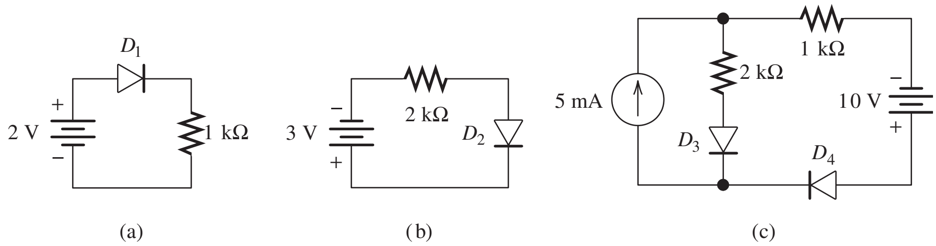


Figure 10.17 Circuits for Exercise 10.8.

In general, we cannot decide on the state of a particular diode until we have found a combination of states that works for all of the diodes in the circuit.

Notice in Example 10.5 that even though current flows in the forward direction of D_2 for our first guess about diode states (D_1 off and D_2 on), the correct solution is that D_2 is off. Thus, in general, we cannot decide on the state of a particular diode until we have found a combination of states that works for all the diodes in the circuit.

For a circuit containing n diodes, there are 2^n possible states. Thus, an exhaustive search eventually yields the solution for each circuit.

Exercise 10.6 Show that the condition D_1 off and D_2 off is not valid for the circuit of Figure 10.16(a). □

Exercise 10.7 Show that the condition D_1 on and D_2 on is not valid for the circuit of Figure 10.16(a). □

Exercise 10.8 Find the diode states for the circuits shown in Figure 10.17. Assume ideal diodes.

Answer **a.** D_1 is on; **b.** D_2 is off; **c.** D_3 is off and D_4 is on. □

10.5 PIECEWISE-LINEAR DIODE MODELS

Sometimes, we want a more accurate model than the ideal-diode assumption, but do not want to resort to nonlinear equations or graphical techniques. Then, we can use **piecewise-linear models** for the diodes. First, we approximate the actual volt–ampere characteristic by straight-line segments. Then, we model each section of the diode characteristic with a resistance in series with a constant-voltage source. Different resistance and voltage values are used in the various sections of the characteristic.

Consider the resistance R_a in series with a voltage source V_a shown in Figure 10.18(a). We can write the following equation, relating the voltage and current of the series combination:

$$v = R_a i + V_a \tag{10.7}$$

The current i is plotted versus v in Figure 10.18(b). Notice that the intercept on the voltage axis is at $v = V_a$ and that the slope of the line is $1/R_a$.

Given a straight-line volt–ampere characteristic, we can work backward to find the corresponding series voltage and resistance. Thus, after a nonlinear volt–ampere characteristic has been approximated by several straight-line segments, a circuit model consisting of a voltage source and series resistance can be found for each segment.

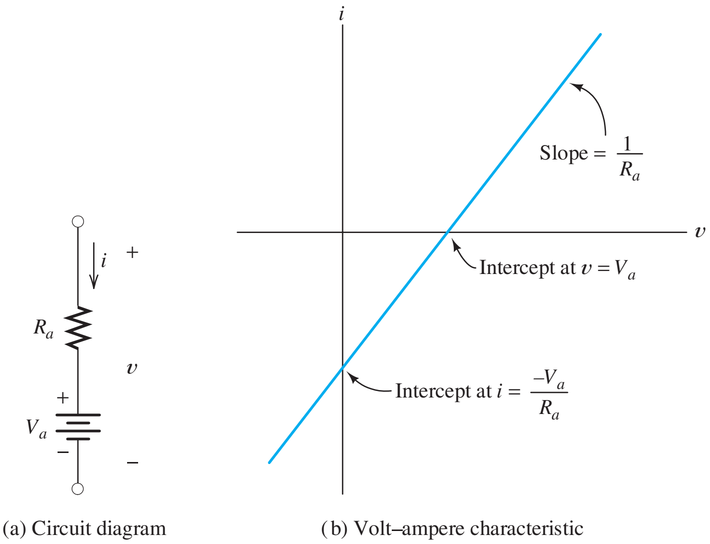


Figure 10.18 Circuit and volt–ampere characteristic for piecewise-linear models.

