Answers to Selected Problems

Chapter 1

1.1 $i = 2\text{A}$
1.4 $\Delta Q = 1.5\text{ C}$
1.7 **(a)** P = −18 W (supplied) **(b)** P = −18 W (supplied)
1.10 **(a)** P = −12 W (supplied) **(b)** P = 24 W (absorbed)
1.13 $P_2 = 48\text{ W}$ (absorbed)
1.17 $P_{36V} = -144\text{ W}$, $P_1 = 48\text{ W}$, $P_2 = 48\text{ W}$, $P_{DS} = -8\text{ W}$, $P_3 = 56\text{ W}$
1.20 $V_x = 18\text{ V}$

Chapter 2

2.1 $I = 0.3\text{ mA}$, $P = 1.8\text{ mW}$
2.4 $R_x = 5\text{ k}\Omega$
2.7 $P_S = 72\text{ W}$
2.10 $I_1 = 6\text{ mA}$, $I_2 = 3\text{ mA}$
2.12 $I_x = -8\text{ mA}$, $I_y = +10\text{ mA}$, $I_z = -2\text{ mA}$
2.14 $I_x = 9\text{ mA}$, $I_y = -10\text{ mA}$, $I_z = -2\text{ mA}$
2.17 $V_x = 3\text{ V}$
2.19 $V_{ad} = 7\text{ V}$
2.22 $V_{ad} = 9\text{ V}$, $V_{ce} = 11\text{ V}$
2.25 $V_x = 10\text{ V}$
2.27 $V_x = 5\text{ V}$
2.29 $P_{30k} = 1.2\text{ mW}$
2.31 $I_o = 90\text{ mA}$
2.34 $I_o = 4\text{ mA}$
2.36 $I_L = 0.4\text{ mA}$
2.39 $R_{AB} = 3\text{ k}\Omega$
2.41 $R_{AB} = 2\text{ k}\Omega$
2.44 **(a)** Min = 950 Ω, Max = 1050 Ω
(b) Min = 460.6 Ω, Max = 479.4 Ω
(c) Min = 19.8 kΩ, Max = 24.2 kΩ
2.47 **(a)** $R_{Nom} = 3\ \Omega$ **(b)** Positive/Negative Tolerances = ±8.33%
2.50 $I_1 = 3\text{ mA}$
2.52 $V_o = -\frac{16}{3}\text{ V}$
2.55 $I_o = 2\text{ mA}$
2.58 $V_S = 12\text{ V}$
2.60 $V_S = 48\text{ V}$
2.63 $V_S = 38\text{ V}$
2.65 $V_S = 30\text{ V}$
2.68 $I_S = 4.5\text{ A}$
2.70 $I_o = 6\text{ mA}$
2.72 $P = 63\text{ mW}$
2.75 $I_o = 4\text{ A}$
2.78 $V_o = 10\text{ V}$
2.80 $V_o = 2\text{ V}$
2.83 $I_o = -20\text{ mA}$
2.86 Power gain = $1.422\ \frac{\text{kW}}{\text{W}}$
2.87 $P_{10k} = 10\text{ mW}$
2FE-1 P = 1.2 W
2FE-4 $I_o = \frac{-4}{9}\text{ mA}$

Chapter 3

3.1 $I_o = 1$ mA
3.3 $V_2 = 22$ V
3.5 $I_o = 0.6$ mA
3.8 $I_o = 1.25$ mA
3.10 $I_o = 2$ mA, $I_1 = -6$ mA
3.13 $I_o = -1$ mA
3.15 $V_o = \frac{-5}{6}$ V
3.18 $I_o = -1.5$ mA
3.21 $V_o = 2$ V
3.24 $I_o = -4.8$ mA
3.27 $V_o = 4.36$ V
3.30 $I_o = 1.5$ mA
3.33 $V_o = \frac{4}{3}$ V
3.36 $I_o = -0.4$ mA
3.39 $V_o = 32.25$ V
3.42 $V_o = 4$ V
3.44 $V_o = \frac{4}{3}$ V
3.47 $I_o = 7$ mA
3.50 $I_o = 5.2$ mA
3.53 $I_o = 0.4$ mA
3.56 $V_o = 6$ V
3.59 $V_o = \frac{8}{5}$ V
3.62 $V_o = 3$ V
3.65 $V_o = 6$ V
3.68 $V_o = \frac{-7}{8}$ V
3.70 $V_o = -5$ V
3.73 $\frac{V_o}{i_S} = -1$
3FE-1 $V_o = \frac{10}{3}$ V
3FE-4 $V_o = -3.27$ V
3FE-6 $V_o = 6$ V

Chapter 4

4.1 $I_o = \frac{8}{7}$ mA
4.3 $V_o = 0.75$ V
4.5 $I_o = \frac{-16}{5}$ mA
4.8 $V_o = -4.25$ V
4.10 $I_o = 2.4$ mA
4.12 $I_o = 0.5$ mA
4.15 $I_o = 0.4$ mA
4.18 $V_o = 10.5$ V
4.21 $V_o = 2$ V
4.24 $I_o = \frac{-7}{5}$ mA
4.27 $I_o = -1$ mA
4.29 $I_o = -0.2$ mA
4.31 $I_o = 0.67$ mA
4.33 $V_o = 4.8$ V
4.36 $V_o = 8$ V
4.39 $V_o = \frac{8}{5}$ V
4.42 $I_o = 2$ mA
4.44 $I_o = 1.25$ mA
4.47 $V_o = 1.55$ V
4.50 $R_{AB} = 1$ kΩ
4.52 $V_o = -6$ V
4.55 $I_o = 5.71$ mA
4.58 $V_o = 0.43$ V
4.61 $V_o = 2.18$ V
4.64 $I_o = 1.2$ mA
4.67 $V_o = 258$ mV
4.70 $R_L = 2$ kΩ, $P_L = 12.5$ mW
4.72 $R_L = 6$ kΩ, $P_L = \frac{25}{6}$ mW
4.75 $V_o = 2$ V
4FE-1 $P_L = 8$ mW
4FE-3 $R_L = 12.92$ Ω

Chapter 5

5.1 $v(t = 4) = 40$ V

5.3 $C = 120\ \mu$F

5.5 $i(t) = \pm 2.92 \cos 377t$ A

5.7 **(a)** $i(t) = 4.52 \cos 377t$ A

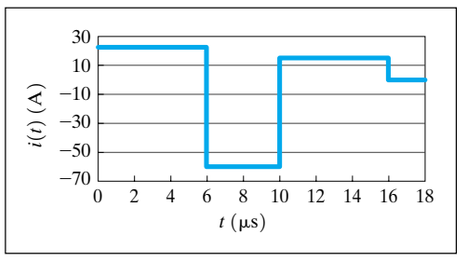
(b) $w(t) = 360 \sin(754t - 90°)$ mJ

5.9
$$v(t) = 100t \text{ V} \qquad 0 \le t \le 2 \text{ ms}$$
$$= 0.2 \text{ V} \qquad t > 2 \text{ ms}$$

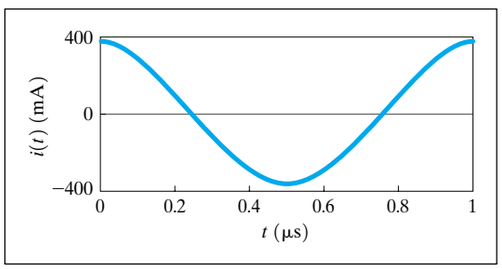
5.11
$$i(t) = 6 \text{ mA} \qquad 0 \le t \le 2 \text{ ms}$$
$$= -6 \text{ mA} \qquad 2 \le t \le 4 \text{ ms}$$

5.14
$$i(t) = 0.6 \text{ A} \qquad 0 \le t \le 2 \text{ s}$$
$$= -2.4 \text{ A} \qquad 2 \le t \le 3 \text{ s}$$
$$= 0.6 \text{ A} \qquad 3 \le t \le 5 \text{ s}$$
$$= 0 \qquad t > 5 \text{ s}$$

5.16
$$i(t) = 24 \text{ A} \qquad 0 \le t \le 6\ \mu\text{s}$$
$$= -60 \text{ A} \qquad 6 \le t \le 10\ \mu\text{s}$$
$$= 16 \text{ A} \qquad 10 \le t \le 16\ \mu\text{s}$$
$$= 0 \qquad t > 16\ \mu\text{s}$$



5.19 $i(t) = 377 \cos(2000\pi t)$ mA



5.21 **(a)** $v(t) = 75.4 \cos 377t$ V

(b) $w(t) = 0.1 - 0.1 \cos 754t$ J

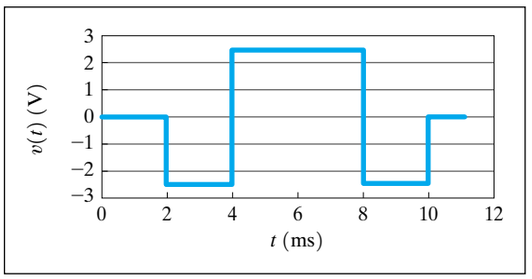
5.24 **(a)**
$$v(t) = 0, \qquad t < 0$$
$$= 250e^{-t}\ \mu\text{V}, \qquad t > 0$$

