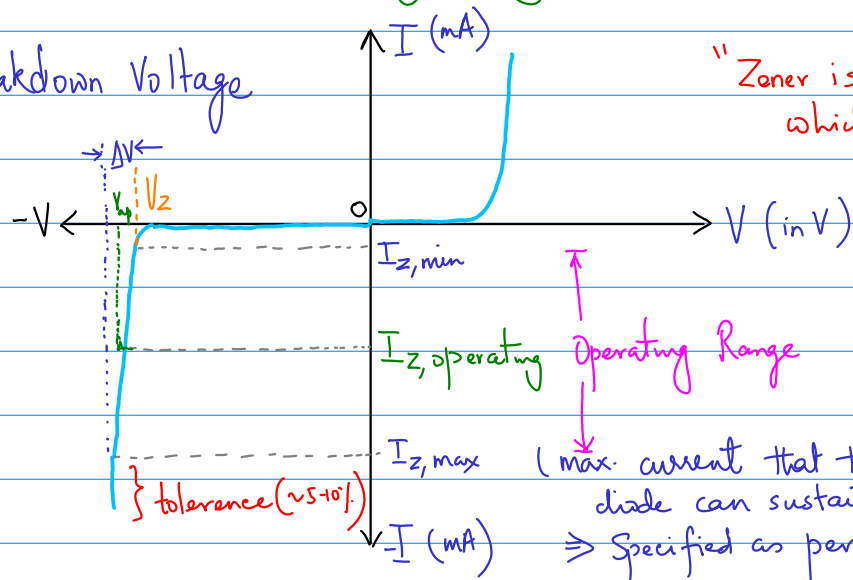


Zener Diode : Voltage Regulation

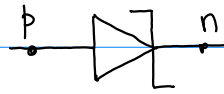
V_Z : Zener Breakdown Voltage



"Zener is a special diode which is operated in reverse bias!"

(max. current that the given Zener diode can sustain w/o burning)
 \Rightarrow Specified as per power rating

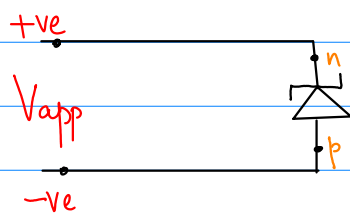
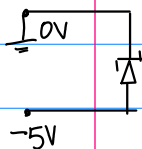
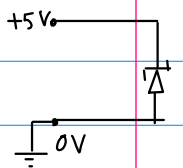
Circuit Model of a Zener Diode in Reverse-Bias :



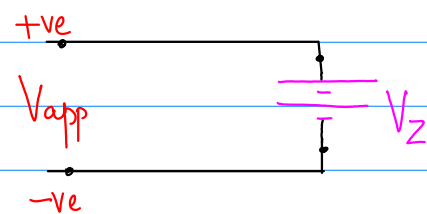
Circuit Symbol.

(i) Zener in ON-state : $V_{app} \geq V_Z$ (Breakdown voltage of the Zener Diode)

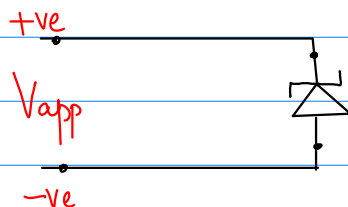
Reverse Bias



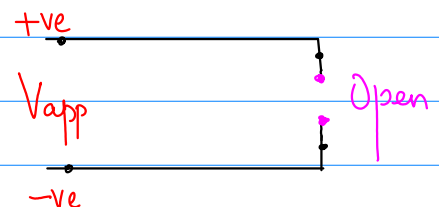
$$V_{app} \geq V_Z \Rightarrow$$



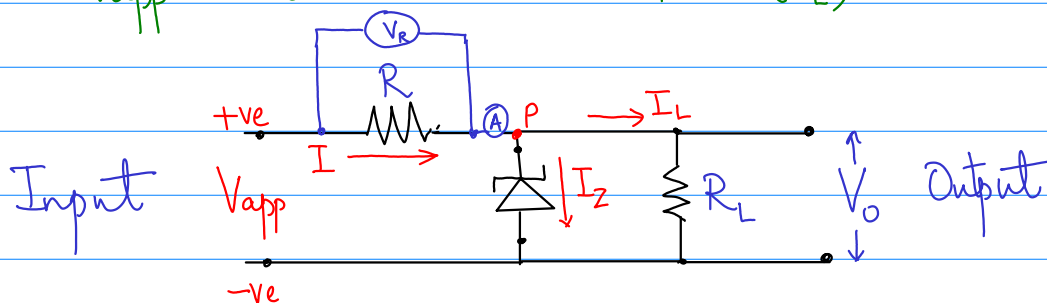
(ii) Zener in OFF-state : $0 < V_{app} < V_Z$



$$0 < V_{app} < V_Z \Rightarrow$$



① V_{app} and the load resistance (R_L) are constant:



