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Sub: Electronic Devices

1. Define semiconductor & its types Find the relationship between σ, n, μ_e and q.

→ semiconductor is a material that has a conductivity in between insulator and conductor.

Two types of semiconductor:

i) Intrinsic semiconductor
An intrinsic semiconductor is a pure semiconductor without any significant dopant species present.

ii) Extrinsic semiconductor
Extrinsic semiconductor are semiconductor that are doped with specific impurities.

The relationship between σ, n, μ_e and q
Total current density within intrinsic semiconductor is

$$J = J_e + J_n$$
$$= qn\mu_e E + qp\mu_n E$$
$$= (n\mu_e + p\mu_n) qE$$

$$J = \sigma E \quad \text{—— (1)}$$

where n = no of e^- per unit volume
p = no of hole per unit volume
q = charge of e^- or hole in columb
E = Applied electric field strength
σ = conductivity of semiconductor

From eq^n (1), current density within a semiconductor is directly proportional to applied electrical field strength.

For intrinsic semiconductor

$n = p = n_i$, (n_i = intrinsic concentration)

and value of n_i is given by,

$$n_i^3 = A T^3 \exp\left(\frac{-E_{G0}}{KT}\right)$$

where,

A = constant = 2.33×10^{43}

K = Boltzmann's constant

E_{G0} = Energy gap in eV at absolute zero tempr

T = tempr

Now eq^n (1) becomes,

$$J = (n_i \mu_e + n_i \mu_h) q E$$

$$\therefore J = (\mu_e + \mu_h) n_i q E \quad \text{——— (3)}$$

So, conductivity of intrinsic semiconductor is

$$\sigma_i = (\mu_e + \mu_h) n_i q$$

Intrinsic conductivity increases at the rate of 5% per °C for Ge & 7% per °C for Si.

Conductivity in Extrinsic s/c

The conductivity of intrinsic semiconductor is

$$\sigma = (\mu_e + \mu_h) n_i q$$
$$= (n\mu_e + p\mu_h) q$$

for n type semiconductor is
$n \gg p$
so, $\sigma = n\mu_e q$

for p type semiconductor is
$p \gg n$
so, $\sigma = p\mu_h q$

2. Discuss the formation of PN junction of s/c along with VI characteristics in both forward & reverse biased condition.

When a block of P-type semiconductor is joined with a block of N-type semiconductor, then a junction is formed in between them, which is called PN junction.

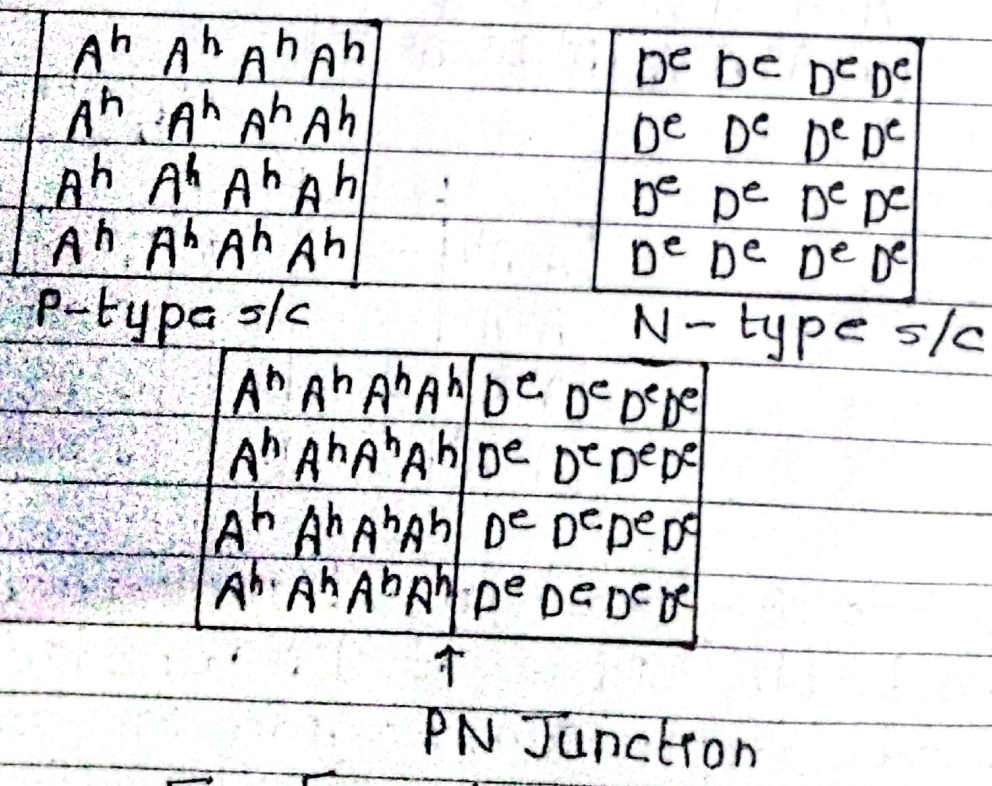


Fig:- formation of PN junction.

Here,

A = Acceptor atom (Trivalent)
D = Donar atom (Pentavalent)
e = electron
h = hole

During the formation of PN junctions, the e^-s from N-type s/c move towards the P-type ~~to~~ s/c & combine with the holes. The donor atoms of N-type losses e^- so it becomes +ve charged ion (D^+) where as the Acceptor atom of P-type accepts e^-s, so it becomes -ve charged ion (A^-)

A^h A^h A^- A^-	D^+ D^+ D^e D^e
A^h A^h A^- A^-	D^+ D^+ D^e D^e
A^h A^h A^- A^-	D^+ D^+ D^e D^e
A^h A^h A^- A^-	D^+ D^+ D^e D^e

Depletion region (Barrier region)

A^h A^h	- -	+ +	D^e D^e
A^h A^h	- -	+ +	D^e D^e
A^h A^h	- -	+ +	D^e D^e
A^h A^h	- -	+ +	D^e D^e

These +ve & -ve changed ions form a layer on both sides of PN junction which is called depletion region or barrier

region. This depletion region prevents the further movements of e^-s from N-type to P-type s/c. The +ve & -ve charge ions of depletion region (also called space charge) offers certain potential difference or voltage, which is called barrier potential or depletion potential or junction potential.

The value of barrier potential for silicon is 0.7V and is 0.3V for Germanium.

Voltage, Current (VI) characteristics of PN Junction Diode

If 'V' is the voltage (applied) accross a diode & 'I' be the current flowing through it, then the relationship between V & I is given by,

$$I = I_s \left(e^{\frac{V}{\eta V_T}} - 1 \right) \quad \text{--- (1)}$$

where, I_s = reverse saturation current

V_T = thermal voltage = 0.026V at room temp^r

η = constant $(1 \leq \eta \leq 2)$

when eq^n (1) is plotted in a graph, then VI characteristics of diode is obtained as shown below:

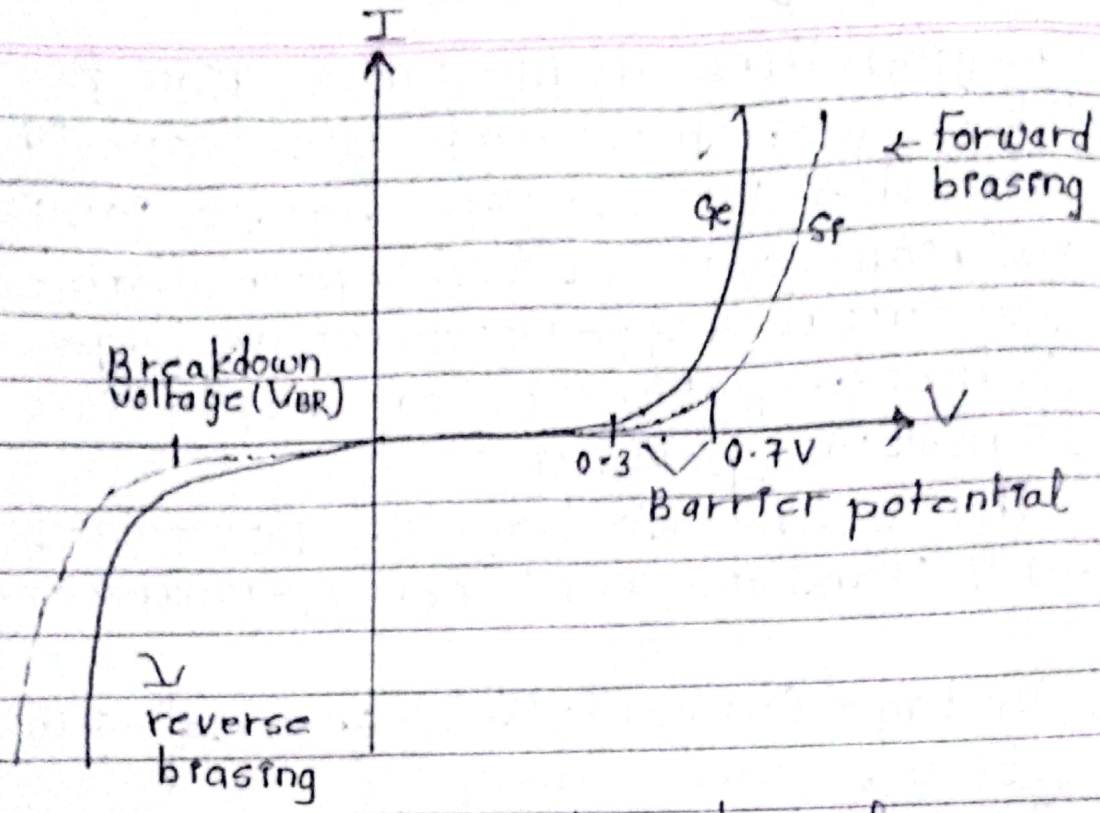


Fig: VI characteristics of a diode

When a diode is forward biased, small amount of current flows through it untill the supply voltage is greater than barrier potential.

When the supply voltage exceeds the barrier potential, then the current rises sharply as shown in above figure.
Also, when the diode is reverse biased, negligible amount of current flows through it, but if the supply voltage exceeds the breakdown voltage (V_{BR}), the diode is broken down (destroyed) & it acts as short circuit due to which the current

increases sharply as shown in above figure.

8. How tempr effect the VI characteristics of PN junction diode. If reverse saturation current of diode is 5nA at 35°C, find reverse saturation current at 235°C.

The VI characteristics of PN junction diode is given by,

$$I = I_s(e^{V/nV_T} - 1) \quad \text{——— (1)}$$

In above eqn (1), reverse saturation current I_s & thermal voltage V_T are temperature dependent factors.

When temperature increases V_T also increases which cause I to decrease. Similarly on increase in temperature I_s also increases (i.e. I_s doubles for every 10°C rise in tempr) due to which I increases. Since the effect of increase of I_s is greater than the effect of increase of V_T, the current through diode increases with the increase in temperature.

The effect of temperature in VI characteristic of diode can be shown as below:-

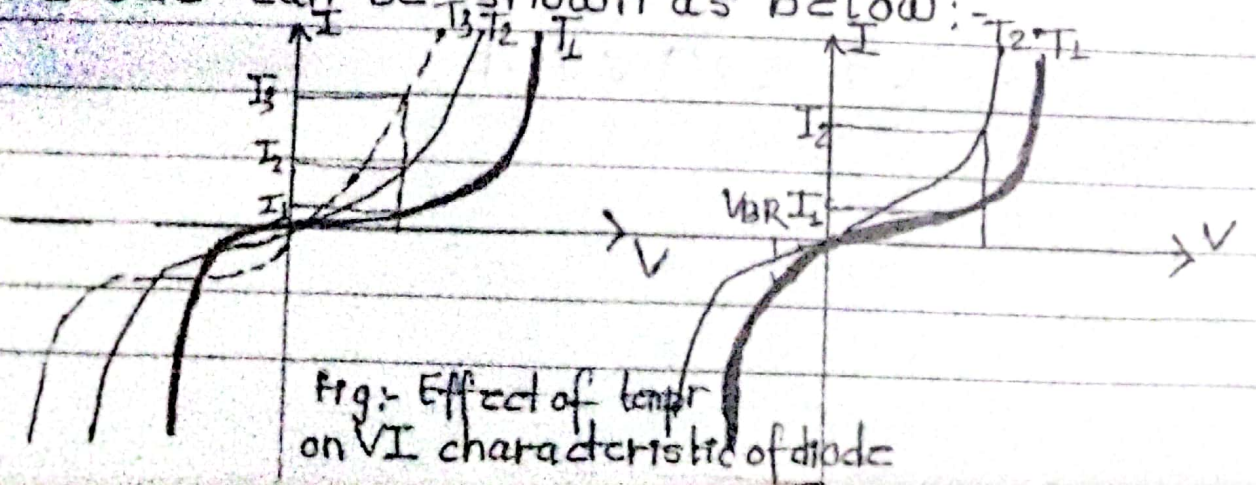


Fig:- Effect of tempr on VI characteristic of diode

The VI characteristics of diode shift towards left as temperature increased. From figure(graph), it is observed that $T_3 > T_2 > T_1$ thus $I_3 > I_2 > I_1$ i.e. as temperature is increased, current increases sharply.

Reverse saturation current at 235°c when revere saturation current of diode is 5nA at 35°C.

Solution:

Given:-

$I_{S1} = 5nA$ at $T_1 = 35°C$

$I_{S2} = ?$ at $T_2 = 235°C$

As we know that reverse saturation current I_S doubles for every 10°C rise in tempr.

i.e. $I_{S2} = 2^n I_{S1}$

where,

$$n = \frac{T_2 - T_1}{10}$$

$$= \frac{235° - 35°}{10} = \frac{200}{10} = 20$$

$$\therefore I_{S2} = 2^{20} \times 5nA$$

$$=$$

4. "Transition capacitance is inversely proportional to the square root of the applied reverse voltage." Justify the statement.

When a diode is reverse biased, the depletion region increases. The depletion region consists of a layer of positive & negative charged ions. These ions behave as +ve & -ve plate of a parallel plate capacitor due to which capacitive effect is produced in a diode, known as transition capacitance.

Thus transition capacitance is the capacitive effect shown by diode when it is reverse biased.

The transition capacitance of a diode is given by,

$$C_T = \frac{\epsilon A}{W} \quad \text{——— (1)}$$

where, ϵ = permitivity
A = Area of cross section (of a junction)
W = width of depletion region

Also, Depletion width (W) is expressed by,

$$W^2 = \frac{2\epsilon V_B}{e}\left[\frac{1}{N_A} + \frac{1}{N_D}\right] \quad \text{——— (2)}$$

where, N_A = No of Acceptor atoms
N_D = No of Donar atoms
ϵ = Permitivity
e = charge of e^-
V_B = [junction voltage = $V_0 - V_R$] = applied voltage
(V_0 = contact potential and V_R is negative voltage applied to diode)

From eq^n (i) & (ii)

$$C_T = \frac{\epsilon A}{\sqrt{\frac{2\epsilon V_B}{e}\left[\frac{1}{N_A}+\frac{1}{N_D}\right]}}$$

$$= \frac{\epsilon A}{\sqrt{\frac{2\epsilon V_B(N_A+N_D)}{e N_A N_D}}}$$

$$C_T = \epsilon A * \sqrt{\frac{e N_A N_D}{2\epsilon V_B(N_A+N_D)}}$$

$$C_T \propto \frac{1}{\sqrt{V_B}} \quad \text{——— (3)}$$

Thus, transition capacitance is inversely proportional to the square root of applied reverse voltage, V_B.

5 What is Junction capacitance. Establish a relation for diffusion capacitance. Differentiate between transition & diffusion capacitance.

The depletion region across the junction behaves as an insulating material or dielectric constant of the capacitor and the P&N sides act as parallel plates.
Thus, the junction exhibits the property of capacitance & is called junction capacitance or diode capacitance.

