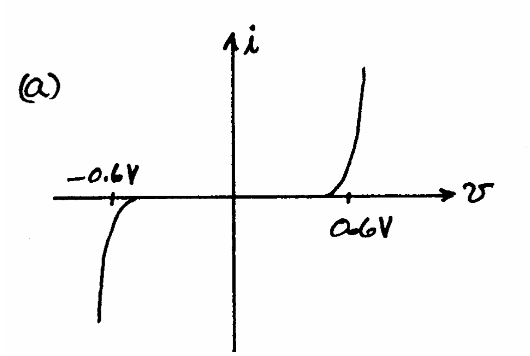
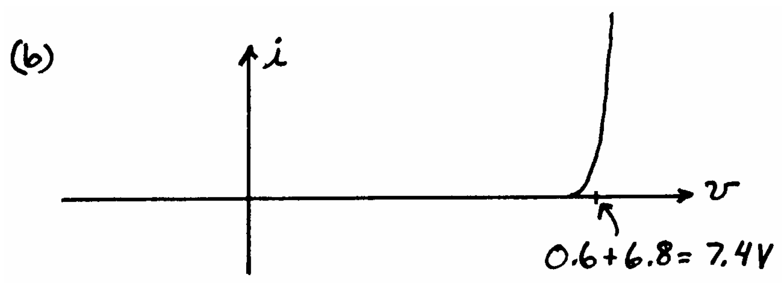
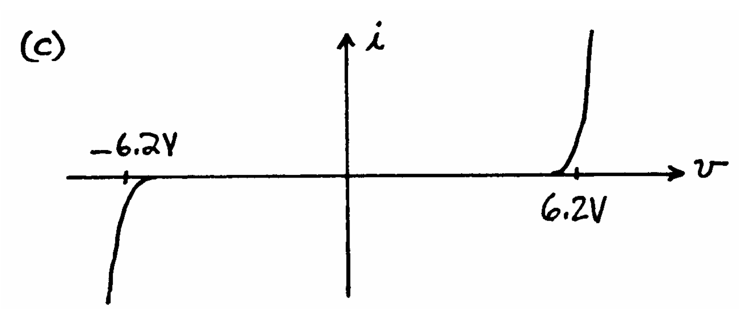
CHAPTER 10

P10.6*







P10.8* The approximate form of the Shockley Equation is $i_D = I_s \exp(v_D / nV_T)$.

Taking the ratio of currents for two different voltages, we have

$$\frac{i_{D1}}{i_{D2}} = \frac{\exp(v_{D1} / nV_T)}{\exp(v_{D2} / nV_T)} = \exp\left[(v_{D1} - v_{D2}) / nV_T\right]$$

Solving for n we obtain:

$$n = \frac{v_{D1} - v_{D2}}{V_T \ln(i_{D1} / i_{D2})} = \frac{0.600 - 0.680}{0.026 \ln(1/10)} = 1.336$$

Then we have

$$I_s = \frac{i_{D1}}{\exp(v_{D1} / nV_T)} = 3.150 \times 10^{-11} \text{ A}$$

P10.15* (a) By symmetry, the current divides equally and we have

$I_A = I_B = 100$ mA

(b) We have

$$i_D = I_s\left[\exp(v/nV_T) - 1\right]$$
$$\cong I_s \exp(v/nV_T)$$

Solving for I_s, we obtain

$$I_s = \frac{i_D}{\exp(v/nV_T)}$$

For diode *A*, the temperature is $T_A = 300$ K, and we have

$$V_{TA} = \frac{kT_A}{q} = \frac{1.38\times 10^{-23}\times 300}{1.6\times 10^{-19}} = 25.88 \text{ mV}$$
$$I_{sA} = \frac{0.100}{\exp(0.700/0.02588)} = 1.792\times 10^{-13} \text{ A}$$

For diode *B*, we have $T = 305$ K, and

$$I_{sB} = 2I_{sA} = 3.583\times 10^{-13} \text{ A}$$
$$V_{TB} = 26.31 \text{ mV}$$

Applying Kirchhoff's current law, we have

$$0.2 = I_A + I_B$$
$$0.2 = (1.792\times 10^{-13})\exp(v/0.02588) + (3.583\times 10^{-13})\exp(v/0.02631)$$

Solving for v by trial and err, we obtain $v \cong 697.1$ mV, $I_A = 87$ mA, and $I_B = 113$ mA.

