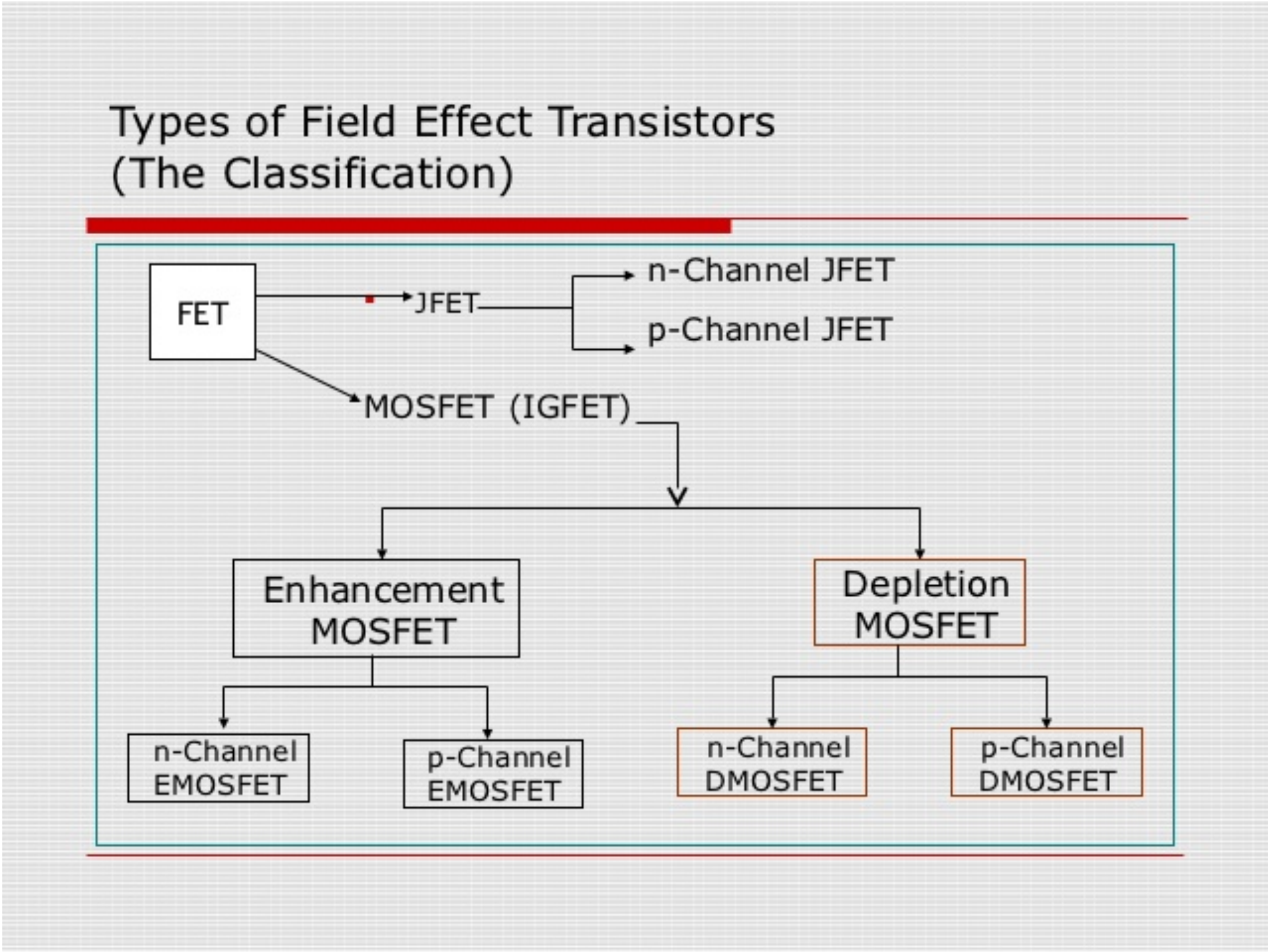
Also, since $\alpha \sim 1$, and $\alpha = I_C/I_E$ that means $I_C \sim I_E$



Field Effect Transistor

- FET is a device in which the flow of current through the conducting region is controlled by an electric field .Hence the name Field Effect Transistor.
- As current conduction is only by majority carriers , it is said to be a uni polar device.

