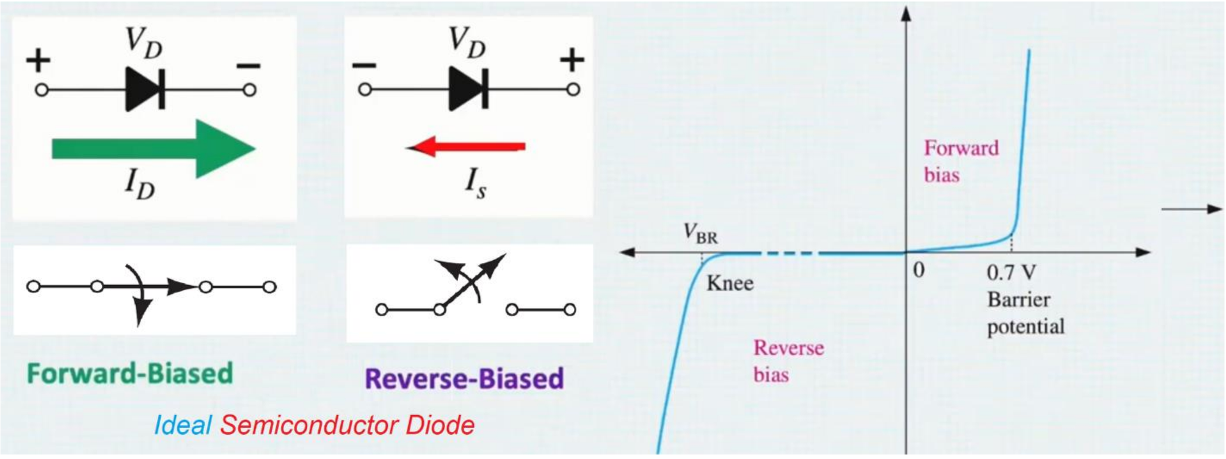
الكلية	كلية الهندسة
القسم	قسم الهندسة الكهربائية
المادة باللغة الانجليزية	Fundamentals of Electronics I
المادة باللغة العربية	أسس الإلكترونيك ١
المرحلة الدراسية	الثانية
اسم التدريسي	حامد ردام حسين
عنوان المحاضرة باللغة الانجليزية	SEMICONDUCTOR DIODES
عنوان المحاضرة باللغة العربية	ثنائيات أشباه الموصلات
رقم المحاضرة	5
المصادر والمراجع	Electronic Devices and Circuit Theory 11thEdition by Robert L. Boylestad, Louis Nashelsky
	Electronic Devices 9th Edition by Thomas L. Floyd

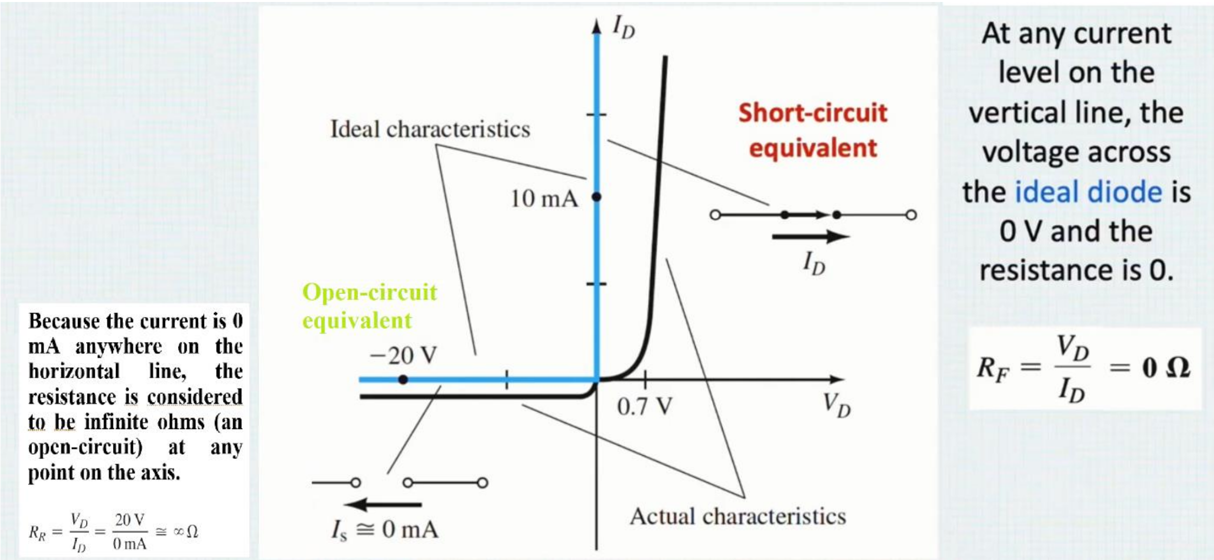
Lecture 4: Ideal VS Practical Diodes and resistance levels

1. Ideal Diode

- PN junction will permit a generous flow of charge when forward-biased and a very small level of current when reverse-biased.
- The semiconductor diode behaves in a manner like a mechanical switch.

