Unit - 1

Introduction to Electronics

* Generation of Computers.

1] First Generation computers [1940 - 1959]
→ used vacuum tubes as basic components for memory and circuitry for CPU [Central Processing Unit].
Ex:- ENIAC - Electronic numerical Integrator & Calculator
→ Size of computers were very big.

2] Second Generation Computers [1959 - 1964]
→ These computers used transistors.
→ transistors were cheaper, consumed less power, more compact in size, more reliable and faster.

3] Third Generation computers [1964 - 1970]
→ These computers used Integrated Circuits [ICs] in place of transistors.
→ This development made computers smaller in size, reliable, and efficient.

4] Fourth Generation Computers [1970 - present time]
→ Computers of fourth generation used Very large Scale Integrated [VLSI] Circuits.
→ VLSI circuits made it possible to have microcomputers
→ Computers became more powerful, compact, reliable and affordable.

5] Fifth Generation computers.
→ future generation in which human intelligence will be utilized. i.e Artificial Intelligence

* Impact of Electronics in Society
→ 1] Mobile phone
2] Personal Computers, laptops etc.
3] TVs and Radios
4] Medical electronics :- X-ray machines, Electrocardiograph (ECG)
5] Audio Systems :- stereo amplifier, record player.
6] Line communication :- telegraphy, telephony, telex, teleprinters.
7] Defense systems :- RADAR, Guided missiles etc.

\# Impact of Electronics in Industry
1) Mechatronics
2) Computer Aided Design [CAD]
3) Computer Aided machines which are numerically controlled (NC) and computer numerically controlled [CNC]
4) Remote Sensing and controlling systems.
5) Inspection and Quality control instruments.

Electronic Components

- Active
  - Sources
  - Changers.
- Passive
  - Resistor
  - Capacitor
  - Inductor

- Comparison of Active & Passive Components.

	Parameter	Active element	Passive element.
1.	Defination	Active components are those which introduce gain or amplify signal.	Passive components are those which do not introduce gain or do not amplify signal
2.	Direction of Operation	Unidirectional	Bi-directional
3.	External Source	Required	Not Required.
4.	Source of Energy	Some are source of Energy and provide power to the circuit	never source of Energy. stores & dissipates power present in ckt.
5.	flow of current	Can control flow of current	Cannot control flow of current.
6.	Power Gain	Provide power gain	donot Provide
7.	Examples	Diode, transistor, op-amp etc.	Resistor, Capacitor, Inductor.

* Resistor :

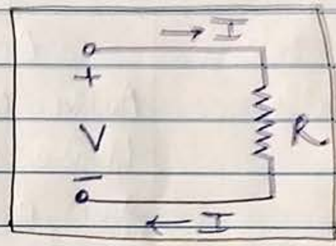
It opposes the flow of current.

$\boxed{\text{unit} - \Omega}$

Symbol:- fixed 

Variable 

- Working of Resistor:-



→ the resistor is a two-terminal component that resists or limits the current flowing through it and as a result of that voltage drop is produced across its terminal.

$$\boxed{R = \frac{V}{I}}$$

- Classification of Resistor

Resistor
- Linear resistor
  - fixed
    - Wire wound
    - Carbon Composition
    - Thin film
    - Thick film
  - Variable
    - wire wound
    - Potentiometer
    - Trimmer
- non-linear resistor
  - TDR
  - VDR
  - LDR
  - Photoresistor

* Colour Coding of Resistor :-

Colour	First Band	Second Band	Third band	Fourth band
Black	0	0	$\times 10^0$	-
Brown	1	1	$\times 10^1$	-
Red	2	2	$\times 10^2$	-
Orange	3	3	$\times 10^3$	-
Yellow	4	4	$\times 10^4$	-
Green	5	5	$\times 10^5$	-
Blue	6	6	$\times 10^6$	-
Violet	7	7	$\times 10^7$	-
Grey	8	8	$\times 10^8$	-
White	9	9	$\times 10^9$	-
Gold				$\pm 5\%$
Silver				$\pm 10\%$
No Colour				$\pm 20\%$

* Examples:-

1] Red Red Brown Gold = 220 Ω ± 5%

2] Violet Green Orange Gold = 75 KΩ ± 5%

3] Red Red Yellow Silver = 220 KΩ ± 10%

4] Yellow Grey Red Gold = 4.8 KΩ ± 5%

6] Green Blue violet Gold = 560 MΩ ± 5%

7] Grey Brown Green Gold = 8.1 MΩ ± 5%

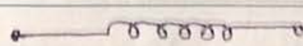
8] Brown Black Orange Gold = 10KΩ ± 5%

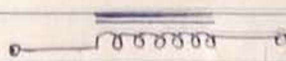
* Inductor :-

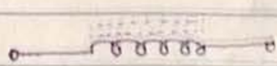
→ Inductor stores Energy in form of magnetic field.

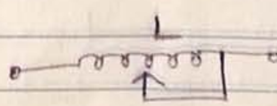
Unit → H (Henry)

Symbol:-

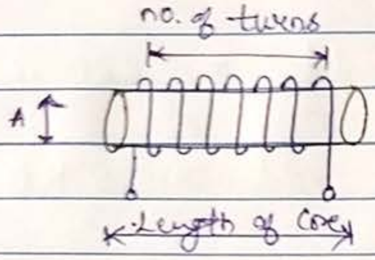
(a) Air core 

(b) Iron core 

(c) Ferrite core 

(d) Variable  or 

* Construction and Working principle



→ It consist of a conducting wire [Copper or Aluminium] wound into a coil on the core.

→ Core can be iron, air, paper, plastic etc.

→ When an electric current is passed through it, a magnetic field is created.

→ this magnetic field helps to store the electric current for short time, even if the supply is removed.

→ when the magnetic field around the coil collapses, the electric current also falls off.

- Expression for the inductance (L)

$$L = \frac{\mu_0 \mu_r N^2 A}{\cancel{I}\, l}$$

N = number of turns
A = Area of cross-section of core
l = length of magnetic path

μ_0 = permeability of free space
$= 4\pi \times 10^{-7}$ H/m

μ_r = Relative permeability of the core material.

Types of inductor

According to core material
- Air core
- iron core
- ferrite core

According to applications
- filter chokes
- Tube light chokes or ballast
- Audio frequency chokes
- Tuning inductors
- IF & RF tuning coils.
- Transformer.

* Application

1. Radio
2. Relay
3. Transformer
4. filter circuit
5. tuning ckt.
6. amplifier
7. RF choke.

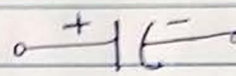
\# Capacitors :-

→ It stores the energy in the form of charge.

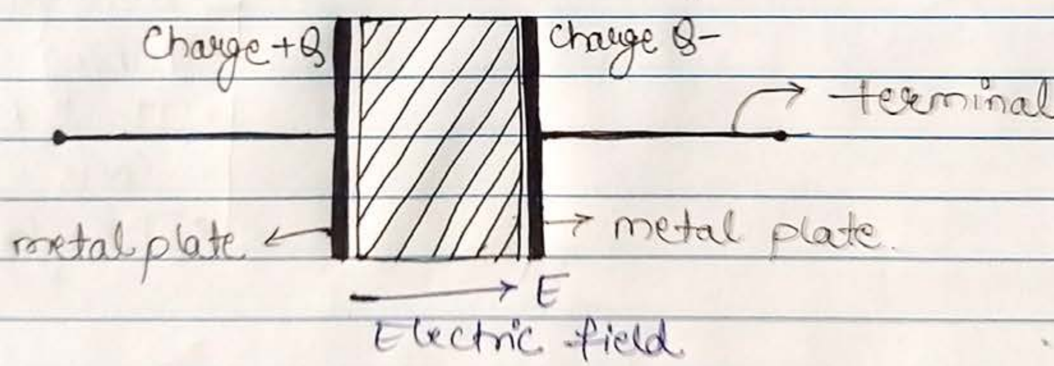
unit :- F (farad)

symbol :- fixed 

variable 

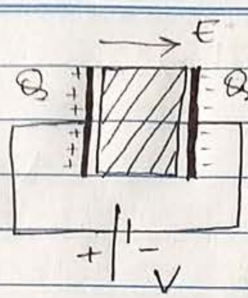
electrolytics 

\- Construction and Working Principle



→ A Capacitor consists of 2 conducting parallel plates separated by a dielectric.

→ when a DC voltage is placed across a capacitor, the positive charge is collected on one plate & negative charge is collected on other plate.

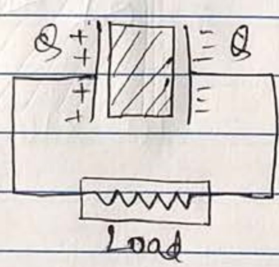


DC Voltage

$$C = \frac{Q}{V}$$

→ An electric field will from inside the capacitor dielectric from positive to negative plate.

→ After some time, capacitor holds maximum amount of charge as per its capacitance with respect to applied V.
this time span is called charging time of the capacitor.

→ 

if the 2 ends get shorted through a load, a current will flow through this load from plate 1 to plate 2 up to all charges get vanished from both plates.
this time span is known as discharging time of capacitor.

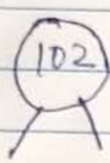
Types of Capacitors

- Fixed Capacitors
  - non-electrolytic
    - paper C
    - mica C
    - Ceramic C
  - Electrolytic
- Variable Capacitors
  - Gang capacitor
  - Trimmers.

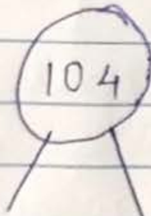
* Numerical Code for Ceramic Disc Capacitors

→

$= 10 \times 10^{3}\,pF = 10^{4} \times 10^{-12}\,F$
$= 10^{-8}\,F = 10\,nF$
$= \cancel{0.1 \times 10^{-9}F} = \cancel{0.1\,nF}$



$= 10 \times 10^{2}\,pF = 10^{3} \times 10^{-12}\,F = 1\,nF$



$= 10 \times 10^{4}\,pF = 10^{5} \times 10^{-12}\,F = 10^{-7}\,F$
$= 0.1\,\mu F$

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Expression for Capacitance 'C'

→ Capacitance is the ability of a body to store electric charge.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

ε_0 = Permittivity of free space
= 8.854×10^{-12} F/m

ε_r = Relative permittivity of the dielectric material

A = area of each plate
d = Distance between the plates.

Application of Capacitor.

1. in filter circuit
2. tuning circuit
3. timing circuit.
4. tank circuit.
5. Computer motherboard
6. monitor circuit.

Sources.

Sources → DC Sources, AC Sources.

1. D.C Sources.

→ a) Batteries → convert chemical energy into electrical energy.

b) Generators → convert mechanical energy into electrical energy.

c) Rectifiers: Convert alternating current (A.C.) into direct current (D.C.)

2. AC Sources

a] Alternators: convert mechanical energy into electrical energy

b] Invertors: convert direct current (D.C) into Alternating current (A.C).

Changers or Modulators

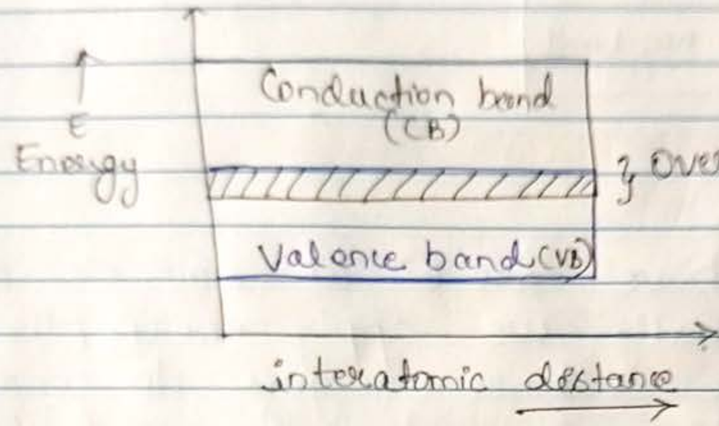
→ They change or modulate the shape of the regular periodic waveform of the input voltage or current either by changing amplitude or frequency

→ ex:- BJT, diode, FETs etc.