Types of FET


Types of Field Effect Transistors
(The Classification)
FET
JFET
n-Channel JFET
p-Channel JFET
MOSFET (IGFET)
Enhancement MOSFET
Depletion MOSFET
n-Channel EMOSFET
p-Channel EMOSFET
n-Channel DMOSFET
p-Channel DMOSFET

Introduction.. (Advantages of FET over BJT)

- High input impedance (MΩ)
  (Linear AC amplifier system)
- Temperature stable than BJT
- Smaller than BJT
- Can be fabricated with fewer processing
- BJT is bipolar – conduction both hole and electron
- FET is unipolar – uses only one type of current carrier
- ~~Less noise compare to BJT~~
- Usually use as an Amplifier and logic switch

Disadvantages of FET

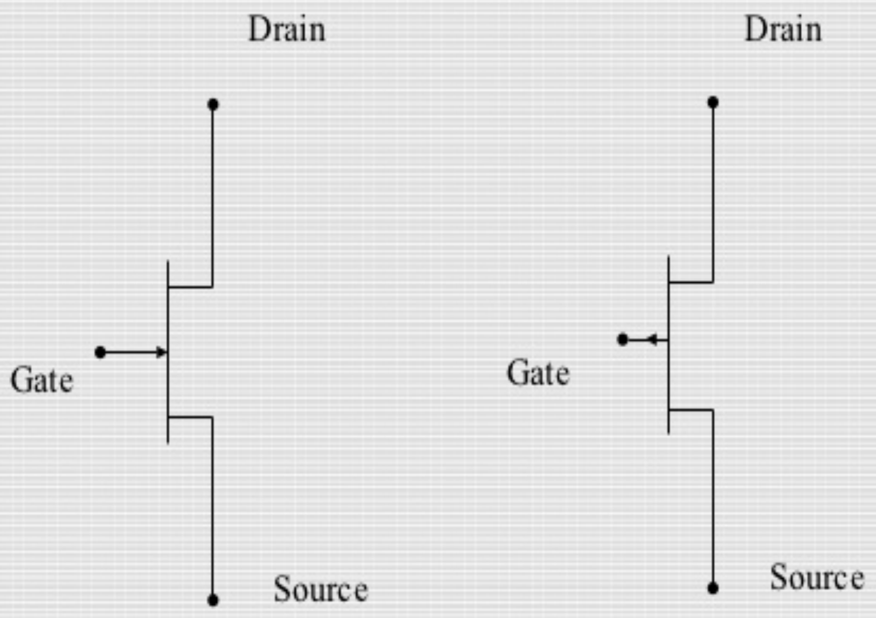
- Easy to damage compare to BJT

JFET

Junction field-effect transistor..

- There are 2 types of JFET
  - n-channel JFET
  - p-channel JFET
- Three Terminal
  - Drain – D
  - Gate -G
  - Source – S