→ Relation for diffusion capacitance
When a diode is forward biased, there is a movement of electron & holes through the PN junction. This movement of charged carrier give rise to a capacitive effect in a diode, which is called diffusion capacitance.
→ In forward biasing of a diode, there is transition capacitance but it suppressed by the capacitive effect because of movement of charged ions.
The diffusion capacitance of a diode is given by,

$$C_D = \frac{dQ}{dV} \quad \text{——— (1)}$$

And we have,

$$Q = It = I \cdot \tau$$

where $t = \tau$ = mean life time of a carrier = constant from eqn(1)

$$C_D = \frac{d(I\tau)}{dV}$$

$$= \tau \frac{dI}{dV} \quad \text{——— (2)}$$

The VI characteristics of a diode is

$$I = I_s\left(e^{\frac{V}{nV_T}} - 1\right)$$

$$= I_s e^{\frac{V}{nV_T}}$$

on differentiating w.r.t. to V,

$$\frac{dI}{dV} = I_s \cdot \frac{1}{nV_T} e^{\frac{V}{nV_T}}$$

$$= I_s \frac{e^{\frac{V}{nV_T}}}{nV_T}$$

$$= \frac{I}{nV_T}$$

Now eq^n (2) become

$$C_D = \tau \cdot \frac{I}{nV_T}$$

$$= \frac{I\tau}{nV_T}$$

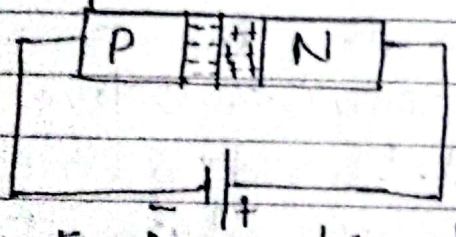
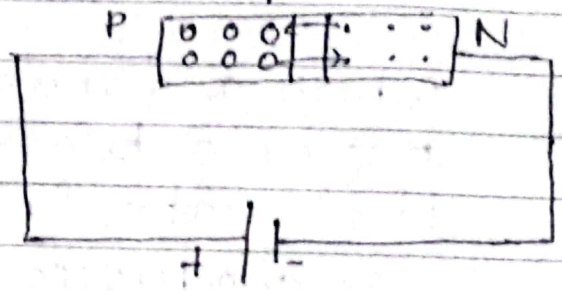
where, I = current flowing through a diode

τ = constant (mean life time of a carrier)

n = constant

V_T = thermal voltage

since τ, n and V_T are constant. Thus Diffusion capacitance is directly proportional to the current flowing through a diode.

Transition capacitance	Diffusion capacitance
1. The capacitive effect shown by diode when it is reverse biased is called transition capacitance.	1. The capacitive effect shown by diode when it is forward biased is called diffusion capacitance.
2. When diode is reverse biased, the depletion region widens, the depletion region consists of +ve & -ve charge ions, behaves as parallel plate capacitor, Due to which capacitive effect arises in diode & is a transition capacitance.  Fig: Reverse biased diode	2. When a diode is forward biased, the +ve & -ve charge carriers move through the PN junction. This movement of charge carrier gives an capacitive effect, known as diffusion capacitance  fig: Forward biased diode
3. The transition capacitance of diode can be expressed as: $C_T = \frac{\epsilon A}{W}$ where ϵ = Permittivity, A = Area of crosssection of depletion region.	3. The diffusion capacitance of diode is expressed as: $C_D = \frac{I}{nV_T}\tau$ where τ = mean lifetime of carriers, I = forward current of diode, n = constant ($1 \le n \le 2$)

W = width of depletion region	V_T = Thermal voltage
4. The transition capacitance is inversely proportional to the reverse voltage	4. Diffusion capacitance is directly proportional to the forward current of diode.

6. What do you mean by reverse recovery time of PN diode? Explain.

When a diode is forward biased it conducts current (switch ON) & when it is reverse biased it doesn't conduct current (s/w OFF)

When a forward biased diode is suddenly reverse biased, the diode doesn't change its state from conduction (switch ON) to non conduction (s/w OFF). the diode takes certain time to change its state from conduction (forward biased) to non-conduction (reverse biased), which is called reverse recovery time (diode switching time) of a diode.

When the forward biased diode is reverse biased, the current simply reverse & stay measurable for certain period of time, called storage time (t_s).

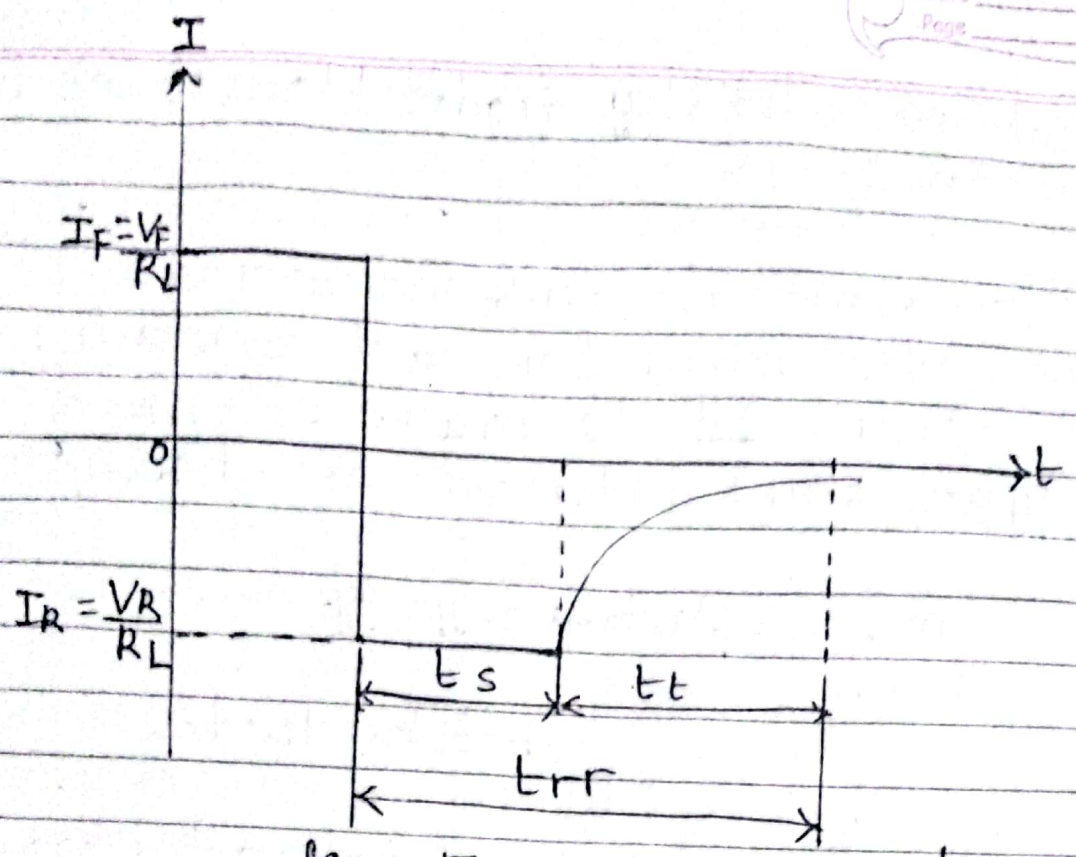


fig :- Reverse recovery time of diode.

After the storage phase has passed, the current gradually decreases & becomes zero to take diode into non-conduction state (reverse bias). This period of time is called transition time (t_t).

The reverse recovery time (t_{rr}) is the sum of storage time (t_s) & transition time (t_t).

i.e. $t_{rr} = t_s + t_t$

7. What is schottky diode How it is different from PN diode.

⇒ It is a metal semiconductor diode designed to be used for fast switching applications. It is made of metal and n-type semiconductor as shown in fig.

