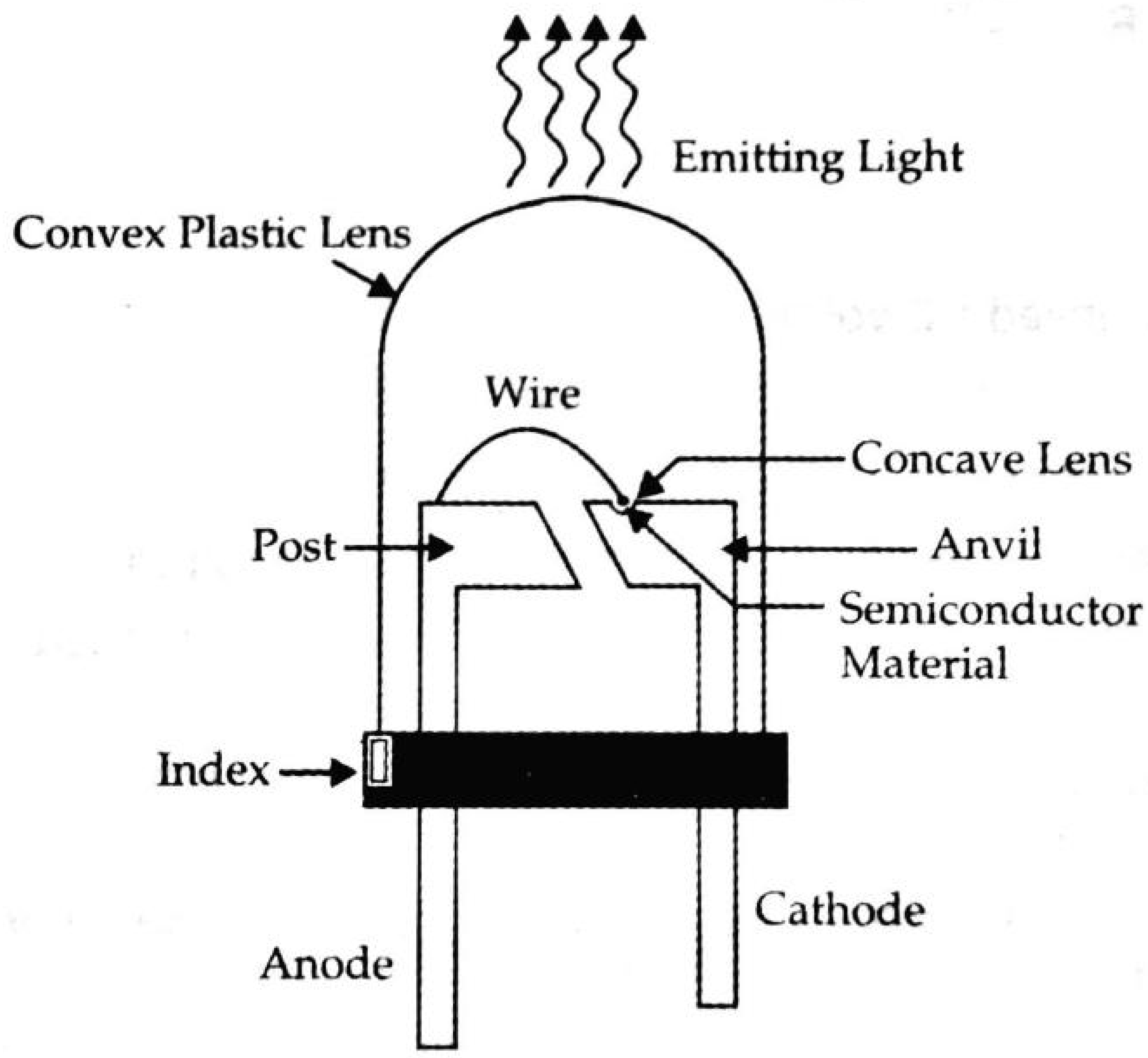
1.10 Light Emitting Diode

LED is a type of p-n junction diode that emits light when it is forward biased. Therefore, when LED is forward biased by a voltage source, conversion of electrical energy into light energy takes place. LEDs are the solid state semiconductor devices, which converts electrical energy into visible light. The working of LEDs is based on the principle of electroluminescence, which is an optical and electrical phenomenon of a material that emits light when electric current passes through it. LEDs are consist of anode, cathode, semiconductor material in reflective die, a wire, and convex and concave lenses, transparent plastic body, an anvil, and index. All the components have its significances. There are various features of an LED, they are as follows:

- Gives high range of frequency and high efficiency
- Results in longer life as compared to other lighting source
- Consumes very little power
- Maintains Ecology at disposal

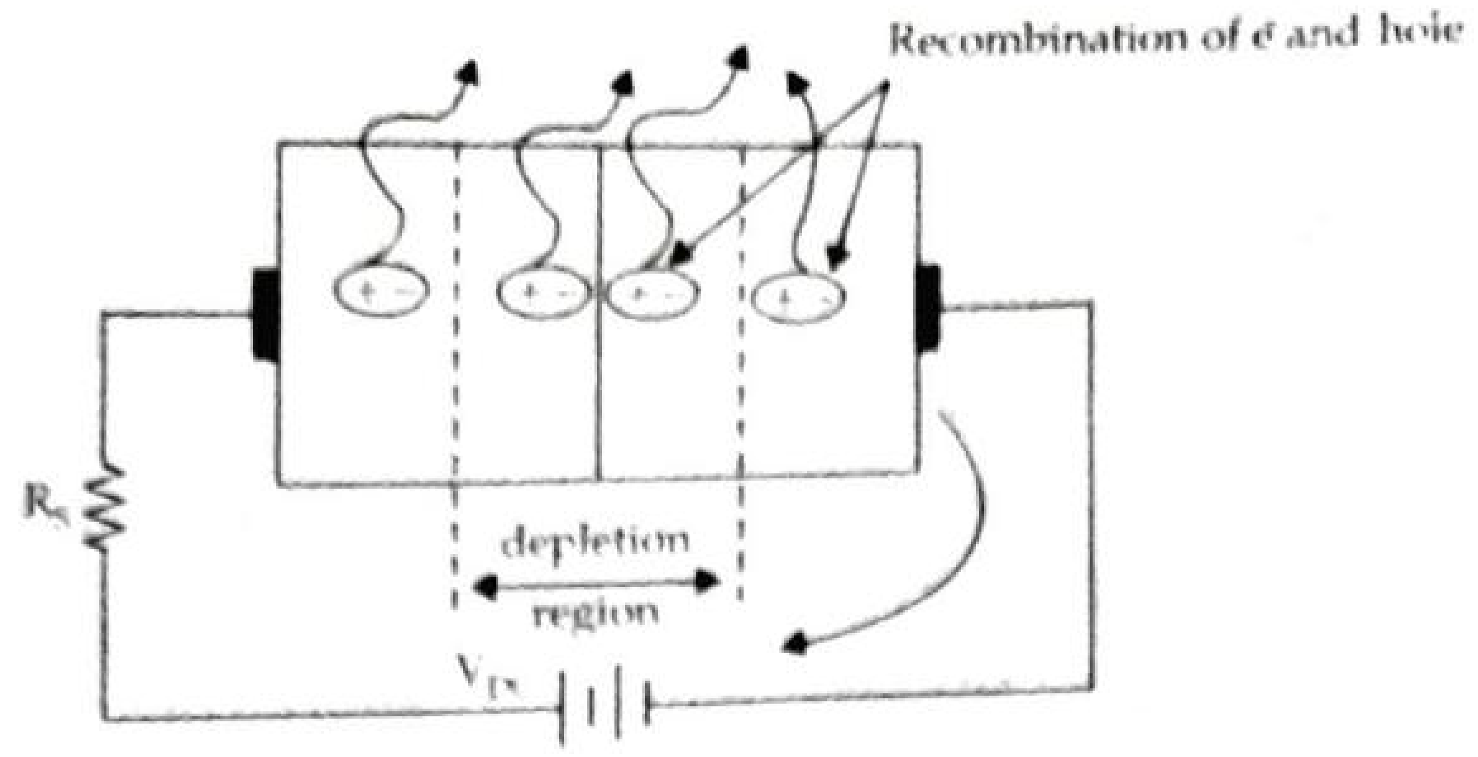
Figure 56 shows the constructional details of an LED:



▲ **Figure 56: Displaying Constructional Details of an LED**

Figure 56 shows that the length of cathode leg is different from the length of anode leg so that, you can easily identify the anode and cathode in an LED. A flat surface structure is made on the body of LED at the cathode side for identification of cathode it is just a general method to distinguish between anode and cathode of an LED. A wire of very thin diameter is connected between the anode and the semiconductor material. The external body of an LED is made of transparent plastic with a curvature of convex lens. This convex lens is used to magnify the emitted radiation. The working of an LED is similar to that of other electronic components as all the components need power, in similar way LED also requires power to work. Power to the LED can be given with DC source only. When a LED is connected to a DC source, the forward biasing of diode takes place and electric current passes through the thin wire that emits radiation. These radiations are in the form of light. These radiations are then magnified by the external body of the LED, which is in the form of convex lens. The magnification increases the luminosity of light and the appearance is brighter.

Figure 57 shows the operating process of a LED:



▲ **Figure 57: Displaying Operation Process of an LED**

The LED is always operated in the forward-bias region, which means that the p-type junction is connected to the positive terminal and the n-type junction is connected to the negative terminal of the supply voltage V_{DC}. The resistance R_S is called as current limiting resistor and is connected in series with the LED.

The value of the series resistance R_S is calculated by using the following equation:

$$R_S = \frac{V_{DC} - V_F}{I}$$

where:

V_{DC} = applied DC voltage/supply voltage

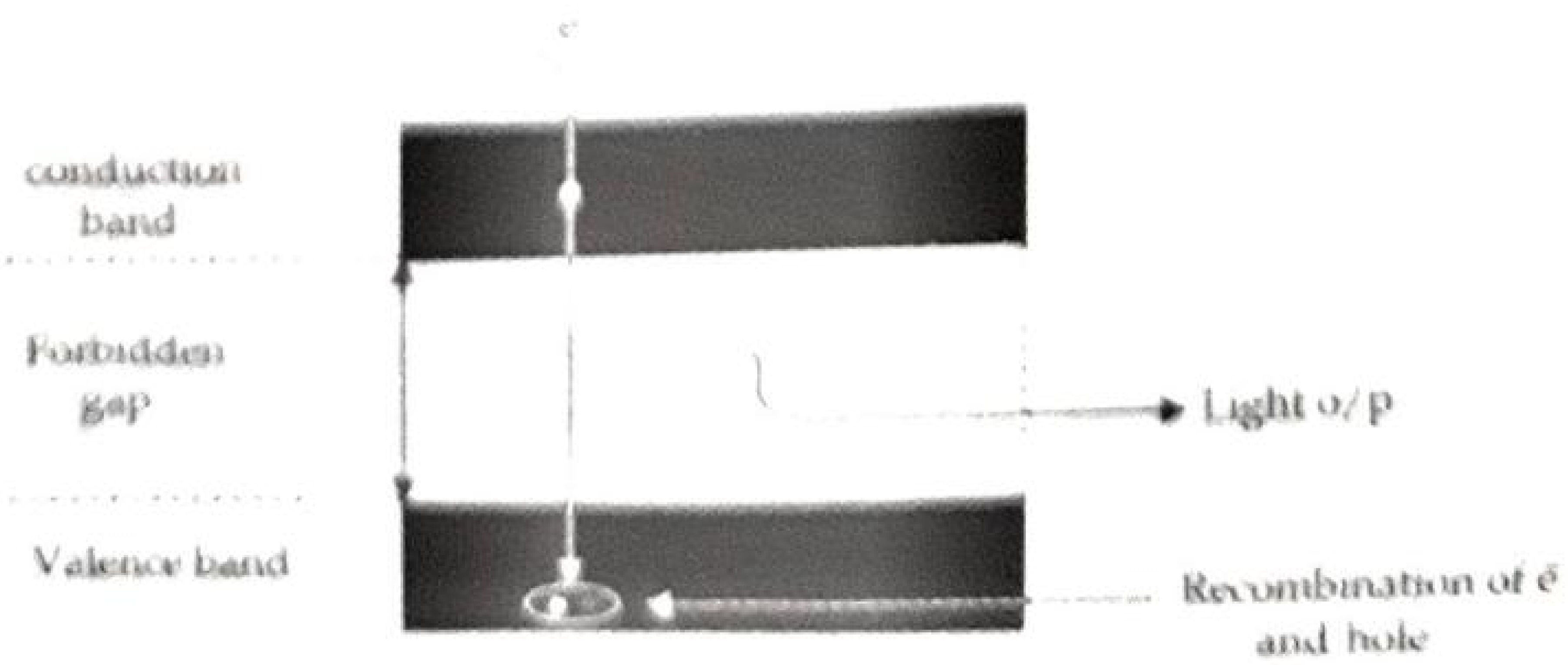
V_F = forward voltage drop across the LED.

