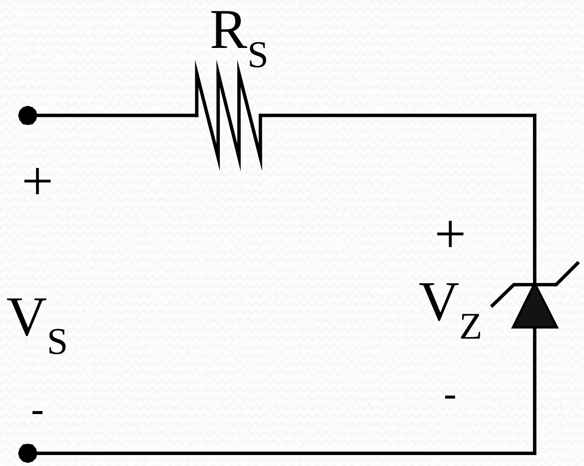
VOLTAGE REGULATOR

Voltage Regulator

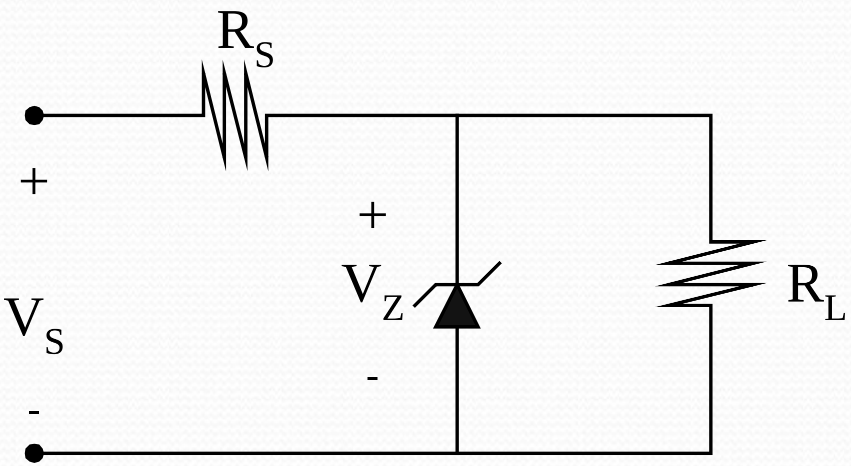
- **Zener diode is a voltage regulator device because it is able to fix the output voltage at a constant value (DC voltage).**

- **R_S is to limit the zener current, I_Z so that it is less than the maximum current, I_{ZM} (to avoid the zener diode from broken).**

Zener as Regulator



A simple regulator circuit



A regulator circuit with load resistance

Voltage Regulator

- **How to determine whether the zener acts as a regulator or not??**
  - **Use Thevenin Theorem**
  - **See example**

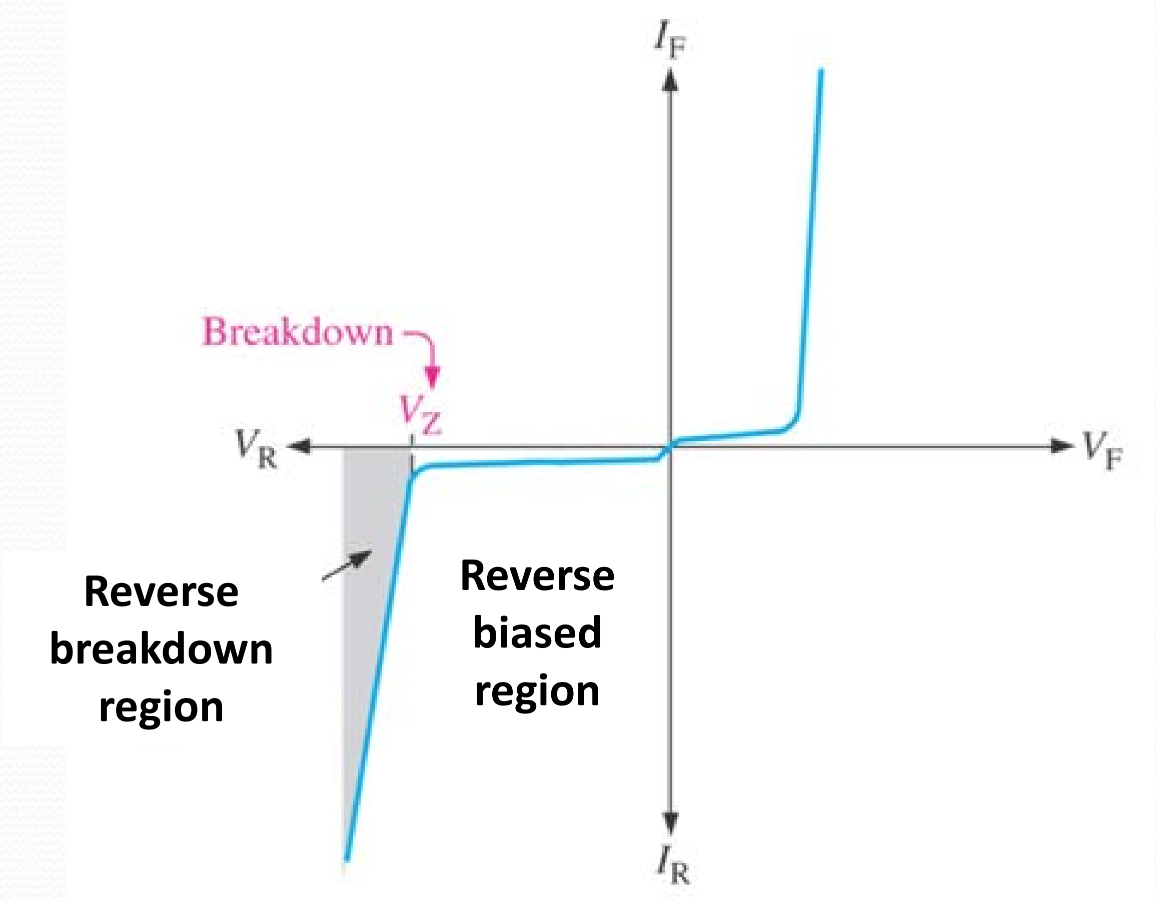
- **If $V_{TH}<V_Z$, regulation does not occur.**