P10.19 The load-line equation is

$$V_s = R_s i_x + v_x$$

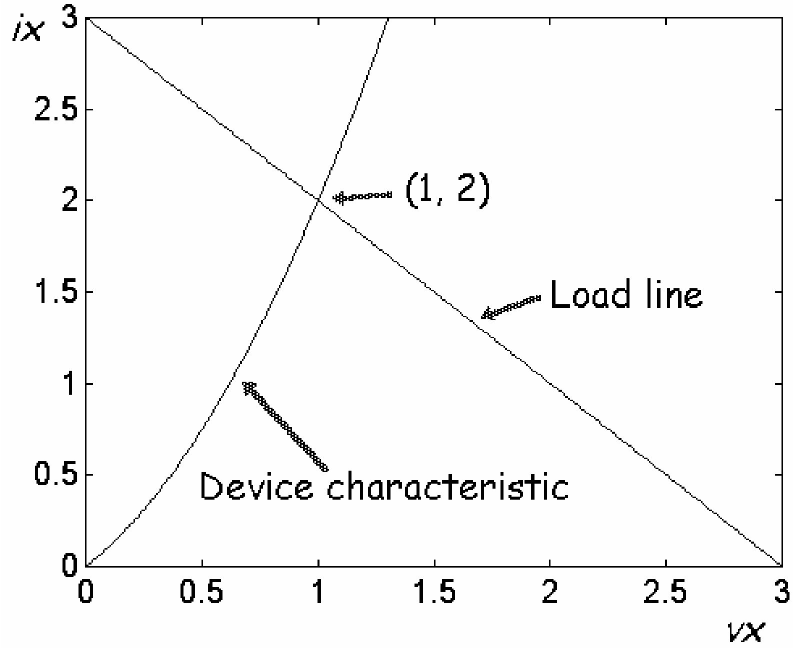
Substituting values this becomes

$$3 = i_x + v_x$$

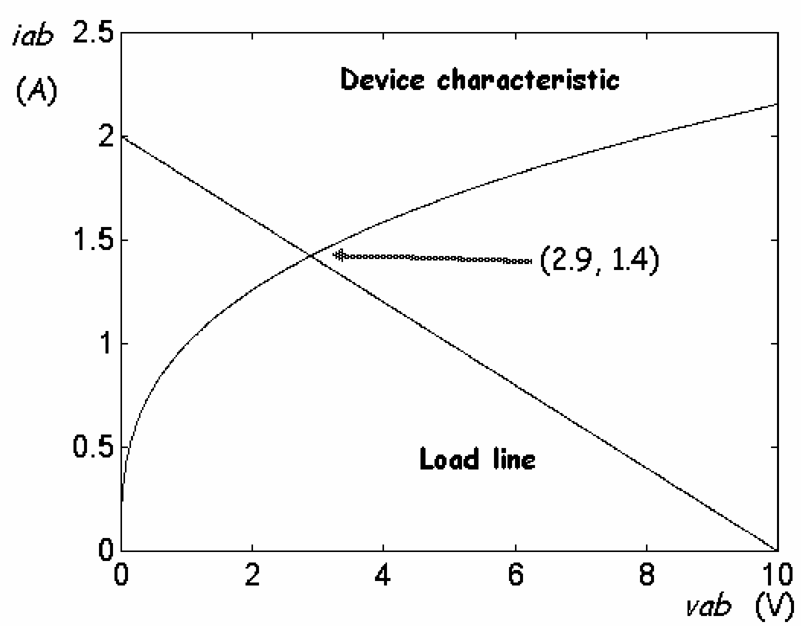
Next we plot the nonlinear device characteristic equation

$$i_x = v_x + v_x^2$$

and the load line on the same set of axes. Finally the solution is at the intersection of the load line and the characteristic as shown:



P10.29* The Thévenin resistance is $R_t = V_{oc} / I_{sc} = 10 / 2 = 5\ \Omega$. Also the Thévenin voltage is $V_t = V_{oc} = 10$ V. The load line equation is $10 = 5i_{ab} + v_{ab}$. We plot the load line and nonlinear device characteristic and find the solution at the intersection as shown below.



