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اسم التدريسي	م.د. مصطفى عدنان حمود
عنوان المحاضرة باللغة الانجليزية	**Diode Applications**
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Lecture 3

Diode Applications

3.1 LOAD-LINE ANALYSIS

The circuit of Figure 1 is the simplest of diode configurations. It will be used to describe the analysis of a diode circuit using its **actual characteristics**. Solving the circuit of Figure 1 is all about finding the current and voltage levels that will satisfy both the characteristics of the diode and the chosen network parameters at the same time.

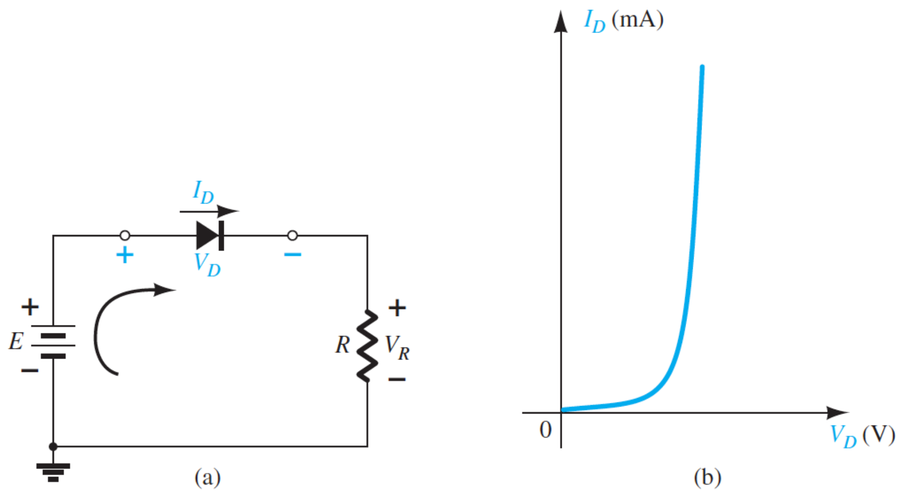


Figure 1: Series diode configuration: (a) circuit; (b) characteristics.

In Figure 2 the diode characteristics are placed on the same set of axes as a straight line defined by the parameters of the network. The straight line is called a *load line* because the intersection on the vertical axis is defined by the applied load R. The analysis to follow is therefore called load-line analysis. The intersection of the two curves will define the solution for the network and define the current and voltage levels for the network.

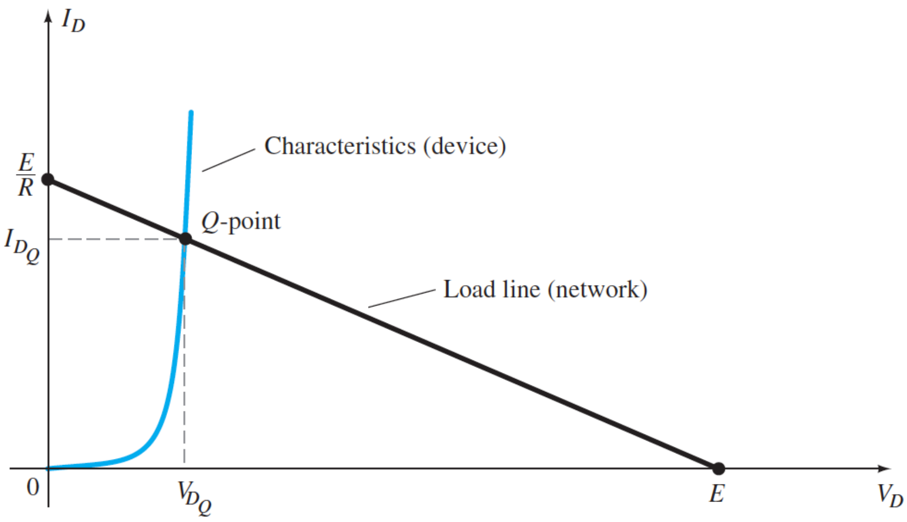


Figure 2: Drawing the load line and finding the point of operation.

