



Answers to Selected Problems

Chapter 1

- 1.1 8.85 ms
 1.3 38 m/s
 1.5 $361.934 \mu\text{m}^2$
 1.7 0.962 aJ
 1.9 6480 J
 1.11 a) 400 W, delivering
 b) Entering
 c) Gain
 1.15 a) 3.1 mW
 b) $1.24 \mu\text{J}$
 c) $21.67 \mu\text{J}$
 1.18 a) 0.5 W
 b) 2 mJ
 1.21 a) 1.68 ms
 b) 666 mW
 c) 2.97 mJ
 1.26 1740 W

Chapter 2

- 2.3 yes; 720 W
 2.8 2240 W
 2.11 a) 4 A
 b) 144 V
 c) 768 W

- 2.16 a) 2 A
 b) $p_{5\Omega} = 320 \text{ W}$; $p_{25\Omega} = 400 \text{ W}$; $p_{70\Omega} = 280 \text{ W}$;
 $p_{10\Omega} = 360 \text{ W}$; $p_{8\Omega} = 800 \text{ W}$
 c) 2160 W
 2.21 a) 60Ω
 b) 2000 W
 2.26 a) 0 A
 b) -60 mA
 c) -240 mA
 2.29 $v_1 = -50 \text{ mV}$; $v_g = 6.25 \text{ mV}$

Chapter 3

- 3.3 80 W
 3.6 a) 16Ω
 b) 6Ω
 3.10 33.75 kV
 3.13 $i_g = 12.5 \text{ A}$; $i_o = 2 \text{ A}$
 3.16 26.67Ω
 3.20 a) 66 V
 b) $P_{R_1} = 1.88 \text{ W}$; $P_{R_2} = 1.32 \text{ W}$
 c) $R_1 = 17,672 \Omega$; $R_2 = 12,408 \Omega$
 3.26 $v_x = 16 \text{ V}$; $P = 75.2 \text{ W}$
 3.32 -0.1664%
 3.36 -27.03%
 3.46 300 mW

1012 ■ ANSWERS TO SELECTED PROBLEMS

- 3.51 $2 \text{ k}\Omega$
 3.54 a) 120Ω
 b) 60 W
 3.56 a) 4 A
 b) 1.1 A
 c) 6 V
 d) 2500 W

Chapter 4

- 4.2 40 W (absorbing)
 4.5 10 V
 4.9 $v_1 = 100 \text{ V}; v_2 = 20 \text{ V}$
 4.13 1 A
 4.17 a) 2000 W
 b) $35,000 \text{ W}$
 4.20 26 V
 4.26 602.5 W
 4.30 a) $i_a = 9.8 \text{ A}; i_b = -0.2 \text{ A}; i_c = -10 \text{ A}$
 b) $i_a = -1.72 \text{ A}; i_b = 1.08 \text{ A}; i_c = 2.8 \text{ A}$
 4.33 a) -1.0 mA
 b) 8.5 mW
 c) 0.225 mW
 4.35 98 W
 4.38 600 W
 4.44 2 A
 4.51 a) 3 mA
 b) 345 mW
 4.54 a) 1 A
 b) 1 A
 4.56 $v_{\text{Th}} = 48 \text{ V}; R_{\text{Th}} = 16 \Omega$
 4.59 $v_{\text{Th}} = 52 \text{ V}; R_{\text{Th}} = 6 \Omega$
 4.62 $i_{\text{N}} = 8 \text{ mA}; R_{\text{N}} = 10 \text{ k}\Omega$
 4.65 a) $150 \text{ k}\Omega$
 b) -1.56%
 4.69 $v_{\text{Th}} = 0 \text{ V}; R_{\text{Th}} = 18.75 \Omega$
 4.74 $R_o = 2.5 \Omega, 22.5 \Omega$
 4.77 a) 2.5Ω
 b) 2250 W
 4.80 3.77%
 4.82 a) 35Ω
 b) 505.4 W
 c) $21,364 \text{ W}$
 4.84 25 V
 4.87 $i_o = 2 \text{ A}; v_o = -136 \text{ V}$
 4.90 a) 4 A
 b) 160 W
 4.96 40 W
 4.98 0 A
 4.101 $v_1 = 37.5 \text{ V}; v_2 = 105 \text{ V}$

Chapter 5

- 5.2 $-200 \mu\text{A}$
 5.4 a) -400 mV
 b) -6.8 V
 c) $20 \mu\text{A}$
 d) $111.67 \mu\text{A}$
 5.6 -3.1 mA
 5.8 a) $0 \leq \sigma < 0.2$
 b) $200 \mu\text{A}$
 5.11 a) $415.38 \text{ k}\Omega$
 b) $650.37 \mu\text{A}$
 5.13 $0 \leq R_f \leq 75 \text{ k}\Omega$
 5.17 a) $108 \text{ k}\Omega$
 b) $270 \mu\text{W}$
 5.22 a) 7.56 V
 b) $-3.97 \leq v_g \leq 3.97 \text{ V}$
 c) $35 \text{ k}\Omega$
 5.26 a) 56.3 mV
 b) $114.3 \text{ k}\Omega$
 c) $80 \text{ k}\Omega$
 5.29 $R_b = 1200 \Omega; R_f = 2000 \Omega$
 5.33 $v_{o1} = 15.85 \text{ V}; v_{o2} = 13.6 \text{ V}$

