Electronic Devices

Course Teacher
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Prepared By
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Reference book:

Electronic Devices and Circuit Theory (Chapter-2)

Robert L. Boylestad and L. Nashelsky , (11^{th} Edition)

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Objectives

- ✯Understand the concept of load-line analysis and how it is applied to diode networks.

- ✯Become familiar with the use of equivalent circuits to analyze series, parallel, and series-parallel diode networks.

LOAD-LINE ANALYSIS

- The load line plots all possible combinations of diode current (I_D) and voltage (V_D) for a given circuit.
- The maximum I_D equals E/R, and the maximum V_D equals E.
- The point where the load line and the characteristic curve intersect is the Q-point, which identifies I_D and V_D for a particular diode in a given circuit.

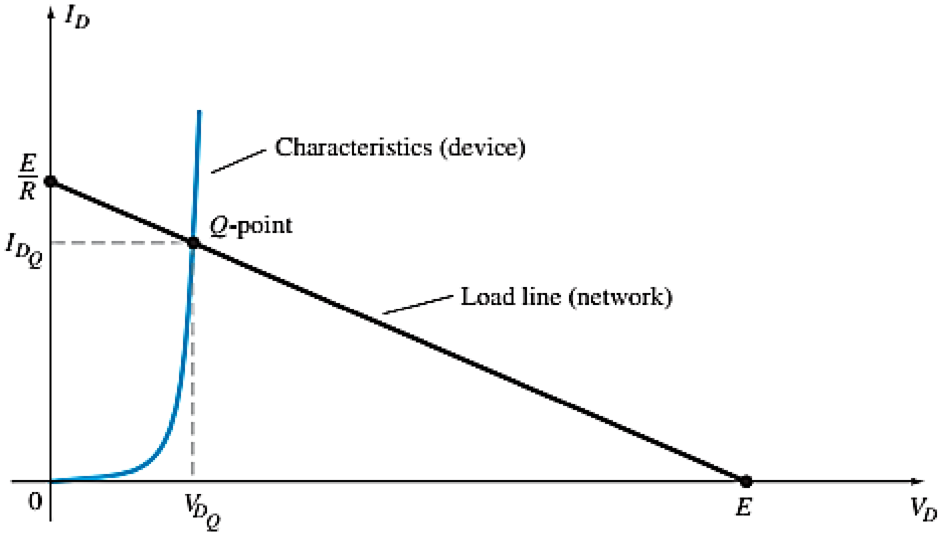


FIG. 2.2
Drawing the load line and finding the point of operation.

LOAD-LINE ANALYSIS

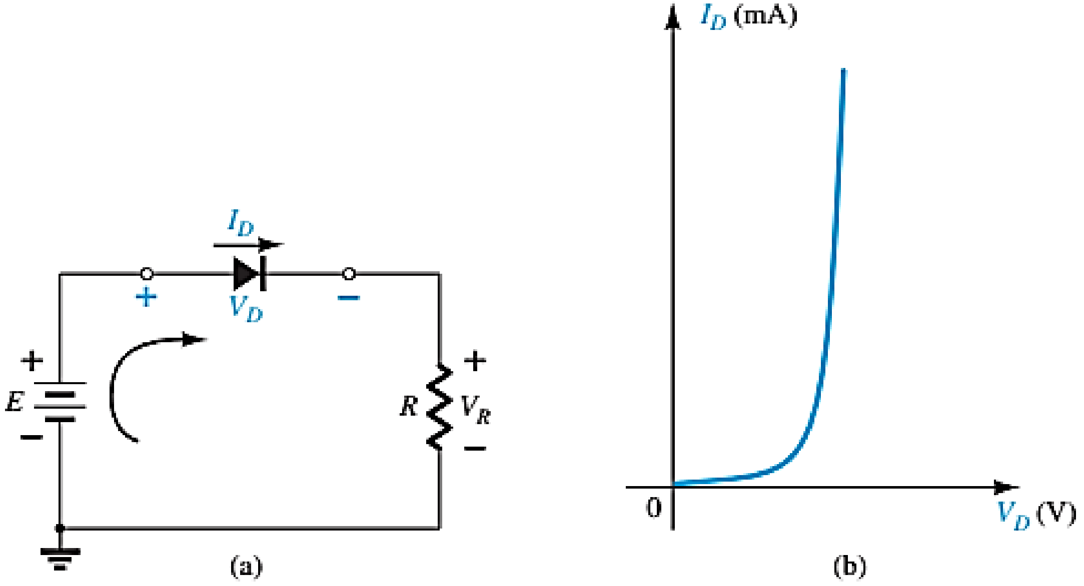


FIG. 2.1
Series diode configuration: (a) circuit; (b) characteristics.