Voltage Regulator....

- Referring to zener **I-V charateristic curve**, if the voltage across the zener diode zener is between **0-V_Z**, the zener diode is operating in the **reverse bias region**, thus it **DOES NOT** functioned as a regulator.

- V_{TH} must **at least** the **same value as V_Z** ($V_{TH} \geq V_Z$) so that the diode **CAN** function as a voltage regulator because it is operating in **reverse breakdown region.**

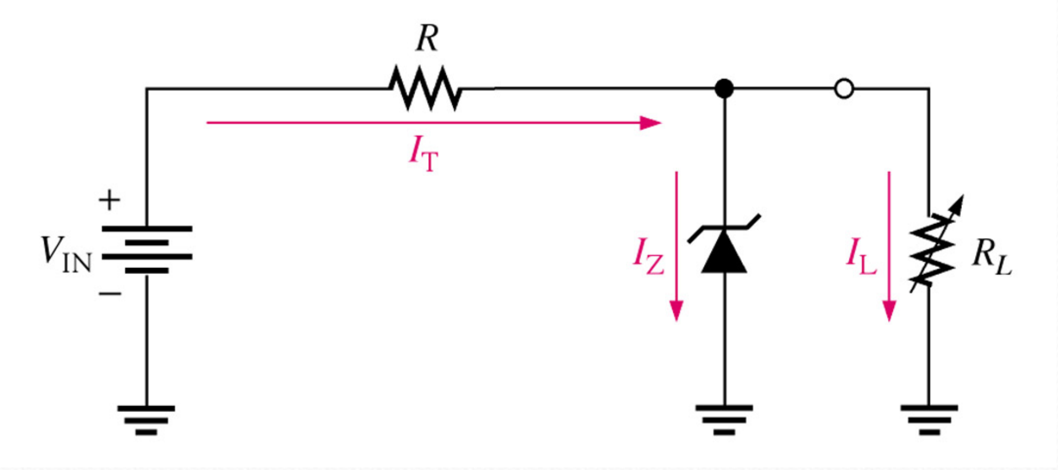
Zener I-V Charateristic



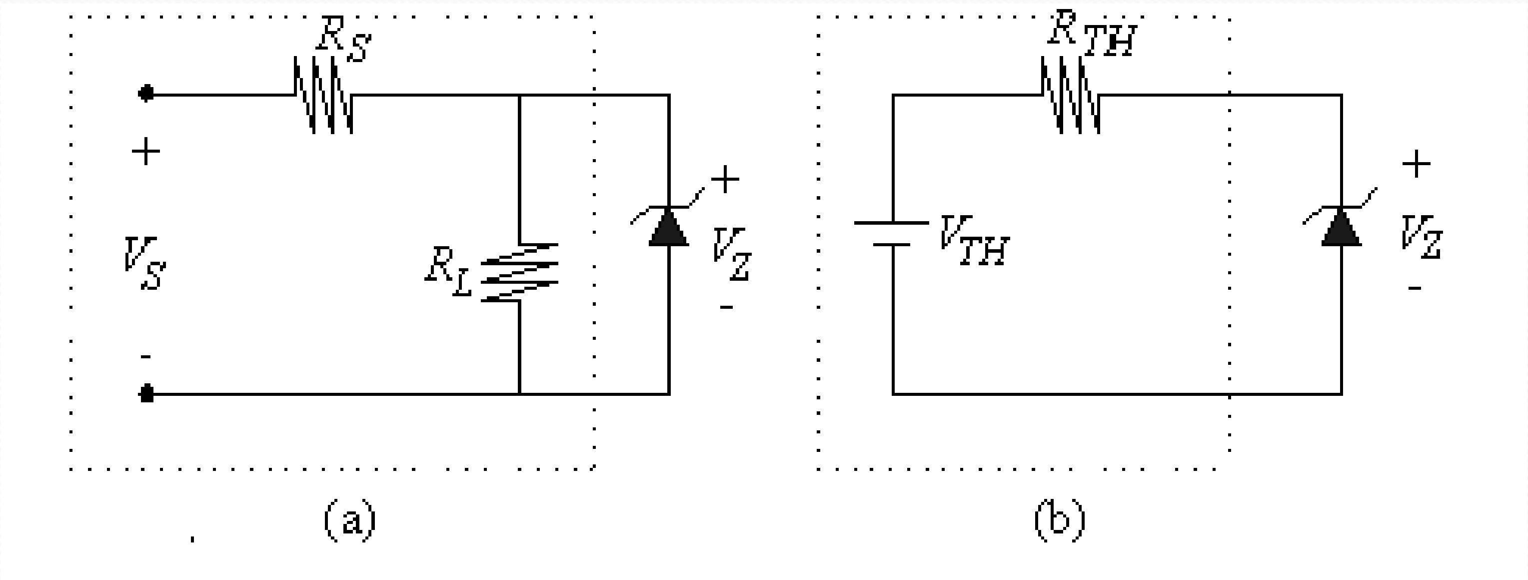
Zener Diode Regulator

In this simple illustration of zener regulation circuit, the zener diode will "adjust" its impedance based on varying input voltages and loads (R_L) to be able to maintain its designated zener voltage.

