12/07/21

BEEE (AIML-C)

Zener Diode :-

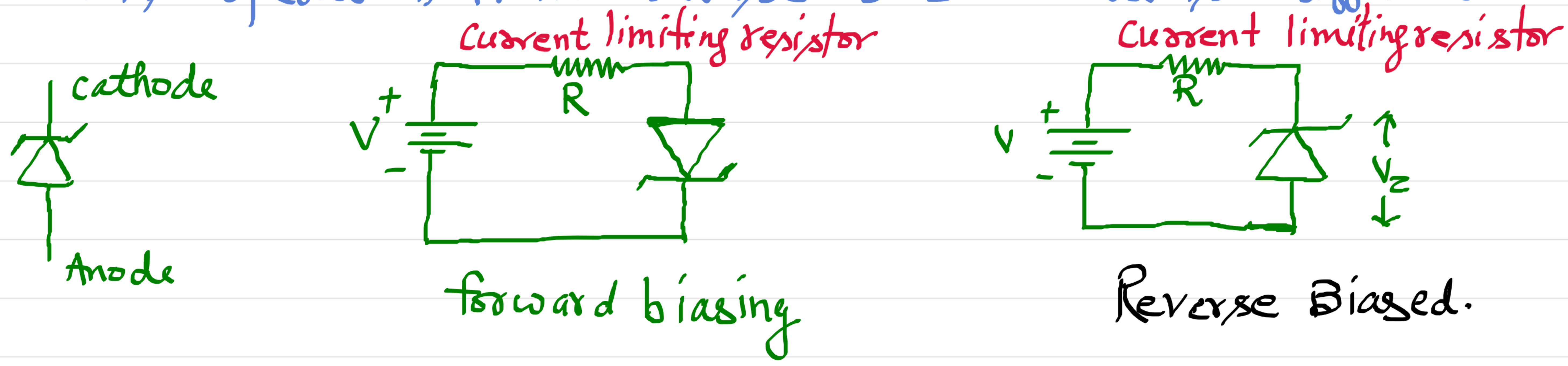
Topic :- Introduction, Breakdown mechanisms (Zener breakdown & Avalanche Breakdown) characteristics, Zener resistance, zener diode as voltage regulator.

Zener Diode :-

* Its construction is similar to p-n junction.
* At the time of construction the zener diodes, the reverse voltage is adjusted precisely b/w 3V to 200V.
* The doping level of the impurity added to manufacture the zener diode is controlled in order to adjust the precise value of break down voltage.

Operating Principle :-

A zener diode can be forward bias or reverse bias. Its operation in forward biased mode is same as that of p-n junction diode but its operation in the reverse biased mode is different.

