Answers to Selected Problems

CHAPTER 1

1.1 $I = 2$ A

1.7 W = 1440 J

1.11 **(a)** 5 V, + top

(b) 5 V, + bottom

(c) 5 V, + bottom

(d) 5 V, + top

1.14 **(a)** $I = -2$ A

(b) $V_1 = -12$ V

1.18 **(a)** $P_1 = 12$ W

$P_2 = 24$ W

(b) $P_1 = -72$ W

$P_2 = 48$ W

1.21 $P_2 = 48$ W absorbed

1.24 **(a)** $P_1 = 16$ W absorbed

$P_2 = 8$ W absorbed

$P_{12\text{ V}} = 24$ W supplied

(b) $P_1 = 40$ W absorbed

$P_2 = 24$ W absorbed

$P_3 = 16$ W supplied

$P_{24\text{ V}} = 48$ W supplied

1.28 $P_1 = 48$ W absorbed

$P_2 = 48$ W absorbed

$P_3 = 56$ W absorbed

$P_{36\text{ V}} = 144$ W supplied

$P_{\text{D.S.}} = 8$ W

CHAPTER 2

2.2 $R_x = 5\ \text{k}\Omega$

2.6 $G_x = 200\ \mu S$

2.11 $I_1 = 6$ mA

$I_2 = 3$ mA

2.15 $I_x = -3$ mA

2.19 $V_{da} = -9$ V

$V_{be} = 9$ V

2.25 $V_x = 10$ V

2.30 $V_S = -2$ V

2.39 $V_o = 36$ V

2.45 $I_L = 2.4$ mA

2.49 $R_{AB} = 12\ \text{k}\Omega$

2.53 $R_{AB} = 2\ \text{k}\Omega$

2.57 $I_{\max} = 18.22$ mA $P_{\max} = 182.2$ mW

$I_{\min} = 17.51$ mA $P_{\min} = 175.1$ mW

2.64 $I_1 = -3$ mA

2.68 $I_o = 0.33$ mA

2.72 $V_S = -92.4$ V

2.77 $V_o = -12$ V

2.82 $V_o = 3$ V

2.87 $V_S = 41$ V

2.92 $V_S = 30$ V

2.98 $I_o = -4$ mA

2.103 $g = 4$

2.109 $I_o = 2$ A

2.113 $I_o = 0.67$ A

CHAPTER 3

3.1 $I_o = 1$ mA

3.5 $I_o = 0.6$ mA

3.9 $V_o = -3.6$ V

3.14 $I_o = -1$ mA

3.20 $V_A = 2.5$ V

$V_B = -0.33$ V

3.27 $V_o = 2$ V

3.32 $V_o = 5$ V

3.36 $V_1 = 11.5$ V
$V_2 = 12$ V
$V_3 = 12$ V
$V_4 = 6.5$ V

3.41 $V_o = 8$ V

3.46 $V_o = 1.33$ V

3.49 $V_o = 15$ V

3.54 $V_o = -5$ V

3.59 $I_o = 2.88$ mA

3.63 $V_o = 6.67$ V

3.69 $I_o = 2.67$ mA

3.73 $I_o = 1.64$ mA

3.79 $V_o = 7.57$ V

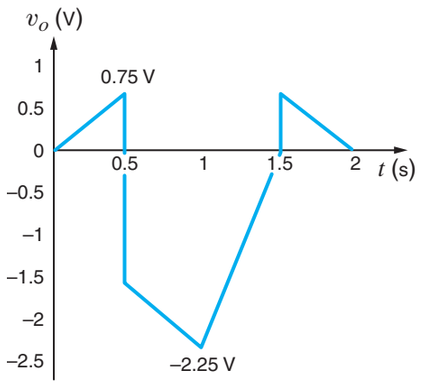
3.84 $V_o = 6$ V

3.89 $V_o = -3.33$ V

3.95 $I_o = 2.88$ mA

CHAPTER 4

4.1



4.9 $\frac{V_o}{V_{in}} = 7.06$
$I_o = 606\ \mu$A

4.12 $I_1 = 1$ mA $\quad I_2 = 0$ A $\quad I_3 = 1$ mA

4.17 **(a)** $V_o = 4V_1 - V_2$
(b) $V_o = 2$ V
(c) $4\text{ V} \le V_2 \le 28\text{ V}$

4.21 $\frac{i_o}{v_1} = -\frac{1}{R_I}$

4.25 $V_o = 0$ V

4.30 $V_o = -11.2$ V

4.35 $V_o = -11.43$ V

4.38 $v_o = v_1\left[1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}\right]\left(-\frac{R_2}{R_1}\right)$