* Classification of solids depending upon Energy Band diagram.

⇒

1] Conductors



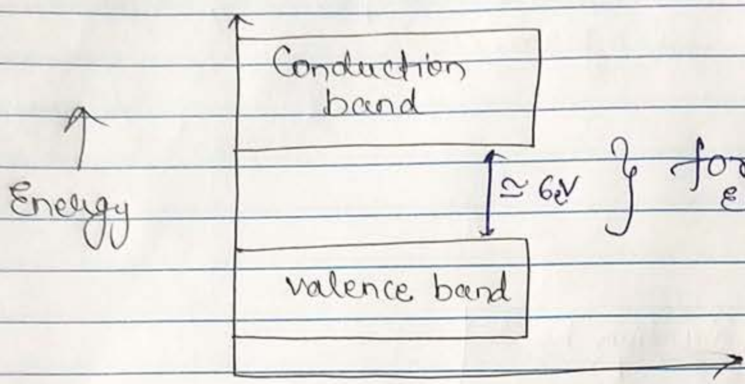
Valence band :- the range or band of energy possessed by valence e^-.

Conduction band :- the range or band of energy possessed by e^- conducting electricity.

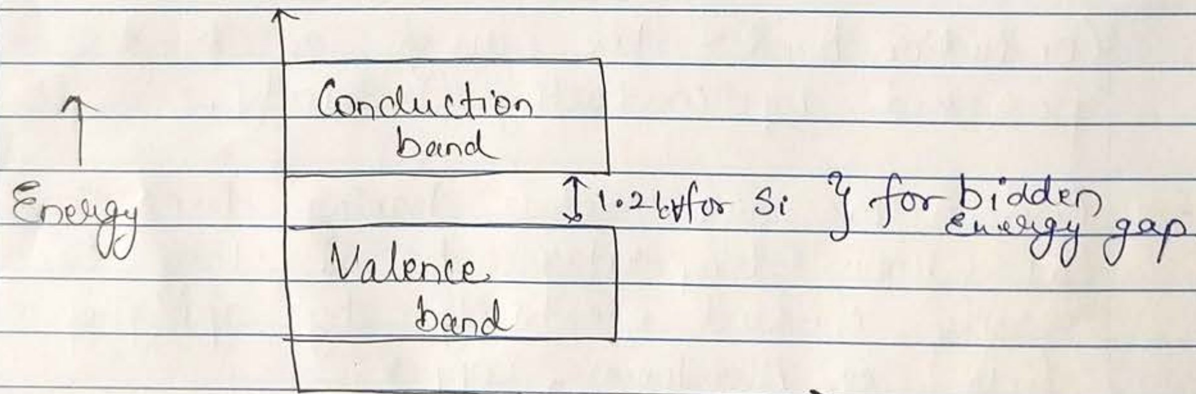
→ Conductors are metals having free e^- at room temperature hence they can easily conduct electricity by applying electric field eg. Aluminium, Copper.

2] Insulators.

→ The forbidden energy gap is very large in Insulators & thus there are no free e^- hence they are bad conductor of electricity e.g. wood, plastic.



5] Semi Conductors.
→ they don't have free e⁻ at room temp. but if externally we apply energy [thermal, voltage] some valence e⁻ goes to conduction band and are available for conduction. (as forbidden energy gap is small)
Eg. silicon, Germanium



* forbidden energy band or gap:-
→ The energy required for valence e⁻ to jump to conduction band to become free e⁻ is called forbidden energy band or gap.

Semiconductor

- Semiconductor
  - Intrinsic
  - Extrinsic
    - P-type
    - N-type

Intrinsic semiconductor

→ Intrinsic → Pure

- intrinsic semiconductors are the semiconductors in their purest possible form.

- at room temperature they behave as insulators and increase in temperature or application of voltage does not increase their conductivity significantly.

→ ∴ they are not practically used for manufacturing of devices.

Extrinsic semiconductor.

→ Extrinsic → impure.

We can obtain the extrinsic semiconductors from intrinsic ones by adding impurities to them.

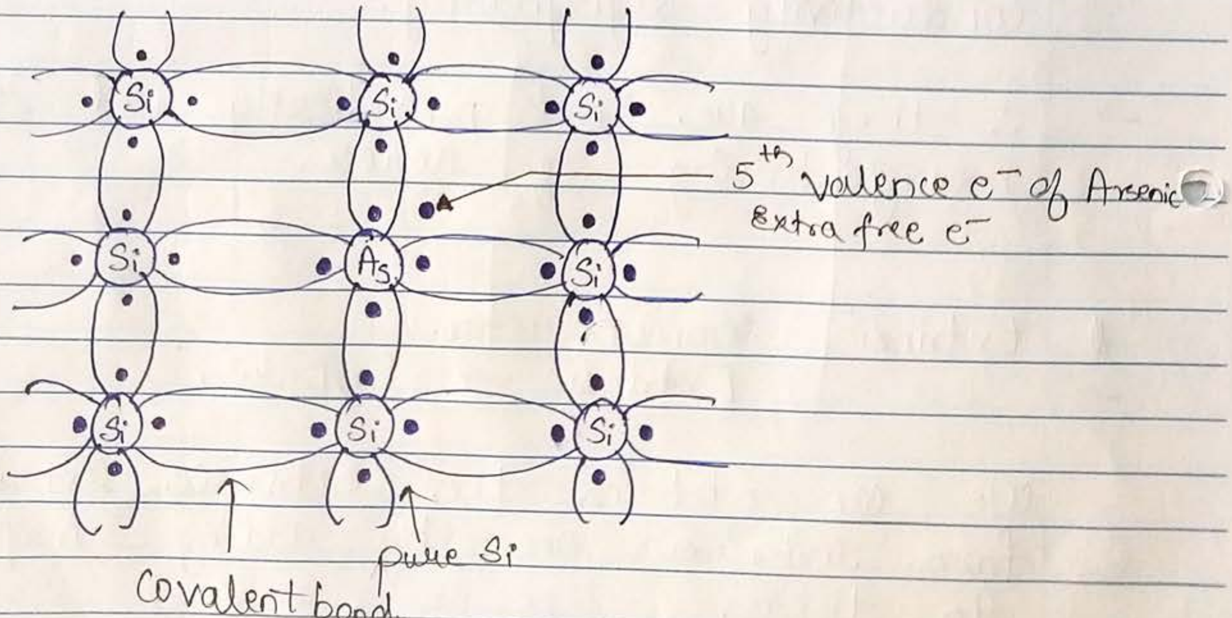
→ The process of adding impurities is called as **Doping**.

→ Due to doping, the conductivity of the semiconductors increase.

→ The material which is being used as impurity in the process of doping is called as dopant.

→ The impurities are of 2 types.
1) Donor impurity
2) Acceptor impurity.

* n-type semiconductors:



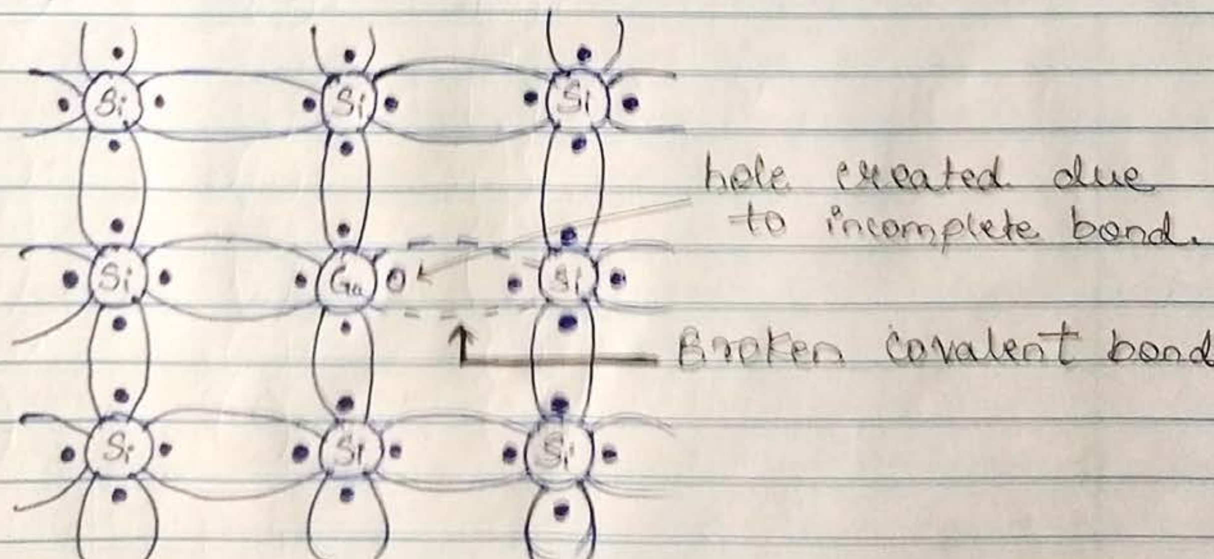
→ the pentavalent element is the one which has 5 valence e^-.
Ex: Antimony, Arsenic & phosphorous.

→ the N-type semiconductor is formed by adding a small amount of pentavalent impurity to the pure silicon or Germanium material which acts as a base material.

→ in N-type semiconductors conduction largely takes place due to free e^-

majority carries	→ free e^-
minority carrier	→ holes.

★ P-type semiconductors.



→ trivalent atoms are those which has 3 valence e^-
Ex: Boron, Gallium and Indium.

→ In p-type semiconductors are formed by adding trivalent atoms.
the 3 valence e^- of Ga form bond with Si valence e^- and one hole is created.

→ the conduction largely takes place due to holes.

holes → majority carriers
electrons → minority carriers.

* Difference between Conductor, Semiconductor & Insulator.

Parameter	Conductor	Semiconductor	Insulator
1. flow of Current	Due to move-ment of free e^-	Due to movement of e^- & holes	No current
2. Resistivity	low	Moderate	High
3. Temperature coefficient of resistance	Positive	Negative	Negative
4. forbidden Energy gap	No or very low	Small [1.21eV for Si]	very large ($\simeq$ 6V)
5. Definition	The material which allow flow of current when voltage is applied	the material whose conducti-vity lies between conductor & insulator.	the material which do not allow flow of current
6. Example	Copper, Alu-minium etc.	Silicon, Germanium etc	Paper, Rubber, Wood etc.
7. Application	Conducting wires, Transformer etc.	Diode, transistors etc.	home appliances, Sports equipment, for protection against high voltage.

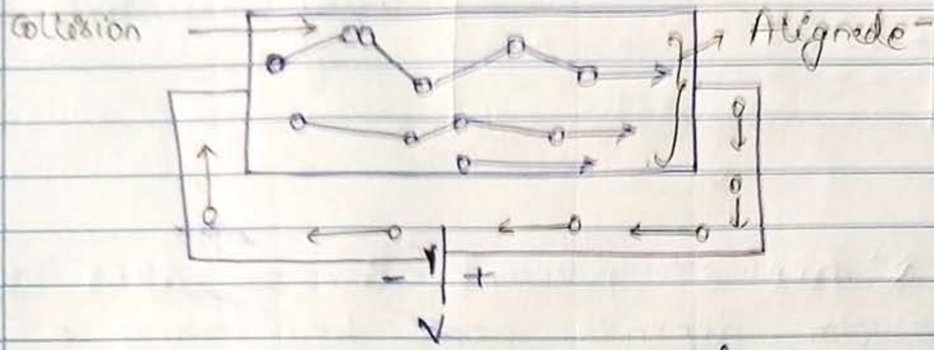
Difference between Intrinsic & Extrinsic semiconductor.

Parameter	Intrinsic Semiconductor.	Extrinsic Semiconductor
1.] form of Semiconductor	Pure form	Impure form
2. Conductivity	poor	comparatively better
3. Carrier concentration	Equal amount of e^- & holes are present in conduction & valence band	majority carrier concentration is depends on type of extrinsic semiconductor
4. Type	no types	P type & N type
5. Example	Si, Ge etc.	GeAs, GeP, SiAs, SiP etc.

Current in Semiconductors.

1.] Drift Current.

