Zener diodes

Zener diode is a special purpose diode used for. Voltage Regulation.

It is the diode formed by the heavily doped P and N type S/cs.

This diode can work in breakdown region and hence used for voltage Regulation

The breakdown occuring zener diodes is known as Zener Breakdown.

Mechanism :- As the P-N S/cs are heavily doped therefore the width of depletion region of the P-N junction will be less due to which the Electric field intensity in the layer becomes very high.

On increasing the reverse bias Voltage the electric field intensity in the depletion layer becomes so much high that it breaks the covalent bond of the ~~at~~ ions or atoms, thereby increasing the no. of free charge carriers and leads to increase in the current at random

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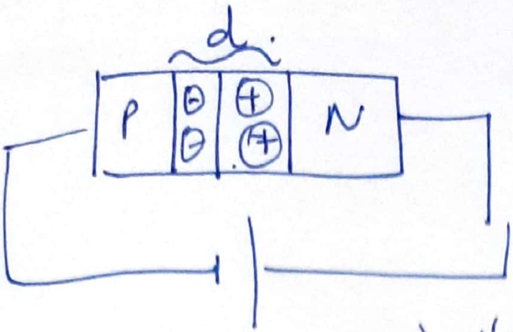
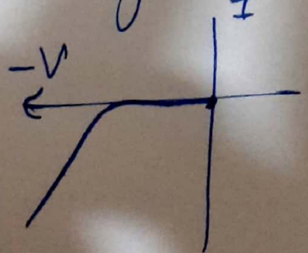
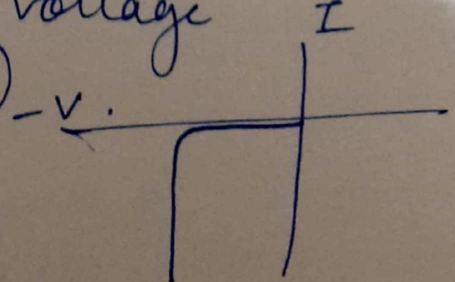


V_r.

'd' becomes very less.