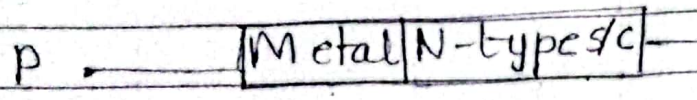
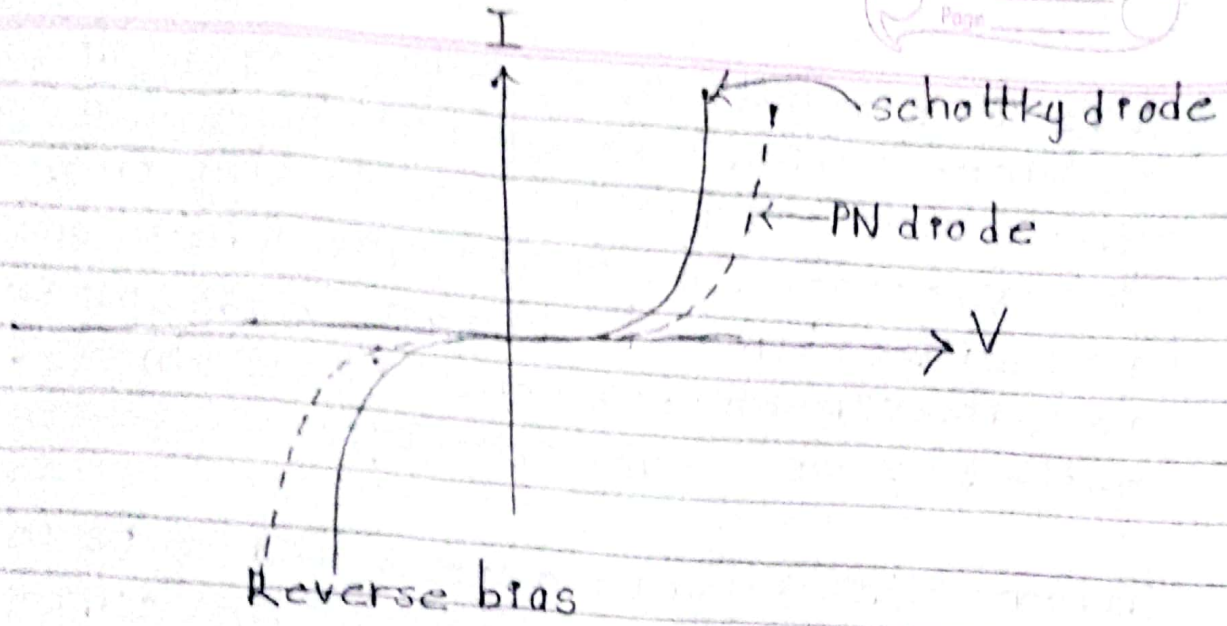


fig: schottky diode.

⇒ The PN diode is made up of P-type s/c and N-type s/c. whereas schottky diode is made up of metal and N-type semiconductor. Similarly, schottky diode is unipolar whereas PN diode is bipolar. The barrier potential of si-diode is 0.7V where as that of schottky is 0.7V whereas that of schottky is 0.15V to 0.45V which is less than that of PN diode. In this way schottky diode is different from PN diode.

The VI characteristics of PN & schottky diode is,



8. Explain VI characteristics of tunnel diode with help of necessary diagram. Also mention its applications.

VI characteristics of Tunnel Diode

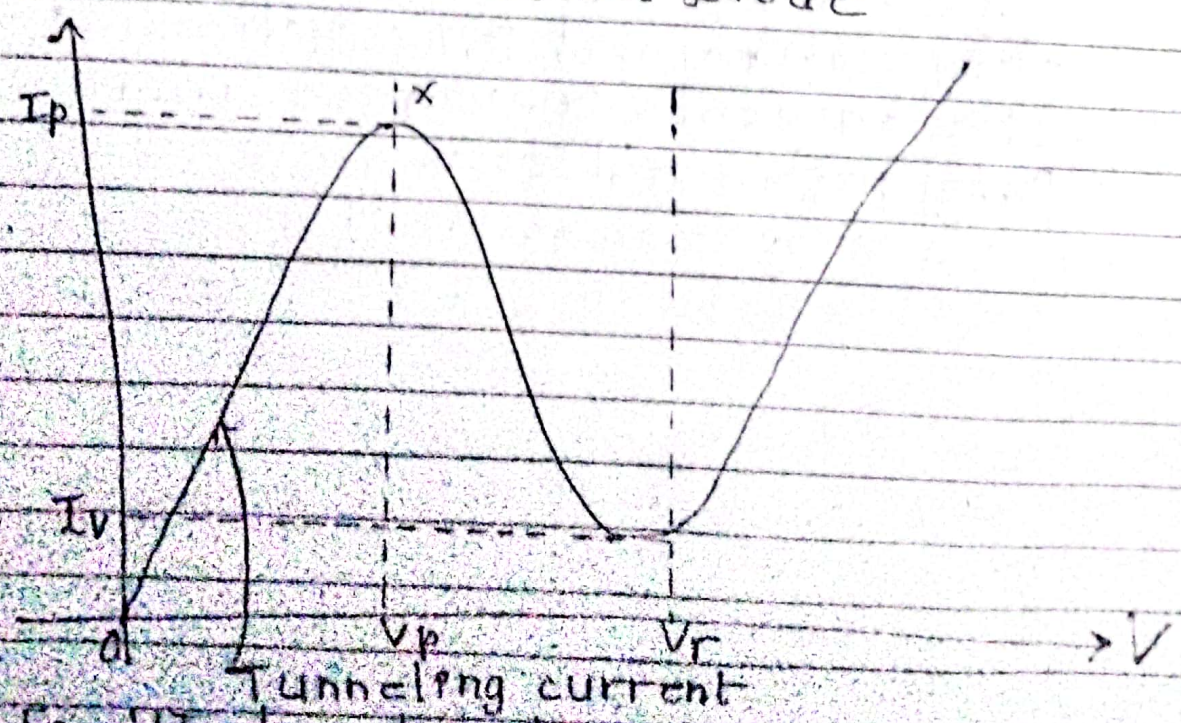


Fig: VI characteristics of Tunnel Diode.

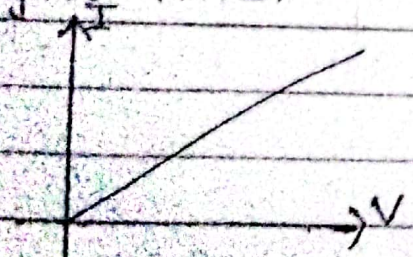
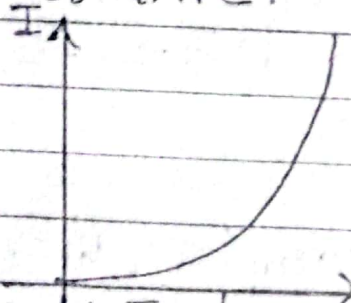
When a small +ve voltage is applied across a tunnel diode, it starts to conduct current. When the voltage is gradually increased the current also increases. when the voltage across tunned diode $V = V_p$ (peak voltage), maximum current flow through it, called peak current I_p:

When the voltage across diode is increased beyond V_p (i.e. $V > V_p$), the current start to decrease. The current becomes minimum called valley current, I_v, when the voltage across diode is equal to valley voltage ($V = V_v$).

When the voltage is increased beyond V_v ($V > V_v$), the tunnel diode gains the property of normal PN junction diode & the the current increases gradually like in PN junction diode.

9. What are linear devices? Differentiate between linear & non-linear devices.

→ Those devices which follows ohms law are linear devices. Linear devices have linear relationship between input and output i.e. voltage and current. Example :- Resistor, inductor, capacitor.

Linear Devices	Non-Linear Devices
(i) These devices follows ohm's law.	(i) These electronic devices doesnot follow ohm's law.
(ii) Linear devices follows Network theorems such as Thevenin's, Norton's superposition theorems	(ii) Non-Linear Devices doesnot follow Network theorems.
(iii) The VI characteristics of linear devices is straight line.  Fig: VI characteristics of linear devices	(iii) The VI characteristics of Non-linear devices is not st. line.  Fig: VI characteristics of non-linear devices
(iv) Examples: Resistor, Inductor	(iv) Examples: Diode, Transistor

10. Explain non-linear devices along with its properties. Verify with appropriate example, non linear device doesn't follow the principle of superposition.

→ The electronic devices which do not follow ohm's law ($V \neq IR$) or whose VI-characteristics is not straight line are called non-linear devices.

Properties of Non-Linear devices

1. They do not follow ohm's law.
2. Their VI characteristics is not a straight line.
3. They do not follow the network theorem like Thevenins Theorem, Norton's Theorem, superposition theorem etc.
4. The circuits containing non linear devices can be analyzed by using KVL or KCL.
5. The internal resistance of non-linear device depends on the operating conditions like temperature, current, voltage etc.
6. Examples are: Diode, Transistors, FET etc.

Verification of non-linear device doesnot follow the principle of superposition.