→



→ when an external electric field is present across the semiconduct the velocity of e^- increases indefeinitely and it experices a force of attraction due to Electric field.

→ and this makes the e^- to move in direction of Electric field or resultant. (some energy is lost in collision of e^-s).

→ the movement of e^- due to presence of Electric field is known as Drift and current due to drift is called as Drift current.

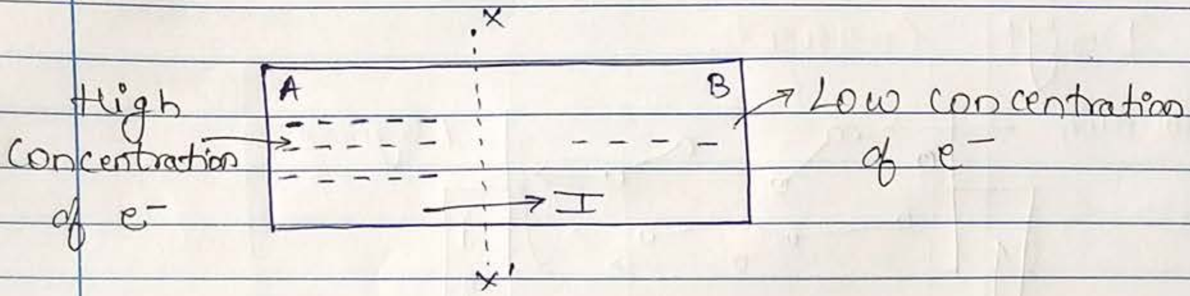
→ the velocity with which e^- move is called drift velocity. (v)

$$v = \mu E$$

E → applied electric field in V/m

μ → mobility of electron

* Diffusion Current.



→ no. of e^+ free e^- present in an area of semiconductor depends upon how many e^- are being generated & how many are again recombining.

→ ∴ two equal area of semiconductor may not have same no. of e^-s.

∴ ~~th~~ e^- concentration is different in this areas. & there exists a concentration gradient.

→ Due to this the e^-s move from high concentration to low concentration.

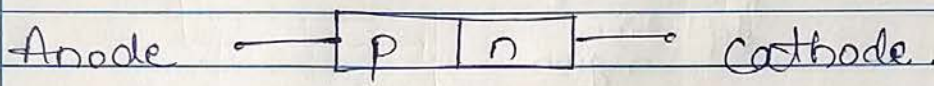
→ this movement of e^- is called as Diffusion. and current due to diffusion is called as diffusion current.

→ $\boxed{\text{Total current density} = \text{drift current} + \text{diffusion current}}$

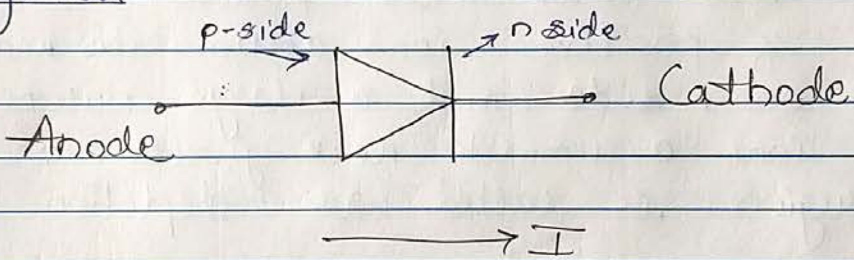
* P-n junction diode.

→ diode → means having "two electrodes"

p-n junction itself forms the most basic semiconductor device called semiconductor diode.



Symbol :-

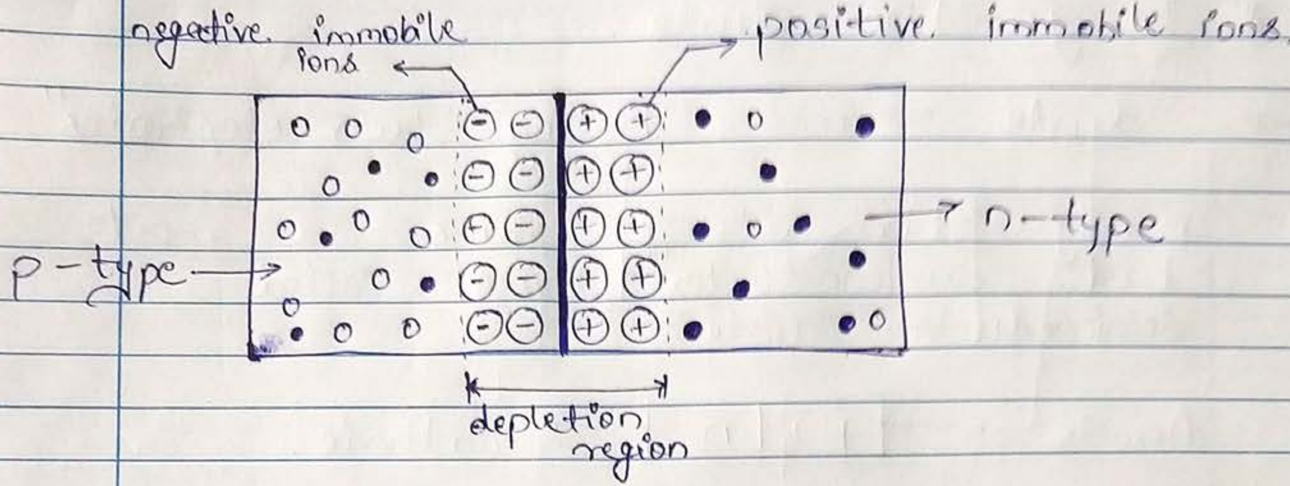


* Depletion Region

→ the free e^- from n side will diffuse into the p side & recombine with the holes present there.

→ each e^- diffusing into p side will leave behind a positive immobile ion on the n side

→ a negative immobile ion is formed when an e^- combines with a hole on p side.



→ due to this recombination process, a large number of positive ions accumulate near the junction on n side and a large number of negative ions accumulate near junction on p side. this region is called as depletion region.

→ due to the presence of immobile positive & negative ions on opposite side of junction. an electric field is created across the jn. this electric field is known as "barrier potential" or "junction potential" or cut in voltage.

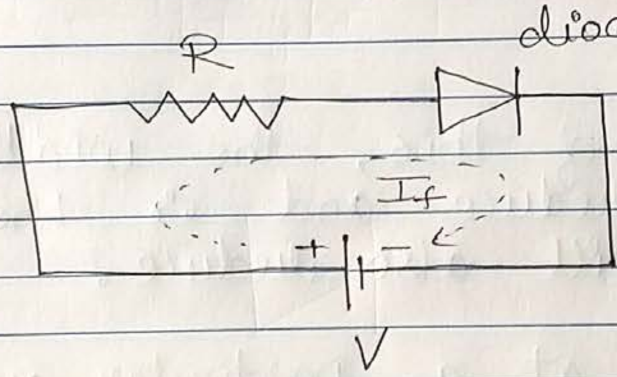
Barrier potential for

$$\boxed{\begin{array}{c}\text{Silicon} \rightarrow 0.6\,V \\ \text{Germanium} \rightarrow 0.2\,V\end{array}}$$

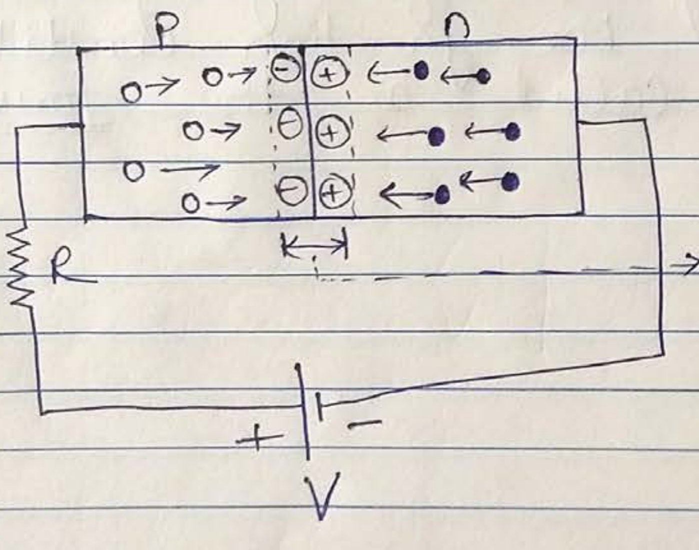
Biasing the pn junction

Biasing
- forward biasing
- Reverse biasing.

Forward bias.



→ when p-side is connected to +ve terminal of source & n-side is connected to -ve terminal of source then the diode is said to be forward bias.



Current limiting Resistance

width of depletion region decreases.

→ Due to the negative terminal of source the free e^- from n-side are pushed towards p-side and e^- starts converting the +ve immobile ions into neutral atoms.

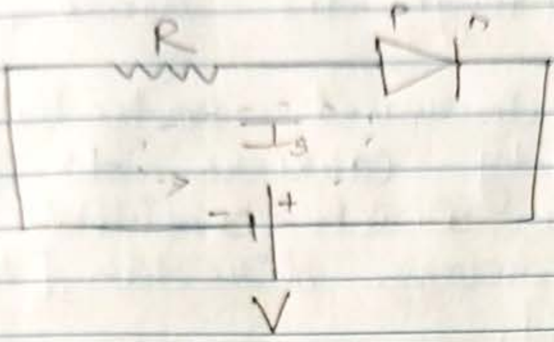
→ Similarly, due to +ve terminal of source the holes from p-side are pushed towards n-side and holes starts converting the -ve immobile ions into neutral atoms.

→ As a result of this, the width of depletion region will reduce and ∴ the barrier potential will also reduce.

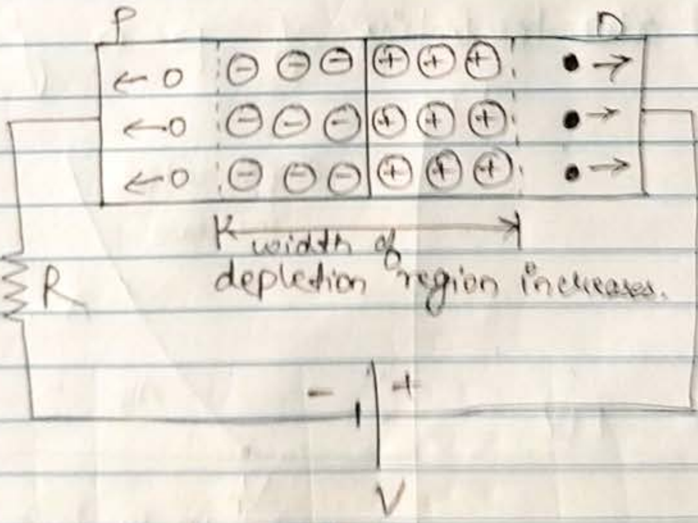
→ Eventually, at a particular value of voltage the depletion region will collapse and large no. of. e^- & holes can cross the junction.

→ The large no. of majority carriers crossing the junction constitute a current called as the forward current (I_F)

Reverse biasing



→ when p-side of is connected to −ve terminal & n side is connected to +ve terminal of source then the diode is said to be reverse biased.