The value of V_F depends on the following parameters:

- **LED current**: Refers to the minimum current required for working of LED.
- **Color**: Refers to LED colors listed in Table 6, and each color has its own wave length. Therefore different color of the LED needs different forward voltage.
- **Tolerances**: Refers to the range of maximum and minimum forward voltage across which a LED can work.

The value of V_F is taken between 1.5 V and 2.5 V. The value of current (I) may be in the range of 10 mA–20 mA. This current decides the light output produced by the LED, such as brightness. If the value of current is higher then, brightness is more. In other words, we can say that the value of current is directly proportional to brightness.

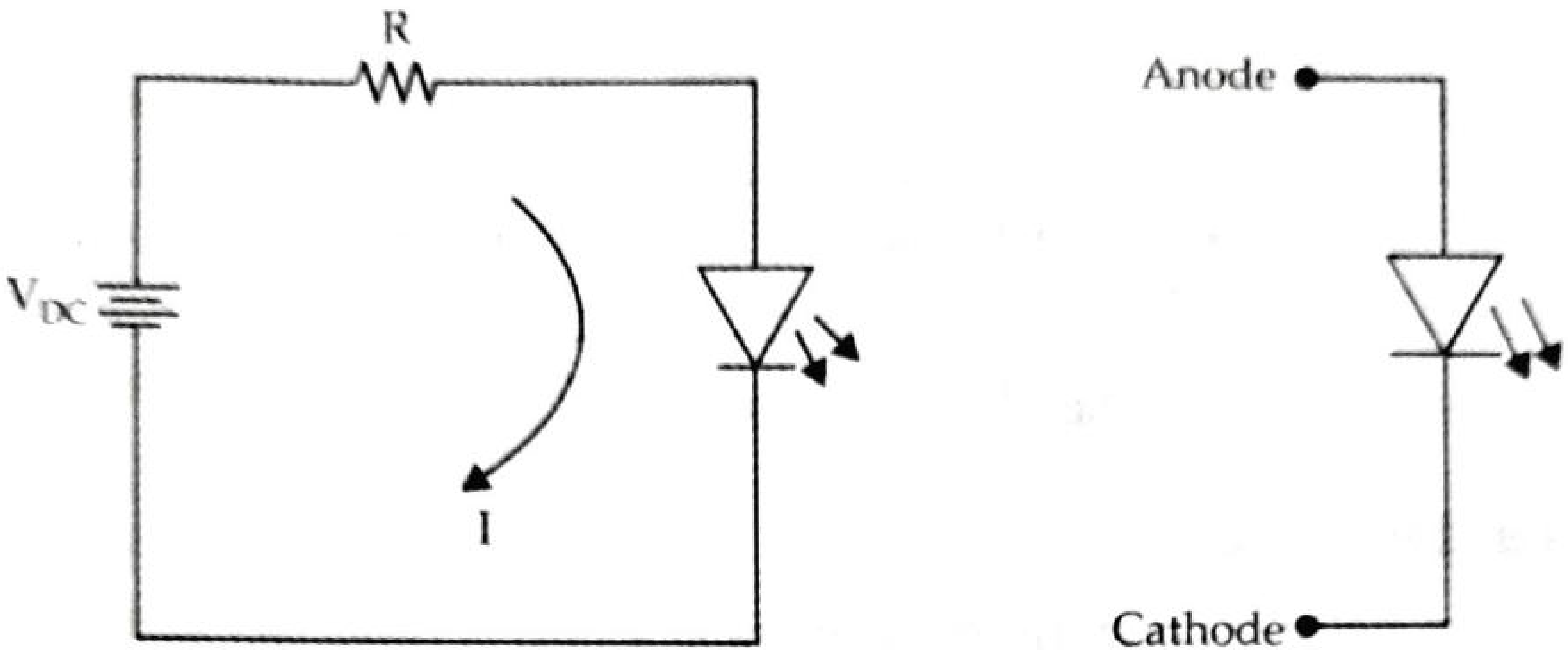
When the voltage V_{DC} is applied to the diode, electrons in the n-region crosses the junction and combines with the holes in the p-region. Figure 58 shows the energy level diagram for a p-n junction diode:



▲ **Figure 58: Explaining the Energy Level Diagram for a p-n Junction Diode**

The electrons in the CB are having higher energy level than the holes in the VB. When recombination takes place, the electrons return to the VB, i.e. lower energy level by emitting an equivalent light output. This process of recombination and releasing of light is called as electroluminescence.

Figure 59 (a) and (b) show the LED biasing and LED symbol, respectively:



(a) LED Biasing (b) LED Symbol

▲ Figure 59: Displaying Biasing and Symbol of the LED

The two arrows shown in Figure 59(b) indicate emission of light.

Materials for LED

The LEDs are made up of semiconductor material similar to the p-n junction diode. The availability of the semiconductor makes the LED discrete so the LED can be distinguished on the basis of color display, wavelength, voltages, and other properties as well. The most popular semiconductor materials are used for manufacturing LEDs are as follows:

- Gallium Arsenide (GaAs)
- Gallium Arsenide phosphide (GaAsP)
- Gallium phosphide (GaP)

The value of energy band gap is same for a material, due to which a constant output is obtained. The wavelength of the emitted light decides the LED color and forbidden energy gap. The LEDs are made from various semiconductor materials.

Table 6 lists the available colors, corresponding material with voltage drop, and wavelength range:

Table 6: Colors, Wavelength Range, Voltage Drop, and Corresponding Materials of LED

Color	Semiconductor material	Voltage (V)	Wavelength (nm)
Infrared	GaAs	$\Delta V < 1.9$	$\lambda > 760$
Red	GaAsP GaP	$1.63 < \Delta V < 2.03$	$760 > \lambda > 610$
Orange	GaAsP GaP	$2.03 < \Delta V < 2.10$	$610 > \lambda > 590$
Yellow	GaAsP GaP	$2.10 < \Delta V < 2.18$	$590 > \lambda > 570$
Green	GaP	$1.9 < \Delta V < 4.0$	$570 > \lambda > 500$

Table 6: Colors, Wavelength Range, Voltage Drop, and Corresponding Materials of LED			
Color	**Semiconductor material**	**Voltage (V)**	**Wavelength (nm)**
Blue	Indium gallium nitride (InGaN)	$2.48 < \Delta V < 3.7$	$500 > \lambda > 4500$
Violet	Indium gallium nitride (InGaN)	$2.76 < \Delta V < 4.0$	$450 > \lambda > 400$
Purple	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic	$2.48 < \Delta V < 3.7$	multiple types
White	Blue/UV diode with yellow phosphor	$\Delta V = 3.5$	Broad spectrum

