Answers to problems

Chapter 1

1. (a) Source; 6 W. (b) 110 C; 330 J.
2. Sources: A and E. Sinks: B, C, and D. 27 W.
3. 9 Ω; 1/2 S.
4. $V_{AE}=1$ V; $V_{BE}=1$ V; $V_{CE}=-0.5$ V; $I_{AB}=0$; $I_{CB}=-0.3$ A.
5. 0.624 J; 2.63 kV.
6. $+1/84\ \mu$F.
7. 1 H; 2 A; $-1/2$ V; 8 J.

Chapter 2

1. 5 V; 40.8 mΩ.
2. (a) 700 V; 250 Ω. (b) 2.8 A; 4 mS.
3. 0.347 V; 0.207 V.
4. 104 V.
5. $(21V_1-V_2)/109$ A; $(12V_1+15V_2)/109$ A; $(13V_1-11V_2)/109$ A
   1/109 A; 21/109 A; 18/109 A
   2/21 V; 109/21 Ω.
6. 11 V; $5\frac{1}{2}$ V.
7. Four; two; -5.37 V.
8. 1/2 A.
9. $18\frac{1}{3}$ A; $71\frac{2}{3}$ V.
10. $5r/4\ \mu$A.
11. 10 kΩ; 30 kΩ.
12. 2 Ω; 4.5 Ω.
13. 5/6 Ω.
14. 40 mΩ (approx); 4 A (approx).
15. Minimum at third load point; 1.32×10^{-4} m^2

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Chapter 3

1. $(E^2+\frac{1}{2}E_m^2)/R$; $(E^2+\frac{1}{2}E_m^2)^{1/2}$.
2. (a) $1/\sqrt{3}$; $2/\sqrt{3}$ (b) $1/\sqrt{2}$; $\pi/2\sqrt{2}$.
3. (a) $10+j10=14.1\underline{/45}$; $0.05-j0.05=0.07\underline{/-45}$.
   (b) $10-j10=14.1\underline{/-45}$; $0.05+j0.05=0.07\underline{/45}$.
   (c) $25.9+j18.55=31.9\underline{/35.7}$; $0.25-j0.18=0.031\underline{/-35.7}$.
4. $460\cos\omega t$.
5. $144\underline{/33.7}$; 17.14 Ω; 109 mH; 139 μF.
6. 288 V.
7. 45°; 45°.
8. $\omega=[(1/C_1+1/C_2+1/C_3)/L]^{1/2}$.
12. 4.26 kΩ; 213 pF; 39.2 kΩ; 2.62×10^{-3}.
13. $1/(\omega_0^2C_1C_2R)+j(1/\omega_0C_1+1/\omega_0C_2)$
15. $R+j(\omega L-1/\omega C-1/\omega C_1)$; $-j(\omega M-1/\omega C_1)$.
16. $C_0/(1+1/Q^2)$.
17. 35.6 kHz; 0.15 V.
18. (a) $20+j20$; $2.83\cos(10t-45)$. (c) $\omega_1=\sqrt{50}$; $\omega_2=\sqrt{150}$.
19. 15.9 kHz

Chapter 4

1. (a) 43.6 W; 129.2 W; 61.7 W. (b) 234 W; +207 VAr. (c) 0.75.
2. $-j1.77\,\Omega$ or $+j7.69\,\Omega$.
3. $66.7\underline{/-53.1}$ A; $82.1\underline{/6.1}$ kV.
4. (a) $21.5\underline{/-63.4}$ A; $9.57\underline{/53.13}$ A; $19.2\underline{/-36.9}$ A.
   (b) $5+j10\,\Omega$; $15-j20\,\Omega$. (c) $10+j7.5\,\Omega$.
5. 3.31 A; 110 W; 210 VAr.
6. $1.2\underline{/0}$ A; $0.4\underline{/180}$ A; $0.28\underline{/135}$ A.
7. (a) $237\underline{/-3.16}$ V. (b) $250\underline{/-3.8}$ V.
8. 96.5%; 6.36 A. Readings on primary: 500 A; 545 V; 26 kW.
9. (a) 8 Ω. (b) 1/4 A; 1/2 W. (c) $2\frac{1}{2}$ W; $17\frac{1}{2}$ W.
10. 2.1×10^{-8} W; 2.8×10^{-8} W; 13×10^{-8} F.
11. Ratio = 1 : 11; 1.25 mV.
12. (a) $10-j12\,\Omega$. (b) 19.4 W.
13. $R=50\,\Omega$; $X=0\,\Omega$; 1/2 W; 79.1 μH; 317 pF.
14. 0.33 μF (Z_1), 0.33 mH (Z_2) or 0.33 mH (Z_1), 0.33 μF (Z_2). Ratio: 0.33.
15. 11.1 Ω.

