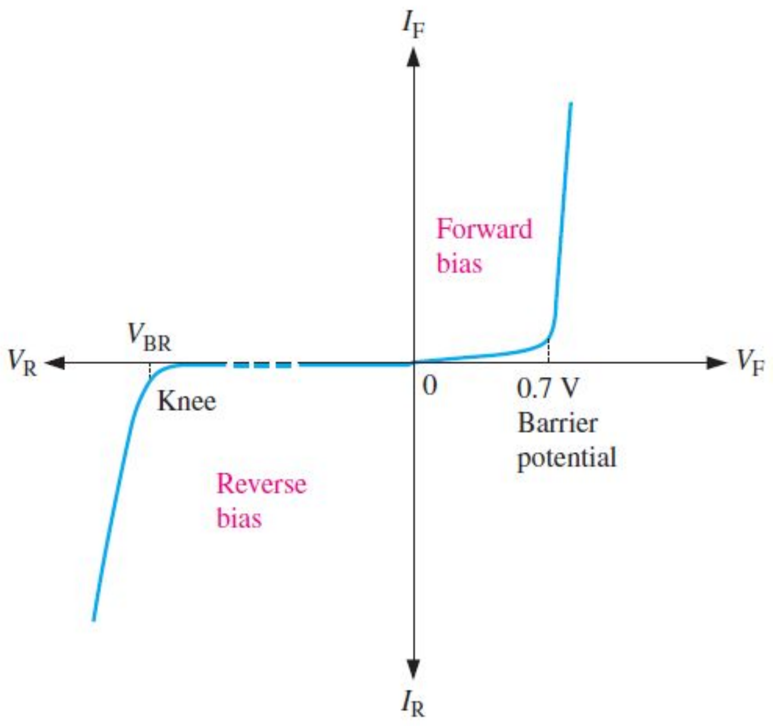
Diode Characteristics

Complete I-V characteristic curve

When a voltage applied across PN junction then the total current I_D flowing through the junction is given as:

$$I_D = I_o[e^{\frac{V}{\eta V_T}} - 1]$$

$$V_T = \frac{KT}{q}$$



If V is positive then the PN Junction is FB
If V is negative then the PN Junction is RB

Effect of temperature on reverse saturation current

- The higher the junction temperature, the greater the saturation current.
- A useful approximation to remember is this: I_S doubles for each 10°C rise.

$$Percentage\ \Delta Is = 100\%\, for\, 10^0\, increase\, of\, temperature$$

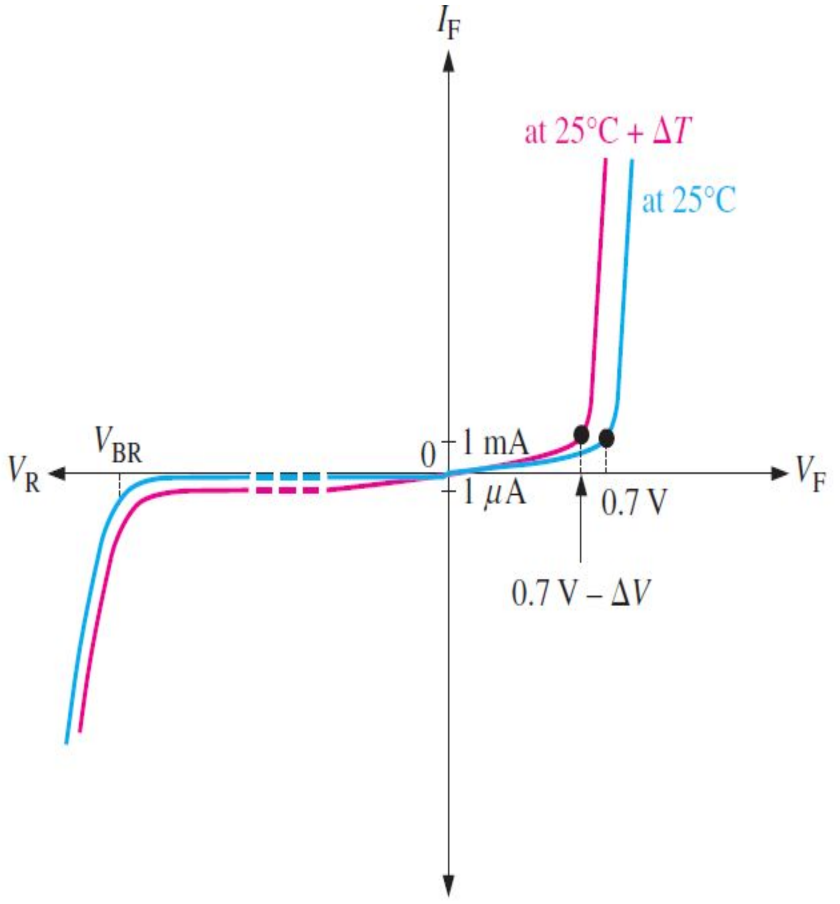
$$Percentage\ \Delta Is = 7\%\, per\, {}^0C\, rise\, of\, temperature$$

