Problems

In the following problems, assume $V_{D_{on}} = 800 \text{ mV}$ for the constant-voltage diode model.

1. Plot the I/V characteristic of the circuit shown in Fig. 3.63.

![Figure 3.63](image1)

2. If the input in Fig. 3.63 is expressed as $V_X = V_0 \cos \omega t$, plot the current flowing through the circuit as a function of time.

3. Plot $I_X$ as a function of $V_X$ for the circuit shown in Fig. 3.64 for two cases: $V_B = -1 \text{ V}$ and $V_B = +1 \text{ V}$.

![Figure 3.64](image2)

4. If in Fig. 3.64, $V_X = V_0 \cos \omega t$, plot $I_X$ as a function of time for two cases: $V_B = -1 \text{ V}$ and $V_B = +1 \text{ V}$.

5. For the circuit depicted in Fig. 3.65, plot $I_X$ as a function of $V_X$ for two cases: $V_B = -1 \text{ V}$ and $V_B = +1 \text{ V}$.

![Figure 3.65](image3)

6. Plot $I_X$ and $I_{D1}$ as a function of $V_X$ for the circuit shown in Fig. 3.66. Assume $V_B > 0$.

![Figure 3.66](image4)

7. For the circuit depicted in Fig. 3.67, plot $I_X$ and $I_{R1}$ as a function of $V_X$ for two cases: $V_B = -1 \text{ V}$ and $V_B = +1 \text{ V}$.
Sec. 3.5 Applications of Diodes

8. In the circuit of Fig. 3.68, plot $I_X$ and $I_{R_1}$ as a function of $V_X$ for two cases: $V_B = -1$ V and $V_B = +1$ V.

Figure 3.68

9. Plot the input/output characteristics of the circuits depicted in Fig. 3.69 using an ideal model for the diodes. Assume $V_B = 2$ V.

Figure 3.69

10. Repeat Problem 9 with a constant-voltage diode model.

11. If the input is given by $V_{in} = V_0 \cos \omega t$, plot the output of each circuit in Fig. 9 as function of time. Assume an ideal diode model.

12. Plot the input/output characteristics of the circuits shown in Fig. 3.70 using an ideal model for the diodes.

13. Repeat Problem 12 with a constant-voltage diode model.

14. Assuming the input is expressed as $V_{in} = V_0 \cos \omega t$, plot the output of each circuit in Fig. 12 as a function of time. Use an ideal diode model.

15. Assuming a constant-voltage diode model, plot $V_{out}$ as a function of $I_{in}$ for the circuits shown in Fig. 3.71.

16. In the circuits of Fig. 3.71, plot the current flowing through $R_1$ as a function of $V_{in}$. Assume a constant-voltage diode model.
17. For the circuits illustrated in Fig. 3.71, plot $V_{out}$ as a function of time if $I_{in} = I_0 \cos \omega t$. Assume a constant-voltage model and a relatively large $I_0$.

18. Plot $V_{out}$ as a function of $I_{in}$ for the circuits shown in Fig. 3.72. Assume a constant-voltage diode model.

19. Plot the current flowing through $R_1$ in the circuits of Fig. 3.72 as a function of $I_{in}$. Assume a constant-voltage diode model.

20. In the circuits depicted in Fig. 3.72, assume $I_{in} = I_0 \cos \omega t$, where $I_0$ is relatively large. Plot $V_{out}$ as a function of time using a constant-voltage diode model.

21. For the circuits shown in Fig. 3.73, plot $V_{out}$ as a function of $I_{in}$ assuming a constant-voltage model for the diodes.
Sec. 3.5 Applications of Diodes

Figure 3.73

22. Plot the current flowing through $R_1$ as a function of $I_{in}$ for the circuits of Fig. 3.73. Assume a constant-voltage diode model.

23. Plot the input/output characteristic of the circuits illustrated in Fig. 3.74 assuming a constant-voltage model.

Figure 3.74

24. Plot the currents flowing through $R_1$ and $D_1$ as a function of $V_{in}$ for the circuits of Fig. 3.74. Assume constant-voltage diode model.

25. Plot the input/output characteristic of the circuits illustrated in Fig. 3.75 assuming a constant-voltage model.

26. Plot the currents flowing through $R_1$ and $D_1$ as a function of $V_{in}$ for the circuits of Fig. 3.75. Assume constant-voltage diode model.

27. Plot the input/output characteristic of the circuits illustrated in Fig. 3.76 assuming a constant-voltage model.
28. Plot the currents flowing through $R_1$ and $D_1$ as a function of $V_{in}$ for the circuits of Fig. 3.76. Assume constant-voltage diode model.

29. Plot the input/output characteristic of the circuits illustrated in Fig. 3.77 assuming a constant-voltage model and $V_B = 2\,\text{V}$.

30. Plot the currents flowing through $R_1$ and $D_1$ as a function of $V_{in}$ for the circuits of Fig. 3.77. Assume constant-voltage diode model.

31. Beginning with $V_{D,\text{on}} \approx 800\,\text{mV}$ for each diode, determine the change in $V_{out}$ if $V_{in}$ changes from $+2.4\,\text{V}$ to $+2.5\,\text{V}$ for the circuits shown in Fig. 3.78.

32. Beginning with $V_{D,\text{on}} \approx 800\,\text{mV}$ for each diode, calculate the change in $V_{out}$ if $I_{in}$ changes from $3\,\text{mA}$ to $3.1\,\text{mA}$ in the circuits of Fig. 3.79.

