Appendix H

ANSWERS TO SELECTED ODD-NUMBERED PROBLEMS

Chapter 1

5. 3 h
7. CGS
9. MKS = CGS = 20°C
K = SI = 293.15
11. 45.72 cm
13. **(a)** 15×10^{3} **(b)** 30×10^{-3}
(c) 7.4×10^{6} **(d)** 6.8×10^{-6}
(e) 402×10^{-6} **(f)** 200×10^{-12}
15. **(a)** 10^{4} **(b)** 10
(c) 10^{9} **(d)** 10^{-2}
(e) 10 **(f)** 10^{31}
17. **(a)** 10^{-1} **(b)** 10^{-4}
(c) 10^{9} **(d)** 10^{-9}
(e) 10^{42} **(f)** 10^{3}
19. **(a)** 10^{6} **(b)** 10^{-2}
(c) 10^{32} **(d)** 10^{-63}
21. **(a)** 10^{-6} **(b)** 10^{-3}
(c) 10^{-8} **(d)** 10^{9}
(e) 10^{-16} **(f)** 10^{-1}
23. **(a)** 0.006 **(b)** 400
(c) 5000, 5, 0.005
(d) 0.0003, 0.3, 300
25. **(a)** 90 s **(b)** 144 s
(c) 50×10^{3} μs
(d) 160 mm **(e)** 120 ns
(f) 41.898 days **(g)** 1.02 m
27. **(a)** 2.54 m **(b)** 1.219 m
(c) 26.7 N **(d)** 0.1348 lb
(e) 4921.26 ft
(f) 3.2187 m **(g)** 8530.17 yd
29. 670.62×10^{6} mph
31. 2.045 s
33. 67.06 days
35. $900
37. 345.6 m
39. 47.29 min/mile
41. **(a)** 4.74×10^{-3} Btu
(b) 7.098×10^{-4} m^3
(c) 1.2096×10^{5} s
(d) 2113.38 pints
43. 5.000
45. 2.949

Chapter 2

3. **(a)** 18 mN **(b)** 2 mN
(c) 180 μN
7. **(a)** 72 mN
(b) $Q_1 = 20\ \mu$C, $Q_2 = 40\ \mu$C
9. 3.1 A
11. 90 C
13. 0.5 A
15. 1.194 A > 1 A (yes)
17. **(a)** 1.248 million
(b) 0.936 million, sol. = (a)
19. 252 J
21. 4 C
23. 3.533 V
25. 5 A
27. 25 h
29. 0.773 h
31. 60 Ah:40 Ah = 1.5:1, 50% more with 60 Ah
33. 545.45 mA, 129.6 kJ
43. 600 C

Chapter 3

1. **(a)** 500 mils **(b)** 10 mils
(c) 4 mils **(d)** 1000 mils
(e) 240 mils **(f)** 3.937 mils
3. **(a)** 0.04 in. **(b)** 0.03 in.
(c) 0.2 in. **(d)** 0.025 in.
(e) 0.00278 in. **(f)** 0.009 in.
5. 73.33 Ω
7. 3.581 ft
9. **(a)** $R_{silver} > R_{copper} > R_{aluminum}$
(b) silver 9.9 Ω,
copper 1.037 Ω,
aluminum 0.34 Ω
11. **(a)** 21.71 $\mu\Omega$ **(b)** 35.59 $\mu\Omega$
(c) increases **(d)** decreases
13. 942.28 mΩ
15. **(a)** #8: 1.1308 Ω. #18: 11.493 Ω
(b) #18: #8 = 10.1641:1 ≅ 10:1.
#18: #8 = 1:10.164 ≅ 1:10
17. **(a)** 1.087 mA/CM
(b) 1.384 kA/in.^{2}
(c) 3.6127 in.^{2}
19. **(a)** 21.71 $\mu\Omega$ **(b)** 35.59 $\mu\Omega$
21. 0.15 in.
23. 2.409 Ω
25. 3.67 Ω
27. 0.046 Ω
29. **(a)** 40.29°C **(b)** −195.61°C
31. **(a)** $\alpha_{20} \cong 0.00393$
(b) 83.61°C
33. 1.751 Ω
35. 142.86
41. −30°C: 10.2 kΩ.
100°C: 10.15 kΩ
43. 6.5 kΩ
47. **(a)** Red Red Brown Silver
(b) Yellow Violet Red Silver
(c) Blue Gray Orange Silver
(d) White Brown Green Silver
49. yes
51. **(a)** 0.1566 S **(b)** 0.0955 S
(c) 0.0219 S
57. **(a)** 10 fc: 3 kΩ. 100 fc: 0.4 kΩ
(b) neg. (c) no—log scales
(d) −321.43 Ω/fc

Chapter 4

1. 15 V
3. 4 kΩ
5. 72 mV
7. 54.55 Ω
9. 28.571 Ω
11. 1.2 kΩ
13. **(a)** 12.632 Ω **(b)** 4.1 MJ
17. 800 V
19. 1 W
21. **(a)** 57,600 J
(b) 16×10^{-3} kWh
23. 2 s
25. 196 μW
27. 4 A
29. 9.61 V
31. 0.833 A, 144.06 Ω
33. **(a)** 0.133 mA **(b)** 66.5 mAh
35. **(c)** ≅ 70.7 mA
37. **(a)** 12 kW
(b) 10,130 W < 12,000 W (yes)
39. 16.34 A
41. **(a)** 238 W **(b)** 17.36%
43. **(a)** 1657.78 W
(b) 15.07 A
(c) 19.38 A
45. 65.25%
47. 80%
49. **(a)** 17.9%
(b) 76.73%, 328.66% increase
51. **(a)** 1350 J
(b) W doubles, P the same
53. 6.67 h
55. **(a)** 50 kW **(b)** 240.38 A
(c) 90 kWh
57. $2.19

Chapter 5

1. **(a)** 20 Ω, 3 A
(b) 1.63 MΩ , 6.135 μA
(c) 110 Ω, 318.2 mA
(d) 10 kΩ, 12 mA

3. **(a)** 16 V **(b)** 4.2 V
5. **(a)** 0.388 A (CW)
(b) 2.087 A (CCW)
7. **(a)** 5 V **(b)** 70 V
9. 3.28 mA, 7.22 V
11. **(a)** 70.6 Ω, 85 mA (CCW),
$V_1 = 2.8045$ V,
$V_2 = 0.4760$ V,
$V_3 = 0.850$ V,
$V_4 = 1.870$ V
(b)–(c) $P_1 = 0.2384$ W,
$P_2 = 0.0405$ W,
$P_3 = 0.0723$ W,
$P_4 = 0.1590$ W
(d) all $\frac{1}{2}$ W
13. **(a)** 225 Ω, 0.533 A
(b) 8 W
(c) 15 V
15. All V_{ab} (+ −)
(a) 66.67 V **(b)** −8 V
(c) 20 V **(d)** 0.18 V
17. **(a)** 12 V **(b)** 24 V
(c) 60 Ω **(d)** 0.4 A
(e) 60 Ω
19. **(a)** $R_s = 80\ \Omega$
(b) 0.2 W $< \frac{1}{4}$ W
21. $R_1 = 3$ kΩ, $R_2 = 15$ kΩ
23. **(a)** $R_1 = 0.4$ kΩ, $R_2 = 1.2$ kΩ,
$R_3 = 4.8$ kΩ
(b) $R_1 = 0.4$ MΩ,
$R_2 = 1.2$ MΩ,
$R_3 = 4.8$ MΩ
25. **(a)** I (CW) = 6.667 A,
$V = 20$ V
(b) I (CW) = 1 A,
$V = 10$ V
27. **(a)** 20 V, 26 V, 35 V,
−12 V, 0 V
(b) −6 V, −47 V, 9 V
(c) −15 V, −38 V
29. $V_0 = 0$ V, $V_4 = 10$ V,
$V_7 = 4$ V, $V_{10} = 20$ V,
$V_{23} = 6$ V, $V_{30} = -8$ V,
$V_{67} = 0$ V, $V_{56} = -6$ V,
I(up) = 1.5 A
31. 2 Ω
33. 100 Ω
35. 1.52%

Chapter 6

1. **(a)** 2, 3, 4 **(b)** 2, 3 **(c)** 1, 4
3. **(a)** 6 Ω, 0.1667 S
(b) 1 kΩ, 1 mS
(c) 2.076 kΩ, 0.4817 mS
(d) 1.333 Ω, 0.75 S
(e) 9.948 Ω, 100.525 mS
(f) 0.6889 Ω, 1.4516 S
5. **(a)** 18 Ω **(b)** $R_1 = R_2 = 24\ \Omega$
7. 120 Ω
9. **(a)** 0.8571 Ω, 1.1667 S
(b) $I_s = 1.05$ A, $I_1 = 0.3$ A,
$I_2 = 0.15$ A, $I_3 = 0.6$ A
(d) $P_1 = 0.27$ W,
$P_2 = 0.135$ W,
$P_3 = 0.54$ W,
$P_{del} = 0.945$ W
(e) R_1, $R_2 = \frac{1}{2}$ W, $R_3 = 1$ W
11. **(a)** 66.67 mA **(b)** 225 Ω
(c) 8 W
13. **(a)** $I_s = 7.5$ A, $I_1 = 1.5$ A
(b) $I_s = 9.6$ mA, $I_1 = 0.8$ mA
15. 1260 W
17. **(a)** 4 mA **(b)** 24 V
(c) 18.4 mA
19. **(a)** $I_1 = 3$ mA, $I_2 = 1$ mA,
$I_3 = 1.5$ mA
(b) $I_2 = 4\ \mu$A, $I_3 = 1.5\ \mu$A,
$I_4 = 5.5\ \mu$A, $I_1 = 6\ \mu$A
21. **(a)** $R_1 = 5\ \Omega$, $R_2 = 10\ \Omega$
(b) $E = 12$ V, $I_2 = 1.333$ A,
$I_3 = 1$ A, $R_3 = 12\ \Omega$,
$I = 4.333$ A
(c) $I_1 = 64$ mA, $I_3 = 16$ mA,
$I_2 = 20$ mA, $R = 3.2$ kΩ,
$I = 36$ mA
(d) $E = 30$ V, $I_1 = 1$ A,
$I_2 = I_3 = 0.5$ A,
$R_2 = R_3 = 60\ \Omega$,
$P_{R_2} = 15$ W
23. **(a)** $I_1 = 4$ A, $I_2 = 8$ A
(b) $I_1 = 2$ A, $I_2 = 4$ A,
$I_3 = 1$ A, $I_4 = 1.333$ A
(c) $I_1 = 272.73$ mA,
$I_2 = 227.27$ mA,
$I_3 = 90.91$ mA,
$I_4 = 500$ mA
(d) $I_2 = 4.5$ A, $I_3 = 8.5$ A,
$I_4 = 8.5$ A
25. **(a)** $I = 4$ A, $I_2 = 4$ A,
$I_1 = 3$ A
27. $R_1 = 6$ kΩ, $R_2 = 1.5$ kΩ,
$R_3 = 0.5$ kΩ
29. $I = 3$ A, $R = 2\ \Omega$
31. **(a)** 6.13 V
(b) 9 V
(c) 9 V
33. **(a)** 4 V **(b)** 3.997 V
(c) 3.871 V **(d)** 3 V
(e) R_m large as possible
35. No! 4-V supply reversed

