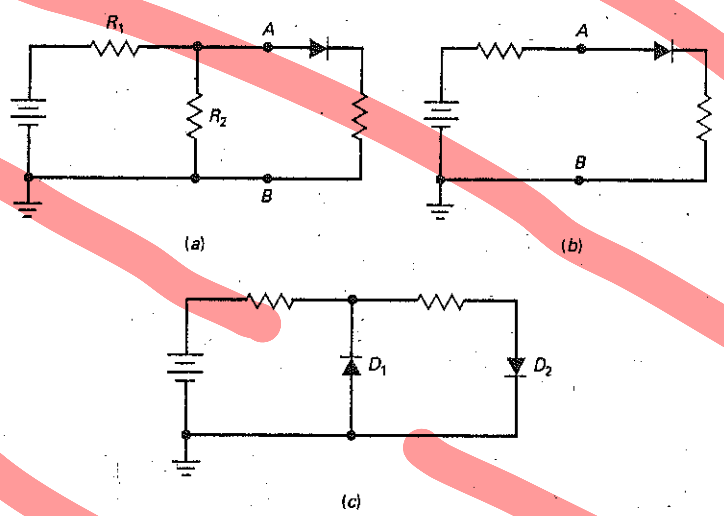
Figure 3-3



PRACTICE PROBLEM 3-1 Are the diodes of Fig. 3-3*c* forward biased or reverse biased?

Example 3-2

A diode has a power rating of 5 W. If the diode voltage is 1.2 V and the diode current is 1.75 A, what is the power dissipation? Will the diode be destroyed?

SOLUTION

$$P_D = (1.2\text{ V})(1.75\text{ A}) = 2.1\text{ W}$$

This is less than the power rating, so the diode will not be destroyed.

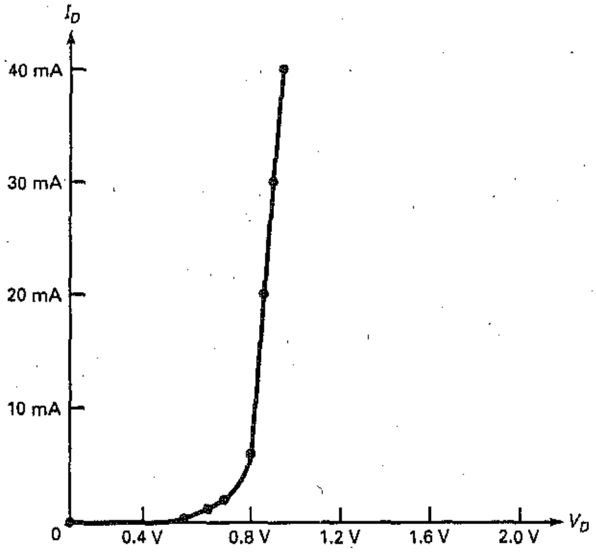
PRACTICE PROBLEM 3-2 Referring to Example 3-2, what is the diode's power dissipation if the diode voltage is 1.1 V and the diode current is 2 A?

3-2 The Ideal Diode

Figure 3-4 shows a detailed graph of the forward region of a diode. Here you see the diode current I_D versus diode voltage V_D. Notice how the current is approximately zero until the diode voltage approaches the barrier potential. Somewhere in the vicinity of 0.6 to 0.7 V, the diode current increases. When the diode voltage is greater than 0.8 V, the diode current is significant and the graph is almost linear.

Depending on how a diode is doped and its physical size, it may differ from other diodes in its maximum forward current, power rating, and other characteristics. If we need an exact solution, we would have to use the graph of

Figure 3-4 Graph of forward current.



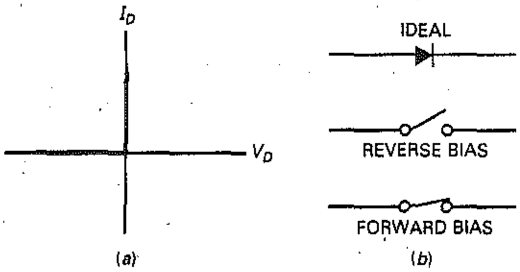
the particular diode. Although the exact current and voltage points will differ from one diode to the next, the graph of any diode is similar to Fig. 3-4. All silicon diodes have a knee voltage of approximately 0.7 V.

Most of the time, we do not need an exact solution. This is why we can and should use approximations for a diode. We will begin with the simplest approximation, called an **ideal diode.** In the most basic terms, what does a diode do? It conducts well in the forward direction and poorly in the reverse direction. Ideally, a diode acts like a perfect conductor (zero resistance) when forward biased and like a perfect insulator (infinite resistance) when reverse biased.

Figure 3-5*a* shows the current-voltage graph of an ideal diode. It echoes what we just said: zero resistance when forward biased and infinite resistance when reverse biased. It is impossible to build such a device, but this is what manufacturers would produce if they could.

Is there any device that acts like an ideal diode? Yes. An ordinary switch has zero resistance when closed and infinite resistance when open. Therefore, an ideal diode acts like a switch that closes when forward biased and opens when reverse biased. Figure 3-5*b* summarizes the switch idea.

Figure 3-5 (*a*) Ideal diode curve; (*b*) ideal diode acts like a switch.



Example 3-3

Use the ideal diode to calculate the load voltage and load current in Fig. 3-6*a*.

SOLUTION Since the diode is forward biased, it is equivalent to a closed switch. Visualize the diode as a closed switch. Then, you can see that all of the source voltage appears across the load resistor:

$$V_L = 10\ \text{V}$$

With Ohm's law, the load current is:

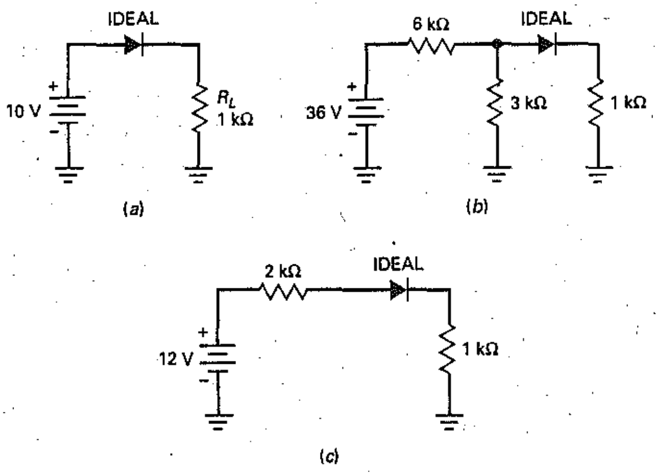
$$I_L = \frac{10\ \text{V}}{1\ \text{k}\Omega} = 10\ \text{mA}$$

PRACTICE PROBLEM 3-3 In Fig. 3-6*a*, find the ideal load current if the source voltage is 5 V.

Example 3-4

Calculate the load voltage and load current in Fig. 3-6*b* using an ideal diode.

Figure 3-6



SOLUTION One way to solve this problem is to Thevenize the circuit to the left of the diode. Looking from the diode back toward the source, we see a voltage divider with 6 kΩ and 3 kΩ. The Thevenin voltage is 12 V, and the Thevenin resistance is 2 kΩ. Figure 3-6*c* shows the Thevenin circuit driving the diode. (If you have any problem understanding this, review Example 1-3.)

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.