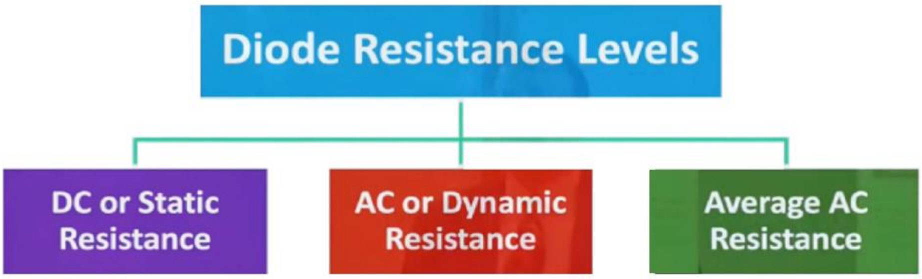


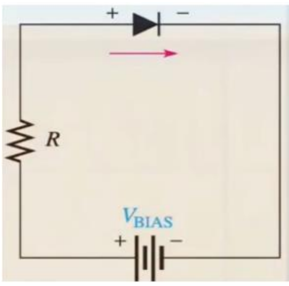
2. Ideal Versus actual Diode Characteristic



3. Diode Resistance levels

- As the operating point of a diode moves from one region to another, the resistance of the diode will change due to the nonlinear shape of the characteristic curve.





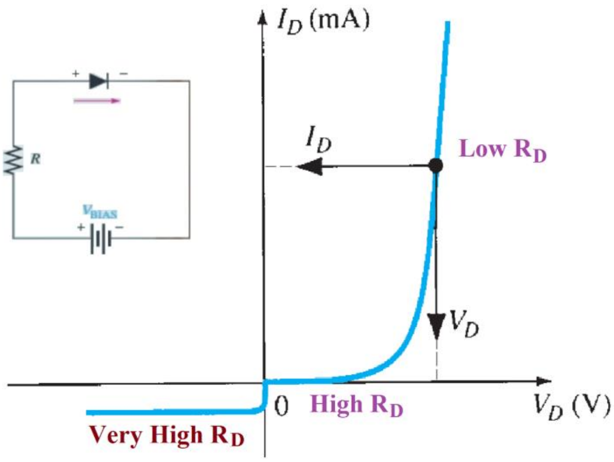
4. *DC or static resistance*

- The application of a dc voltage to a diode will result in an operating point on the characteristic curve that will not change with time.

- The dc resistance of the diode:

$$R_D = \frac{V_D}{I_D}$$

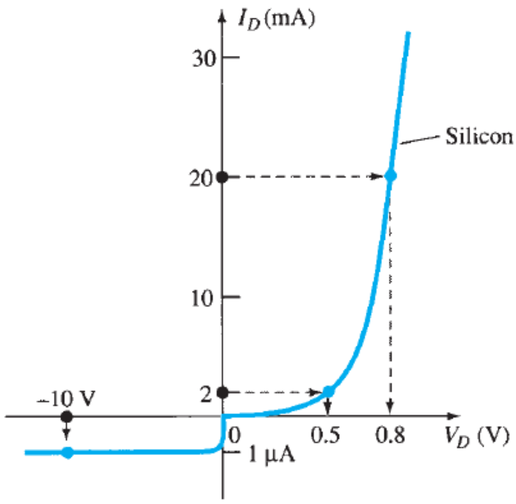
- Typically, the dc resistance of a diode in the active will range from about 10Ω to 80Ω.



In general, the higher the current through a diode, the lower is the dc resistance level.

