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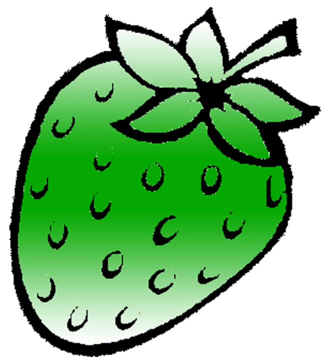

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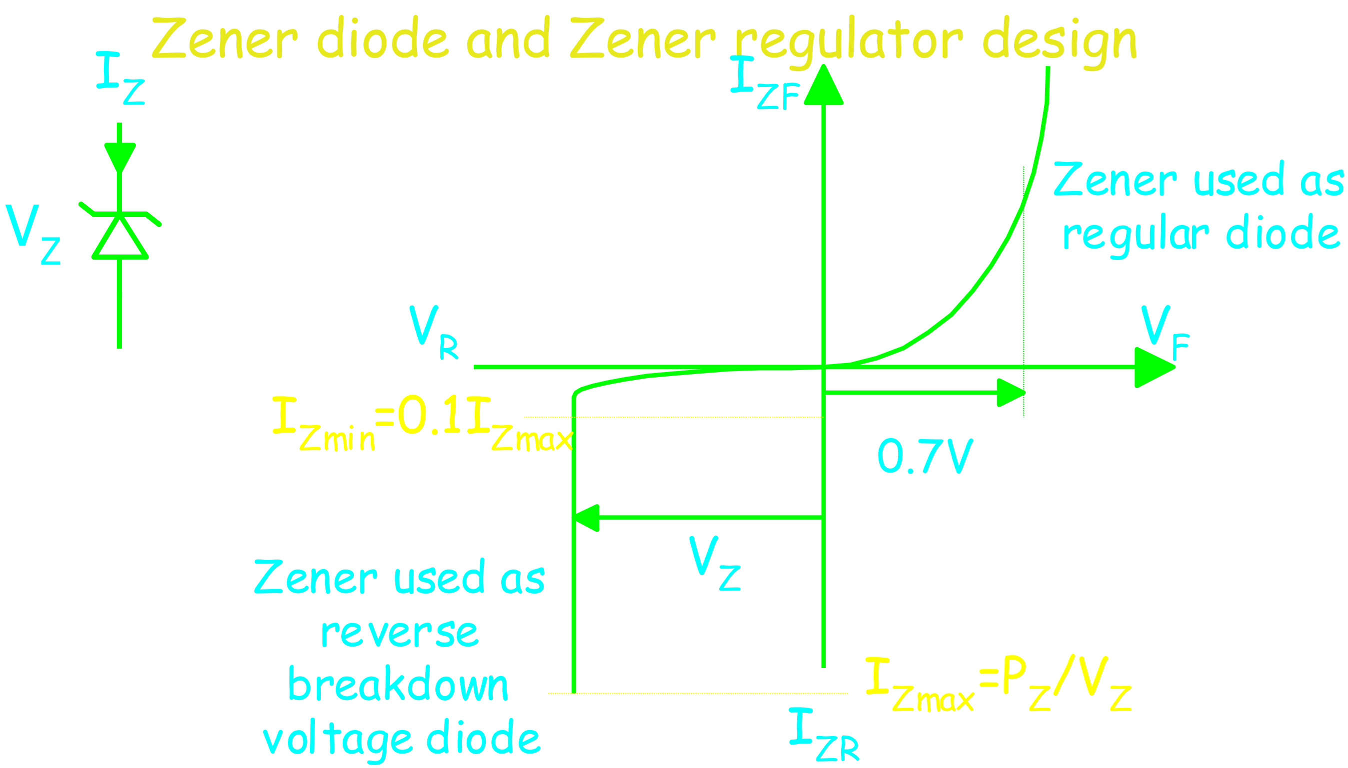
Zener Diode
and
Zener Voltage Regulator

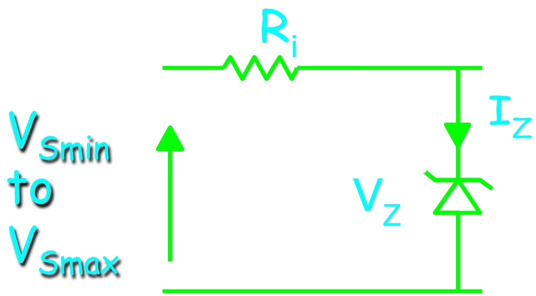
Function of Voltage Regulator

Regulated power supply = output dc is constant (stable) at different loads or at varying ac supply conditions

Zener diode



Zener diode design conditions



• Whether input voltage is V_{Smin} or V_{Smax} , the output voltage will be constant at Zener breakdown voltage V_Z

• Constant output voltage is the regulated output voltage and the circuit is Zener regulator circuit.