CHAPTER 5

5.1 $I_o = 1.14$ mA

5.5 $I_o = -3.2$ mA

5.9 $I_o = -2$ mA

5.14 $V_o = 14.4$ V

5.19 $I_o = 0.909$ mA

5.22 $I_o = 1.6$ mA

5.28 $V_o = 4.8$ V

5.33 $I_o = 5$ mA

5.37 $V_o = 65.79$ V

5.44 $I_o = 1.6$ mA

5.50 $I_o = 2.57$ mA

5.55 $I_o = 0.909$ mA

5.59 $R_{Th} = 400\ \Omega$

5.65 $V_o = -0.316$ V

5.70 $V_o = -5$ V

5.76 $P_{2\text{ mA}} = 12$ mW

5.81 $V_o = 2$ V

5.85 $I_o = -0.5$ mA

5.94 $I_o = 1.6$ mA

5.98 $R_L = 99.0\ \Omega$

CHAPTER 6

6.3 $v = 40$ V

6.6 $i(t) = 9.23\cos 377t$ A

6.9 $v(t) = \begin{cases} 0 \text{ V} & t < 0 \\ 100\,t\text{V} & 0 < t < t_1 \\ 0.2 \text{ V} & t > t_1 \end{cases}$

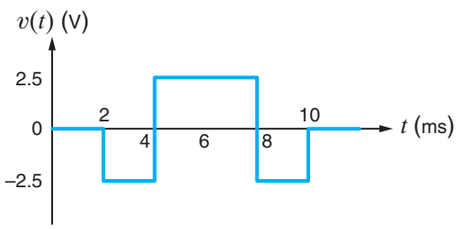
6.13 $i(t) = \begin{cases} 0 & t < 0 \\ -12 \text{ mA} & 0 < t < t_1 \\ 0 & t_1 < t < t_2 \\ 8 \text{ mA} & t_2 < t < t_3 \\ 0 & t > t_3 \end{cases}$

6.17 $v(t) = \begin{cases} 0 & t < 0 \\ 2500t^2 \text{ V} & 0 < t < t_1 \\ 4 \text{ V} & t > t_1 \end{cases}$

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

(b) $w(t) = 0.2\sin^2 377t$ J

6.27



6.33 $i(t) = \begin{cases} 0 \text{ A} & t < 0 \\ t/2 \text{ A} & 0 \le t \le 2 \text{ ms} \\ (3 \times 10^{-3} - t) \text{ A} & 2 \text{ ms} \le t \le 3 \text{ ms} \\ 0 \text{ A} & t \ge 3 \text{ ms} \end{cases}$

6.38 **(a)** $L = 10 \text{ mH} \pm 10\%$ $\quad 9 \text{ mH} \le L \le 11 \text{ mH}$

(b) $L = 2 \text{ nH} \pm 5\%$ $\quad 1.9 \text{ nH} \le L \le 2.1 \text{ nH}$

(c) $L = 68\ \mu\text{H} \pm 10\%$ $\quad 61.2\ \mu\text{H} \le L \le 74.8\ \mu\text{H}$

