B.Sc (Engg.), Part-1, Odd Semester Exam-2018

2. a) Define conductor, semiconductor and insulator in terms of energy band diagram.

Conductor: The electrical materials which have overlapping valence and conduction bands are called conductor. The forbidden band is absent i.e F.B=0
For example: Fe, Cu, Ag etc.

Semi-conductor: Materials which have almost an empty conduction band and almost filled valence band with a very narrow energy gap (of the order of 1 eV) separating the two.

Insulator: The element with large energy gap between conduction & valance band (of several eV) are insulators.

b) Discuss the formation process of P-type and N-type extrinsic semiconductor with proper diagram.

Ans: When a tetravalent intrinsic material (Si, C, Ge, Sn, Pb) gets doped by trivalent elements like Al, B, Ga, etc and form p-type extrinsic semi-conductor.

If we add Al to Si then the following diagram is got,

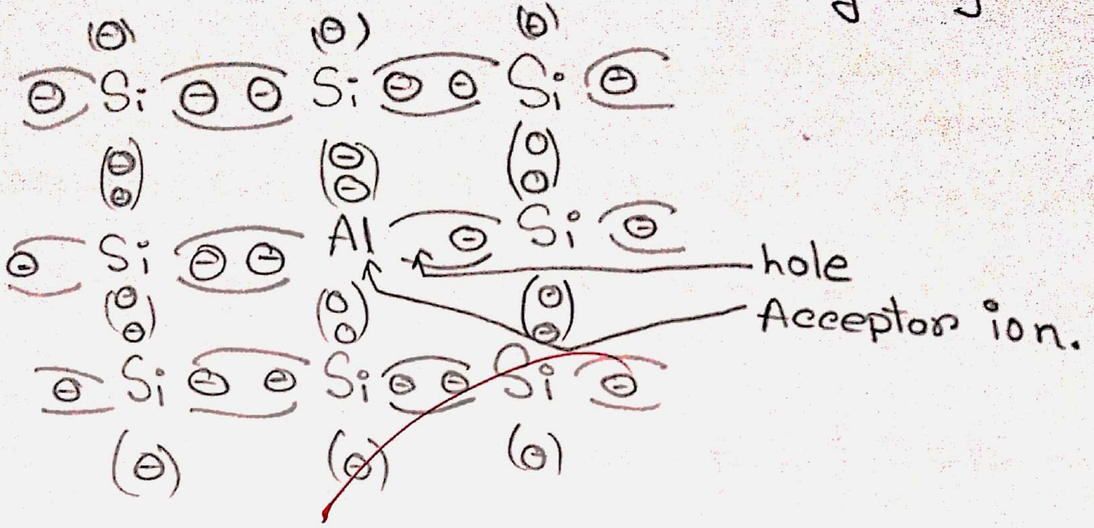


Figure: P-type extrinsic material.

N-type extrinsic semi-conductor: When a tetravalent intrinsic material (Si, C, Ge, etc) gets mixed with pentavalent ~~in~~ elements like P, As, Sb etc and form n-type extrinsic semi-conductor.

If we add P to Si then the following diagram is found.

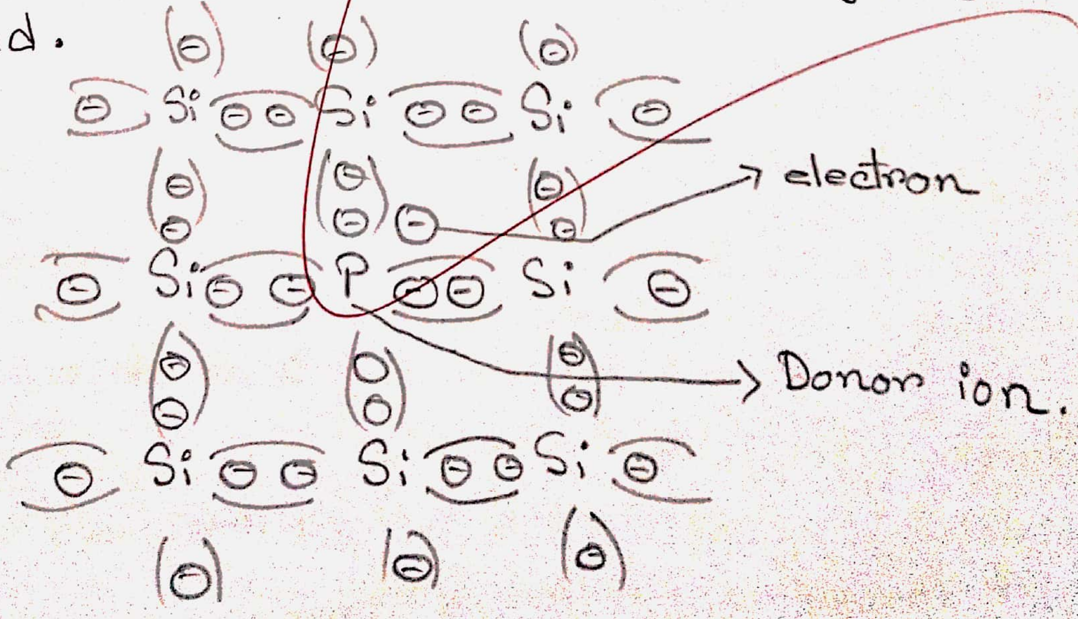


Figure: N-type extrinsic material.