- *The change in saturation current is 7 percent for each Celsius degree rise*.

Effect of temperature on barrier potential:

- When the diode is conducting, the junction temperature is higher than the ambient temperature because of the heat created by recombination.
- An increase in junction temperature, creates more free electrons and holes in the doped regions, it causes narrower of depletion region
- Less barrier potential at higher junction temperatures
- The barrier potential of a silicon diode decreases by 2 mV for each degree Celsius rise.

$$\Delta V = (-2mV/\,^{0}C)\Delta T$$



Effect of temperature on V-I characteristics

- The reverse saturation current I_s nearly doubles for every 10^0 C rise in temperature.

$$I_{s(T_2)} = I_{s(T_1)} 2^{\left(\frac{T_2 - T_1}{10}\right)}$$

- When temperature increases by 1^0 C, the junction voltage drops by -2.5 mV.

$$\frac{dV}{dT} = -2.5mV / {}^oC$$

Equivalent circuit of diode

- Shockley's equation gives the exponential relationship between current and voltage.
- The diode characteristic can be approximated by replacing the

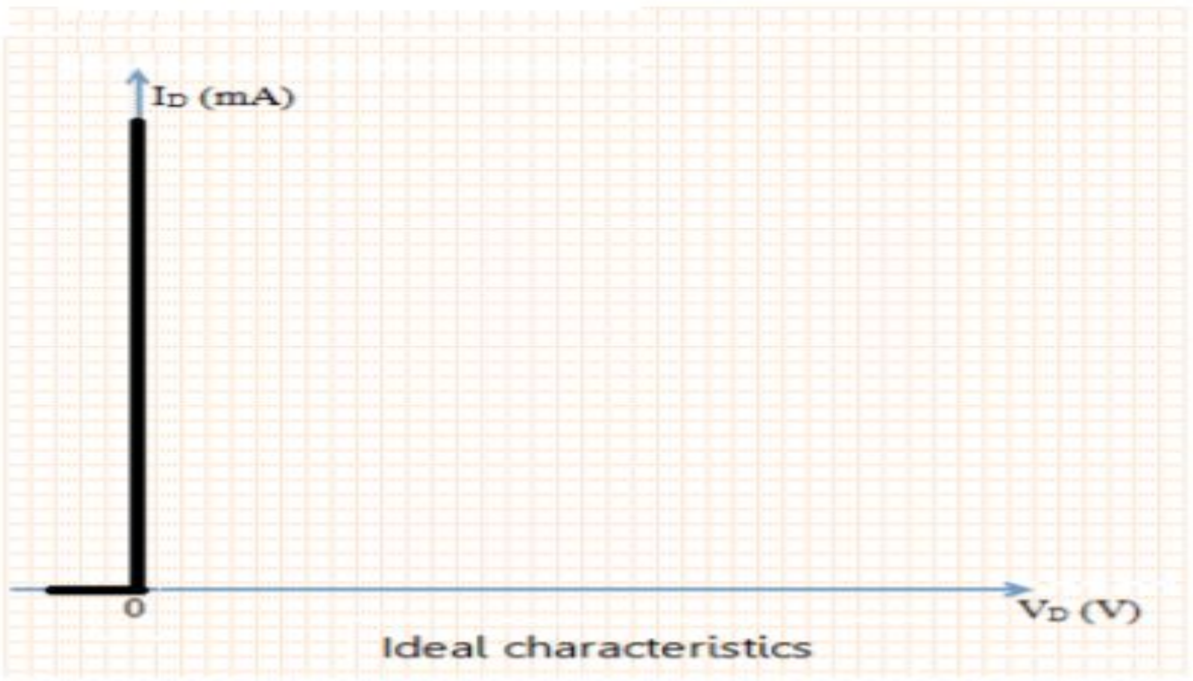
  diode in the circuit with its equivalent circuit.
- An equivalent circuit is a combination of elements that best represents the actual terminal characteristics of the device.
- The diode in the circuit can be replaced by other elements without severely affecting the behavior of circuit.
- Equivalent circuit makes the network/complex circuit analysis simpler.