6.43 $P_{R_2} = 21.33$ W $\quad w_C = 144$ J

6.49 $V_2 = 8$ V $\quad V_1 = 4$ V

6.54 $C_T = 2\ \mu$F

6.60 $C_{\text{eq}} = 3.18\ \mu$F

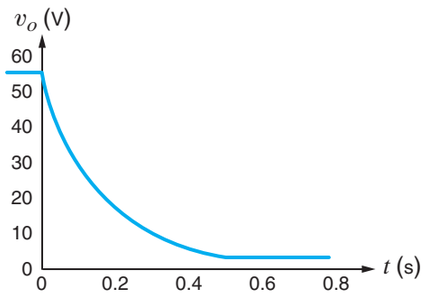
6.67 $L_{AB} = 6$ mH

6.73 $v_o(t) = 3.81\cos(377t)$ V

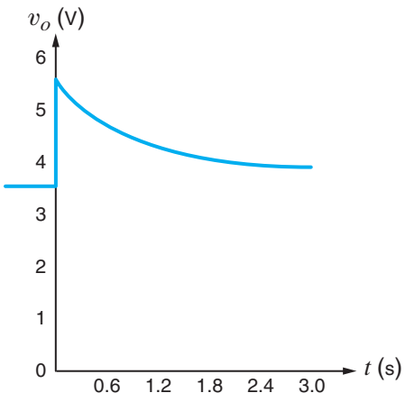
CHAPTER 7

7.3 $v_C(t) = 12 - 8e^{-\frac{t}{0.6}}$ V

7.8 $v_o(t) = 4 + 50e^{-7.5t}$ V

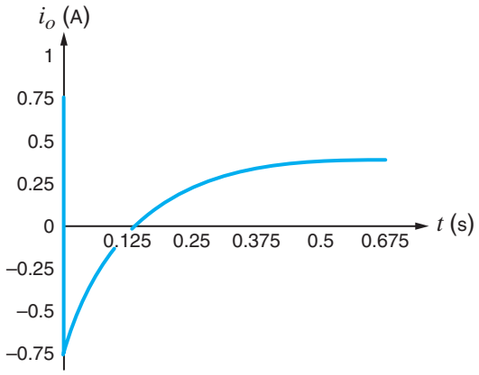


7.12 $v_o(t) = 4 + 1.6e^{-\frac{t}{0.6}}$ V



7.19 $i_o(t) = 0.67e^{-5t}$ A

7.23 $i_o(t) = 0.375 - 1.125e^{-8t}$ A



7.28 $i_o(t) = 2 + 0.5e^{-3.75t}$ mA

7.33 $v_o(t) = 4.36e^{-2.73t}$ V

7.37 $i_o(t) = 3 + 0.33e^{-1.67t}$ mA

7.41 $i_o(t) = 2.4 - 2.4e^{-2.5\times10^5 t}$ mA

7.47 $v_o(t) = 12 - 3e^{-6t}$ V

7.52 $i(t) = -5 + 2.5e^{-4t}$ A

7.57 $v_o(t) = 16 - 2.8e^{-1.5t}$ V

7.63 $v_o(t) = \begin{cases} 8 - 8e^{-1.25t} \text{ V} & 0 \le t \le 1 \\ 5.71e^{-1.25(t-1)} \text{ V} & t > 1 \end{cases}$

7.68 $v_R(0^+) = -8$ V

$i_2(0^+) = 0$ A

$i_1(\infty) = 0$ A

7.72 $L = 2$ H

$R_1 = 3\ \Omega$

$R_2 = 5\ \Omega$

7.75 **(a)** $s^2 + 2s + 5 = 0$

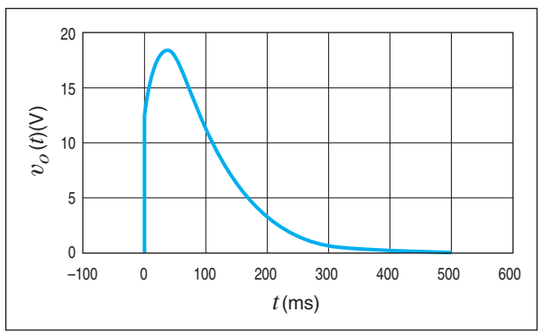
(b) $s_{1,2} = \dfrac{-2 \pm \sqrt{4 - 20}}{2} = -1 \pm j2$ rad/s

(c) underdamped!

$v_1(t) = e^{-t}[A_1 \cos 2t + A_2 \sin 2t]$

7.80 $v(t) = e^{-4t}[10 \cos 2t + 40 \sin 2t]$ V

7.85 $v_o(t) = 12e^{-20t} + 720te^{-20t}$ V



7.90 $i(t) = (4.04e^{-T_2 t} - 1.54e^{T_1 t})$ A $\quad T_1 = 0.08$ s, $T_2 = 12.42$ s

7.95 $i(t) = e^{-3t}[3 \cos t + 5.4 \sin t]$ A

CHAPTER 8

8.1 $f = 63.7$ Hz $\quad T = 15.7$ ms

8.5 **(a)** $i = v/R \quad i(t) = 5\cos(377t + 180°)$ A

$\mathbf{I} = 5\angle 180°$ A

(b) $i(t) = 6\sin(377t + 45°) = 6\cos(377t - 45°)$ A

$\mathbf{I} = 6\angle -45°$

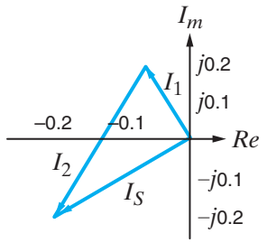
8.9 $\mathbf{Z} = 1.00 + j3.77\ \Omega$

8.14 $\mathbf{Z} = 2.83\angle 16.9°\ \Omega$

8.18 $v(t) = 5.16\cos(377t + 45.1°)$ V

8.23 $L = 10$ mH

8.29 $v_o(t) = 7.08\cos(10^4 t + 36.8°)$ V



8.36 $\mathbf{V}_o = 45\angle -23.1°$ V

8.41 $\mathbf{I}_o = 2.83\angle 45°$ A

8.46 $\mathbf{Z} = -0.508 + j0.586\ \Omega$

$\mathbf{Z} = 0.776\angle 130.9°\ \Omega$

8.52 $\mathbf{V}_o = 3.58\angle 153.4°$ V

8.58 $\mathbf{V}_o = 4.56\angle 37.9°$ V

8.64 $\mathbf{V}_o = 5.55\angle 86.8°$ V

8.69 $\mathbf{V}_o = 2.53\angle 71.6°$ V

8.73 $\mathbf{V}_o = 4.71\angle -98.1°$ V

8.77 $\mathbf{I}_o = 2\angle -36.9°$ A

8.82 $\mathbf{V}_o = 5.55\angle 86.8°$ V

8.88 $\mathbf{V}_{oc} = -4 + j4$V $\quad \mathbf{Z}_{\text{Th}} = 2.24\angle 117°\ \Omega$