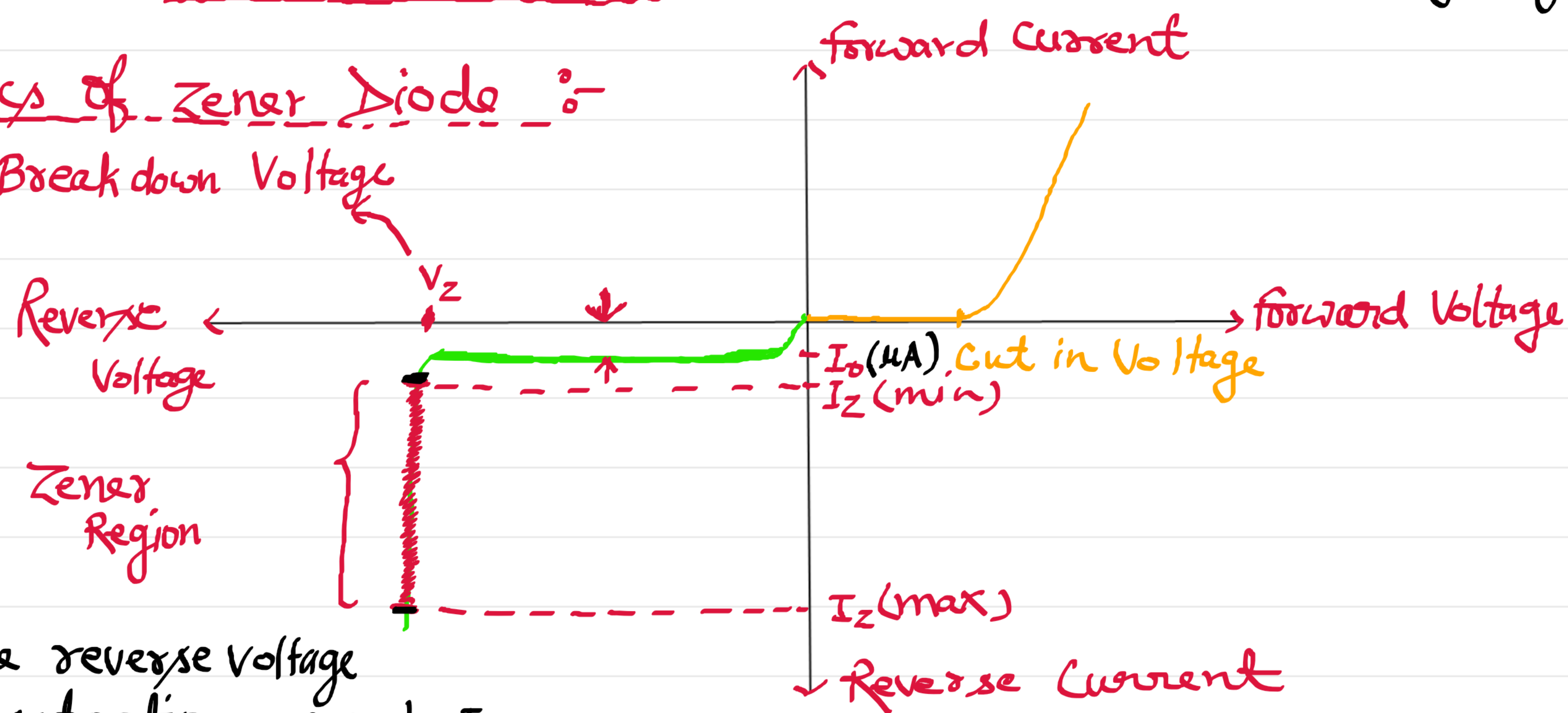


* Zener diode in the reverse biased mode is used as a voltage regulator

VI characteristics of Zener Diode :-

I_0 = Reverse saturation current.

V_Z = Breakdown Zener voltage



* As we increase the reverse voltage initially a reverse saturation current I_0 flow (in μA range). This current flows due to the minority charge carriers.
* At a certain voltage of reverse voltage, the reverse current increases suddenly and sharply. This is the indication of breakdown. This breakdown voltage is called as zener breakdown voltage or zener voltage (V_Z)

* This zener voltage can be controlled by controlling the doping level of p-n regions at the time of manufacturing.

* After breakdown, the voltage across zener diode remains constant equal to V_Z. Any increase in the source voltage will result in the increase of reverse zener current.

* The zener current after the reverse breakdown must be controlled by resistor R. This is essential to avoid any damage due to excessive heating.

Equivalent ckt of Zener Diode (When diode is in zener region) :-

* **Breakdown mechanism in zener diode :-**

* Zener Breakdown ($V_Z < 5V$ or $5 < V_Z < 8$)

* Avalanche Breakdown. ($V_Z > 8$ Volt)

Zener Breakdown :-

When a reverse voltage (5V or less) is applied to a zener diode, it causes a very intense electric field across the depletion region. Such a intense electric field is strong enough to pull some of the valence electrons into the conduction band by breaking their co-valent bonding. These electrons then becomes free electrons which are available for conduction.

A large no. of such free e^- will constitute a large reverse current through zener diode. This is known as zener breakdown.

In zener breakdown, the breakdown voltage depends on the tempr of p-n junction. The breakdown voltage decreases with increase in tempr.