• Zener current will becomes less I_{Zmin} at V_{Smin} and it will increase to I_{Zmax} at V_{Smax}

• Minimum Zener current I_{Zmin} should not less than 10% I_{Zmax} to maintain constant V_Z

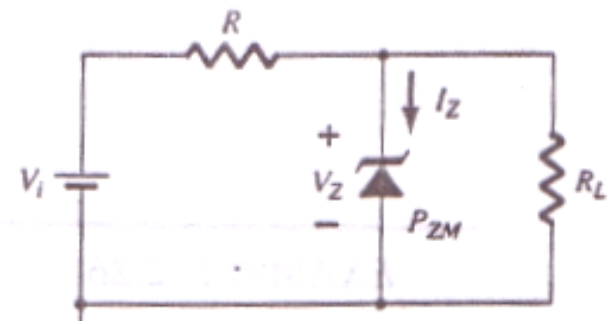
• Maximum Zener current I_{Zmax} should not more than P_Z/V_Z not to burn the Zener diode

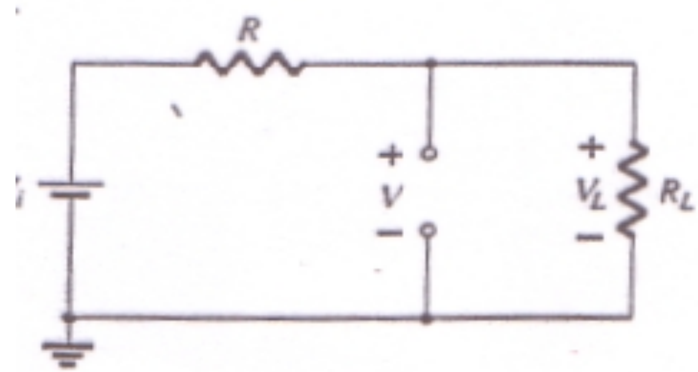
Basic Zener Regulator

- If V<Vz

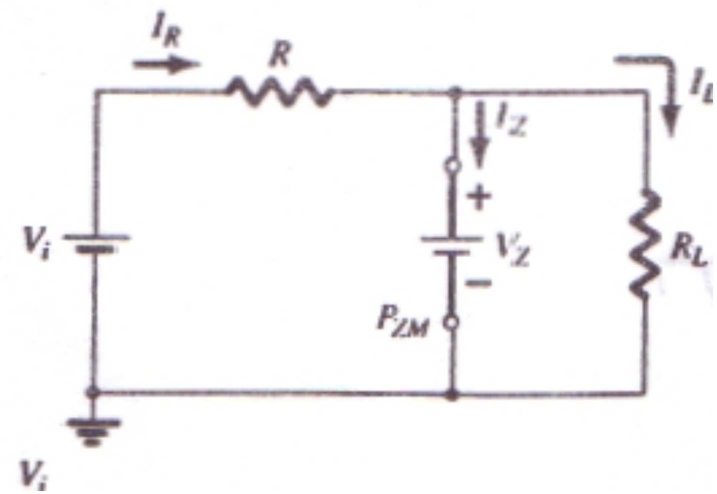
- The Zener diode is “off" else the Zener diode is “on"

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





- If $V > V_Z$
- If the Zener is on
- Then $V_L = V_Z$ (i.e the load voltage is held fixed ' LOCKED ' to the zener voltage Vz)
- $I_Z = I_R - I_L$