Chapter 7

1. **(a)** series: E, R_1, and R_4,
parallel: R_2 and R_3
(b) series: E and R_1,
parallel: R_2 and R_3
(c) series: E, R_1, and R_5;
R_3 and R_4
parallel: none
(d) series: R_6 and R_7,
parallel: E, R_1, and R_4;
R_2 and R_5
3. **(a)** yes (KCL) **(b)** 3 A
(c) yes (KCL) **(d)** 4 V
(e) 2 Ω **(f)** 5 A
(g) $P_1 = 12$ W, $P_2 = 18$ W,
$P_{del} = 50$ W
5. **(a)** 4 Ω
(b) $I_s = 9$ A, $I_1 = 6$ A, $I_2 = 3$ A
(c) 6 V
7. $I_1 = 6$ A, $I_2 = 16$ A, $I_3 = 0.8$ A,
$I = 22$ A
9. **(a)** 4 A
(b) $I_2 = 1.333$ A, $I_3 = 0.6665$ A
(c) $V_a = 8$ V, $V_b = 4$ V
11. **(a)** 5 Ω, 16 A
(b) $I_{R_2} = 8$ A, $I_3 = I_9 = 4$ A
(c) $I_8 = 1$ A **(d)** 14 V
13. **(a)** $V_G = 1.9$ V, $V_s = 3.65$ V
(b) $I_1 = I_2 = 7.05\ \mu$A,
$I_D = 2.433$ mA
(c) 6.268 V
(d) 8.02 V
15. **(a)** 0.6 A
(b) 28 V
17. **(a)** $I_2 = 1.667$ A, $I_6 = 1.111$ A,
$I_8 = 0$ A
19. **(a)** 1.882 Ω
(b) $V_1 = V_4 = 32$ V
(c) 8 A ←
(d) 1.882 Ω
21. **(a)** 6.75 A
(b) 32 V
23. 8.333 Ω
25. **(a)** 24 A
(b) 8 A
(c) $V_3 = 48$ V, $V_5 = 24$ V,
$V_7 = 16$ V
(d) $P(R_7) = 128$ W,
$P(E) = 5760$ W
27. 4.44 W
29. **(a)** 64 V
(b) $R_{L_2} = 4$ kΩ,
$R_{L_3} = 3$ kΩ
(c) $R_1 = 0.5$ kΩ,
$R_2 = 1.2$ kΩ,
$R_3 = 2$ kΩ
31. **(a)** yes **(b)** $R_1 = 750\ \Omega$,
$R_2 = 250\ \Omega$
(c) $R_1 = 745\ \Omega$, $R_2 = 255\ \Omega$
33. **(a)** 1 mA **(b)** $R_{shunt} = 5$ mΩ
35. **(a)** $R_s = 300$ kΩ
(b) 20,000
37. 0.05 μA

Chapter 8

1. 28 V
3. **(a)** $I_1 = 12$ A, $I_s = 11$ A
(b) $V_s = 24$ V, $V_3 = 6$ V
5. **(a)** 3 A, 6 Ω **(b)** 4.091 mA, 2.2 kΩ
7. **(a)** 8 A **(b)** 8 A
9. 9.6 V, 2.4 A
11. **(a)** 5.4545 mA, 2.2 kΩ
(b) 17.375 V **(c)** 5.375 V
(d) 2.443 mA
13. **(I)** CW: $I_{R_1} = 1.445$ mA;
down: $I_{R_3} = 9.958$ mA;
CCW: $I_{R_2} = 8.513$ mA
(II) CW: $I_{R_1} = 2.0316$ mA;
left: $I_{R_2} = 0.8$ mA;
CW: $I_{R_3} = I_{R_4} = 1.2316$ mA
15. **(d)** left: 63.694 mA
17. **(a)** CW: $I_{R_1} = -\frac{1}{7}$ A;
CW: $I_{R_2} = -\frac{5}{7}$ A
$I_{R_3} = \frac{4}{7}$ A (down)
(b) CW: $I_{R_1} = -3.0625$ A;
CW: $I_{R_3} = 0.1875$ A
$I_{R_2} = 3.25$ A (up)
19. **(I)** CW: $I_1 = 1.8701$ A;
CW: $I_2 = -8.5484$ A;
$V_{ab} = -22.74$ V
(II) CW: $I_2 = 1.274$ A;
CW: $I_3 = 0.26$ A;
$V_{ab} = -0.904$ V
21. **(a)** 72.16 mA, −4.433 V
(b) 1.953 A, −7.257 V
23. **(a)** All CW
$I_1 = 0.0321$ mA
$I_2 = -0.8838$ mA
$I_3 = -0.968$ mA
$I_4 = -0.639$ mA
(b) All CW
$I_1 = -3.8$ A
$I_2 = -4.2$ A
$I_3 = 0.2$ A
25. **(a)** CW,
$I_1 = -\frac{1}{7}$ A, $I_2 = -\frac{5}{7}$ A
(b) CW,
$I_1 = -3.0625$ A,
$I_2 = 0.1875$ A
27. **(I)** **(a)** CW
(b) $I_1 = 1.871$ A,
$I_2 = -8.548$ A
(c) $I_{R_1} = 1.871$ A,
$I_{R_2} = -8.548$ A,
$I_{R_3} = 10.419$ A
29. $I_{5\Omega}$ (CW) = 1.9535 A,
$V_a = -7.26$ V
31. **(a)** All CW,
$I_1 = 0.0321$ mA,
$I_2 = -0.8838$ mA,
$I_3 = -0.968$ mA,
$I_4 = -0.639$ mA
(b) All CW,
$I_1 = 3.8$ A, $I_2 = -4.2$ A,
$I_3 = 0.2$ A
33. **(I)** **(b)** $V_1 = -14.86$ V,
$V_2 = -12.57$ V
(c) $V_{R_1} = V_{R_4} =$
$V_1 = -14.86$ V,
$V_{R_2} = V_2 = -12.57$ V,
$V_{R_3} = 9.71$ V (+ −)
(II) **(b)** $V_1 = -2.556$ V,
$V_2 = 4.03$ V
(c) $V_{R_1} = V_1 = -2.556$ V,
$V_{R_2} = V_{R_5} = V_2 = 4.03$ V,
$V_{R_4} = V_{R_3} = V_2 - V_1$
$= 6.586$ V
35. **(I)** $V_1 = 7.238$ V,
$V_2 = -2.453$ V,
$V_3 = 1.405$ V
(II) $V_1 = -6.64$ V,
$V_2 = 1.288$ V,
$V_3 = 10.676$ V
37. **(a)** $V_1 = 10.083$ V,
$V_2 = 6.944$ V,
$V_3 = -17.056$ V
(b) $V_1 = 48$ V, $V_2 = 64$ V
39. **(b)** **(I)** $V_1 = -14.86$ V,
$V_2 = -12.57$ V
(II) $V_1 = -2.556$ V,
$V_2 = 4.03$ V
(c) **(I)** $V_{R_1} = V_{R_4} = -14.86$ V,
$V_{R_2} = -12.57$ V
$V_{R_3} = V_1 + 12 - V_2$
$= 9.71$ V
(II) $V_{R_1} = -2.556$ V,
$V_{R_2} = V_{R_5} = 4.03$ V
$V_{R_3} = V_{R_4} = V_2 - V_1$
$= 6.586$ V
41. **(I)** $V_1 = -5.311$ V,
$V_2 = -0.6219$ V,
$V_3 = 3.751$ V
$V_{-5A} = -5.311$ V
(II) $V_1 = -6.917$ V,
$V_2 = 12$ V,
$V_3 = 2.3$ V
$V_{5A} = V_2 - V_1 = 18.917$ V,
$V_{2A} = V_3 - V_2 = -9.7$ V
43. **(b)** $V_{R_5} = 0.1967$ V
(c) no
(d) no
45. **(b)** $I_{R_s} = 0$ A
(c) no
(d) no
47. **(a)** 3.33 mA
(b) 1.177 A
49. **(a)** 133.33 mA
(b) 7 A
51. **(b)** 0.833 mA
53. 4.2 Ω