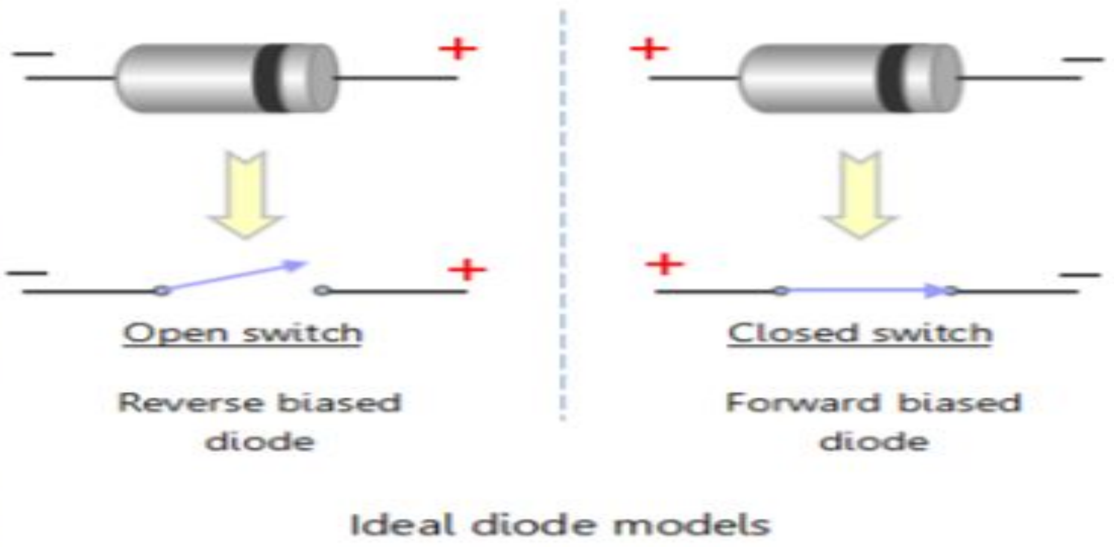
Equivalent circuit of diode

- The diode can be modeled in three different ways depending on the accuracy required.
  1. Ideal Diode Model
  2. Simplified Model
  3. Piece-Wise Linear Model

Ideal Diode Model

- Ideal diode allows the flow of forward current for any value of forward bias voltage. It can be modeled as closed switch under forward bias condition.
- Ideal diode allows zero current to flow under reverse biased condition. It can be modeled as open switch under reverse bias condition.