(b) $w(t) = 1.25\left[1 - 2e^{-t} + e^{-2t}\right]\ \mu$J

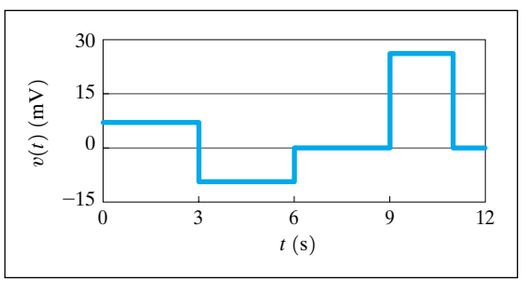
5.27 $v(t = 5 \text{ s}) = -0.91$ V

$w(t = 5 \text{ s}) = 91.97$ J

5.29
$$\begin{aligned} v(t) &= 0 && 0 \le t \le 2 \text{ ms} \\ &= -2.5 \text{ V} && 2 \le t \le 4 \text{ ms} \\ &= 2.5 \text{ V} && 4 \le t \le 8 \text{ ms} \\ &= -2.5 && 8 \le t \le 10 \text{ ms} \\ &= 0 && t > 10 \text{ ms} \end{aligned}$$

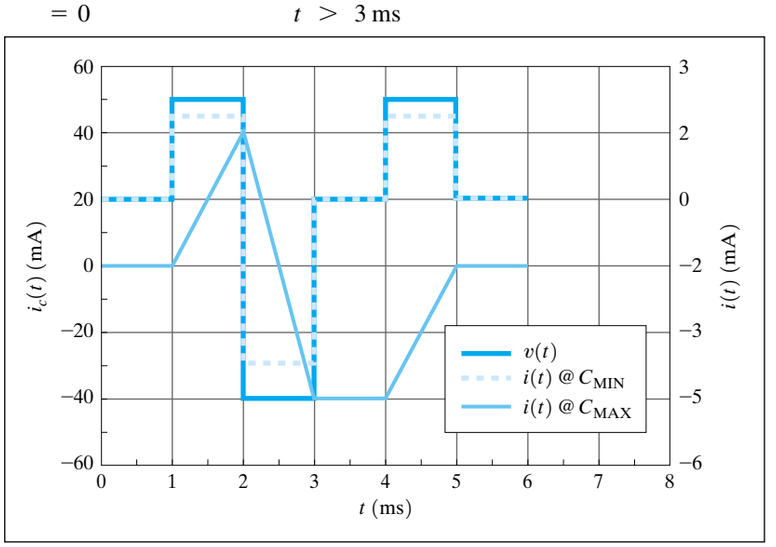


5.31
$$\begin{aligned} v(t) &= 6.67 \text{ mV} && 0 \le t \le 3 \text{ s} \\ &= -10 \text{ mV} && 3 \le t \le 6 \text{ s} \\ &= 0 && 6 \le t \le 9 \text{ s} \\ &= 25 \text{ mV} && 9 \le t \le 11 \text{ s} \\ &= 0 && t > 11 \text{ s} \end{aligned}$$

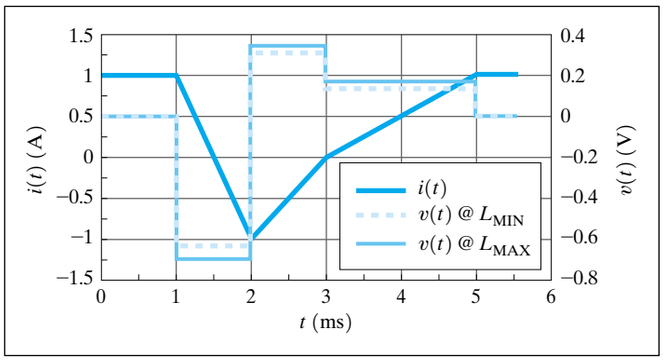


5.33
$$\begin{aligned} i(t) &= 0.5t \text{ A} && 0 \le t \le 2 \text{ ms} \\ &= 3 \times 10^{-3} - t \text{ A} && 2 \le t \le 3 \text{ ms} \\ &= 0 && t > 3 \text{ ms} \end{aligned}$$

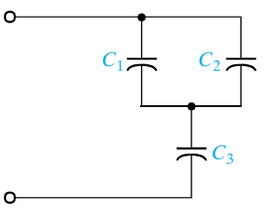
5.36



5.38



5.41 $C_1 = 1\ \mu\text{F}$, $C_2 = 3\ \mu\text{F}$, and $C_3 = 4\ \mu\text{F}$



5.44 $V_o = 12\ \text{V}$

5.46 $C = 3\ \mu\text{F}$

5.49 $C_T = 2\ \mu\text{F}$

5.51 $C_T = 9\ \mu\text{F}$

5.54 **(a)** $C_{\text{NOM}} = 1.43\ \mu\text{F}$

(b) $C_{\text{MIN}} = 1.254\ \mu\text{F}$, $C_{\text{MAX}} = 1.606\ \mu\text{F}$

(c) $\%_{\text{MIN}} = -12.3\%$, $\%_{\text{MAX}} = 12.3\%$

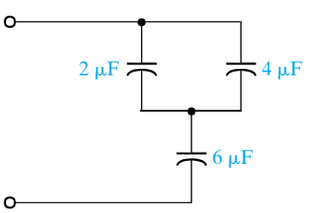
5.56 $L = 20\ \text{mH}$

5.59 $L_{AB} = 5\ \text{mH}$

5.61 $L_{AB} = 6\ \text{mH}$

5.64 $C = 1.25\ \mu\text{F}$

5FE-1



Chapter 6

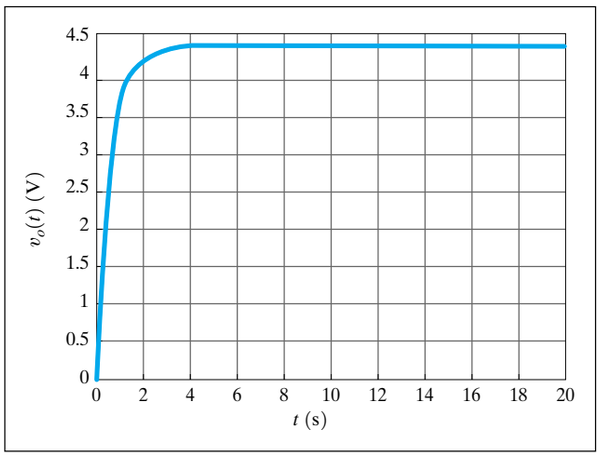
6.1 $v_C(t) = 12 - 8e^{-t/0.6}\ \text{V}, t > 0$

6.3 $v_C(t) = 6e^{-t/0.4}\ \text{V},\ t > 0$

6.5 $i_o(t) = \dfrac{2}{3}e^{-10t}\ \text{A},\ t > 0$

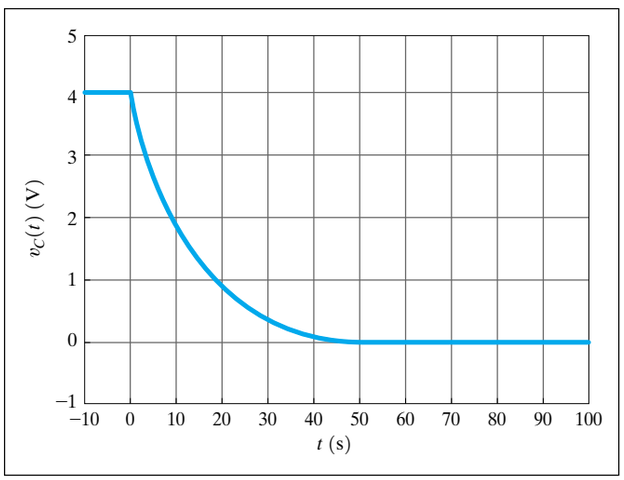
6.7 $v_o(t) = \dfrac{48}{11}\left(1 - e^{-11t/6}\right)$ V, $t > 0$