3.(a) What is a PN junction diode? Show the V-I characteristics of a PN junction diode.

Ans: When a p-type (trivalent) element added with n-type (pentavalent) element then the junction formed is pn junction diode.

The V-I characteristics of a PN-junction diode is ~~discu~~ stated below-

During forward-bias:

1. The positive end of the voltage creator with p-type material and negative-potential to n-type material. The ~~en~~ junction of p-n at the middle has depletion layer.
2. As the junction resistance is very low, pressure is ~~tat~~ created by potential creator current will gradually flow. As a result depletion layer decreases slowly.
3. The voltage at which short circuit occurs allowing full current to flow is knee voltage.

During reverse-bias:

1. The junction resistance is very high & no-current initially flow through the circuit.
2. However, small current of uA, flow through the circuit. ~~Da~~ Due to minority carriers in junction.

3) If applied reverse voltage is increased continuously, the kinetic energy of the minority carries may become high enough to knock out e⁻ from semiconductor atom.

4) The voltage is then called zenor voltage and at this stage breakdown of junction may occur. The sudden increase of reverse current and a sudden fall of resistance of barrier region.

So, these are the characteristics of V-I flow of a PN junction diode.

b) Differentiate between Zener breakdown & avalanche breakdown.

Zener breakdown: The maximum reverse-bias potential that causes breakdown of zenor voltage is called Zenor breakdown.

Avalanche breakdown: During forward bias due to the major carrier the level of current suddenly or sharply increase then this phenomenon is called --- —

6 (a) What are the classification of circuit components? Define active and passive components.

Ans: Circuit components are classified into two catagory

① Active Component: Those devices or component which require external source to their operation. examples are: Diode, transistor etc.

② Passive Components: Those devices or component which ~~re~~ does not require external source to their operation. examples are: Resistor, capacitor, inductor etc.

b) State and explain Kirchhoff's Current law.

Ans: Kirchhoff's Current law (KCL): The algebric sum of the current meeting at a junction in an electrical circuit is always Zero.

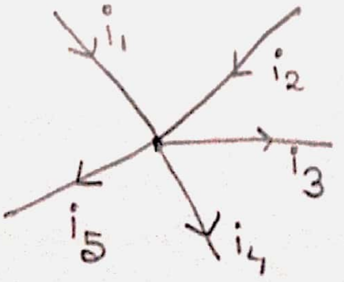


Figure: Current entering and exiting a node.

Here,

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

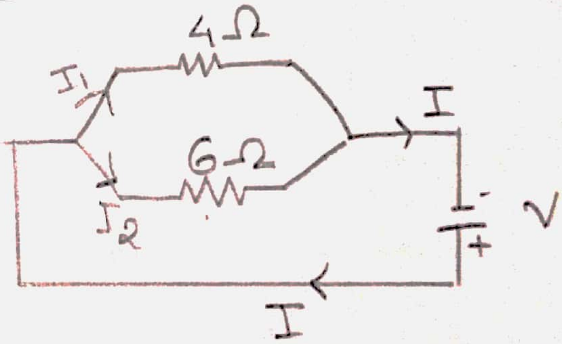
$$i_1 + i_2 = i_3 + i_4 + i_5$$

c) Write the current division formula when only 2 resistance is connected in parallel, 2 resistor of 4Ω and 6Ω are connected in parallel, If the total current is 30A, find individual current throughout each resistor.

Ans: Current division formula for 2 parallel resistance:

$$I_1 = \frac{R_2}{R_1+R_2} \times I \quad , \quad I_2 = \frac{R_1}{R_1+R_2} \times I.$$

The circuit diagram for the calculation:



$$I_1 = \frac{R_2}{R_1+R_2} \times I$$

$$= \frac{6}{10} \times 30$$

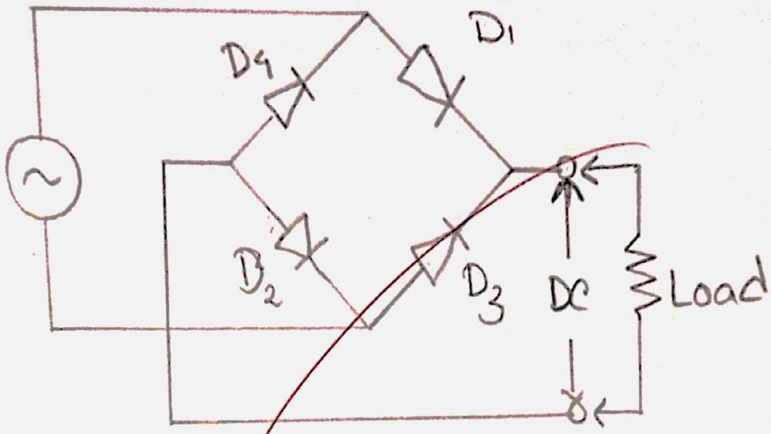
$$= 18 \text{ A}.$$

Similarly, $I_2 = \frac{R_1}{R_1+R_2} \times I = \frac{4}{10} \times 30 = 12 \text{ A}.$

8. a) What is rectifier? Show the circuit diagram of a full wave rectifier.

Ans: The process of converting AC to DC is called rectification and the instrument is called rectifier.

The circuit diagram of a full wave rectifier is given below:



b) Define voltage regulation (VR) and Peak Inverse Voltage (PIV).

Voltage regulation (VR): The percentage of voltage difference between no load and full load voltage of a transformer with respect to it's full load voltage. $V_R = \frac{V_{nl} - V_{fl}}{V_{fl}} \times 100\%$.

Peak Inverse Voltage (PIV): The maximum voltage that a diode or other device can withstand in the reverse-biased direction before breakdown. It is also known as Reverse Breakdown voltage.

"keywords"

*The three semiconductors used ~~mostly~~ frequently in the construction of electronic devices are Ge; Si and ~~GaS~~ GaAs.

Covalent bonding and intrinsic materials

The bonding of atoms of a pure tetravalent element (Si or Ga) crystal lattice ~~by~~ strengthened by sharing of electrons; is called covalent bonding. The pure ~~cy~~ crystal is known as intrinsic material.

*The term intrinsic is applied to any semiconductor material that has been carefully refined to reduce the number of impurities to a very low level- essentially as pure as can be made available through modern technology.

*Semiconductor materials have a negative temperature co-efficient.

*The farther an e^- is from the nucleus, the higher is the energy state, and any electron that has left it's parent atom has a higher energy state than any ~~ene~~ e^- in every shell.

*An electron in the valence band of silicon must absorb more energy than one in the valence band of germanium to become a free carrier. Similary, an electron in the valence band of gallium arsenide must gain more energy than one in silicon or germanium to enter conduction band.

$E_g = 0.67 eV$ (Ge), $E_g = 1.1 eV$ (Si), $E_g = 1.43 eV$ (GaAs).

Extrinsic materials: n-type and p-type materials

* A semiconductor material that has been subjected to the doping process is called an extrinsic material.

N-type material

*Diffused impurity with five valence electron are called donor atom.

* P-type material *

* The diffused impurities with three valence electron are called acceptor atoms.

* Electron versus hole flow *

*A valence e^- acquiring sufficient E_k breaks through it's covalent bond as free e^-. Then such e^- creates hole which are later on filled by them and the cycle continues.

* Majority & Minority Carriers *

* In an n-type the e^- is called majority and the hole is called minority carrier.

* In an p-type the hole is called majority and th e^- is called minority carrier.

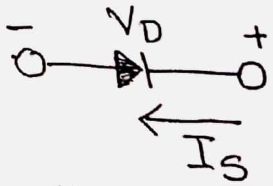
* Semi-Conductor diode *

* No Applied Bias ($V = 0V$) *

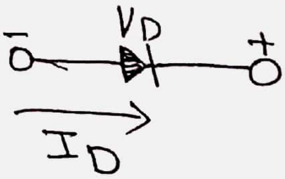
* The region of uncovered positive and negative ions is called the depletion region due to the "depletion" of free carrier in that region.

* In absence of an applied bias across a semi-conductor diode, the net flow of charge in one direction is zero.

* Reverse-Bias Condition ($V_D < 0\ V$)



* Forward bias Condition ($V_D > 0\ V$)



$$I_D = I_S\left(e^{V_D/nV_T} - 1\right)$$

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

k = Boltzmann's Constant $= 1.38 \times 10^{-23}\ J/K$

$q = 1.6 \times 10^{-19}\ C$

T = kelvin temp.

I_D = Current of diode.

I_S = Reverse saturated current

n = Ideality factor.

V_D = Applied forward bias voltage

V_T = Thermal Voltage

* The maximum reverse-bias potential that can be applied before entering the zener region is called peak inverse voltage, or peak reverse voltage.

Zener Region

* Knee voltage: where the voltage current increases very sharply.

$V_K = 0.3$ (Ge), $V_K = 0.7$ (Si), $V_K = 1.2$ (GaAs).

Temperatur effects

* In forward-bias region the characteristics of a silicon diode shifts to the left at a rate of 2.5 mV per Celcius degree increase in tempe-rature.

