Now that we have a series circuit, we can see that the diode is forward biased. Visualize the diode as a closed switch. Then, the remaining calculations are:

$$I_L = \frac{12\text{ V}}{3\text{ k}\Omega} = 4\text{ mA}$$

and

$$V_L = (4\text{ mA})(1\text{ k}\Omega) = 4\text{ V}$$

You don't have to use Thevenin's theorem. You can analyze Fig. 3-6*b* by visualizing the diode as a closed switch. Then, you have 3 kΩ in parallel with 1 kΩ, equivalent to 750 Ω. Using Ohm's law, you can calculate a voltage drop of 32 V across the 6 kΩ. The rest of the analysis produces the same load voltage and load current.

PRACTICE PROBLEM 3-4 Using Fig. 3-6*b*, change the 36 V source to 18 V and solve for the load voltage and load current using an ideal diode.

3-3 The Second Approximation

The ideal approximation is all right in most troubleshooting situations. But we are not always troubleshooting. Sometimes, we want a more accurate value for load current and load voltage. This is where the *second approximation* comes in.

Figure 3-7*a* shows the graph of current versus voltage for the second approximation. The graph says that no current exists until 0.7 V appears across the diode. At this point, the diode turns on. Thereafter, only 0.7 V can appear across the diode, no matter what the current.

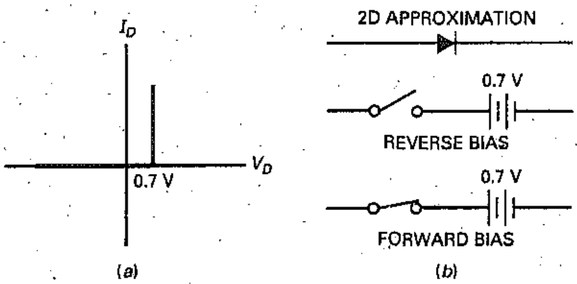
Figure 3-7*b* shows the equivalent circuit for the second approximation of a silicon diode. We think of the diode as a switch in series with a barrier potential of 0.7 V. If the Thevenin voltage facing the diode is greater than 0.7 V, the switch will close. When conducting, then the diode voltage is 0.7 V for any forward current.

On the other hand, if the Thevenin voltage is less than 0.7 V, the switch will open. In this case, there is no current through the diode.

GOOD TO KNOW

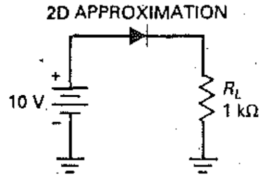
When you troubleshoot a circuit that contains a silicon diode that is supposed to be forward biased, a diode voltage measurement much greater than 0.7 V means that the diode has failed and is in fact open.

Figure 3-7 (*a*) Diode curve for second approximation; (*b*) equivalent circuit for second approximation.



Example 3-5

Figure 3-8



Use the second approximation to calculate the load voltage, load current, and diode power in Fig. 3-8.

SOLUTION Since the diode is forward biased, it is equivalent to a battery of 0.7 V. This means that the load voltage equals the source voltage minus the diode drop:

$$V_L = 10\text{ V} - 0.7\text{ V} = 9.3\text{ V}$$

With Ohm's law, the load current is:

$$I_L = \frac{9.3\text{ V}}{1\text{ k}\Omega} = 9.3\text{ mA}$$

The diode power is

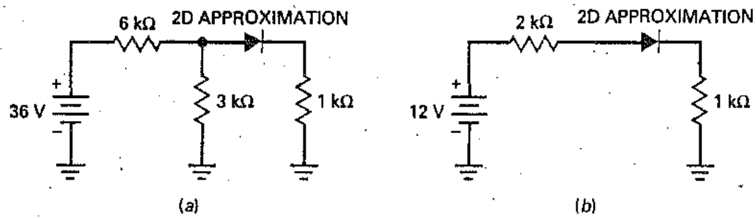
$$P_D = (0.7\text{ V})(9.3\text{ mA}) = 6.51\text{ mW}$$

PRACTICE PROBLEM 3-5 Using Fig. 3-8, change the source voltage to 5 V and calculate the new load voltage, current, and diode power.

Example 3-6

Calculate the load voltage, load current, and diode power in Fig. 3-9*a* using the second approximation.

Figure 3-9 (*a*) Original circuit; (*b*) simplified with Thevenin's theorem.



SOLUTION Again, we will Thevenize the circuit to the left of the diode. As before, the Thevenin voltage is 12 V and the Thevenin resistance is 2 kΩ. Figure 3-9*b* shows the simplified circuit.

Since the diode voltage is 0.7 V, the load current is:

$$I_L = \frac{12\text{ V} - 0.7\text{ V}}{3\text{ k}\Omega} = 3.77\text{ mA}$$

The load voltage is:

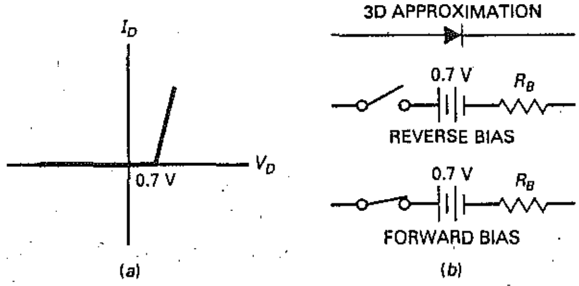
$$V_L = (3.77\text{ mA})(1\text{ k}\Omega) = 3.77\text{ V}$$

and the diode power is:

$$P_D = (0.7\text{ V})(3.77\text{ mA}) = 2.64\text{ mW}$$

PRACTICE PROBLEM 3-6 Repeat Example 3-6 using 18 V as the voltage source value.

Figure 3-10 (*a*) Diode curve for third approximation; (*b*) equivalent circuit for third approximation.



3-4 The Third Approximation

In the *third approximation* of a diode, we include the bulk resistance R_B. Figure 3-10*a* shows the effect that R_B has on the diode curve. After the silicon diode turns on, the voltage increases linearly with an increase in current. The greater the current, the larger the diode voltage because of the voltage drop across the bulk resistance.

The equivalent circuit for the third approximation is a switch in series with a barrier potential of 0.7 V and a resistance of R_B (see Fig. 3-10*b*). When the diode voltage is larger than 0.7 V, the diode conducts. During conduction, the total voltage across the diode is:

$$V_D = 0.7\text{ V} + I_D R_B \qquad (3\text{-}5)$$

Often, the bulk resistance is less than 1 Ω, and we can safely ignore it in our calculations. A useful guideline for ignoring bulk resistance is this definition:

$$\textbf{Ignore bulk: } R_B < 0.01 R_{TH} \qquad (3\text{-}6)$$

This says to ignore the bulk resistance when it is less than 1/100 of the Thevenin resistance facing the diode. When this condition is satisfied, the error is less than 1 percent. The third approximation is rarely used by technicians because circuit designers usually satisfy Eq. (3-6).

Example 3-7

The 1N4001 of Fig. 3-11*a* has a bulk resistance of 0.23 Ω. What is the load voltage, load current, and diode power?

SOLUTION Replacing the diode by its third approximation, we get Fig. 3-11*b*. The bulk resistance is small enough to ignore because it is less than 1/100 of the load resistance. In this case, we can use the second approximation to solve the problem. We already did this in Example 3-6, where we found a load voltage, load current, and diode power of 9.3 V, 9.3 mA, and 6.51 mW.