33. In Problem 32, determine the change in the current flowing through the 1-k$\Omega$ resistor in each circuit.
Sec. 3.5 Applications of Diodes

![Diode Circuits](image)

Figure 3.77

Figure 3.78

34. Assuming $V_{in} = V_p \sin \omega t$, plot the output waveform of the circuit depicted in Fig. 3.80 for an initial condition of $+0.5 \text{ V}$ across $C_1$. Assume $V_p = 5 \text{ V}$.

35. Repeat Problem 34 for the circuit shown in Fig. 3.81.

36. Suppose the rectifier of Fig. 3.32 drives a 100-Ω load with a peak voltage of 3.5 V. For a 1000-μF smoothing capacitor, calculate the ripple amplitude if the frequency is 60 Hz.

37. A 3-V adaptor using a half-wave rectifier must supply a current of 0.5 A with a maximum ripple of 300 mV. For a frequency of 60 Hz, compute the minimum required smoothing capacitor.

38. Assume the input and output grounds in a full-wave rectifier are shorted together. Draw the output waveform with and without the load capacitor and explain why the circuit does not operate as a rectifier.

39. Plot the voltage across each diode in Fig. 3.38(b) as a function of time if $V_{in} = V_0 \cos \omega t$. Assume a constant-voltage diode model and $V_D > V_{D, on}$.

40. While constructing a full-wave rectifier, a student mistakenly has swapped the terminals of $D_3$ as depicted in Fig. 3.82. Explain what happens.

41. A full-wave rectifier is driven by a sinusoidal input $V_{in} = V_0 \cos \omega t$, where $V_0 = 3 \text{ V}$
42. Suppose the negative terminals of $V_{in}$ and $V_{out}$ in Fig. 3.38(b) are shorted together. Plot the input-output characteristic assuming an ideal diode model and explaining why the circuit does not operate as a full-wave rectifier.

43. Suppose in Fig. 3.43, the diodes carry a current of 5 mA and the load, a current of 20 mA. If the load current increases to 21 mA, what is the change in the total voltage across the three diodes? Assume $R_1$ is much greater than $3r_d$.

44. In this problem, we estimate the ripple seen by the load in Fig. 3.43 so as to appreciate the regulation provided by the diodes. For simplicity, neglect the load. Also, $f_{in} = 60$ Hz, $C_1 = 100 \, \mu F$, $R_1 = 1000 \, \Omega$, and the peak voltage produced by the transformer is equal to 5
Sec. 3.5 Applications of Diodes

V.
(a) Assuming \( R_1 \) carries a relatively constant current and \( V_{D_{on}} \approx 800 \) mV, estimate the ripple amplitude across \( C_1 \).
(b) Using the small-signal model of the diodes, determine the ripple amplitude across the load.

45. In the limiting circuit of Fig. 3.51, plot the currents flowing through \( D_1 \) and \( D_2 \) as a function of time if the input is given by \( V_0 \cos \omega t \) and \( V_0 > V_{D_{on}} + V_{B1} \) and \( -V_0 > -V_{D_{on}} - V_{B2} \).

46. Design the limiting circuit of Fig. 3.51 for a negative threshold of \(-1.9 \) V and a positive threshold of \(+2.2 \) V. Assume the input peak voltage is equal to 5 V, the maximum allowable current through each diode is 2 mA, and \( V_{D_{on}} \approx 800 \) mV.

47. We wish to design a circuit that exhibits the input/output characteristic shown in Fig. 3.83. Using 1-k\( \Omega \) resistors, ideal diodes, and other components, construct the circuit.

![Figure 3.83](Image)

48. “Wave-shaping” applications require the input/output characteristic illustrated in Fig. 3.84. Using ideal diodes and other components, construct a circuit that provides such a character-

![Figure 3.84](Image)

49. Suppose a triangular waveform is applied to the characteristic of Fig. 3.84 as shown in Fig. 3.85. Plot the output waveform and note that it is a rough approximation of a sinusoid. How should the input-output characteristic be modified so that the output becomes a better approximation of a sinusoid?

SPICE Problems
In the following problems, assume \( I_s = 5 \times 10^{-16} \) A.

50. The half-wave rectifier of Fig. 3.86 must deliver a current of 5 mA to \( R_1 \) for a peak input level of 2 V.
(a) Using hand calculations, determine the required value of \( R_1 \).
(b) Verify the result by SPICE.
Chap. 3  Diode Models and Circuits

51. In the circuit of Fig. 3.87, $R_1 = 500$ $\Omega$ and $R_2 = 1$ k$\Omega$. Use SPICE to construct the input/output characteristic for $-2$ V $< V_{in} < +2$ V. Also, plot the current flowing through $R_1$ as a function of $V_{in}$.

52. The rectifier shown in Fig. 3.88 is driven by a 60-Hz sinusoid input with a peak amplitude of 5 V. Using the transient analysis in SPICE,

(a) Determine the peak-to-peak ripple at the output.
(b) Determine the peak current flowing through $D_1$.
(c) Compute the heaviest load (smallest $R_L$) that the circuit can drive while maintaining a ripple less than 200 mV$_{pp}$. 

![Figure 3.85](image1)

![Figure 3.86](image2)

![Figure 3.87](image3)

![Figure 3.88](image4)
53. The circuit of Fig. 3.89 is used in some analog circuits. Plot the input/output characteristic for $-2 \ V < V_{in} < +2 \ V$ and determine the maximum input range across which $|V_{in} - V_{out}| < 5 \ \text{mV}$.

![Figure 3.89](image)

54. The circuit shown in Fig. 3.90 can provide an approximation of a sinusoid at the output in response to a triangular input waveform. Using the dc analysis in SPICE to plot the input/output characteristic for $0 < V_{in} < 4 \ V$, determine the values of $V_{B1}$ and $V_{B2}$ such that the characteristic closely resembles a sinusoid.

![Figure 3.90](image)