The intersections of the load line on the characteristics of Figure 2 can be determined by first applying Kirchhoff's voltage law in the clockwise direction, which results in

$$+E - V_D - V_R = 0$$

or

$$E = V_D + I_D R \tag{2.1}$$

If we set $V_D = 0$ V in Eq. (2.1) and solve for I_D, we have the magnitude of I_D on the vertical axis. Therefore, with $V_D = 0$ V, Eq. (2.1) becomes

$$\begin{aligned} E &= V_D + I_D R \\ &= 0\,\text{V} + I_D R \end{aligned}$$

and

$$I_D = \frac{E}{R}\bigg|_{V_D = 0\,\text{V}} \tag{2.2}$$

as shown in Fig. 2.2 . If we set $I_D = 0$ A in Eq. (2.1) and solve for V_D, we have the magnitude of V_D on the horizontal axis. Therefore, with $I_D = 0$ A, Eq. (2.1) becomes

$$E = V_D + I_D R$$
$$= V_D + (0\text{ A})R$$

and
$$\boxed{V_D = E|_{I_D = 0\text{ A}}} \qquad \textbf{(2.3)}$$

EXAMPLE 2.1 For the series diode configuration of Fig. 2.3a, employing the diode characteristics of Fig. 2.3b, determine:

a. V_{D_Q} and I_{D_Q}.
b. V_R.

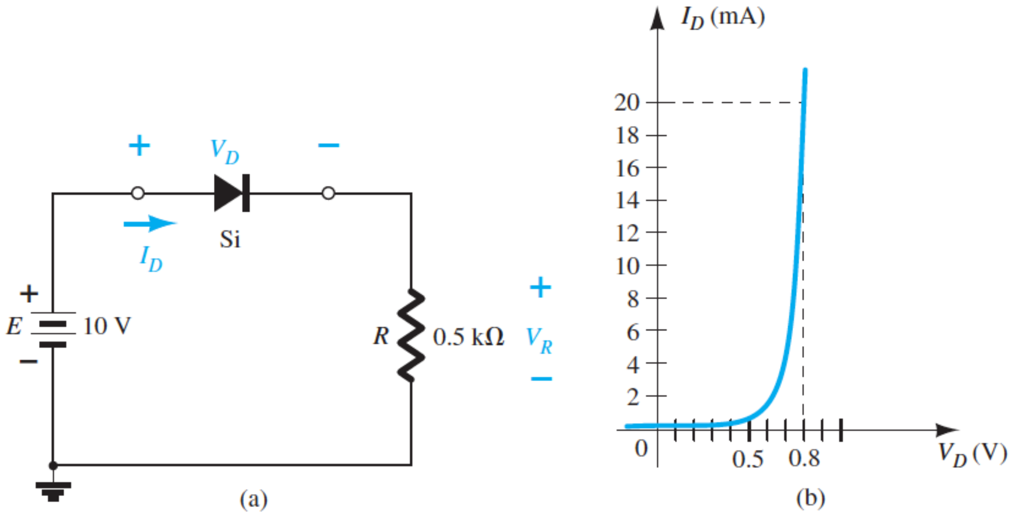


FIG. 2.3
(a) Circuit; (b) characteristics.

Solution:

a. Eq. (2.2): $I_D = \dfrac{E}{R}\Big|_{V_D = 0\text{ V}} = \dfrac{10\text{ V}}{0.5\text{ k}\Omega} = 20\text{ mA}$

Eq. (2.3): $V_D = E|_{I_D = 0\text{ A}} = 10\text{ V}$

The resulting load line appears in Fig. 2.4. The intersection between the load line and the characteristic curve defines the Q-point as

$$V_{D_Q} \cong \mathbf{0.78\ V}$$
$$I_{D_Q} \cong \mathbf{18.5\ mA}$$

The level of V_D is certainly an estimate, and the accuracy of I_D is limited by the chosen scale. A higher degree of accuracy would require a plot that would be much larger and perhaps unwieldy.