- 5.40 a) -39.997
 b) $4.02 \mu\text{V}$
 c) 8000.644Ω
 d) $v_o/v_g = -40$; $v_n = 0 \text{ V}$; $R_g = 8000 \Omega$
- 5.42 $23.89 \text{ k}\Omega$

Chapter 6

- 6.3 a) $100e^{-10t}(1 - 10t) \text{ mV}$
 b) -18.32 mW
 c) delivering
 d) 1.83 mJ
 e) 3.38 mJ
- 6.5 a) $i = 0$, $t < 0$
 $i = 16t$, $0 \leq t \leq 25 \text{ ms}$
 $i = 0.8 - 16t$, $25 \leq t \leq 50 \text{ ms}$
 $i = 0t$, $50 \text{ ms} < t$
- b) $v = 0$, $t < 0$
 $v = 6 \text{ V}$, $0 \leq t \leq 25 \text{ ms}$
 $v = -6 \text{ V}$, $25 \leq t \leq 50 \text{ ms}$
 $v = 0$, $50 \text{ ms} < t$
 $p = 0$, $t < 0$
 $p = 96t \text{ W}$, $0 \leq t \leq 25 \text{ ms}$
 $p = 96t - 4.8 \text{ W}$, $25 \leq t \leq 50 \text{ ms}$
 $p = 0$, $50 \text{ ms} < t$
 $w = 0$, $t < 0$
 $w = 48t^2 \text{ J}$, $0 \leq t \leq 25 \text{ ms}$
 $w = 48t^2 - 4.8t + 0.12 \text{ J}$, $25 \leq t \leq 50 \text{ ms}$
 $w = 0$, $50 \text{ ms} < t$
- 6.7 a) $-8.75e^{-2500t} + 18.75e^{-7500t} \text{ V}$
 b) $152.44 \mu\text{s}$
- 6.9 a) 2.77 ms
 b) 64.27 V
- 6.12 1007 W , absorbing
- 6.16 a) $250 \mu\text{J}$
 b) 19.31 mJ
- 6.18 a) $1.25 \mu\text{C}$
 b) 5 V
 c) $2 \mu\text{J}$
- 6.21 20 H
- 6.25 5 nF , with initial voltage of 10 V , positive at the bottom
- 6.27 32.19 ms
- 6.31 a) $54,031.25 \text{ nJ}$
 b) $44,031.25 \text{ nJ}$
 c) $10,000 \text{ nJ}$
 d) 18.51%
 e) 1.39 ms
- 6.35 a) $60 + 5780e^{-4t} - 5840e^{-5t} \text{ V}$
 b) 0 V
 c) $960 + 92,480e^{-4t} - 94,400e^{-5t} - 92,480e^{-9t} + 93,440e^{-10t} \text{ W}$
 d) 960 W
 e) $p_{5\Omega} = 720 \text{ W}$; $p_{20\Omega} = 180 \text{ W}$; $p_{60\Omega} = 60 \text{ W}$
- 6.39 a) 0.85
 b) 28 mH
 c) 7
- 6.44 $v(t) = \frac{1}{3}v_s(t) + v(0)$, so moving the button has no effect on the change in $v(t)$

Chapter 7

- 7.1 a) 25Ω
 b) 12.5 ms
 c) 312.5 mH
 d) 2.5 J
 e) 10.06 ms
- 7.3 33.33%
- 7.5 a) $i_1(0^-) = i_2(0^-) = 0.2 \text{ mA}$
 b) $i_1(0^+) = 0.2 \text{ mA}$; $i_2(0^+) = -0.2 \text{ mA}$
 c) $0.2e^{-10^6t} \text{ mA}$, $t \geq 0$
 d) $-0.2e^{-10^6t} \text{ mA}$, $t \geq 0^+$
 e) The current in the resistor can change instantaneously.
- 7.7 48.64%
- 7.9 a) 200 A
 b) 220 A
 c) $307.6 \mu\text{s}$ (6 mH , not 2 mH)

- c) 7812.5Ω
 d) $(-8000 + j6000) \text{ rad/s}$; $(-8000 - j6000) \text{ rad/s}$
 e) 6250Ω
- 8.15 $45e^{-8000t} \cos 6000t - 60e^{-8000t} \sin 6000t \text{ V}$
 8.20 $-140e^{-2000t} + 200e^{-8000t} \text{ V}$
 8.24 $v_o = 0$ for $t \geq 0$, so the circuit goes directly into steady-state when the switch is closed
 8.27 $12e^{-800t} \cos 600t + 16e^{-800t} \sin 600t \text{ V}$
 8.29 $40 - 40e^{-5000t} \cos 5000t - 40e^{-5000t} \sin 5000t \text{ V}$
 8.32 $50e^{-40t} - 50e^{-160t} \text{ V}$
 8.35 $60e^{-10t} \sin 70t \text{ mA}$
 8.37 a) $20e^{-1000t} - 5e^{-4000t} \text{ mA}$
 b) $80e^{-1000t} - 5e^{-4000t} \text{ V}$
 8.44 a) $5000t e^{-250t} + 20e^{-250t} \text{ V}$
 b) $100 - 12,500te^{-250t} - 100e^{-250t} \text{ mA}$
 8.48 a) 300 V
 b) $-12,000 \text{ V/s}$
 c) $300e^{-80t} \cos 60t - 200e^{-80t} \sin 60t \text{ V}$