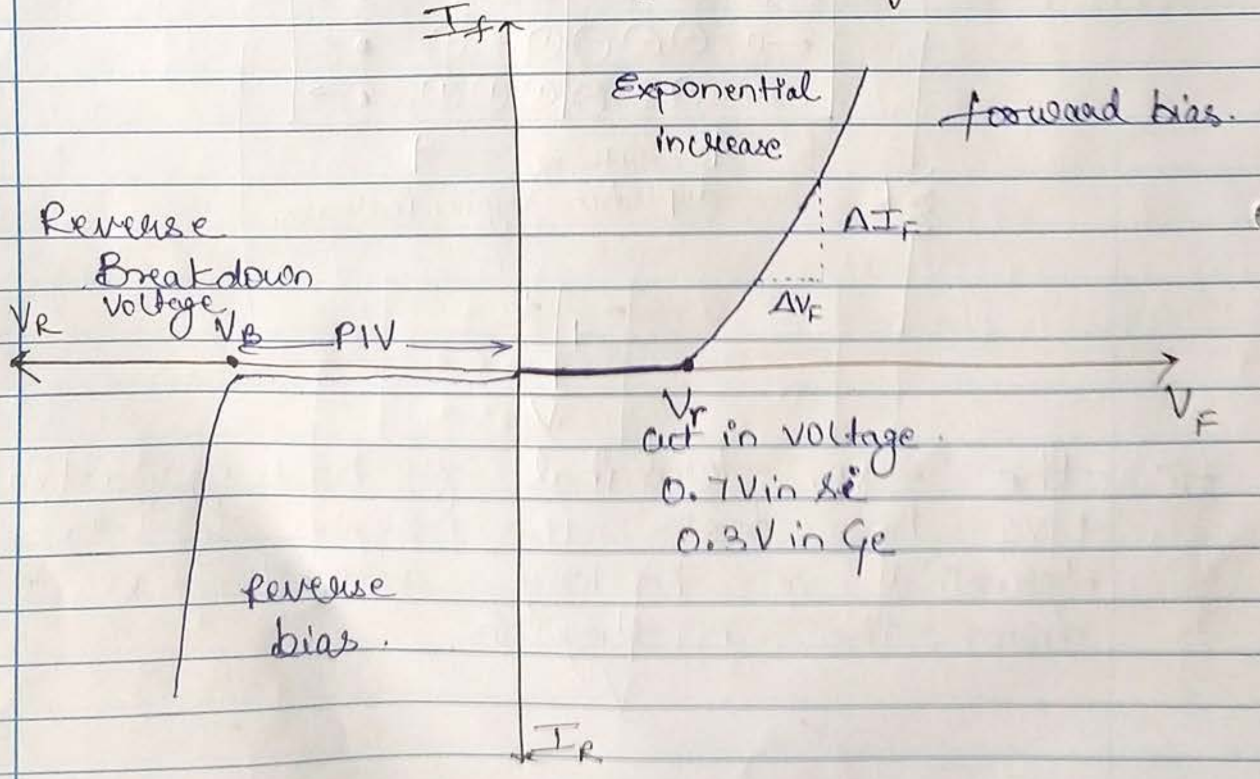
→ the −ve terminal of battery attracts +ve holes from the p region & +ve terminal of battery attracts −ve e^- from the n region.

→ this increases width of depletion region because of which current cannot flow through the diode.

→ But the increased potential barrier helps minority carriers to cross the junction which consititute a small current in reverse direction. [few μA for Ge and nA for Si].

→ this current is called as reverse saturation current which flows due to minority charge carriers.

* V-I Characteristics of p-n junction diode



→ the dyamic forward bias resistance of diode is given by,

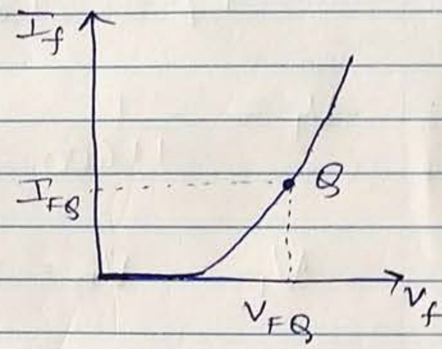
$$R_f = \frac{\Delta V_f}{\Delta I_f} \ \Omega$$

→ PIV :- Peak inverse Voltage is maximum reverse bias voltage the diode can withstand without breakdown.

→ Static resistance of diode,

$$R = \frac{V_{FQ}}{I_{FQ}}$$

Q → Quiescent point or fixed dc point



* Diode Current Equation.

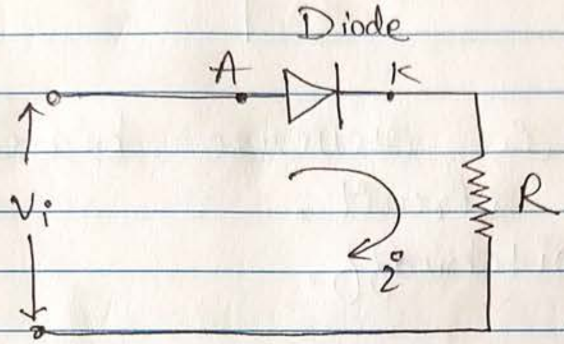
$$\boxed{I_F = I_0 \left(e^{V_f/\eta V_T} - 1 \right)}$$

I_f ⇒ forward bias current
I_0 ⇒ Reverse saturation current
V_f ⇒ forward bias voltage
η ⇒ 2 for Si
1 for Ge.

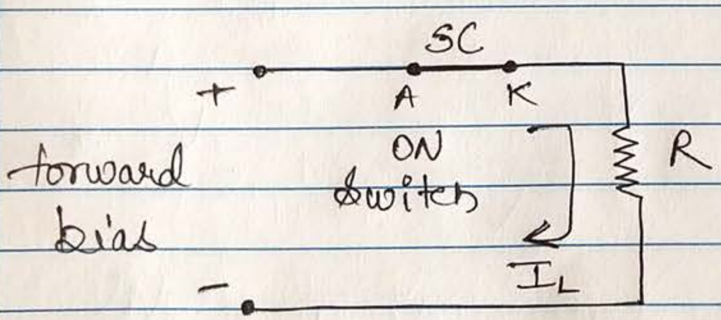
* Diode as switch

→ Diode is unidirectional device i.e. it allows the current to flow only in one direction when it is forward biased.

→ Due to this property it can be used as switch.

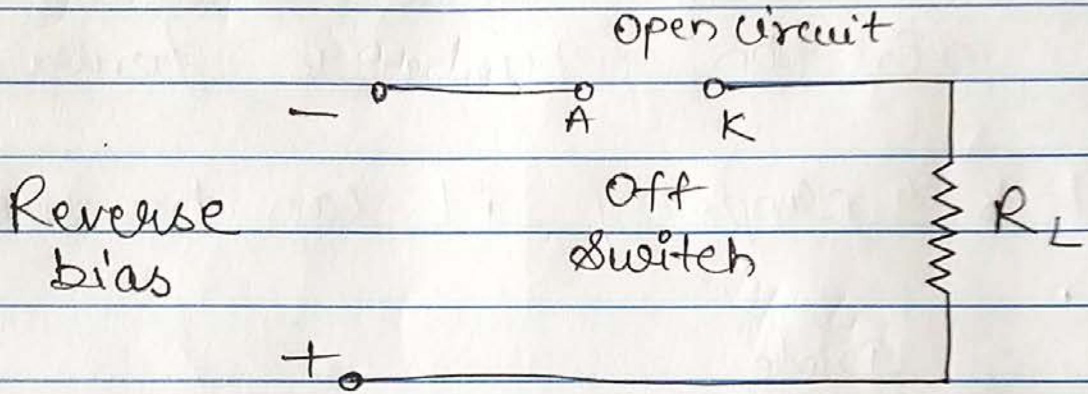


(i) When diode is forward bias.



→ When the ideal diode is forward biased, it acts as short circuit. Hence the switch is ON.

(ii) when diode is Reverse biased.

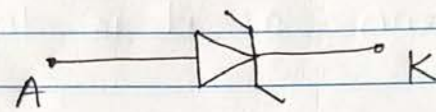


→ when diode is reverse biased it acts as open circuit.
Therefore act as switch is off.

Special purpose diodes.

i] Zener diode. & Working

Symbol



→ it is a special purpose diode which is used in reverse biased condition.

→ when forward bias it behave as ordinary diode.

→ But when used in reverse bias, after breakdown voltage it goes into breakdown region where voltage across the diode remains almost constant

→ A Zener diode is heavily doped to reduce the breakdown voltage.

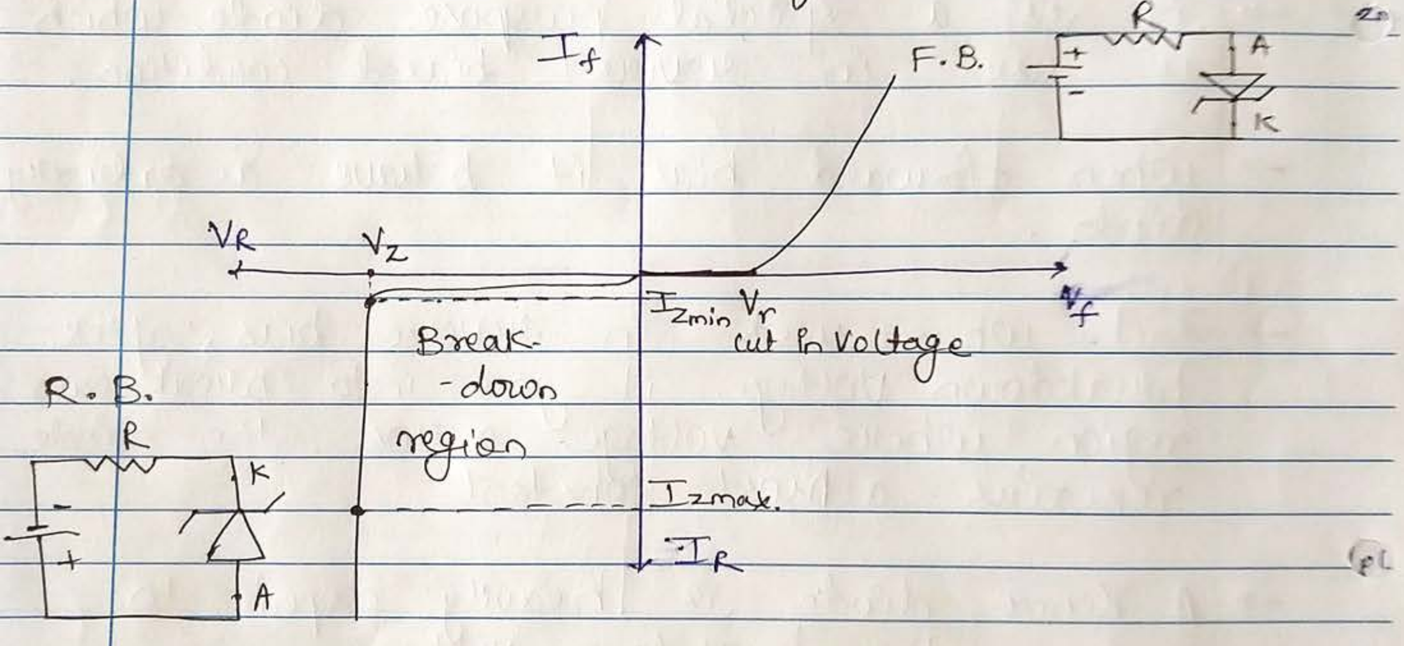
→ ∴ width of depletion region is small
∴ Electric field with depletion region is high (as $E = \frac{V}{d}$)

⇒ the high density Electric field causes direct breaking of bonds at particular reverse bias voltage, hence large reverse current flows. It is <u>zener breakdown.</u>

→ Zener breakdown voltage is less than 6 V
[also called Zener Voltage V_z)

→ Zener diode can be reused again after zener breakdown as it is temporary.

* V-I characteristics of Zener diode.



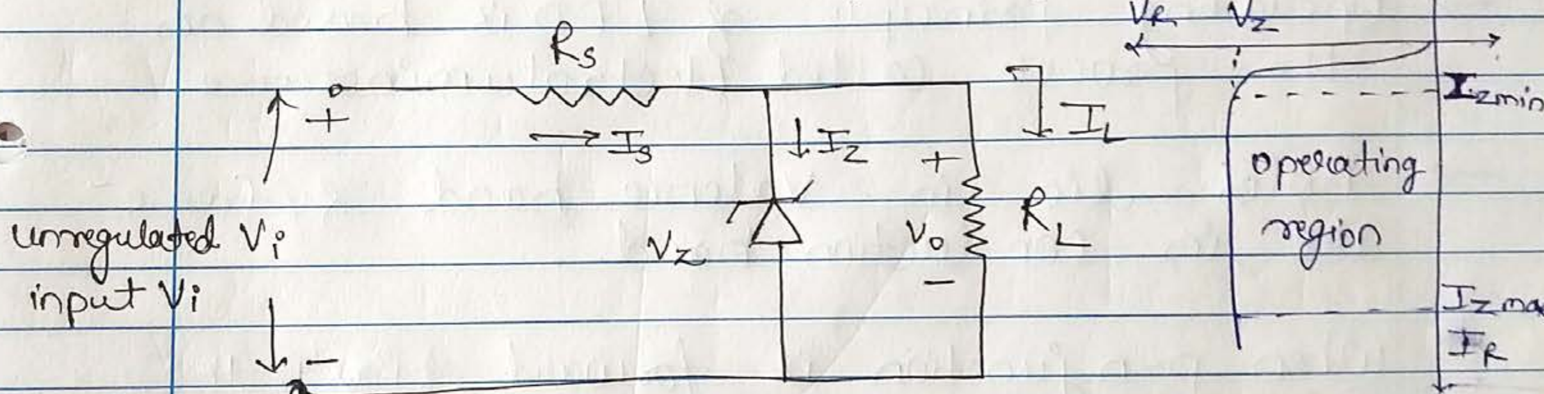
- I_{zmin} ⇒ It is minimum diode current at which diode enters in breakdown region.

