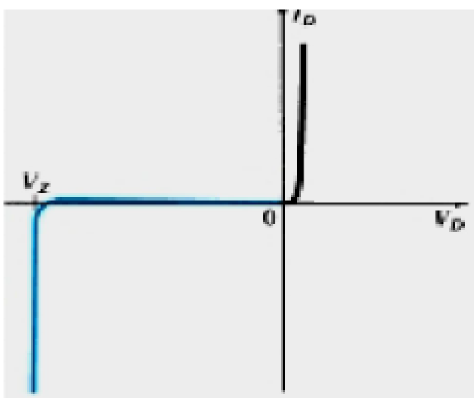
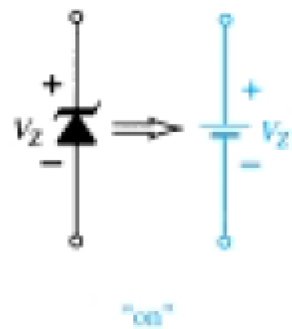
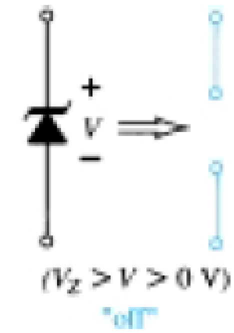
Zener diode

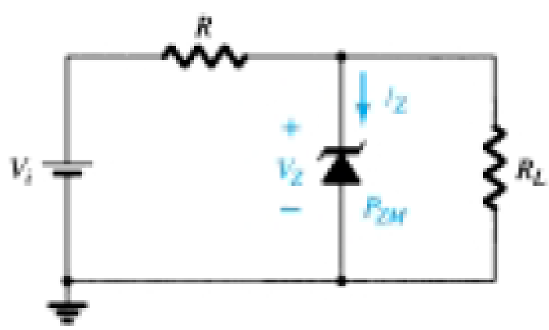
The analysis of networks employing Zener diodes is quite similar to that applied to the analysis of semiconductor diodes in previous sections. the state of the diode must be determined followed by a substitution of the appropriate model the Zener model to be employed for the "on" state will support a current in the symbol can be as shown in Fig. a. For the "off" state as defined by a voltage less than V_Z but greater than 0 V with the polarity indicated in Fig. b, the Zener equivalent is the open circuit that appears in the figure below.

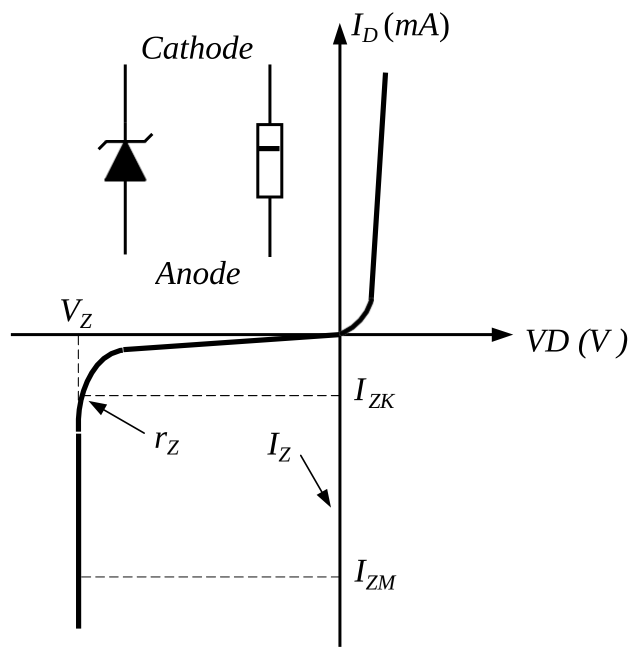






a b





For zener diode in an electrical network there operation modes are:

(a) Fixed V_i, Variable R_L

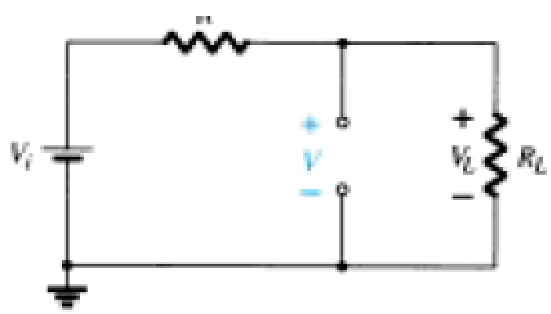
Due to the offset voltage V_Z, there is a specific range of resistor values (and therefore load current) which will ensure that the Zener is in the "on" state. Too small a load resistance R_L will result in a voltage V_L across the load resistor less than V_Z , and the Zener device will be in the "off" state.