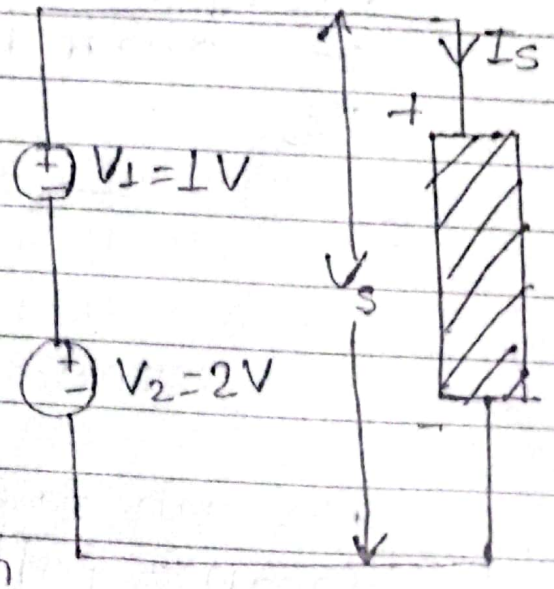
Consider a non-linear device (square-law device) whose VI characteristics of eqn is given by,

$$I_s = A(V_s - V_{TR})^2 \quad \text{--- (1)}$$

where, I_s = current through non-linear device
V_s = voltage across non-linear device
V_{TR} = Threshold voltage = 0
A = constant = $1\,mA/V^2$

Then $I_s = 1 * (V_s - 0)^2 = V_s^2$ --- (2)

Now, connect the non-linear device in a simple circuit as shown in figure.



Here, using KVL,

$$-V_1 - V_2 + V_s = 0$$
$$V_s = V_1 + V_2$$
$$= 1 + 2 = 3V$$

From eqn (2),

$$I_s = V_s^2 = (3)^2 = 9\,mA$$

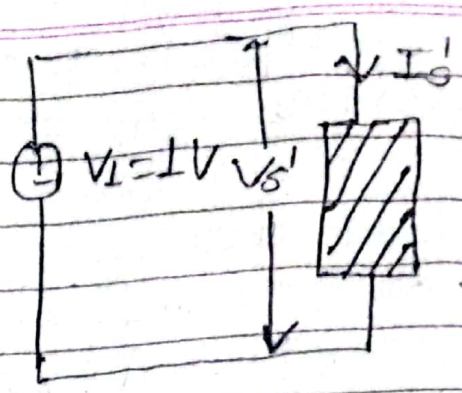
To apply superposition theorem,

1) Considering source V_1 only,

Here,

$V_s' = V_1 = 1V$

$I_s' = (V_s')^2 = 1mA$



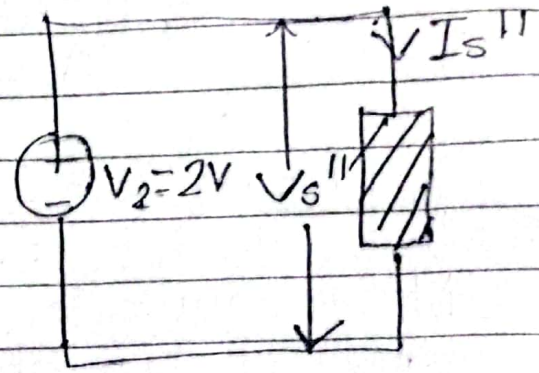
2) Considering source V_2 only,

Here, $V_s'' = V_2$

$I_s'' = (V_s'')^2$

$= 2^2$

$= 4mA$



Now, current through a non-linear device according to superposition theorem is,

$I_{s1} = I_s' + I_s''$

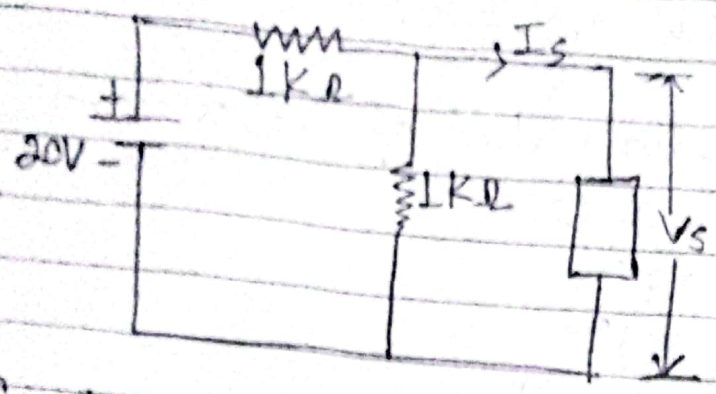
$= 1 + 4$

$= 5mA$

since $I_s \neq I_{s1}$

We can say that non-linear device doesnot follow principle of superposition

Q: Find I_s & V_s for the circuit shown below:



Also find its piecewise linear model.

Soln:-

We know that;

$$I_s = A(V_s - V_{TR})^2$$

where

$$A = 1mA/V^2 \ \& \ V_{TR} = 0$$

$$\therefore I_s = 1 * (V_s - 0)^2$$

$$= V_s^2$$

Applying KCL at node A,

$$I = I_1 + I_s$$

$$\frac{20 - V_s}{1} = \frac{V_s}{1} + I_s$$

$$20 - V_s = V_s + I_s$$

$$20 - V_s = V_s + V_s^2$$

$$20 - 2V_s - V_s^2 = 0$$

$$V_s^2 + 2V_s - 20 = 0$$

On solving we get,

$V_s = 3.58V$ or $-5.58V$

neglecting -ve value of V_s, we get

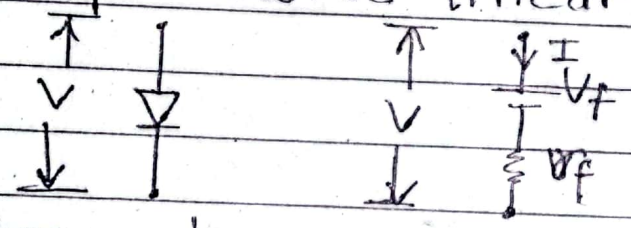
$\therefore V_s = 3.58V$

and $I_s = V_s^2$

$= (3.58)^2$

$= 12.82 mA$

The piecewise linear model of a diode is



~~forward~~

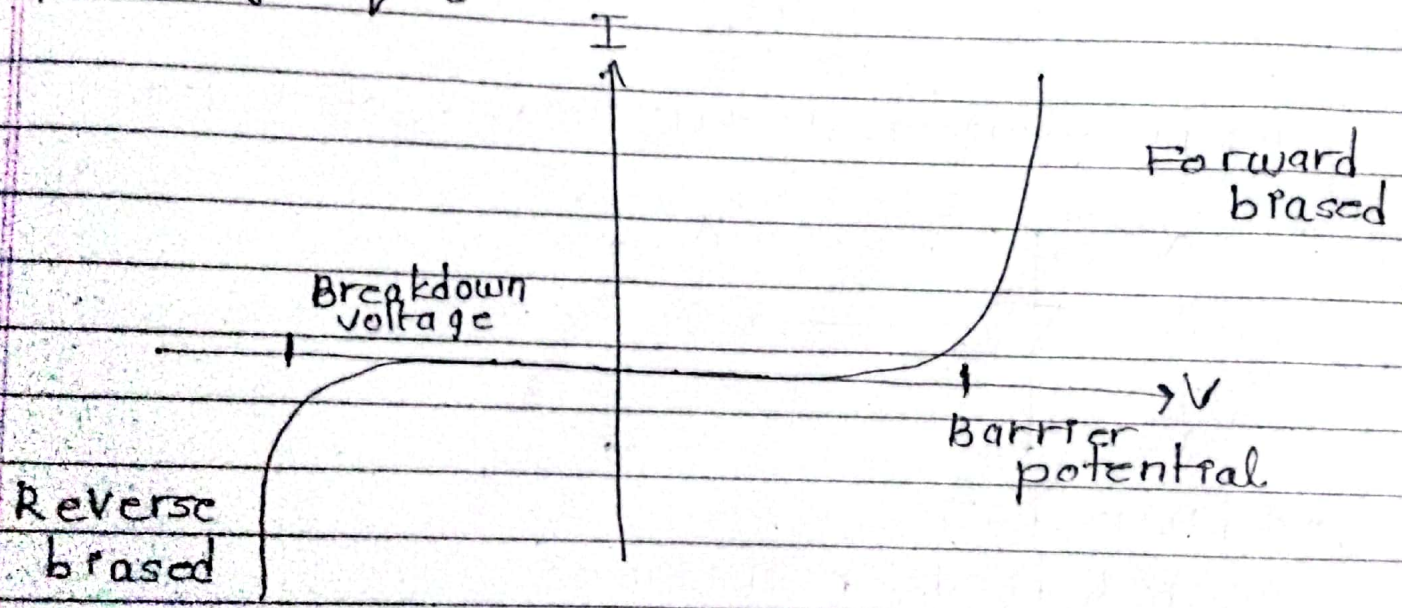
12. "Diode is a non-linear device." Justify the statement.