- I_{zmax} ⇒ It is maximum zener diode current the diode can withstand without breakdown

- r_z ⇒ dynamic resistance $= \frac{\Delta V_z}{I_z}$

\# Application of Zener diode
→ In regulated power supply
→ In wave shaping circuits.
→ as shunt voltage regulator
→ protection circuit for MOSFET and OP-Amp.

– Zener diode as Voltage regulator.



→ When zener diode operates in breakdown region, the voltage across the diode remains constant even if there is change in current.
→ ∴ Zenear diode is connected in parallel with the load to stablize the o/p voltage.

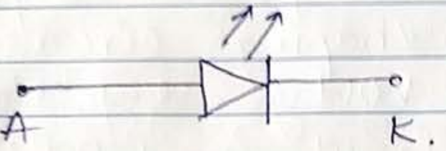
R_S → Current limiting Resistance.
R_L → Load resistance.

$$V_0 = V_Z = V_i - I_S . R_S$$

$$I_S = I_Z + I_L$$

* Light Emitting diode (LED)

Symbol:-



Principle of Operation

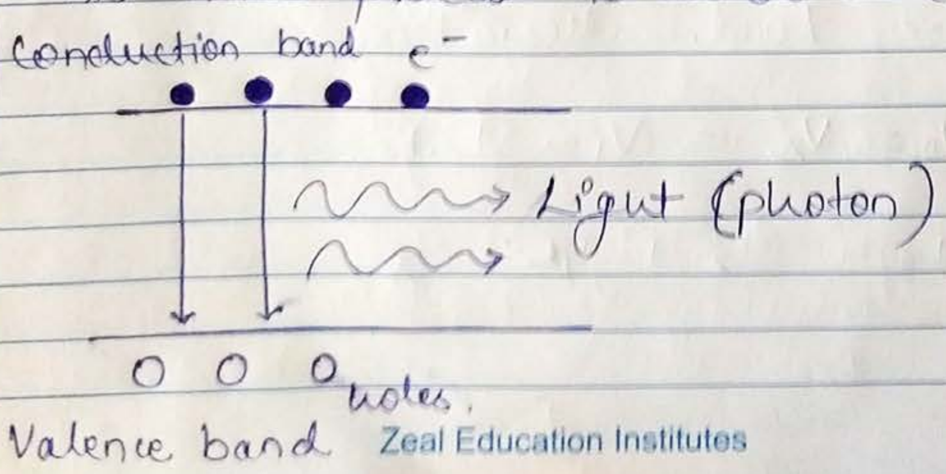
→ Operating principle of LED is based on the process called Electroluminescence.

→ holes lie in Valence band & free e^- are in conduction band.

→ When p-n junction is forward bias, the e^- from n side are diffused in p-side where e^- recombine with holes.

→ the movement of e^- takes place from higher energy level to lower energy level ∴ there is a release of energy in the form of light due to this movement.

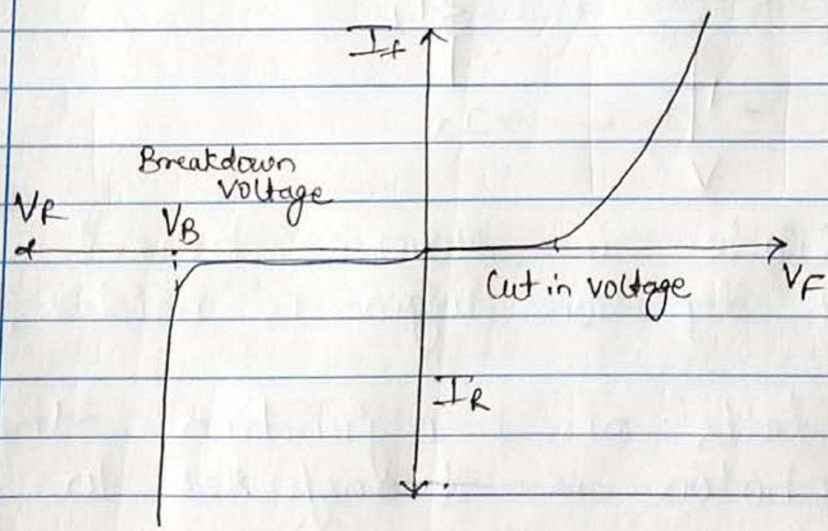
→ this entire process is called Electroluminescence.

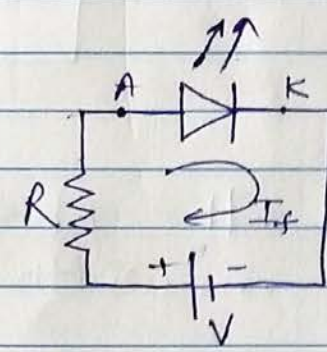


Colour of Emitted light

Material Used	Colour of emitted light
Gallium Arsenic (GaAs)	Infra-red
Gallium phosphide (GaP)	Green
Silicon Carbide	Yellow
GaAsP	Red

V-I characteristics of LED



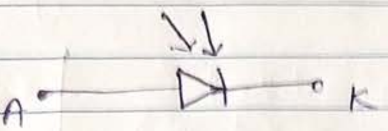


Application

→ decorative lights
→ alpha numerical display in digital intruments.
→ traffic light
→ Seven segment LED display.
→ as indicators of various alarm.

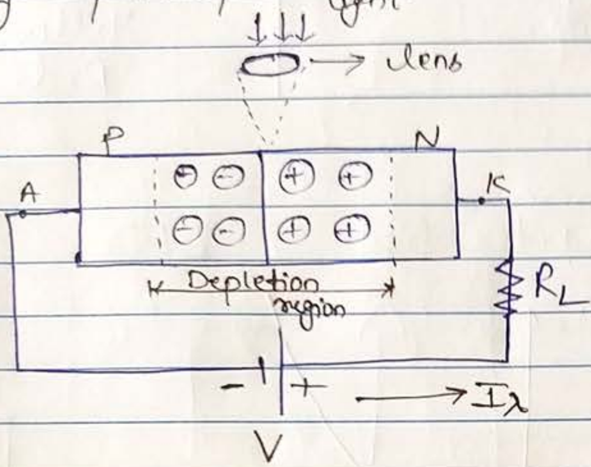
* Photodiode.

→ Symbol



Working principle:-

→



→ The photodiode is reverse biased
∴ width of depletion region is wider.

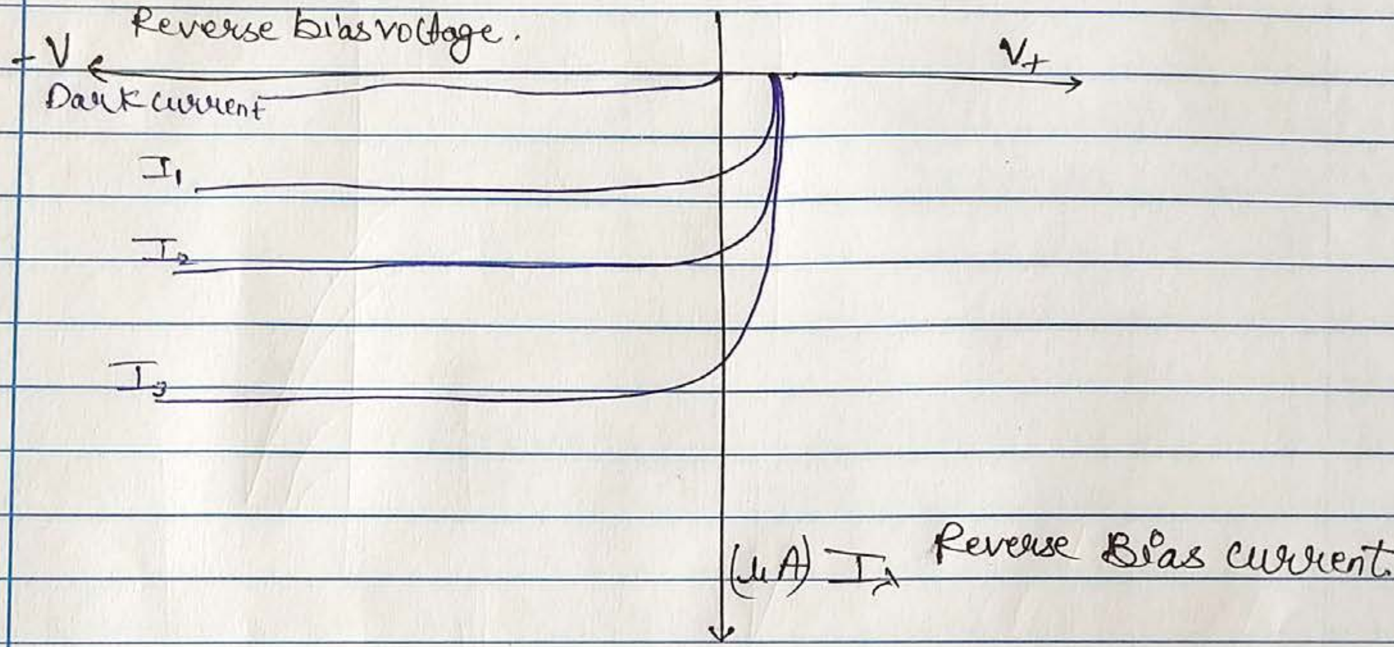
→ When light falls on p-n junction, the energy of photon is transferred to the junction.

→ Due to this bonds are broken in depletion region & electron hole pairs are generated.

→ In the depletion region on p-type, electrons are generated which are minority carrier on p-side. They travel to positive terminal of reverse bias voltage and gives reverse bias current. (I_λ)

→ As intensity of light increases, more e^--hole pair are generated & reverse current also increases.

V-I characteristics of Photodiode.



- Dark current

→ It is the current in photo-diode when there is no light.

→ It is due to thermally generated minority carriers.

Application

→ photo-relay circuit

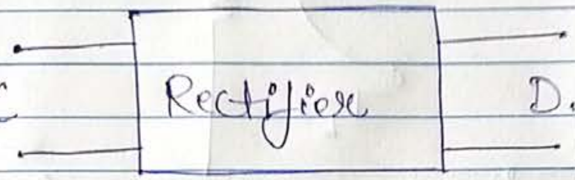
→ optical communication

→ light intensity meter

→ Burglar alarms.

* Rectifiers

→ Rectifier is an electronic device which convert AC into DC voltage or current.