8.93 $\mathbf{V}_o = 4\angle 90°$ V

8.98 $\mathbf{V}_o = 37.6\angle -60.7°$ V

8.103 $\mathbf{I}_o = 17.7\angle -137°$ A

CHAPTER 9

9.2 $v(t) = 20\cos(\omega t + 66.9°)$ V
$p(t) = 40\cos(2\omega t + 96.9°) + 32.0$ W

9.8 $P = 4.31$ W

9.13 $P_{1\,\Omega} = 2.25$ W

9.18 $P_{I_S} = 0.660$ W supplied
$P_{V_S} = 0.394$ W supplied

9.23 $P_{R_L} = 9.92$ W

9.28 $\mathbf{Z}_L = 2 + j2\ \Omega$
$P_L = 1.05$ W

9.34 $\mathbf{Z}_L = 2.8 + j0.4\ \Omega$
$P_L = 1.32$ W

9.39 $\mathbf{Z}_L = 4 + j1\ \Omega$
$P_L = 5.00$ W

9.43 $V_{\text{rms}} = 1.87$ V

9.49 $I_{\text{rms}} = 3.27$ A

9.53 pf $= 0.833$

9.57 pf $= 0.65$ lagging

9.63 $\mathbf{V}_S = 303\angle 11.1°$ V_{rms}
$\text{pf}_S = 0.73$ lagging

9.67 $\text{pf}_S = 0.72$ lagging
$\mathbf{S}_{V_S} = 46.3\angle 43.8°$ kVA

9.73 $C = 563\ \mu\text{F}$

9.79 $|\mathbf{I}_{\text{man}}| = \begin{cases} 238\text{ mA} & \text{dry skin} \\ 14.4\text{ A} & \text{wet skin} \end{cases}$

CHAPTER 10

10.5 $\dfrac{\mathbf{V}_o}{\mathbf{V}_S} = 0.140\angle 24.8°$

10.11 $\mathbf{V}_o = 10.15\angle 10.8°$ V

10.15 $\mathbf{V}_o = 2.17\angle 5.19°$ V

10.18 $\mathbf{I}_o = 3.25\angle 66.0°$ A

10.25 $\mathbf{V}_o = 1.24\angle -120°$ V

10.31 $\mathbf{V}_o = 12.2\angle 15.0°$ V

10.36 $\mathbf{V}_o = 2.5\angle 36.9°$ V

10.40 $\mathbf{Z}_{\text{in}} = 4.6 + j3.2\ \Omega$

10.47 $w(t = 1\text{ ms}) = 94.1\ \mu\text{J}$

10.52 $\mathbf{V}_1 = 5.36\angle 3.4°$ V
$\mathbf{V}_2 = n\mathbf{V}_1 = 10.72\angle 3.4°$ V
$\mathbf{I}_2 = -\mathbf{I}_1/n = 1.90\angle 138°$ A

10.57 $\mathbf{I}_1 = -1.84\angle 0°$ A $\quad \mathbf{V}_1 = 6.48\angle 0°$ V
$\mathbf{I}_2 = 0.46\angle 0°$ A $\quad \mathbf{V}_2 = 25.9\angle 0°$ V

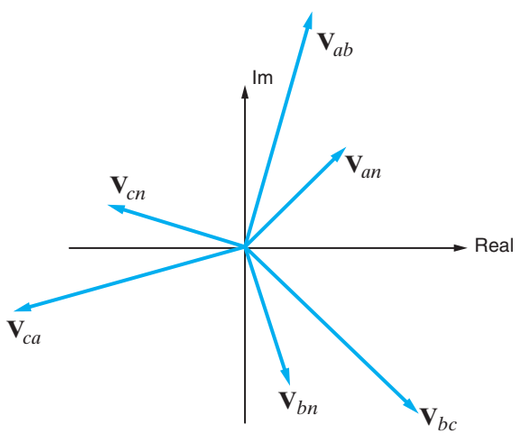
10.63 $\mathbf{V}_o = 1.80\angle -140°$ V

10.69 $\mathbf{V}_S = 14.14\angle 165°$ V

10.73 $\mathbf{V}_S = 30.9\angle 153°$ V

CHAPTER 11

11.2 $\mathbf{V}_{an} = 100\angle 45°$ V rms
$\mathbf{V}_{bn} = 100\angle -75°$ V rms
$\mathbf{V}_{cn} = 100\angle 165°$ V rms
$\mathbf{V}_{ab} = 100\sqrt{3}\angle 75° = 171\angle 75°$ V rms
$\mathbf{V}_{bc} = 171\angle -45°$ V rms
$\mathbf{V}_{ca} = 171\angle -165°$ V rms



11.9 $\mathbf{I}_{aA} = 2.00\angle -73.6°$ A rms
$\mathbf{I}_{bB} = 2.00\angle 166°$ A rms
$\mathbf{I}_{cC} = 2.00\angle 46.4°$ A rms

