UNIT 10 ELECTRONICS AND COMMUNICATION

Warm greetings:

Dear students

Welcome all. In this class we are going to discuss about

- Breakdown mechanism
  - **Zener breakdown**
  - **Avalanche breakdown**
- Zener diode
- Optoelectronic devices

Breakdown mechanism :

- The reverse current or the reverse saturation current due to the minority charge carriers is small. If the reverse bias applied to a *p-n* junction is increased beyond a point, the junction breaks down and the reverse current rises sharply.
- The voltage at which breakdown happens is called the breakdown voltage and it depends on the width of the depletion region, which in turn depends on the doping level.
- A normal *p-n* junction diode gets damaged at this point. Specially designed diodes like Zener diode can be operated at this region and can be used for the purpose of voltage regulation in circuits.
- There are two mechanisms that are responsible for breakdown under increasing reverse voltage.

i) Zener breakdown:

- Heavily doped *p-n* junctions have narrow depletion layers whose width is of the order of $<10^{-6}$ m.
- When a reverse voltage across this junction is increased to the breakdown limit, a very strong electric field of strength 3×10^{7} V m^{-1} is set up across the narrow layer.
- This electric field is strong enough to break or rupture the covalent bonds in the lattice and thereby generating electron-hole pairs. This effect is called **Zener effect**.
- Even a small further increase in reverse voltage produces a large number of charge carriers.

- Hence the junction has very low resistance in the breakdown region. This process of emission of electrons due to the rupture of covalent bonds in the lattice due to strong electric field is known as **internal field emission or field ionization**. The electric field required for this is of the order of 10^6 V m^{-1}.

ii) Avalanche breakdown:

- ✓ Avalanche breakdown occurs in lightly doped junctions which have wide depletion layers.
- ✓ In this case, the electric field is not strong enough to produce breakdown.
- ✓ Alternatively, the thermally generated minority charge carriers accelerated by the electric field gain sufficient kinetic energy and they collide with the semiconductor atoms while passing through the depletion region.
- ✓ This leads to the breaking up of covalent bonds generating electron-hole pairs.
- ✓ The newly generated charge carriers are also accelerated by the electric field resulting in more collisions and further production of charge carriers.
- ✓ This cumulative process leads to an avalanche of charge carriers across the junction and consequently reduces the reverse resistance. The diode current increases sharply.

Zener diode:

Zener diode is a heavily doped silicon diode used in reverse biased condition and is named after its inventor Clarence Melvin Zener. It is specially designed to be operated in the breakdown region. The doping level of the silicon diode can be varied to have a wide range of breakdown voltages from 2 V to over 1000 V.

As explained in the previous section, Zener breakdown occurs due to the breaking up of covalent bonds by the strong electric field set up in the depletion region by the reverse voltage. It produces an extremely large number of electrons and holes which constitute the reverse saturation current.

The current is limited by both external resistance and power dissipation of the diode. A Zener diode is shown in Figure 10.19(a) and its circuit symbol is given in Figure 10.19(b).

It looks like an ordinary *p-n* junction diode except that *n*-side lead resembles the shape of the letter 'z'. The arrow head points the direction of conventional current. In Figure 10.19(a), black ring indicates the *n*-side lead.

Figure 10.19 Zener diode
(a) Commercial picture (b) Circuit symbol

V-I Characteristics of Zener diode:

The circuit to study the forward and reverse characteristics of a Zener diode is shown in Figure 10.20(a) and Figure 10.20 (b). The V-I characteristics of a Zener diode is shown in Figure 10.20(c).

The forward characteristic of a Zener diode is similar to that of an ordinary *p-n* junction diode. It starts conducting approximately around 0.7 V. However, the reverse characteristics is highly significant in Zener diode.

The increase in reverse voltage normally generates very small reverse current. While in Zener diode, when the reverse voltage is increased to the breakdown voltage (VZ), the increase in current is very sharp.

The voltage remains almost constant throughout the breakdown region. In Figure 10.20(c), I_Z(max) represents the maximum reverse current. If the reverse current is increased further, the diode will be damaged. The important parameters of the reverse characteristics are

- ✓ Zener breakdown voltage, V_Z
- ✓ Minimum current to sustain breakdown, $I_{(Zmin)}$
- ✓ Maximum current limited by maximum power dissipation, $I_{(Zmax)}$

The Zener diode is operated in the reverse bias condition with the voltage greater than VZ and current less than $I_{Z(max)}$. The reverse characteristic is not exactly vertical which means that the diode possesses some small resistance called Zener dynamic impedance.

Zener resistance is the inverse of the slope of the curve in the breakdown region. It means an increase in the Zener current produces only a very small increase in the reverse voltage. However this can be neglected.

The voltage of an ideal Zener diode does not change once it goes into breakdown. In other words, **V_Z remains almost constant even when I_Z increases considerably**.