* In reverse-bias region of the reverse saturated current of a si diode doubles for every 10°C rise

* The reverse breakdown voltage of a semiconductor diode will increase or decrease with temperature depending on Zener potential.

Ideal versus Practical

* The semiconductor diode behaves in a manner similar to a mechanical switch in that it can control whether current will flow between two terminals.

*The semiconductor diode is different from a mechanical switch in the sense that when the switch is closed it will only permit current to flow in one direction.

*$R_F = \frac{V_D}{I_D} = \frac{0\,V}{5\,mA} = 0\,\Omega$ [Short-circuit equivalent]

*At any current level on the vertical line, the voltage across the ideal diode is 0V and the resistance is $0\,\Omega$.

*Because the current is 0 mA anywhere on the horizontal line, the resistance is $\infty\,\Omega$ at any point on the axis.

*Resistance level: Change of ~~et~~ resistance of diode due to non-linear shape of the characteristic curve.

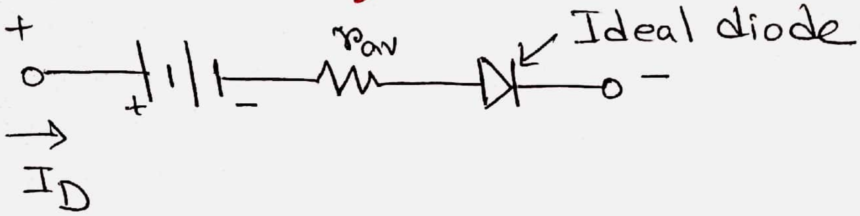
*DC or Static $R_D = \frac{V_D}{I_D}$

*AC or Dynamic $r_d = \frac{\Delta V_d}{\Delta I_d}$

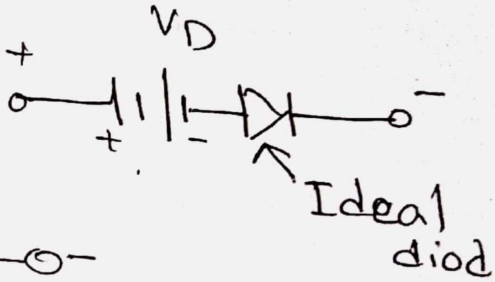
*The derivative of a func at a point is equal to the slope of the tangent line drawn at that point.

*$r_d = \frac{26\,mV}{I_D}$, $r_d' = \left(\frac{26\,mV}{I_D} + r_B\right)$ ohms.

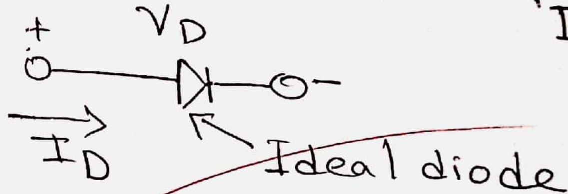
Diode equivalent Circuits:



*Simplified equivalent Circuit



*Ideal equivalent circuit



*Transistion and diffusion capacitance.

ϕ

*Reverse Recovery time. (RRT) : time required to stop conduction.

4

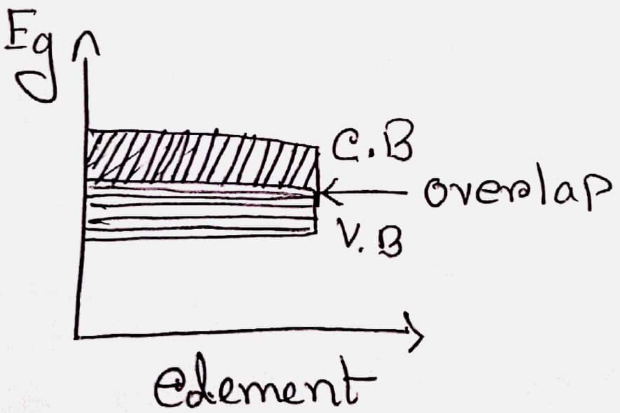
Ans to the Q no - 1 (a)

Semiconductor :- The material in which electrical conduction is smaller than conductor but more than in ~~is~~ insulation are semi-conductor. Certain semi-conductors including silicon, gallium, arsenide etc.

Band diagrams of Conductor, Insulator & semi-conductor are given below :-

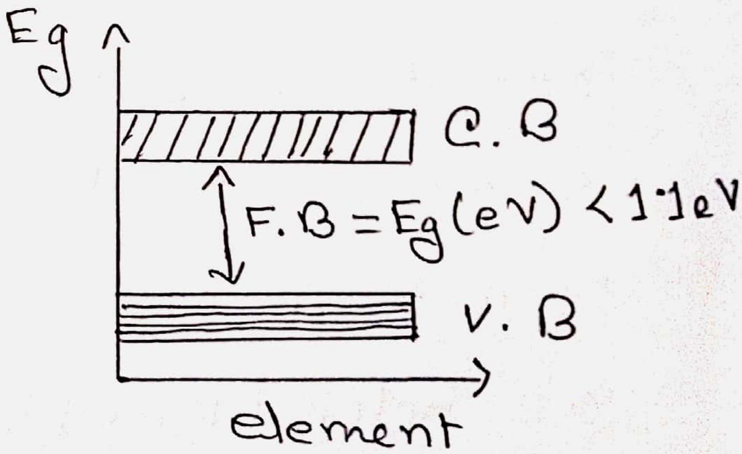
Let,
C.B = Conduction band
V.B = Valance band
F.B = Forbidden band.