To determine the minimum load resistance of Fig. below that will turn the Zener diode on, simply calculate the value of RL that will result in a load voltage $V_L = V_Z$.

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

$$R_{Lmin} = \frac{V_Z R}{V_i - V_Z}$$

$$I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}}$$



Resulting in a minimum I_Z when I_L is a maximum and a maximum I_Z when I_L is a minimum value since I_R is constant.

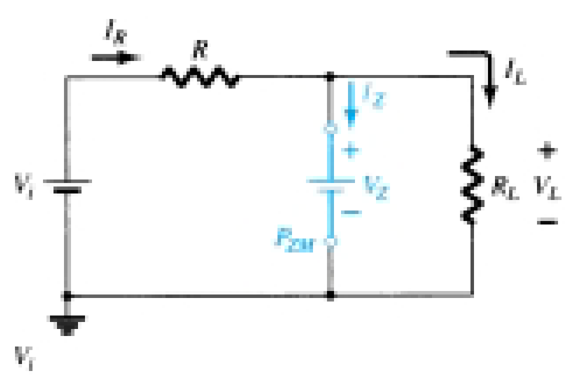
Since I_Z is limited to I_{ZM} as provided on the data sheet, it does affect the range of R_L and therefore I_L. Substituting I_{ZM} for I_Z establishes the minimum I_L as

$$I_Z = I_R - I_L$$

$$I_{Lmin} = I_R - I_{ZM}$$

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$

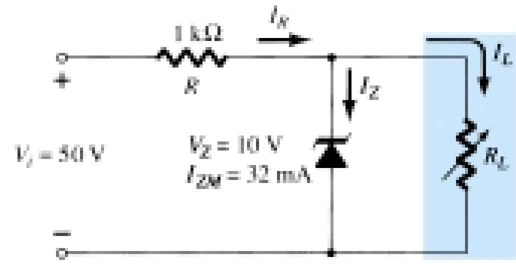
$$\boxed{I_{ZM} = \frac{P_{Z(\max)}}{V_Z}}$$



EXAMPLE:

(a) For the network of Figure below, determine the range of R_L and I_L that will result in V_{RL} being maintained at 10 V.

(b) Determine the maximum wattage rating of the diode.



Solution

(a) To determine the value of RL that will turn the Zener diode on, apply

$$R_{L_{\min}} = \frac{RV_Z}{V_i - V_Z} = \frac{(1\ \mathrm{k\Omega})(10\ \mathrm{V})}{50\ \mathrm{V} - 10\ \mathrm{V}} = \frac{10\ \mathrm{k\Omega}}{40} = \mathbf{250\ \Omega}$$

The voltage across the resistor R is then determined by

$$V_R = V_i - V_Z = 50\ \mathrm{V} - 10\ \mathrm{V} = \mathbf{40\ V}$$

And

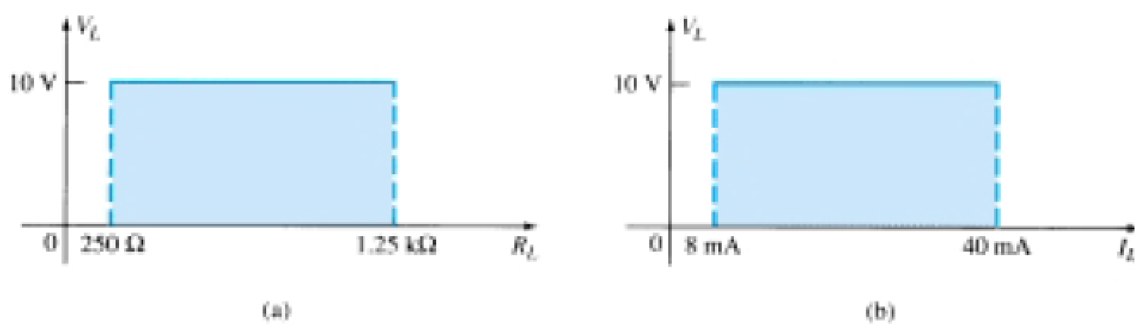
$$I_R = \frac{V_R}{R} = \frac{40\ \mathrm{V}}{1\ \mathrm{k\Omega}} = \mathbf{40\ mA}$$