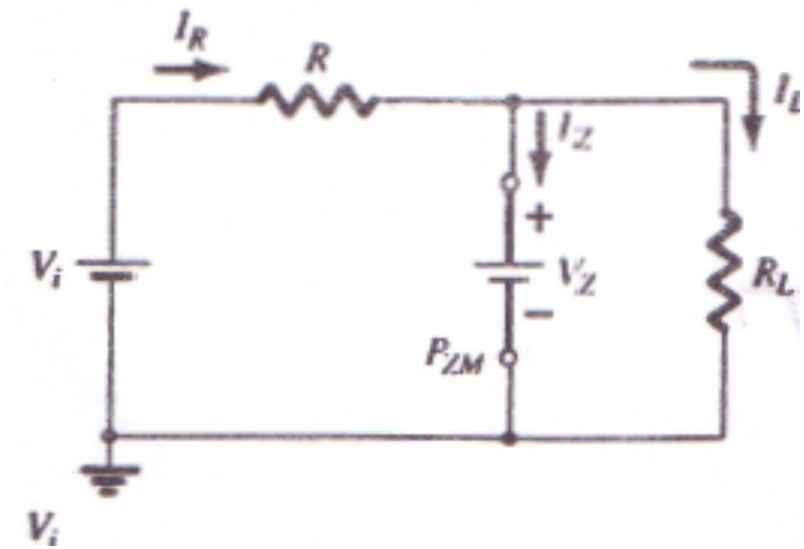


NOTE :

The maximum power dissipation for the zener diode is fixed and given by,

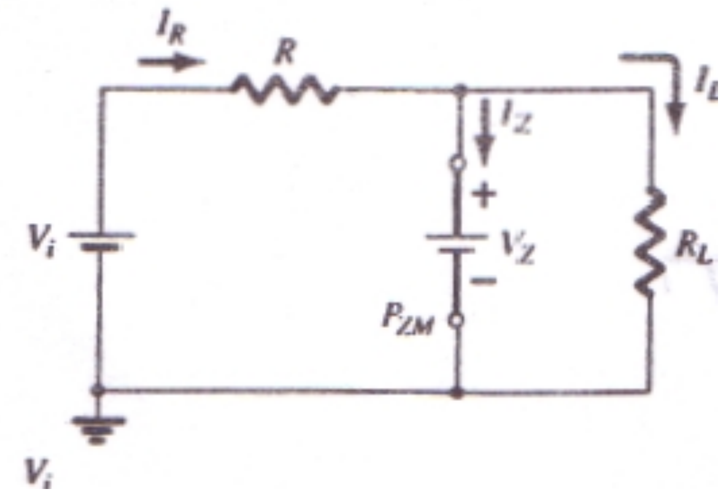
$$P_D = V_Z I_{Z\,max}$$

Working of Zener Regulator under varying Vin



V_{in} increases	→	$I = I_L + I_Z$ increases	→	I_L is constant (V_Z/R_L)	→	So I_Z increases ($I_Z = I - I_L$)	→	As long $I_Z < I_{Zmax}$, V_Z is constant i.e. output voltage is constant
V_{in} decreases	→	$I = I_L + I_Z$ decreases	→	I_L is constant (V_Z/R_L)	→	So I_Z decreases ($I_Z = I - I_L$)	→	As long $I_Z > I_{Zmin}$, V_Z is constant i.e. output voltage is constant

Working of Zener Regulator under varying Load (R_L)

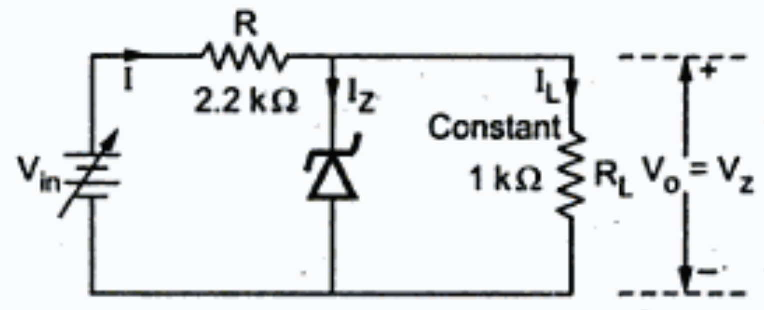


R_L increases I_L decreases	→	$I = \frac{V_{in} - V_Z}{R}$ constant	→	$I_Z = I - I_L$ increases	→	As long $I_Z < I_{Zmax}$, V_Z is constant i.e. output voltage is constant.
R_L decreases I_L increases	→	$I = \frac{V_{in} - V_Z}{R}$ constant	→	$I_Z = I - I_L$ decreases	→	As long $I_Z > I_{Zmin}$, V_Z is constant i.e. output voltage is constant.

Problem 1

For a zener regulator shown in the Fig. calculate the range of input voltage for which output will remain constant.