$= 0, \qquad t > 0$



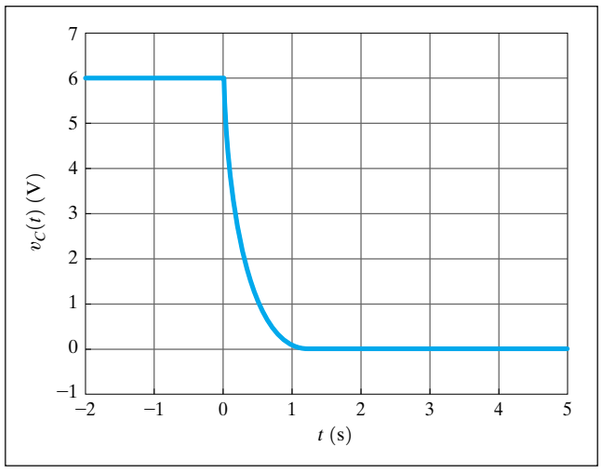
6.9 $v_C(t) = 4$ V, $\qquad t < 0$

$= 4e^{-t/1.2}$ V, $\qquad t > 0$



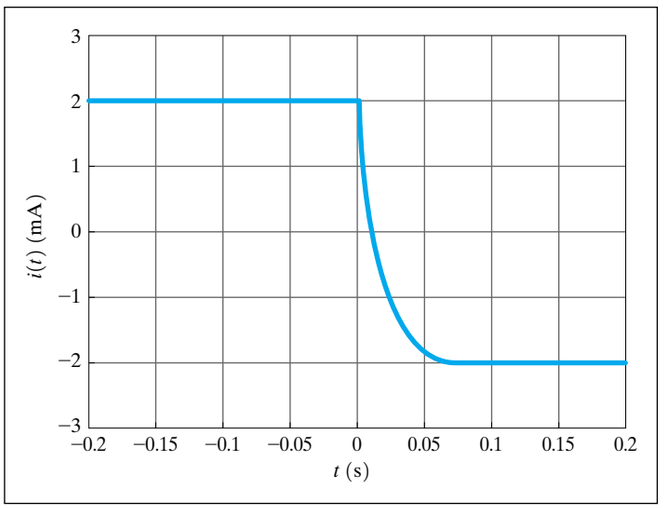
6.12 $v_C(t) = 6\,\text{V}, \qquad t < 0$

$= 6e^{-15t/4}\,\text{V}, \qquad t > 0$

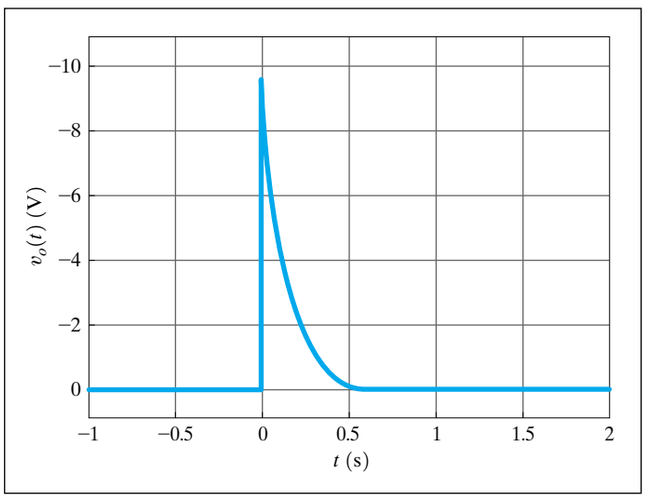


6.15 $i(t) = 2\,\text{mA}, \qquad t < 0$

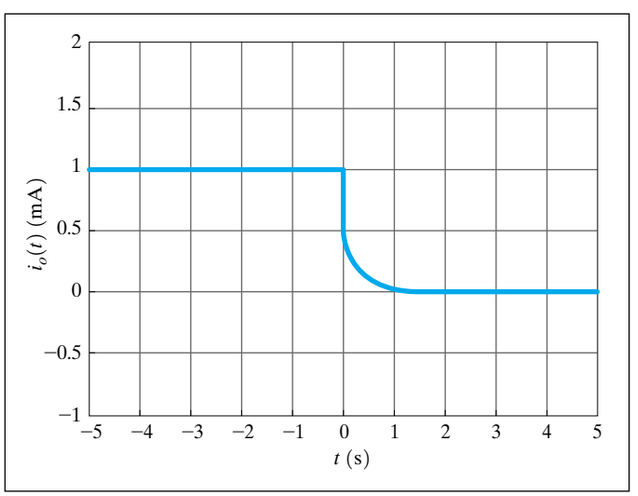
$= \left(4e^{-2\times10^6 t} - 2\right)\text{mA}, \quad t > 0$



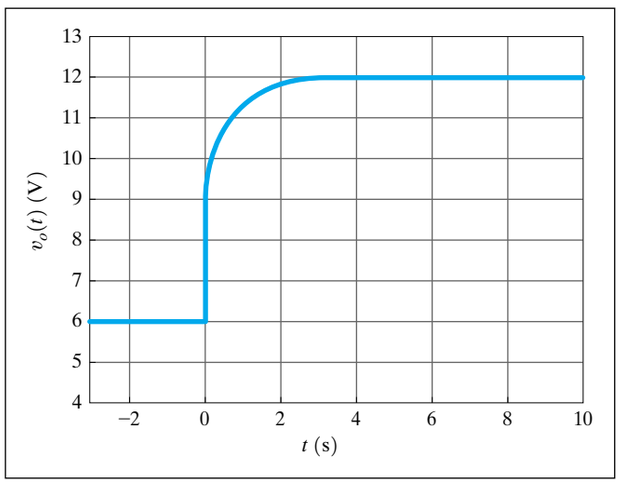
6.18 $v_o(t) = 0, \quad t < 0$
$= -9.6e^{-9.6t}\ \text{V}, \quad t > 0$



6.21 $i_o(t) = 1\ \text{mA}, \quad t < 0$
$= 0.5e^{-(10/3)t}\ \text{mA}, \quad t > 0$



6.24 $v_o(t) = 6, \quad t < 0$
$= 12 - 3e^{-5t/3}\,\text{V}, \quad t > 0$



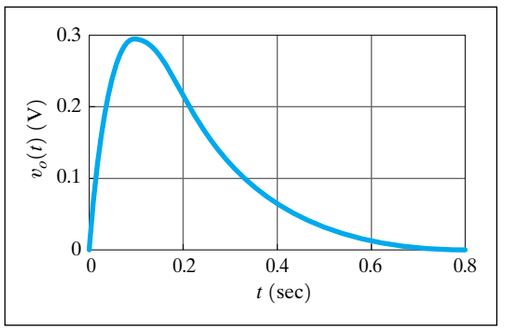
6.27 $i_o(t) = -3e^{-10t}\,\text{A}, \; t > 0$
6.30 $v_o(t) = 9e^{-5t/3}\,\text{V}, \; t > 0$
6.33 $i_o(t) = 2.4\left(1 - e^{-2.5\times10^5 t}\right)\text{mA}, \; t > 0$
6.36 $i_o(t) = 2 - \dfrac{e^{-3t}}{4}\,\text{mA}, \; t > 0$
6.39 $v_o(t) = 1.5e^{-t/0.6}\,\text{V}, \; t > 0$
6.42 $v_o(t) = -3.6e^{-8t}\,\text{V}, \; t > 0$
6.45 $i_o(t) = -0.5e^{-5t}\,\text{mA}, \; t > 0$
6.47 $v_o(t) = -6e^{-4t}\,\text{V}, \; t > 0$
6.50 $v_o(t) = -4e^{-0.889\times10^6 t}\,\text{V}, \; t > 0$
6.52 $i_o(t) = \dfrac{4}{3} - \dfrac{2}{15}e^{-9t/2}\,\text{A}, \; t > 0$
6.55 **(a)** $\text{s}^2 + 6\text{s} + 8 = 0$
(b) $\text{s} = -2, \text{s} = -4$
(c) $i_o(t) = \text{k}_1 e^{-2t} + \text{k}_2 e^{-4t}$
6.58 **(a)** $\text{s}^2 + 6\text{s} + 10 = 0$
(b) $\text{s} = -3 + \text{j}, \text{s} = -3 - \text{j}$
(c) $v_o(t) = k_1 e^{-3t}\cos t + \text{k}_2 e^{-3t}\sin t$
6.61 $v(t) = 10e^{-4t}\cos 2t - 40e^{-4t}\sin 2t$

6.64 $v_o(t) = 0 \qquad t < 0$

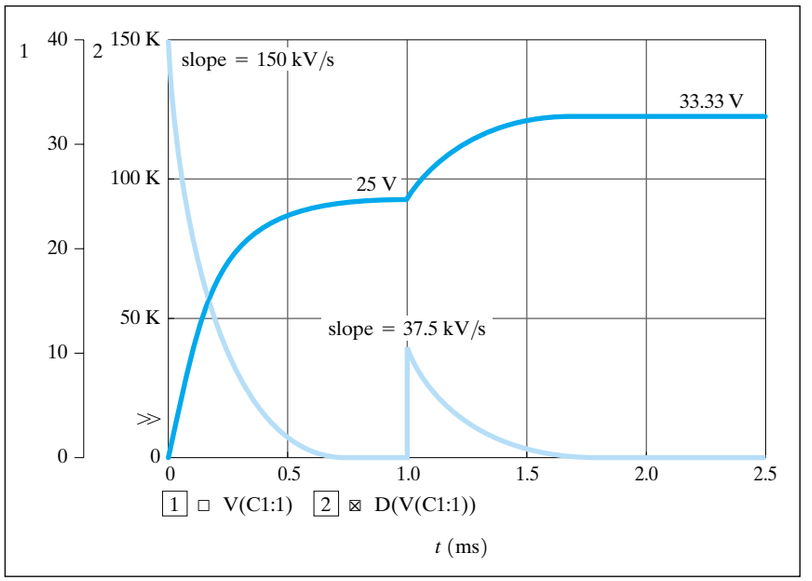
$= 16.67\left(e^{-2\times10^5 t} - e^{-8\times10^5 t}\right)\text{V}, \quad t > 0$