P10.32 (a) The diode is on, $V = 0$ and $I = \frac{10}{2700} = 3.70$ mA.

(b) The diode is off, $I = 0$ and $V = 10$ V.

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

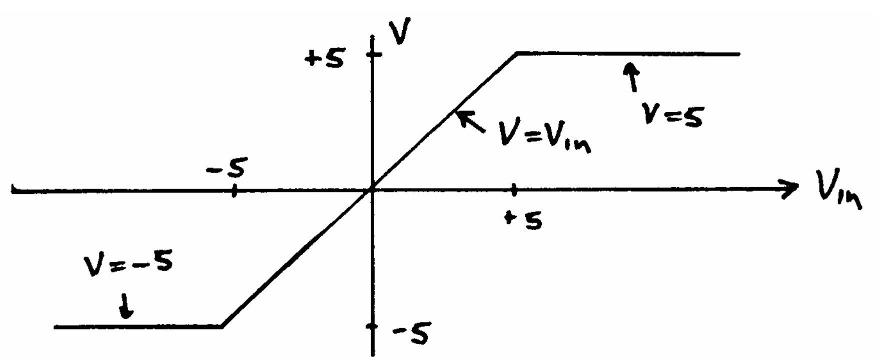
(d) The diode is on, $I = 5$ mA and $V = 5$ V.

P10.34 (a) D_1 is on, D_2 is on, and D_3 is off. $V = 7.5$ volts and $I = 0$.

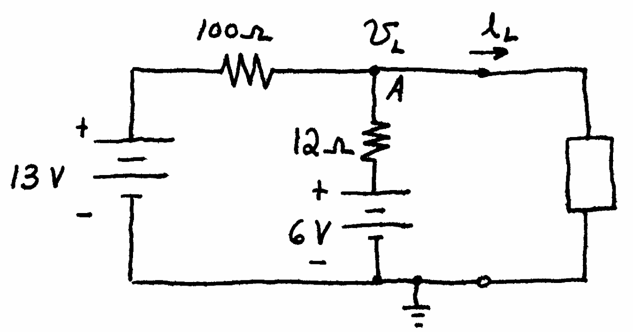
(b)

V_{in}	D_1	D_2	D_3	D_4	V	I
0	on	on	on	on	0	0
2	on	on	on	on	2 V	2 mA
6	off	on	on	off	5 V	5 mA
10	off	on	on	off	5 V	5 mA

The plot of V versus V_{in} is:



P10.41* For small values of i_L, the Zener diode is operating on line segment C of Figure 10.19, and the equivalent circuit is



Writing a KCL equation at node A, we obtain:

$$\frac{v_L - 13}{100} + \frac{v_L - 6}{12} + i_L = 0$$

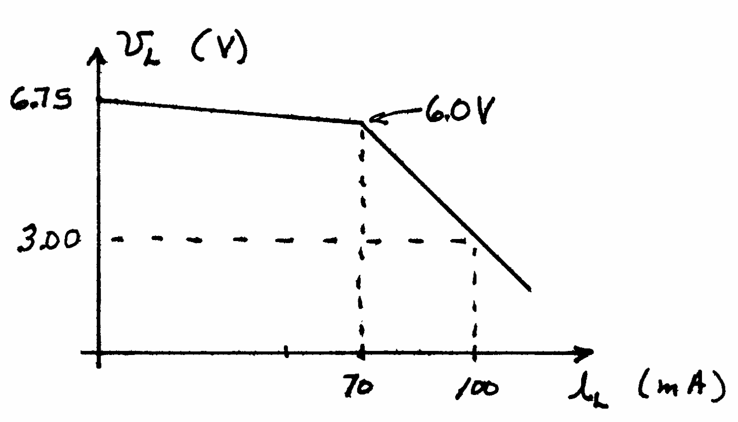
Solving we obtain

$$v_L = 6.75 - 10.71 i_L$$

This equation is valid for $v_L \geq 6$ V. When $0 \leq v_L \leq 6$ V, the Zener diode operates on line segment *B*, for which the Zener is modeled as an open circuit and we have