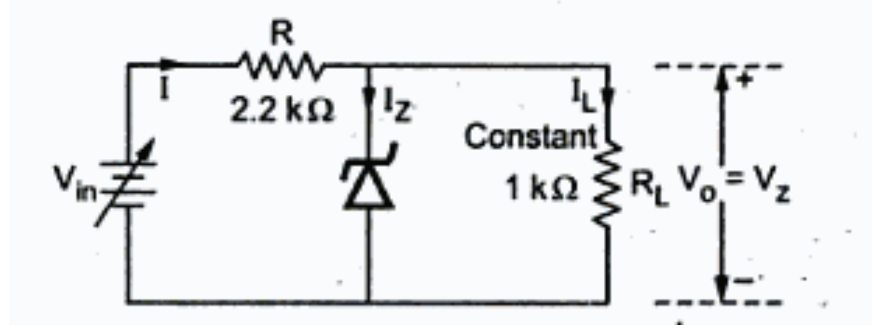
$V_Z = 6.1V,\ I_{Zmin} = 2.5\ mA,\ I_{Zmax} = 25\ mA,\ r_Z = 0\ \Omega$



$R_L = 1\ k\Omega,\ V_Z = 6.1\ V$

$$I_L = \frac{V_Z}{R_L} = \frac{6.1}{1\times 10^3} = 6.1\ \text{mA constant}$$

Solution Example 1



For $V_{in(min)}$, $I_Z = I_{Zmin} = 2.5$ mA

$I = I_{Zmin} + I_L = 2.5 + 6.1 = 8.6$ mA

$$V_{in(min)} = V_Z + IR = 6.1 + 8.6\times10^{-3}\times2.2\times10^{3} = 25.02 \text{ V}$$

For $V_{in(max)}$, $I_Z = I_{Zmax} = 25$ mA

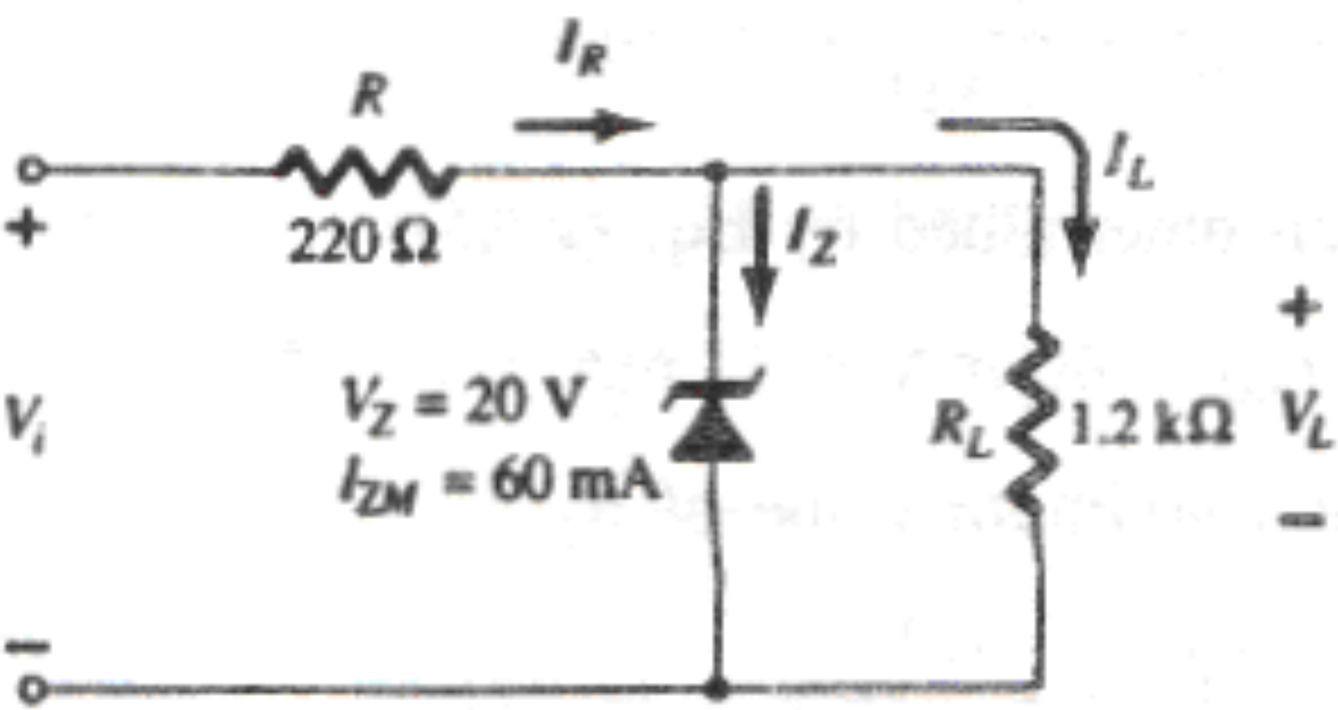
$I = I_{Zmax} + I_L = 25 + 6.1 = 31.1$ mA