Conductor.



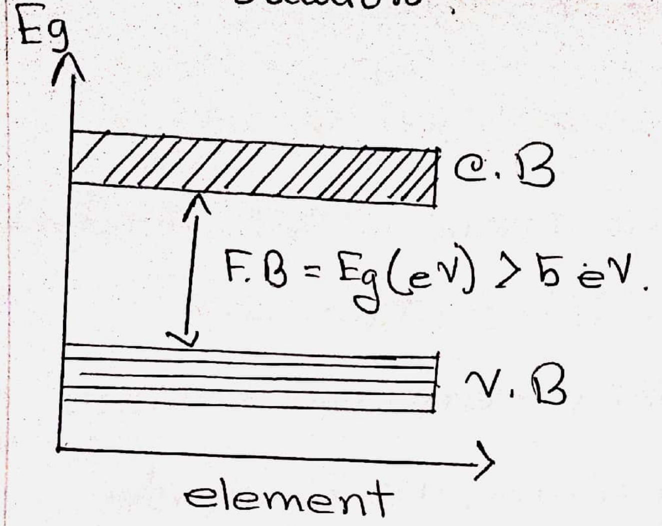
In Conductor F.B = 0

Semi-conductor



The value of F.B is less than 1.1 eV So, at certain temperature ~~to~~ they conduct electricity

Insulator.



The ~~for F.B~~ F.B is ~~sho~~ so high energy that e^- cannot gain that amount and go to C.B.

For this insulator ~~do~~ elements don't conduct electricity.

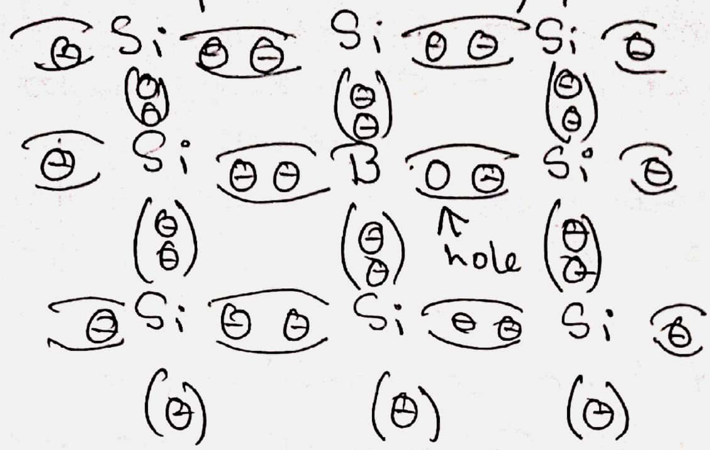
Ans to Q no - 1 (b)

The discussion of p-type & n-type semiconductor is given below-

P-Type Semiconductor: The semiconductor in which trivalent (valance 3 elements) are ~~do~~, added to tetravalent is p-type semiconductor. In it's formation there is a vacant space for electron known as hole. Elements like Al, B, Ga ~~et~~ are added with Si, Ge etc to form p-type semiconductor.

The diffused impurity with three valance e^- are know as acceptor atoms

An example of p-type semiconductor-



$B(5) = \underbrace{1s^2}_{2}\ \underbrace{2s^2 2p^1}_{3}$

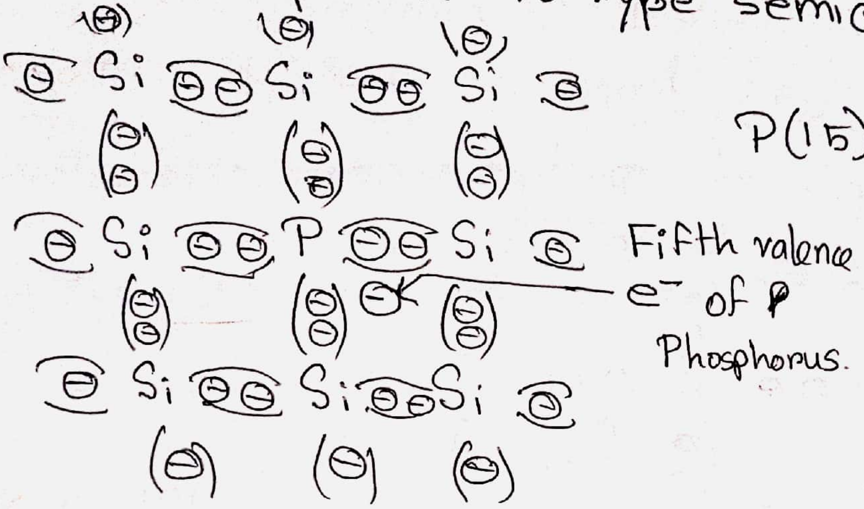
$Si(14) = \underbrace{1s^2}_{2}\ \underbrace{2s^2 2p^6}_{8}\ \underbrace{3s^2\ 3p^2}_{4}$