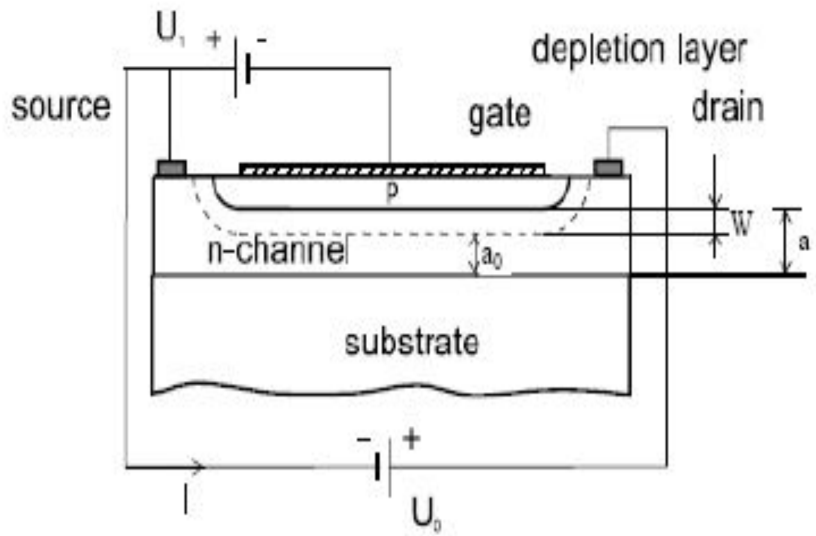
SYMBOLS



n-channel JFET p-channel JFET

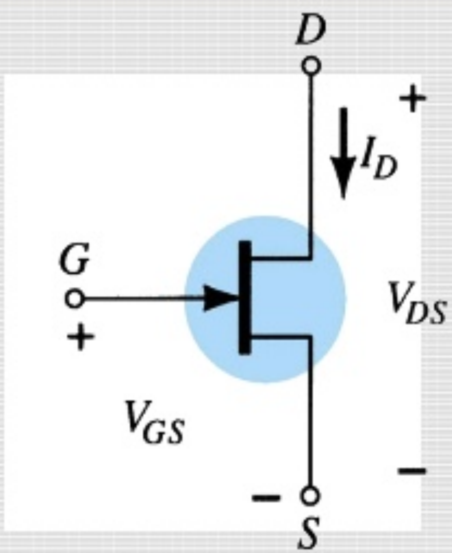
N-Channel JFET

- Junction FET (JFET)

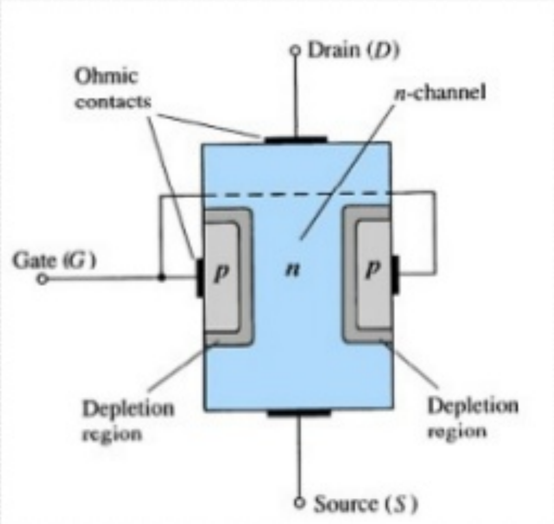


The gate-channel insulator consists of the DEPLETION REGION, i.e. the same material as the channel.

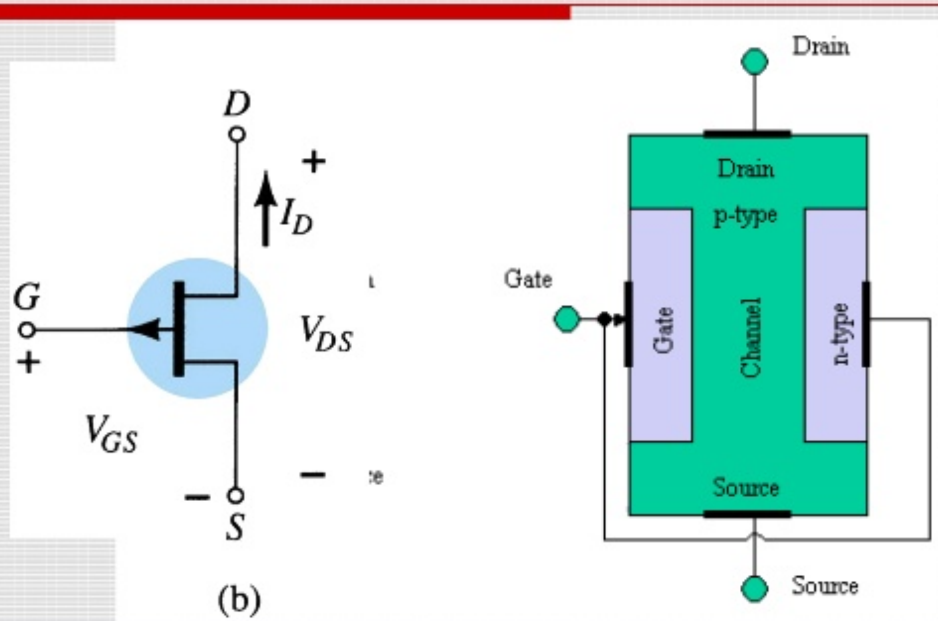
N-channel JFET..