11.13 $\mathbf{Z} = 3.5 - j1\ \Omega$

11.16 $\mathbf{V}_{ab} = 217\angle 40°$ V rms

11.23 $\mathbf{Z}_L = 10 + j12\ \Omega$

11.29 $|\mathbf{V}_{AB}| = 199$ V rms

11.34 $\mathbf{V}_{AB} = 208\angle 60°$ V rms

11.37 $\mathbf{V}_{an} = 103\angle 43.7°$ V rms
$\mathbf{V}_{bn} = 103\angle -76.3°$ V rms
$\mathbf{V}_{cn} = 103\angle 163.7°$ V rms

11.41 $\mathbf{I}_{AN1} = 9.38\angle -4.39°$ A rms
$\mathbf{I}_{BN1} = 9.38\angle -124.4°$ A rms
$\mathbf{I}_{CN1} = 9.38\angle 115.6°$ A rms

11.47 $\mathbf{Z}_L = 12\angle 25°\ \Omega$

11.54 $\mathbf{S}_3 = 18.4\angle 49.4°$ kVA

11.59 $\text{pf}_{\text{new}} = 0.966$ lagging

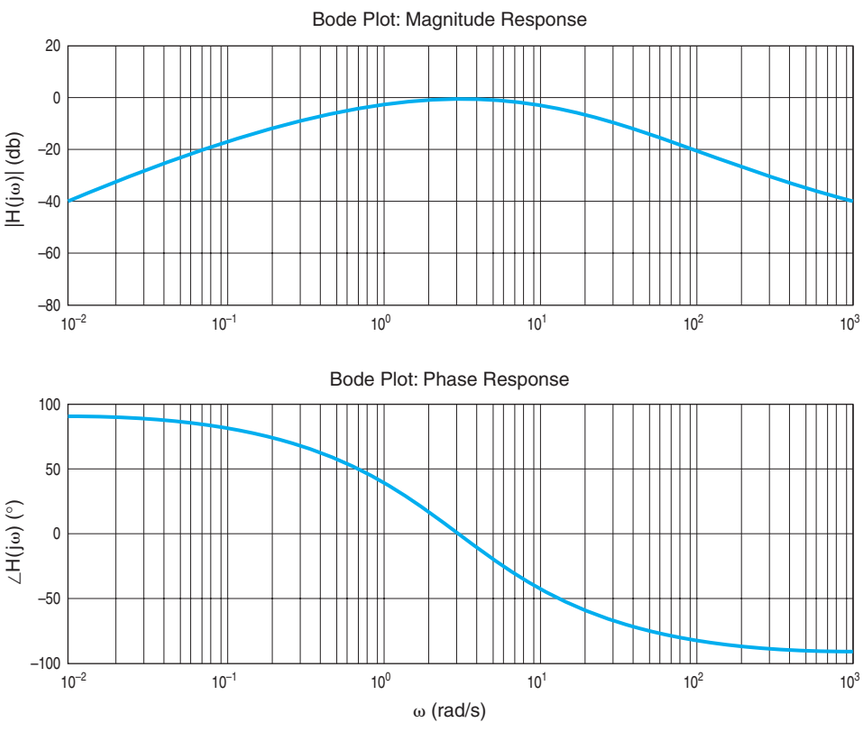
11.63 $C = 16.4\ \mu\text{F}$

CHAPTER 12

12.1 $$\mathbf{Z} = R\left[\frac{s^2 + \frac{s}{RC} + \frac{1}{LC}}{s^2 + \frac{1}{LC}}\right]$$

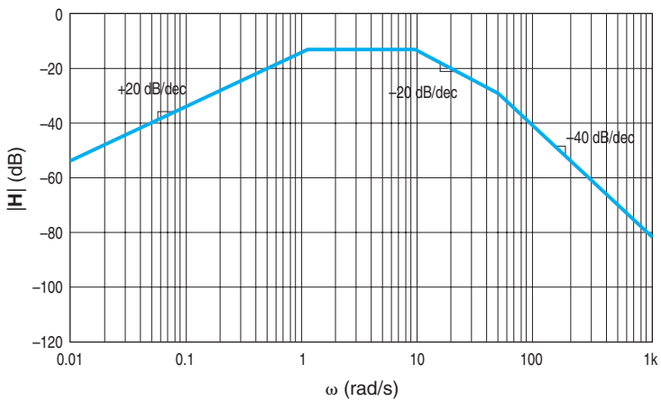
12.5 $$\mathbf{Z}_i = \frac{1.8s + 1}{s}$$