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

$$\boxed{E = V_D + I_D R}$$

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

$$\boxed{I_D = \frac{E}{R}\bigg|_{V_D = 0\,\mathrm{V}}}$$

$$\begin{aligned} E &= V_D + I_D R \\ &= V_D + (0\,\mathrm{A})R \end{aligned}$$

$$\boxed{V_D = E\big|_{I_D = 0\,\mathrm{A}}}$$

LOAD-LINE ANALYSIS

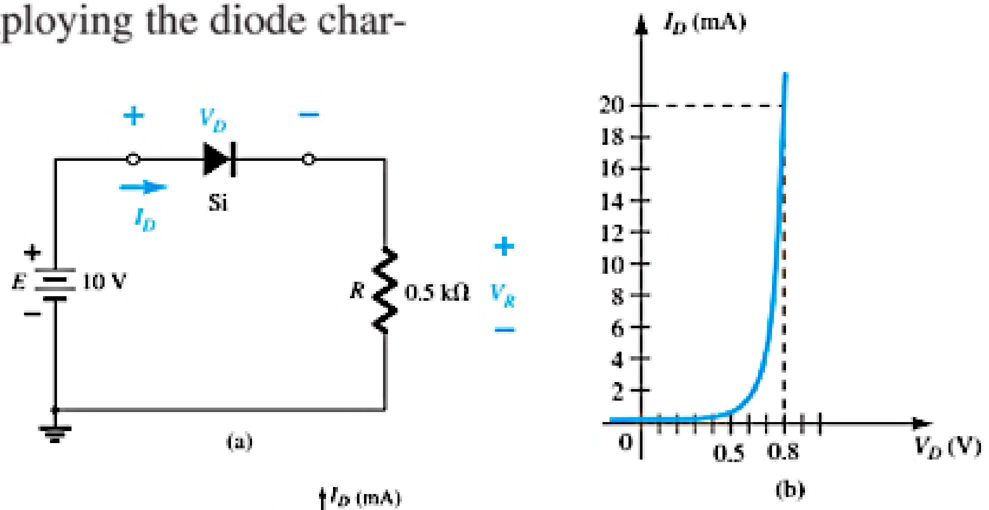
EXAMPLE 2.1 For the series diode configuration of Fig. 2.3a, employing the diode characteristics of Fig. 2.3b, determine:

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

Solution:

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

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



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

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

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

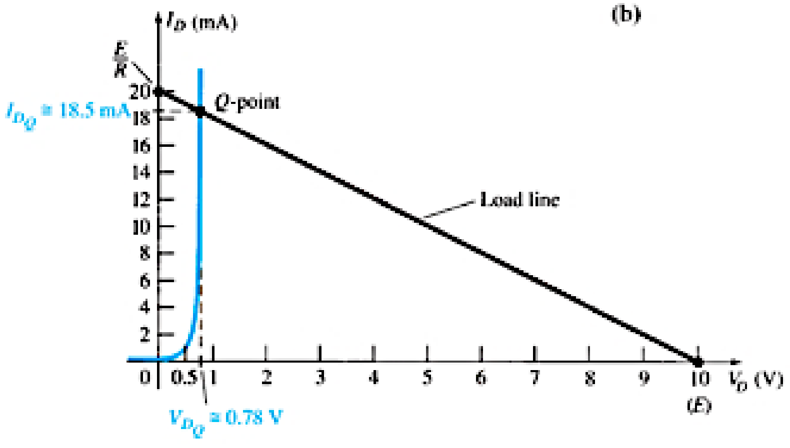


FIG. 2.4
Solution to Example 2.1.