- Input Current through the resistor R

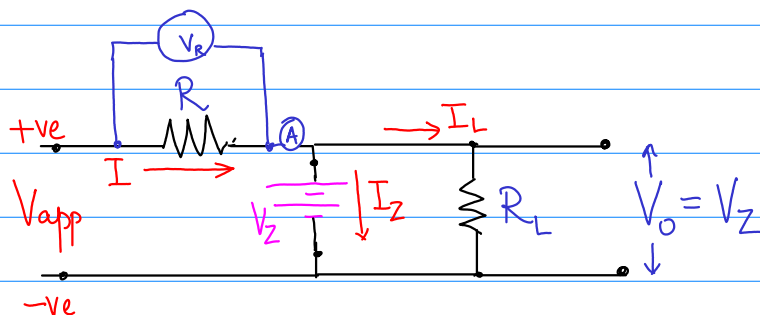
$$I = I_Z + I_L \quad \text{-----} \textcircled{1}$$

- Voltage drop across ' R ': $V_R = V_{app} - V_o \quad \text{-----} \textcircled{2}$

- The value of resistance $R = \frac{V_{app} - V_o}{I_Z + I_L} \quad \text{----} \textcircled{3}$

Note: When we design the ckt properly, the load voltage (V_o) remains essentially constant (equal to V_Z) even though ^{either} input voltage V_{app} or the load resistance ' R_L ' may vary over a wide range.

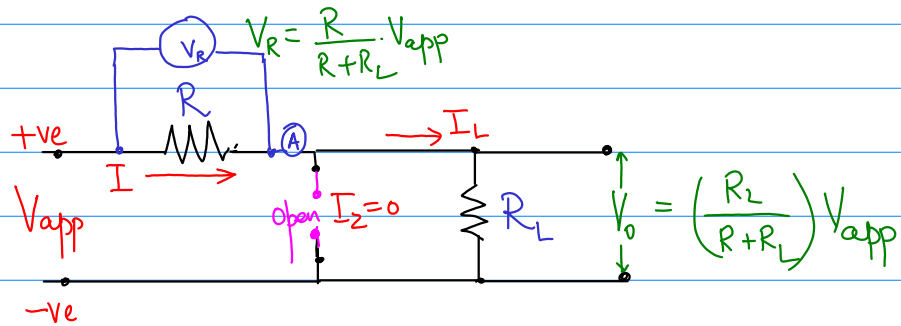
Case(i): $V_{app} \geq V_Z$ (ie, Zener is 'ON')



$$(a) \quad I_Z = I - I_L \quad ; (b) \quad I_L = \frac{V_Z}{R_L}$$

$$(c) \quad \text{Power dissipated in Zener } P_Z = I_Z V_Z$$

Case (ii) $0 < V_{app} < V_Z$ (Zener is "OFF-state")



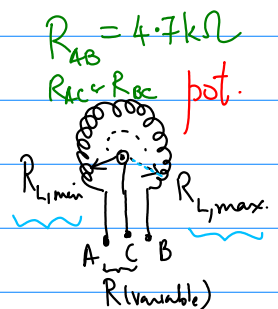
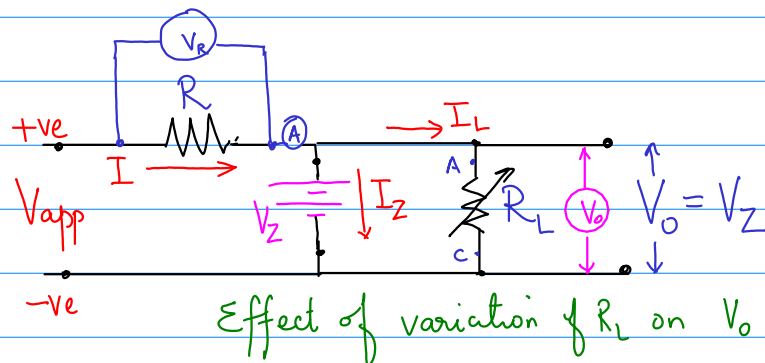
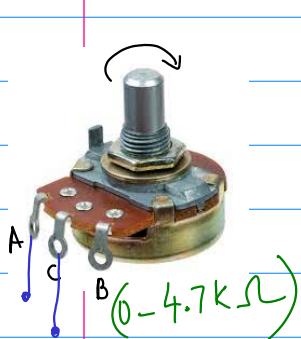
- $I_Z = 0$
 $\Rightarrow I = I_L$