$$\therefore \quad V_{in(max)} = V_Z + IR = 6.1 + 31.1\times10^{-3}\times2.2\times10^{3} = 74.52 \text{ V}$$

Thus the range of input voltage is **25.02 V** to **74.52 V**, for which output will be constant.

Example 2

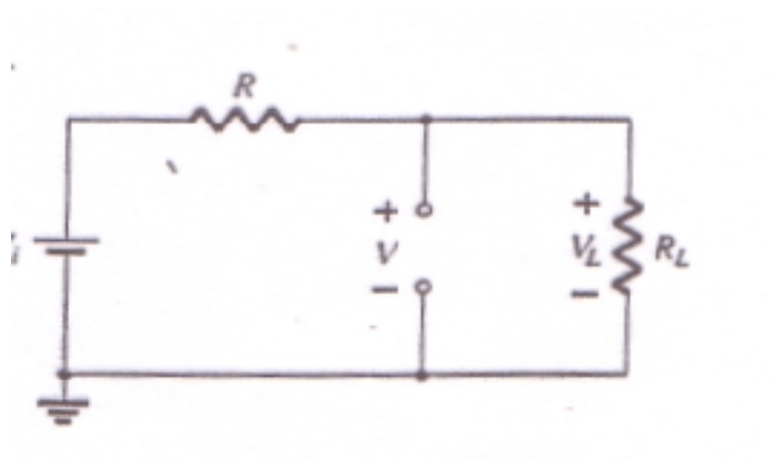
- Determine the range of values of Vi that will maintain the Zener diode in the "on" state



Solution - Example 2

If $V < V_z$ Zener diode is in Off state

By Voltage Divider Theorem



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

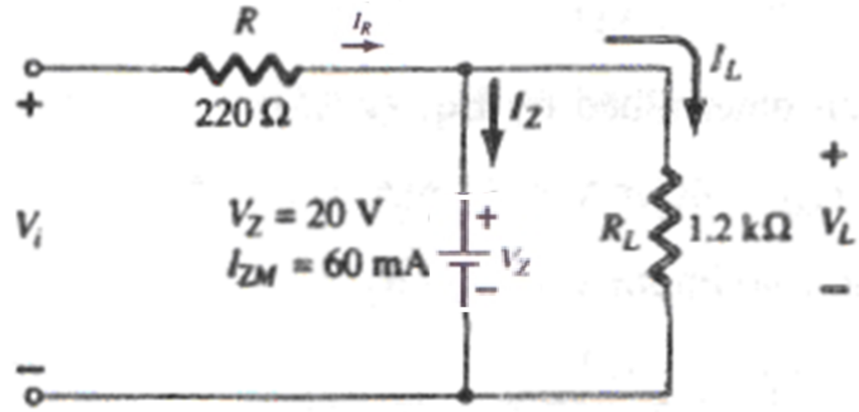
$$V_{i\min} = \frac{(R_L + R)V_Z}{R_L} = 23.67V$$

Solution (Example 2)