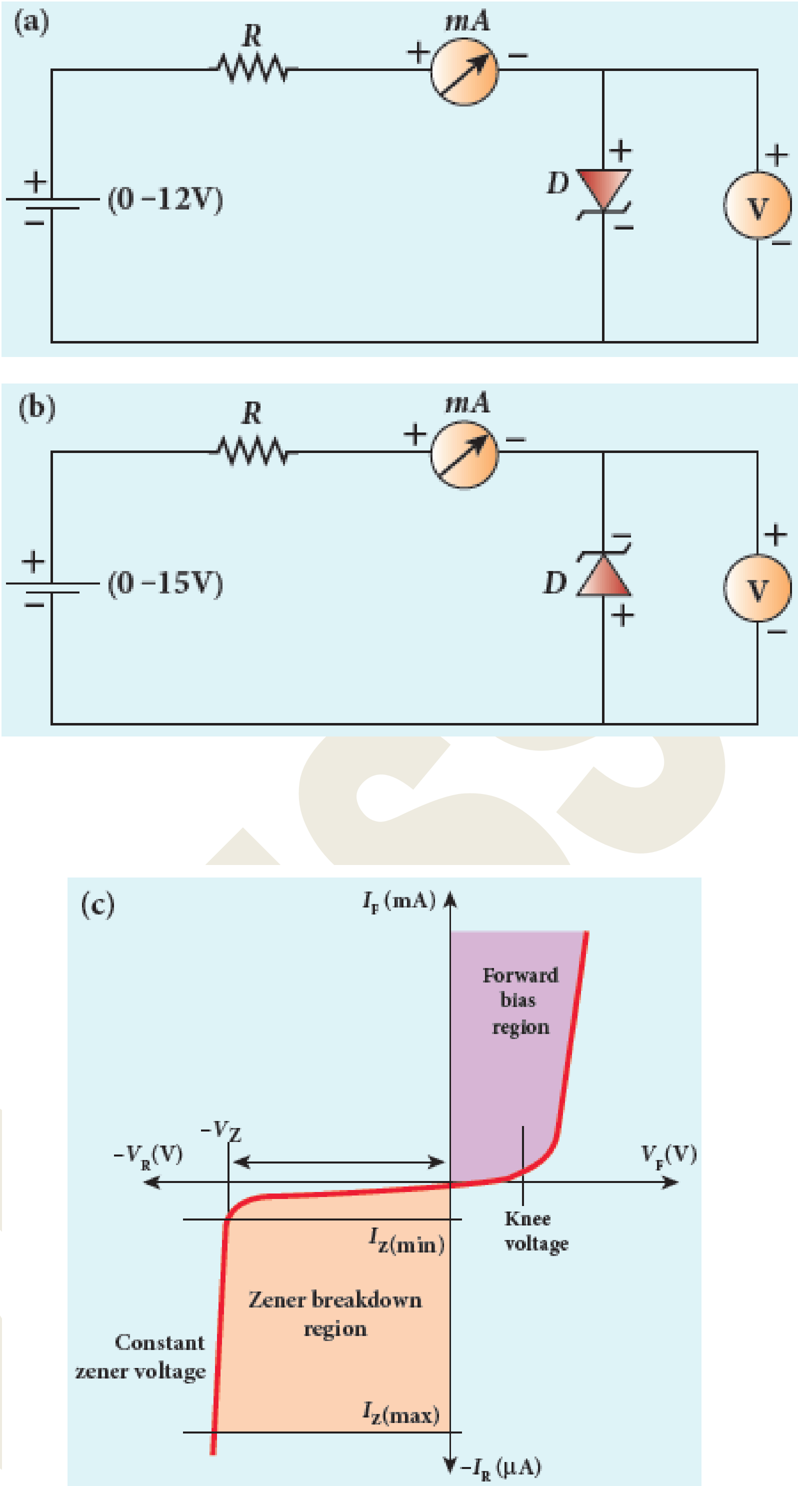

Figure 10.20 Zener diode (a) Forward bias (b) Reverse bias (c) V-I characteristics

Applications:

The zener diode can be used

- as voltage regulator
- for calibrating voltages
- to provide fixed reference voltage in a network for biasing
- to protect of any gadget against damage from accidental application of excessive voltage.

Zener diode as a voltage regulator:

✓ Zener diode working in the breakdown region can serve as a voltage regulator whose circuit diagram is given in Figure 10.21.

✓ A series resistance *R*s of suitable value is used to limit the Zener current to avoid any damage to the diode. This resistance also plays a role in voltage regulation.

✓ The fluctuating DC input voltage is applied to the circuit and constant output voltage V_o is taken across the load resistance *R*L which is connected in parallel with Zener diode.

✓ The output voltage is maintained constant as long as the input voltage is greater than V_Z.

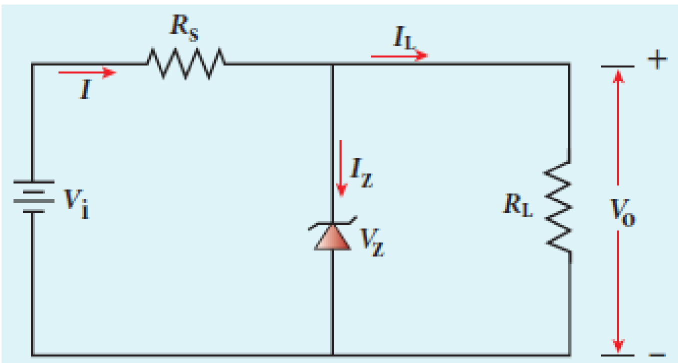

Figure 10.21 Circuit to study voltage regulation by Zener diode

✓ If the input DC voltage is increased, the Zener current increases thereby increasing current through R_s and the voltage drop across R_s is also increased.

✓ The increased current flows through the diode without affecting the I_L. Since Zener diode is operated in the breakdown region, the Zener breakdown voltage across the diode is nearly constant even though the reverse bias current through the diode increases considerably.

- ✓ The increase in input voltage is dropped across R_s and hence it is also called dropping resistance. Because of the parallel connection, the voltage across R_L is also equal to Zener breakdown voltage which is taken as constant output voltage V_0.
- ✓ If the input DC voltage is decreased, the diode takes a smaller current and the voltage drop across Rs is reduced. Thus, the output voltage V_0 remains constant.
- ✓ To sum up, if there is any change in input voltage, the voltage drop across RL changes accordingly. But the voltage across Zener diode or voltage across R_L remains constant. Thus the Zener diode acts as a voltage regulator.

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