Zener current will increase or decrease directly with voltage input changes. The zener current will increase or decrease inversely with varying loads. Again, the zener has a finite range of operation.



Thevenin Equivalent Circuit



Examples of zener as voltage regulator

Cases in Zener Regulator Circuits

Zener Diode

- Three types of Zener analysis
  - Fixed V_S and R_L
  - Fixed V_S and variable R_L
  - Variable V_S and fixed R_L

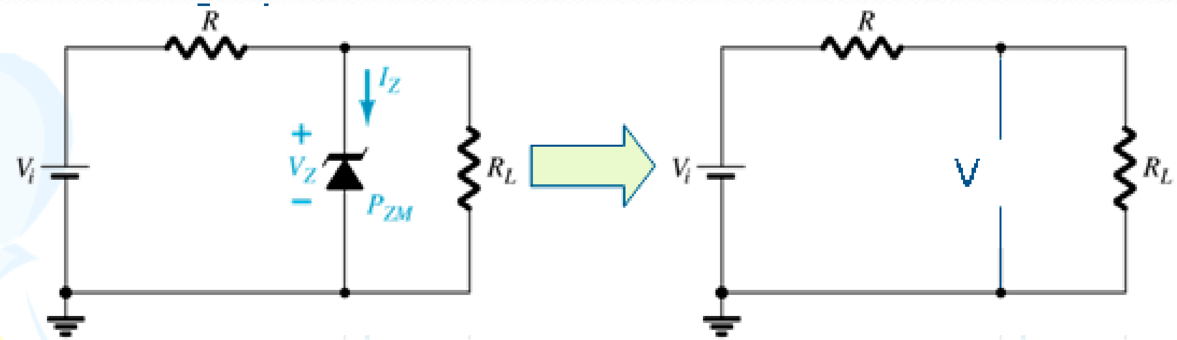
Zener Diode

- Fixed V_S and R_L

The applied dc voltage is fixed, as the load resistor.

The analysis :

1. Determine the state of the Zener diode by removing it from the network and calculating the voltage across the resulting open circuit.