$$v_L = 13 - 100 i_L$$

Plotting these equations results in



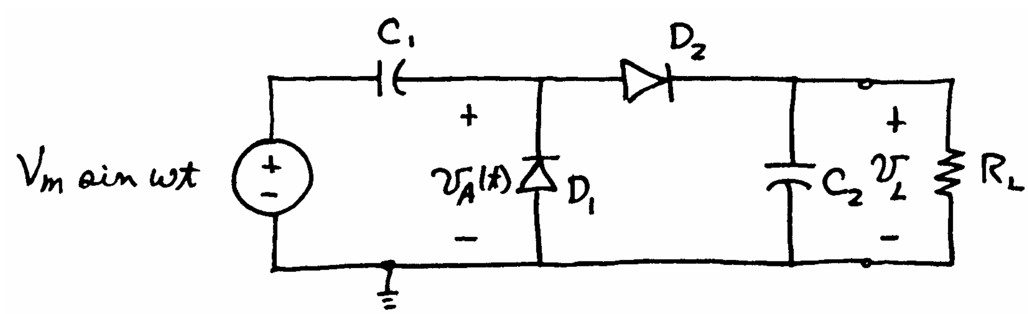
P10.51* For a half-wave rectifier, the capacitance required is given by Equation 10.10 in the text.

$$C = \frac{I_L T}{V_r} = \frac{0.25(1/60)}{0.2} = 20833\ \mu\text{F}$$

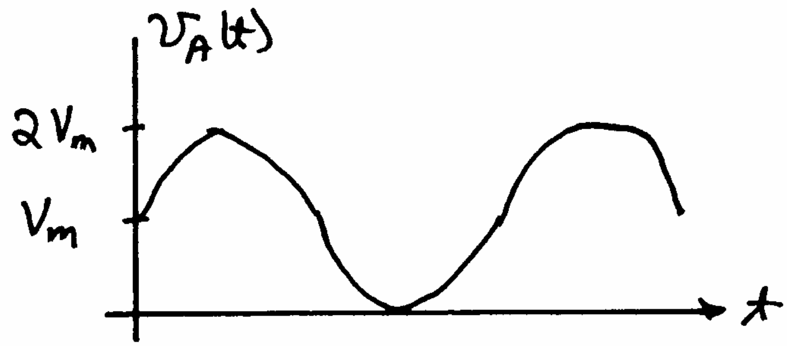
For a full-wave rectifier, the capacitance is given by Equation 10.12 in the text:

$$C = \frac{I_L T}{2V_r} = \frac{0.25(1/60)}{2(0.2)} = 10416\ \mu\text{F}$$

P10.61

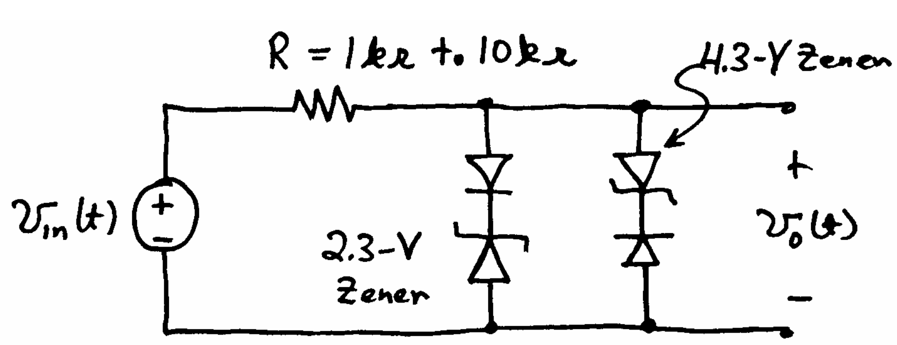


The capacitor C_1 and diode D_1 act as a clamp circuit that clamps the negative peak of $v_A(t)$ to zero. Thus, the waveform at point A is:



Diode D_2 and capacitor C_2 act as a half-wave peak rectifier. Thus, the voltage across R_L is the peak value of $v_A(t)$. Thus, $v_L(t) \cong 2V_m$. This is called a voltage-doubler circuit because the load voltage is twice the peak value of the ac input. The peak inverse voltage is $2V_m$ for both diodes.