then I_{Lmax}=40mA ,The minimum level of I_L is then determined

$$I_{L_{\min}} = I_R - I_{ZM} = 40\ \mathrm{mA} - 32\ \mathrm{mA} = \mathbf{8\ mA}$$

$$R_{L_{\max}} = \frac{V_Z}{I_{L_{\min}}} = \frac{10\ \mathrm{V}}{8\ \mathrm{mA}} = \mathbf{1.25\ k\Omega}$$

A plot of *VL* versus *RL* appears in Fig.



(b)

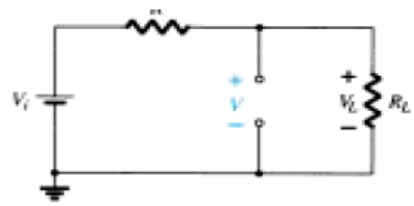
$$P_{\max} = V_Z I_{ZM} = (10\ \mathrm{V})(32\ \mathrm{mA}) = \mathbf{320\ mW}$$

(b) Fixed R_L, Variable V_i

For fixed values of *RL* in Fig. below, the voltage V_i must be sufficiently large to turn the Zener diode on. The minimum turn-on voltage $V_i = V_{imin}$ is determined by

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

$$V_{i_{min}} = \frac{(R_L + R)V_Z}{R_L}$$

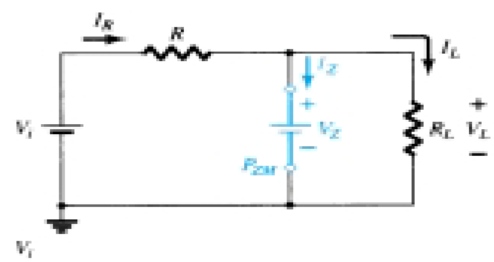


V_i is limited by the maximum Zener current. The maximum value of I_{ZM}. Since

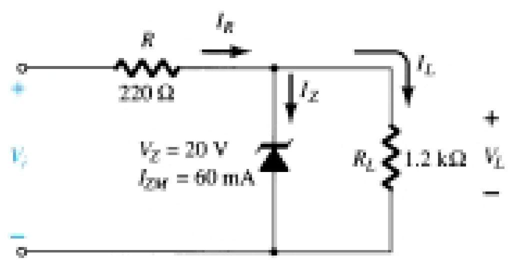
$$I_{R_{max}} = I_{ZM} + I_L$$

$$V_{i_{max}} = I_{R_{max}} R + V_Z$$

$$I_{ZM} = \frac{P_{Z(max)}}{V_Z}$$



EXAMPLE: Determine the range of values of Vi that will maintain the Zener diode of Figure below in the “on” state.



Solution

$$V_{i_{min}} = \frac{(R_L + R)V_Z}{R_L} = \frac{(1200\ \Omega + 220\ \Omega)(20\ V)}{1200\ \Omega} = \mathbf{23.67\ V}$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{20\ V}{1.2\ k\Omega} = 16.67\ mA$$

$$I_{R_{max}} = I_{ZM} + I_L = 60\ mA + 16.67\ mA$$

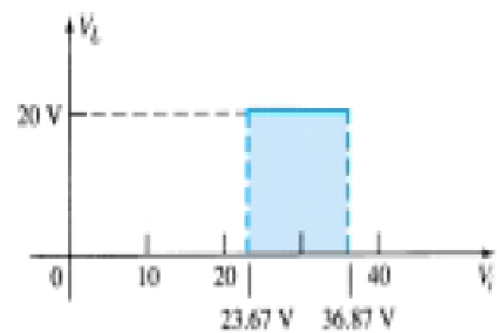
$$= 76.67\ mA$$

$$V_{i_{max}} = I_{R_{max}} R + V_Z$$

$$= (76.67\ mA)(0.22\ k\Omega) + 20\ V$$

$$= 16.87\ V + 20\ V$$

$$= \mathbf{36.87\ V}$$



A plot of V_L versus V_i is provided in Fig.