Avalanche Breakdown in Zener diodes :-

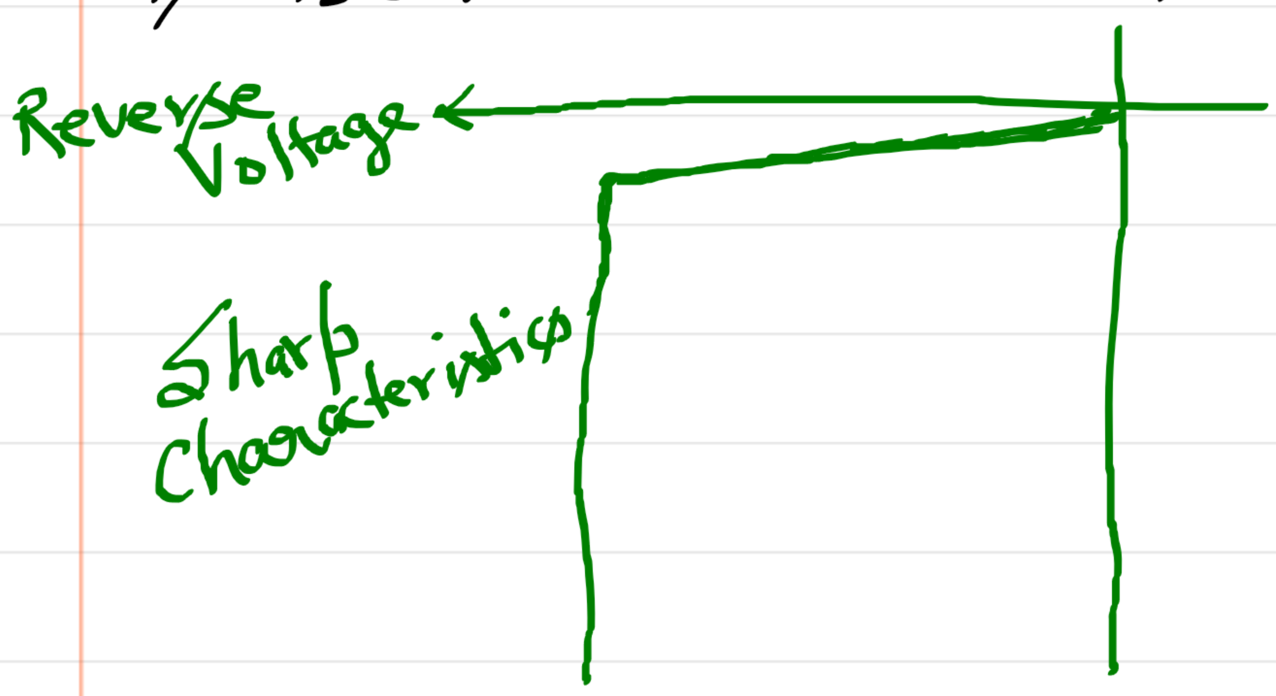
$V_Z > 8V$.