Figure: P-type semiconductor doped with Boron.

N-type SemiConductor:-

When pentavalent element (valance is 5) ~~is added with~~ tetravalent semiconductor is called n-type semiconductor. In it's formation there electrons outside bond which resonance ~~ar~~ carries the currents as majority carriers. Elements like P, As, Sb are added with Si, ~~Se~~ Ge, Sn etc. this diffused impurity with five valence e^- are donor atoms.

An example of n-type semiconductor:

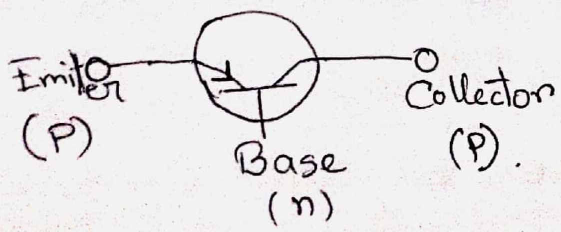
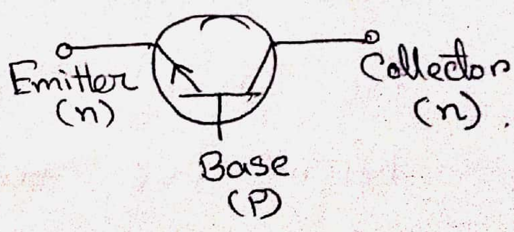


$P(15) = \underset{2}{\underline{1s^2}}\ \underset{8}{\underline{2s^2 2p^6}}\ \underset{5}{\underline{3s^2 3p^3}}$

Figure: n-type semiconductor with Phosphorus doping.

Ans to Q no - 1 (c)

The difference between p-n-p and n-p-n are given below:-

p-n-p	n-p-n
1. Two blocks of p-type semiconductor are separated by one thin block of n-type semiconductor.	1. The transistor in which two n-type layer are separated by p-type layer in middle.
2. 	2. 

P-n-P	n-P-n
3. Full form- Positive Negative Positive ~~sem~~ transistor	3. Full form- Negative, Positive Negative transistor.
4. The Emitter-Base junction is forwad biased.	4. The Collector base junction is forward biased.
5. Majority charge carrier hole	5. Majority charge carrier electron.

Q

Ans to the Q no- 2 a

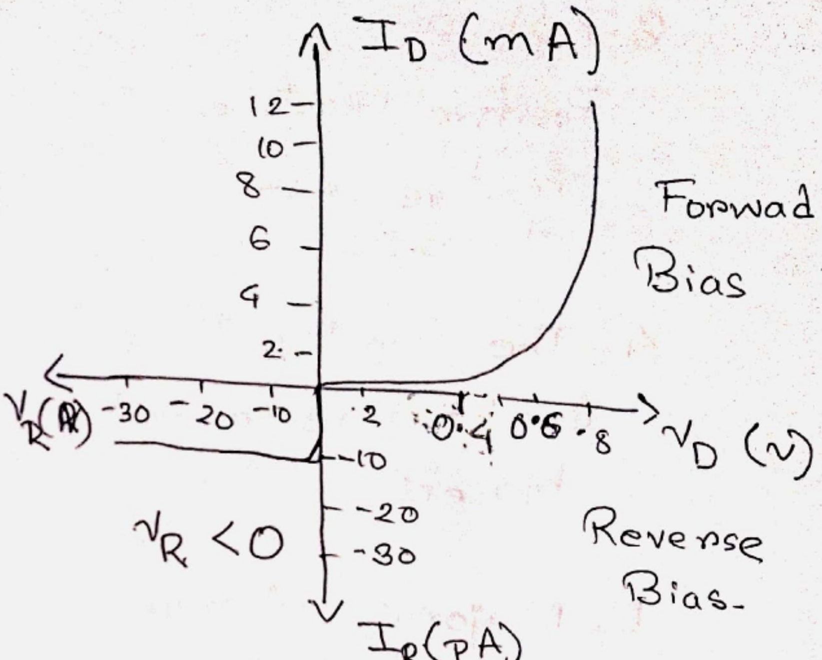
Transistor: A transistor is a three-layer semiconductor device consisting of either two n-type and one p-type layer of material ~~former~~ called n-p-n transistor or two P-type and one n-type layer of material called p-n-p transistor. It works on DC supply and used as rectifier of electric current.