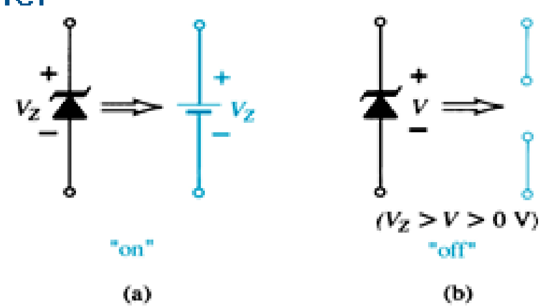


Calculate the V using voltage divider rule:

$$V = V_L = \frac{R_L V_i}{R_L + R}$$

if V ≥ Vz , the Zener diode is on

if V < Vz, the Zener diode is off



Zener Diode

2. Substitute the appropriate equivalent circuit and solve for the desired unknowns.

- For the on state diode, the voltages across parallel elements must be the same.

$$V_L = V_Z$$

The Zener diode current is determined by KCL:

$$I_Z = I_R - I_L$$

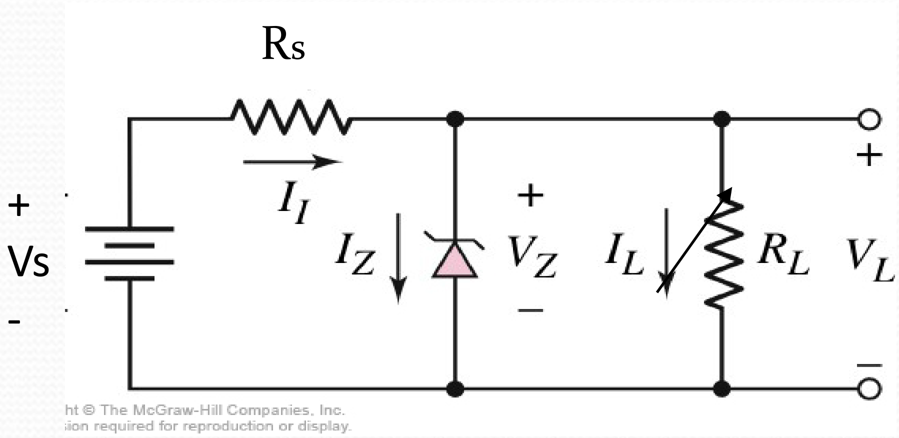
The power dissipated by the Zener diode is determined by:

$$P_Z = V_Z I_Z$$

- For the off state diode, the equivalent circuit is open-circuit.

Zener Diode

- Fixed V_S and Variable R_L



Step 1- get the R_{Lmin} so that zener is on.

$$V_L = \frac{R_L Vs}{R_S + R_L} \longrightarrow R_{L\min} = \frac{R_S V_Z}{V_S - V_Z}$$

- if $R_L \geq R_{Lmin}$, zener diode ‘on’, so that $V_L = V_Z$

Step 2: Calculate the I_Z using KCL: 2 condition

1. If R_{Lmin} , then I_{Lmax} and I_{Zmin} because of constant I_1
2. If R_{Lmax}, then I_{Lmin} and I_{Zmax}

Zener Diode

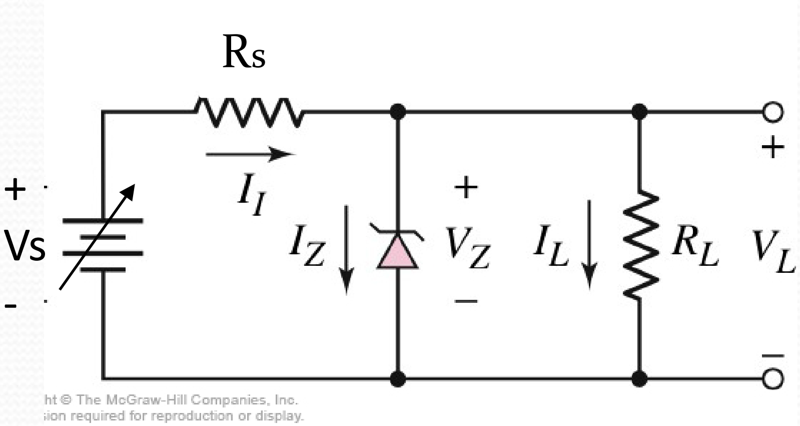
$$I_{Z\min or\max} = I_{1\text{constant}} - I_{L\max or\min}$$

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

$$I_1 = \frac{V_S - V_Z}{R_S}$$

Zener Diode

- Variable V_S and fixed R_L



Step 1- get the V_{Smin} so that zener is on.

$$V_L = \frac{R_L V s}{R_S + R_L} \longrightarrow V_{S\min} = \frac{(R_L + R_S) V_Z}{R_L}$$

if $V_S \geq V_{Smin}$, zener diode will 'on', so that $V_L = V_Z$

Step 2: Calculate the I_Z using KCL: 2 condition

1. if V_{Smin} , then I_{1min} and I_{Zmin} because of constant I_L
2. if V_{Smax}, thenI_{1max} and I_{Zmax}