b. $V_R = E - V_D = 10\text{ V} - 0.78\text{ V} = \mathbf{9.22\ V}$

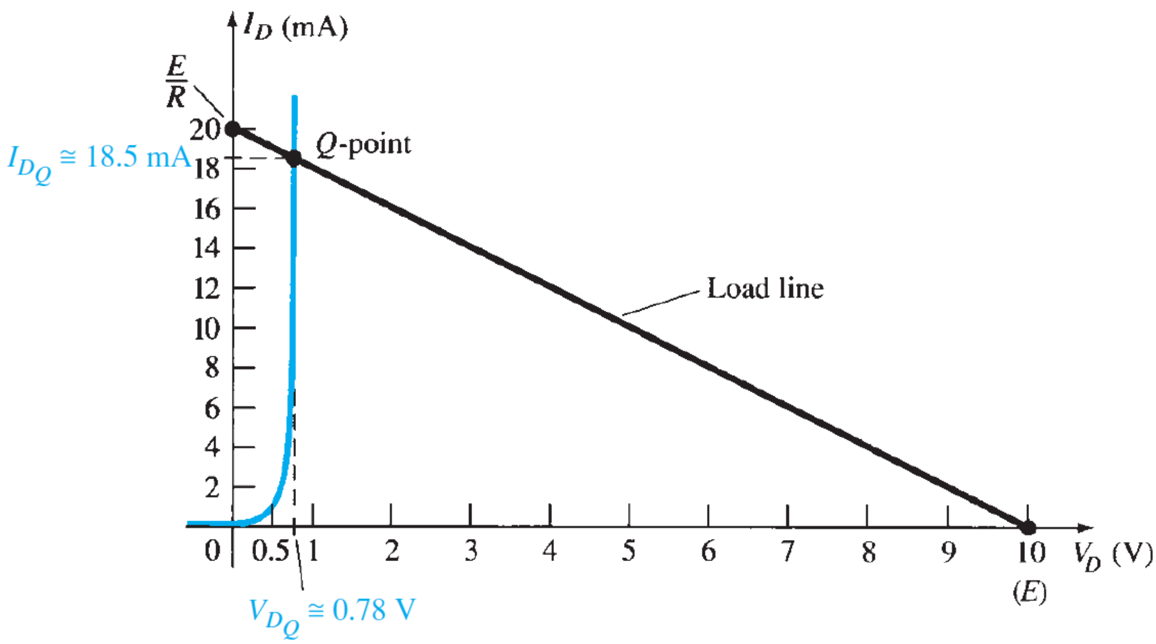


FIG. 2.4

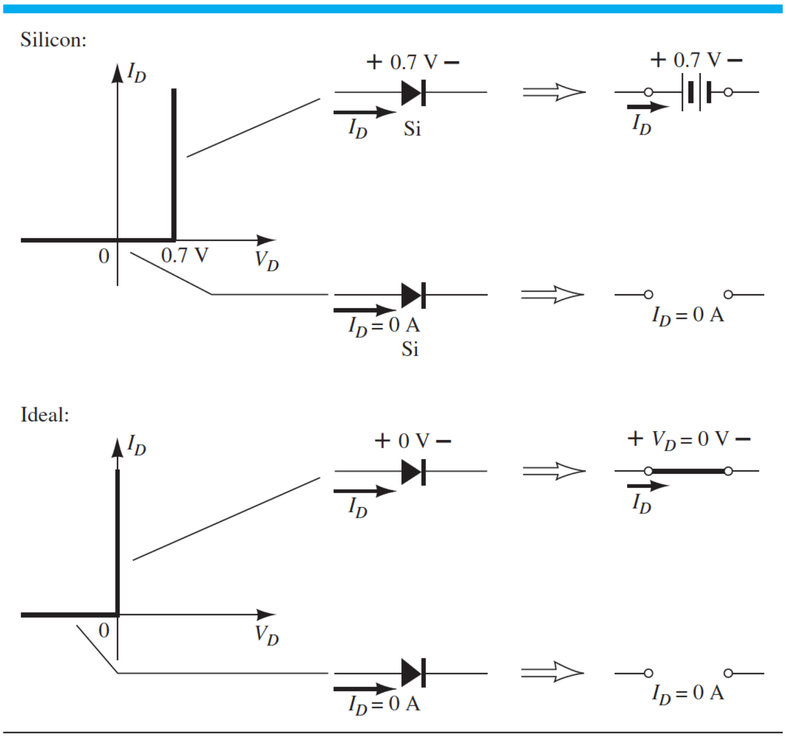
Solution to Example 2.1.