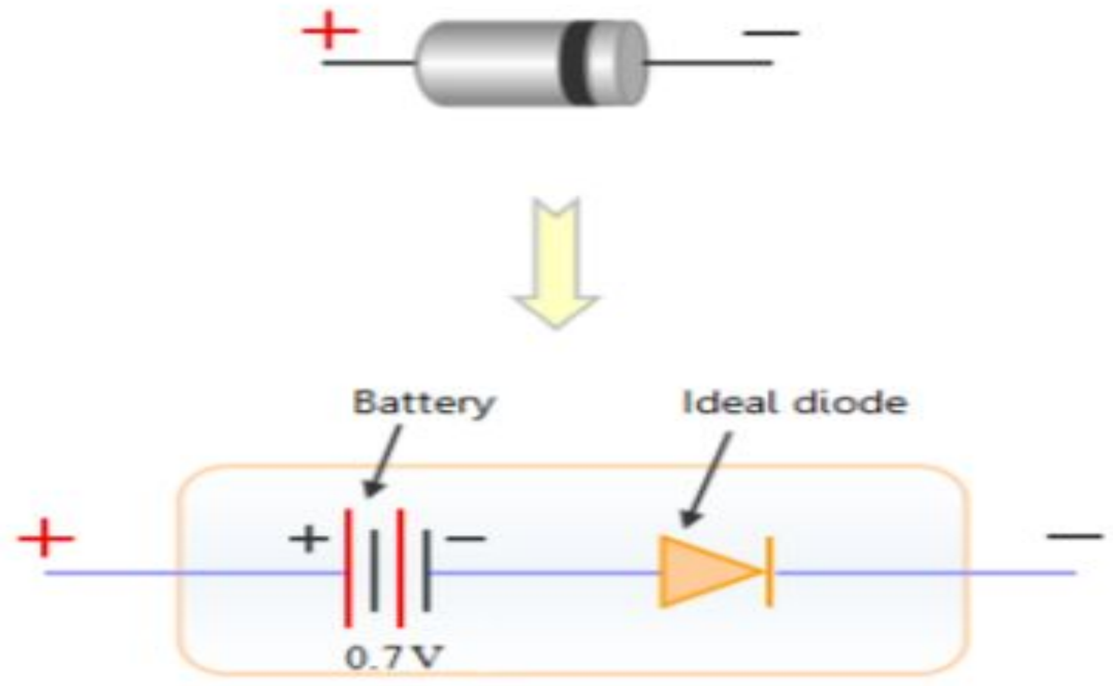




Simplified Model

- The equivalent circuit in simplified model consists of a battery and an ideal diode.