Chapter 9

- 9.1 a) $2000\pi \text{ rad/s}$
 b) $10 \cos(2000\pi t + 54^\circ) \text{ A}$
- 9.4 a) 2000 Hz
 b) $150 \cos(4000\pi t - \frac{\pi}{3}) \text{ V}$
- 9.8 169.71 V
- 9.11 a) 50 Hz
 b) 0°
 c) -90°
 d) 40Ω
 e) 127.32 mH
 f) $j40 \Omega$
- 9.14 $1.5 \cos(5000t + 36.87^\circ) \text{ mA}$
- 9.17 5000 rad/s
- 9.21 a) $L = 0.2 \text{ H}, 0.8 \text{ H}$
 b) for $L = 0.2 \text{ H}$, $i_g = 40 \cos 10,000t \text{ mA}$ for $L = 0.8 \text{ H}$, $i_g = 20 \cos 10,000t \text{ mA}$
- 9.24 a) 8000 rad/s

- b) $5 \cos 8000t \text{ V}$
- 9.29 a) $5/\underline{72^\circ} \Omega$
 b) i_g lags v_g by $50 \mu\text{s}$
- 9.31 $50 \cos(5000t - 106.26^\circ) \text{ V}$
- 9.34 $31.62 \cos(8000t - 71.57^\circ) \text{ V}$
- 9.39 $\mathbf{I}_N = 6.4 - j4.8 \text{ A}$; $Z_N = 50 - j25 \Omega$
- 9.41 $\mathbf{V}_{Th} = 60/\underline{-36.87^\circ} \text{ V}$; $Z_{Th} = 8.64 + j11.52 \Omega$
- 9.43 $\mathbf{V}_{Th} = 15/\underline{36.87^\circ} \text{ V}$; $Z_{Th} = 96 + j72 \Omega$
- 9.47 $15 + j5 \text{ V}$
- 9.54 $9.49 \cos(40,000t - 18.43^\circ) \text{ A}$
- 9.58 $i_a = 22.02 \cos(10,000t - 50.53^\circ) \text{ A}$
 $i_b = 24.02 \cos(10,000t + 50.74^\circ) \text{ A}$
- 9.63 30Ω
- 9.68 $800 + j600 \Omega$
- 9.72 a) $2.15 \cos(10^5 t - 21.80^\circ) \text{ V}$
 b) 4.64 V

Chapter 10

- 10.1 a) $P = 2404.16 \text{ W (abs)}$; $Q = 2404.16 \text{ VAR (abs)}$
 b) $P = 155.29 \text{ W (abs)}$; $Q = -579.56 \text{ VAR (del)}$
 c) $P = -427.53 \text{ W (del)}$; $Q = -1174.62 \text{ VAR (del)}$
 d) $P = -307.82 \text{ W (del)}$; $Q = 845.72 \text{ VAR (del)}$
- 10.4 a) 60 V (rms)
 b) 300 W
- 10.6 80Ω
- 10.8 $P = 56.25 \text{ mW}$; $Q = -70.3125 \text{ mVAR}$; $|S| = 90.044 \text{ mVA}$
- 10.10 a) $\text{pf}_1 = 0.96$ lagging; $\text{rf}_1 = 0.28$; $\text{pf}_2 = 0.80$ leading; $\text{rf}_2 = -0.60$; $\text{pf}_3 = 0.6$ leading; $\text{rf}_3 = -0.8$
 b) $\text{pf} = 0.74$ leading; $\text{rf} = -0.67$
- 10.13 a) 160 W
 b) -40 W
 c) 60 W
 d) -80 VAR
 e) generate