12.9 $$\mathbf{H}(j\omega) = \frac{10(j\omega)}{(j\omega + 1)(j\omega + 10)}$$

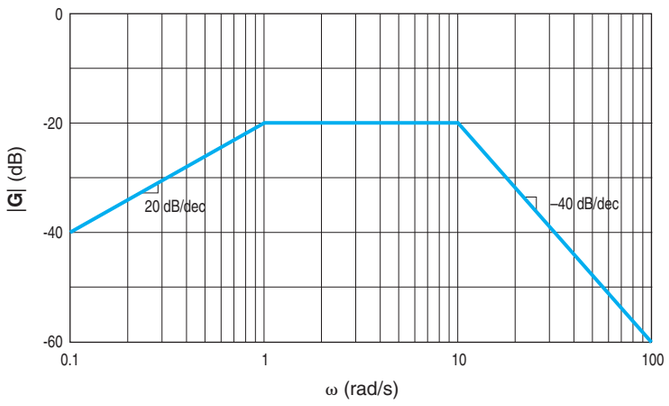


12.13 $\mathbf{H}(j\omega) = \dfrac{100(j\omega)}{(j\omega + 1)(j\omega + 10)(j\omega + 50)}$

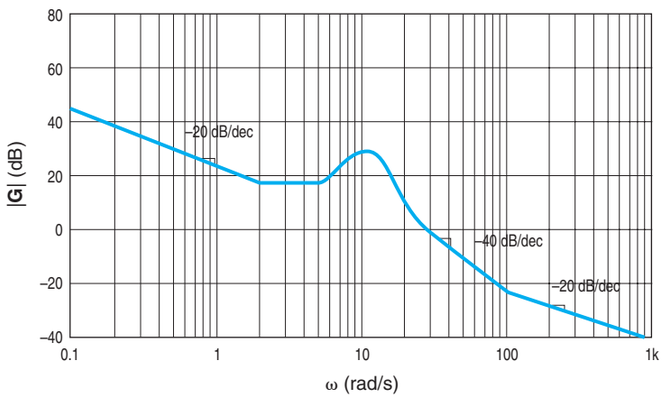
$$|\mathbf{H}|\Big|_{\omega=\frac{1}{100}} \simeq 2 \times 10^{-3} = -54 \text{ dB}$$



12.17 $|\mathbf{G}|\Big|_{\omega=0.1} \approx \dfrac{10(0.1)}{1(10)^2} = \dfrac{1}{100} = -40 \text{ dB}$



12.23 $|\mathbf{G}|\Big|_{\omega=0.1} \approx \dfrac{10(2)(100)}{(0.1)(100)} = 200 = 46 \text{ dB}$



12.29 $\mathbf{H}(j\omega) = \dfrac{5.33 \times 10^4 (j\omega + 1)(j\omega + 120)}{(j\omega + 10)(j\omega + 80)^2}$

12.34 $\mathbf{G}(j\omega) = \dfrac{288(j\omega + 100)^2}{j\omega(j\omega + 900)\left[(j\omega)^2 + j4\omega + 400\right]}$

12.39 $\omega_o = 7.07$ krad/s
$Q = 14.14$
$\omega_{\max} = 7.06$ krad/s
$|\mathbf{V}_{o\max}| = 84.9$ V

12.44 $Q = 3.33$
$C = 100\ \mu$F
BW $= 300$ rad/s

12.49 $R = 2000\ \Omega$
$C = 25\ \mu$F
$L = 10$ nH

12.53 $L_{\text{new}} = 50\ \mu$H
$C_{\text{new}} = 12.5\ \mu$F
$R = 2\ \Omega$

12.57 Filter is highpass

12.63 **(a)** $I_{ABC} = 50\ \mu$A
$R_G = 100$ kΩ
(b) $0.952\text{ mS} \le g_m \le 1.053\text{ mS}$

12.69 **(a)** $R_G = 100$ MΩ
(b) $R = 500\ \Omega$

12.75 Arbitrarily select $C = 1$ nF, yields $R = 6.87$ kΩ

CHAPTER 13

13.1 $\mathcal{L}\left[f(t)\right] = e^{-(s+a)}$

13.5 $\mathbf{F}(s) = e^{-(s+a)}\left\{\dfrac{\omega\cos\omega}{(s+a)^2+\omega^2} + \dfrac{(s+a)\sin\omega}{(s+a)^2+\omega^2}\right\}$

13.8 $\mathbf{F}(s) = \dfrac{e^{-(s+a)}}{s+1}$

13.12 **(a)** $f(t) = \dfrac{1}{6}\left[1 + 3e^{-2t} - 4e^{-3t}\right]u(t)$
(b) $f(t) = \dfrac{1}{2}\left[1 - 2e^{-t} + 3e^{-2t}\right]u(t)$

13.16 **(a)** $f(t) = 10e^{-t}\cos(t - 90°)u(t)$
(b) $f(t) = 10e^{-2t}\cos(t)u(t)$

13.21 **(a)** $f(t) = \left[-\dfrac{1}{2}e^{-2t} + 1.58e^{-t}\cos(t - 18.4°)\right]u(t)$
(b) $f(t) = \left[\delta(t) - e^{-2t}\cos(t + 90°)\right]u(t)$

13.27 **(a)** $f(t) = \left[te^{-t} - 3e^{-t} + 4e^{-2t}\right]u(t)$
(b) $f(t) = \dfrac{1}{16}\left[t - 4te^{-4t} - e^{-4t}\right]u(t)$