Chapter 9

1. **(a)** CW: $I_{R_1} = \frac{5}{6}$ A, $I_{R_2} = 0$ A,
CW: $I_{R_3} = \frac{5}{6}$ A
(b) E_1: 5.33 W, E_2: 0.333 W
(c) 8.333 W **(d)** no
3. **(a)** down: 4.4545 mA
(b) down: 3.11 A
5. **(a)** 6 Ω, 6 V
(b) 2 Ω: 0.75 A,
30 Ω: 0.1667 A,
100 Ω: 0.0566 A
7. **(I)** 2 Ω, 84 V **(II)** 1.579 kΩ, −1.149 V
9. **(I)** 45 Ω, −5 V **(II)** 2.055 kΩ, 16.772 V
11. 4.041 kΩ, 9.733 V
13. **(I):** 14 Ω, 2.571 A,
(II): 7.5 Ω, 1.333 A
15. **(a)** 9.756 Ω, 0.95 A
(b) 2 Ω, 30 A
17. **(a)** 10 Ω, 0.2 A
(b) 4.033 kΩ, 2.9758 mA
19. **(I)** **(a)** 14 Ω
(b) 23.14 W
(II) **(a)** 7.5 Ω
(b) 3.33 W
21. **(a)** 9.756 Ω, 2.2 W
(b) 2 Ω, 450 W
23. 0 Ω
25. 500 Ω
27. 39.3 μA, 220 mV
29. 2.25 A, 6.075 V
35. **(a)** 0.357 mA **(b)** 0.357 mA
(c) yes

Chapter 10

1. 9×10^3 N/C
3. 70 μF
5. 50 V/m
7. 8×10^3 V/m
9. 937.5 pF
11. mica
13. **(a)** 10^6 V/m **(b)** 4.96 μC
(c) 0.0248 μF
15. 29,035 V
17. **(a)** 0.5 s **(b)** $20(1 - e^{-t/0.5})$
(c) 1τ: 12.64 V, 3τ: 19 V,
5τ: 19.87 V
(d) $i_C = 0.2 \times 10^{-3} e^{-t/0.5}$
$v_R = 20e^{-t/0.5}$
19. **(a)** 5.5 ms
(b) $100(1 - e^{-t/(5.5\times10^{-3})})$
(c) 1τ: 63.21 V, 3τ: 95.02 V,
5τ: 99.33 V
(d)
$i_C = 18.18 \times 10^{-3} e^{-t/(5.5\times10^{-3})}$
$v_R = 60e^{-t/(5.5\times10^{-3})}$
21. **(a)** 10 ms

(b) $50(1 - e^{-t/(10\times10^{-3})})$
(c) $10 \times 10^{-3} e^{-t/(10\times10^{-3})}$
(d) $v_C \cong 50$ V, $i_C = 0$ A
(e) $v_C = 50e^{-t/(4\times10^{-3})}$
$i_C = -25 \times 10^{-3} e^{-t/(4\times10^{-3})}$

23. (a) $80(1 - e^{-t/(1\times10^{-6})})$
(b) $0.8 \times 10^{-3} e^{-t/(1\times10^{-6})}$
(c) $v_C = 80e^{-t/(4.9\times10^{-6})}$
$i_C = 0.163 \times 10^{-3} e^{-t/(4.9\times10^{-6})}$

25. (a) 10 μs **(b)** 3 kA **(c)** yes

27. (a) $v_C = 52$ V $- 40$ V $e^{-t/123.8\text{ms}}$
$i_C = 2.198$ mA $e^{-t/123.8\text{ms}}$

29. 1.386 μs

31. $R = 54.567$ kΩ

33. (a) $v_C = 60(1 - e^{-t/0.2\text{s}})$,
0.5 s: 55.07 V, 1 s: 59.596 V
$i_C = 60 \times 10^{-3}\ e^{-t/0.2\text{s}}$
0.5 s: 4.93 mA,
1 s: 0.404 mA
$v_{R_1} = 60\ e^{-t/0.2\text{s}}$
0.5 s: 4.93 V, 1 s: 0.404 V
(b) $t = 0.405$ s, 1.387 s longer

35. (a) 19.634 V
(b) 2.31 s
(c) 1.155 s

37. (a) $v_C = 3.275(1 - e^{-t/52.68\text{ms}})$
$i_C = 1.216 \times 10^{-3}\ e^{-t/52.68\text{ms}}$

39. (a) $v_C = 27.2 - 25.2\ e^{-t/18.26\text{ms}}$
$i_C = 3.04$ mA $e^{-t/18.26\text{ms}}$

41. 0–4 ms: 0.3 mA,
4–6 ms: 0.9 mA,
6–7 ms: 3 mA,
7–10 ms: 0 mA,
10–13 ms: -3.2 mA,
13–15 ms: 1.8 mA

43. 0–4 ms: 0 V,
4–6 ms: -8 V,
6–16 ms: 20 V,
16–18 ms: 0 V,
18–20 ms: -12 V,
20–25 ms: 0 V

45. $V_1 = 10$ V, $Q_1 = 60$ μC,
$V_2 = 6.67$ V, $Q_2 = 40$ μC,
$V_3 = 3.33$ V, $Q_3 = 40$ μC

47. (a) 56.54 V
(b) 42.405 V
(c) 14.135 V
(d) 43.46 V
(e) 433.44 ms

49. 8640 pJ

51. (a) 5 J
(b) 0.1 C
(c) 200 A
(d) 10 kW
(e) 10 s

Chapter 11

1. Φ: 5×10^4 maxwells,
5×10^4 lines. B: 8 gauss,
51.616 lines

3. (a) 0.04 T

5. 952.4×10^3 At/Wb

7. 2624.67 At/m

9. 2.133 A

11. (a) $N_1 = 60$ t
(b) 13.34×10^{-4} Wb/Am

13. 2.687 A

15. 1.35 N

17. (a) 2.028 A **(b)** $\cong$2 N

19. 6.1×10^{-3} Wb

21. (a) $B = 1.5(1 - e^{-H/700\text{At/m}})$
(c) $H = -700 \log_e(1 - B/1.5\text{ T})$
(e) Eq: 40.1 mA

Chapter 12

1. 4.25 V

3. 14 turns

5. 15.65 μH

7. (a) 2.5 V **(b)** 0.3 V
(c) 200 V

9. 0−3 ms: 0 V. 3−8 ms: 1.6 V.
8−13 ms: -1.6 V.
13−14 ms: 0 V.
14−15 ms: 8 V.
15−16 ms: –8 V.
16−17 ms: 0 V.

11. 0−5 μs: 4 mA. 10 μs: -8 mA.
12 μs: 4 mA. 12−16 μs: 4 mA.
24 μs: 0 mA.

13. (a) 2.27 μs
(b) $5.45 \times 10^{-3}(1 - e^{-t/2.27\mu\text{s}})$
(c) $v_L = 12e^{-t/2.27\mu\text{s}}$
$v_R = 12(1 - e^{-t/2.27\mu\text{s}})$
(d) i_L: $1\tau = 3.45$ mA,
$3\tau = 5.179$ mA,
$5\tau = 5.413$ mA.
v_L: $1\tau = 4.415$ V,
$3\tau = 0.598$ V,
$5\tau = 0.081$ V.

15. (a) $i_L = 4.186$ mA $-$
3.814 mA $e^{-t/13.95\mu\text{s}})$
$v_L = -32.8$ V $e^{-t/13.95\mu\text{s}}$

17. (a) $v_L = 20$ V $e^{-t/1\mu\text{s}}$
$i_L = 2$ mA$(1 - e^{-t/1\mu\text{s}})$
(b) $i_L = 2$ mA $e^{-t/0.5\mu\text{s}}$
$v_L = -40$ V $e^{-t/0.5\mu\text{s}}$

19. (a) $i_L = 6$ mA$(1 - e^{-t/0.5\mu\text{s}})$
$v_L = 12$ V $e^{-t/0.5\mu\text{s}}$
(b) $i_L = 5.188$ mA $e^{-t/83.3n\text{s}}$
$v_L = -62.256$ V $e^{-t/83.3n\text{s}}$

21. 25.68 μs

23. (a) $i_L = 3.638 \times$
$10^{-3}\ (1 - e^{-t/6.676\mu\text{s}})$
$v_L = 5.45\ e^{-t/6.676\mu\text{s}}$
(b) 2.825 mA, 1.2186 V
(c) $i_L = 2.825 \times$
$10^{-3} e^{-t/2.128\mu\text{s}}$
$v_L = -13.27\ e^{-t/2.128\mu\text{s}}$

25. (a) 0.243 V
(b) 29.47 V
(c) 18.96 V
(d) 2.025 ms

27. (a) 20 V
(b) 12 μA
(c) 5.376 μs
(d) 0.366 V

29. $i_L = -3.478$ mA $-$
7.432 mA $e^{-t/173.9\mu\text{s}}$
$v_L = 51.28$ V $e^{-t/173.9\mu\text{s}}$

31. (a) 8 H
(b) 4 H

33. L: 4 H, 2 H
R: 5.7 kΩ, 9.1 kΩ

35. $V_1 = 16$ V, $V_2 = 0$ V,
$I_1 = 4$ mA

37. $V_1 = 10$ V
$I_1 = 2$ A
$I_2 = 1.33$ A

39. $W_C = 360$ μJ
$W_L = 12$ J

Chapter 13

1. (a) 10 ms **(b)** 2 **(c)** 100 Hz
(d) amplitude $= 5$ V,
$V_{p\text{-}p} = 6.67$ V

3. 10 ms, 100 Hz

5. (a) 60 Hz **(b)** 100 Hz
(c) 29.41 Hz **(d)** 40 kHz

7. 0.25 s

9. $T = 50$ μs

11. (a) $\pi/4$ **(b)** $\pi/3$ **(c)** $\frac{2}{3}\pi$
(d) $\frac{3}{2}\pi$ **(e)** 0.989π **(f)** 1.228π

13. (a) 3.14 rad/s
(b) 20.94×10^3 rad/s
(c) 1.57×10^6 rad/s
(d) 157.1 rad/s

15. (a) 120 Hz, 8.33 ms
(b) 1.34 Hz, 746.27 ms
(c) 954.93 Hz, 1.05 ms
(d) 9.95×10^{-3} Hz, 100.5 s