1016 ■ ANSWERS TO SELECTED PROBLEMS

- f) 0.6 leading
g) -0.8
- 10.16 a) 492.37 V(rms)
b) 102.31 μs
c) lags by 2.21° or 102.31 μs
- 10.19 a) $72 - j24 \Omega$
b) 0.9487 leading
- 10.22 0.2727 leading
- 10.24 a) 414.72 W
b) 501.4 Ω
c) 1671.33 Ω
d) 37.02 W
e) 8.93 %
- 10.28 a) 129.15 V(rms)
b) 240 W
c) 1188.36 μF
d) 126.49 V(rms)
e) 221.184 W
- 10.31 a) 9 W
b) 20 Ω
c) 17.31 W; yes
d) 18.75 W
e) $R_o = 30 \Omega$; $L_o = 9 \text{ mH}$
f) yes
- 10.34 a) $30 + j10 \text{ k}\Omega$
b) 16.875 mW
- 10.37 a) 312.5 W
b) 10 %
- 10.39 a) -1700 kVAR
b) deliver
c) 0.3328 leading
d) 625 A(rms)
e) 520.83 A(rms)
- 10.43 612.5 W
- 10.46 a) $140 \angle 0^\circ \text{ V(rms)}$
b) 280 W
- c) 9.72 %
- 10.54 $20 + j0 \Omega$
- 10.57 a) 100 W
b) 44.44 %
c) 225 W
- 10.60 a) $a_1 = 5$; $a_2 = 40$
b) 800 mW
c) 4 V(rms)
- 10.65 $R_1 = R_2 = R_3 = 8 \Omega$
- Chapter 11**
- 11.3 a) 0 A
b) $226.99 \angle 116.48^\circ \text{ V}$
c) $387.79 \angle 86.48^\circ \text{ V}$
d) unbalanced
- 11.6 a) 32.84 A(rms)
b) 12,845.94 V(rms)
- 11.10 $3.93 \angle -122.69^\circ \text{ A}$
- 11.14 a) $\mathbf{I}_{AB} = 92 \angle -36.87^\circ \text{ A}$; $\mathbf{I}_{BC} = 92 \angle -156.87^\circ \text{ A}$;
 $\mathbf{I}_{CB} = 92 \angle 83.13^\circ \text{ A}$
b) $\mathbf{I}_{aA} = 159.35 \angle -66.87^\circ \text{ A}$;
 $\mathbf{I}_{bB} = 159.35 \angle -186.87^\circ \text{ A}$;
 $\mathbf{I}_{cC} = 159.35 \angle 53.13^\circ \text{ A}$;
c) $\mathbf{I}_{ba} = 92 \angle -36.87^\circ \text{ A}$; $\mathbf{I}_{cb} = 92 \angle -156.87^\circ \text{ A}$;
 $\mathbf{I}_{ac} = 92 \angle 83.13^\circ \text{ A}$
- 11.18 a) $651 + j246 \text{ kVA}$
b) 99.54 %
- 11.20 a) 138.46 A(rms)
b) 0.892 lagging
- 11.22 6990.62 V
- 11.24 a) 468.91 A
b) 66.2 kVAR
- 11.27 a) 4551.4 V
b) 97.96 %
- 11.32 a) 7776 VAR
b) 7776 VAR
- 11.37 a) $W_{m1} = 14,296.61 \text{ W}$; $W_{m2} = 29,261.53 \text{ W}$

- b) $P_A = 9976.61 \text{ W}$; $P_B = 24,941.53 \text{ W}$; $P_C = 8640 \text{ W}$
- 11.40 a) $84.83 \mu\text{F}$
 b) $254.5 \mu\text{F}$
 c) 101.8 A
- 11.42 a) $16.71 \mu\text{F}$
 b) $50.14 \mu\text{F}$

Chapter 12

- 12.4 As $\epsilon \rightarrow 0$, the amplitude goes to ∞ , the duration goes to 0, and the area is independent of ϵ
- 12.8 a) $\frac{1}{(s+a)^2}$
 b) $\frac{\omega}{(s^2 + \omega^2)}$
 c) $\frac{\omega \cos \theta + s \sin \theta}{(s^2 + \omega^2)}$
 d) $\frac{s}{s^2 - 1}$
 e) $\frac{\sinh \theta + s \cosh \theta}{(s^2 - 1)}$
- 12.11 a) $\frac{1}{(s+a)^2}$
 b) $\frac{s}{(s+a)^2}$
 c) $\mathcal{L}\{-ate^{-at}\} = \frac{s}{(s+a)^2}$
- 12.16 a) $\frac{-20e^{-2s}}{s+5}$
 b) $\frac{8(e^{-s} - 2e^{-2s} + 2e^{-4s} - e^{-5s})}{s^2}$
- 12.26 a) $(3e^{-t} + 6e^{-2t} + 9e^{-3t})u(t)$
 b) $(5 + 8e^{-2t} + 12e^{-4t})u(t)$
 c) $[5e^{-2t} + 10e^{-6t} \cos(8t - 53.13^\circ)]u(t)$
 d) $[8 + 50e^{-7t} \cos(24t + 16.26^\circ)]u(t)$
- 12.28 a) $10\delta(t) + [-5e^{-2t} + 30e^{-3t}]u(t)$
 b) $5\delta(t) + 4.46e^{-2t} \cos(t + 116.57^\circ)u(t)$
 c) $\delta'(t) + 5\delta(t) + [10e^{-10t} - 10e^{-15t}]u(t)$
- 12.33 $[10e^{-4000t} \sin 3000t]u(t) \text{ V}$
- 12.37 a) $f(\infty) = \infty$; $f(0^+) = 8$
 b) $f(\infty) = 10$; $f(0^+) = 30$
 c) $f(\infty) = \infty$; $f(0^+) = 1$
 d) $f(\infty) = 0$; $f(0^+) = 1$
 e) $f(\infty) = 0$; $f(0^+) = 16$
- 12.41 $v_o(\infty) = V_{dc}$; $v_o(0^+) = 0$ $i_o(\infty) = \frac{V_{dc}}{R}$; $i_o(0^+) = 0$