Iz = 60mA

VL = 20V

IL = VL / RL
= 20 / 1.2K
= 16.67mA

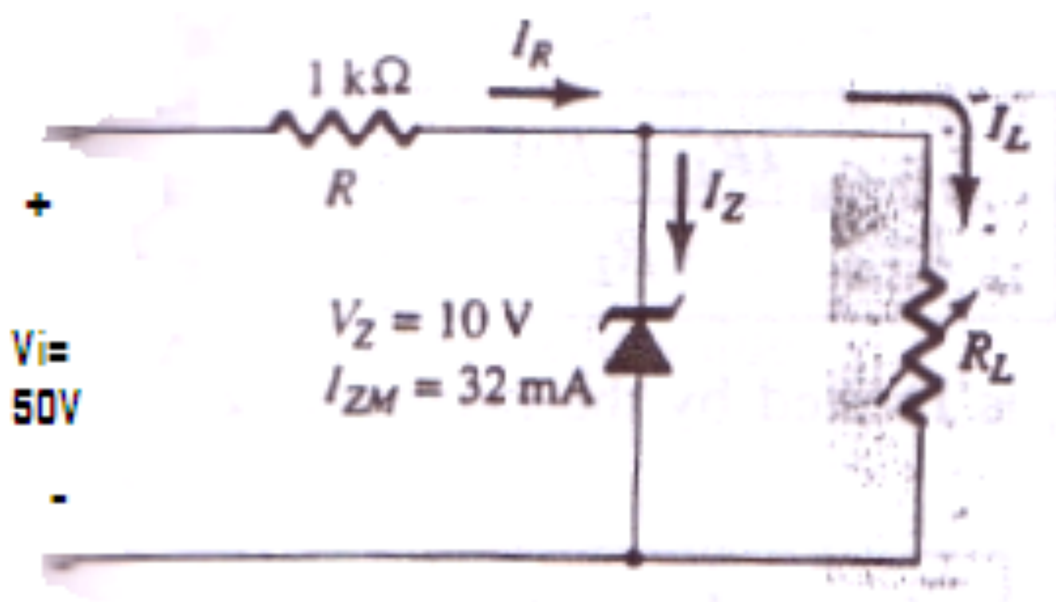


$$I_{R\max} = I_{ZM} + I_L = 76.67mA$$

$$V_{i\max} = I_{R\max}R + V_Z = 36.87V$$

Example 3

- (a) For the network shown, determine the range of R_L and I_L that will result in V_Z being maintained at 50 V
- (b) Determine the maximum wattage rating of the diode



Solution (Example 3)

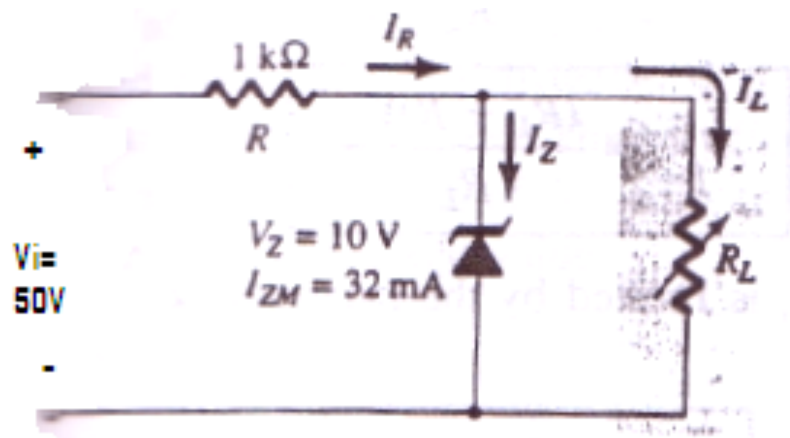
$$R_{L\min} = \frac{RV_Z}{V_i - V_Z} = 250\Omega$$

$$V_R = V_i - V_Z = 40V$$

$$I_R = \frac{V_R}{R} = 40mA$$

$$I_{L\min} = I_R - I_{ZM} = 8mA$$

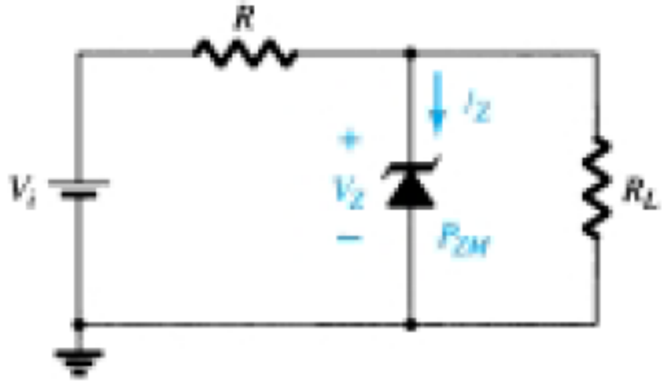
$$R_{L\max} = \frac{V_Z}{I_{L\max}} = 1.25k\Omega$$

