At the intersections of the respective load lines with the diode characteristic, we have

(a) $v_D \approx 1.08 \text{ V} \quad i_D \approx 9.2 \text{ mA}$
(b) $v_D \approx 1.18 \text{ V} \quad i_D \approx 13.8 \text{ mA}$
(c) $v_D \approx 0.91 \text{ V} \quad i_D \approx 4.5 \text{ mA}$

**Exercise 3.2**

The equivalent circuit is shown on the next page. Solving for the voltages across the diodes we obtain $v_{D1} = 10 \text{ V}$ and $v_{D2} =$
3 V. However \( v_{D1} > 0 \) and \( v_{D2} > 0 \) are not consistent with the assumption that the diodes are off.

![Diode Circuit Diagram]

**Exercise 3.3**

Assuming that the diodes are on, the equivalent circuit is:

![Equivalent Circuit Diagram]

Solving for the currents, we determine that \( i_{D1} = (10 - 3)/4000 = 1.75 \) mA and \( i_{D2} = 3/6000 - i_{D1} = -1.25 \) mA. However \( i_{D2} < 0 \) is inconsistent with the assumption that \( D_2 \) is on.

**Exercise 3.4**

(a)

![Diode Circuit with Voltage and Current]

Assume \( V_D \) or \( I_D \)

- On: \( I_D = 2 \) mA
- Off: \( V_D = +2 \) V

\( V_D = +2 \) is inconsistent with the assumption that \( D_1 \) is off. On the other hand, \( I_D = 2 \) mA is consistent with the assumption that \( D_1 \) is on. Thus we conclude that \( D_1 \) is on and \( I_D = 2 \) mA.
(b) \[ \text{Assume} \quad \text{Solve for} \]
\[ \begin{align*}
D_2 & \quad V_D \\
\text{on} & \quad I_D = -1.5 \text{mA} \\
\text{off} & \quad V_D = -3 \text{V}
\end{align*} \]

In this case the results are consistent with \( D_2 \) off.

(c) \[ \begin{align*}
5 \text{mA} \quad \uparrow \\
1 \text{k}\Omega \\
2 \text{k}\Omega
\end{align*} \]

\[ \begin{align*}
\text{Assume} \quad \text{Solve circuit} \\
D_3 \quad D_4 & \quad \text{for} \quad V_D's \quad \text{and} \quad I_D's
\end{align*} \]

\[ \begin{align*}
\text{off} & \quad \text{off} \quad \text{impossible} - \text{no closed path for} \quad 5 \text{mA} \\
\text{off} & \quad \text{on} \quad I_D = 5 \text{mA} \quad V_D = -5 \text{V} \\
\text{on} & \quad \text{off} \quad I_D = 5 \text{mA} \quad V_D = 20 \text{V} \\
\text{on} & \quad \text{on} \quad I_D = -1.67 \text{mA} \quad I_D = 6.67 \text{mA}
\end{align*} \]

Thus we conclude that \( D_3 \) is off and \( D_4 \) is on.

Exercise 3.5

Exercise 3.5
The voltage drops by approximately \((2 \text{ mV/°C}) \times 5\) diodes = 10 mV/°C. For a 10° increase in temperature the reference voltage decreases by 100 mV for a percentage change of \(0.1/3 \approx 3.33\%\).

**Problem 3.9**

(a)

\[4 = 1.5I + V \quad (I \text{ in milliamperes})\]

\[V_a = V \approx 0.8V \quad I_a = I \approx 2.13\text{ mA}\]

(b)

\[IV = 400I_x + V_x \quad (I_x \text{ in amperes})\]
\[ I_b = I_x \approx 1.65\text{mA} \quad V_b = V_x + 200I_x \times 0.66\text{V} \]

\[ 0.5 = 250I_x + V_x \quad \text{See Load line above.} \]
\[ I_c = I_x \approx 1.15\text{mA} \]
\[ V_c = 0.5 - V_x \approx 0.29 \]
Problem 3.12

(a) $V_a = I_a + V_x$

For each value of $I_a$, add voltages.

(b) $V_b = I = V_x$

For each value of $V_b$, add currents.

$I_b = I + I_x$
Problem 3.13

The ideal diode model has \( v_D = 0 \) if \( i_D \geq 0 \), and \( i_D = 0 \) if \( v_D \leq 0 \). The volt-ampere characteristic is shown in Figure 3.8 in the book.

Problem 3.14

After solving a circuit using the ideal diode model, we must check to see that \( i_D \) is greater than zero for diodes assumed to be on. We must check to see that \( v_D \) is less than zero for diodes assumed to be off.

Problem 3.15

(a) The diode is on. \( V = 0 \) and \( I = \frac{10 \text{ volts}}{2.7 \text{ k}\Omega} = 3.70 \text{ mA} \).

(b) The diode is off. \( I = 0 \) and \( V = 10 \text{ volts} \).

(c) The diode is on. \( V = 0 \) and \( I = 0 \).

(d) The diode is on. \( I = 5 \text{ mA} \) and \( V = 5 \text{ volts} \).

Problem 3.16

(a) \( D_1 \) is on and \( D_2 \) is off. \( V = 10 \text{ volts} \) and \( I = 0 \).

(b) \( D_1 \) is on and \( D_2 \) is off. \( V = 6 \text{ volts} \) and \( I = 6 \text{ mA} \).

(c) Both diodes are on. \( V = 30 \text{ volts} \) and \( I = 33.6 \text{ mA} \).

Problem 3.17

(a) \( D_1 \) is on, \( D_2 \) is on, and \( D_3 \) is off. \( V = 7.5 \text{ volts} \) and \( I = 0 \).

(b)

<table>
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<th>( D_1 )</th>
<th>( D_2 )</th>
<th>( D_3 )</th>
<th>( D_4 )</th>
<th>( V ) (volts)</th>
<th>( I ) (mA)</th>
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</tbody>
</table>

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Problem 3.20

(a) $V_o = V_m$

(b) $V_o$

Problem 3.21

(a) For a half-wave rectified sine wave, we have:

$$V_{avg} = \frac{1}{T} \int_0^T v(t) \, dt = \frac{1}{T} \int_0^{T/2} V_m \sin(\omega t) \, dt = \frac{V_m}{\omega T} \left[ -\cos(\omega t) \right]_0^{T/2} = \frac{2V_m}{2\pi} = \frac{V_m}{\pi}$$

(We have used the fact that $\omega T = 2\pi$.)

(b) For a full-wave rectified sine wave, we have:

$$V_{avg} = \frac{1}{T} \int_0^T v(t) \, dt = \frac{1}{T} \left[ \int_0^{T/2} V_m \sin(\omega t) \, dt + \int_{T/2}^T -V_m \sin(\omega t) \, dt \right]$$

Integrating evaluating and using the fact that $\omega T = 2\pi$, we obtain

$$V_{avg} = \frac{2V_m}{\pi}$$