Chapter 13

- 13.4 a) $\frac{2.5 \times 10^6(s + 2000)}{(s^2 + 2000s + 5 \times 10^6)}$
 b) zero at -2000 rad/s poles at $-1000 \pm j2000 \text{ rad/s}$
- 13.7 no zeros; one pole at -1 rad/s
- 13.11 $[-45te^{-5t} + 24e^{-5t}]u(t) \text{ V}$
- 13.14 $158.11e^{-4000t} \cos(3000t - 124.7^\circ)u(t) \text{ V}$
- 13.16 $[-50 + 50e^{-1000t}]u(t) \text{ V}$
- 13.20 a) $I_o = \frac{10,000}{(s+30)^2(s+80)}$
 $V_o = \frac{50,000s}{(s+30)^2(s+80)}$
 b) $i_o = [200te^{-30t} - 4e^{-30t} + 4e^{-80t}]u(t) \text{ A}$
 $v_o = [-30,000te^{-30t} + 1600e^{-30t} - 1600e^{-80t}]u(t) \text{ V}$
- 13.23 a) $\frac{-6 \times 10^5}{(s^2 + 10,000s + 16 \times 10^6)}$
 b) $[100e^{-8000t} - 100e^{-2000t}]u(t) \text{ V}$
- 13.25 $V_o = \frac{30}{s} - \frac{100}{s+5000} + \frac{50}{s+10,000}$
 $v_o(t) = [30 - 100e^{-5000t} + 50e^{-10,000t}]u(t) \text{ V}$
- 13.29 a) $I_a = \frac{8/3}{s} - \frac{8/3}{s+6}$; $I_b = \frac{4/3}{s} + \frac{8/3}{s+6}$
 b) $i_a = [(8/3) - (8/3)e^{-6t}]u(t) \text{ A}$; $i_b = [(4/3) + (8/3)e^{-6t}]u(t) \text{ A}$
 c) $V_a = \frac{400/3}{s^2} + \frac{400/9}{s} - \frac{400/9}{s+6}$
 $V_b = \frac{400/3}{s^2} - \frac{800/9}{s} + \frac{800/9}{s+6}$
 $V_c = \frac{400/3}{s^2} + \frac{400/9}{s} - \frac{400/9}{s+6}$
 d) $v_a = [(400/3)t + (400/9) - (400/9)e^{-6t}]u(t) \text{ V}$
 $v_b = [(400/3)t - (800/9) + (800/9)e^{-6t}]u(t) \text{ V}$
 $v_c = [(400/3)t + (400/9) - (400/9)e^{-6t}]u(t) \text{ V}$
- 13.32 a) $[256e^{-40,000t} - 4e^{-10,000t}]u(t) \text{ V}$

1018 ■ ANSWERS TO SELECTED PROBLEMS

- b) $[75 + 5e^{-10,000t} - 80e^{-40,000t}]u(t)$ mA
 c) From the circuit, $v_o(\infty) = 0$ V and $i_o(\infty) = 75$ mA, which agrees with answers in (a) and (b)

13.37 $[-300e^{-25t} + 300\sqrt{5}e^{-5t} \cos(10t + 63.43^\circ)]u(t)$ mA

13.38 a) 540 mJ

b) $I_1 = \frac{3}{s + 10,000}$; $I_2 = \frac{-2}{s + 10,000}$

c) $i_1 = 3e^{-10,000t}u(t)$ A; $i_2 = -2e^{-10,000t}u(t)$ A

d) $w_{600\Omega} = 270$ mJ;
 $w_{1350\Omega} = 270$ mJ

e) $w = 180$ mJ; $I_1 = \frac{3}{s + 30,000}$;
 $I_2 = \frac{-2}{s + 30,000}$; $i_1 = 3e^{-30,000t}u(t)$ A;
 $i_2 = -2e^{-30,000t}u(t)$ A;
 $w_{600\Omega} = 90$ mJ;
 $w_{1350\Omega} = 90$ mJ

13.43 a) $\frac{-250 \times 10^6}{s(s + 2500)(s + 5000)}$
 b) $[-20 + 40e^{-2500t} - 20e^{-5000t}]u(t)$ V
 c) 277.26 μ s
 d) 5000 V/s

13.45 246.28 ms

13.48 a) $\frac{6 \times 10^4(s + 4000) + 96 \times 10^6}{s(s + 2000)(s + 3000)}$
 b) $[56 - 108e^{-2000t} + 52e^{-3000t}]u(t)$ V

13.50 a) $\frac{-10^4(s + 5000)}{s(s + 25,000)}$
 b) zero at -5000 rad/s; poles at 0 and $-25,000$ rad/s

13.53 a) $\frac{-0.5(s - 20)}{(s + 20)}$
 b) zero at 20 rad/s; pole at -20 rad/s

13.57 a) $y(t) = 0, \quad t < 0$
 $y(t) = 400t, \quad 0 \leq t \leq 8$
 $y(t) = 400(16 - t), \quad 8 \leq t \leq 16$
 $y(t) = 0, \quad 16 \leq t \leq \infty$
 b) $y(t) = 0, \quad t < 0$
 $y(t) = 200t, \quad 0 \leq t \leq 8$

$y(t) = 1600, \quad 8 \leq t \leq 16$
 $y(t) = 200(24 - t), \quad 16 \leq t \leq 24$
 $y(t) = 0, \quad 24 \leq t \leq \infty$

c) $y(t) = 0, \quad t < 0$
 $y(t) = 400t, \quad 0 \leq t \leq 0.5$
 $y(t) = 200, \quad 0.5 \leq t \leq 8$
 $y(t) = 400(8.5 - t), \quad 8 \leq t \leq 8.5$
 $y(t) = 0, \quad 8.5 \leq t \leq \infty$