6.67 $i(t) = \frac{32}{7}e^{-8t} - \frac{4}{7}e^{-t}\,\text{A}, \quad t > 0$

6.70 $v_o(t) = 8te^{-10t}\,\text{V}, \quad t > 0$



6.72



6.75 $R = 2.5\,\text{k}\Omega,\ C = 10\,\text{pF},\ L = 333\,\mu\text{H}$

6FE-2 $v_o(t = 1\text{s}) = 3.79\,\text{V}$

Chapter 7

7.1 T = 0.16 s, f = 63.66 Hz

7.3 $i_1(t)$ leads $i_2(t)$ by −85°
$i_2(t)$ leads $i_3(t)$ by 145°
$i_1(t)$ leads $i_3(t)$ by 60°

7.6 **(a)** $i(t) = 8\cos(377t + 68°)$ A, $\mathbf{I} = 8\angle 68°$ A

(b) $i(t) = 4\cos(377t + 64°)$ A, $\mathbf{I} = 4\angle 64°$ A

7.8 $\mathbf{Z} = 1 + j1\ \Omega$

7.10 $\mathbf{Z} = 1.6 + j0.8\ \Omega$

7.13 $\mathbf{Z} = 5.1 + j4.96\ \Omega$

7.16 $\mathbf{Z} = 5\angle -37°\ \Omega$

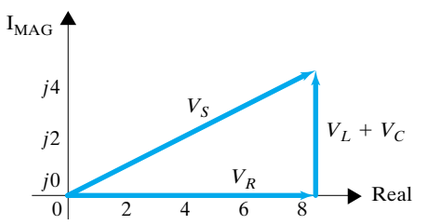
7.18 $C = 431\ \mu$F

7.20 $i(t) = 4.37\cos(377t + 0.75°)$ A

7.22 $\mathbf{V}_R = 8.74\angle 0.75°$ V

$\mathbf{V}_L = 16.47\angle 90.75°$ V

$\mathbf{V}_C = 11.59\angle -89.25°$ V



7.25 $\mathbf{I}_R = 9.99\angle 27.84°$ A and $\mathbf{I}_C = 0.38\angle 117.84°$ A

7.28 $\mathbf{V}_o = 10\angle -53.1°$ V

7.31 $\mathbf{V}_o = 1.414\angle 15°$ V

7.34 $\mathbf{I}_o = 5.89\angle -48.4°$ A

7.37 $\mathbf{V}_S = -8.54\angle -20.56°$ V

7.40 $\mathbf{I}_S = 8 + j4$ A

7.42 $\mathbf{Z} = 2\angle 83°\ \Omega$

7.44 $\mathbf{I}_o = 4.69\angle 78.69°$ A

7.47 $\mathbf{V}_o = 3.09\angle -23.83°$ V

7.49 $\mathbf{V}_o = 3.58\angle 153.43°$ V

7.52 $\mathbf{V}_o = 5.55\angle -86.9°$ V

7.55 $\mathbf{V}_o = 0.8 + j2.4$ V

7.58 $\mathbf{V}_o = 5.41 \angle 4.57°$ V

7.61 $\mathbf{I}_o = 2 \angle -37°$ A

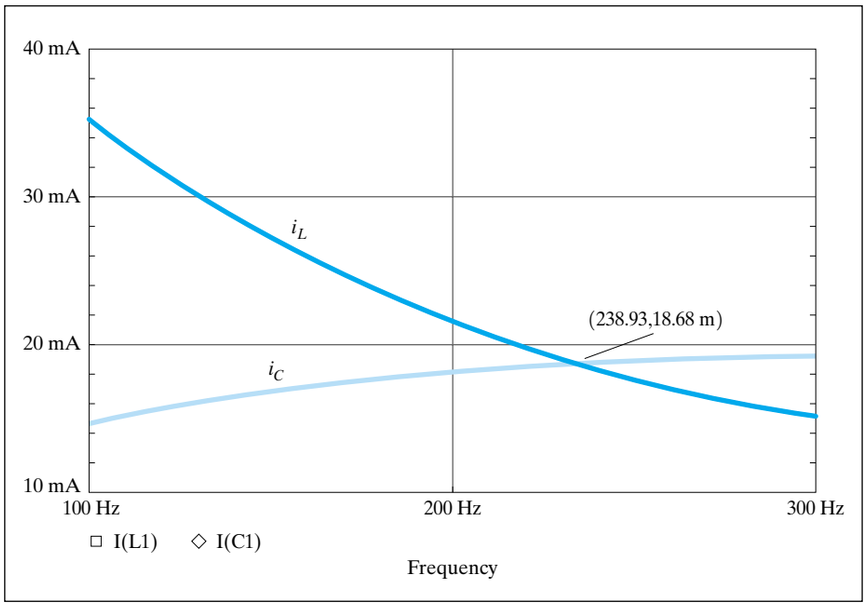
7.64 $\mathbf{V}_o = 9.03 \angle 51.3°$ V

7.67 $\mathbf{V}_o = 1.3 \angle 12.5°$ V

7.70 $\mathbf{V}_x = 48.59 \angle -21.37°$ V

7.73 $\mathbf{V}_o = 2.53 \angle -18.43°$ V

7.76 PROBE results show that the voltage and current phases are equal at 238.9 Hz.



7FE-1 $\mathbf{V}_o = 5.06 \angle -71.6°$ V

7FE-4 $\dfrac{\mathbf{V}_o}{\mathbf{V}_S} = -133.33$

Chapter 8

8.1 **(a)** $v_a(t) = -L_1 \dfrac{di_1(t)}{dt} - M \dfrac{di_2(t)}{dt}$

$v_b(t) = -L_2 \dfrac{di_2(t)}{dt} - M \dfrac{di_1(t)}{dt}$

(b) $v_c(t) = L_1 \dfrac{di_1(t)}{dt} + M \dfrac{di_2(t)}{dt}$

$v_d(t) = L_2 \dfrac{di_2(t)}{dt} + M \dfrac{di_1(t)}{dt}$

8.4 **(a)** $v_a(t) = L_1 \dfrac{di_1(t)}{dt} + M \dfrac{di_2(t)}{dt}$

$v_b(t) = -L_2 \dfrac{di_2(t)}{dt} - M \dfrac{di_1(t)}{dt}$

(b) $v_c(t) = -v_a(t) = -L_1 \dfrac{di_1(t)}{dt} - M \dfrac{di_2(t)}{dt}$

$v_d(t) = -v_b(t) = L_2 \dfrac{di_2(t)}{dt} + M \dfrac{di_1(t)}{dt}$

8.7 $\mathbf{V}_o = 2.98 \angle 26.57°$ V

8.9 $\mathbf{V}_o = 2.24 \angle -153.43°$ V

8.11 $\mathbf{V}_o = 20.86 \angle 4.32°$ V

8.14 $\mathbf{I}_o = 1.78 \angle 42°$ A

8.17 $-\mathbf{V}_1 = \mathbf{I}_1(R_1 + j\omega L_1) + j\omega M \mathbf{I}_3$

$\mathbf{V}_1 = \mathbf{I}_2\left(j\omega L_2 - \dfrac{j}{\omega C_1}\right) - j\omega L_2 \mathbf{I}_3$

$0 = j\omega M \mathbf{I}_1 - j\omega L_2 \mathbf{I}_2 + \mathbf{I}_3(R_2 + j\omega L_2 + j\omega L_3)$

8.20 $\mathbf{V}_o = 1.36 \angle -85.4°$ V

8.23 $\mathbf{V}_o = 0.64 \angle -71.57°$ V

8.26 $\mathbf{V}_o = 5.79 \angle 86.31°$ V

8.29 $\mathbf{V}_o = 8.76 \angle 158.8°$ V

8.32 $\mathbf{I}_o = 2.78 \angle -56.31°$ A

8.35 $\mathbf{Z}_{\text{source}} = 1.56 \angle 42.27°\ \Omega$

8.38 $\mathbf{Z}_{\text{IN}} = 1.94 \angle -33.69°\ \Omega$

8.41 $L_2 = 3.6$ mH

8.44 $i_1(t) = 2.46 \cos(100t + 143.1°)$ mA

$i_2(t) = 1.54 \cos(100t - 178.24°)$ mA

8.47 $\mathbf{V}_1 = 8.89 \angle 30°$ V, $\mathbf{I}_1 = 1.11 \angle 30°$ A

$\mathbf{V}_2 = 4.44 \angle -150°$ V, $\mathbf{I}_2 = 2.22 \angle -150°$ A

8.49 $\mathbf{I}_1 = 3.16 \angle -41.56°$ A, $\mathbf{V}_1 = 4.47 \angle 3.44°$ V