LOAD-LINE ANALYSIS

$$R_D = \frac{V_{D_Q}}{I_{D_Q}} = \frac{0.78\ \text{V}}{18.5\ \text{mA}} = 42.16\ \Omega$$

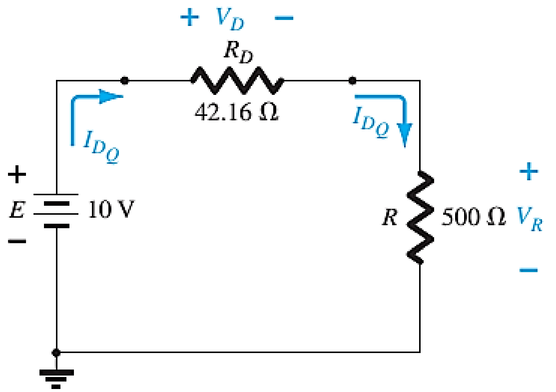


FIG. 2.5
Network quivalent to Fig. 2.4.

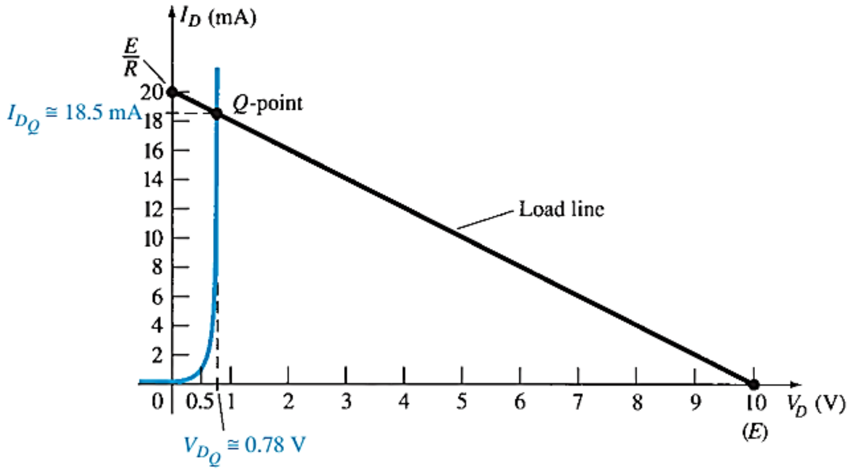


FIG. 2.4
Solution to Example 2.1.

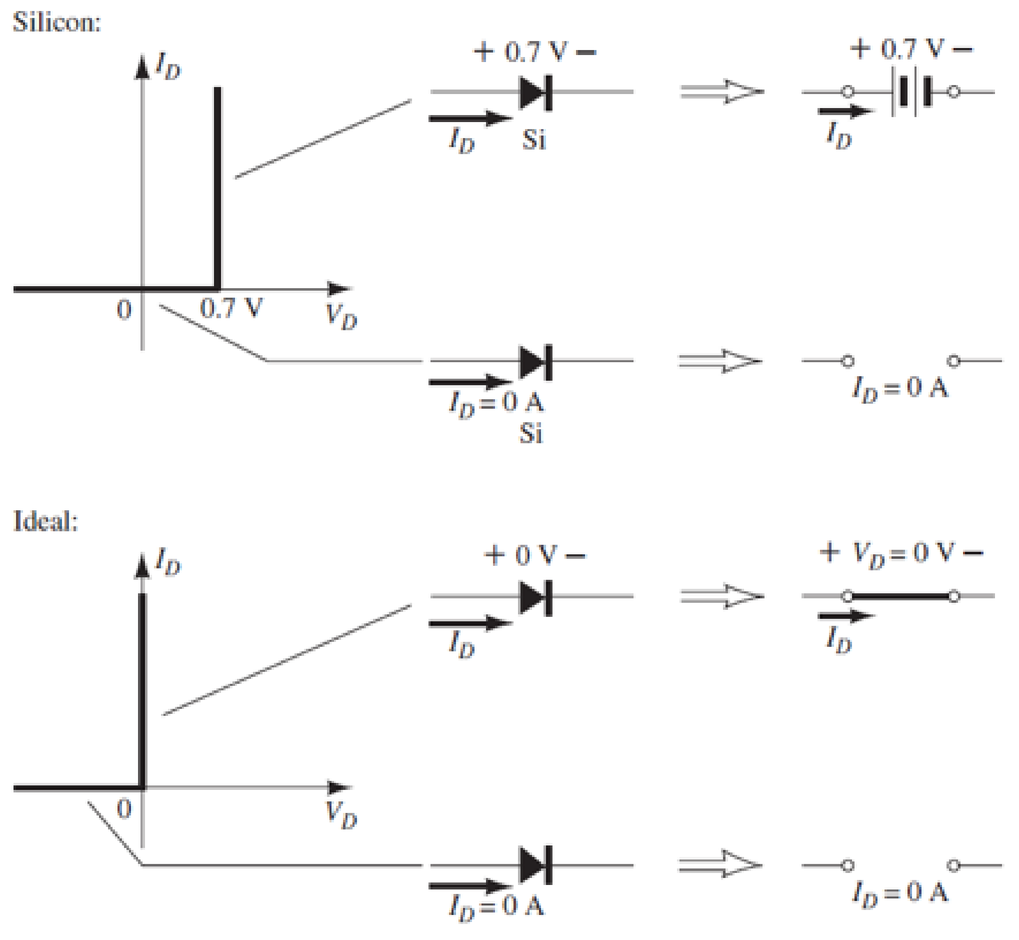
$$I_D = \frac{E}{R_D + R} = \frac{10\ \text{V}}{42.16\ \Omega + 500\ \Omega} = \frac{10\ \text{V}}{542.16\ \Omega} \cong \mathbf{18.5\ mA}$$