13.63 a) $20(1 - e^{-80,000t})$ V, $0 \leq t \leq 50 \mu$ s
 $20(e^4 - 1)e^{-80,000t}$ V, 50μ s $\leq t \leq \infty$

b) decrease

c) The circuit with $R = 400 \Omega$

13.65 7.539 V

13.68 -27.43 V

13.72 $50 \cos(8000t + 36.87^\circ)$ V

13.75 a) $\frac{s(s + 9000)}{(s + 2000)(s + 4000)}$
 b) $[35e^{-2000t} - 25e^{-4000t}]u(t)$ V
 c) $11.68 \cos(2000t + 30.98^\circ)$ V

13.82 a) $0.6\delta(t) - 2400e^{-4000t}u(t)$ V
 b) $i_L(0) = 30$ A; $v_o(0) = 0.6\delta(t)$ V;
 $i_L(t) = 30e^{-4000t}$ A

13.84 a) $[20 + (20/3) \cos 2t]u(t)$ A
 b) $(40/3) \cos 2tu(t)$ A
 c) $20 \sin 2tu(t)$ V
 d) yes

Chapter 14

14.1 a) 1989.44 Hz
 b) $H(j\omega_c) = 0.7071 \angle -45^\circ$
 $H(j0.2\omega_c) = 0.9806 \angle -11.31^\circ$
 $H(j8\omega_c) = 0.1240 \angle -82.87^\circ$
 c) $v_o(\omega_c) = 339.41 \cos(12,500t - 45^\circ)$ mV;
 $v_o(0.2\omega_c) = 470.68 \cos(2500t - 11.31^\circ)$ mV;
 $v_o(8\omega_c) = 59.54 \cos(100,000t - 82.87^\circ)$ mV

14.3 a) $\frac{(1/RC)}{s + \left(\frac{R + R_L}{RR_L C}\right)}$
 b) 0 rad/s

- c) $\frac{R_L}{R + R_L}$
d) $\frac{1}{RC}[1 + (R/R_L)]$
e) $\omega_c = 13,333.33 \text{ rad/s}$; $H(j\omega_c) = 0.9375$;
 $H(j\omega_c) = 0.6629 \angle -45^\circ$;
 $H(j0.2\omega_c) = 0.9193 \angle -11.31^\circ$;
 $H(j8\omega_c) = 0.1163 \angle -82.87^\circ$
- 14.7 a) 1591.55 Hz
b) $H(j\omega_c) = 0.7071 \angle 45^\circ$
 $H(j0.1\omega_c) = 0.0995 \angle 84.29^\circ$
 $H(j10\omega_c) = 0.995 \angle 5.71^\circ$
c) $v_o(\omega_c) = 565.69 \cos(10,000t + 45^\circ) \text{ mV}$
 $v_o(0.1\omega_c) = 79.6 \cos(1000t + 84.29^\circ) \text{ mV}$
 $v_o(10\omega_c) = 796.03 \cos(100,000t + 5.71^\circ) \text{ mV}$
- 14.12 a) 1 Mrad/s
b) 159.15 kHz
c) 7.5
d) 935.55 krad/s
e) 148.9 kHz
f) 1068.89 krad/s
g) 170.12 kHz
h) 133.33 krad/s or 21.22 kHz
- 14.15 $\beta = 10 \text{ krad/s} = 1.59 \text{ kHz}$; $\omega_{c1} = 75.16 \text{ krad/s}$;
 $f_{c1} = 11.96 \text{ kHz}$; $\omega_{c2} = 85.16 \text{ krad/s}$; $f_{c2} = 13.55 \text{ kHz}$;
- 14.23 a) $\frac{K(s^2 + \omega_o^2)}{(s^2 + \beta s + \omega_o^2)}$; $K = \frac{R_L}{R + R_L}$; $\omega_o^2 = \frac{1}{LC}$;
 $\beta = \left(\frac{RR_L}{R + R_L}\right) \frac{1}{L}$
b) $1/\sqrt{LC}$
c) $\left(\frac{RR_L}{R + R_L}\right) \frac{1}{L}$
d) $\frac{L/\sqrt{LC}}{[(RR_L)/(R + R_L)]}$
e) 0
f) K
g) K
- h) $\pm \frac{R_{\text{eq}}}{2L} + \sqrt{\left(\frac{R_{\text{eq}}}{2L}\right)^2 + \frac{1}{LC}}$; $R_{\text{eq}} = \frac{RR_L}{R + R_L}$
- 14.25 a) $L = 12.5 \text{ mH}$; $R = 5 \text{ k}\Omega$
b) 12.5
- 14.27 a) 8 Mrad/s
b) 1.27 MHz
c) 16
d) 7.75 Mrad/s
e) 1.25 MHz
f) 8.25 Mrad/s
g) 1.31 MHz
h) 79.58 kHz
- 14.30 a) $\omega = 0$ and $\omega = 2783.88 \text{ rad/s}$
b) 1968.5 rad/s
c) 12.11 dB
- 14.36 $[1 + 10e^{-10t} - 11e^{-100t}]u(t)$
- 14.39 63.7 times larger