→ Diode is a non-linear device because the voltage & current relationship of a diode is not a straight line.

The VI characteristics of a diode is,

$$I = I_s\left(e^{\frac{V}{nV_T}} - 1\right) \quad \text{--- (1)}$$

plotting eqn (1)



Clearly, the obtained graph of diode is non-linear. Diode is non-linear device.

13. Find piecewise linear model of silicon diode with $I_s = 10^{-11} A$ & $n = 1.6$ in the vicinity of operating point $I_D = 1mA$.

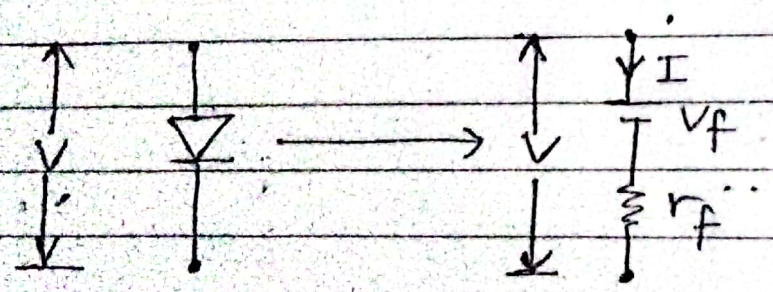
Soln:

Given,

Diode current $(I_D) = 1\,mA$
$= 1 \times 10^{-3} A$

$I_s = 10^{-11} A$
$n = 1.6$
$r_f = ?$
$V_f = ?$

The piecewise linear model of a diode is,



we know that,
forward diode resistance

$$r_f = \frac{nV_T}{I}$$

$$= \frac{1.6 \times 0.026}{1 \times 10^{-3}}$$

$$= 41.6\,\Omega$$

Also,

$V_f = V - I r_f$ ——— (i)

we know that,

$I = I_s (e^{V/nV_T} - 1)$

or $\frac{I}{I_s} = e^{V/nV_T} - 1$

or, $\frac{1 \times 10^{-3}}{10^{-11}} = e^{V/(1.6 \times 0.026)} - 1$

or, $10^8 + 1 = e^{V/0.0416}$

or, $\ln(10^8 + 1) = \frac{V}{0.0416}$

or, $V = 0.0416 * 18.42$

$\therefore V = 0.766V$

Again from eqn(i)

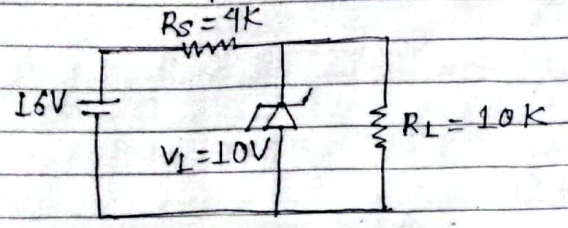
$V_f = V - I * r_f$

$= 0.766 - 10^3 * 41.6$

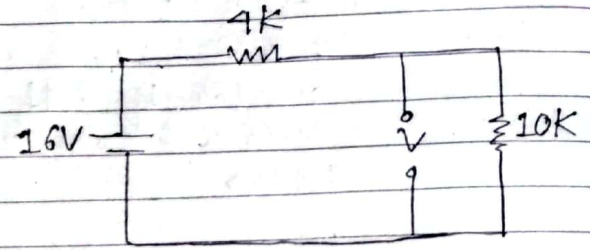
$= 0.766 - 0.0426$

$= 0.723V$

15. For the circuit shown below. Find
(i) o/p voltage
(ii) current through zener diode
(iii) voltage across Rs
(iv) Power dissipitated across zener diode.



First step to find diode is ON or OFF. for this remove zener diode and find open circuit voltage.



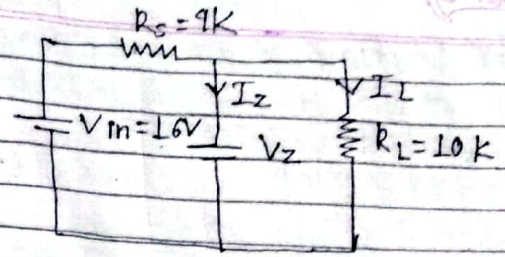
$$V = \frac{10}{4+10} \times 16$$

$$V = \frac{10}{14} \times 16$$

$$V = 11.42 \text{ volt}$$

$\because V > V_Z$ so diode is ON.

diode is ON, so replace zener diode with voltage source Vz.



(i) o/p voltage $(V_L) = V_Z = 10V$

(ii) For I_Z

$$I = \frac{V_{in} - V_Z}{R_s} = \frac{16-10}{4} = 1.5 \text{ mA}$$

and,

$$I_L = \frac{V_L}{R_L}$$

$$= \frac{10}{10} = 1 \text{ mA}$$

$$\therefore I_Z = I - I_L$$

$$= 1.5 - 1$$

$$= 1 \text{ mA}$$

(iii) $V_{Rs} = V_{in} - V_Z$

$$= 16 - 10$$

$$= 6V$$

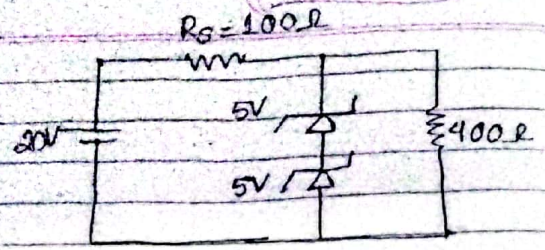
(iv) Power dissipated across zener diode

$$P_Z = I_Z \cdot V_Z$$

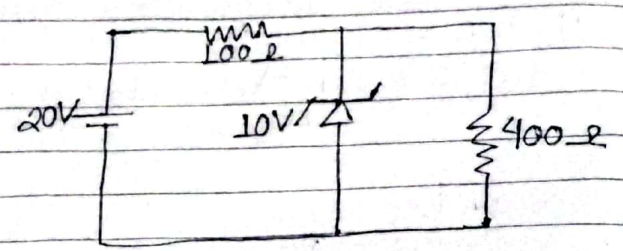
$$= 0.5 \times 10 = 5 \text{ mwatt}$$

$$= 5 \times 10^{-3} \text{ watt}$$

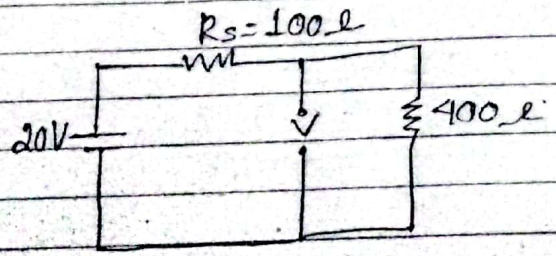
(b) we have to find,
(i) V_L
(ii) I_z
(iii) V_{Rs}
(iv) P_z



The simplified form of circuit is;



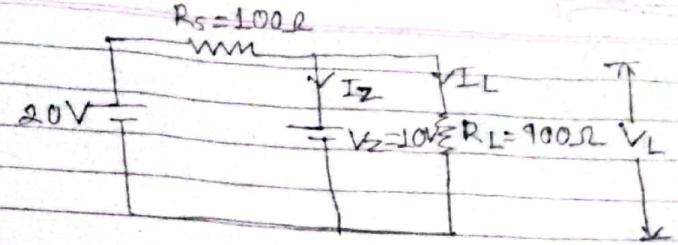
Lets find circuit is ON or OFF. For this remove zener diode and find open circuit voltage.



Here, $V = \frac{400}{400+100} \times 20$

$= 16V$

$\therefore V > V_z$ so, diode is ON. Replacing diode by voltage source.