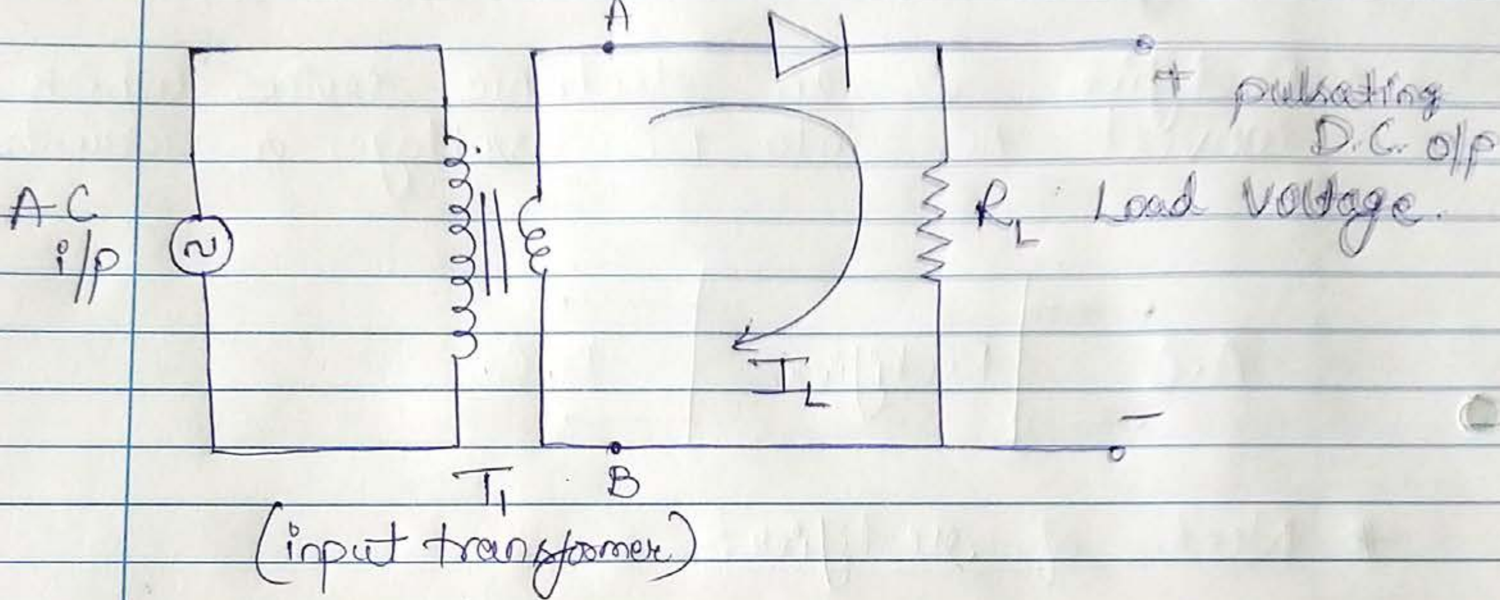
* Need of rectifier :-

- Every electronic circuit requires a dc power source for its operation
- DC supply is obtained from AC supply.
- ∴ it is needed to convert available AC supply into DC supply.

* Rectifier

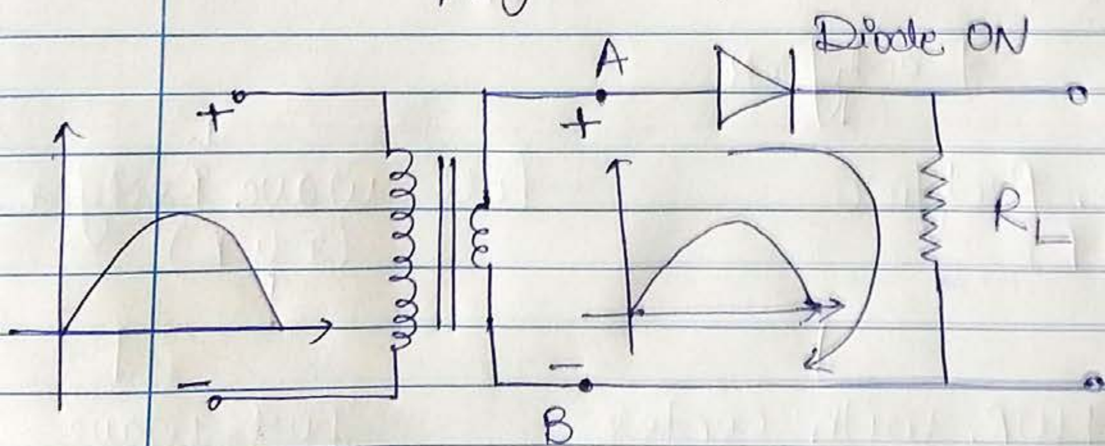
- Half wave Rectifier (HWR)
- Full wave Rectifier (FWR)
  - FWR with center tapped transformer
  - Full wave bridge rectifier

* Half wave rectifier



→ In half wave rectifier, the rectifier is ON only during one half cycle of the AC supply.

* Operation in positive half cycle of AC supply [0 − π]



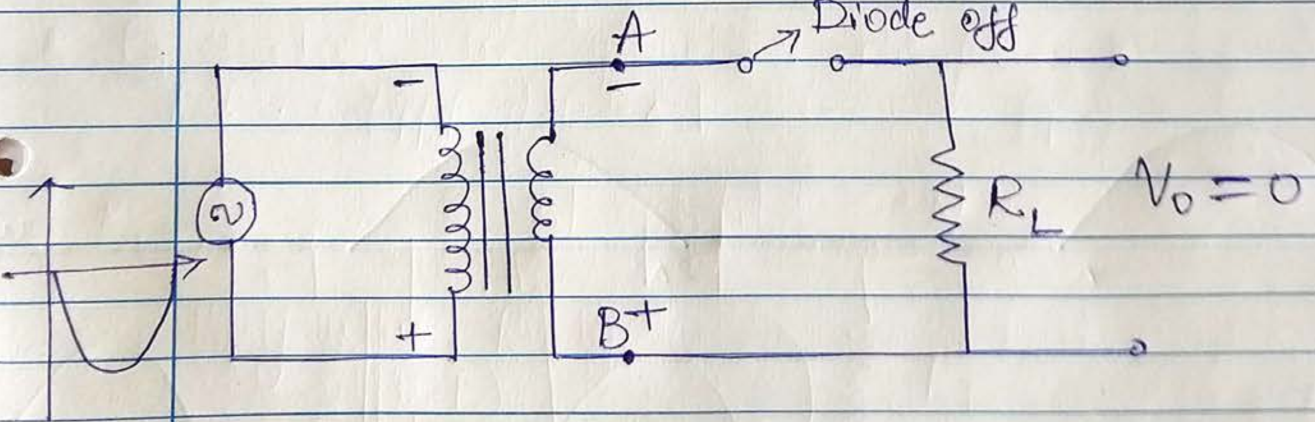
→ In positive half cycle of AC supply $(0-\pi)$, the secondary voltage V_{AB} is positive i.e. A is positive with respect to B.

→ ∴ the Diode is forward biased & starts conducting.

→ ∴ the secondary voltage V_{AB} appears almost as it is across the load resistance (R_L)

→ ∴ load voltage is positive.

* Operation in negative half cycle of AC supply $(\pi$ to $2\pi)$.

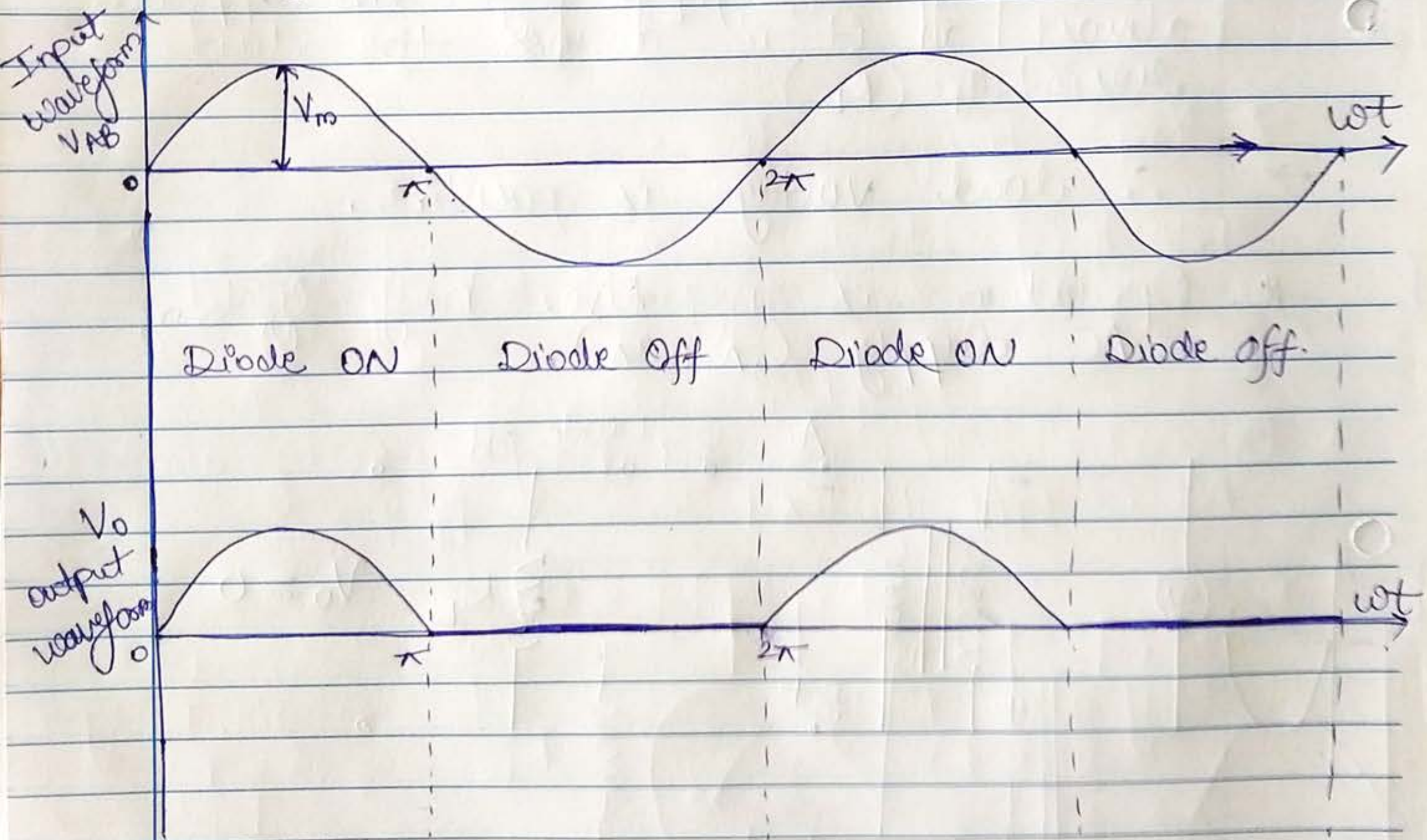


→ In negative half cycle, secondary voltage V_{AB} is negative, i.e. A is negative with respect to B.

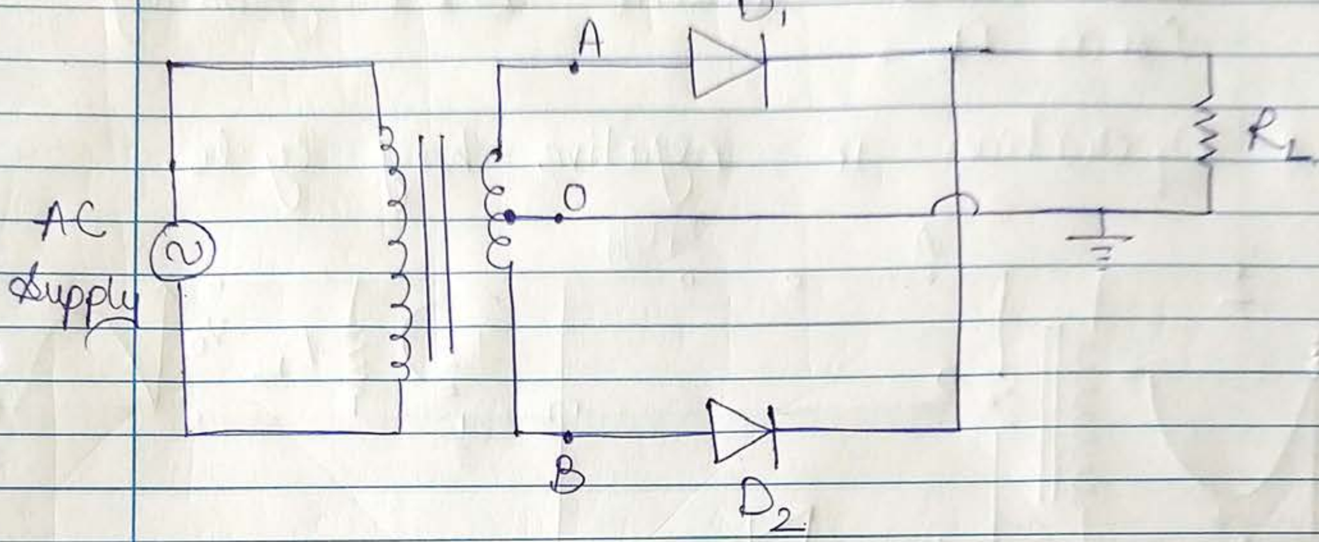
→ ∴ The diode is reverse biased & it behaves like off switch (very high resistance).