Chapter 15

- 15.2 a) $-\frac{C_1(s + 1/R_1C_1)}{C_2(s + 1/R_2C_2)}$
b) $-R_2/R_1$
c) $-C_1/C_2$
d) As $\omega \rightarrow 0$, the capacitors act like open circuits; as $\omega \rightarrow \infty$, the capacitors act like short circuits.
- 15.9 a) $L = 1 \text{ H}$; $C = 1 \text{ F}$; $R = 0.04 \Omega$
b) $R' = 3.6 \text{ k}\Omega$; $L' = 0.9 \text{ H}$; $C' = 0.11 \text{ nF}$
- 15.16 a) $L_{\text{scaled}} = 40 \text{ mH}$; $R_{\text{scaled}} = 105 \text{ k}\Omega$
b) $[15 + e^{-100,000t} - 16e^{-400,000t}]u(t) \text{ mA}$
- 15.18 a) $k_m = 10$; $k_f = 2500$
b) $[-100 + 84e^{-2500t} + 36e^{-5000t}]u(t) \text{ A}$
- 15.26 a) $n = 4$
b) -48.16 dB
- 15.42 a) $(1/36) \text{ F}$
b) $R_1 = 2.25 \Omega$; $R_2 = 18 \Omega$; $R_3 = 2 \Omega$

1020 ■ ANSWERS TO SELECTED PROBLEMS

- c) $C_1 = 250 \text{ pF}$; $R_1 = 28.65 \text{ k}\Omega$; $R_2 = 229.18 \text{ k}\Omega$; $R_3 = 25.46 \text{ k}\Omega$
 d) $R_1 = R_2 = 12.73 \text{ k}\Omega$; $C = 250 \text{ pF}$
- 15.46 a) $s^6/(D_4D_5D_6)$, where $D_4 = (s^2 + 10,360\pi s + 4\pi^2 10^8)$ $D_5 = (s^2 + 20,000\pi\sqrt{2}s + 4\pi^2 10^8)$; $D_6 = (s^2 + 38,640\pi s + 4\pi^2 10^8)$
 b) -3 dB
- 15.48 a) $R_1 = R_2 = 11 \text{ k}\Omega$
 b) $C = 360 \text{ pF}$; $R_1 = R_2 = 11 \text{ k}\Omega$
 d) $\frac{s^3}{(s + 8\pi 10^4)(s^2 + 8\pi 10^4 s + 64\pi^2 10^8)}$
 e) -3.01 dB
- 15.56 a) 19.99 dB
 b) -19.99 dB
 c) yes
 d) 17.43 dB
 e) -17.43 dB
 f) It is very nearly the cutoff frequency.

Chapter 16

- 16.3 a) $\frac{4V_m}{\pi} \sum_{n=1,3,5}^{\infty} \frac{1}{n} \sin n\omega_o t \text{ V}$
 b) $\frac{2V_m}{\pi} \left[1 + 2 \sum_{n=1}^{\infty} \frac{1}{1-4n^2} \cos n\omega_o t \right] \text{ V}$
 c) $\frac{V_m}{\pi} + \frac{V_m}{2} \sin \omega_o t + \frac{2V_m}{\pi} \sum_{n=2,4,6}^{\infty} \frac{1}{1-n^2} \cos n\omega_o t \text{ V}$
- 16.8 a) $\omega_{oa} = 69,813.17 \text{ rad/s}$; $\omega_{ob} = 785,398.16 \text{ rad/s}$
 b) $f_{oa} = 11,111.11 \text{ Hz}$; $f_{ob} = 125 \text{ kHz}$
 c) $a_{va} = 0$; $a_{vb} = 18.75 \text{ V}$
 d) $a_{va} = 0$; $a_{ka} = 0$ for all k ; $b_{ka} = 0$ for k even;
 $b_{ka} = \frac{200}{\pi k} \left[2 - \cos \frac{\pi k}{3} \right]$ for all k odd;
 $a_{vb} = 18.75$; $a_{kb} = \frac{50}{k\pi} \left[\sin \frac{k\pi}{4} + \sin \frac{k\pi}{2} \right]$

- e) $v_a(t) = \frac{200}{\pi} \sum_{n=1,3,5}^{\infty} \frac{1}{n} (2 - \cos \frac{n\pi}{3}) \sin n\omega_o t$
 $v_b(t) = 18.75 + \frac{50}{\pi} \sum_{n=1}^{\infty} \frac{1}{n} (\sin \frac{n\pi}{4} + \sin \frac{n\pi}{2}) \cos n\omega_o t$
- 16.11 a) $\frac{I_m}{4} + \frac{4I_m}{\pi^2} \sum_{n=1}^{\infty} \frac{(1 - \cos \frac{n\pi}{2})}{n^2} \cos n\omega_o t$
 b) $\frac{I_m}{4} + \frac{4I_m}{\pi^2} \sum_{n=1}^{\infty} \frac{(1 - \cos \frac{n\pi}{2}) \cos n\pi}{n^2} \cos n\omega_o t$
- 16.15 a) 100 Hz
 b) no
 c) yes
 d) yes
 e) yes
 f) $a_v = 0$; $a_k = 0$ for all k ; $b_k = 0$ for all k even;
 $b_k = \frac{80}{\pi^2 k^2} \sin \frac{k\pi}{4}$ for all k odd
- 16.22 a) $\frac{V_m}{2R} + \frac{2V_m}{\pi} \sum_{n=1,3,5}^{\infty} \frac{\sin(n\omega_o t - \theta_n)}{n\sqrt{R^2 + (n\omega_o L)^2}} \text{ A}$
 b) $i = \frac{V_m}{R} - \frac{V_m}{R(1 + e^{-x})} e^{t/\tau}$ for $0 \leq t \leq \frac{T}{2}$;
 $i = \frac{V_m}{R(1 + e^{-x})} e^{-[t-(T/2)]/\tau}$ for $\frac{T}{2} \leq t \leq T$
- 16.25 a) $17.5 \cos(10,000t + 88.81^\circ) + 26.14 \cos(30,000t - 95.36^\circ) + 168 \cos(50,000t) + 17.32 \cos(70,000t + 98.3^\circ) \text{ V}$
 b) The fifth harmonic
- 16.28 $-6.4 \cos(50,000t) \text{ A}$
- 16.30 a) 117.55 V
 b) -2.04%
 c) 69.276 V ; -0.0081%
- 16.33 a) $0.755 V_m$
 b) $0.7906 V_m$
 c) -4.5%
- 16.35 a) 1055 W