17. 104.7 rad/s

23. 0.4755 A

25. 11.537°, 168.463°

29. (a) v leads i by 10°
(b) i leads v by 70°
(c) i leads v by 80°
(d) i leads v by 150°

31. (a) $v = 25\sin(\omega t + 30°)$
(b)
$i = 3 \times 10^{-3} \sin(6.28 \times 10^3 t - 60°)$

33. $\frac{1}{3}$ ms

35. 0.388 ms

37. (a) 0.4 ms

(b) 2.5 kHz
(c) −25 mV

39. **(a)** 1.875 V **(b)** −4.778 mA

41. **(a)** 40 μs
(b) 25 kHz
(c) 17.13 mV

43. **(a)** 2 sin 377t
(b) 100 sin 377t
(c) 84.87×10^{-3} sin 377t
(d) 33.95×10^{-6} sin 377t

45. 2.16 V

47. 0 V

49. **(a)** $T = 40\ \mu$s, $f = 25$ kHz,
$V_{av} = 20$ mV,
$V_{rms} = 34.6$ mV
(b) $T = 100\ \mu$s, $f = 10$ kHz,
$V_{av} = -0.3$ V,
$V_{rms} = 367$ mV

Chapter 14

3. **(a)** 3770 cos 377t
(b) 452.4 cos(754t + 20°)
(c) 4440.63 cos(157t − 20°)
(d) 200 cos t

5. **(a)** 210 sin 754t
(b) 14.8 sin(400t − 120°)
(c) 42×10^{-3} sin(ωt + 88°)
(d) 28 sin(ωt + 180°)

7. **(a)** 1.592 H **(b)** 2.654 H
(c) 0.8414 H

9. **(a)** 100 sin(ωt + 90°)
(b) 8 sin(ωt + 150°)
(c) 120 sin(ωt − 120°)
(d) 60 sin(ωt + 190°)

11. **(a)** 1 sin(ωt − 90°)
(b) 0.6 sin(ωt − 70°)
(c) 0.8 sin(ωt + 10°)
(d) 1.6 sin(377t + 130°)

13. **(a)** ∞ Ω **(b)** 530.79 Ω
(c) 265.39 Ω **(d)** 17.693 Ω
(e) 1.327 Ω

15. **(a)** 9.31 Hz **(b)** 4.66 Hz
(c) 18.62 Hz **(d)** 1.59 Hz

17. **(a)** 6×10^{-3} sin(200t + 90°)
(b) 33.96×10^{-3} sin(377t + 90°)
(c) 44.94×10^{-3} sin(374t + 300°)
(d) 56×10^{-3} sin(ωt + 160°)

19. **(a)** 1334 sin(300t − 90°)
(b) 37.17 sin(377t − 90°)
(c) 127.2 sin 754t
(d) 100 sin(1600t − 170°)

21. **(a)** C **(b)** $L = 254.78$ mH
(c) $R = 5\ \Omega$

25. 318.47 mH

27. 5.067 nF

29. **(a)** 0 W **(b)** 0 W
(c) 122.5 W

31. 192 W

33. 40 sin(ωt − 50°)

35. **(a)** 2 sin(157t − 60°)
(b) 318.47 mH **(c)** 0 W

37. **(a)** $i_1 = 2.828 \sin(10^4 t + 150°)$,
$i_2 = 11.312 \sin(10^4 t + 150°)$
(b) $i_s = 14.14 \sin(10^4 t + 150°)$

39. **(a)** 5 ∠36.87°
(b) 2.83 ∠45°
(c) 16.38 ∠77.66°
(d) 806.23 ∠82.87°
(e) 1077.03 ∠21.80°
(f) 0.00658 ∠81.25°
(g) 11.78 ∠−49.82°
(h) 8.94 ∠153.43°
(i) 61.85 ∠−104.04°
(j) 101.53 ∠−39.81°
(k) 4326.66 ∠123.69°
(l) 25.495×10^{-3} ∠−78.69°

41. **(a)** 15.033 ∠86.19°
(b) 60.208 ∠4.76°
(c) 0.30 ∠88.09°
(d) 2002.5 ∠−87.14°
(e) 86.182 ∠93.73°
(f) 38.694 ∠−94°

43. **(a)** 11.8 + j 7
(b) 151.9 + j 49.9
(c) 4.72×10^{-6} + j 71
(d) 5.2 + j 1.6
(e) 209.3 + j 311
(f) −21.2 + j 12
(g) 7.03 + j 9.93
(h) 95.698 + j 22.768

45. **(a)** 6 ∠−50°
(b) 0.2×10^{-3} ∠140°
(c) 109 ∠−230°
(d) 76.471 ∠−80°
(e) 4 ∠0°
(f) 0.71 ∠−16.49°
(g) 4.21×10^{-3} ∠161.1°
(h) 18.191 ∠−50.91°

47. **(a)** $x = 4$, $y = 3$
(b) $x = 4$
(c) $x = 3$, $y = 6$ or
$x = 6$, $y = 3$
(d) 30°

49. **(a)** 56.569 sin(377t + 20°)
(b) 169.68 sin 377t
(c)
11.314×10^{-3} sin(377t + 120°)
(d) 7.07 sin(377t + 90°)
(e) 1696.8 sin(377t − 120°)
(f) 6000 sin(377t − 180°)

51.
$i_1 = 2.537 \times 10^{-5}$ sin(ωt + 96.79°)

53. $i_T = 18 \times 10^{-3}$ sin 377t

Chapter 15

1. **(a)** 6.8 Ω ∠0°
(b) 754 Ω ∠90°
(c) 15.7 Ω ∠90°
(d) 265.25 Ω ∠−90°
(e) 318.47 Ω ∠−90°
(f) 200 Ω ∠0°

3. **(a)** 88×10^{-3} sin ωt
(b) 9.045 sin(377t + 150°)
(c) 2547.02 sin(157t − 50°)

5. **(a)** 4.24 Ω ∠−45°
(b) 3.04 kΩ ∠80.54°
(c) 1617.56 Ω ∠88.33°

7. **(a)** 10 Ω ∠36.87°
(c) $\mathbf{I}$ =10 A ∠−36.87°,
$\mathbf{V}_R = 80$ V ∠−36.87°,
$\mathbf{V}_L = 60$ V ∠53.13°
(f) 800 W **(g)** 0.8 lagging

9. **(a)** 1660.27 Ω ∠−73.56°
(b) 8.517 mA ∠73.56°
(c) $\mathbf{V}_R = 4.003$ V ∠73.56°,
$\mathbf{V}_L = 13.562$ V ∠−16.44°
(d) 34.09 mW, 0.283 leading

11. **(a)** 3.16 kΩ ∠18.43°
(c) 3.18 μF, 6.37 H
(d) $\mathbf{I} = 1.3424$ mA ∠41.57°,
$\mathbf{V}_R = 4.027$ V ∠41.57°,
$\mathbf{V}_L = 2.6848$ V ∠131.57°,
$\mathbf{V}_C = 1.3424$ V ∠−48.43°
(g) 5.406 mW
(h) 0.9487 lagging

13. **(a)** 40 mH **(b)** 220 Ω

15. **(a)** $\mathbf{V}_1 = 37.97$ V ∠−51.57°,
$\mathbf{V}_2 = 113.92$ V ∠38.43°
(b) $\mathbf{V}_1 = 55.80$ V ∠26.55°,
$\mathbf{V}_2 = 12.56$ V ∠−63.45°

17. **(a)** $\mathbf{I} = 39$ mA ∠126.65°,
$\mathbf{V}_R = 1.17$ V ∠126.65°,
$\mathbf{V}_C = 25.86$ V ∠36.65°
(b) 0.058 leading
(c) 45.63 mW
(g) $\mathbf{Z}_T = 30\ \Omega - j\ 512.2\ \Omega$

19. $\mathbf{Z}_T = 3.2\ \Omega + j\ 2.4\ \Omega$

25. **(a)** $\mathbf{Z}_T = 3\ \Omega + j\ 8\ \Omega$,
$\mathbf{Y}_T = 41.1$ mS − j 109.5 mS
(b) $\mathbf{Z}_T = 60\ \Omega - j\ 70\ \Omega$,
$\mathbf{Y}_T = 7.1$ mS + j 8.3 mS
(c) $\mathbf{Z}_T = 200\ \Omega - j\ 100\ \Omega$,
$\mathbf{Y}_T = 4$ mS + j 2 mS

27. **(a)** $\mathbf{Y}_T = 538.52$ mS ∠−21.8°
(c) $\mathbf{E} = 3.71$ V ∠21.8°,
$\mathbf{I}_R = 1.855$ A ∠21.8°,
$\mathbf{I}_L = 0.742$ A ∠−68.2°
(f) 6.88 W
(g) 0.928 lagging
(h) $e = 5.25 \sin(377t + 21.8°)$,
$i_R = 2.62 \sin(377t + 21.8°)$,
$i_L = 1.049 \sin(377t - 68.2°)$,
$i_s = 2.828 \sin 377t$

29. **(a)** $\mathbf{Y}_T = 129.96$ mS ∠−50.31°
(c) $\mathbf{I}_s = 7.8$ A ∠−50.31°,
$\mathbf{I}_R = 5$ A ∠0°
$\mathbf{I}_L = 6$ A ∠−90°