$$V_R = \frac{RE}{R_D + R} = \frac{(500\ \Omega)(10\ \text{V})}{42.16\ \Omega + 500\ \Omega} = \mathbf{9.22\ V}$$

SERIES DIODE CONFIGURATIONS

TABLE 2.1

Approximate and Ideal Semiconductor Diode Models.



SERIES DIODE CONFIGURATIONS

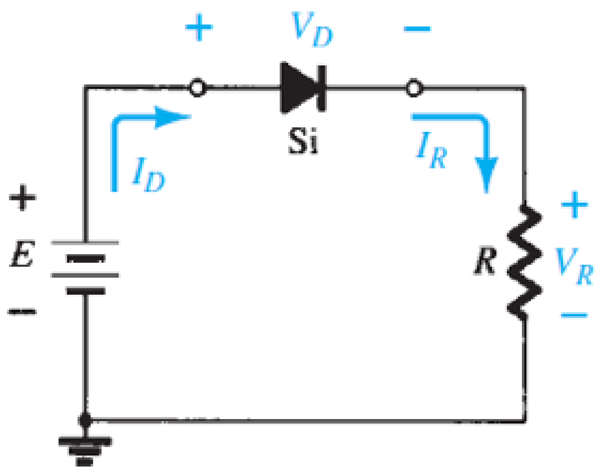


FIG. 2.8
Series diode configuration.

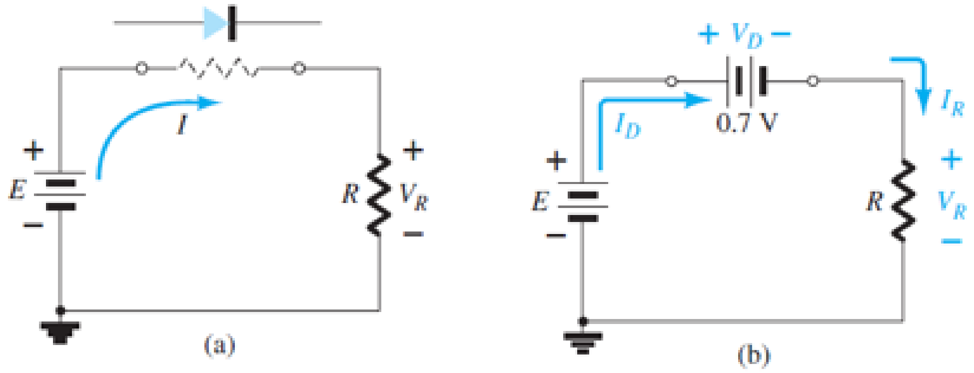


FIG. 2.9
(a) Determining the state of the diode of Fig. 2.8; (b) substituting the equivalent model for the "on" diode of Fig. 2.9a.

SERIES DIODE CONFIGURATIONS

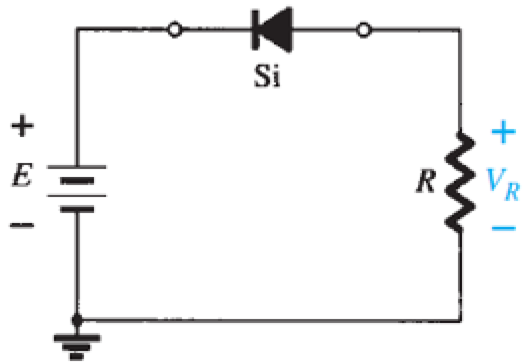


FIG. 2.10
Reversing the diode of Fig. 2.8.