- b) 167.93 V
c) 11.07 A
- 16.38 41.52 mW
- 16.41 $\frac{I_m}{\pi^2 n^2} \left[2 \cos \frac{n\pi}{2} + n\pi \frac{\sin n\pi}{2} - 2 \right]$
- 16.44 a) 130.59 V
b) 121.49 V
c) -6.97 %
- 16.47 a) $A_1 \sin \omega_o t - A_3 \sin 3\omega_o t + A_5 \sin 5\omega_o t - A_7 \sin 7\omega_o t$
b) odd
c) yes
d) yes
- 16.50 $100 + 12.81 \cos(5000t - 146.04^\circ) + 0.16 \cos(15,000 - 169.13^\circ)$ V

Chapter 17

- 17.1 a) $\frac{-j4\pi A}{\pi^2 - 4\omega^2} \sin 2\omega$
b) $\frac{4A}{\omega^2 \tau} \left[1 - \cos \frac{\omega\tau}{2} \right]$
- 17.4 a) $\frac{2(a^2 - \omega^2)}{(a^2 + \omega^2)^2}$
b) $-j48a\omega \frac{a^2 - \omega^2}{(a^2 + \omega^2)^4}$
c) $\frac{a}{a^2 + (\omega - \omega_o)^2} + \frac{a}{a^2 + (\omega + \omega_o)^2}$
d) $\frac{-ja}{a^2 + (\omega - \omega_o)^2} + \frac{ja}{a^2 + (\omega + \omega_o)^2}$
e) $e^{-j\omega t_o}$
- 17.19 a) $6e^{-50t} u(t)$ mA
b) yes
- 17.23 a) $3\text{sgn}(t) - 8e^{-10t} u(t) + 2e^{-40t} u(t)$ V
b) -3 V
c) -3 V
d) $(3 - 8e^{-10t} + 2e^{-40t})u(t)$
e) yes
- 17.26 a) 75 cos(40,000 - 143.13°) mA
b) 75 cos(40,000 - 143.13°) mA

- 17.29 a) $(-40e^{-200t} - 40e^{-800t} + 135e^{-400t})u(t) - 35e^{400t}u(-t)$ A
b) -10 A
c) -10 A
d) yes, the current in L cannot change instantaneously
- 17.31 a) 8 V
b) 8 V
- 17.34 35.88 %
- 17.36 64.69 %
- 17.38 a) 18.17 %
b) 27.23 %
c) 10.57 %

Chapter 18

- 18.2 $z_{11} = 20 \Omega; z_{12} = 18 \Omega; z_{21} = 18 \Omega; z_{22} = 22 \Omega$
- 18.5 $a_{11} = -4 \times 10^{-4}; a_{12} = -20 \Omega; a_{21} = -0.5 \mu\text{S}; a_{22} = -0.02$
- 18.8 $y_{11} = 0.05 \text{ S}; y_{12} = y_{21} = -\frac{1}{80} \text{ S}; y_{22} = \frac{1}{64} \text{ S}$
- 18.10 $h_{11} = (30 + j10) \Omega; h_{12} = 0; h_{21} = -5; h_{22} = (1 - j/3) \text{ S}$
- 18.15 $h_{11} = 200 \Omega; h_{12} = 0.2; h_{21} = 16; h_{22} = 27.5 \text{ mS}$
- 18.20 $y_{11} = \frac{s+1}{s^2+s+1}; y_{12} = y_{21} = \frac{-s}{s^2+s+1}$
 $y_{22} = \frac{s(s+1)}{s^2+s+1}$
- 18.23 a) $h_{11} = R + sL - \frac{(sM)^2}{R + sL}; h_{12} = \frac{-sM}{R + sL};$
 $h_{21} = \frac{sM}{R + sL}; h_{22} = \frac{1}{R + sL}$
b) $h_{12} = -h_{21}; \Delta h = \frac{(R + sL)^2 - (sM)^2}{(R + sL)^2} + \frac{(sM)^2}{(R + sL)^2} = 1$
- 18.30 15.625
- 18.32 a) -28 V(rms)
b) 11.2 mW
c) 2.88 μW

1022 ■ ANSWERS TO SELECTED PROBLEMS

18.35 a) $z_{11} = z_{22} = s^2 + 1/s$; $z_{12} = z_{21} = 1/s$

b) $v_2 = [25 - 25e^{-t} + 18.9e^{-t/2} \cos(t\sqrt{7}/2 + 90^\circ)]u(t)$ V

18.38 3.9 V dc