(f) 300 W
(g) 0.638 lagging
(h) $e = 84.84 \sin 377t$,
$i_R = 7.07 \sin 377t$,
$i_L = 8.484 \sin(377t - 90°)$,
$i_s = 11.03 \sin(377t - 50.31°)$
31. (a) $\mathbf{Y}_T = 0.416$ mS $\angle 36.897°$
(c) $L = 10.61$ H, $C = 1.326\ \mu$F
(d) $\mathbf{E} = 8.498$ V $\angle -56.897°$,
$\mathbf{I}_R = 2.833$ mA $\angle -56.897°$,
$\mathbf{I}_L = 2.125$ mA $\angle -146.897°$,
$\mathbf{I}_C = 4.249$ mA $\angle 33.103°$
(g) 24.078 mW
(h) 0.8 leading
(i)
$e = 12.016 \sin(377t - 56.897°)$,
$i_R = 4 \sin(377t - 56.897°)$,
$i_L = 3 \sin(377t - 146.897°)$,
$i_C = 6 \sin(377t + 33.103°)$
33. (a) $\mathbf{I}_1 = 18.09$ A $\angle 65.241°$,
$\mathbf{I}_2 = 8.528$ A $\angle -24.759°$
(b) $\mathbf{I}_1 = 11.161$ A $\angle 0.255°$,
$\mathbf{I}_2 = 6.656$ A $\angle 153.690°$
39. (a) $R_p = 94.73\ \Omega$,
$X_p = 52.1\ \Omega$ (C)
(b) $R_p = 4$ kΩ,
$X_p = 4$ kΩ (C)
41. (a) $\mathbf{E} = 176.68$ V $\angle 36.44°$,
$\mathbf{I}_R = 0.803$ A $\angle 36.44°$,
$\mathbf{I}_L = 2.813$ A $\angle -53.56°$
(b) 0.804 lagging
(c) 141.86 W
(f) $\mathbf{I}_C = 1.11$ A $\angle 126.43°$
(g) $\mathbf{Z}_T = 142.15\ \Omega + j\ 104.96\ \Omega$
43. $R = 4\ \Omega$, $X_L = 3.774\ \Omega$

Chapter 16

1. (a) $1.2\ \Omega\ \angle 90°$
(b) 10 A $\angle -90°$
(c) 10 A $\angle -90°$
(d) $\mathbf{I}_2 = 6$ A $\angle -90°$,
$\mathbf{I}_3 = 4$ A $\angle -90°$
(e) 60 V $\angle 0°$
3. (a) $\mathbf{Z}_T = 3.87\ \Omega\ \angle -11.817°$,
$\mathbf{Y}_T = 0.258$ S $\angle 11.817°$
(b) 15.504 A $\angle 41.817°$
(c) 3.985 A $\angle 82.826°$
(d) 47.809 V $\angle -7.174°$
(e) 910.71 W
5. (a) 0.375 A $\angle 25.346°$
(b) 70.711 V $\angle -45°$
(c) 33.9 W
7. (a) 1.423 A $\angle 18.259°$
(b) 26.574 V $\angle 4.763°$
(c) 54.074 W
9. (a) $\mathbf{Y}_T = 0.099$ S $\angle -9.709°$
(b) $\mathbf{V}_1 = 20.4$ V $\angle 30°$,
$\mathbf{V}_2 = 10.887$ V $\angle 58.124°$
(c) 1.933 A $\angle 11.109°$
11. 33.201 A $\angle 38.89°$
13. 139.71 mW

Chapter 17

3. (a) $\mathbf{Z} = 21.93\ \Omega\ \angle -46.85°$,
$\mathbf{E} = 10.97$ V $\angle 13.15°$
(b) $\mathbf{Z} = 5.15\ \Omega\ \angle 59.04°$,
$\mathbf{E} = 10.3$ V $\angle 179.04°$
5. (a) 5.15 A $\angle -24.5°$
(b) 0.442 A $\angle 143.48°$
7. (a) 13.07 A $\angle -33.71°$
(b) 48.33 A $\angle -77.57°$
9. -3.165×10^{-3} **V** $\angle 137.29°$
11. $\mathbf{I}_{1k\Omega} = 10$ mA $\angle 0°$
$\mathbf{I}_{2k\Omega} = 1.667$ mA $\angle 0°$
13. $\mathbf{I}_L = 1.378$ mA $\angle -56.31°$
15. (a) $\mathbf{V}_1 = 19.86$ V $\angle 43.8°$,
$\mathbf{V}_2 = 8.94$ V $\angle 106.9°$
(b) $\mathbf{V}_1 = 19.78$ V $\angle 132.48°$,
$\mathbf{V}_2 = 13.37$ V $\angle 98.78°$
17. $\mathbf{V}_1 = 220$ V $\angle 0°$
$\mathbf{V}_2 = 96.664$ V $\angle -12.426°$
$\mathbf{V}_3 = 100$ V $\angle 90°$
19. (left) $\mathbf{V}_1 = 14.62$ V $\angle -5.86°$
(top) $\mathbf{V}_2 = 35.03$ V $\angle -37.69°$
(right) $\mathbf{V}_3 = 32.4$ V $\angle -73.34°$
(middle) $\mathbf{V}_4 = 5.677$ V $\angle 23.53°$
21. $\mathbf{V}_1 = 4.372$ V $\angle -128.66°$
$\mathbf{V}_2 = 2.253$ V $\angle 17.628°$
23. $\mathbf{V}_1 = -10.667$ V $\angle 0°$
$\mathbf{V}_2 = -6$ V $\angle 0°$
25. $-2451.92\mathbf{E}_i$
27. (a) No
(b) 1.76 mA $\angle -71.54°$
(c) 7.03 V $\angle -18.46°$
29. Balanced
31. $R_x = R_2R_3/R_1$
$L_x = R_2L_3/R_1$
33. (a) 11.57 A $\angle -67.13°$
(b) 36.9 A $\angle 23.87°$

Chapter 18

1. (a) 6.095 A $\angle -32.115°$
(b) 3.77 A $\angle -93.8°$
3. $i = 0.5\,\text{A} + 1.581 \sin(\omega t - 26.565°)$
5. 6.261 mA $\angle -63.43°$
7. -22.09 V $\angle 6.34°$
9. 19.62 V $\angle 53°$
11. $\mathbf{V}_s = 10$ V $\angle 0°$
13. (a) $\mathbf{Z}_{Th} = 21.312\ \Omega\ \angle 32.196°$
$\mathbf{E}_{Th} = 2.131$ V $\angle 32.196°$
(b) $\mathbf{Z}_{Th} = 6.813\ \Omega\ \angle -54.228°$
$\mathbf{E}_{Th} = 57.954$ V $\angle 11.099°$
15. (a) $\mathbf{Z}_{Th} = 4\ \Omega\ \angle 90°$
$\mathbf{E}_{Th} = 4$ V $+ 10$ V $\angle 0°$
(b) $\mathbf{I} = 0.5$ A $+$
$1.11\text{A} \angle -26.565°$
17. (a) $\mathbf{Z}_{Th} = 4.472$ kΩ $\angle -26.565°$
$\mathbf{E}_{Th} = 31.31$ V $\angle -26.565°$
(b) $\mathbf{I} = 6.26$ mA $\angle 63.435°$
19. $\mathbf{Z}_{Th} = 4.44$ kΩ $\angle -0.031°$
$\mathbf{E}_{Th} = -444.45 \times 10^3\mathbf{I}\ \angle 0.255°$
21. $\mathbf{Z}_{Th} = 5.099$ kΩ $\angle -11.31°$
$\mathbf{E}_{Th} = -50$ V $\angle 0°$
23. $\mathbf{Z}_{Th} = -39.215\ \Omega\ \angle 0°$
$\mathbf{E}_{Th} = 20$ V $\angle 53°$
25. $\mathbf{Z}_{Th} = 607.42\ \Omega\ \angle 0°$
$\mathbf{E}_{Th} = 1.62$ V $\angle 0°$
27. (a) $\mathbf{Z}_N = 21.312\ \Omega\ \angle 32.196°$,
$\mathbf{I}_N = 0.1$ A $\angle 0°$
(b) $\mathbf{Z}_N = 6.813\ \Omega\ \angle -54.228°$,
$\mathbf{I}_N = 8.506$ A $\angle 65.324°$
29. (a) $\mathbf{Z}_N = 9.66\ \Omega\ \angle 14.93°$,
$\mathbf{I}_N = 2.15$ A $\angle -42.87°$
(b) $\mathbf{Z}_N = 4.37\ \Omega\ \angle 55.67°$,
$\mathbf{I}_N = 22.83$ A $\angle -34.65°$
31. (a) $\mathbf{Z}_N = 9\ \Omega\ \angle 0°$,
$\mathbf{I}_N = 1.333$ A $+ 2.667$ A $\angle 0°$
(b) 12 V $+ 2.65$ V $\angle -83.66°$
33. $\mathbf{Z}_N = 5.1$ kΩ $\angle -11.31°$,
$\mathbf{I}_N = -1.961 \times 10^{-3}$ **V** $\angle 11.31°$
35. $\mathbf{Z}_N = 5.1$ kΩ $\angle -11.31°$,
$\mathbf{I}_N = 9.81$ mA $\angle 11.31°$
37. $\mathbf{Z}_N = 6.63$ kΩ $\angle 0°$
$\mathbf{I}_N = 0.792$ mA $\angle 0°$
39. (a) $\mathbf{Z}_L = 8.32\ \Omega\ \angle 3.18°$,
1198.2 W
(b) $\mathbf{Z}_L = 1.562\ \Omega\ \angle -14.47°$,
1.614 W
41. 40 kΩ, 25 W
43. (a) 9 Ω **(b)** 20 W
45. (a) 1.414 kΩ **(b)** 0.518 W
49. 25.77 mA $\angle 104.4°$

Chapter 19

1. (a) 120 W
(b) $Q_T = 0$ VAR, $S_T = 120$ VA
(c) 0.5 A
(d) $I_1 = \frac{1}{6}$ A, $I_2 = \frac{1}{3}$ A
3. (a) 400 W, -400 VAR (C),
565.69 VA, 0.7071 leading
(c) 5.66 A $\angle 135°$
5. (a) 500 W, -200 VAR (C),
538.52 VA
(b) 0.928 leading
(d) 10.776 A $\angle 21.875°$
7. (a) R: 200 W, L,C: 0 W
(b) R: 0 VAR, C: 80 VAR,
L: 100 VAR
(c) R: 200 VA, C: 80 VA,
L: 100 VA
(d) 200 W, 20 VAR (L),
200.998 VA, 0.995 (lagging)
(f) 10.05 A $\angle -5.73°$