$\mathbf{I}_2 = 1.58 \angle 138.44°$ A, $\mathbf{V}_2 = 8.94 \angle 3.44°$ V

8.52 $\mathbf{Z}_{\text{IN}} = 1.5 + j0.25\ \Omega$

8.55 $\mathbf{Z}_S = 16 - j1\ \Omega$

8.58 $\mathbf{V}_o = 44.72 \angle -153°$ V

8.60 $\mathbf{I}_S = 2.91 \angle -75.95°$ A

8.62 $\mathbf{V}_o = 15.78 \angle 189.46°$ V

8.65 $\mathbf{V}_o = 1.8 \angle -139.86°$ V

8FE-1 $\mathbf{Z}_S = 4.88 \angle 19.75°\ \Omega$

8FE-4 $P = 11.1$ W

Chapter 9

9.1 $p(t) = 11.51 + 14.4\cos(2\omega t + 113.1°)$ W

9.3 $P = 1.58$ W

9.5 $P_S = 4.31$ W, $P_{2\Omega} = 3.06$ W, $P_{4\Omega} = 1.23$ W

9.8 $P_{\text{ABS}} = 35.95$ W

9.11 $P_{4\Omega} = 10.4$ W

9.13 $P_R = 4.5$ W

9.16 $P_R = 2.5$ W

9.18 $P_R = 32.49$ W

9.21 $\mathbf{Z}_L = 5\ \Omega$, $P_L = 5.28$ W

9.24 $\mathbf{Z}_L = 0.55\underline{/33.69°}\ \Omega$, $P_{\text{MAX}} = 0.42$ W

9.26 $\mathbf{Z}_L = 0.9 - j0.3\ \Omega$, $P_{\text{MAX}} = 2$ W

9.29 $\mathbf{Z}_L = 2.83\underline{/8.13°}\ \Omega$, $P_{\text{MAX}} = 1.32$ W

9.32 $\mathbf{Z}_L = 0.2 + j0.4\ \Omega$, $P_{\text{MAX}} = 28.9$ W

9.34 $V_{\text{rms}} = 2.31$ V

9.37 $V_{\text{rms}} = 1.63$ V

9.40 $V_{\text{rms}} = 2.67$ V

9.43 $V_L = 440$ V rms

9.46 $\theta = 36.87°$

9.49 $PF = 0.65$ Lagging

9.51 $\mathbf{V}_S = 281.02\underline{/8.75°}$ V rms

$PF_{\text{source}} = 0.756$ Lagging

9.54 $\mathbf{V}_S = 320.06\underline{/9.95°}$ V rms

9.57 $C = 567.6\ \mu$F

9.60 $C = 305\ \mu$F

9.63 $PF = 0.88$ Lagging

9.65 $I = 18$ A

9.68 $I_{\text{touch}} = 1.26$ A rms, no current near the heart

9FE-1 $C = 927.6\ \mu$F

9FE-3 $\mathbf{Z}_L = 0.4 - j1.2\ \Omega$

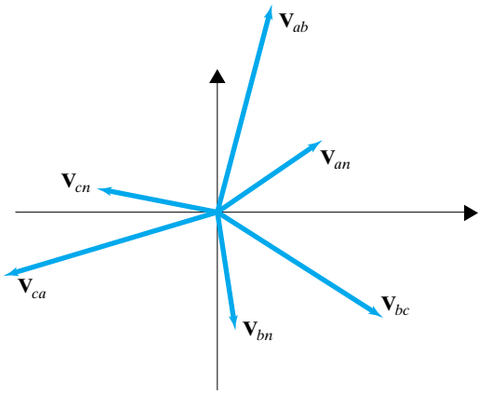
Chapter 10

Typically, only the *a*-phase information is listed. The two remaining phases are shifted by −120° and −240°, respectively.

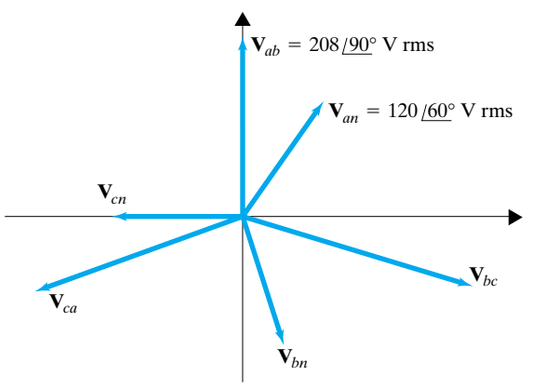
10.1 $\mathbf{V}_{ab} = 173\underline{/25°}$ V rms

$\mathbf{V}_{bc} = 173\underline{/-45°}$ V rms

$\mathbf{V}_{ca} = 173\underline{/-165°}$ V rms



10.4 $\mathbf{V}_{ab} = 208 \angle 90°$ V rms
$\mathbf{V}_{bc} = 208 \angle -30°$ V rms
$\mathbf{V}_{ca} = 208 \angle -150°$ V rms



10.7 $\mathbf{I}_{an} = 2.45 \angle -14°$ A rms

10.10 $\mathbf{I}_{an} = 5.56 \angle 6.3°$ A rms
$\mathbf{V}_{an} = 111.1 \angle 59.40°$ V rms

10.13 $\mathbf{V}_{ab} = 217.4 \angle 40°$ V rms

10.16 $\mathbf{Z}_L = 15.62 \angle 39.8°\ \Omega$

10.19 $\mathbf{I}_{aA\,\text{Max}} = 67.42$ A rms

10.22 $\mathbf{Z}_L = 19.95 + j21.93\ \Omega$

10.25 $\mathbf{V}_{ab} = 242.11 \angle 40.09°$ V rms

10.28 $\mathbf{I}_{aA} = 19.52 \angle 39.4°$ A rms

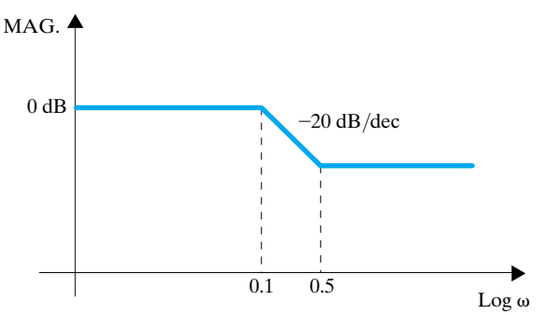
10.31 $\mathbf{Z}_L = 70.48 - j25.65\ \Omega$
10.34 $\mathbf{Z}_L = 32.18\angle 25^\circ\ \Omega$
10.37 $\mathbf{I}_{AN} = 9.37\angle -4.4^\circ$ A rms
10.40 $\mathbf{I}_{ab} = 8.64\angle 57.9^\circ$ A rms
10.43 $\mathbf{I}_{aA} = 37.35\angle -1^\circ$ A rms, $P_{Y\ Load} = 7.434$ kW
10.46 $|\mathbf{I}_L| = 10.25$ A rms
10.49 $|\mathbf{I}_{aA}| = 148.56$ A rms, $PF_{Load} = 0.74$ Lagging
10.52 $PF_S = 0.91$ Lagging
10.55 $\mathbf{S}_{uL} = 19.94$ kVA@0.60 Lagging
10.58 $PF = 0.97$ Lagging
10.61 $C = 740.9\ \mu$F
10FE-1 $\mathbf{S}_T = 2160\angle 45^\circ$ VA
10FE-4 $P_p = 6.928$ kW

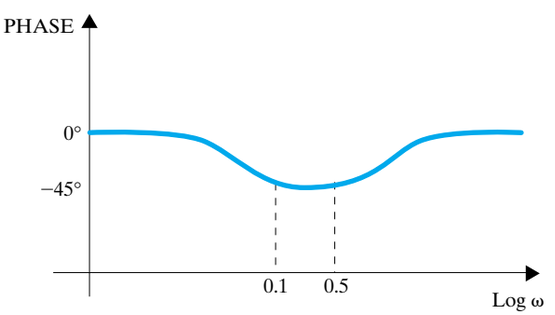
Chapter 11

11.1 $$\mathbf{Z}(s) = \frac{s^2LCR + sL + R}{s^2LC + 1}$$

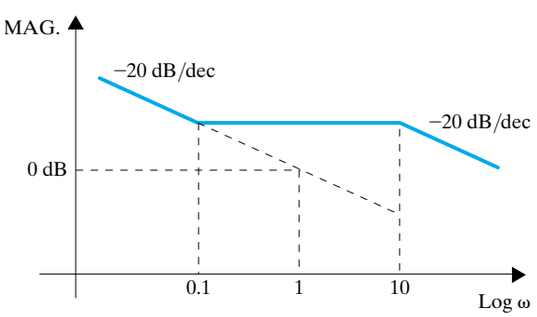
11.4 $$\frac{\mathbf{V}_0}{\mathbf{I}_s} = \frac{8s(s+1)}{2s^2 + 6s + 1}$$