(a)



P-channel JFET..



P-channel JFET

- P channel JFET:
  - Major structure is p-type material (channel) between embedded n-type material to form 2 p-n junction.
  - Current flow : from Source (S) to Drain (D)
  - Holes injected to Source (S) through p-type channel and flowed to Drain (D)

JFET Operating Characteristics

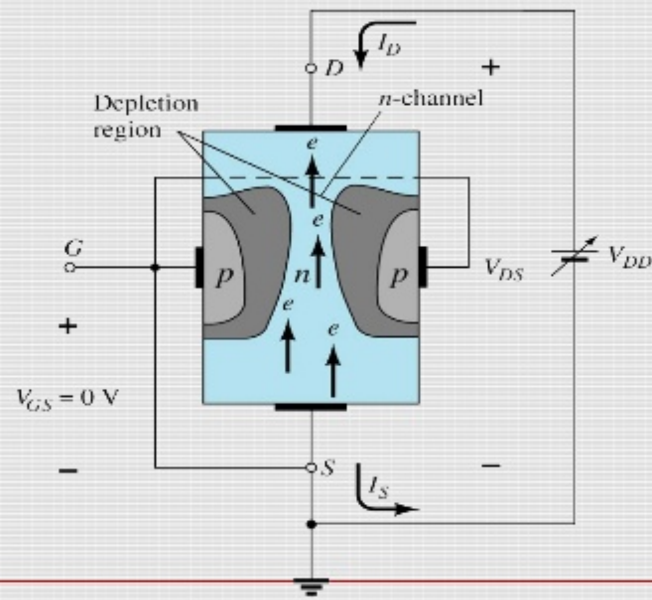
There are three basic operating conditions for a JFET:

- $V_{GS} = 0$, V_{DS} increasing to some positive value
- $V_{GS} < 0$, V_{DS} at some positive value
- Voltage-controlled resistor

JFET Characteristic for V_{GS} = 0 V and $0<V_{DS}<|V_p|$

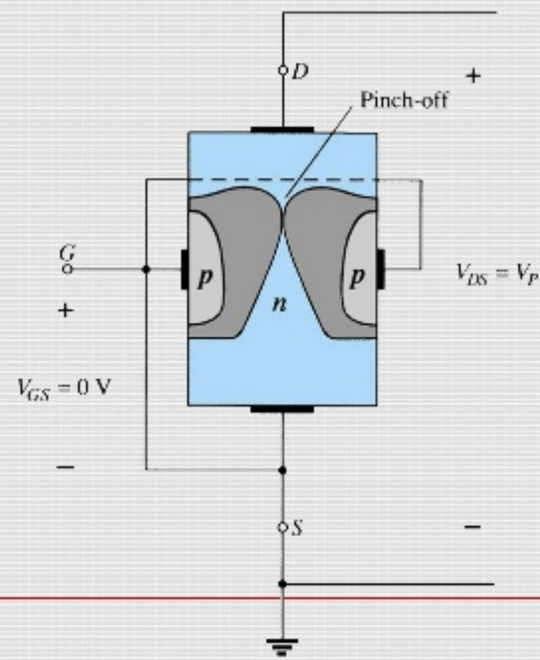
- To start, suppose V_{GS}=0
- Then, when V_{DS} is increased, I_D increases. Therefore, I_D is proportional to V_{DS} for small values of V_{DS}
- For larger value of V_{DS}, as V_{DS} increases, the depletion layer become wider, causing the resistance of channel increases.
- After the pinch-off voltage (V_p) is reached, the I_D becomes nearly constant (called as I_D maximum, I_{DSS}-Drain to Source current with Gate Shorted)