9. **(a)** R: 38.99 W, L: 0 W, C: 0 W
(b) R: 0 VAR, L: 126.74 VAR, C: 46.92 VAR
(c) R: 38.99 VA, L: 126.74 VA, C: 46.92 VA
(d) 38.99 W, 79.82 VAR (L), 88.83 VA, 0.439 (lagging)
(f) 0.31 J
(g) $W_L = 0.32$ J, $W_C = 0.12$ J
11. **(a)** $\mathbf{Z} = 2.30\ \Omega + j\ 1.73\ \Omega$
(b) 4000 W
13. **(a)** 900 W, 0 VAR, 900 VA, 1
(b) 9 A $\angle 0°$
(d) $\mathbf{Z}_1$: $R = 0\ \Omega$, $X_C = 20\ \Omega$
$\mathbf{Z}_2$: $R = 2.83\ \Omega$, $X = 0\ \Omega$
$\mathbf{Z}_3$: $R = 5.66\ \Omega$, $X_L = 4.717\ \Omega$
15. **(a)** 1100 W, 2366.26 VAR, 2609.44 VA, 0.4215 (leading)
(b) 521.89 V $\angle -65.07°$
(c) $\mathbf{Z}_1$: $R = 1743.38\ \Omega$, $X_C = 1307.53\ \Omega$
$\mathbf{Z}_2$: $R = 43.59\ \Omega$, $X_C = 99.88\ \Omega$
17. **(a)** 7.81 kVA
(b) 0.640 (lagging)
(c) 65.08 A
(d) 1105 μF
(e) 41.67 A
19. **(a)** 128.14 W
(b) a–b: 42.69 W, b–c: 64.03 W, a–c: 106.72 W, a–d: 106.72 W, c–d: 0 W, d–e: 0 W, f–e: 21.34 W
21. **(a)** 5 Ω, 132.03 mH
(b) 10 Ω
(c) 15 Ω, 262.39 mH

Chapter 20

1. **(a)** $\omega_s = 250$ rad/s, $f_s = 39.79$ Hz
(b) $\omega_s = 3535.53$ rad/s, $f_s = 562.7$ Hz
(c) $\omega_s = 21{,}880$ rad/s, $f_s = 3482.31$ Hz
3. **(a)** $X_L = 40\ \Omega$
(b) $I = 10$ mA
(c) $V_R = 20$ mV, $V_L = 400$ mV, $V_C = 400$ mV
(d) $Q_s = 20$ (high)
(e) $L = 1.27$ mH, $C = 0.796\ \mu$F
(f) $BW = 250$ Hz
(g) $f_2 = 5.125$ kHz, $f_1 = 4.875$ kHz
5. **(a)** $BW = 400$ Hz
(b) $f_2 = 6200$ Hz, $f_1 = 5800$ Hz
(c) $X_L = X_C = 45\ \Omega$
(d) $P_{\text{HPF}} = 375$ mW
7. **(a)** $Q_s = 10$
(b) $X_L = 20\ \Omega$
(c) $L = 1.59$ mH, $C = 3.98\ \mu$F
(d) $f_2 = 2100$ Hz, $f_1 = 1900$ Hz
9. $L = 13.26$ mH, $C = 27.07$ nF
$f_2 = 8460$ Hz, $f_1 = 8340$ Hz
11. **(a)** $f_s = 1$ MHz
(b) $BW = 160$ kHz
(c) $R = 720\ \Omega$, $L = 0.7162$ mH, $C = 35.37$ pF
(d) $R_l = 56.25\ \Omega$
13. **(a)** $f_p = 159.155$ kHz
(b) $V_C = 4$ V
(c) $I_L = I_C = 40$ mA
(d) $Q_p = 20$
15. **(a)** $f_s = 11{,}253.95$ Hz
(b) $Q_l = 1.77$ (no)
(c) $f_p = 9{,}280.24$ Hz, $f_m = 10{,}794.41$ Hz
(d) $X_L = 5.83\ \Omega$, $X_C = 8.57\ \Omega$
(e) $Z_{T_p} = 12.5\ \Omega$
(f) $V_C = 25$ mV
(g) $Q_p = 1.46$, $BW = 6.356$ kHz
(h) $I_C = 2.92$ mA, $I_L = 3.54$ mA
17. **(a)** $X_C = 30\ \Omega$
(b) $Z_{T_P} = 225\ \Omega$
(c) $\mathbf{I}_C = 0.6$ A $\angle 90°$, $\mathbf{I}_L \cong 0.6$ A $\angle -86.19°$
(d) $L = 0.239$ mH, $C = 265.26$ nF
(e) $Q_p = 7.5$, $BW = 2.67$ kHz
19. **(a)** $f_s = 7.118$ kHz, $f_p = 6.647$ kHz, $f_m = 7$ kHz
(b) $X_L = 20.88\ \Omega$, $X_C = 23.94\ \Omega$
(c) $Z_{T_P} = 55.56\ \Omega$
(d) $Q_p = 2.32$, $BW = 2.865$ kHz
(e) $I_L = 99.28$ mA, $I_C = 92.73$ mA
(f) $V_C = 2.22$ V
21. **(a)** $f_p = 3558.81$ Hz
(b) $V_C = 138.2$ V
(c) $P = 691$ mW
(d) $BW = 575.86$ Hz
23. **(a)** $X_L = 98.54\ \Omega$
(b) $Q_l = 8.21$
(c) $f_p = 8.05$ kHz
(d) $V_C = 4.83$ V
(e) $f_2 = 8.55$ kHz, $f_1 = 7.55$ kHz
25. $R_s = 3.244$ kΩ, $C = 31.66$ nF
27. **(a)** $f_p = 251.65$ kHz
(b) $Z_{T_p} = 4.444$ kΩ
(c) $Q_p = 14.05$
(d) $BW = 17.91$ kHz
(e) 20 nF: $f_p = 194.93$ kHz, $Z_{T_p} = 49.94\ \Omega$, $Q_p = 2.04$, $BW = 95.55$ kHz
(f) 1 nF: $f_p = 251.65$ kHz, $Z_{T_p} = 13.33$ kΩ, $Q_p = 21.08$, $BW = 11.94$ kHz
(g) Network: $L/C = 100 \times 10^3$
part (e): $L/C = 1 \times 10^3$
part (f): $L/C = 400 \times 10^3$
(h) yes, $L/C \uparrow$, $BW \downarrow$

Chapter 21

1. **(a)** 0.2 H
(b) $e_p = 1.6$ V, $e_s = 5.12$ V
(c) $e_p = 15$ V, $e_s = 24$ V
3. **(a)** 158.02 mH
(b) $e_p = 24$ V, $e_s = 1.8$ V
(c) $e_p = 15$ V, $e_s = 24$ V
5. **(a)** 3.125 V **(b)** 391.02 μWb
7. 56.31 Hz
9. 400 Ω
11. 12,000t
13. **(a)** 3
(b) 2.78 W
15. **(a)** 360.56 Ω $\angle 86.82°$
(b) 332.82 mA $\angle -86.82°$
(c) $\mathbf{V}_{R_e} = 6.656$ V $\angle -86.82°$, $\mathbf{V}_{X_e} = 13.313$ V $\angle 3.18°$, $\mathbf{V}_{X_L} = 106.50$ V $\angle 3.18°$
19. 1.354 H
21. $\mathbf{I}_1(R_1 + j\ X_{L_1}) + \mathbf{I}_2(j\ X_m) = \mathbf{E}_1$
$\mathbf{I}_1(j\ X_m) + \mathbf{I}_2(j\ X_{L_2} + R_L) = 0$
23. **(a)** 20 **(b)** 83.33 A **(c)** 4.167 A
(d) $a = \frac{1}{20}$, $I_s = 4.167$ A, $I_p = 83.33$ A
25. **(a)** 25 V $\angle 0°$, 5 A $\angle 0°$
(b) 80 Ω $\angle 0°$ **(c)** 20 Ω $\angle 0°$
27. **(a)** $\mathbf{E}_2 = 40$ V $\angle 60°$, $\mathbf{I}_2 = 3.33$ A $\angle 60°$, $\mathbf{E}_3 = 30$ V $\angle 60°$, $\mathbf{I}_3 = 3$ A $\angle 60°$
(b) $R_1 = 64.52\ \Omega$
29. $[\mathbf{Z}_1 + \mathbf{X}_{L_1}]\mathbf{I}_1 - \mathbf{Z}_{M_{12}}\mathbf{I}_2 + \mathbf{Z}_{M_{13}}\mathbf{I}_3 = \mathbf{E}_1$,
$\mathbf{Z}_{M_{12}}\mathbf{I}_1 - [\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{X}_{L_2}]\mathbf{I}_2 + \mathbf{Z}_2\mathbf{I}_3 = 0$,
$\mathbf{Z}_{M_{13}}\mathbf{I}_1 - \mathbf{Z}_2\mathbf{I}_2 + [\mathbf{Z}_2 + \mathbf{Z}_4 + \mathbf{X}_{L_3}]\mathbf{I}_3 = 0$

Chapter 22

1. **(a)** 120.1 V **(b)** 120.1 V
(c) 12.01 A **(d)** 12.01 A
3. **(a)** 120.1 V **(b)** 120.1 V
(c) 16.98 A **(d)** 16.98 A
5. **(a)** $\theta_2 = -120°$, $\theta_3 = 120°$
(b) $\mathbf{V}_{an} = 120$ V $\angle 0°$, $\mathbf{V}_{bn} = 120$ V $\angle -120°$, $\mathbf{V}_{cn} = 120$ V $\angle 120°$
(c) $\mathbf{I}_{an} = 8$ A $\angle -53.13°$, $\mathbf{I}_{bn} = 8$ A $\angle -173.13°$, $\mathbf{I}_{cn} = 8$ A $\angle 66.87°$
(e) 8 A **(f)** 207.85 V
7. $V_\phi = 127$ V, $I_\phi = 8.98$ A, $I_L = 8.98$ A