Show I-V curve for Si diode.

1. The forward bias region.

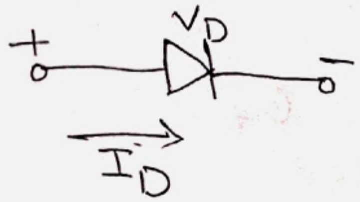
$V_D > 0\ V$

and $I_D > 0\ mA$



2. In Reverse bias region

$V_D < 0\ V$, $I_D = -I_S$



3. The cut in or knee voltage is 0.7 V.

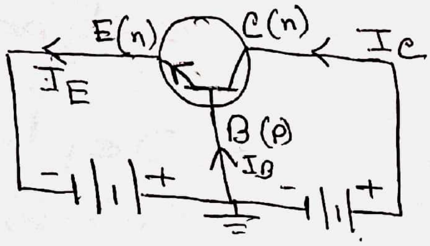
4. The reverse saturation curren is 10pA

5. The breakdown voltage can be as high as 20 kV.

Ans to the Q no- 2(b)

The n-p-n transistor is discussed below-

The Emitter- Base junction is reversed bias and Collector-base junction is forward bias.



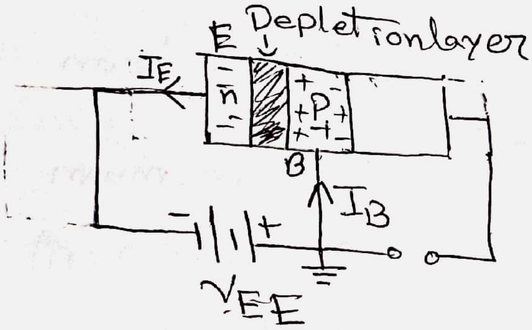


figure: -(a) Reverse bias

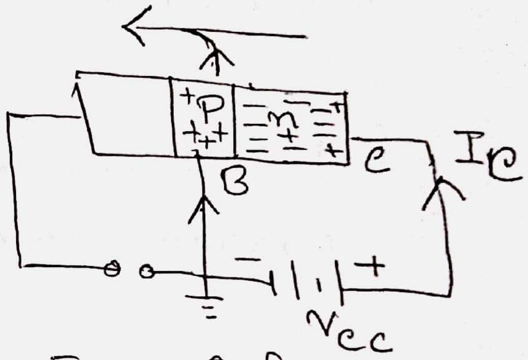
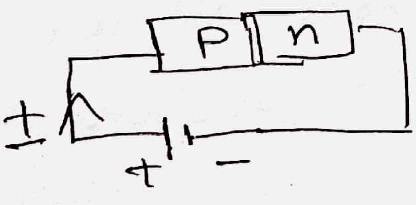
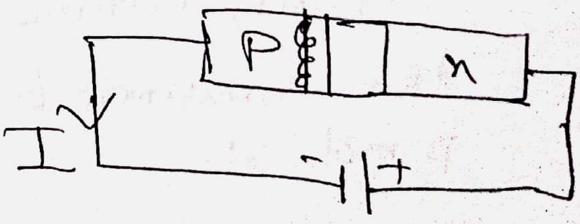
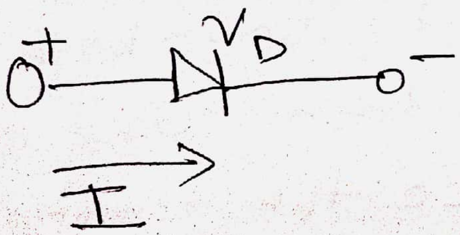
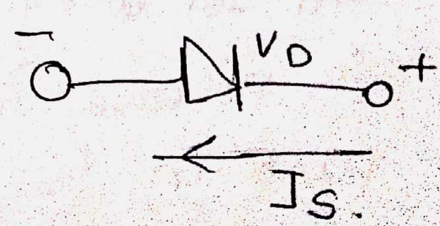


Figure (b) forward bias

In 2nd ~~loop~~ (b) the collector base junction is forward biased. So, large number of majority carriers i.e holes diffuse ~~out~~ across the forward biased p-n junction into p-material.

In 1st (a) figure, the Emitter - base junction is reverse, So, current from Base can pass in less amount to the Emitter by minority carriers.

Ans to the Q no- 2(c)

Forward bias	Reverse bias.
1. The positive potential is joined with p-type and negative with n-type	1. The positive potential with n-type & negative potential is with p-type.
2. Depletion layer decreases	2. Depletion layer increases and ultimately break down occurs.
3. Maximum amount current gained.	3. Minimum amount of current is gained ~~bef~~ before breakdown
4. Electrons i.e majority carriers of n-type carries. current	4. Hole i.e minority carriers in n-type carries current.
5. 	
6. 	6. 