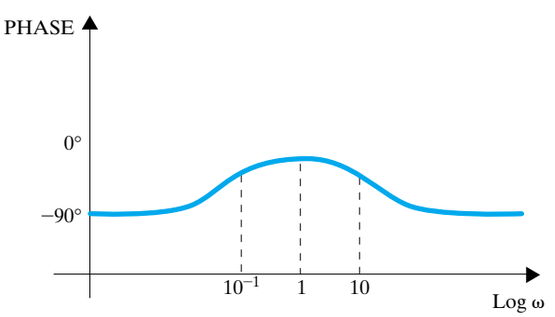
11.7



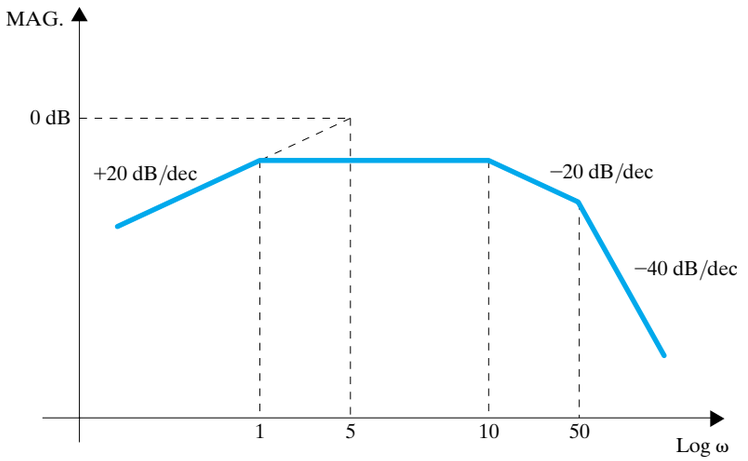


11.10





11.13



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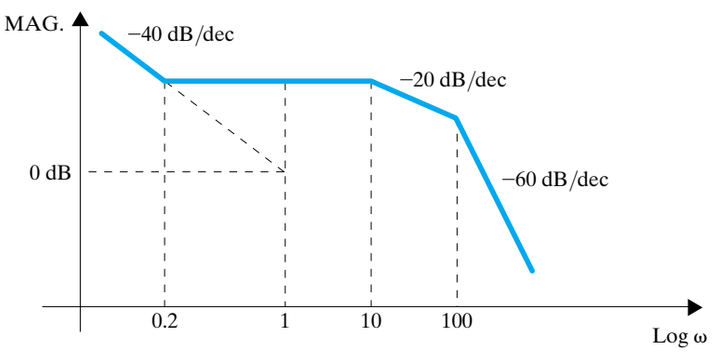

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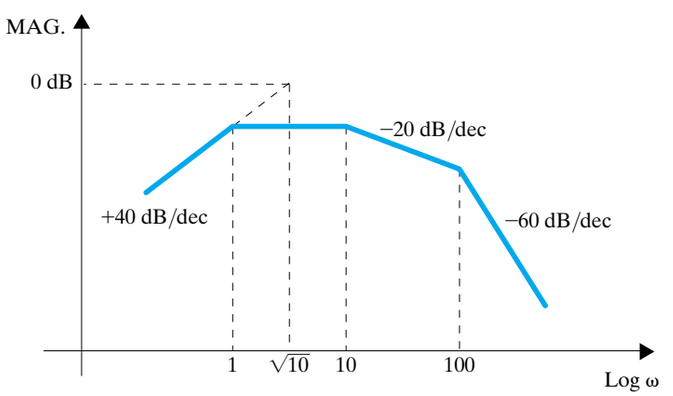

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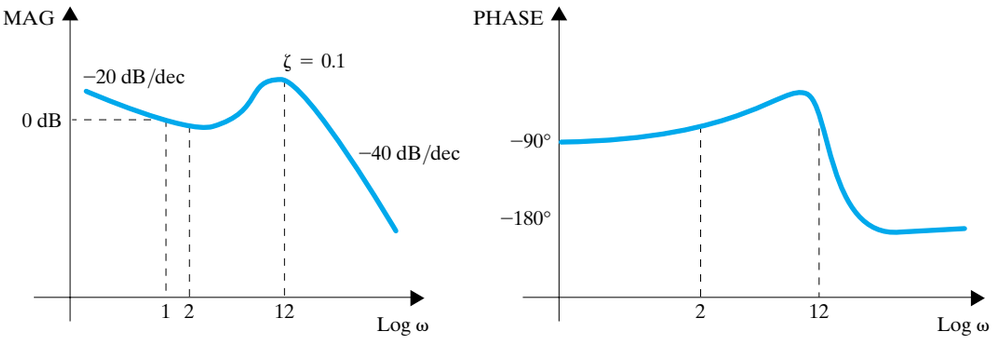
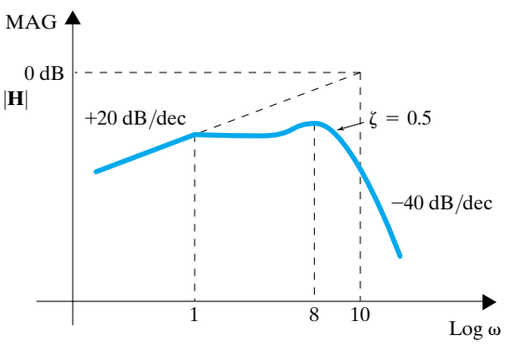


11.25



11.28 $\mathbf{H}(j\omega) = \dfrac{10\left(\dfrac{j\omega}{10} + 1\right)}{(j\omega)\left(\dfrac{j\omega}{20} + 1\right)^2}$

11.31 $\mathbf{H}(j\omega) = \dfrac{1(j\omega)\left(\dfrac{j\omega}{30} + 1\right)}{(j\omega + 1)\left(\dfrac{j\omega}{100} + 1\right)\left(\dfrac{j\omega}{8} + 1\right)^2}$

11.34 $L = 12.5$ mH, $Q = 10.42$, $BW = 192$ r/s

11.37 $\omega_0 = 7071$ r/s, $Q = 14.14$, $\omega_{MAX} = 7062$ r/s, $|\mathbf{V}_o|_{max} = 84.89$ V

11.40 $\omega_0 = 2$ kr/s, $Q = 25$, $BW = 80$ r/s, $P = 18$ W

11.43 $R = 1$ kΩ, $L = 500$ μH

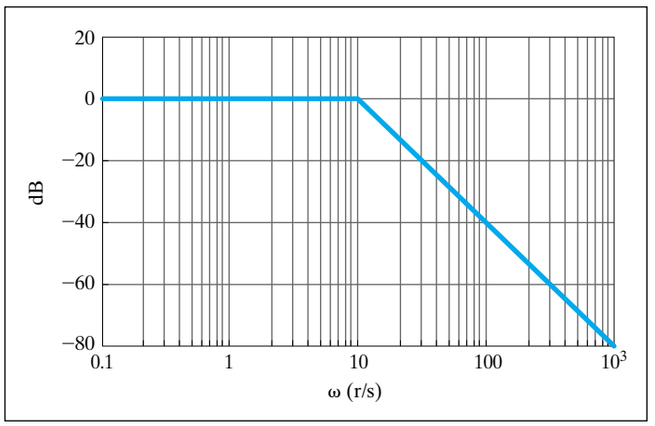
11.46 $\omega_0 = 10$ kr/s, BW $= 100$ r/s, $Q = 100$, $P_{LO} = P_{HI} = 12.5$ kW

11.49 $C = 25$ nF, $L = 10$ μH

11.52 $R_{new} = 20$ kΩ, $L_{new} = 5$ kH, $C = 12.5$ μF

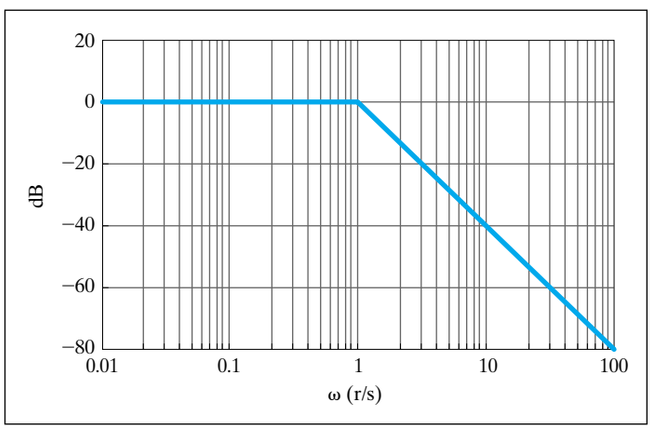
11.55 Low-pass filter

$$\frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1}{\left(\frac{j\omega}{10}\right)^2 + \frac{j\omega}{10} + 1}$$

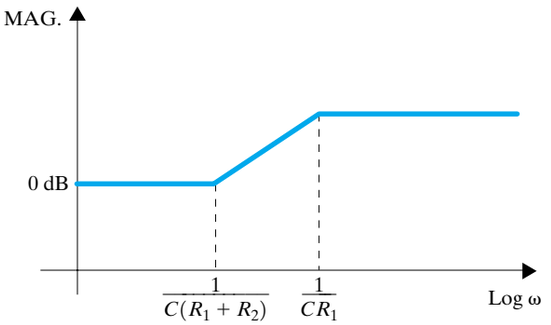


11.57 $\mathbf{G}_v = \dfrac{\left(1 + \dfrac{j\omega L}{R_1}\right)}{1 + j\omega\left(\dfrac{L}{R}\right)} \qquad R = R_1 \| R_2$

A low-pass filter



11.61 $\dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{j\omega C(R_1 + R_2) + 1}{j\omega C R_1 + 1}$, a high-pass filter