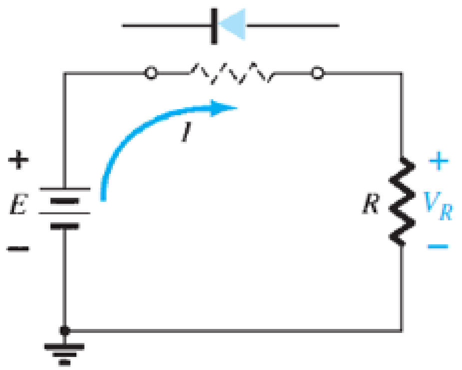


FIG. 2.11
Determining the state of the diode of Fig. 2.10.

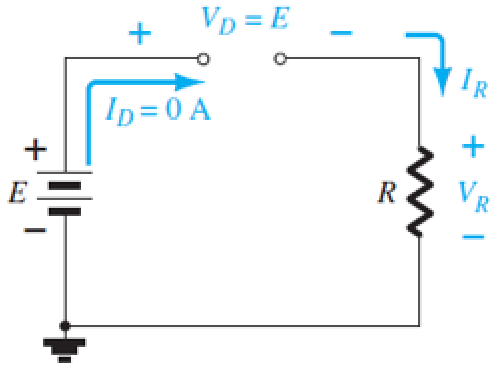


FIG. 2.12
Substituting the equivalent model for the "off" diode of Fig. 2.10.

SERIES DIODE CONFIGURATIONS

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

$$V_D = \mathbf{0.7\ V}$$
$$V_R = E - V_D = 8\ \text{V} - 0.7\ \text{V} = \mathbf{7.3\ V}$$
$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\ \text{V}}{2.2\ \text{k}\Omega} \cong \mathbf{3.32\ mA}$$

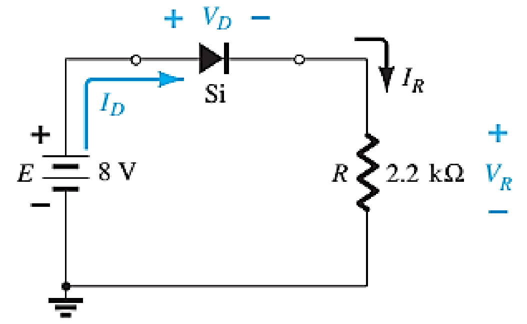
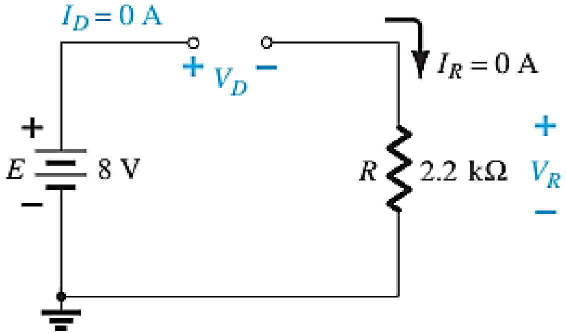


FIG. 2.13
Circuit for Example 2.4.

EXAMPLE 2.5 Repeat Example 2.4 with the diode reversed.

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



SERIES DIODE CONFIGURATIONS

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

$$I_D = \mathbf{0\ A}$$
$$V_R = I_R R = I_D R = (0\ \text{A})\,1.2\ \text{k}\Omega = \mathbf{0\ V}$$
$$V_D = E = \mathbf{0.5\ V}$$

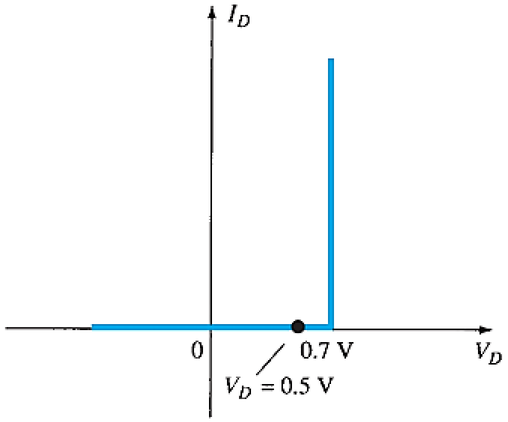


FIG. 2.17
Operating point with E = 0.5 V.