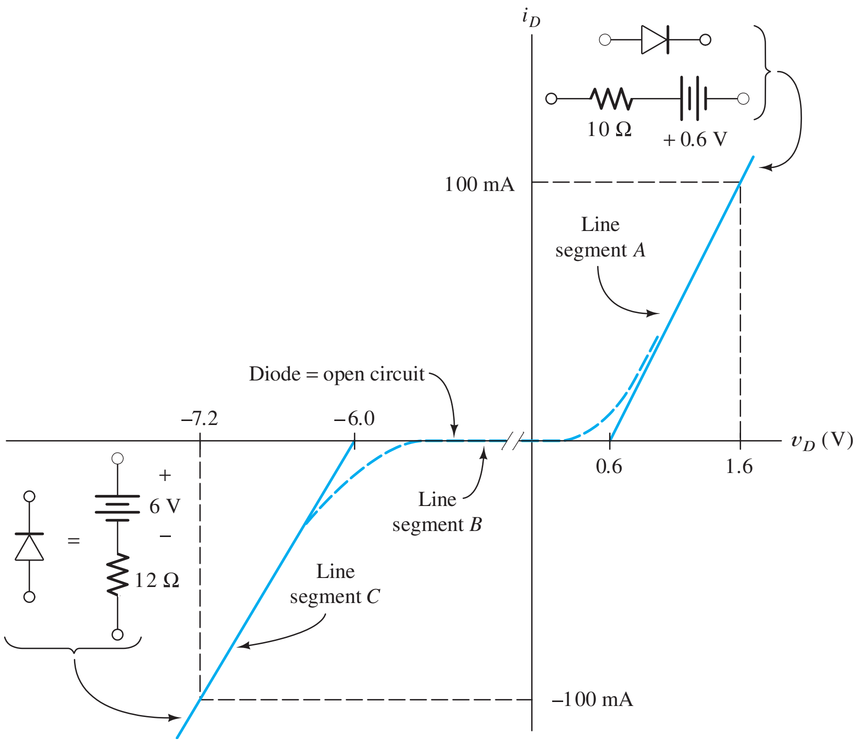


Figure 10.19 Piecewise-linear models for the diode of Example 10.6.

Example 10.6 Piecewise-Linear Model for a Zener Diode

Find circuit models for the Zener-diode volt–ampere characteristic shown in Figure 10.19. Use the straight-line segments shown.

Solution For line segment A of Figure 10.19, the intercept on the voltage axis is 0.6 V and the reciprocal of the slope is 10 Ω. Hence, the circuit model for the diode on this segment is a 10-Ω resistance in series with a 0.6-V source, as shown in the figure. Line segment B has zero current, and therefore, the equivalent circuit for segment B is an open circuit, as illustrated in the figure. Finally, line segment C has an intercept of −6 V and a reciprocal slope of 12 Ω, resulting in the equivalent circuit shown. Thus, this diode can be approximated by one of these linear circuits, depending on where the operating point is located. ■

Example 10.7 Analysis Using a Piecewise-Linear Model

Use the circuit models found in Example 10.6 to solve for the current in the circuit of Figure 10.20(a).

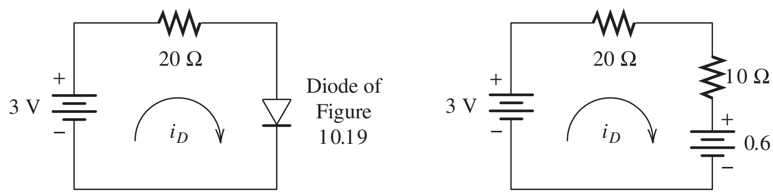
Solution Since the 3-V source has a polarity that results in forward bias of the diode, we assume that the operating point is on line segment A of Figure 10.19. Consequently, the equivalent circuit for the diode is the one for segment A. Using this equivalent circuit, we have the circuit of Figure 10.20(b). Solving, we find that $i_D = 80$ mA. ■

Exercise 10.9 Use the appropriate circuit model from Figure 10.19 to solve for v_o in the circuit of Figure 10.21 if **a.** $R_L = 10$ kΩ and **b.** $R_L = 1$ kΩ. (*Hint:* Be sure that your answers are consistent with your choice of equivalent circuit for the diode—the various equivalent circuits are valid only for specific ranges of diode voltage and current. The answer must fall into the valid range for the equivalent circuit used.)

