9.19 Zener Diode

It has already been discussed that when the reverse bias on a crystal diode is increased, a critical voltage, called *breakdown voltage* is reached where the reverse current increases sharply to a high value. The breakdown region is the knee of the reverse characteristic as shown in Fig. 9.39. The satisfactory explanation of this breakdown of the junction was first given by the American scientist C. Zener. Therefore, the breakdown voltage is sometimes called, *Zener voltage* and the sudden increase in current is known as Zener current.

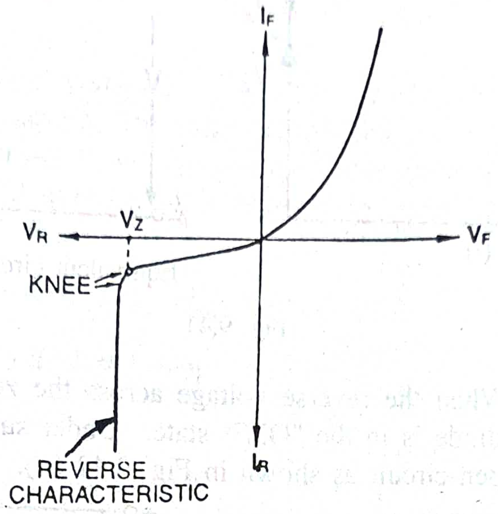


Fig. 9.39

The breakdown or Zener voltage depends upon the amount of doping. If the diode is heavily doped, depletion layer will be thin and consequently the breakdown of the junction will occur at a lower reverse voltage. On the other hand, a lightly doped diode has a higher breakdown voltage. When an ordinary crystal diode is properly doped so that it has a sharp breakdown voltage, it is called a zener diode.

A properly doped crystal diode which has a sharp breakdown voltage is known as a **Zener diode.**

Fig. 9.40 shows the symbol of a zener diode. It may be seen that it is just like an ordinary diode except that the bar is turned into Z-shape. The following points may be noted about the zener diode :

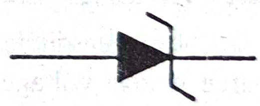


Fig. 9.40

(i) A zener diode is like an ordinary diode except that it is properly doped so as to have a sharp breakdown voltage.

(ii) A zener diode is always reverse connected *i.e.* it is always reverse biased.

(iii) A zener diode has sharp breakdown voltage, called zener voltage V_Z.

(iv) When forward biased, its characteristics are just those of ordinary diode.

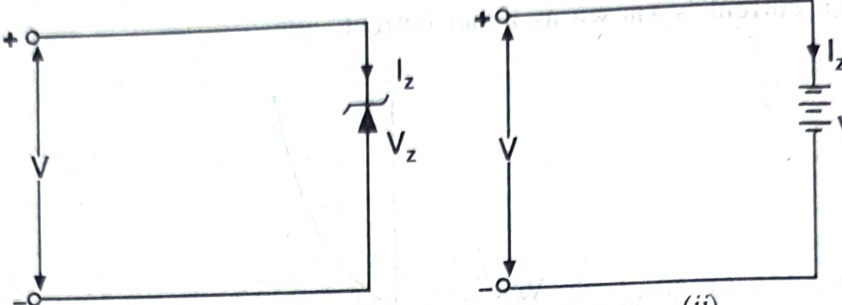
(v) The zener diode is not immediately burnt just because it has entered the *breakdown region. As long as the external circuit connected to the diode limits the diode current to less than *burn out* value, the diode will not burn out.

9.20 Equivalent Circuit of Zener Diode

The analysis of circuits using zener diodes can be made quite easily by replacing the zener diode by its equivalent circuit.

* The current is limited only by both external resistance and the power dissipation of zener diode.

(*i*) **"On" state.** When reverse voltage across a zener diode is equal to or more than breakdown voltage V_Z, the current increases very sharply. In this region, the curve is almost vertical. It means that voltage across zener diode is constant at V_Z even though the current through it changes. Therefore in the breakdown region, an *ideal zener diode can be represented by a battery of voltage V_Z as shown in Fig. 9.41 (*ii*). Under such conditions, the zener diode is said to be in the "on" state.