JFET for V_{GS} = 0 V and $0<V_{DS}<|V_p|$



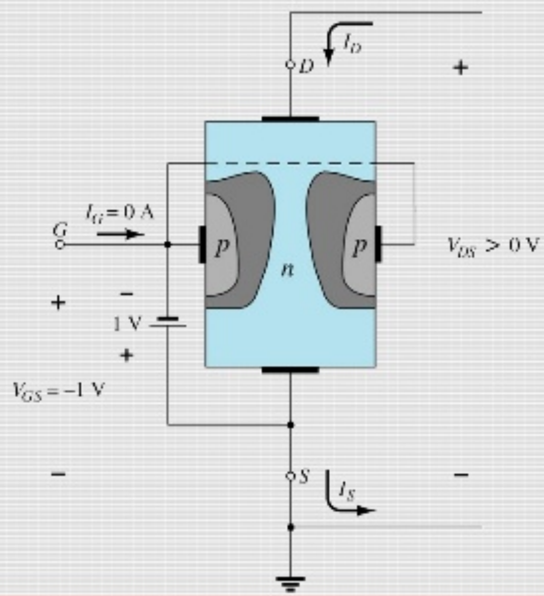
Channel becomes narrower as V_{DS} is increased

Pinch-off (V_{GS} = 0 V, V_{DS} = V_P).



JFET for $V_{GS} < 0$, V_{DS} at some positive value

(Application of a negative voltage to the gate of a JFET)



$V_{GS} < 0$, V_{DS} at some positive value

JFET Characteristic Curve..

- For negative values of V_{GS}, the gate-to-channel junction is reverse biased even with $V_{DS}=0$
- Thus, the initial channel resistance of channel is higher.
- The resistance value is under the control of V_{GS}
- If V_{GS} = pinch-off voltage(V_P)

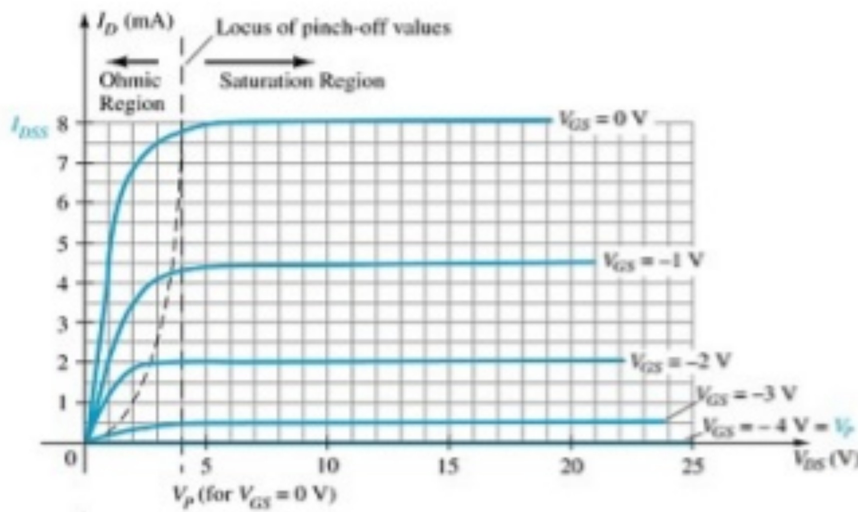
  The device is in cutoff ($V_{GS}=V_{GS(off)} = V_P$)
- The region where I_D constant – The saturation/pinch-off region
- The region where I_D depends on V_{DS} is called the linear/ohmic region