13.32 $f(t) = 2e^{-8(t-1)} - e^{-4(t-1)}u(t-1)$

13.37 $y(t) = \left[e^{-t} - e^{-2t}\right]u(t)$

13.41 *Initial values*
(a) $\lim\limits_{t\to 0} f(t) = 2$
(b) $\lim\limits_{t\to 0} f(t) = 2$
(c) $\lim\limits_{t\to 0} f(t) = 2$

Final values
(a) $\lim\limits_{t\to \infty} f(t) = 4$
(b) $\lim\limits_{t\to \infty} f(t) = 0$
(c) $\lim\limits_{t\to \infty} f(t) = 0$

13.45 $i(t) = 2e^{-4.5t}u(t)$ A

13.48 $v_o(t) = 2.67e^{-1.67t}u(t)$ V

CHAPTER 14

14.1 $\mathbf{Z}_{(s)} = \dfrac{6s + 8}{6s^2 + 16s + 11}$

14.6 $v_o(t) = \left[4\sqrt{2}\,e^{-t}\cos(t - 45°)\right]u(t)$ V

14.11 $v_o(t) = \left[2\sqrt{2}\,e^{-t}\cos(t - 45°)\right]u(t)$ V

14.16 $v_o(t) = \left[2\left(1 - e^{-t}\right)\right]u(t)$ V

14.21 $v_o(t) = \left[4 - 5e^{-t} + 2e^{-2t}\right]u(t)$ V

14.25 $v_o(t) = \left[1.5\left(1 - e^{-4t}\right)\right]u(t)$ V

14.30 $v_o(t) = 9.6e^{-t}u(t)$ V

14.35 $v_o(t) = 1.15\left[e^{-0.42t} - e^{-1.58t}\right]u(t)$ V

14.38 $v_o(t) = 12e^{-2t}u(t)$ V

14.42 $v_o(t) = \left(4 - \dfrac{4}{3}e^{-4t}\right)u(t) - \left(4 - \dfrac{4}{3}e^{-4(t-1)}\right)u(t-1)$ V

14.45 $\dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{s+1}{14s+6}$

14.51 $\dfrac{\mathbf{V}_o}{\mathbf{V}_s} = \dfrac{-s}{s^2 + 2s + 2}$ Roots at $s = \dfrac{-2 \pm \sqrt{4 - 8}}{2} = -1 \pm j1$ {Complex conjugate pales. Network is underdamped!}

14.54 $\omega_o = \sqrt{40}$ rad/s

$2\zeta\omega_o = 22 \Rightarrow \zeta = 1.74$ overdamped

14.59 $v_o(t) = 4.71\cos(t - 45°)$ V

14.63 $v_o(t) = 5.22\cos(2t + 97.8°)$ V

CHAPTER 15

15.3 $f(t) = \sum_{\substack{n=-\infty \\ n \text{ odd}}}^{\infty} \frac{2}{jn\pi} e^{jn\omega_o t}$

15.8 $v(t) = \frac{2}{\pi} \sum_{\substack{n=1 \\ n \text{ odd}}}^{\infty} \frac{3}{n}\sin(n\pi t/2) - \frac{1}{n}\cos(n\pi t/2)$ V

15.13 $a_n = \frac{4}{(n\pi)^2}(\cos(n\pi/2) - 1) + \frac{4}{n\pi}\sin(n\pi/2)$

$a_o = -\frac{1}{4} \quad b_n = 0$

15.18 $v(t) = -\frac{\pi}{4} + \sum_{n=1}^{\infty} \frac{1}{\pi n^2}(\cos(n\pi) - 1)\cos(nt) + \frac{1}{n}(1 - 2\cos(n\pi))\sin(nt)$ V

15.24 $f(t) = -4\sin(20\pi t) - 5\sin(40\pi t) - 3\sin(60\pi t) - 2\sin(80\pi t) - \sin(100\pi t)$

15.29 $v_o(t) = \frac{1}{4} + 0.285\cos(t + 26.6°) + 0.023\cos(t - 49°)$ V

15.32 P = 127.6 W

15.37 $v_o(t) = 1.27\cos(4t - 58°)$ V

15.41 $w = 0.106$ J

CHAPTER 16

16.1 **(a)** $\mathbf{y}_{11} = \left.\frac{\mathbf{I}_1}{\mathbf{V}_1}\right|_{\mathbf{V}_2=0} = \frac{1}{\mathbf{Z}_L}$ $\mathbf{y}_{21} = -\frac{1}{\mathbf{Z}_L}$

$\mathbf{y}_{12} = -\frac{1}{\mathbf{Z}_L}$ $\mathbf{y}_{22} = \frac{1}{\mathbf{Z}_L}$