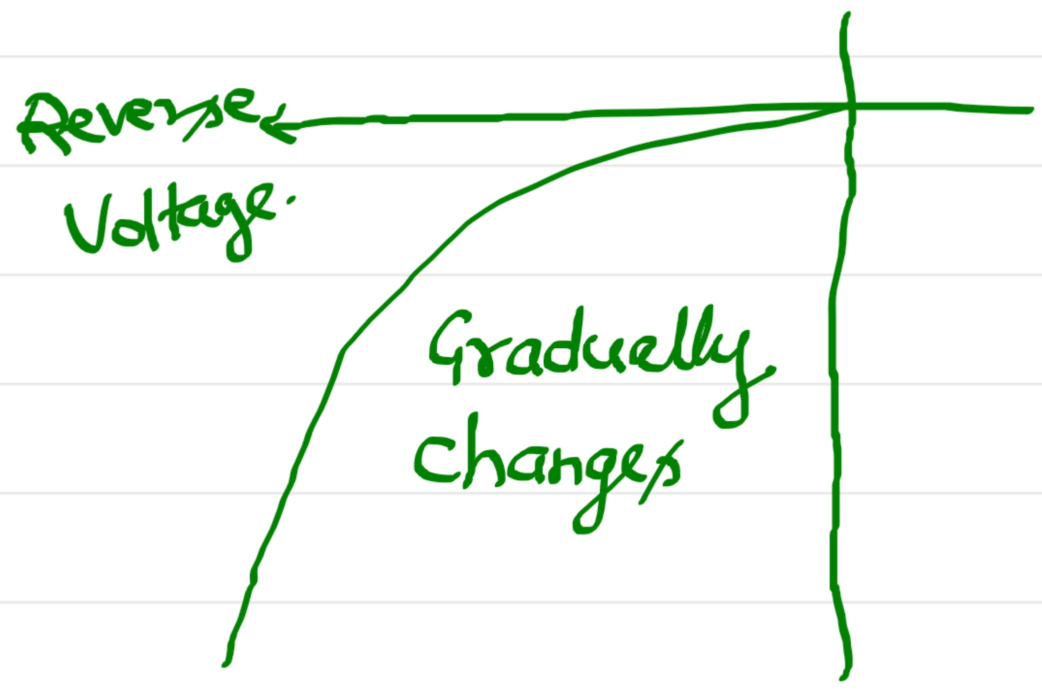
* In reverse biased condition, the conduction will take place due to minority charge chariers. As we increase the reverse voltage applied the zener diode, these minority carriers tend to accelerate. Therfore the kinetic energy associated with them increases.
* While travelling these accelerated minority carriers will collide with the stationary atoms and impart some of kinetic energy to valence electrons present in covelent bonds.

* Due to the additional acquired energy, these valence electrons will break their covalent bonds and jump into the conduction band to become free electron for conduction.

Now these newly generated e^- will be accelerated. They will knock out some more valence electrons by means of collisions. This phenomenon creates the carrier multiplication.

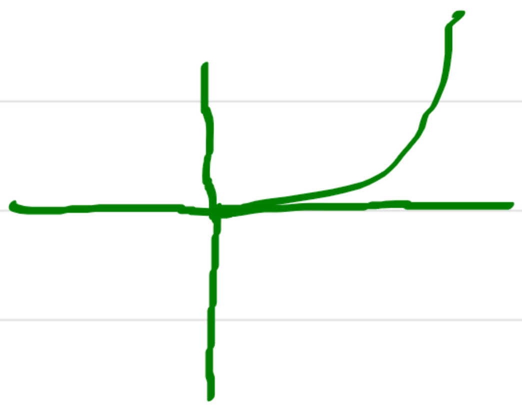
This is known as avalanche effect. A large reverse current starts flowing through zener diode and avalanche breakdown is said to have occured.





Q→ Comparison of Zener breakdown and Avalanche breakdown.

Q→ Comparison of Zener diode and p-n junction.

	Zener diode	p-n junction
1-		
2-	It operates in reverse biased mode.	It operates in forward biased mode.
3-		
4-	Voltage regulator, Voltage limiter etc.	Rectifiers, clipper, clamper, etc.

1- Dynamic resistance $\boxed{r_z = \frac{\Delta V_Z}{\Delta I_Z}}$

2- Zener Voltage (V_Z) :- It is the voltage across zener diode when it is biased to operate in zener region.

V_Z remains constant as long as zener region operate.

Typical values of V_Z are 3.1V, 4.7V, 5.1V, 9.1V, 12V, 15V, 18V etc.