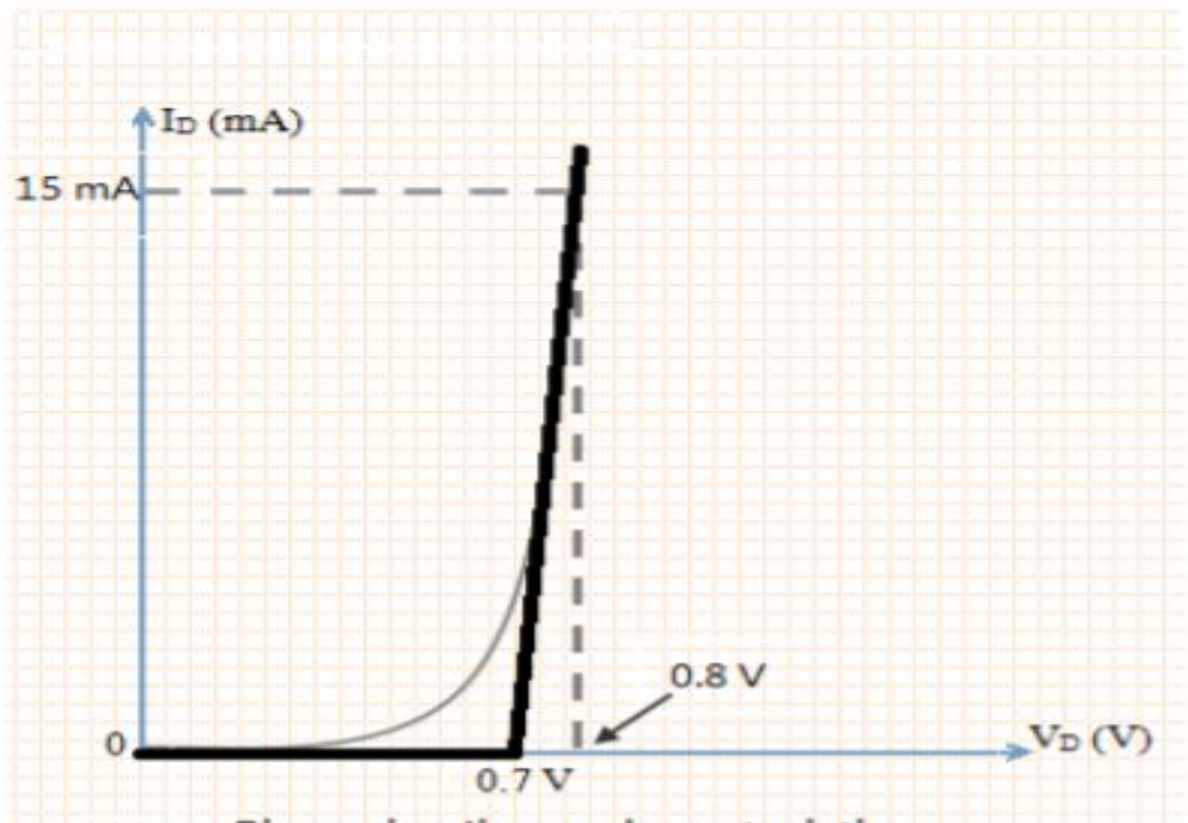
Simplified characteristics



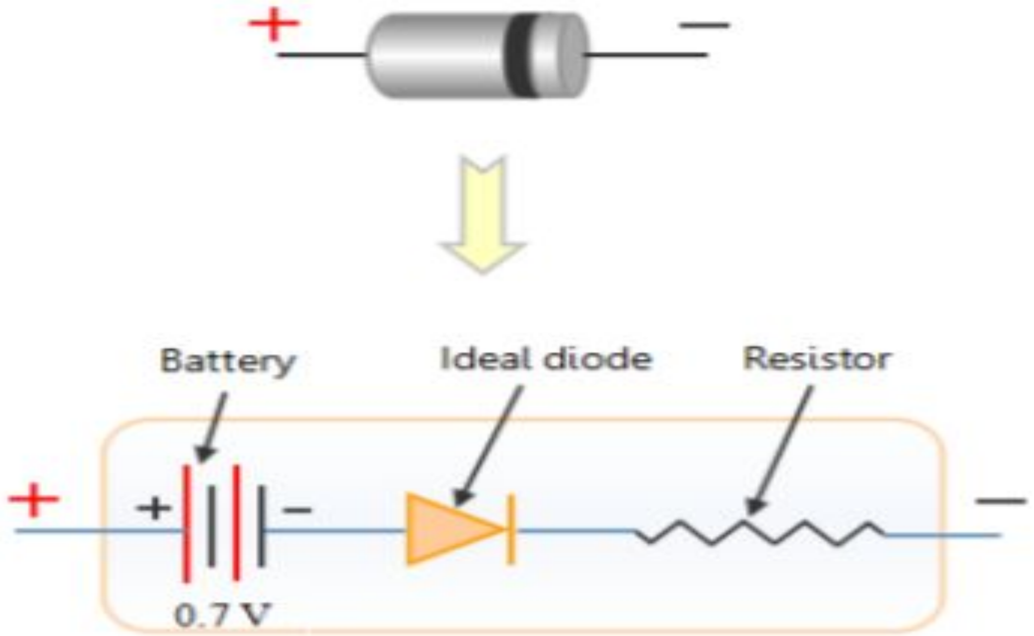
Simplified model

Piece-Wise Linear Model

- Piecewise linear characteristics can be obtained by replacing the diode in the circuit with a resistor, a battery and an ideal diode.



