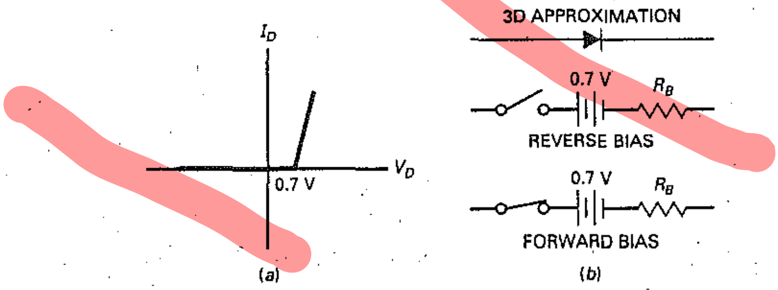
Figure 3-10 (*a*) Diode curve for third approximation; (*b*) equivalent circuit for third approximation.



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:

$$V_D = 0.7\text{ V} + I_D R_B \tag{3-5}$$

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:

$$\textbf{Ignore bulk: } R_B < 0.01R_{TH} \tag{3-6}$$

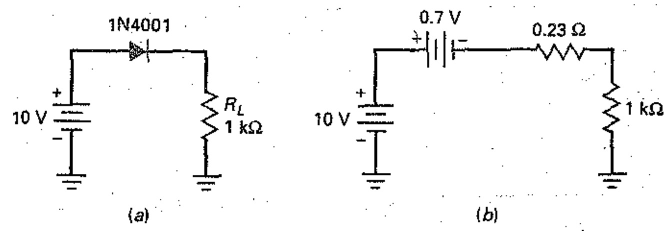
This says to ignore the bulk resistance when it is less than 1/100 of the Thevenin resistance facing the diode. When this condition is satisfied, the error is less than 1 percent. The third approximation is rarely used by technicians because circuit designers usually satisfy Eq. (3-6).

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.

Figure 3-11



Example 3-8

MultiSim

Repeat the preceding example for a load resistance of 10 Ω.

SOLUTION Figure 3-12*a* shows the equivalent circuit. The total resistance is:

$$R_T = 0.23\ \Omega + 10\ \Omega = 10.23\ \Omega$$

The total voltage across R_T is:

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

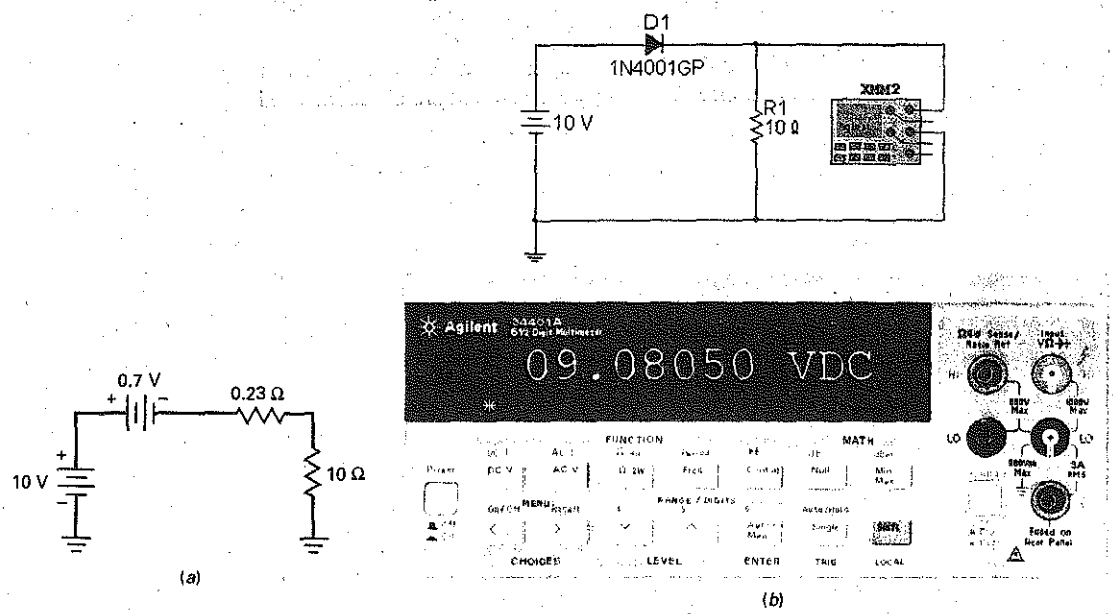
Therefore, the load current is:

$$I_L = \frac{9.3\ \text{V}}{10.23\ \Omega} = 0.909\ \text{A}$$

The load voltage is:

$$V_L = (0.909\ \text{A})(10\ \Omega) = 9.09\ \text{V}$$

Figure 3-12



To calculate the diode power, we need to know the diode voltage. We can get this in either of two ways. We can subtract the load voltage from the source voltage:

$$V_D = 10\text{ V} - 9.09\text{ V} = 0.91\text{ V}$$

or we can use Eq. (3-5):

$$V_D = 0.7\text{ V} + (0.909\text{ A})(0.23\ \Omega) = 0.909\text{ V}$$

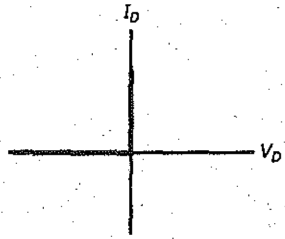
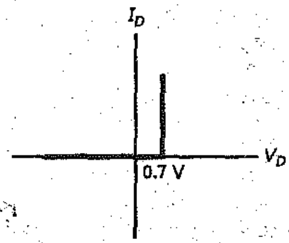
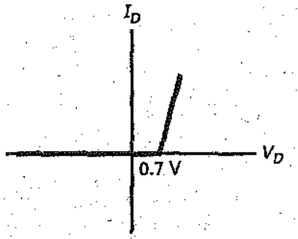
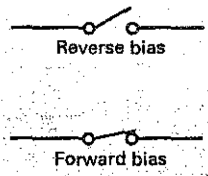
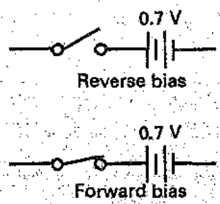
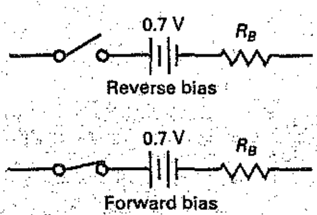
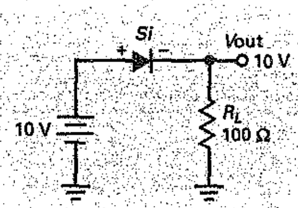
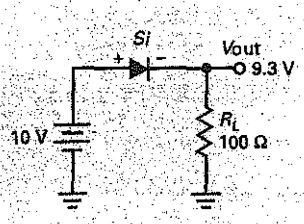
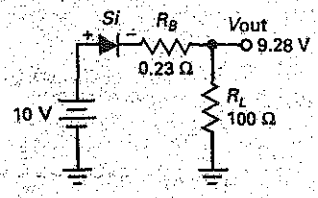
The slight difference in the last two answers is caused by rounding. The diode power is:

$$P_D = (0.909\text{ V})(0.909\text{ A}) = 0.826\text{ W}$$

Two more points. First, the 1N4001 has a maximum forward current of 1 A and a power rating of 1 W, so the diode is being pushed to its limits with a load resistance of 10 Ω. Second, the load voltage calculated with the third approximation is 9.09 V, which is in very close agreement with the MultiSim load voltage of 9.08 V (see Fig. 3-12*b*).

Summary Table 3-1 illustrates the differences between the three diode approximations.

Summary Table 3-1 | Diode Approximations

	First or ideal	Second or practical	Third
When used	Troubleshooting or quick analysis	Analysis at technician level	High-level or engineering-level analysis
Diode curve			
Equivalent circuit			
Circuit example			

PRACTICE PROBLEM 3-8 Repeat Example 3-8 using 5 V as the voltage source value.