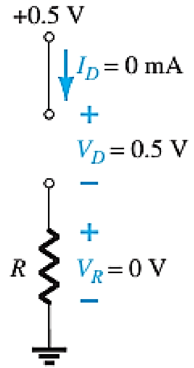


FIG. 2.18
Determining I_D, V_R, and V_D for the circuit of Fig. 2.16.

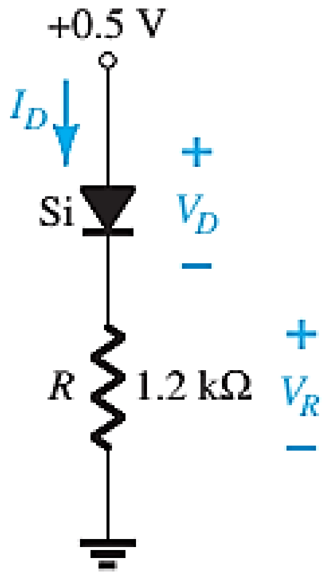


FIG. 2.16
Series diode circuit for Example 2.6.

SERIES DIODE CONFIGURATIONS

EXAMPLE 2.7 Determine V_o and I_D for the series circuit of Fig. 2.19.

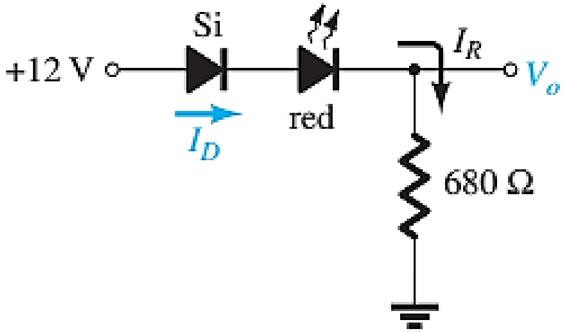


FIG. 2.19
Circuit for Example 2.7.

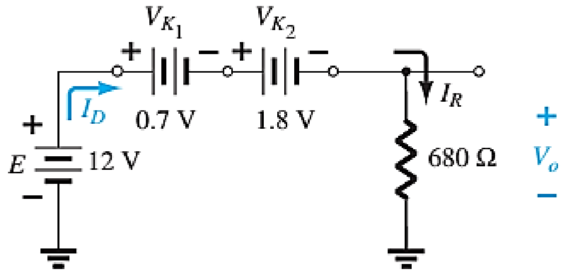


FIG. 2.20
Determining the unknown quantities for Example 2.7.

$$E = 12 \text{ V} > (0.7 \text{ V} + 1.8 \text{ V [Table 1.8]}) = 2.5 \text{ V}.$$

$$V_o = E - V_{K_1} - V_{K_2} = 12 \text{ V} - 2.5 \text{ V} = \mathbf{9.5\ V}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{V_o}{R} = \frac{9.5 \text{ V}}{680\ \Omega} = \mathbf{13.97\ mA}$$

SERIES DIODE CONFIGURATIONS

EXAMPLE 2.8 Determine I_D, V_{D_2}, and V_o for the circuit of Fig. 2.21.

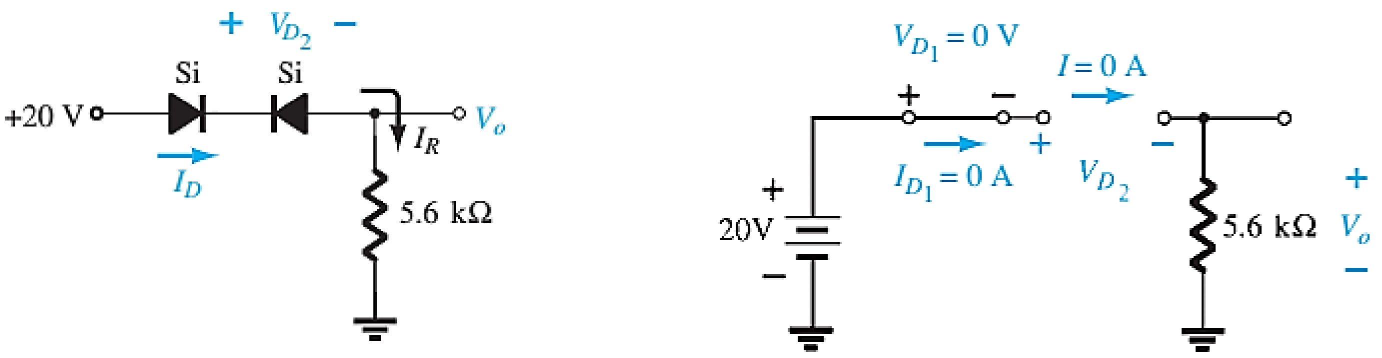


FIG. 2.21
Circuit for Example 2.8.