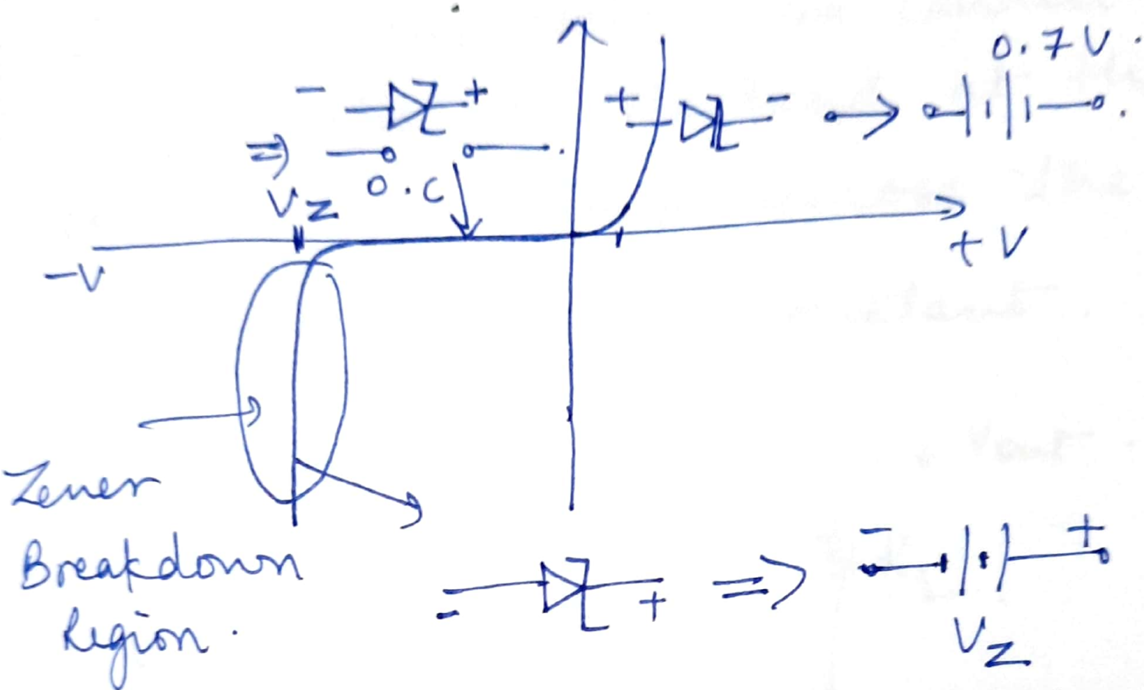
and $E = \frac{V_r}{d}$ becomes high

Difference B/w Avalanche and Zener Breakdown.

Avalanche	Zener.
1) Occurs in lightly doped diode	1) Occurs in heavily doped diode.
2) Mechanism is Collision.	2) Mechanism is high intensity electric field.
3) Shows positive temperature Coefficient	3) Shows negative temperature coefficient.
4) Occurs at higher Voltage	4) Occurs at lower voltage.
5) 	5) 

V-I Characteristics And Equivalent of Zener Diode

Symbol → P N.



① when we forward bias the diode, it will behave like normal diode and replace by a battery of 0.7V.

② when we Reverse bias the diode but gives less than Vz voltage, it will just open circuit.

③. As we give Vz voltage, the voltage becomes const. and the current increases randomly. At This point the diode will behave like a constant voltage source of Magnitude Vz.

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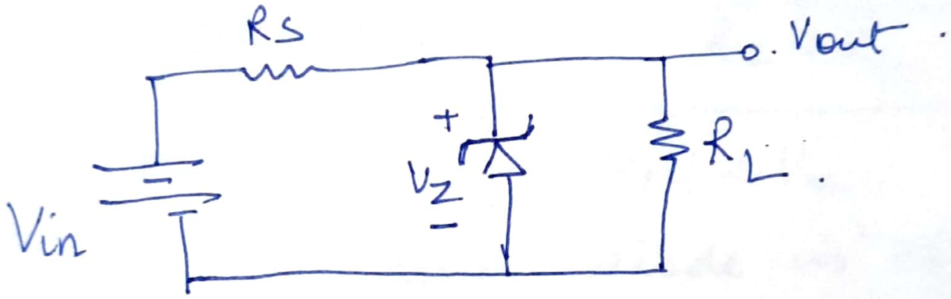
Zener Diode as "Voltage Regulator".

We have seen that when we give the voltage V_Z to the diode in reverse-bias condition, the diode will behave like a constant voltage source. Thus when we connect it in parallel to the load, at that point the voltage across the load will also becomes constant.



- The zener diode should always be connected in reverse bias.
- The diode will be 'ON' when the voltage across it becomes V_Z.
- When the diode becomes 'ON' the o/p voltage (Vout) will also becomes constant i.e $\boxed{V_{out} = V_Z}$
- Rs is connected in the circuit to limit the current in zener diode and to protect the diode.

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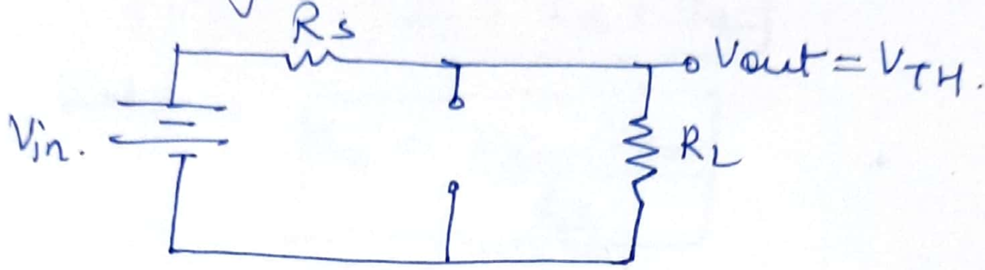
Case 1 :- When V_{in} and R_L both are fixed.