- $V_R = IR$; $V_o = \left[\frac{R_L}{R_L + R} \right] \cdot V_{app}$

- $P_Z = 0$ (since $I_Z = 0$)

② Load Regulation : V_{app} is fixed but R_L is variable

Case (i) : $V_{app} \geq V_Z$ (Zener is 'ON') ($R_{L,min}$ to $R_{L,max}$)



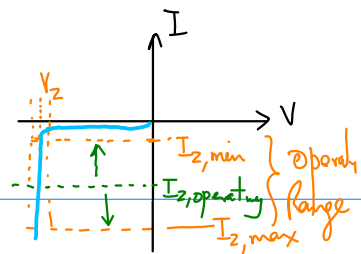
- Input Current $I = \underline{I_Z + I_L} = \text{Constant}$

- $V_o = V_Z = \text{Constant}$

- Here, we are going to vary R_L b/w $R_{L,min}$ to $R_{L,max}$.

- We, know that for $R_{L,min}$; $I_{L,max}$.

Since, $I = I_Z \downarrow + I_L \uparrow = \text{Constant}$
 Input current remains constant



- Similarly ; for $R_{L,max}$; $I_{L,min}$.

Since, $I = I_Z \uparrow + I_L \downarrow = \text{Constant}$

— Since Zener is behaving as a current compensating device when biased at breakdown voltage
 \Rightarrow Working as a voltage regulator

- $V_O = V_Z = \frac{R_L}{R_L + R} \cdot V_{app}$

- For $R_{L,min}$: $V_Z = \frac{R_{L,min}}{R_{L,min} + R} V_{app}$

10V ; $V_Z = 6.2V$
 $R = 100\Omega$

$$\underbrace{R_{L,min}} = \frac{R \cdot V_Z}{V_{app} - V_Z} ; \underbrace{I_{L,max}} = \frac{V_Z}{R_{L,min}}$$

- For $R_{L,max} \Rightarrow I_{L,min}$.

$$I = \underbrace{I_Z \uparrow}_{\text{circled}} + I_L \downarrow = \text{Constant}$$

$I_{ZM} = 50mA$

$\Rightarrow I_Z = I - I_L$

$\underbrace{I_{Z,max}} = I - I_{L,min}$

the min allowable current through the load resistance

$$I = I_Z + I_L$$

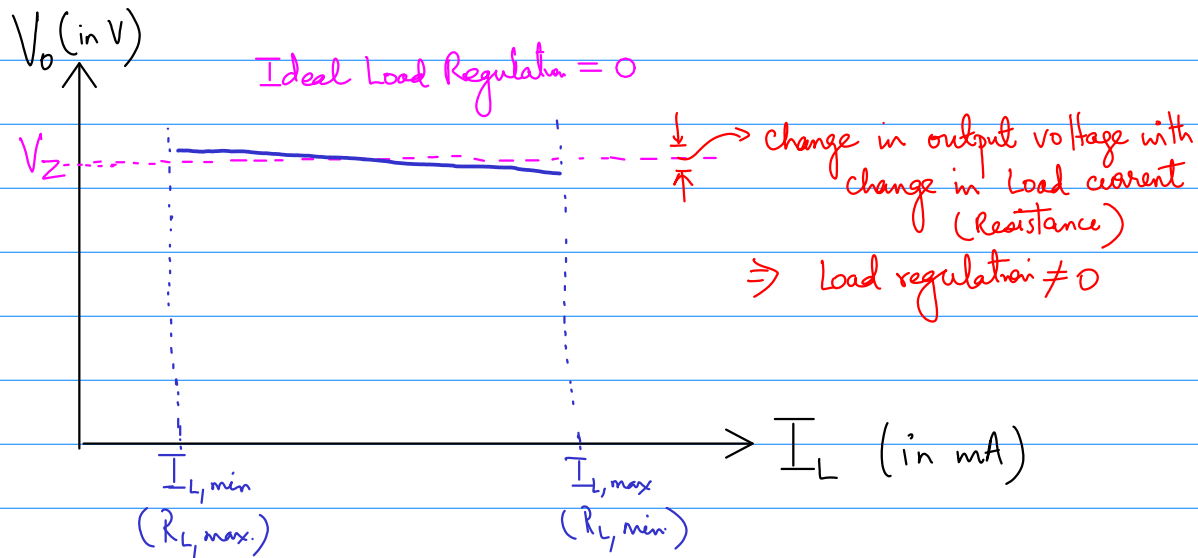
is given as:

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

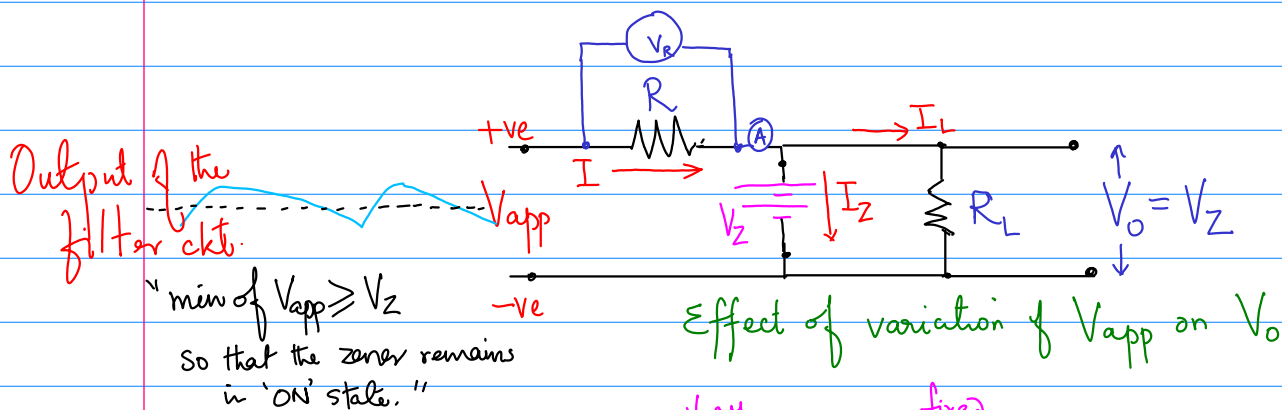
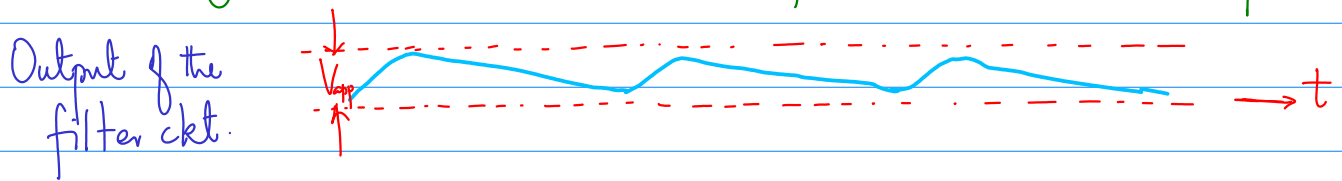
$$I_Z = I - I_L$$

Load is open
 $I_L = 0$

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



③ Line Regulation: Variable input voltage and fixed R_L



Input Current: $I = I_L + I_Z$

a) We are interested to determine the minimum applied voltage so that it keeps the Zener in 'ON' state.

$$V_Z = 6.2V$$

$$6V \leq \underline{V_{app}} < 6.5V$$

$$V_o = \underline{V_Z} = \frac{R_L}{R_L + R} \cdot V_{app, min}$$

$$V_{app, min} = \left(\frac{R + R_L}{R_L} \right) V_Z$$

This is the min. voltage applied to keep the zener diode in ON-state (at breakdown voltage)

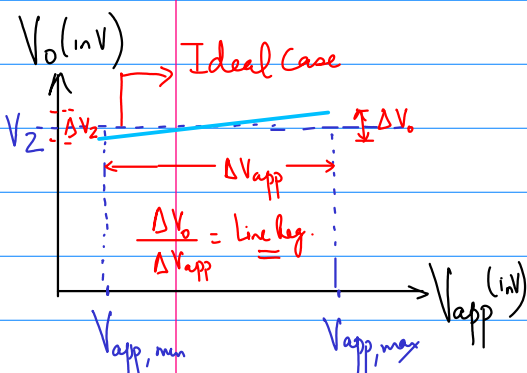
(ii) Since, $I \uparrow = I_Z \uparrow + \underbrace{I_L}_{\text{fixed}}$

$$\Rightarrow I_{max} = I_{Z, max} + I_L$$

Using KVL

$$V_{app} = IR + V_Z$$

$$V_{app, max} = I_{max} \cdot R + V_Z$$



$$V_{app, max} = \left(I_{Z, max} + I_L \right) R + V_Z$$