11.63 $g_m = 100\ \mu\text{S}$ and $I_{ABC} = 5\ \mu\text{A}$

11.66 $L_{\text{eq}} = \dfrac{C}{(g_{m1}g_{m2})}$

11.68 $$\frac{\mathbf{V}_o}{\mathbf{V}_{\text{in}}} = \frac{j\omega g_1/C_2}{-\omega^2 + j\omega\left[\dfrac{g_1 + g_2 + g_3 + g_3\left(\dfrac{C_1}{C_2}\right)}{C_1}\right] + \dfrac{g_1 g_3}{C_1 C_2}}$$

$$\omega_0 = \sqrt{\frac{g_1 g_3}{C_1 C_2}},\ Q = \frac{\sqrt{g_1 g_2 C_1 C_2}}{C_2(g_1 + g_2 + g_3) + C_1 g_3}$$

Band-pass filter

11.71 $C = 100\ \mu\text{F}$, $L = 101\ \text{mH}$

11FE-2 $\omega_0 = 1\ \text{kr/s}$, $R = 4\ \Omega$

11FE-4 $L = 100\ \text{mH}$, $R = 10\ \Omega$

Chapter 12

12.1 $\mathbf{F}(s) = e^{-(s+a)}$

12.4 $$\mathbf{F}(s) = e^{-(s+a)}\left[\frac{\omega\cos\omega}{(s+a)^2 + \omega^2} + \frac{(s+a)\sin\omega}{(s+a)^2 + \omega^2}\right]$$

12.7 $$\mathbf{F}(s) = \frac{e^{-2s}}{(s+1)(s+2)}$$

12.10 $$\mathbf{F}(s) = e^{-(s+a)}\left[\frac{1}{(s+a)^2} + \frac{1}{s+a}\right]$$

12.13 **(a)** $f(t) = \left[\frac{1}{6} + \frac{1}{2}e^{-2t} - \frac{2}{3}e^{-3t}\right]u(t)$

(b) $f(t) = \left[\frac{1}{2} - e^{-t} + \frac{3}{2}e^{-2t}\right]u(t)$

12.15 **(a)** $f(t) = \left(\frac{1}{4}e^{-2t} + \frac{3}{4}e^{-6t}\right)u(t)$

(b) $f(t) = \left(\frac{3}{4} + \frac{1}{4}e^{-4t}\right)u(t)$

12.18 **(a)** $f(t) = 10e^{-t}\cos t\, u(t)$

(b) $f(t) = \left[\frac{1}{5} + 0.62e^{-2t}\cos(t - 108.43°)\right]u(t)$

12.21 **(a)** $f(t) = \left[2e^{-3t}\cos 3t - e^{-3t}\right]u(t)$

(b) $f(t) = \left[1 + e^{-4t}\sin 4t\right]u(t)$

12.24 **(a)** $f(t) = \left[2te^{-2t} + e^{-2t}\right]u(t)$

(b) $f(t) = \left[6 - 5te^{-t} - 6e^{-t}\right]u(t)$

12.27 $f(t) = \left[-3 + 3t + \frac{12}{5}e^{-t} + \frac{2}{3}e^{-2t}\cos(2t - 26.56°)\right]u(t)$

12.30 **(a)** $f(t) = \frac{1}{2}u(t-1) + \frac{1}{2}e^{-2(t-1)}u(t-1)$

(b) $f(t) = \left[5e^{-(t-2)} - 5e^{-3(t-2)}\right]u(t-2)$

12.33 **(a)** $f(t) = \left[-2e^{-(t-1)} + 4e^{-3(t-1)}\right]u(t-1)$

(b) $f(t) = \left[\frac{10}{3}e^{-(t-2)} + \frac{20}{3}e^{-4(t-2)}\right]u(t-2)$

12.36 $y(t) = \left(\frac{1}{3}e^{-t} - \frac{1}{3}e^{-4t}\right)u(t)$

12.39 $f(t) = \left(e^{-t} - e^{-2t}\right)u(t)$

12.42 **(a)** $f(0) = 10, f(\infty) = 0$

(b) $f(0) = 0, f(\infty) = 0$

(c) $f(0) = 2, f(\infty) = 0$

12.45 $i(t) = 4e^{-\frac{9}{2}t}u(t)$ A

12.48 $i_L(t) = \left(4e^{-2t} - e^{-t}\right)u(t)$ A

12FE-2 $v_o(t = 0.1\text{ s}) = 0.24$ V

Chapter 13

13.1 $Z(s) = \dfrac{6s + 8}{6s^2 + 16s + 11}$

13.3 $v(t) = 10\,u(t)$ V

13.5 $i_o(t) = \left(2 - e^{-t} - \frac{4}{3}e^{-\frac{2}{3}t}\right)u(t)$ A

13.7 $v(t) = (5e^{-t} - 4500te^{-t})u(t)$ mV

13.10 $v_o(t) = \frac{6}{7}(1 - e^{-\frac{7t}{4}})u(t)$ V

13.13 $v_o(t) = (1 - 5e^{-4t})u(t)$ V

13.16 $v_o(t) = \left(-\frac{4}{3} + 2e^{-t} - \frac{20}{3}e^{-3t}\right)u(t)$ V

13.19 $v_o(t) = 2\sqrt{2}e^{-t}\cos(t - 45°)u(t)$ V

13.22 $i_o(t) = \left[1 - \frac{2}{3}e^{-\frac{4t}{3}}\right]u(t)$ A

13.25 $v_o(t) = \left(\frac{8}{3} + 4e^{-2t} - \frac{17}{3}e^{-\frac{3t}{2}}\right)u(t)$ V

13.28 $v_o(t) = 5e^{-3t}u(t)$ V, $t > 0$

13.30 $i_o(t) = -e^{\frac{-t}{2}}u(t)$ A, $t > 0$

13.32 $i_o(t) = \frac{3}{2}e^{-\frac{9t}{2}}u(t)$ A, $t > 0$

13.35 $v_o(t) = (4 + 2e^{-\frac{5t}{12}})u(t)$ V, $t > 0$

13.37 $v_o(t) = 1.15\left[e^{-0.42t} - e^{-1.58t}\right]u(t)$ V, $t > 0$

13.40 $v_o(t) = 2.31\left[e^{-0.35t} - e^{-5.65t}\right]u(t)$ V, $t > 0$

13.43 $v_o(t) = (8 - 8e^{-4t})u(t) - \left[8 - 8e^{-4(t-1)}\right]u(t - 1)$ V

13.46 $\frac{\mathbf{V}_o}{\mathbf{V}_S} = \left(1 + \frac{R_1}{R_2}\right)\frac{(1 + sCR)}{1 + sCR_1}$, $R = R_1 \,||\, R_2$

13.49 $$\frac{\mathbf{V}_o}{\mathbf{V}_S} = \frac{\dfrac{-s}{R_1C_1}}{s^2 + s\left(\dfrac{C_1}{C_1C_2R_3} + \dfrac{C_2}{C_1C_2R_3}\right) + \dfrac{R_1R_2}{C_1C_2R_1R_2R_3}}$$

13.52 Yes

13.54 No, overdamped

13.56 $C = 0.5$ F

13.59 $v_o(t) = 4.7\cos(t - 45°)$ V

13.62 $i_o(t) = 12\sqrt{2}\cos(2t + 45°)$ A

13FE-2 $\frac{\mathbf{V}_o}{\mathbf{V}_S} = \frac{s}{s^2 + s + 2}$, the network is underdamped.

Chapter 14

14.1 $$f(t) = \sum_{\substack{n=-\infty \\ n\neq 0 \\ n \text{ odd}}}^{\infty} \frac{2}{jn\pi} e^{jn\omega_0 t}$$

14.3 $$f(t) = \sum_{n=-\infty}^{\infty} \frac{6}{n\pi} e^{-jn\pi t} \sin\left(\frac{n\pi}{5}\right)$$

14.5 $$f(t) = \frac{1}{2} + \sum_{\substack{n=-\infty \\ n\neq 0 \\ n \text{ odd}}}^{\infty} \frac{-2}{n^2\pi^2} e^{jn\pi t}$$

14.8 $$v(t) = \sum_{n=1}^{\infty} (-1)^{n+1} \frac{20}{n\pi} \sin nt$$

14.10 $$a_0 = \frac{1}{4}, b_n = 0$$

$$a_n = \frac{4}{n^2\pi^2}\left[\cos\left(\frac{n\pi}{2}\right) - 1\right] + \frac{2}{n\pi}\sin\left(\frac{n\pi}{2}\right)$$

14.13 $$a_0 = \frac{-\pi}{4}$$

$$a_n = \frac{1}{\pi n^2}(\cos(n\pi) - 1)$$

$$b_n = \frac{1}{n}(1 - 2\cos n\pi)$$

14.16 $$a_0 = \frac{1}{4}$$

$$a_n = \frac{1}{n^2\pi^2}(\cos(n\pi) - 1)$$

$$b_n = \frac{1}{n\pi}(\cos(n\pi) - 2)$$

14.19 $$f(t) = \frac{A}{\pi} + \frac{A}{2}\sin(\pi t) + \sum_{\substack{n=2 \\ n \text{ even}}}^{\infty} \frac{2A}{\pi(1 - n^2)} \cos n\omega_0 t$$