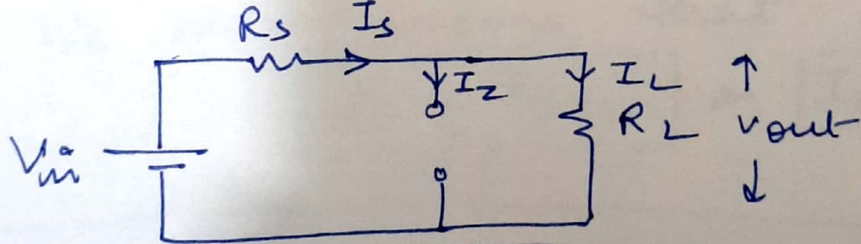
Sol^n **Step 1 :-** find out V_{out} without connecting zener diode in the circuit



$$\boxed{V_{TH} \begin{Bmatrix} V_{out} \text{ without} \\ \text{zener diode} \end{Bmatrix} = \frac{V_{in} \times R_L}{R_S + R_L}.}$$

Condition 1 : if $V_{TH} < V_Z$.

The zener diode is 'off' and it acts as an open circuit.



$$\boxed{\begin{aligned} V_{out} &= V_{TH}. \\ I_Z &= 0 \\ I_S = I_L &= \frac{V_{out}}{R_L}. \end{aligned}}$$

Condition 2 :- if $V_{TH} \geq V_Z$.

The Zener diode is 'ON'

The Diode is replaced by battery of voltage 'V_Z'.

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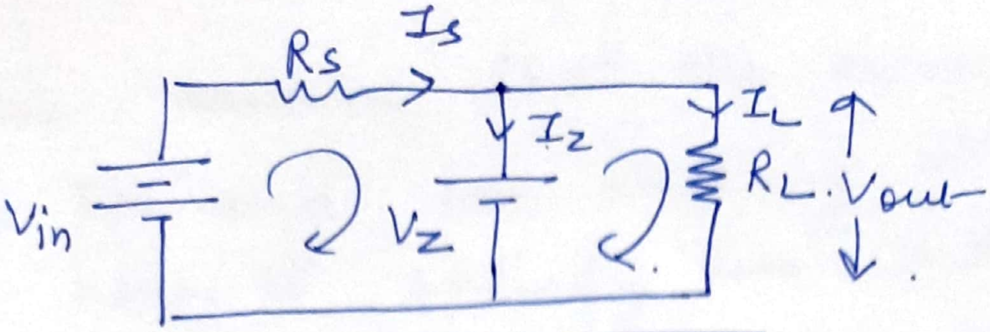


$$\boxed{V_{out} = V_z}$$

We have

$$\boxed{I_s = I_z + I_L}$$

where.

$$\boxed{I_s = \frac{V_{in} - V_z}{R_s}}$$

$$\boxed{I_L = \frac{V_z}{R_L}}$$

$$\Rightarrow \quad I_z = I_s - I_L.$$

or

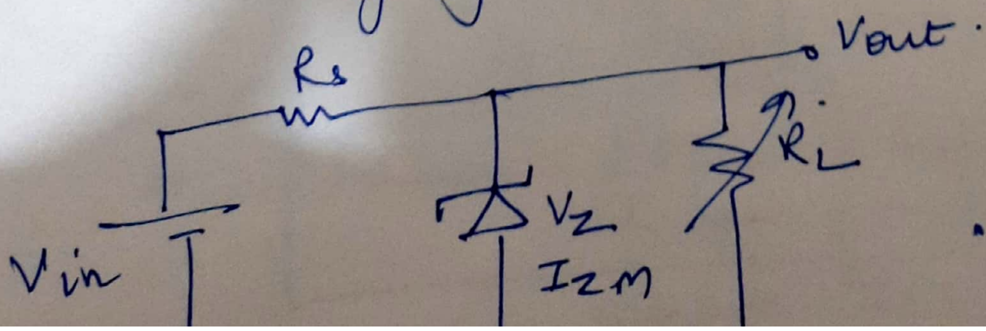
$$\boxed{I_z = \frac{V_{in} - V_z}{R_s} - \frac{V_z}{R_L}}$$

$$\boxed{P_z = V_z I_z}$$

We must ensure that.