(i) $V_L = V_z = 10V$

(ii) $I_z = I - I_L$ —— (1)

also,

$I_L = \frac{V_L}{R_L}$

$= \frac{10}{400}$

$= 0.025A$

and,

$I = \frac{V_{in} - V_z}{R_s}$

$= \frac{20-10}{100}$

$= 0.1A$

$\therefore I_z = 0.1 - 0.025$

$= 0.075A$

$= 7.5mA$

iii) $V_{Rs} = I \times R_s$

$= 0.1 \times 100$

$= 10A$

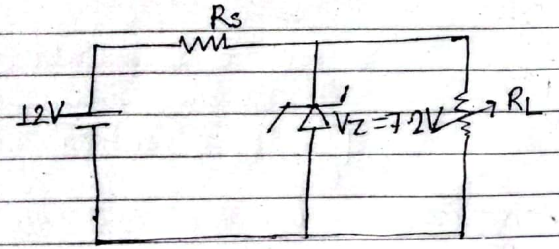
(iv) $P_Z = I_Z V_Z$

$= 7.5\ mA \times 10$

$= 75\ mwatt$

$= 75 \times 10^{-3}$ watt //

16 For the circuit shown below, load current varies from 12 to 100 mA. Find value of series resistance R_S to maintain 7.2V across the load. minimum zener current is 10mA.



we have,

$V_{in} = 12V$

$V_Z = 7.2V$

$I_L(max) = 100\ mA$

$I_L(min) = 12\ mA$

$I_Z(min) = 10\ mA$

$R_S = ?$

we have from circuit,

$I = I_Z + I_L$

$I = I_Z(min) + Z_L(max)$

$= 10 + 100 = 110\ mA$

$\therefore$ series resistance, $R_S = \frac{V_{in} - V_Z}{I} = \frac{(12 - 7.2)V}{110 \times 10^{-3} A}$

$= 43.63\ \Omega$

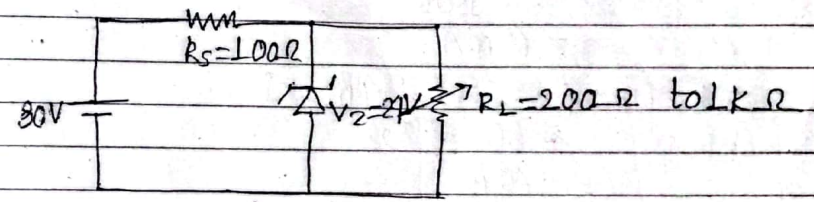
18. A zener regulator has 24V zener voltage with variable load resistance. Calculate:-

(i) max^m & min^m load current

(ii) voltage drop across series resistance

(iii) max^m & min^m power dissipation across load

(iv) minimum value of load resistance to ensure that zener diode is in 'ON' state.



Given,

$V_{in} = 30V$

$R_S = 100\Omega$

$V_Z = 24V$

$R_L(min) = 200\Omega$

$R_L(max) = 1K\Omega = 1000\Omega$

(i) maximum load current, $I_L(max) = \frac{V_L}{R_L(min)} = \frac{V_Z}{R_L(min)}$

$= \frac{12}{200} = 60mA$ ~~120mA~~

& $I_L(min) = \frac{V_L}{R_L(max)}$

$= \frac{18}{1000} \quad \frac{29}{1000}$

$= 29mA$

ii) $P_Z(min) = V_Z . I_Z(min)$

$P_Z(max) = V_Z . I_Z(max)$

Here, $I = \frac{V_{in} - V_Z}{R_S}$

$= \frac{20-29}{100}$

$= 60mA$

$\therefore I_Z(min) = I - I_L(max)$

$= 60 - 120$

$= -60mA$

$\therefore I_Z(max) = I - I_L(min)$

$= 60 - 29$

$= 36mA$

$\therefore P_Z(min) = 29 \times -60 = 1990 mW$

$\therefore P_Z(max) = 29 \times 36 = 869 mW$

iii) voltage drop across series resistance,

$V_R = IR_S$

$= \cancel{60mA \times 100\Omega} = 60 * 100 = 6V$

iv) $R_L(min) = \frac{V_Z * R_S}{V_{in} - V_Z}$

$= \frac{29 * 100}{30 - 29}$

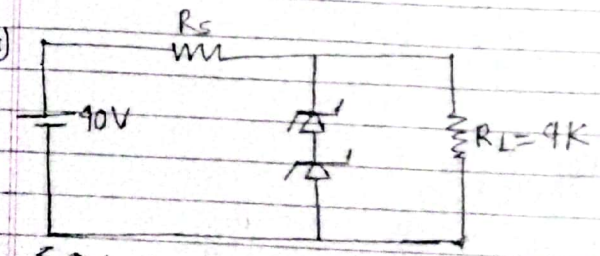
$= \frac{2900}{6}$

$= 900\Omega$

or $0.9K\Omega$ //

19. The zener diode ratings connected in the circuit shown below is 10V, 1mA. Find values of series resistance R_S. so that o/p across the load is regulated.

a)



Given,

$V_{in} = 40V$

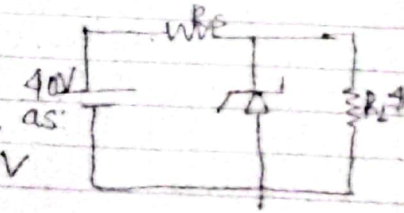
$V_Z = 10V$

$I_Z = 1mA$

$R_L = 9K\Omega = 9000\Omega$

$R_S = ?$

Reconstructing the circuit, as:



Here, we get total $V_Z = 10+10 = 20V$

$\therefore$ series resistance $R_S = \frac{V_{in} - V_Z}{I}$

$= \frac{40-20}{1}$

$= 20K\Omega$ //

Also for I,

$I_L = \frac{V_L}{R_L}$

$= \frac{20}{4000}$

$= \cancel{5A}\ 5mA$

$I = I_L + I_Z$

$= 5 + 0.001$

$= \cancel{6mA}\ 5.001$

$R_S = \frac{40-20}{5.001}$

$= \cancel{3.99}\ 3.99K\Omega$

(b) Sol^n:-

Here,

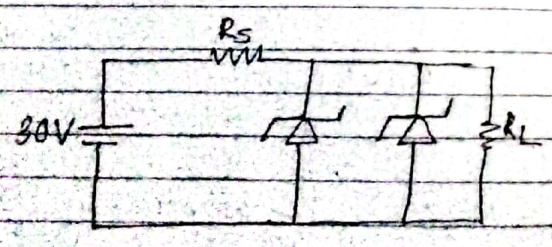
$V_{in} = 30V$

$R_S = ?$

$V_Z = 10V$

$(I_Z)_T = 10+10 = 20mA$

$R_L = 2K$

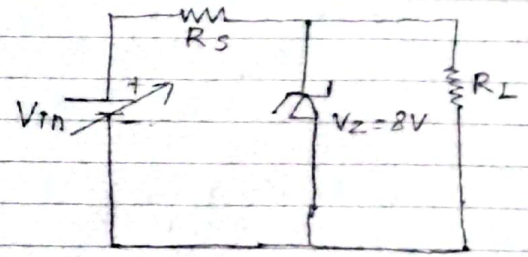


$\therefore$ series resistance $(R_S) = \frac{V_{in} - V_Z}{I}$

$= \frac{30-10}{20}$

$= 1K\Omega$ //

20. Design a zener diode voltage regulator which maintain constant 8V across load for supply voltage of range 10V - 50V. The maxm zener current is $I_{zm} = 40mA$.