14.22 $$f(t) = -4\sin 20\pi t - 5\sin 40\pi t - 3\sin 60\pi t - 2\sin 80\pi t - \sin 100\pi t$$

14.25 $$i_o(t) = \frac{(-1)^{n+1}20}{n\pi} |\mathbf{G}(n)| \cos(nt - 90^\circ + \theta n)$$

$$\mathbf{G}(n) = \frac{jn}{1 + 3jn}, \theta n = \underline{/\mathbf{G}(n)}$$

14.28 $$i_o(t) = 3.18\sin(2\pi t + 89.9^\circ) - 3.18\sin(4\pi t + 89.9^\circ) + 3.18\sin(6\pi t + 89.9^\circ) - 3.18\sin(8\pi t + 89.9^\circ) \text{ mA}$$

14.31 $$\mathbf{V}(\omega) = \frac{2A}{j\omega}(1 - \cos \omega T)$$

14.34 $\mathbf{F}(\omega) = \dfrac{2a}{a^2 + \omega^2}$

14.37 $v_o(t) = \left(e^{-3t} - e^{-4t}\right)u(t)$ V

14.40 $v_o(t) = \dfrac{2}{3}\left[e^{-t} - e^{-4t}\right]u(t)$ V

14FE-1 $a_0 = 0$ since the average value is zero
$a_n = 0$ for all n since this is an odd function
$b_n = 0$ for n even because of half-wave symmetry
$b_n =$ finite numbers for n odd

Chapter 15

15.1 **(a)** $\mathbf{y}_{11} = \dfrac{1}{\mathbf{Z}_L}, \mathbf{y}_{12} = \dfrac{-1}{\mathbf{Z}_L}, \mathbf{y}_{21} = \dfrac{-1}{\mathbf{Z}_L}, \mathbf{y}_{22} = \dfrac{1}{\mathbf{Z}_L}$

(b) $\mathbf{z}_{11} = \mathbf{Z}_L, \mathbf{z}_{12} = \mathbf{Z}_L, \mathbf{z}_{21} = \mathbf{Z}_L, \mathbf{z}_{22} = \mathbf{Z}_L$

15.3 $\mathbf{y}_{11} = \dfrac{1}{14}$ S, $\mathbf{y}_{12} = \dfrac{-1}{21}$ S, $\mathbf{y}_{21} = \dfrac{-1}{21}$ S, $\mathbf{y}_{22} = \dfrac{1}{7}$ S

15.5 $\mathbf{y}_{11} = \dfrac{1}{\mathbf{Z}_1}, \mathbf{y}_{12} = 0, \mathbf{y}_{21} = \dfrac{\gamma}{\mathbf{Z}_2}, \mathbf{y}_{22} = \dfrac{1}{\mathbf{Z}_2}$

15.8 $\mathbf{z}_{11} = 18\ \Omega, \mathbf{z}_{12} = 6\ \Omega, \mathbf{z}_{21} = 6\ \Omega, \mathbf{z}_{22} = 9\ \Omega$

15.11 $\dfrac{\mathbf{V}_o}{\mathbf{V}_1} = -65.6$

15.13 $\dfrac{\mathbf{V}_2}{\mathbf{V}_1} = -438$

15.16 $\mathbf{z}_{11} = R_1, \mathbf{z}_{12} = nR_1, \mathbf{z}_{21} = nR_1, \mathbf{z}_{22} = n^2(R_1 + R_2)$

15.19 $\mathbf{h}_{11} = 6\ \Omega, \mathbf{h}_{12} = 0.5, \mathbf{h}_{21} = -0.5, \mathbf{h}_{22} = \dfrac{1}{8}$ S

15.22 $\mathrm{A} = 1, \mathrm{B} = -j1\ \Omega, \mathrm{C} = 15, \mathrm{D} = 1 - j$

15.25 $\mathbf{A} = \dfrac{R_1 + R_2}{\gamma + R_2}, \mathbf{B} = \dfrac{R_1R_3 + R_2R_3 + R_1R_2 - \gamma R_2}{\gamma + R_2}$

$\mathbf{C} = \dfrac{1}{\gamma + R_2}, \mathbf{D} = \dfrac{R_2 + R_3}{\gamma + R_2}$

15.28 $\mathbf{y}_{11} = \dfrac{5}{11}$ S, $\mathbf{y}_{12} = \dfrac{-2}{11}$ S, $\mathbf{y}_{21} = \dfrac{-2}{11}$ S, $\mathbf{y}_{22} = \dfrac{3}{11}$ S

15.31 $\mathbf{h}_{11} = \dfrac{\mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22}}, \mathbf{h}_{12} = \dfrac{\mathbf{z}_{12}}{\mathbf{z}_{22}}$

$\mathbf{h}_{21} = \dfrac{-\mathbf{z}_{21}}{\mathbf{z}_{22}}, \mathbf{h}_{22} = \dfrac{1}{\mathbf{z}_{22}}$

15.33 $\mathbf{Y}_{1n} = 1\ \text{S}$

15.36 $\mathbf{Z}_T = \begin{bmatrix} 18 & 6 \\ 6 & 9 \end{bmatrix}$

15.39 $\begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} = \begin{bmatrix} 3 & j8 \\ 3 - j & 3 + j8 \end{bmatrix}$

15FE-1 $V_1 = 36\ \text{V}$

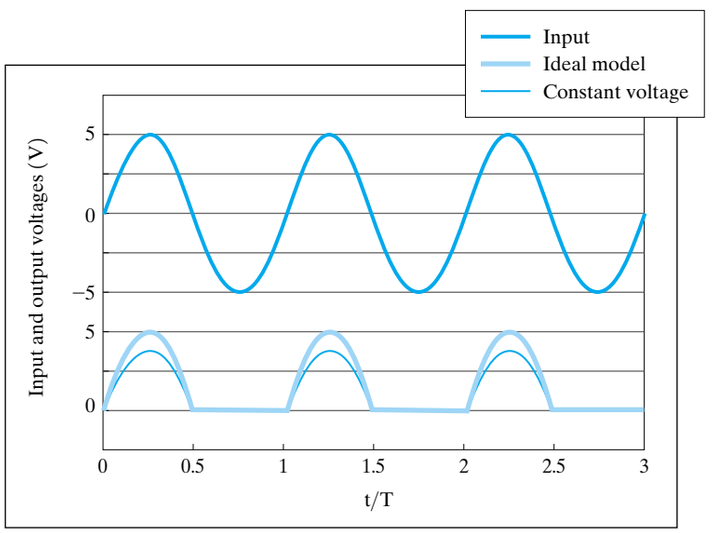
Chapter 16

16.1

$\overline{V_D\,(\text{V})}$	$\overline{I_D\,(\text{A})}$
0	0
0.25	1.7×10^{-11}
0.50	2.9×10^{-7}
0.75	5.0×10^{-3}

16.3 **(a)** 9.4 V, **(b)** 10 V, **(c)** 3.4 V, **(d)** −1 V

16.5



16.8 $\dfrac{V_o}{V_{\text{IN}}} = \dfrac{g_m R_{\text{eq}}}{g_m R_{\text{eq}} + 1}, R_0 = \dfrac{R_{\text{eq}}}{g_m R_{\text{eq}} + 1}$

$\text{R}_{\text{eq}} = R_S \,||\, \text{rds}$

For given values $R_o = 83.3\ \Omega$

A good application is a voltage buffer much like the unity gain buffer op-amp.

16.10 $v_o = \dfrac{g_m R_D}{2}(v_2 - v_1)$

16.12 $R_{\text{ON}} = \dfrac{1}{2}\ \Omega, R_1 = 149.5\ \Omega$

16.13 $R_{\text{ON}} \leq 1.2\ \Omega$

16FE-1 When V_{IN} is greater than 6 V, D_1 is forward biased and D_2 is reverse biased. The circuit reduces to that in Figure A where

$$V_{IN} = 500I + 6$$

and

$$V_o = 300I + 6$$

Solving for V_o yields

$$V_o = 6 + 0.6(V_{IN} - 6)$$

When V_{IN} is less than -2 V, D_2 is forward biased and D_1 is reverse biased. Under these conditions, $V_o = -2$ V. For V_{IN} between -2 V and +6 V, both diodes are reverse biased, no current flows anywhere and $V_o = V_{IN}$. A plot of V_o versus V_{IN} is shown in Figure B.

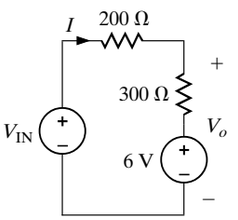


Figure A

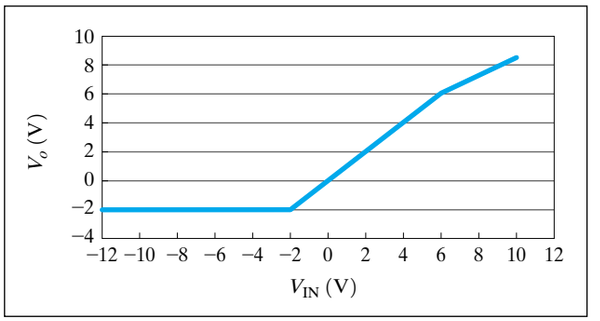


Figure B