Chapter 5

1. (a) $18.6\underline{/3.4}$ A; $18.6\underline{/-116.6}$ A; $18.6\underline{/123.4}$ A.
   (b) $32.1\underline{/-26.6}$ A; $32.1\underline{/-146.6}$ A; $32.1\underline{/93.4}$ A.
   (c) 0.894.

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(d) 20.6 kW.
(e) $(20+j10)/3\,\Omega$.

2. 6.97 A.
3. $15.6 \pm j25.6\,\Omega$.
4. (a) 231 A. (b) 0.986. (c) 94.7 kW.
5. 7.19 kW; 5.74 kW.
6. (a) $V_{ab}=440/\underline{0}$ V; $V_{bc}=440/\underline{-120}$ V; $V_{ca}=440/\underline{120}$ V.
   $I_a=24.7/\underline{-63.6}$ A; $I_b=11.1/\underline{-36.8}$ A; $I_c=35/\underline{124.6}$ A.
   $I_1=3.04/\underline{-90}$ A; $I_2=13.2/\underline{-47.5}$ A; $I_3=22/\underline{120}$ A.
   (c) $V_L=478/\underline{0}$.
7. Power $=W-V^2R/(R^2+X^2)$.
8. (a) 0.513 MW/line. (b) 65.4 MW. (c) 139 kV.
9. 25.5 μF.
10. 6.2 kV (line); 97.7%.
11. 551 A; 400 V.

Chapter 6

1. 1.0 s. (a) 0.69 s; 3 s.
2. (a) 12 mA; zero. (b) $i_c=12e^{-20000t}$.
   (c) Zero; 12 V. (d) 360×10^{-8} J. (e) 720×10^{-8} J.
3. $i_1=\dfrac{V}{R_2}e^{-t/T}$; $i_2=\dfrac{V}{R_1+R_2}(1-e^{-t/T})$; $i=i_1+i_2$.
   $T=CR_1R_2/(R_1+R_2)$; 0.342 mA; 0.25 mA.
4. (a) $i_c=10e^{-100t}$ A; $v_c=200(1-e^{-100t})$ V.
   (b) $i_c=-10e^{-66.7t}$ A; $v_c(0.1)=-100$ V.
   (c) $i_c=15e^{-100t}$ A; $v_c=100(2-3e^{-100t})$ V.
5. 2.3 ms (closing); 0.6 ms (opening).
6. (a) $i_L=8.94\cos(10^3t-63.4)-2e^{-500t}$mA (b) 140°.
7. $(15t+0.3)$ V; 0.3 V.
8. (a) 0.833 mA; 0.833 mA; 0.833 V.
   (b) 0.833 mA; 0.833 mA; 0.833 V; -60 mA/s; -30 mA/s; 1500 V/S.
   (c) 0.083 mA; -0.67 mA; 2.33 V.
9. $R_1=R_2$; $L=CR_1^2$.
10. $R>2\sqrt{(L/C)}-r$.
11. $$\left[LCD^2+\left(CR_3+\frac{L}{R}\right)D+\frac{R_3}{R}+1\right]v_2(t)=$$
    $$\left[LCD^2+\left(CR_3+\frac{L}{R_1}\right)D+\frac{R_3}{R_1}\right]v_1(t)$$
    where $R=R_1R_2/(R_1+R_2)$

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$A_1e^{-\alpha_1 t}+A_2e^{-\alpha_2 t}$ where α_1 and α_2 are given by:

$$\alpha_1,\alpha_2=\left(\frac{R_3}{2L}+\frac{1}{2RC}\right)\pm\left[\left(\frac{R_3}{2L}+\frac{1}{2CR}\right)^2-\frac{1}{LC}\left(1+\frac{R_3}{R}\right)\right]^{1/2}.$$

12. $\frac{E}{2}[e^{-Rt/(L+M)}-e^{-Rt/(L-M)}]$.

13. (a) $v_c(t)=0.67+e^{-\alpha t}(0.33\cos\omega t+3.35\sin\omega t)$
where $\alpha=0.75$, $\omega=0.97$.
(b) $v_c(t)=0.51\cos(2t-130)+e^{-\alpha t}(1.33\cos\omega t+4.93\sin\omega t)$

$$i(t)=\frac{v_c(t)}{2}+\frac{1}{0.5}\frac{d}{dt}v_c(t).$$

14. (a) 0.1 mH; 200. (b) 200 kΩ.