Ans to the Q no- 3 (a)

Op-amp is an electronics device which is used to amplify voltage level.
The characteristics of op-amp:

a) It is an electronics device.
b) High input impedence
c) Low or Zero output impedence
d) It is used to change voltage amplitude
e) Used to acheive very high voltage gain.

Virtual ground:

Using op-amp we can get high voltage gain.

$A_v = -\frac{V_o}{V_i}$

Let,

$A_v = 10^6$

$V_o = -10V.$

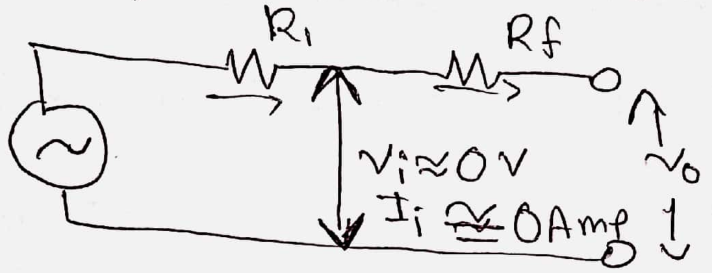
$V_i = -\frac{V_o}{A_v}$

$= -\frac{-10}{10^6}$

$= 10^{-5} V = 0.1 \mu V$

Here input voltage is as low as few micro volt which can be considered 0 V,

Note that we are considering $V_{in} \approx 0V$ which is not exactly 0 V. The fact of $V_{in} \approx 0V$ leads to the concept that at amplifier input there exist a virtual short circuit or virtual ground. The Cocept leads to taking $V_i \approx 0V$ as short which actually is not. And current goes only through R_i & R_f.



$$I = \frac{V_1}{R_1} = -\frac{V_o}{R_f}$$

$$\frac{V_o}{V_1} = -\frac{R_f}{R_1}$$

Ans to the Q no- 3 (b)

Ocillator: An oscillator is an electronic or mechanical device that produces regular oscillations in form of electrical or mechanical energy.

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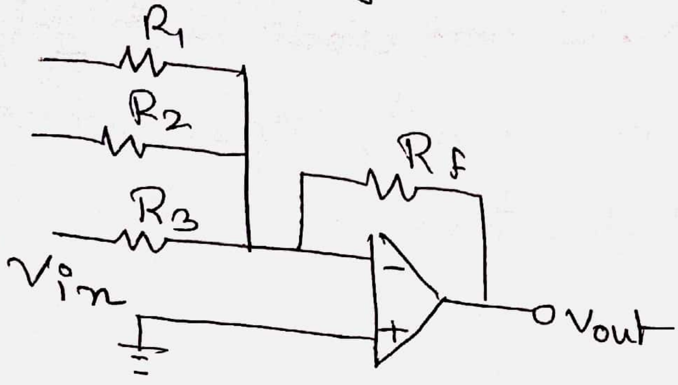
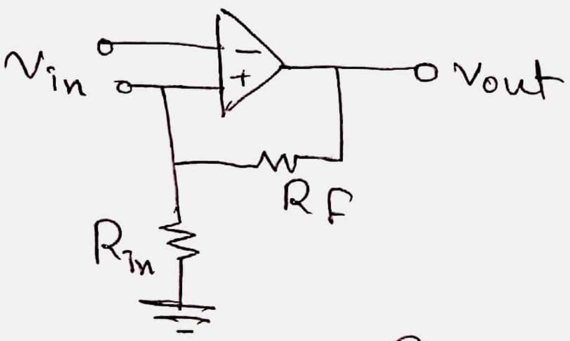
Circuit diagram of Summing Op-Amp:



$$V_{out} = \frac{R_f}{R_1} V_{in} + \frac{R_f}{R_2} V_{in} + \frac{R_f}{R_3} V_{in}$$

Non-inverting:



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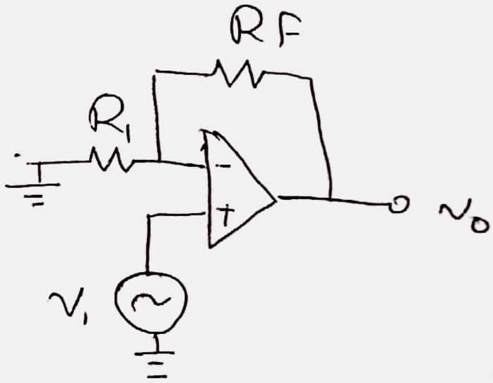

$$A = 1 + \frac{R_f}{R_1}$$

Ans to Q no- 3 (c)

CMRR - Common mode Rejection Rate.

(a) zenor diode is used as Voltage Regular

because zenor diode can pass

current ~~&~~ in both forward and reverse biased condition. Zenor diode is highly doped and it con easily pass current in both ~~current~~ direction.

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