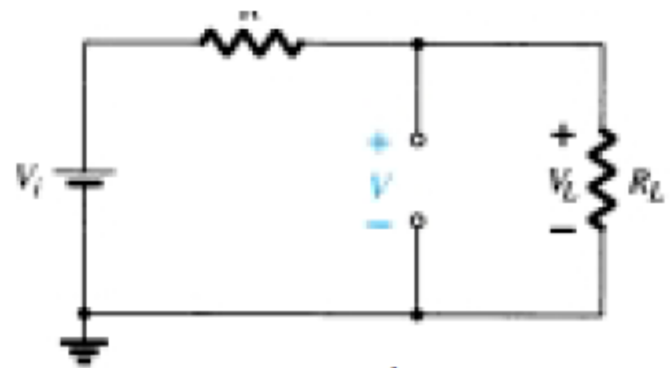


$$P_{\max} = V_Z I_{ZM} = 320mW$$

Analysis for fixed applied DC voltage and load resistor.

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





Determining the state of the Zener diode.

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

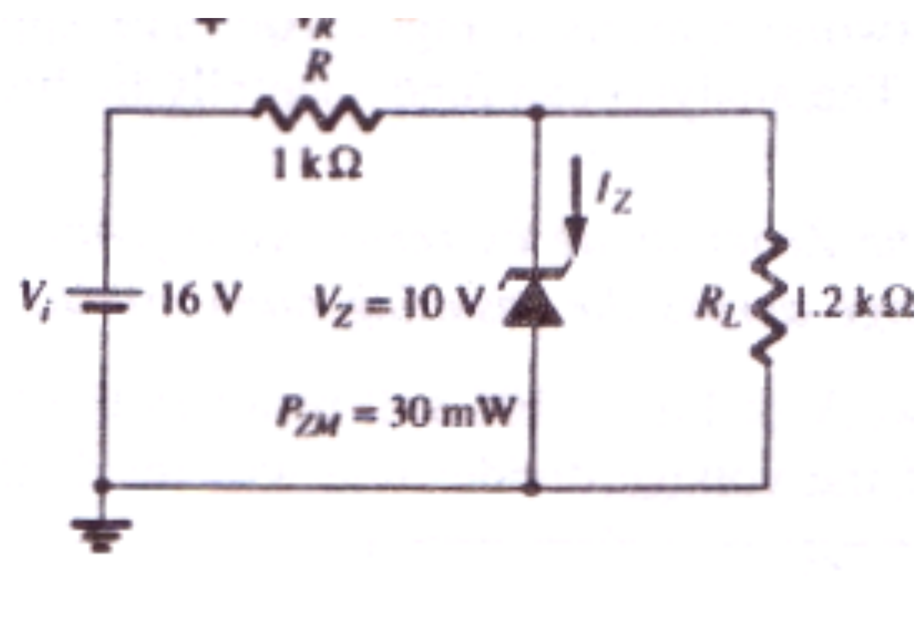
2. *Substitute the appropriate equivalent circuit and solve for the desired unknowns.*

If $V \geq V_Z$, the Zener diode is "on"

If $V < V_Z$, the diode is "off"

Example 4a

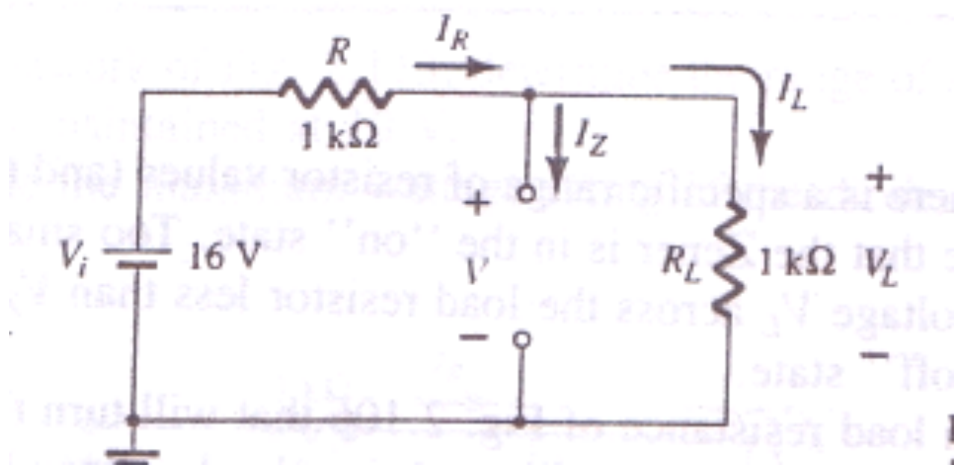
- (a) For the Zener diode network shown, determine V_L, V_R, I_Z, and P_Z.
- (b) Repeat part (a) with R_L = 3 kΩ.