9. **(a)** $\mathbf{E}_{AN} = 12.7\text{ kV} \angle -30°$, $\mathbf{E}_{BN} = 12.7\text{ kV} \angle -150°$, $\mathbf{E}_{CN} = 12.7\text{ kV} \angle 90°$ **(b)** $\mathbf{I}_{an} = 11.285\text{ A} \angle -97.54°$, $\mathbf{I}_{bn} = 11.285\text{ A} \angle -217.54°$, $\mathbf{I}_{cn} = 11.285\text{ A} \angle 22.46°$ **(c)** $\mathbf{I}_L = \mathbf{I}_\phi$ **(d)** $\mathbf{V}_{an} = 12{,}154.28\text{ V} \angle -29.34°$, $\mathbf{V}_{bn} = 12{,}154.28\text{V} \angle -149.34°$, $\mathbf{V}_{cn} = 12{,}154.28\text{ V} \angle 90.66°$

11. **(a)** 120.1 V **(b)** 208 V **(c)** 13.364 A **(d)** 23.15 A

13. **(a)** $\theta_2 = -120°$, $\theta_3 = +120°$ **(b)** $\mathbf{V}_{ab} = 208\text{ V} \angle 0°$, $\mathbf{V}_{bc} = 208\text{ V} \angle -120°$, $\mathbf{V}_{ca} = 208\text{ V} \angle 120°$ **(d)** $\mathbf{I}_{ab} = 9.455\text{ A} \angle 0°$, $\mathbf{I}_{bc} = 9.455\text{ A} \angle -120°$, $\mathbf{I}_{ca} = 9.455\text{ A} \angle 120°$ **(e)** 16.376 A **(f)** 120.1 V

15. **(a)** $\theta_2 = -120°$, $\theta_3 = 120°$ **(b)** $\mathbf{V}_{ab} = 208\text{ V} \angle 0°$, $\mathbf{V}_{bc} = 208\text{ V} \angle -120°$, $\mathbf{V}_{ca} = 208\text{ V} \angle 120°$ **(d)** $\mathbf{I}_{ab} = 86.67\text{ A} \angle -36.87°$, $\mathbf{I}_{bc} = 86.67\text{ A} \angle -156.87°$, $\mathbf{I}_{ca} = 86.67\text{ A} \angle 83.13°$ **(e)** 150.11 A **(f)** 120.1 V

17. **(a)** $\mathbf{I}_{ab} = 15.325\text{ A} \angle -73.30°$, $\mathbf{I}_{bc} = 15.325\text{ A} \angle -193.30°$, $\mathbf{I}_{ca} = 15.325\text{ A} \angle 46.7°$ **(b)** $\mathbf{I}_{Aa} = 26.54\text{ A} \angle -103.31°$, $\mathbf{I}_{Bb} = 26.54\text{ A} \angle 136.68°$, $\mathbf{I}_{Cc} = 26.54\text{ A} \angle 16.69°$ **(c)** $\mathbf{E}_{AB} = 17{,}013.6\text{ V} \angle -0.59°$, $\mathbf{E}_{BC} = 17{,}013.77\text{ V} \angle -120.59°$, $\mathbf{E}_{CA} = 17{,}013.87\text{ V} \angle 119.41°$

19. **(a)** 208 V **(b)** 120.09 V **(c)** 7.076 A **(d)** 7.076 A

21. $V_\phi = 69.28$ V, $I_\phi = 2.89$ A, $I_L = 2.89$ A

23. $V_\phi = 69.28$ V, $I_\phi = 5.77$ A, $I_L = 5.77$ A

25. **(a)** 440 V **(b)** 440 V **(c)** 29.33 A **(d)** 50.8 A

27. **(a)** $\theta_2 = -120°$, $\theta_3 = +120°$ **(b)** $\mathbf{V}_{ab} = 100\text{ V} \angle 0°$, $\mathbf{V}_{bc} = 100\text{ V} \angle -120°$, $\mathbf{V}_{ca} = 100\text{ V} \angle 120°$ **(d)** $\mathbf{I}_{ab} = 5\text{ A} \angle 0°$, $\mathbf{I}_{bc} = 5\text{ A} \angle -120°$, $\mathbf{I}_{ca} = 5\text{ A} \angle 120°$ **(e)** 8.66 A

29. **(a)** $\theta_2 = -120°$, $\theta_3 = 120°$ **(b)** $\mathbf{V}_{ab} = 100\text{ V} \angle 0°$, $\mathbf{V}_{bc} = 100\text{ V} \angle -120°$, $\mathbf{V}_{ca} = 100\text{ V} \angle 120°$ **(d)** $\mathbf{I}_{ab} = 7.072\text{ A} \angle 45°$, $\mathbf{I}_{bc} = 7.072\text{ A} \angle -75°$, $\mathbf{I}_{ca} = 7.072\text{ A} \angle 165°$ **(e)** 12.25 A

31. 2160 W, 0 VAR, 2160 VA, $F_p = 1$

33. 7210.67 W, 7210. 67 VAR (C), 10,197.42 VA, 0.707 leading

35. 7.263 kW, 7.263 kVAR, 10.272 kVA, 0.707 lagging

37. 287.93 W, 575.86 VAR (L), 643.83 VA, 0.4472 lagging

39. 900 W, 1200 VAR (L), 1500 VA, 0.6 lagging

41. $\mathbf{Z}_\phi = 12.98\ \Omega - j\ 17.31\ \Omega$

43. **(a)** 9237.6 V **(b)** 80 A **(c)** 1276.8 kW **(d)** 0.576 lagging **(e)** $\mathbf{I}_{Aa} = 80\text{ A} \angle -54.83°$ **(f)** $\mathbf{V}_{an} = 7773.45\text{ V} \angle -4.87°$ **(g)** $\mathbf{Z}_\phi = 62.52\ \Omega + j\ 74.38\ \Omega$ **(h)** F_p (entire system) = 0.576, F_p (load) = 0.643 (both lagging) **(i)** 93.98%

45. **(b)** $P_T = 5899.64$ W, $P_{\text{meter}} = 1966.55$ W

49. **(a)** 120.09 V **(b)** $I_{an} = 8.492$ A, $I_{bn} = 7.076$ A, $I_{cn} = 42.465$ A **(c)** 4928.5 W, 4928.53 VAR (L), 6969.99 VA, 0.7071 lagging **(d)** $\mathbf{I}_{an} = 8.492\text{ A} \angle -75°$, $\mathbf{I}_{bn} = 7.076\text{ A} \angle -195°$, $\mathbf{I}_{cn} = 42.465\text{ A} \angle 45°$ **(e)** $\mathbf{I}_N = 34.712\text{ A} \angle -42.972°$

Chapter 23

1. **(a)** left: 1.54 kHz, right: 5.623 kHz **(b)** bottom: 0.2153 V, top: 0.5248 V

3. **(a)** 1000 **(b)** 10^{12} **(c)** 1.585 **(d)** 1.096 **(e)** 10^{10} **(f)** 1513.56 **(g)** 10.023 **(h)** 1,258,925.41

5. 1.681

7. −0.301

9. **(a)** 1.845 **(b)** 18.45

11. 13.01

13. 38.49

15. 24.08 dB_s

19. **(a)** $0.1f_c$: 0.995, $0.5f_c$: 0.894, f_c: 0.707, $2f_c$: 0.447, $10f_c$: 0.0995 **(b)** $0.1f_c$: −5.71°, $0.5f_c$: −26.57°, f_c: −45°, $2f_c$: −63.43°, $10f_c$: −84.29°

21. $C = 0.265\ \mu$F, 250 Hz: $A_v = 0.895$, $\theta = -26.54°$, 1000 Hz: $A_v = 0.4475$, $\theta = -63.41°$

23. **(a)** $f_c = 3.617$ kHz, f_c: $A_v = 0.707$, $\theta = 45°$, $2f_c$: $A_v = 0.894$, $\theta = 26.57°$ $0.5f_c$: $A_v = 0.447$, $\theta = 63.43°$ $10f_c$: $A_v = 0.995$, $\theta = 5.71°$ $\frac{1}{10}f_c$: $A_v = 0.0995$, $\theta = 84.29°$

25. $R = 795.77\ \Omega \rightarrow 797\ \Omega$, f_c: $A_v = 0.707$, $\theta = 45°$ 1 kHz: $A_v = 0.458$, $\theta = 63.4°$ 4 kHz: $A_v \cong 0.9$, $\theta = 26.53°$

27. **(a)** $f_{c_1} = 795.77$ Hz, $f_{c_2} = 1989.44$ Hz f_{c_1}: $V_o = 0.656V_i$, f_{c_2}: $V_o = 0.656V_i$ $f_{\text{center}} = 1392.60$ Hz: $V_o = 0.711V_i$ 500 Hz: $V_o = 0.516V_i$, 4 kHz: $V_o = 0.437V_i$ **(b)** $BW \cong 2.9$ kHz, $f_{\text{center}} = 1.94$ kHz

29. **(a)** $f_s = 100.658$ kHz **(b)** $Q_s = 18.39$, $BW = 5473.52$ Hz **(c)** f_s: $A_v = 0.93$ $f_1 = 97{,}921.24$ Hz, $f_2 = 103{,}394.76$ Hz, $f = 95$ kHz: $A_v = 0.392$, $f = 105$ kHz: $A_v = 0.5$ **(d)** $f = f_s$, $V_o = 0.93$ V, $f = f_1 = f_2$, $V_o = 0.658$ V

31. **(a)** $Q_s = 12.195$ **(b)** $BW = 410$ Hz, $f_2 = 5205$ Hz, $f_1 = 4795$ Hz **(c)** f_s: $V_o = 0.024V_i$ **(d)** f_s: V_o still $0.024V_i$