Piecewise-linear characteristics



Piecewise-linear equivalent model

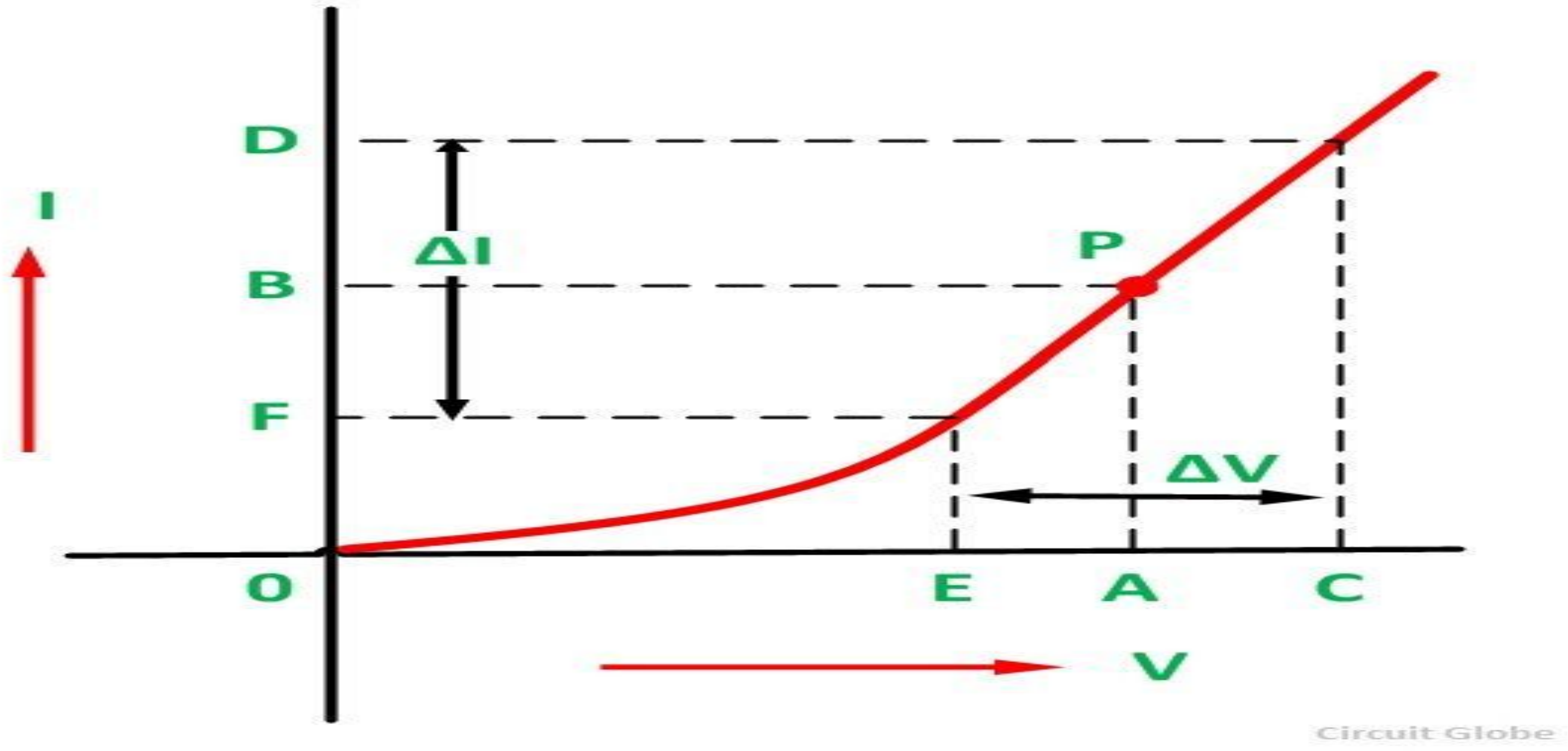
Diode resistance

- Resistance is the opposition offered to the flow of current through the device.
- Diode resistance can be defined as the effective opposition offered by the diode to the flow of current through it.
- Diode offers a small resistance when forward biased, which is called as forward resistance.
- Diode offers a considerable resistance when it is reverse biased, which is called as reverse resistance.
- Diode resistance is classified into two types, static or dynamic depending on whether the current flowing through the device is DC (Direct Current) or AC (Alternating Current), respectively.

Static Resistance

- Static resistance or DC resistance of a PN junction diode defines the diode's resistive nature when a DC source is connected to it.