Example 1.3: Determine the dc resistance levels for the diode of figure below at:

- ID = 2 mA (low level)
- ID = 20 mA (high level)
- VD = -10 V (reverse-biased)



Solution:

a. At $I_D = 2\ mA$, from the curve, $V_D = 0.5\ V$

$$R_D = \frac{V_D}{I_D} = \frac{0.5\ V}{2\ mA} = 250\ \Omega$$

b. At $I_D = 20\ mA$, from the curve, $V_D = 0.8\ V$

$$R_D = \frac{V_D}{I_D} = \frac{0.8\ V}{20\ mA} = 40\ \Omega$$

c. At $V_D = -10\ V$, from the curve, $I_D = -I_S = -1\ \mu A$

$$R_D = \frac{V_D}{I_D} = \frac{10\ V}{1\ \mu A} = 10\ M\Omega$$

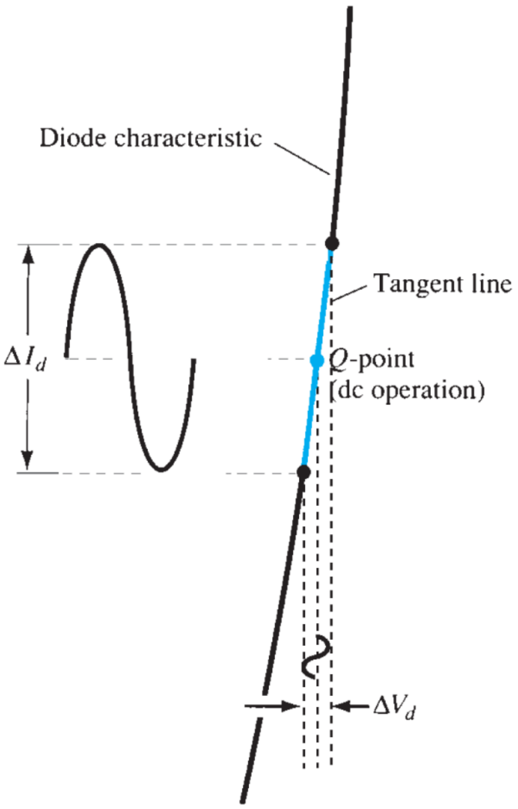
5. *AC or Dynamic Resistance*

- If a sinusoidal voltage is applied, the varying input will move, and the instantaneous operating point will change as well.

- The dynamic resistance r_d Is given by:

$$r_d = \frac{\Delta V_d}{\Delta I_d}$$

- In general, the lower the Q-point of operation (smaller current or lower voltage), the higher is the ac resistance.



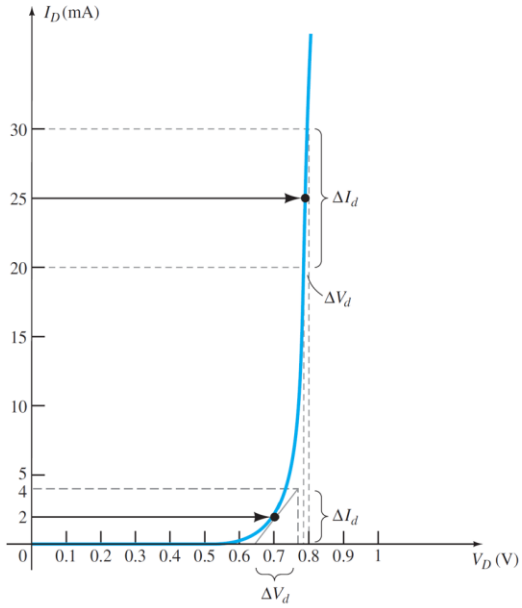
Defining the dynamic or ac resistance.

Example 1.4: For the characteristics of Figure:

a. Determine the **ac resistance** at $I_D = 2\,mA$.

b. Determine the **ac resistance** at $I_D = 25\,mA$.

c. Compare the results of parts (a) and (b) to the **dc resistances** at each current level.



Solution:

a. For $I_D = 2\,mA$

$$\Delta I_d = 4\text{ mA} - 0\text{ mA} = 4\text{ mA}$$
$$\Delta V_d = 0.76\text{ V} - 0.65\text{ V} = 0.11\text{ V}$$

The **ac resistance** is $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.11\,V}{4\,mA} = 27.5\boldsymbol{\Omega}$

b. For $I_D = 25\,mA$

$$\Delta I_d = 30\text{ mA} - 20\text{ mA} = 10\text{ mA}$$
$$\Delta V_d = 0.8\text{ V} - 0.78\text{ V} = 0.02\text{ V}$$

The **ac resistance** is $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.02\,V}{10\,mA} = 2\,\boldsymbol{\Omega}$

c. For $I_D = 2\,mA, V_d = 0.7\,V$ the dc resistance is:

$$R_D = \frac{V_D}{I_D} = \frac{0.7\,V}{2\,mA} = 350\,\boldsymbol{\Omega}$$

Which far exceeds the r_d *of* 27.5 **Ω**

For $I_D = 25\,mA, V_d = 0.79\,V$ the dc resistance is:

$$R_D = \frac{V_D}{I_D} = \frac{0.79\,V}{25\,mA} = 31.62\,\boldsymbol{\Omega}$$

Which far exceeds the r_d of 2 **Ω**

The dynamic resistance (mathematically)