33. **(a)** $f_p = 726.44$ kHz (stop-band) $f = 2.013$ MHz (pass-band)

35. **(a–b)** $f_c = 6772.55$ Hz **(c)** f_c: −3 dB, $\frac{1}{2}f_c$: −6.7 dB, $2f_c$: −0.969 dB, $\frac{1}{10}f_c$: −20.04 dB, $10f_c$: −0.043 dB **(d)** f_c: 0.707, $\frac{1}{2}f_c$: 0.4472, $2f_c$: 0.894 **(e)** f_c: 45°, $\frac{1}{2}f_c$: 63.43°, $2f_c$: 26.57°

37. **(a–b)** $f_c = 13.26$ kHz **(c)** f_c: −3 dB, $\frac{1}{2}f_c$: −0.97 dB, $2f_c$: −6.99 dB

$\frac{1}{10}f_c$: −0.043 dB,
$10f_c$: −20.04 dB
(d) f_c: 0.707, $\frac{1}{2}f_c$: 0.894,
$2f_c$: 0.447
(e) f_c: −45°, $\frac{1}{2}f_c$: −26.57°,
$2f_c$: −63.43°

39. **(a)** $f_1 = 663.15$ Hz, $f_c = 468.1$ Hz
$0 < f < f_c$: +6 dB/octave,
$f > f_c$: −3.03 dB
(b) f_1: 45°, f_c: 54.78°, $\frac{1}{2}f_1$: 63.43°,
$2f_1$: 84.29°

41. **(a)** $f_1 = 19{,}894.37$ Hz
$f_c = 1{,}989.44$ Hz
$0 < f < f_c$: 0 dB,
$f_c < f < f_1$: −6 dB/octave,
$f > f_1$: −20 dB
(b) f_c: −39.29°,
10 kHz: −52.06°,
f_1: −39.29°

43. **(a)** $f_1 = 964.58$ Hz,
$f_c = 7{,}334.33$ Hz
$0 < f < f_1$: −17.62 dB,
$f_1 < f < f_c$: +6 dB/octave,
$f > f_c$: 0 dB
(b) f_1: 39.35°, 1.3 kHz: 43.38°,
f_c: 39.35°

45. **(a)** $f = 180$ Hz $\cong$ −3 dB,
$f = 18$ kHz: −3.105 dB
(b) 100 Hz: 97°,
1.8 kHz: 0.12° $\cong$ 0°,
18 kHz: −61.8°

47. $\mathbf{A}_v = -120/[(1 - j\,50/f)(1 - j\,200/f)(1 - jf/36\text{ kHz})]$

49. $f_c = 2$ kHz, $0 < f < f_c$: 0 dB,
$f > f_c$: −6 dB/octave

51. $f_1 = 1$ kHz, $f_2 = 2$ kHz,
$f_3 = 3$ kHz
$0 < f < f_1$: 0 dB,
$f_1 < f < f_2$: +6 dB/octave
$f_2 < f < f_3$: +12 dB/octave,
$f > f_3$: 13.06 dB

53. **(a)** woofer: 0.673, tweeter: 0.678
(b) woofer: 0.015, tweeter: 0.337
(c) mid-range: 0.998 $\cong$ 1

Chapter 24

1. **(a)** positive-going **(b)** 2 V
(c) 0.2 ms **(d)** 6 V **(e)** 6.5%

3. **(a)** positive-going
(b) 10 mV
(c) 3.2 ms **(d)** 20 mV
(e) 3.4%

5. V_2 of $(V_1 - V_2)/\text{V} = 0.1$ is 13.571 mV

7. **(a)** 120 μs **(b)** 8.333 kHz
(c) maximum = 440 mV,
minimum = 80 mV

9. prf = 125 kHz,
duty cycle = 62.5%

11. **(a)** 8 μs
(b) 2 μs
(c) 125 kHz
(d) 0 V
(e) 3.464 mV

13. 18.88 mV

15. 117 mV

17. $v_o = 4(1 + e^{-t/20\text{ms}})$

19. $i_C = -8 \times 10^{-3}e^{-t}$

21. $i_C = 4 \times 10^{-3}e^{-t/0.2\text{ms}}$
(a) $5\tau = T/2$ **(b)** $5\tau = \frac{1}{5}(T/2)$
(c) $5\tau = 10(T/2)$

23. $0 - T/2$: $v_C = 20$ V,
$T/2 - T$: $v_C = 20e^{-t/\tau}$,
$T - \frac{3}{2}T$: $v_C = 20(1 - e^{-t/\tau})$
$\frac{3}{2}T - T$: $v_C = 20e^{-t/\tau}$

25. $\mathbf{Z}_p = 4.573\text{ M}\Omega\ \angle -59.5°$,
$\mathbf{Z}_s = 0.507\text{ M}\Omega\ \angle -59.5°$

Chapter 25

1. (I) **a.** no **b.** no **c.** yes **d.** no **e.** yes
(II) **a.** yes **b.** yes **c.** yes **d.** yes **e.** no
(III) **a.** yes **b.** yes **c.** no **d.** yes **e.** yes
(IV) **a.** no **b.** no **c.** yes **d.** yes **e.** yes

7. **(a)** 19.04 V **(b)** 4.53 A

9. 71.872 W

11. **(a)** $i = 2 + 2.08\sin(400t - 33.69) + 0.5\sin(800t - 53.13°)$
(b) 2.508 A
(c) $v_R = 24 + 24.96\sin(400t + 33.69°) + 6\sin(800t - 53.13°)$
(d) 30.092 A
(e) $v_L = 16.64\sin(400t + 56.31°) + 8\sin(800t + 36.87°)$
(f) 13.055 V **(g)** 75.481 W

13. **(a)** $i = 1.2\sin(400t + 53.13°)$
(b) 0.848 A
(c) $v_R = 18\sin(400t + 53.13°)$
(d) 12.73 V
(e) $v_C = 18 + 23.98\sin(400t - 36.87°)$
(f) 24.73 V **(g)** 10.79 W

15. $v_o = 2.257 \times 10^{-3}\sin(377t + 93.66°) + 1.923 \times 10^{-3}\sin(754t + 1.64°)$

17. $i_T = 30 + 30.27\sin(20t + 7.59°) + 0.5\sin(40t - 30°)$

Chapter 26

1. $Z_i = 986.84\ \Omega$

3. **(a)** $I_{i_1} = 10\ \mu$A
(b) $Z_{i_2} = 4.5\ \text{k}\Omega$
(c) $E_{i_3} = 6.9$ V

5. $Z_o = 44.59\ \text{k}\Omega$

7. $Z_o = 10\ \text{k}\Omega$

9. **(a)** $\mathbf{A}_v = -392.98$
(b) $\mathbf{A}_{v_T} = -320.21$

11. **(a)** $\mathbf{A}_{v_{NL}} = -2398.8$
(b) $\mathbf{E}_i = 50$ mV
(c) $\mathbf{Z}_i = 1\ \text{k}\Omega$

13. **(a)** $\mathbf{A}_G = 6.067 \times 10^4$
(b) $\mathbf{A}_{G_T} = 4.94 \times 10^4$

15. **(a)** $\mathbf{A}_{v_T} = 1500$
(b) $\mathbf{A}_{i_T} = 187.5$
(c) $\mathbf{A}_{i_1} = 15$, $\mathbf{A}_{i_2} = 12.5$
(d) $\mathbf{A}_{i_T} = 187.5$

17. **(a)** $\mathbf{z}_{11} = (\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3)/(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3)$,
$\mathbf{z}_{12} = \mathbf{Z}_1\mathbf{Z}_3/(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3)$,
$\mathbf{z}_{21} = \mathbf{z}_{12}$,
$\mathbf{z}_{22} = (\mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3)/(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3)$

19. **(a)** $\mathbf{y}_{11} = (\mathbf{Y}_1\mathbf{Y}_2 + \mathbf{Y}_1\mathbf{Y}_3)/(\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3)$,
$\mathbf{y}_{12} = -\mathbf{Y}_1\mathbf{Y}_2/(\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3)$,
$\mathbf{y}_{21} = \mathbf{y}_{12}$,
$\mathbf{y}_{22} = (\mathbf{Y}_1\mathbf{Y}_2 + \mathbf{Y}_2\mathbf{Y}_3)/(\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3)$

21. $\mathbf{h}_{11} = \mathbf{Z}_1\mathbf{Z}_2/(\mathbf{Z}_1 + \mathbf{Z}_2)$,
$\mathbf{h}_{21} = -\mathbf{Z}_1/(\mathbf{Z}_1 + \mathbf{Z}_2)$,
$\mathbf{h}_{12} = \mathbf{Z}_1/(\mathbf{Z}_1 + \mathbf{Z}_2)$,
$\mathbf{h}_{22} = (\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3)/(\mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3)$

23. $\mathbf{h}_{11} = (\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_3)/(\mathbf{Y}_1\mathbf{Y}_2 + \mathbf{Y}_1\mathbf{Y}_3)$,
$\mathbf{h}_{21} = -\mathbf{Y}_2/(\mathbf{Y}_2 + \mathbf{Y}_3)$,
$\mathbf{h}_{12} = \mathbf{Y}_2/(\mathbf{Y}_2 + \mathbf{Y}_3)$,
$\mathbf{h}_{22} = \mathbf{Y}_2\mathbf{Y}_3/(\mathbf{Y}_2 + \mathbf{Y}_3)$

25. **(a)** 47.62 **(b)** −99

27. $\mathbf{Z}_i = 9{,}219.5\ \Omega\ \angle -139.4°$,
$\mathbf{Z}_o = 29.07\ \text{k}\Omega\ \angle -86.05°$

29. $\mathbf{h}_{11} = 2.5\ \text{k}\Omega$, $\mathbf{h}_{12} = 0.5$,
$\mathbf{h}_{21} = -0.75$, $\mathbf{h}_{22} = 0.25$ mS