3.2 SERIES DIODE CONFIGURATIONS

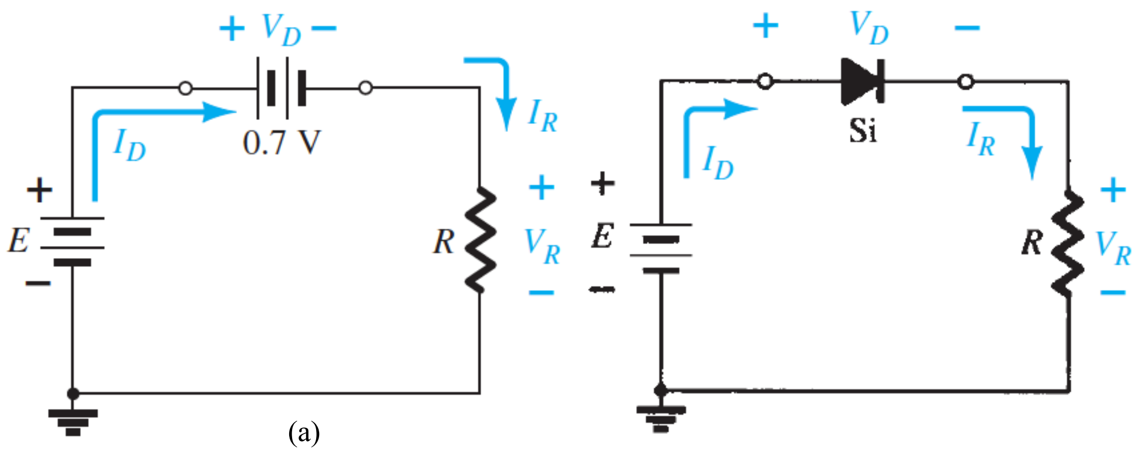
This is a valid approximation for the vast majority of applications that employ diodes. Using this fact will result in the approximate equivalents for a silicon diode and an ideal diode that appear in Table 1 . For the conduction region the only difference between the silicon diode and the ideal diode is the vertical shift in the characteristics, which is accounted for in the equivalent model by a dc supply of 0.7 V opposing the direction of forward current through the device. For voltages less than 0.7 V for a silicon diode and 0 V for the ideal diode the resistance is so high compared to other elements of the network that its equivalent is the open circuit. For a Ge diode the offset voltage is 0.3 V and for a GaAs diode it is 1.2 V. Otherwise the equivalent networks are the same. For each diode the label Si, Ge, or GaAs will appear along with the diode symbol. For networks with ideal diodes the diode symbol will appear as shown in Table 1 without any labels.

Table 1

Approximate and Ideal Semiconductor Diode Models.



In general, a diode is in the "on" state if the current established by the applied sources is such that its direction matches that of the arrow in the diode symbol, and $V_D \geq 0.7$ V for silicon, $V_D \geq 0.3$ V for germanium, and $V_D \geq 1.2$ V for gallium arsenide.



$$V_D = V_K \tag{2.4}$$

$$V_R = E - V_K \tag{2.5}$$

$$I_D = I_R = \frac{V_R}{R} \tag{2.6}$$

Where $V_K = 0.7$ V for Silicon diode (Si)

$V_K = 0.3$ V for germanium diode (Ge)

$V_K = 1.2$ V for gallium arsenide (GaAs)

EXAMPLE 2.4 For the series diode configuration of Fig. 2.13, determine V_D, V_R, and I_D.