Given that,

$I_{zm} = 40mA$

$V_Z = 8V$

$V_L = 5V$

$V_{in}(min) = 10V$

$V_{in}(max) = 50V$

For min condition,

$V_Z = \frac{R_L}{R_L + R_S} * V_{in}(min)$

$\frac{8}{10} = \frac{R_L}{R_L + R_S}$

$0.8R_L + 0.8R_S = R_L$

$0.8R_S = 0.2R_L$

$R_L = 4R_S$ —— (1)

For max,

$V_{in}(max) = I_{max}R_S + V_Z$

$50 = I_{Zmax}R_S + 8$

$42 = I_{Zmax} + I_L$

$42 = \cancel{I_{Zmax}}\ 40 + I_L$

$I_L = 2$

also;

$R_L = \frac{V_L}{I_L} = \frac{5}{.2} = 2.5\,K\Omega$

Thus, $R_S = \frac{R_L}{4} = \frac{2.5}{4} = 0.625\,K\Omega$

$\therefore R_S = 625\,\Omega$ and $R_L = 2500\,\Omega$ Ans//

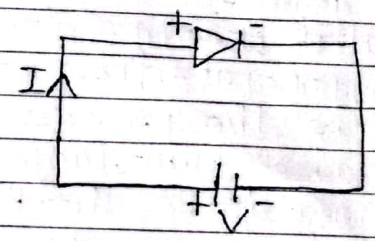
21. Write short Notes on:-

a) Static & dynamic resistance

> Static Resistance

It is also called DC Resistance. If 'V' be the dc voltage applied to a diode and 'I' be the current flowing through it, then the ratio of V and I is called static resistance of a diode

i.e. $R_{DC} = \frac{V}{I}$



> Dynamic Resistance ~~AC~~

It is also called AC Resistance. When the voltage applied across a diode is changed by ΔV, then the current flowing through it will also change in current ΔI. The ratio of change in voltage to change in current is called dynamic or AC resistance of a diode.

i.e. $r_{AC} = \frac{\Delta V}{\Delta I} = \frac{dV}{dI}$

b) Avalanche & zener breakdown

Avalanche Breakdown

When a diode is reverse biased, the free e-s present on it can gain (high) sufficient energy from supply voltage. These highly energetic e-s move with greater speed & can breakdown (rupture) a covalent bond to generate free e-s (i.e. a e^- can raupture a covalent bond & generate two free e-s). These newly generated free e-s also gain energy & further generate free e-s by rupturing covalent bonds. The process continues & in a short period of time, large no of free e-s are generated in a diode. The flows of these e-s give rise to large current. This phenomenon is called avalanche breakdown.

the avalanche breakdown occurs in a diode with higher breakdown voltage.

2) Zener Breakdown.

When a diode is reverse biased, the supplied reverse voltage can generate an electric field. Due to which covalent bonds are ruptured & free e-s are generated. If the diode has lower breakdown voltage, then the supply voltage can rupture (break down) large no of covalent bonds & generate large no of free e-s, due to which large no of current flows through a diode. This phenomenon is called zener breakdown.

zener breakdown occurs in zener diode with smaller breakdown voltage (zener voltage, V_Z).

c) Zener diode as a voltage Regulator.

To use zener diode as a voltage regulator, following condition must be satisfied,

i) zener diode must be operated in reverse bias & connected in parallel with load.

ii) Input voltage must be greater than zener voltage ($V_{in} > V_Z$) i.e. it must be operated in a breakdown region.

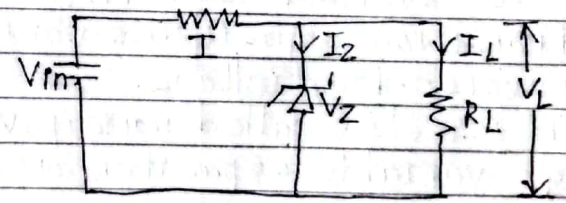


Fig: zener diode as a voltage regulator

Here,

V_{in} = I/p voltage

R_S = source resistance

R_L = load resistance

I = source current

I_L = load current

I_Z = zener ~~voltage~~ current

V_Z = zener voltage

V_L = load voltage

When zener diode regulate voltage across load, the load voltage will be equal to zener voltage.

i.e. $V_L = V_Z$

From above figure,

$$I = I_Z + I_L$$

and, $V_L = I_L . R_L$

d) Varactor Diode

The varactor diode is a variable capacitor diode. It is a reverse-biased PN junction diode whose transition capacitance varies with the applied reverse-bias voltage.

The varactor is also called varicap, volt cap, epicap, voltage variable capacitor, or tunning capacitor.

A reverse-biased PN junction diode possesses transition capacitance C_T which is given by

$$C_T = \frac{\epsilon A}{W}$$

where, ϵ = permittivity

A = Area of cross-section

W = width of depletion region

When the reverse-bias voltage 'V' is varried, the width of depletion region 'W' varies due to which C_T also varies. Thus, C_T can be controlled by varying reverse-voltage. This property of reverse-biased PN junction diode is called varactor.

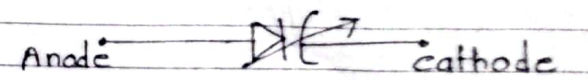


Fig: symbol of varactor

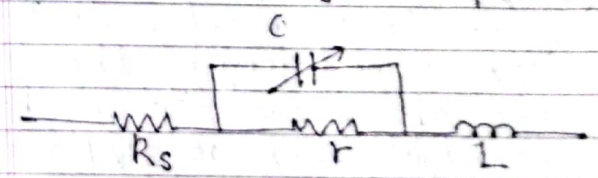


Fig: Equivalent circuit

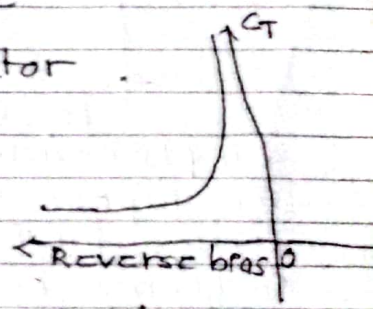


Fig: characteristics curve

Varactor diodes are used in:

- Tunning circuits
- FM modulators
- Adjustable bandpass filters
- Automatic frequency control devices

e) Piecewise linear model of a diode

The V-I relationship for a diode is given by

$$I = I_s(e^{V/nV_T} - 1) \quad \text{——} (1)$$

where, I_s = reverse-saturation current
n = constant $(1 \le n \le 2)$

If we plot above eqn, we get a non-linear characteristics as shown in figure below

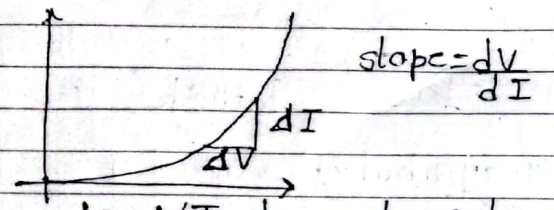


Fig: VI characteristics of a diode

In piecewise linear modeling of the diode, we represent the above non-linear characteristics by two straight lines OA & AB as shown in figure below.

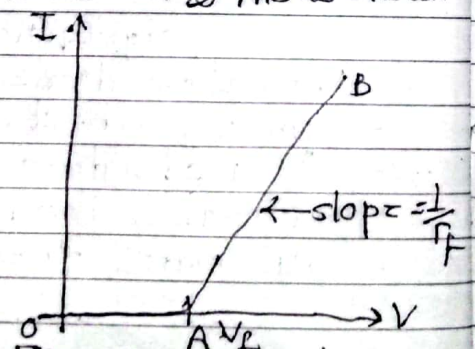


Fig: Piecewise linear model of a diode

Equation of line OA:

$I = 0$ for $V < V_f$

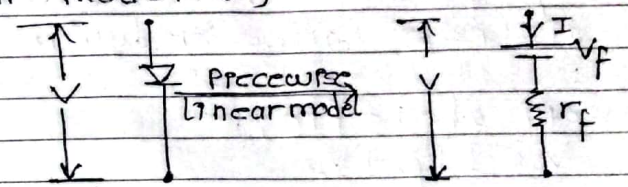
Equation of line AB;

$I = \frac{V - V_f}{r_f}$ for $V > V_f$

Thus we represent the non-linear characteristics of a diode in piecewise linear model as,

$$I = \begin{cases} 0 & \text{for } V < V_f \\ \frac{V - V_f}{r_f} & \text{for } V > V_f \end{cases}$$

So, we can represent a diode in piecewise linear model as,



we know that,

$$\text{slope} = \frac{1}{r_f}$$

or, $\frac{dI}{dV} = \frac{1}{r_f}$

$$r_f = \frac{dV}{dI} \quad \text{——} (1)$$

we have,

$$I = I_s(e^{V/nV_T} - 1)$$

$$I = I_s e^{V/nV_T} \quad (\because \text{neglecting } 1)$$

on differentiating w.r.t V.

$$\frac{dI}{dV} = I_s \cdot \frac{1}{nV_T} \cdot e^{\frac{V}{nV_T}} = \frac{I_s e^{\frac{V}{nV_T}}}{nV_T} = \frac{I}{nV_T}$$

$$\text{or, } \frac{dV}{dI} = \frac{nV_T}{I}$$

$$r_f = \frac{nV_T}{I}$$

Here, r_f = forward diode resistance or
air resistance or dynamic resistance

Also, from above fig;

$$V = Ir_f + V_f$$

$$\therefore V_f = V - Ir_f$$