3- Power dissipation (P_Z) :- $\boxed{P_Z = V_Z \times I_Z}$

max. power dissipation $P_{Z(max)} = V_Z \times I_{Z(max)}$

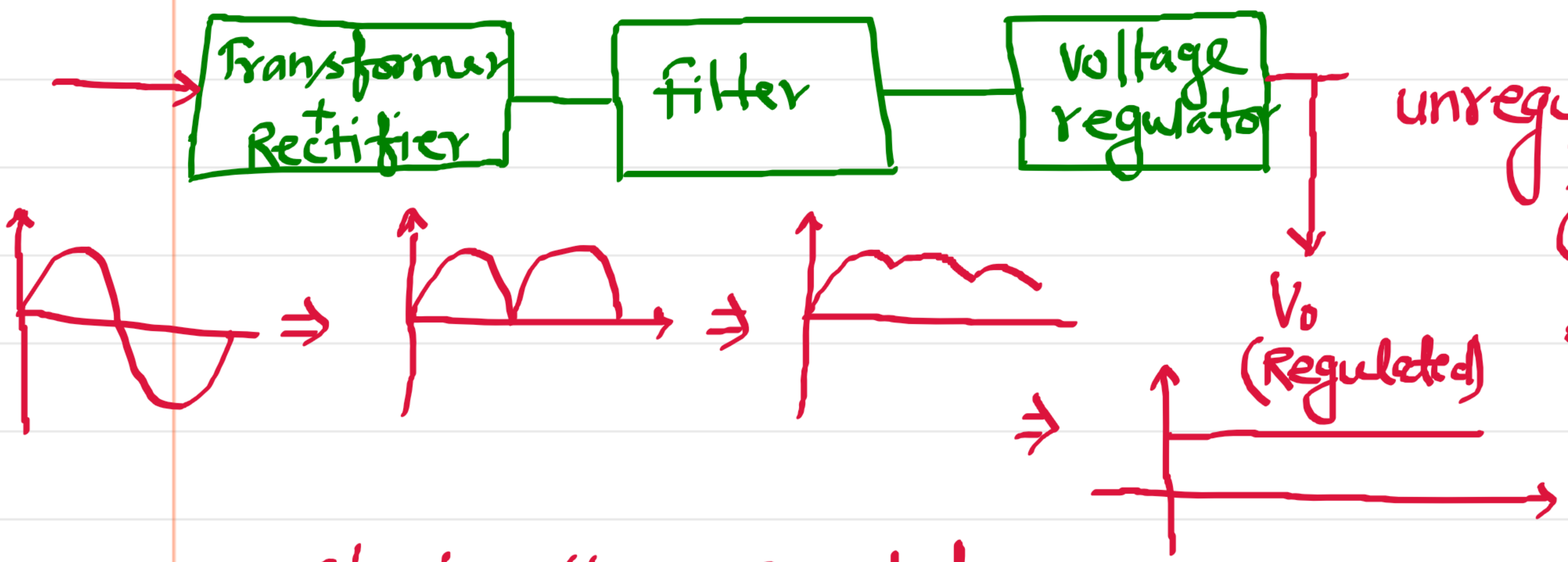
4- Maximum reverse current (I_Z max) :-

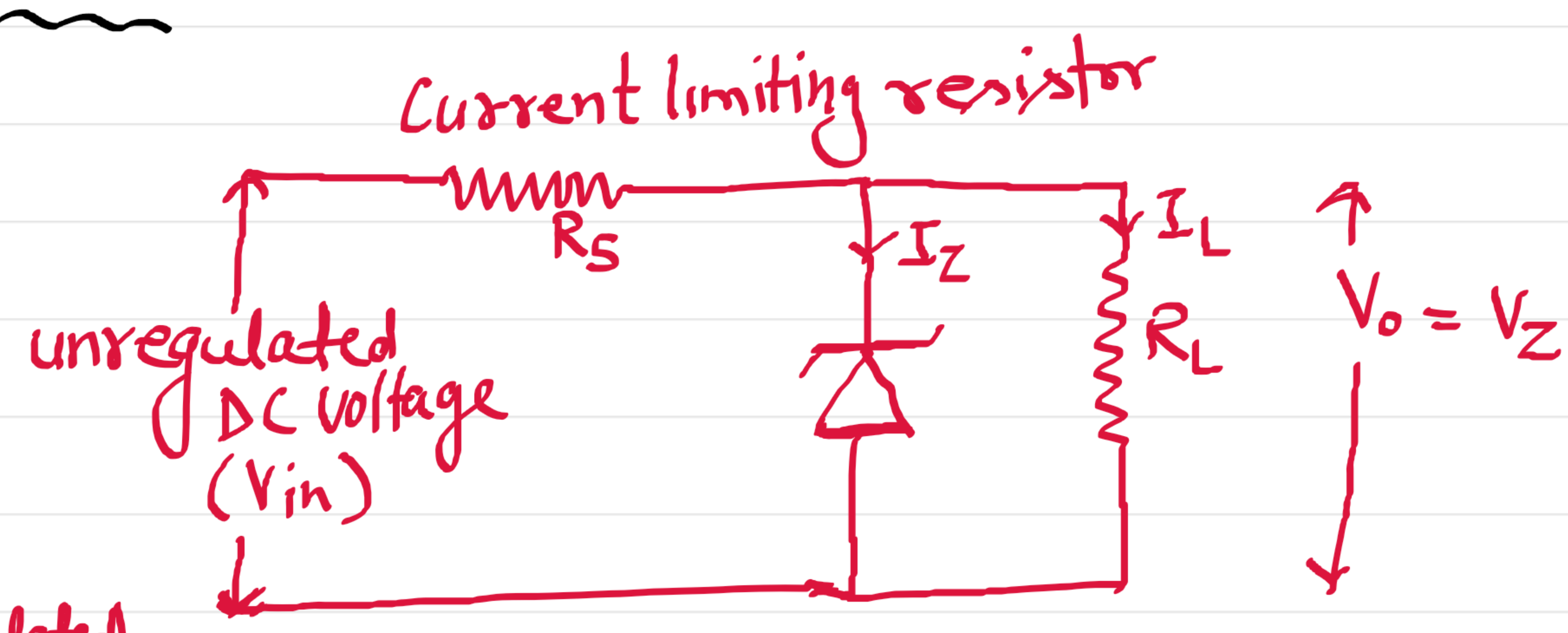
It is the maximum reverse current that can flow through a zener diode with damaging it due to excessive he