(*i*)

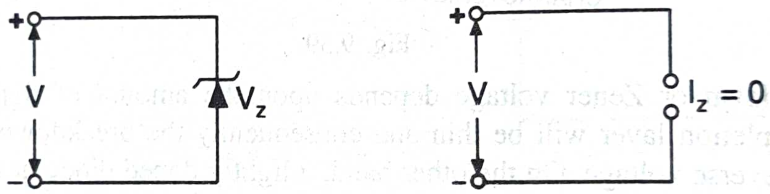
$V \geq V_Z$

(*ii*)

Equivalent circuit of zener for "on" state

Fig. 9.41

(*ii*) **"OFF" state.** When the reverse voltage across the zener diode is less than V_Z but greater than 0V, the zener diode is in the "OFF" state. Under such conditions, the zener diode can be represented by an open-circuit as shown in Fig. 9.42 (*ii*).



(*i*)

$V_Z > V > 0$

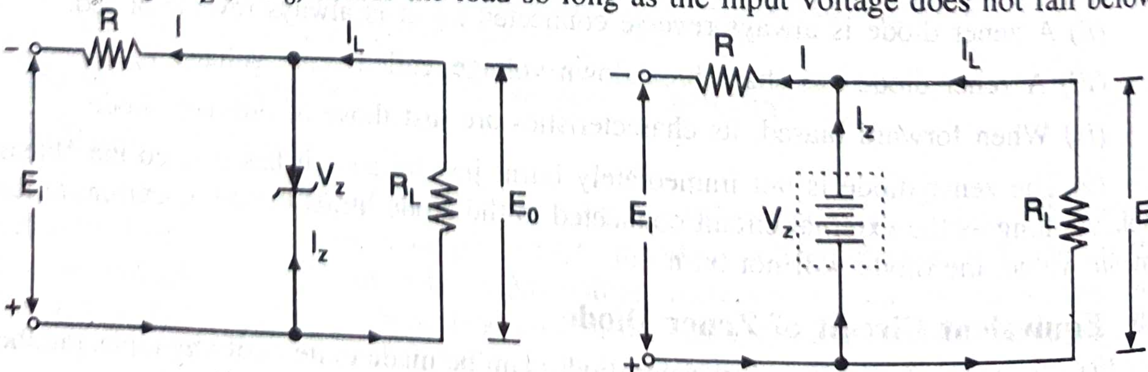
(*ii*)

Equivalent circuit of zener for "off" state

Fig. 9.42

9.21 Zener Diode as Voltage Stabiliser

A zener diode can be used as a voltage regulator to provide a constant voltage from a source whose voltage may vary over sufficient range. The circuit arrangement is shown in Fig. 9.43 (*i*). The zener diode of zener voltage V_Z is reverse connected across the load R_L across which constant output is desired. The series resistance R absorbs the output voltage fluctuations so as to maintain constant voltage across the load. It may be noted that the zener will maintain a constant voltage V_Z (= E_0) across the load so long as the input voltage does not fall below V_Z.



(*i*)

(*ii*)

Fig. 9.43

* This assumption is fairly reasonable as the impedance of zener diode is quite small in the breakdown region.

When the circuit is properly designed, the load voltage E_0 remains essentially constant (equal to V_Z) even though the input voltage E_i and load resistance R_L may vary over a wide range.

(i) Suppose the input voltage increases. Since the zener is in the breakdown region, the zener diode is equivalent to a battery V_Z as shown in Fig. 9.43 *(ii)*. It is clear that output voltage remains constant at V_Z (= E_0). The excess voltage is dropped across the series resistance R. This will cause an increase in the value of total current I. The zener will conduct the increase of current in I while the load current remains constant. Hence, output voltage E_o remains constant irrespective of the changes in the input voltage E_i.

(ii) Now suppose that input voltage is constant but the load resistance R_L decreases. This will cause an increase in load current. The extra current can not come from the source because drop in R (and hence source current I) will not change as the zener is within its regulating range. The additional load current will come from a decrease in zener current I_Z. Consequently, the output voltage stays at constant value.

$$\text{Voltage drop across } R = E_i - E_o$$

$$\text{Current through } R,\ I = I_Z + I_L$$

Applying ohm's law, we have,

$$R = \frac{E_i - E_o}{I_Z + I_L}$$