Solution (Example 4a)

- $$V = \frac{R_L V_i}{R + R_L} = 8.73 \quad V$$

- Since V<Vz then the diode is off and the circuit becomes



$$V_L = V = 8.73 \quad V$$

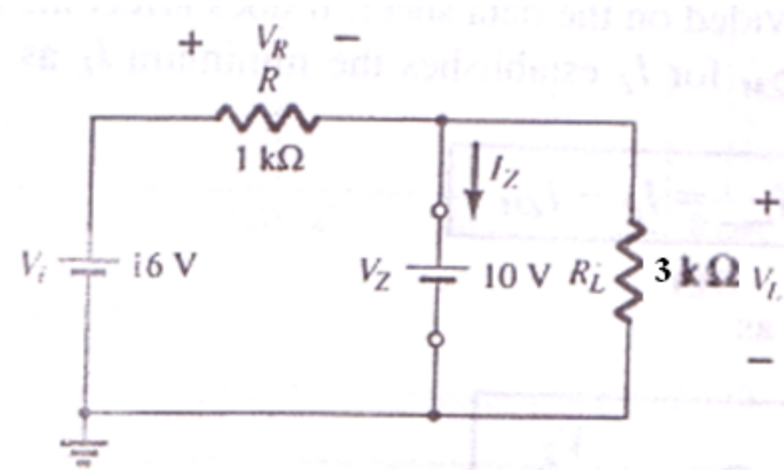
$$V_R = V_i - V_L = 7.27 \quad V$$

$$I_Z = 0 \quad A$$

$$P_Z = V_Z I_Z = 0 \quad W$$

Solution (Example 4 b)

$$V = \frac{R_L V_i}{R + R_L} = \frac{3\ \text{k}\Omega(16\ \text{V})}{1\ \text{k}\Omega + 3\ \text{k}\Omega} = 12\ \text{V}$$



- **Since V > Vz**
- **Now the diode is on and the circuit becomes**

Solution (Example 4 b)

$V_L = V_Z = \mathbf{10\ V}$

$V_R = V_i - V_L = 16\ \text{V} - 10\ \text{V} = \mathbf{6\ V}$

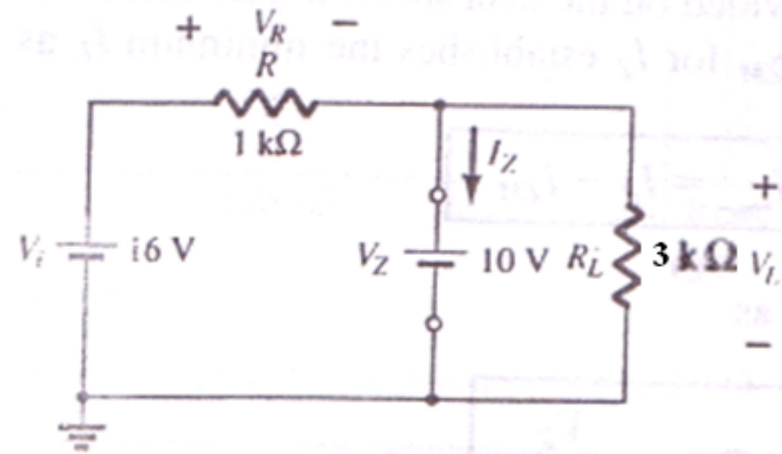
$I_L = \dfrac{V_L}{R_L} = \dfrac{10\ \text{V}}{3\ \text{k}\Omega} = 3.33\ \text{mA}$

$\text{I}_R = \dfrac{V_R}{R} = \dfrac{6\ \text{V}}{1\ \text{k}\Omega} = 6\ \text{mA}$

$I_Z = I_R - I_L$ [Eq. (2.18)]

$= 6\ \text{mA} - 3.33\ \text{mA}$

$= \mathbf{2.67\ mA}$



The power dissipated,

$$P_Z = V_Z I_Z = (10\ \text{V})(2.67\ \text{mA}) = \mathbf{26.7\ mW}$$

which is less than the specified $P_{ZM} = 30$ mW.