→ ∴ load voltage & load current both are zero.

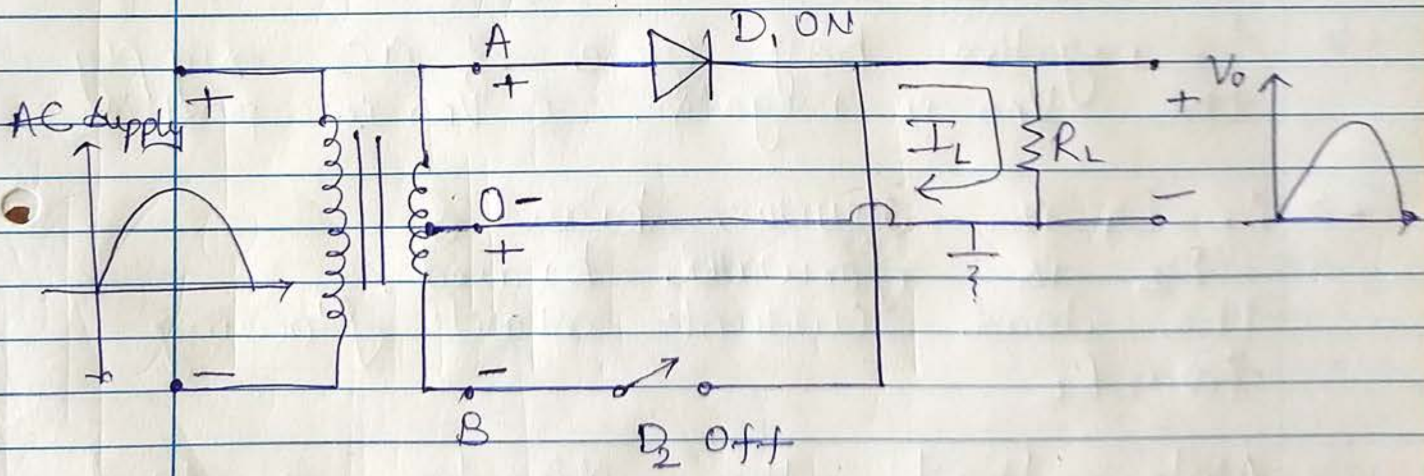
Waveforms



* full wave rectifier with center tapped transformer.



* Operation in positive half cycle.



→ In positive half cycle, V_{AO} is positive & V_{BO} is negative, due to center tapped transformer [V_{AO} & V_{BO} are equal & opposite to each other].

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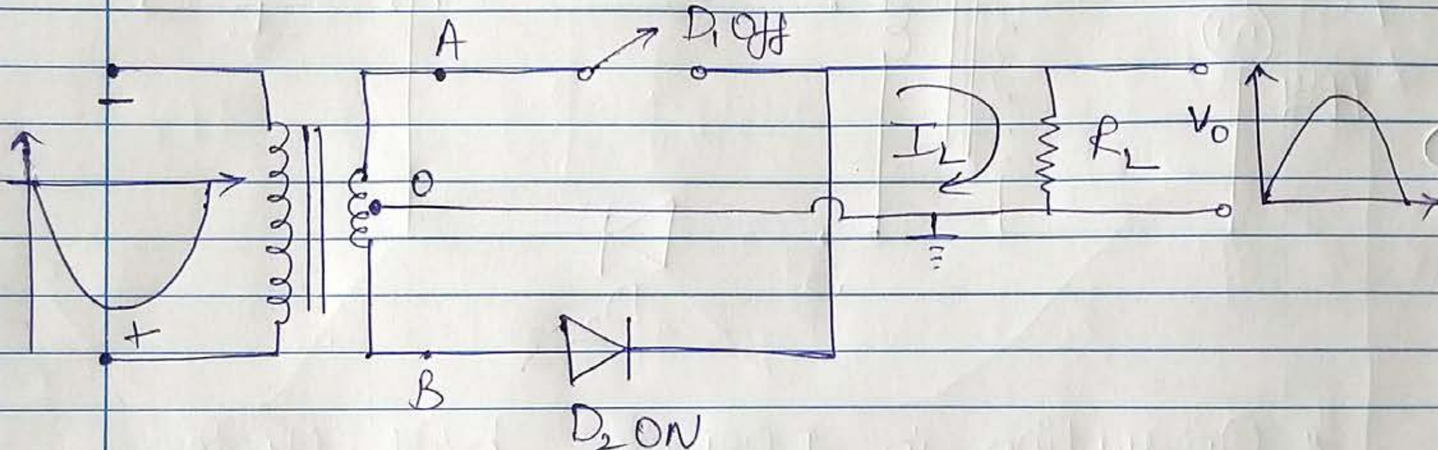
→ ∴ Diode D_1 is forward biased & Diode D_2 is reverse biased. The load current start flowing from R_L.

Operation in negative half cycle.

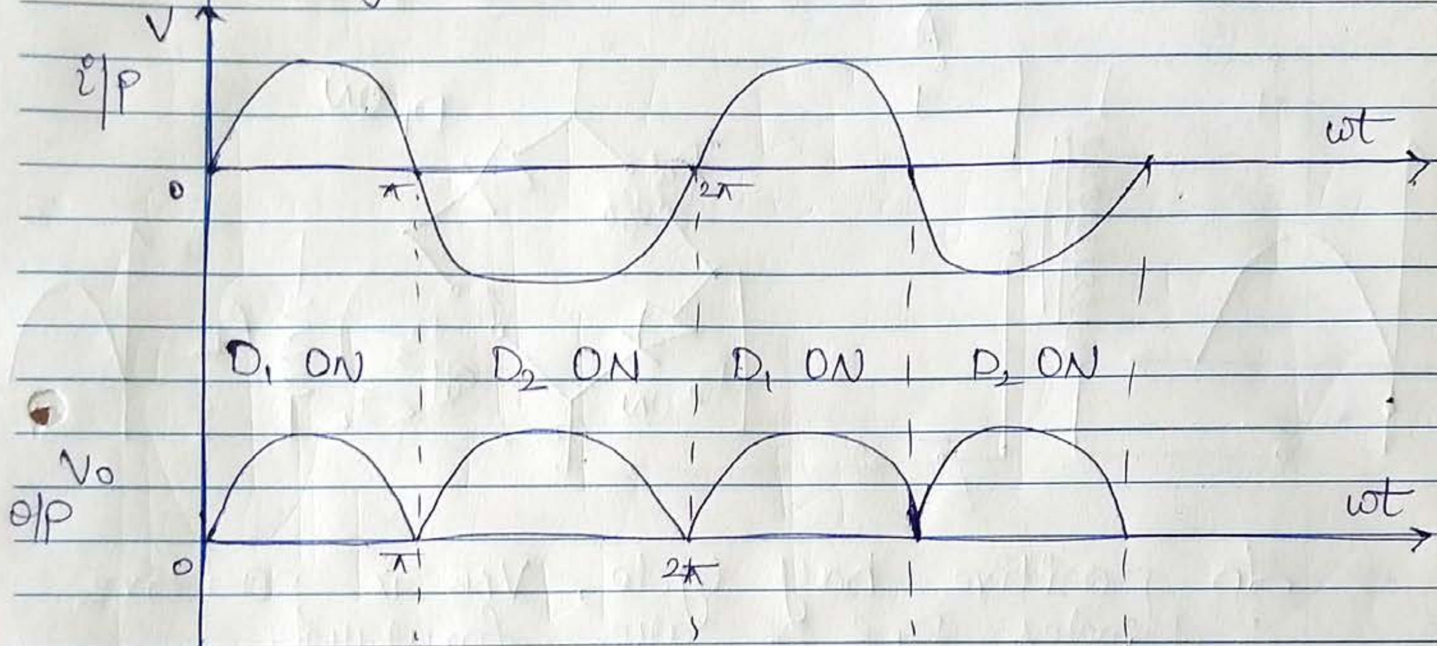


→ In negative half cycle of ac supply the V_{AO} is negative & V_{BO} is positive

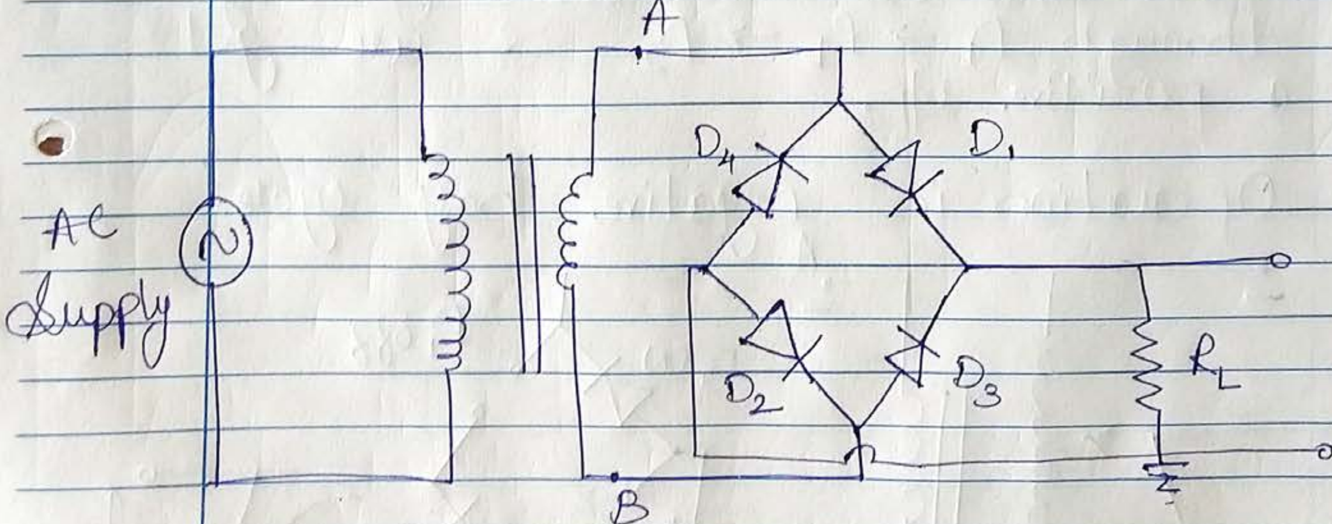
→ ∴ D_1 is reverse biased & D_2 is forward biased. The load current start flowing from R_L

→ Note that the direction of load current I_L is same as that in positive half cycle.
∴ load current continues to be positive.