Answer **a.** $v_o = 6.017$ V; **b.** $v_o = 3.333$ V. □

Exercise 10.10 Find a circuit model for each line segment shown in Figure 10.22(a). Draw the circuit models identifying terminals a and b for each equivalent circuit.

Answer See Figure 10.22(b). Notice the polarity of the voltage sources with respect to terminals a and b. □



(a) Circuit diagram

(b) Circuit with diode modeled by the equivalent circuit for the forward-bias region

Figure 10.20 Circuit for Example 10.7.

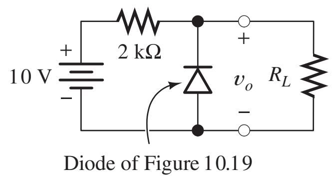
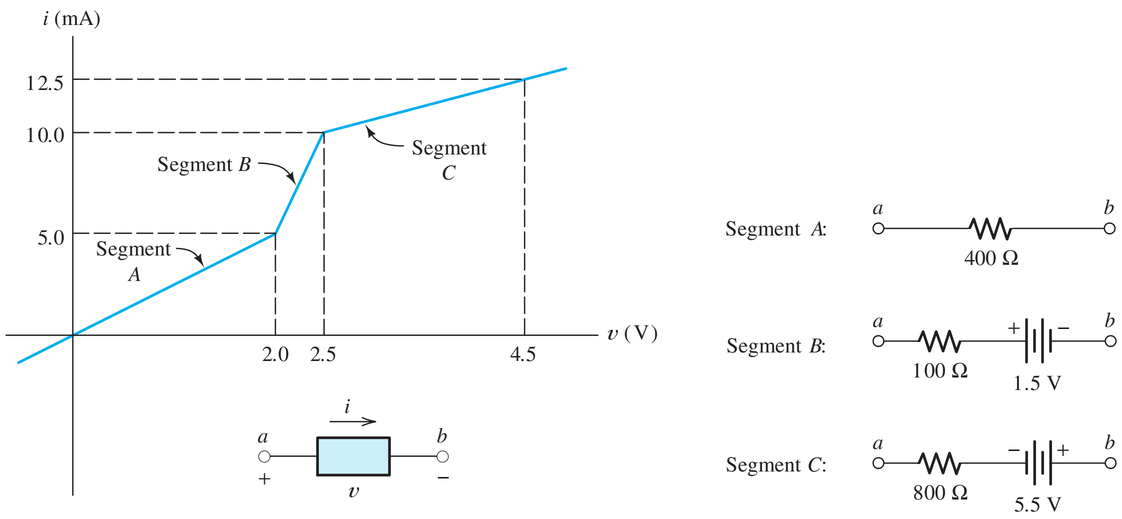


Figure 10.21 Circuit for Exercise 10.9.



(a) Volt–ampere characteristic

(b) Equivalent circuits

Figure 10.22 Hypothetical nonlinear device for Exercise 10.10.

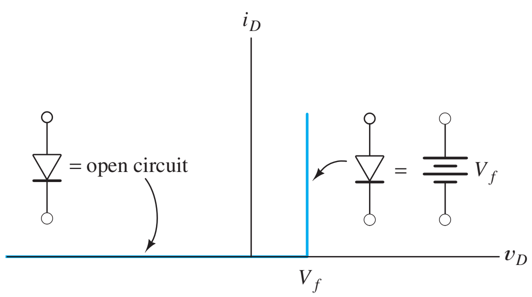


Figure 10.23 Simple piecewise-linear equivalent for the diode.

Simple Piecewise-Linear Diode Equivalent Circuit

Figure 10.23 shows a simple piecewise-linear equivalent circuit for diodes that is often sufficiently accurate. It is an open circuit in the reverse-bias region and a constant voltage drop in the forward direction. This model is equivalent to a battery in series with an ideal diode.

10.6 RECTIFIER CIRCUITS

Now that we have introduced the diode and some methods for analysis of diode circuits, we consider some additional practical circuits. First, we consider several types of **rectifiers**, which convert ac power into dc power. These rectifiers form the basis for electronic **power supplies** and battery-charging circuits. Typically, a power supply takes power from a raw source, which is often the 60-Hz ac power line, and delivers steady dc voltages to a load such as computer circuits or television circuits. Other applications for rectifiers are in signal processing, such as demodulation of a radio signal. (*Demodulation* is the process of retrieving the message, such as a voice or video signal.) Another application is precision conversion of an ac voltage to dc in an electronic voltmeter.