$V_{GS} < 0$, V_{DS} at some positive value

JFET Operating Characteristics

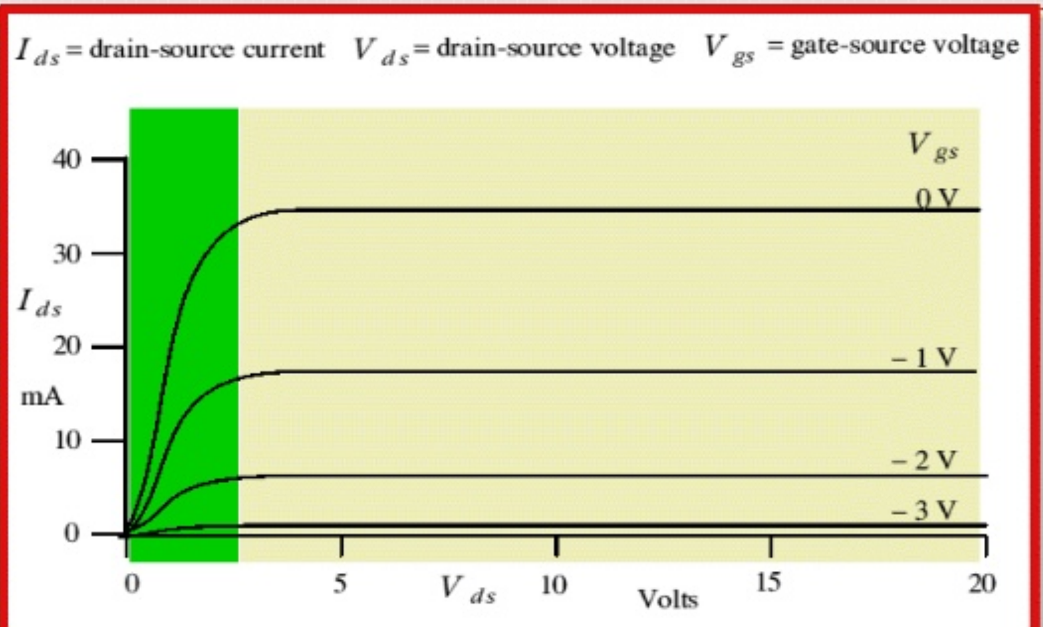
As V_{GS} becomes more negative:

- **The JFET experiences pinch-off at a lower voltage (V_P).**
- **I_D decreases ($I_D < I_{DSS}$) even though V_{DS} is increased.**
- **Eventually I_D reaches 0 A. V_{GS} at this point is called V_p or $V_{GS(off)}$.**



Also note that at high levels of V_{DS} the JFET reaches a breakdown situation. I_D increases uncontrollably if $V_{DS} > V_{DSmax}$.

Characteristics for n-channel JFET

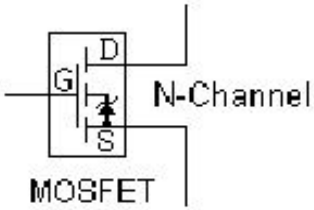


'Characteristic curves for a typical N-channel JFET.

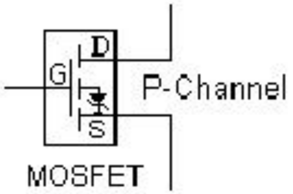
MOSFET

- MOSFET Field effect transistor is a uni polar transistor, which acts as a voltage-controlled current device.