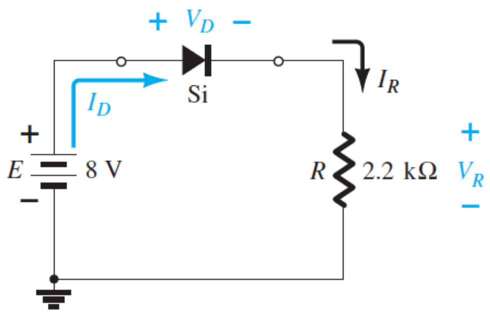


FIG. 2.13
Circuit for Example 2.4.

Solution: Since the applied voltage establishes a current in the clockwise direction to match the arrow of the symbol and the diode is in the "on" state,

$$V_D = \mathbf{0.7\ V}$$

$$V_R = E - V_D = 8\text{ V} - 0.7\text{ V} = \mathbf{7.3\ V}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\text{ V}}{2.2\text{ k}\Omega} \cong \mathbf{3.32\ mA}$$

EXAMPLE 2.5 Repeat Example 2.4 with the diode reversed.

Solution: Removing the diode, we find that the direction of I is opposite to the arrow in the diode symbol and the diode equivalent is the open circuit no matter which model is employed. The result is the network of Fig. 2.14, where $I_D = \mathbf{0\ A}$ due to the open circuit. Since $V_R = I_R R$, we have $V_R = (0)R = \mathbf{0\ V}$. Applying Kirchhoff's voltage law around the closed loop yields

$$E - V_D - V_R = 0$$

and

$$V_D = E - V_R = E - 0 = E = 8\ \text{V}$$

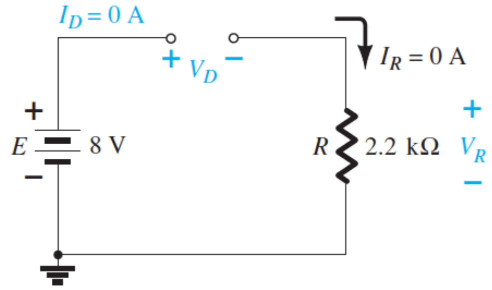


FIG. 2.14
Determining the unknown quantities for Example 2.5.

keep the following in mind for the analysis to follow:

An open circuit can have any voltage across its terminals, but the current is always 0 A. A short circuit has a 0-V drop across its terminals, but the current is limited only by the surrounding network.

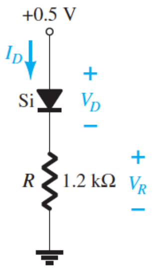


FIG. 2.16
Series diode circuit for Example 2.6.

EXAMPLE 2.6 For the series diode configuration of Fig. 2.16, determine V_D, V_R, and I_D.

Solution: Although the "pressure" establishes a current with the same direction as the arrow symbol, the level of applied voltage is insufficient to turn the silicon diode "on." The point of operation on the characteristics is shown in Fig. 2.17, establishing the open-circuit equivalent as the appropriate approximation, as shown in Fig. 2.18. The resulting voltage and current levels are therefore the following:

$$I_D = \mathbf{0\ A}$$

$$V_R = I_R R = I_D R = (0\ \text{A})\,1.2\ \text{k}\Omega = \mathbf{0\ V}$$

and

$$V_D = E = \mathbf{0.5\ V}$$

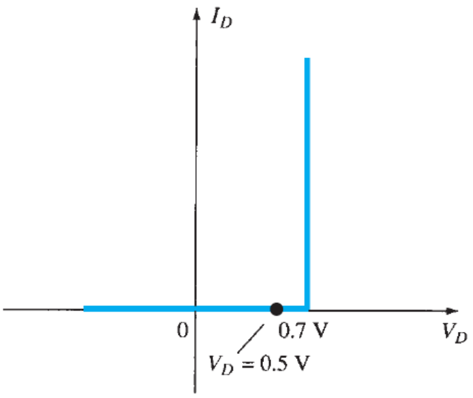


FIG. 2.17
Operating point with E = 0.5 V.