$$\boxed{P_z \leq P_{zm}.} \quad \text{or} \quad \boxed{I_z \leq I_{zM}}$$

<u>Case II</u> :- V_{in} is fixed, R_L is varying



We assume that the zener diode is 'ON' and for making it 'ON' we have to satisfy two conditions i.e $\underline{V_Z}$ (minimum voltage across the diode so that the diode is 'ON').

and $\underline{I_{ZM}}$ (The maximum current which could flow through the diode).

Here, since R_L is varying, then the load current (I_L) will also be varying as the O/P voltage is fixed.

i.e $$I_L = \frac{V_Z}{R_L} \Rightarrow I_{L\,max} = \frac{V_Z}{R_{L\,min}}$$

$$\text{and } I_{L\,min} = \frac{V_Z}{R_{L\,max}}.$$

Since V_{in}, R_s and V_z are fixed.

Thus. I_s is constant

$\Rightarrow \downarrow I_Z = I_s - I_L \uparrow$. (Thus we have to find out the range of R_L).

or $I_{Z\,min} = I_s - I_{L\,max}$.

and $I_{Z\,max} = I_s - I_{L\,min}$

$$\Rightarrow \boxed{I_{L\,min} = I_s - I_{ZM}} \text{ --- } (1)$$

$$\text{or } \boxed{R_{L\,max} = \frac{V_Z}{I_{L\,min}}} \text{ --- } (2).$$

where $\boxed{I_s = \frac{V_{in} - V_Z}{R_s}}$

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$R_{L\,min}$

The minimum voltage of V_{TH} should be V_Z so that the diode is 'ON'

$\Rightarrow$ or by default $I_{Z\,min} = 0$.

$$\Rightarrow \quad I_{Z\,min} = I_S - I_{L\,max}.$$

$$\Rightarrow \quad I_{L\,max} = I_S - 0 = I_S.$$

or

$$\boxed{R_{L\,min} = \frac{V_Z}{I_{L\,max}}}$$

Case III :- V_{in} is varying, R_L is fixed.

In this case also we assume the diode is 'ON' and for making it 'ON', we have to find out the range of Vin.

For V_{in} (min) we have.

$$I_S = I_L + I_Z$$

here $I_L = \frac{V_Z}{R_L}$ is fixed.

I_S is varying and hence I_Z is varying.

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$\Rightarrow \quad I_{s\,min} = I_{z\,min} + I_L.$

by default $I_{z\,min} = 0.$

$\Rightarrow \quad I_{s\,min} = I_L = \frac{V_z}{R_L}$

or $\quad \frac{V_{in\,min} - V_z}{R_s} = \frac{V_z}{R_L}$

or $\quad V_{in\,min} = \frac{V_z R_s + V_z R_L}{R_L}.$

$$\boxed{V_{in\,min} = V_z \left(\frac{R_s + R_L}{R_L}\right).}$$

For $\underline{V_{in\,max}}$

$I_{s\,max} = I_L + I_{z\,max}$

$\Rightarrow \quad I_{s\,max} = \frac{V_z}{R_L} + I_{zM}.$

or $\quad \frac{V_{in\,max} - V_z}{R_s} = \frac{V_z}{R_L} + I_{zm}.$

or
$$\boxed{V_{in\,max} = \left(\frac{V_z}{R_L} + I_{zM}\right) R_s + V_z}$$

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