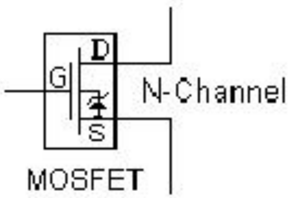
Types of MOSFET



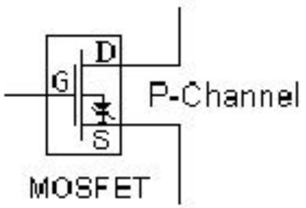
Enhancement Mode



Enhancement Mode

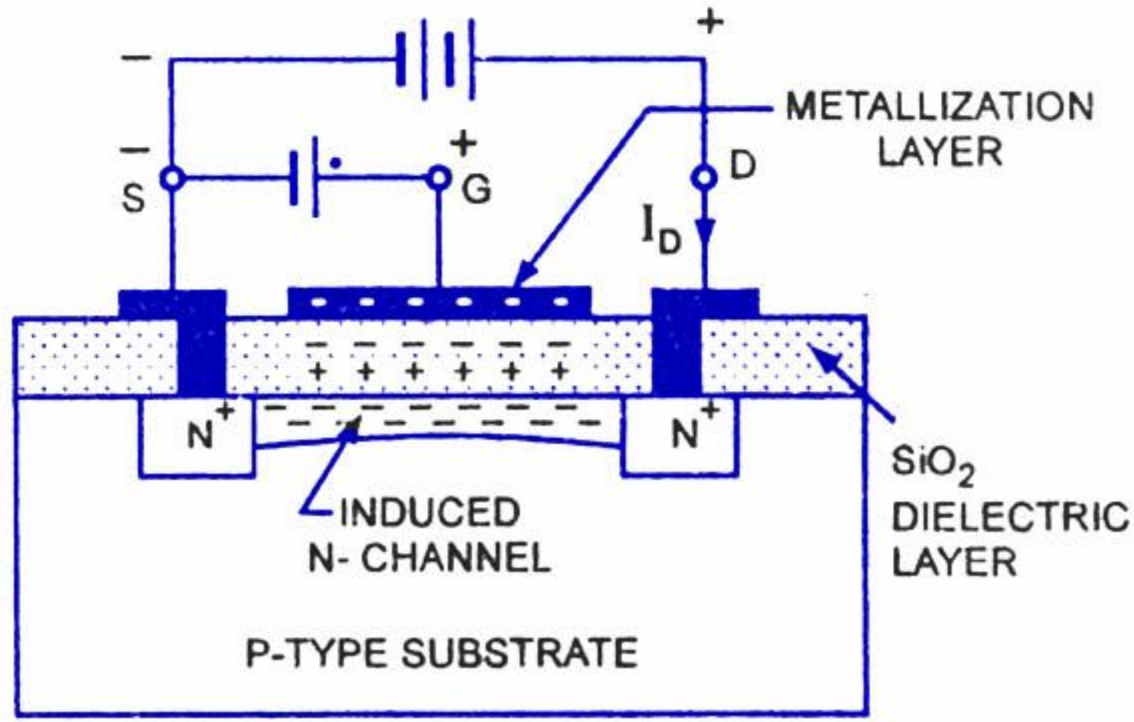


Depletion Mode



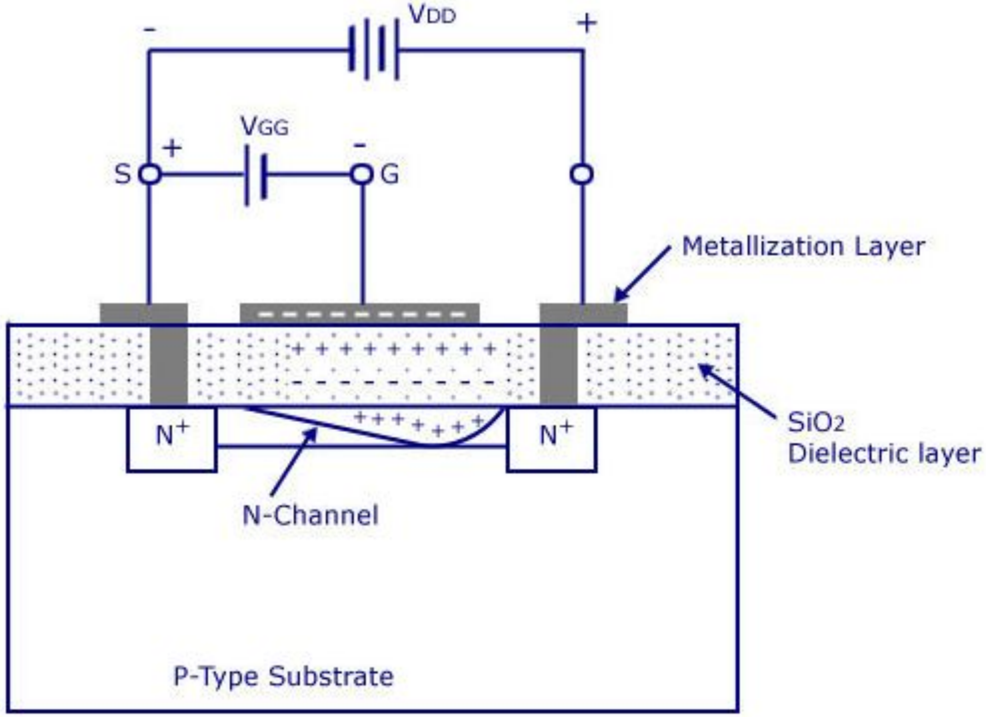
Depletion Mode

N channel Enhancement MOSFET



Operation of N-Channel E-MOSFET

N channel Depletion MOSFET



Depletion Mode Operation

- In an n-channel MOSFET, the channel is made of n-type semiconductor, so the charges free to move along the channel are negatively charged
- In a p-channel device the free charges which move from end-to-end are positively charged

VI Characteristics of MOSFET