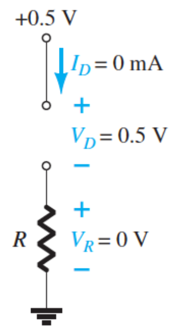


FIG. 2.18
Determining I_D, V_R, and V_D for the circuit of Fig. 2.16.

EXAMPLE 2.8 Determine I_D , V_{D2}, and V_o for the circuit of Fig. 2.21 .

Solution: There is a match in current direction for one silicon diode but not for the other silicon diode. The combination of a short circuit in series with an open circuit always results in an open circuit and I_D = 0 A, as shown in Fig. 2.23.

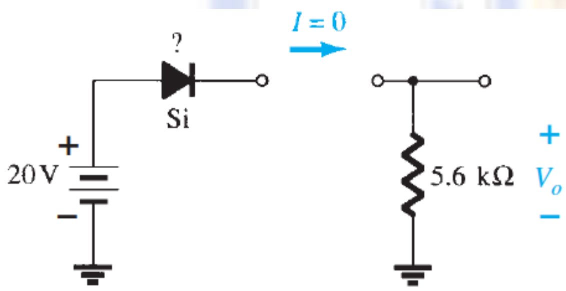


FIG. 2.23
Substituting the equivalent state for the open diode.

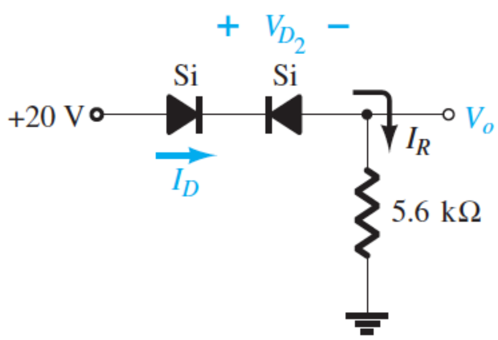


FIG. 2.21
Circuit for Example 2.8.

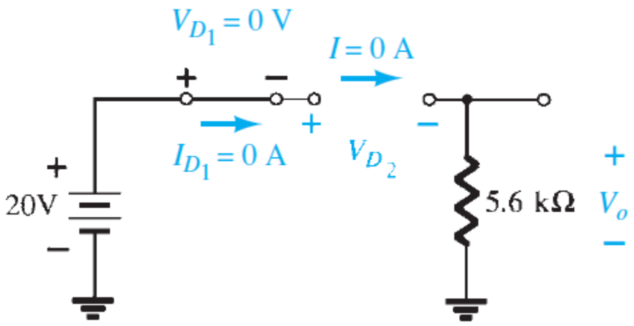


FIG. 2.24
Determining the unknown quantities for the circuit of Example 2.8.

The conditions described by $I_D = 0$ A and $V_{D_1} = 0$ V are indicated in Fig. 2.24. We have

$$V_o = I_R R = I_D R = (0\text{ A})R = \mathbf{0\ V}$$

and

$$V_{D_2} = V_{\text{open circuit}} = E = \mathbf{20\ V}$$

Applying Kirchhoff's voltage law in a clockwise direction gives

$$E - V_{D_1} - V_{D_2} - V_o = 0$$

and

$$V_{D_2} = E - V_{D_1} - V_o = 20\text{ V} - 0 - 0$$
$$= \mathbf{20\ V}$$

with

$$V_o = \mathbf{0\ V}$$

EXAMPLE 2.9 Determine I, V_1, V_2, and V_o for the series dc configuration of Fig. 2.25.

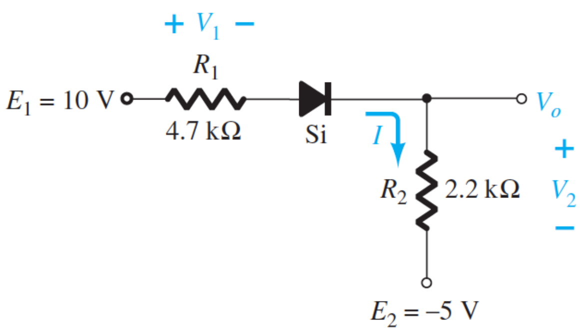


FIG. 2.25
Circuit for Example 2.9.