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

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

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

Applying Kirchhoff's voltage law in a clockwise direction gives

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

and

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

$$= \mathbf{20 \text{ V}}$$

SERIES DIODE CONFIGURATIONS

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

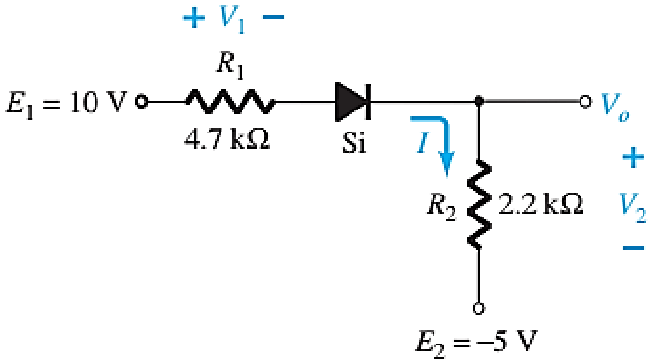


FIG. 2.25
Circuit for Example 2.9.

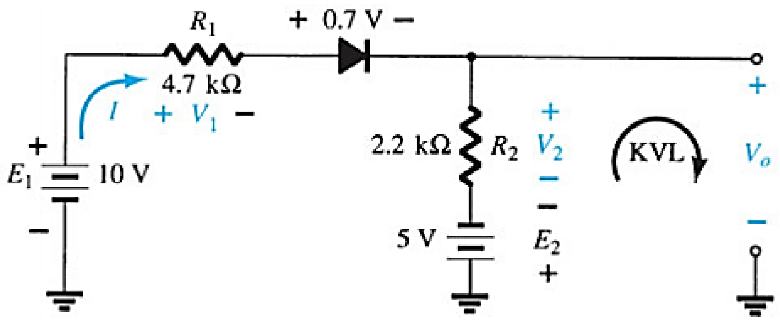


FIG. 2.27
Determining the unknown quantities for the network of Fig. 2.25. KVL, Kirchhoff voltage loop.

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

$$\cong \mathbf{2.07\text{ mA}}$$

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

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

Applying KVL,

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

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

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.

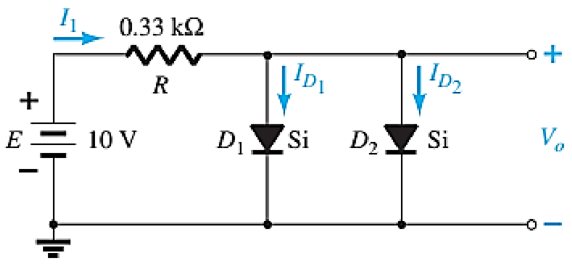


FIG. 2.28
Network for Example 2.10.

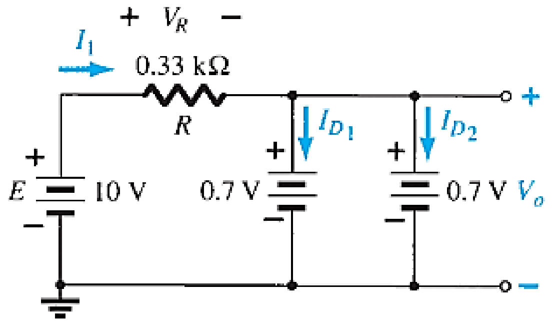


FIG. 2.29
Determining the unknown quantities for the network of Example 2.10.

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

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

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

- ***See Example 2.11***

SERIES-PARALLEL CONFIGURATIONS

EXAMPLE 2.12 Determine the voltage V_o for the network of Fig. 2.35.