5- Minimum Zener Current ($I_{Z\,min}$) (Knee Current) (I_{ZK}) :-
It is the current flowing the diode at the point of reverse breakdown. It is beginning of zener region.

13/07/2021

Zener diode as Voltage regulator :-





⇒ Shunt Voltage Regulator.
⇒ Series voltage Regulator.

* Operation of Zener Regulator :-

1- The input voltage vin is an unregulated dc voltage which is obtained from rectifier and filter combination. R_S is current limiting resistor. R_L is load resistor. The input voltage V_{in} should be always higher than the V_Z.

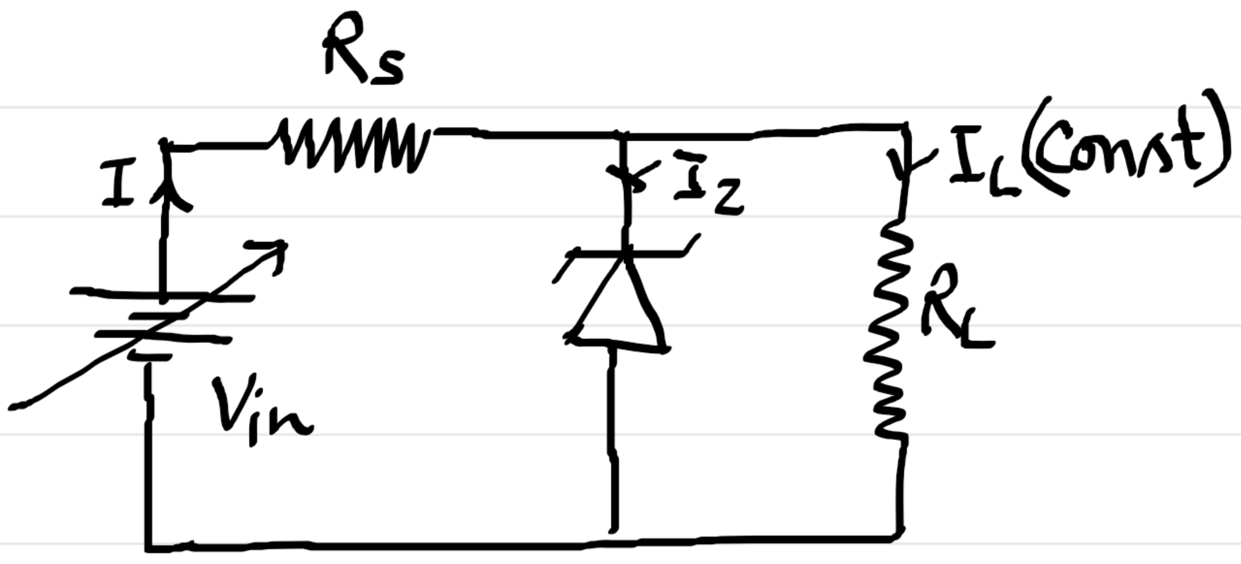
2- If V_{in} is higher than V_Z and I_Z is between $I_{Z\,min}$ and $I_{Z\,max}$ then voltage across the zener diode will remain constant equal to V_Z irrespective of any change in V_{in} and I_L.
As the output voltage is constant and equal to V_Z we get regulated output voltage.