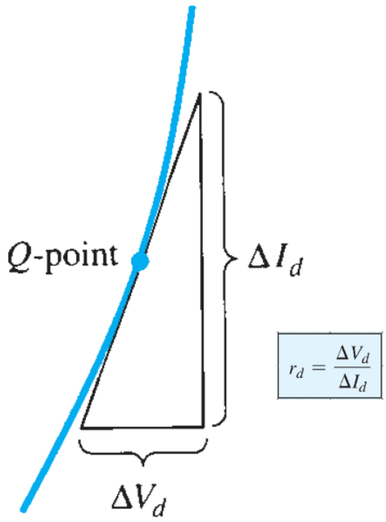
By taking the derivative of equation

$$I_D = I_S(e^{V_D/nV_T} - 1)$$

$$\frac{dV_D}{dI_D} = r_d = \frac{nV_T}{I_D}$$

Substituting $n = 1$ *and* $V_T = 26\,mV$

$$r_d = \frac{26\,mV}{I_D}$$



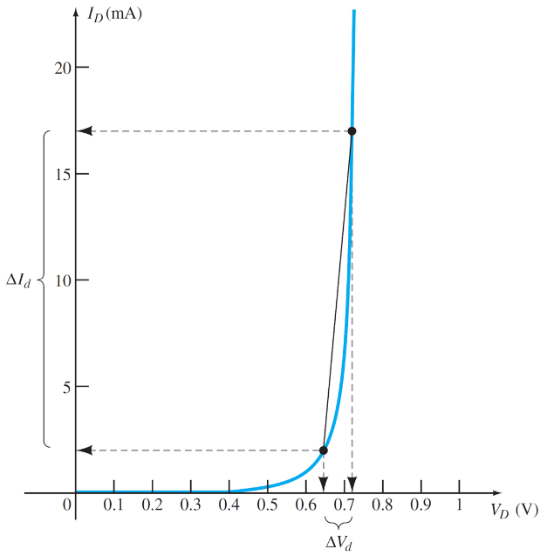
This equation is accurate only for values of I_D In the vertical-rise section of the curve.

6. *Average AC Resistance*

- If the **input signal is sufficiently large** to produce a broad swing, the resistance associated with the device for this region is called the **average ac resistance**.

- The **average ac resistance** is the resistance determined by a **straight line** drawn between the two intersections established by the **maximum** and **minimum** values of **input voltage**.

$$r_{av} = \left.\frac{\Delta V_d}{\Delta I_d}\right|_{\text{pt. to pt.}}$$



$$\Delta I_d = 17\text{ mA} - 2\text{ mA} = 15\text{ mA}$$

$$\Delta V_d = 0.725\text{ V} - 0.65\text{ V} = 0.075\text{ V}$$

$$r_{av} = \frac{\Delta V_d}{\Delta I_d} = \frac{0.075\,V}{15\,mA} = 5\ \Omega$$

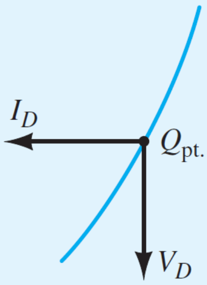
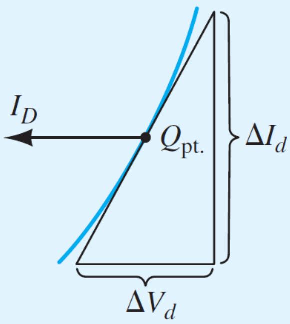
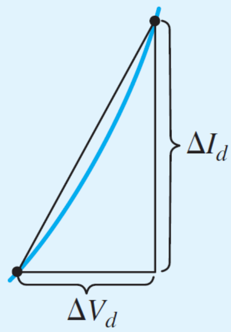
$r_{av} = 5\ \Omega$ defines a value that is considered the average of the ac values from 2 mA to 17 mA.

7. *Summary Table*

Table 1.6 was developed to reinforce the important conclusions of the last few pages and to emphasize the differences among the various resistance levels.

TABLE 1.6

Resistance Levels

Type	Equation	Special Characteristics	Graphical Determination
DC or static	$R_D = \frac{V_D}{I_D}$	Defined as a point on the characteristics	
AC or dynamic	$r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{26\text{ mV}}{I_D}$	Defined by a tangent line at the Q-point	
Average ac	$r_{av} = \frac{\Delta V_d}{\Delta I_d}\bigg\vert_{\text{pt. to pt.}}$	Defined by a straight line between limits of operation	

7. Problem to solve by yourself

In your textbook Solve Problems under sections

1.7 and 1.8

24 to 35 Pages 52 and 53