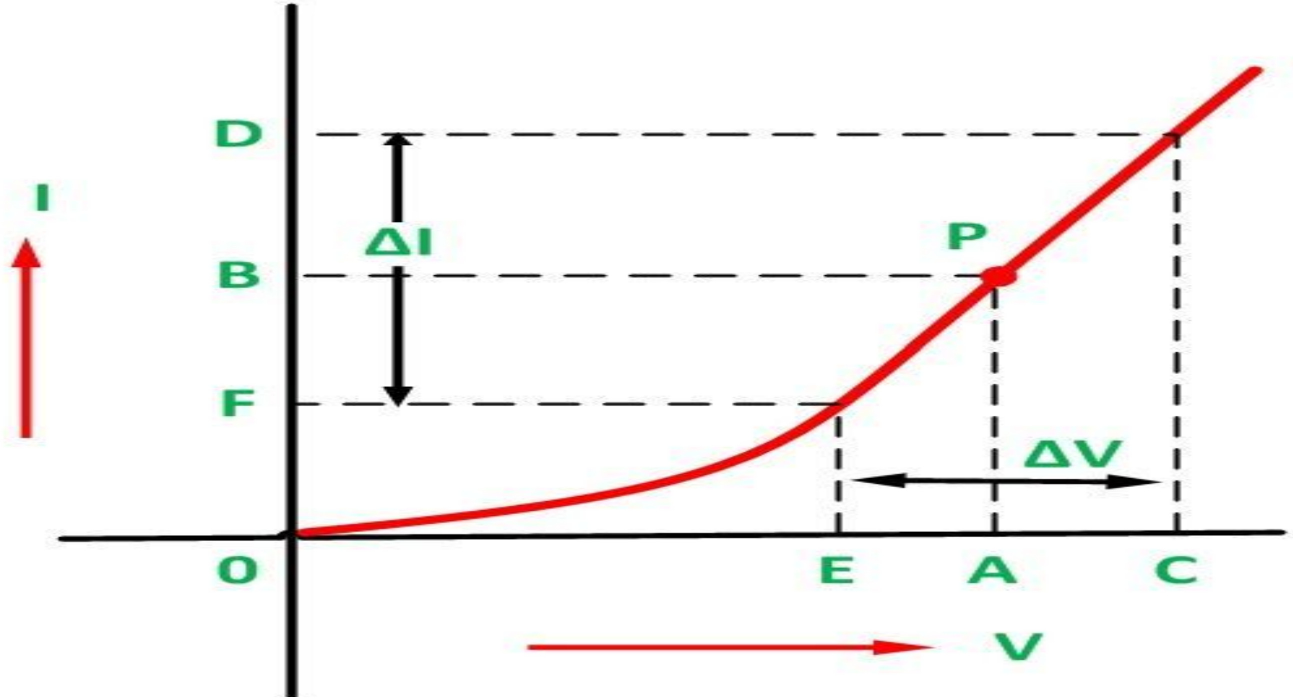
$$R_{DC} = \frac{V}{I}$$



Dynamic Resistance

- Dynamic resistance is the resistance offered by the diode to the flow of AC current through it when it is connected it in a circuit which has an AC voltage source.

$$r_{ac} = dV/dI = nV_T/I$$



Why Si diode is preferred over Ge diode

- Primary reason:
  - $I_s(Ge) > I_s(Si)$:Si diode acts as better switch
  - $PIV(Ge) < PIV(Si)$:Si diode gives better operatable range
  - $E_G(Ge) < E_G(Si)$:Si diode gives better thermal range

- Secondary reason:

  Abundant raw material is available for Si.

The reverse saturation current at 300^0 K of a PN Junction Ge diode is 5μA. Find the voltage applied across the diode to obtain a forward current of 50 mA.

Q2. Determine the current through a diode at 20^0 C with a reverse saturation current of 50nA and applied forward bias voltage of 0.6V.

- Q1. Current through the diode $I_d = I_s(e^{kV_D/T_K} - 1)$

$$I_s = 50 * 10^{-9} A$$

$$T_k = 273 + 20 = 293^0 K$$

$$V_d = 0.6V$$

$$\text{k} = \frac{q}{\eta K} = \frac{11600}{\eta}$$

$\eta = 2$ (ideality factor, it a constant, 2 for Si, 1 for Ge)

$$I_d = 7.19mA$$

Q2. Assuming a barrier potential of 0.7 V at an ambient temperature of 25°C, what is the barrier potential of a silicon diode when the junction temperature is 100°C? At 0° C?

- Q2. When the junction temperature is 100°C, the change in barrier potential is:

$$\Delta V = (-2mV/{}^{0}C)\Delta T$$

$$\Delta T = (100^{0}C - 25^{0}C) = 75^{0}C$$

$$\Delta V = -2mV \times 75^{0}C = -150mV$$

 Due to change in temp, the barrier potential decreases 0.15V from the voltage at room temperature

$$V_b = 0.7 - 0.15 = 0.65V$$

 When the junction temperature is 100°C, the change in barrier potential is:

$$\Delta T = (0^{0}C - 25^{0}C) = -25^{0}C$$

$$\Delta V = -2mV \times -25^{0}C = 50mV$$

$$V_b = 0.7 + 0.05 = 0.75V$$