3- I_Z should not be higher than $I_{Z(max)}$ otherwise excessive power dissipation will damage the zener diode.

4- I_Z should not be less than $I_{Z(min)}$ either because then the zener diode cannot operate in the zener region and can't maintain the constant voltage across it.

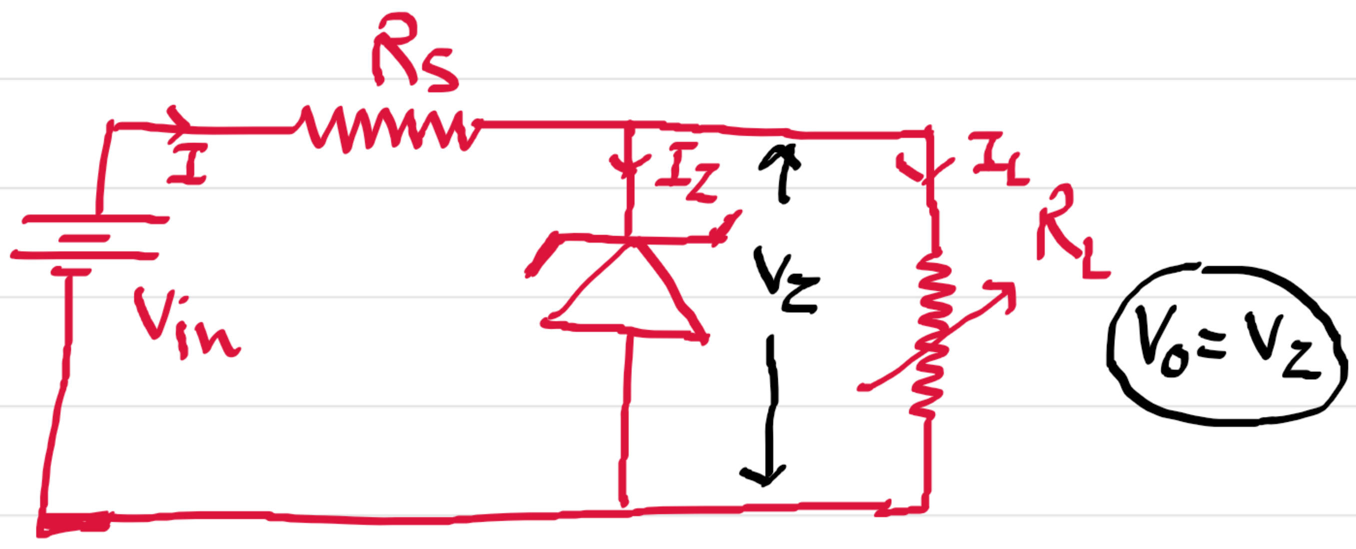
1- Regulating action with a varying input voltage (constant I_L) :-

If V_{in} increases
⇓
I increases
⇓
But I_L ⇒ const.
$I = I_Z + I_L$
so I_Z will increase
⇓
$I_Z < I_{Z(max)}$, then zener diode operates in zener region and output voltage remains const.



If V_{in} decreases
⇓
I decreases
⇓
I_L ⇒ Constant
$I = I_Z + I_L$
⇓
I_Z decrease
⇓
$I_Z > I_{Z(min)}$, then the zener diode operate in zener region and output voltage remains const.