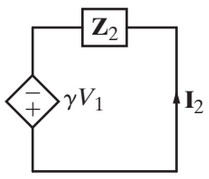
(b) $\mathbf{z}_{11} = \left.\frac{\mathbf{V}_1}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0} = \mathbf{Z}_L$ $\mathbf{z}_{21} = \left.\frac{\mathbf{V}_2}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0} = \mathbf{Z}_L$

$\mathbf{z}_{12} = \mathbf{Z}_L$ $\mathbf{z}_{22} = \mathbf{Z}_L$

16.7 $\mathbf{y}_{11} = \left.\frac{\mathbf{I}_1}{\mathbf{V}_1}\right|_{\mathbf{V}_2=0} = \frac{1}{\mathbf{Z}_1}$ $\mathbf{y}_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{V}_2}\right|_{\mathbf{V}_1=0} = \frac{1}{\mathbf{Z}_2}$

$\mathbf{y}_{21} = \left.\frac{\mathbf{I}_2}{\mathbf{V}_1}\right|_{\mathbf{V}_2=0} = \frac{\gamma}{\mathbf{Z}_2}$ $\mathbf{y}_{12} = \left.\frac{\mathbf{I}_1}{\mathbf{V}_2}\right|_{\mathbf{V}_1=0} = 0$

For $\mathbf{y}_{21}$



$\mathbf{I}_2 = \frac{\gamma\mathbf{V}_1}{\mathbf{z}_2}$

$\frac{\mathbf{I}_2}{\mathbf{V}_1} = \frac{\gamma}{\mathbf{z}_2}$

16.11 $\frac{\mathbf{V}_2}{\mathbf{V}_1} = -438$

16.18 $\mathbf{h}_{11} = \left.\frac{\mathbf{V}_1}{\mathbf{I}_1}\right|_{\mathbf{V}_2=0} = R_1 // R_2 = \frac{2}{3}\,\Omega$

$\mathbf{h}_{21} = \left.\frac{\mathbf{I}_2}{\mathbf{I}_1}\right|_{\mathbf{V}_2=0} = \frac{-R_1}{R_1 + R_2} = -\frac{1}{3}$

$\mathbf{h}_{12} = \left.\frac{\mathbf{V}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_1=0} = \frac{R_1}{R_1 + R_2} = \frac{1}{3}$

$\mathbf{h}_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{V}_2}\right|_{\mathbf{I}_1=0} = \frac{1}{R_3 // (R_1 + R_2)} = \frac{2}{3}\,S$

16.22 **(a)** $\mathbf{A} = \left.\frac{\mathbf{V}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = 1$ $\mathbf{B} = \left.\frac{\mathbf{V}_1}{-\mathbf{I}_2}\right|_{\mathbf{V}_2=0} = \mathbf{Z}_L$

$\mathbf{C} = \left.\frac{\mathbf{I}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = 0$ $\mathbf{D} = \left.\frac{\mathbf{I}_1}{-\mathbf{I}_2}\right|_{\mathbf{V}_2=0} = 1$

(b) $\mathbf{A} = \left.\frac{\mathbf{V}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = 1$ $\mathbf{B} = \left.\frac{\mathbf{V}_1}{-\mathbf{I}_2}\right|_{\mathbf{V}_2=0} = 0$

$\mathbf{C} = \left.\frac{\mathbf{I}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = \frac{1}{\mathbf{Z}_L}$ $\mathbf{D} = \left.\frac{\mathbf{I}_1}{-\mathbf{I}_2}\right|_{\mathbf{V}_2=0} = 1$

16.26 $\mathbf{A} = \left.\dfrac{\mathbf{V}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = \dfrac{R_1 + R_2}{\gamma + R_1}$

$\mathbf{B} = \dfrac{R_1R_2 + R_1R_3 + R_2R_3 - \gamma R_2}{\gamma + R_2}$

$\mathbf{C} = \left.\dfrac{\mathbf{I}_1}{\mathbf{V}_2}\right|_{\mathbf{I}_2=0} = \dfrac{1}{\gamma + R_2}$

$\mathbf{D} = \left.\dfrac{\mathbf{I}_1}{-\mathbf{I}_2}\right|_{\mathbf{V}_2=0} = \dfrac{R_2 + R_3}{\gamma + R_2}$

16.32 $\mathbf{z}_{11} = \dfrac{\mathbf{y}_{22}}{\Delta\mathbf{y}} = 3\Omega$ $\quad \mathbf{z}_{21} = \dfrac{-\mathbf{y}_{21}}{\Delta\mathbf{y}} = 2\Omega$

$\mathbf{z}_{12} = \dfrac{-\mathbf{y}_{12}}{\Delta\mathbf{y}} = 2\Omega$ $\quad \mathbf{z}_{22} = \dfrac{\mathbf{y}_{11}}{\Delta\mathbf{y}} = 5\Omega$

16.37 $\mathbf{Y}_{\text{in}} = \dfrac{2 + j2}{1 + j2}\,\text{S}$

16.42 $\mathbf{V}_o = 2.32\angle 157^\circ\ \text{V}$