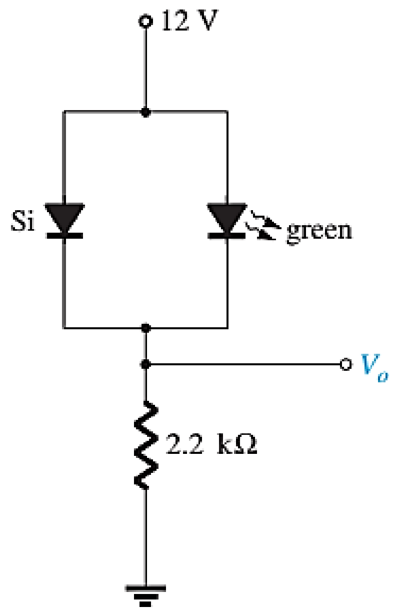


FIG. 2.35
Network for Example 2.12.

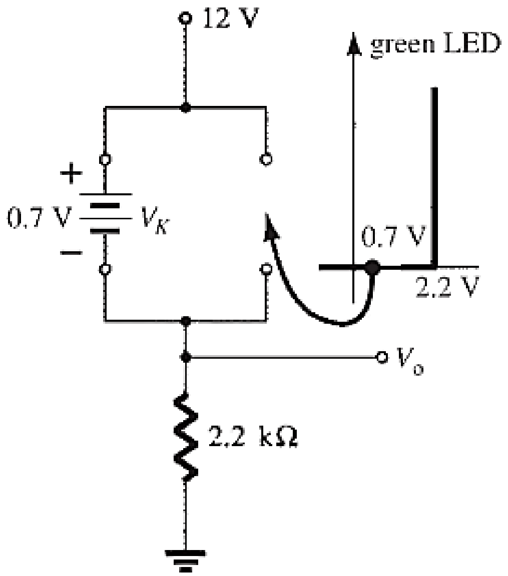


FIG. 2.36
Determining V_o for the network of Fig. 2.35.

$$V_o = 12\text{ V} - 0.7\text{ V} = \mathbf{11.3\text{ V}}$$

SERIES-PARALLEL CONFIGURATIONS

EXAMPLE 2.13 Determine the currents I_1, I_2, and I_{D_2} for the network of Fig. 2.37.

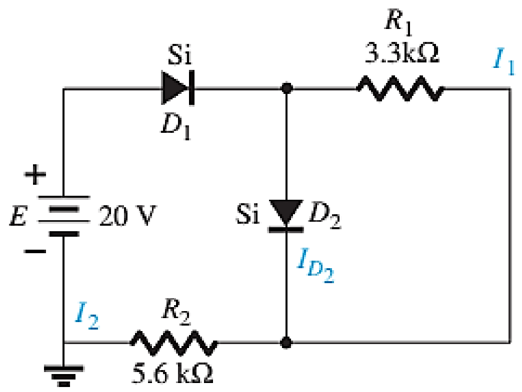


FIG. 2.37
Network for Example 2.13.

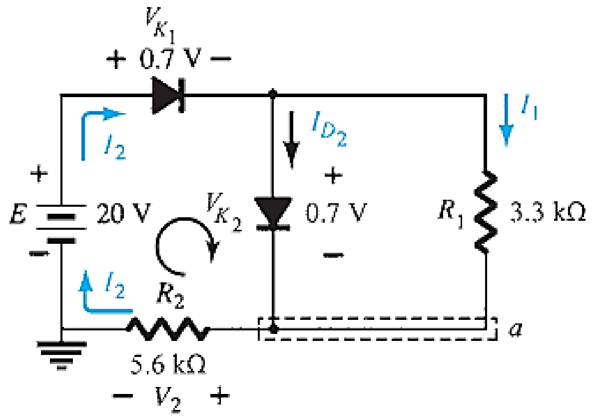


FIG. 2.38
Determining the unknown quantities for Example 2.13.

$$I_1 = \frac{V_{K_2}}{R_1} = \frac{0.7\text{ V}}{3.3\text{ k}\Omega} = \mathbf{0.212\text{ mA}}$$

$$-V_2 + E - V_{K_1} - V_{K_2} = 0$$

$$V_2 = E - V_{K_1} - V_{K_2} = 20\text{ V} - 0.7\text{ V} - 0.7\text{ V} = \mathbf{18.6\text{ V}}$$

$$I_2 = \frac{V_2}{R_2} = \frac{18.6\text{ V}}{5.6\text{ k}\Omega} = \mathbf{3.32\text{ mA}}$$

$$I_{D_2} + I_1 = I_2$$

$$I_{D_2} = I_2 - I_1 = 3.32\text{ mA} - 0.212\text{ mA} \cong \mathbf{3.11\text{ mA}}$$

- ***See Example 2.14 and 2.15***

Thank You