2- Regulation Action with a varying load (V_{in} const)



if R_L increases

$\Downarrow$

I_L decreases

But I = Constant

$I = I_Z + I_L$

$I_Z = I - I_L$

hence I_Z increases

V_o = constant as long as $I_Z < I_Z(max)$

if R_L decreases

$\Downarrow$

I_L increase

But I = constant

$I = I_Z + I_L$

$I_Z = I - I_L$

hence I_Z will decrease

V_o = Constant as long as as $I_Z > I_Z(min)$

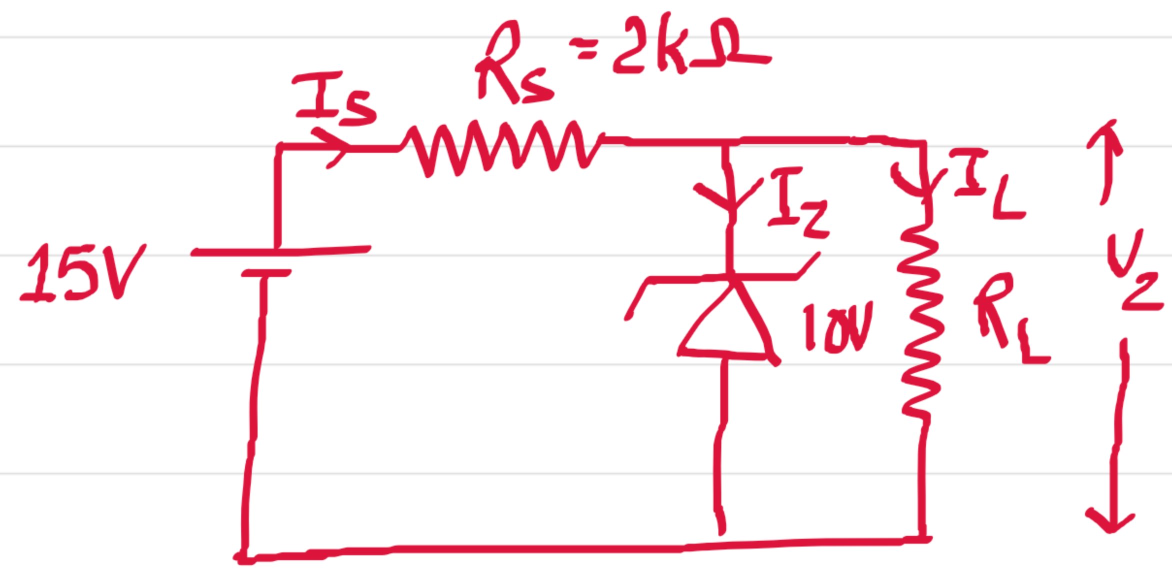
Limitations of Zener Diodes :-

1- Larger power dissipates across R_S.

2- The output voltage of zener regulator is equal to V_Z. This is a constant voltage. Due to this these voltage regulator cannot be made adjustable.

3- Corresponding to large change in the load current, there will be a large changes in zener current. This results in a large power wastage.

Numerical :- Calculate I_S, I_Z, I_L and P_Z.
(i) $R_L = 10\,k\Omega$ and (ii) $R_L = 2k\Omega$.



Soln :-

$$I_S = \frac{V_S - V_Z}{R_S}$$

$$= \frac{15 - 10}{2k\Omega} = 2.5 \times 10^{-3}\ \text{Amp}.$$

for $R_L = 10k\Omega$,

$$I_L = V_Z/R_L = \frac{10}{10k\Omega} = 1\ mA.$$

$$I_Z = I_S - I_L \Rightarrow 2.5 - 1 = 1.5\ mA.$$

for $R_L = 2k\Omega$, $I_L = V_Z/R_L = \frac{10}{2k\Omega} = 5 \times 10^{-3}$ Amp.

Power $P_Z = V_Z I_Z = 10\,V \times 1.5 \times 10^{-3}\,\text{Amp} = 15 \times 10^{-3}\,W$
$= 15\,W$.