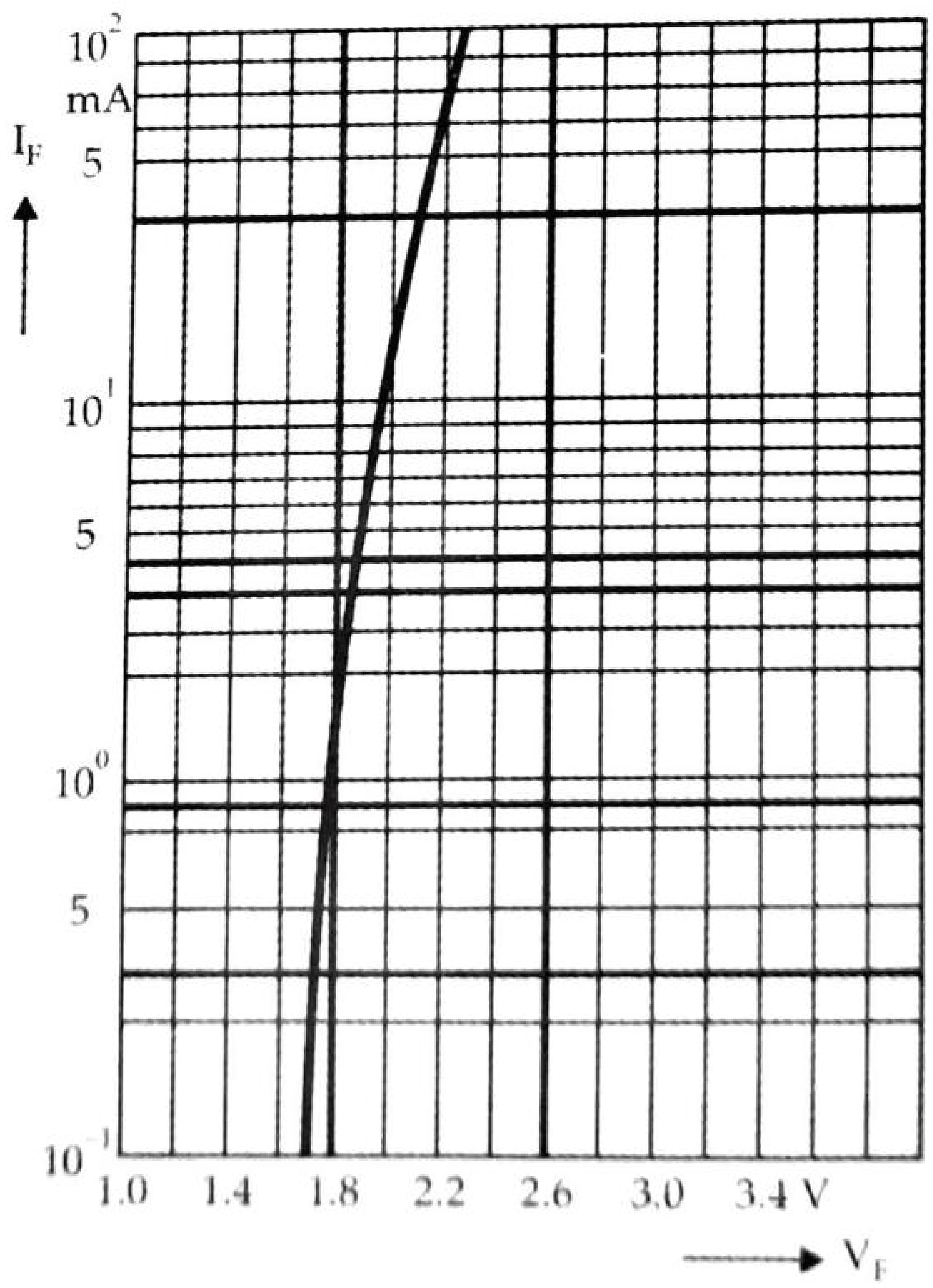
Let us now learn about the LED characteristics.

LED Characteristics

The relation between current and voltage in a LED is given as:

$$I = I_o e^{\left\{\frac{q(V - IR_S)}{\eta kT}\right\}}$$

The preceding equation shows that the relation between V and I in a LED is exponential. Figure 60 shows the V-I characteristic of the LED:



▲ **Figure 60: Showing the V-I Characteristics of the LED**

The other important characteristics of LED are as follows:

- Luminosity of LED is directly proportional to the operating current
- With increase in temperature, maximum forward current must be derated

- Luminosity decreases with increase in temperature
- Response time of LED is in the range of 1—100 ns
- Maximum efficiency can be obtained at a range of 10 mA to 30 mA

Let us now learn about the display modes of a LED.

LED Display

The major function of the LED is to emit light, which results in producing visible effect. Therefore, we can say that LED is a tool from electronics that is used for visual communication and lighting purpose. LED has a wide area of application such as display board, lighting boards, and traffic signals. There are about six types of LED display, which are as follows:

- Seven-segment display
- Nine-segment display
- 14-segment display
- Bar graph display
- Dot matrix display
- Vane display