Solution:

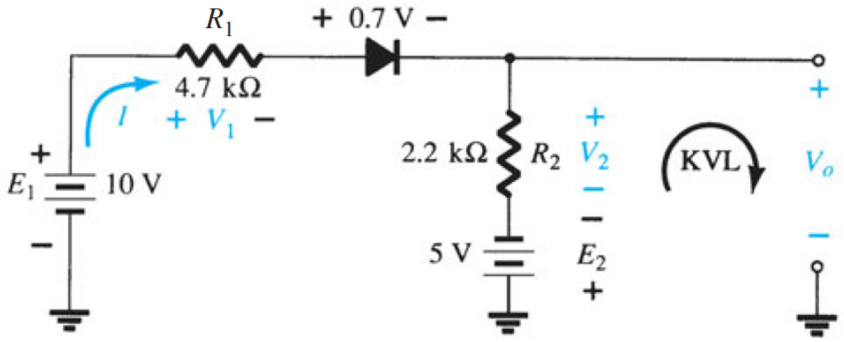


FIG. 2.27

Determining the unknown quantities for the network of Fig. 2.25. KVL, Kirchhoff voltage loop.

$$I = \frac{E_1 + E_2 - V_D}{R_1 + R_2} = \frac{10\text{ V} + 5\text{ V} - 0.7\text{ V}}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = \frac{14.3\text{ V}}{6.9\text{ k}\Omega}$$
$$\cong \mathbf{2.07\ mA}$$

and the voltages are

$$V_1 = IR_1 = (2.07\text{ mA})(4.7\text{ k}\Omega) = \mathbf{9.73\ V}$$
$$V_2 = IR_2 = (2.07\text{ mA})(2.2\text{ k}\Omega) = \mathbf{4.55\ V}$$

Applying Kirchhoff's voltage law to the output section in the clockwise direction results in

$$-E_2 + V_2 - V_o = 0$$

and $$V_o = V_2 - E_2 = 4.55\text{ V} - 5\text{ V} = \mathbf{-0.45\ V}$$

The minus sign indicates that V_o has a polarity opposite to that appearing in Fig. 2.25.

3.3 Parallel and series-parallel configurations

EXAMPLE 2.10 Determine V_o, I_1, I_{D_1}, and I_{D_2} for the parallel diode configuration of Fig. 2.28.

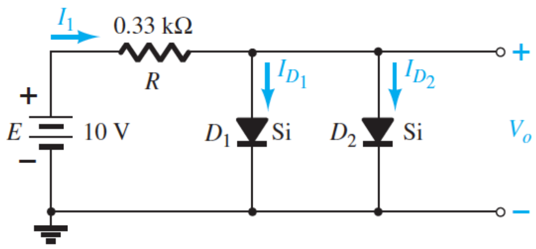


FIG. 2.28
Network for Example 2.10.

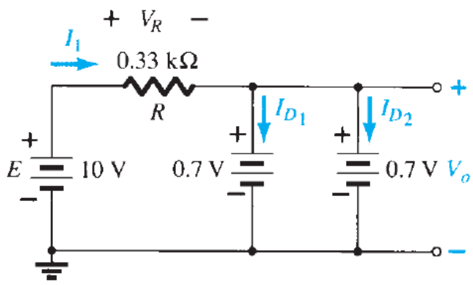


FIG. 2.29
Determining the unknown quantities for the network of Example 2.10.

Solution

$$V_o = \mathbf{0.7\ V}$$

The current is

$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\text{ V} - 0.7\text{ V}}{0.33\text{ k}\Omega} = \mathbf{28.18\ mA}$$

Assuming diodes of similar characteristics, we have

$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\text{ mA}}{2} = \mathbf{14.09\ mA}$$