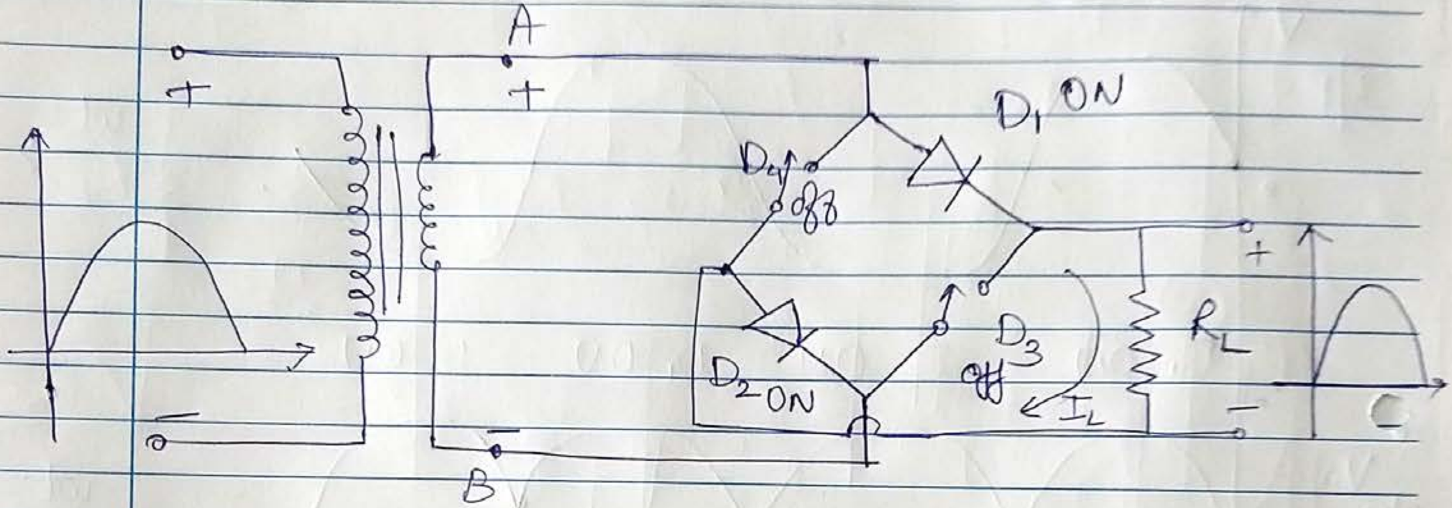
* Waveform of FWR



* Full wave Bridge Rectifier.



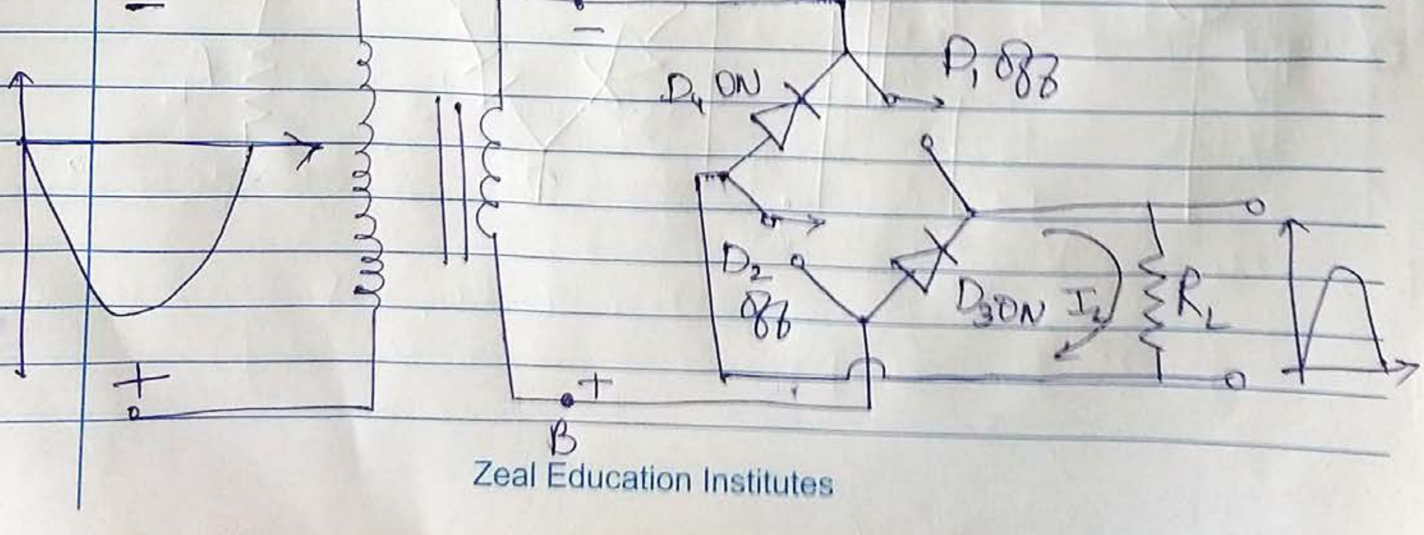
* Operation in positive half cycle.



→ In positive half cycle, V_{AB} is positive
∴ Diodes D_1 & D_2 are forward biased & D_3 & D_4 are reverse biased.

→ ∴ the load current starts flowing through $D_1 \rightarrow R_L \rightarrow D_2$ & we get a positive o/p.

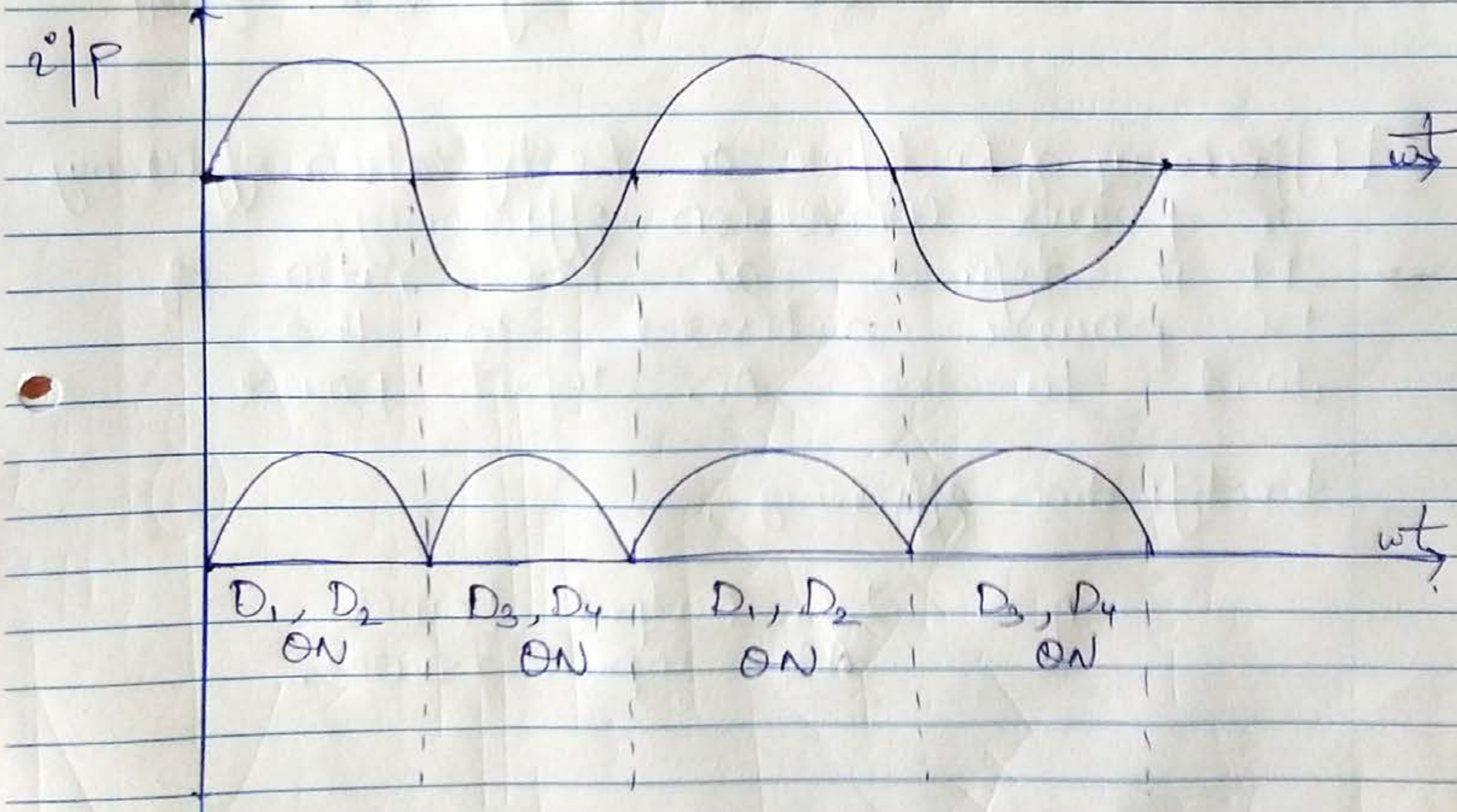
* Operation in negative half cycle.



→ In the negative half cycle V_{AB} is negative ∴ Diodes D_1 & D_2 are reverse biased & D_3, D_4 are forward biased.

→ The load current starts flowing through $D_3 \rightarrow R_L \rightarrow D_4$, the load current has same direction as in positive half cycle.
∴ it remains positive.

* Waveform of Bridge Rectifier



* Important parameters.

1] Ripple factor (RF)

→ the rectifier o/p consist of AC as well as DC components.

→ the ripple factor measures percentage of AC component in the rectifier output.

$$\text{Ripple factor} = \frac{\text{RMS value of AC component of o/p}}{\text{DC or average value of o/p}}$$

2] Efficiency of Rectifier or Rectification efficiency or power conversion efficiency.

→ It is defined as the ratio of DC power delivered to the load to the AC input power.

Rectification efficiency,

$$\eta = \frac{\text{DC output Power}}{\text{AC input power}}$$

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3] Transformer Utilization factor (TUF)

→ TUF indicates how well the i/p transformer is being utilized.

→ It is defined as the ratio of dc output power to the AC power rating of the transformer.

$$TUF = \frac{\text{DC output Power}}{\text{AC power rating of transformer}}$$

4] Peak Inverse voltage (PIV)

→ PIV is the maximum negative voltage which appears across a non-conducting reverse biased diode.

5] Ripple frequency.

→ It is the frequency of the pulsating load voltage waveform.

Parameter	HWR	FWR centre tapped	FW Bridge Rect.
1] $I_L dc$ DC or avg. load current	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
2) $V_L dc$ max. avg. load voltage	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$	$\frac{2V_m}{\pi}$
3] $I_L rms$ RMS load current	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
4] $V_L rms$ RMS load voltage	$\frac{V_m}{2}$	$\frac{V_m}{\sqrt{2}}$	$\frac{V_m}{\sqrt{2}}$
5] Pdc DC load power	$\frac{I_m^2}{\pi^2} R_L$	$\frac{4 I_m^2 R_L}{\pi^2}$	$\frac{4 I_m^2 R_L}{\pi^2}$
6] Rectification efficiency(η)	40%	81.2%	81.2%
7] TUF	28.7%	69.3%	81.2%
9] Ripple factor	121%	48%	48%

Ripple frequency	f_r 50 Hz	$2f_r$ 100 Hz	$2f_r$ 100 Hz
No. of diodes used	1	2	4
) PIV	V_m	$2V_m$	V_m
peak load current	$I_m = \frac{V_m}{(R_s + R_F + R_L)}$	$I_m = \frac{V_m}{(R_s + R_F + R_L)}$	$I_m = \frac{V_m}{(R_s + 2R_F + R_L)}$

* Advantages, Disadvantages & Application of Rectifier

ctifier	Advantages	Disadvantages	Application
R.	1.] Simple constr-uction. 2.] Small size 3.] Requires less no. of components.	1.] high Ripplefactor 2.] low rectification efficiency. 3.] low TUF 4.] low DC o/p voltage & current 5.] Larger filter components are required	1.] used in the eliminators for pocket radios. 2.] eliminators for walkman 3.] low cost power supplies.
R. ter ped	1.] Better recti-fication efficiency 2.] Better TUF 3.] low ripple factor as comp-ared to HWR	1.] Cost of center tapped transformer is high. 2.] Size of diodes are larger & they are costly.	1.] high current power supplies. 2.] Laboratory power supplies 3.] Battery Chargers. 4.] power supplie for various

Bridge Rectifier	1.] high Rectification efficiency. 2.] high TUF 3.] requires small size transformer. 4.] high averge output voltage	1.] no. of diodes used is 4 instead of 2 for FWR 2.] As two diodes conduct simul--taneously, the voltage drop ↑ & o/p voltage ↓	1.] Batter[illegible] charge[illegible] 2.] DC pow[illegible] supplies f[illegible] various ele[illegible] circuit. 3.] laborat[illegible] dc power supplies. 4.] high cur[illegible] power supp[illegible]