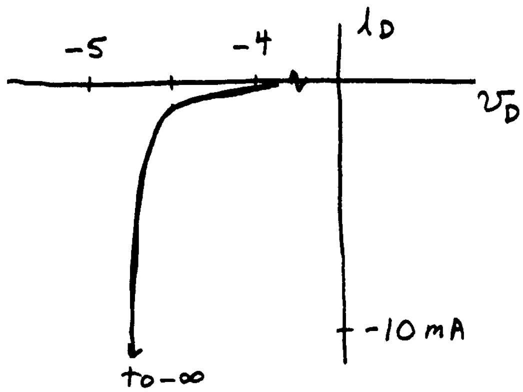
P10.62* A suitable circuit is:



P10.70 We are given

$$i_D = \frac{-10^{-6}}{\left(1 + v_D/5\right)^3} \quad \text{for } -5 \text{ V} < v_D < 0$$

A plot of this is:



v_D	i_D
0	−1 μA
−3	−15.6 μA
−4	−125 μA
−4.5	−1 mA
−4.77	−10 mA
−5	−∞

The dynamic resistance is:

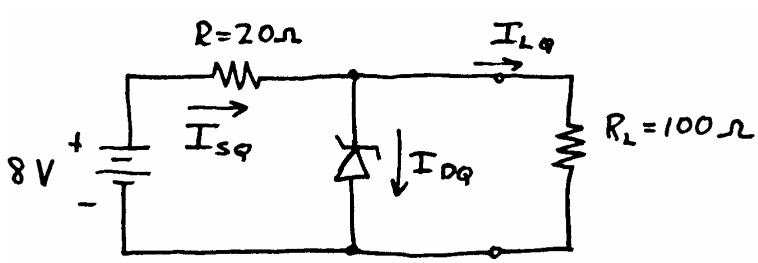
$$r_D = \left(\frac{di_D}{dv_D}\right)^{-1} = 1.67 \times 10^6 \times \left(1 + \frac{v_D}{5}\right)^4$$

To find the dynamic resistance at a given Q-point, we evaluate this expression for $v_D = V_{DQ}$.

For $I_{DQ} = -1.0$ mA, we have $V_{DQ} = -4.5$ V and $r_D = 167\ \Omega$.

For $I_{DQ} = -10.0$ mA, we have $V_{DQ} = -4.77$ V and $r_D = 7.48\ \Omega$.

P10.73* To find the Q-point, we ignore the ac ripple voltage and the circuit becomes:



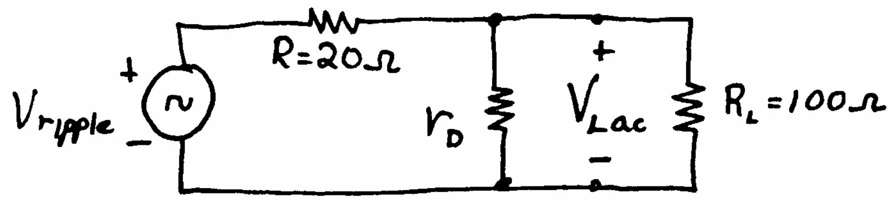
Thus, we have:

$$I_{sQ} = \frac{8-5}{20} = 150 \text{ mA}$$

$$I_{LQ} = 5/100 = 50 \text{ mA}$$

$$I_{DQ} = I_{sQ} - I_{LQ} = 100 \text{ mA}$$

The small-signal or ac equivalent circuit is:



where r_D is the dynamic resistance of the Zener diode. Using the voltage-division principle, the ripple voltage across the load is

$$V_{Lac} = V_{ripple} \times \frac{R_p}{R + R_p}$$

where $R_p = \frac{1}{1/R_L + 1/r_D}$ is the parallel combination of the load resistance and the dynamic resistance of the diode. Substituting values, we find

$$V_{Lac} = 10 \times 10^{-3} = 1 \times \frac{R_p}{20 + R_p}$$

Solving, we find $R_p = 0.202\ \Omega$. Then, we have:

$R_p = 0.202 = \frac{1}{1/100 + 1/r_D}$ which yields $r_D = 0.202\ \Omega$.