16. $v_c(t)=10(8-7e^{-0.318t})$;
$i(t)=1+3.5e^{-0.318t}$.

17. (a) $a=v_2(0)$; $b=2i_L(0)$; $c=\frac{1}{2}[3v_1(0)+v_2(0)]$.
(b) $v_2(0)=1$; $i_L(0)=1$; $v_1(0)=1$.
(c) $v_2(t)=1-e^{-t}-\frac{2}{\sqrt{3}}e^{-t/2}\sin\frac{\sqrt{3}}{2}t$.

18. $V(s)=\frac{10}{s^2}(1-e^{-0.1s})\frac{1}{s}e^{-0.1s}$

$$i(t)=\left[10C-\frac{10}{\omega}\sqrt{\left(\frac{C}{L}\right)}e^{-\alpha t}\cos(\omega t-\phi_1)\right]u(t)$$
$$-\left[10C-\frac{10}{\omega}\sqrt{\left(\frac{C}{L}\right)}e^{-\alpha(t-0.1)}\cos\{\omega(t-0.1)-\phi_1\}\right.$$
$$\left.+\frac{1}{\omega L}e^{-\alpha(t-0.1)}\sin\omega(t-0.1)\right]u(t-0.1)$$

where $\omega^2=(1/LC)-(R/2L)^2$; $\phi_1=\tan^{-1}(\alpha/\omega)$; $\alpha=R/2L$.

20. $V_2(s)=0.5/[(s+4)(4s^2+4s+2)]$;
$v_2(t)=(1/100)e^{-4t}+(1/2\sqrt{50})e^{-0.5t}\cos(0.5t-98.1)$.

21. $v_0(t)=5[e^{-\alpha_1 t}-e^{-\alpha_2 t}]u(t)$
$-5[e^{-\alpha_1(t-a)}-e^{-\alpha_2(t-a)}]u(t-a)$
where $\alpha_1\approx 5\times10^{-3}$, $\alpha_2\approx 2\times10^{6}$, $a=5\times10^{-6}$.

23. $H(s)=1/(s^3+2s^2+2s+1)$.

24. $R(\min)=2\left[\frac{L}{C}(1+k)\right]^{1/2}$.

25. $F(s)=\frac{\alpha(s+\alpha)-\beta^2}{(s+\alpha)^2-\beta^2}$.

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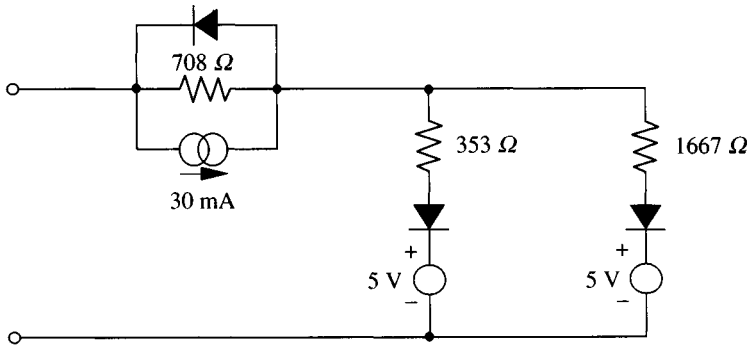
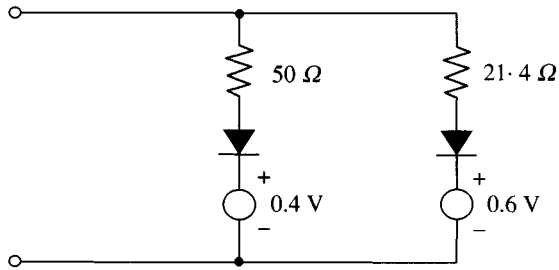
Chapter 7

1. 10.3 mA; 2.2 V.
2. 10.8 mA; 2.05 V;19 mW; 0.8 mW.
3. 5.1 mA; 7.3 V; 2.4 V; 4.9 V; $R_{\text{d.c.}} = 1430\,\Omega$; $R_{\text{a.c.}} = 788\,\Omega$.
4. (a) $0.61\,\text{k}\Omega < R < 2.9\,\text{k}\Omega$. (b) -0.17 V or 0.46 V.
5. (a) 7 V. (b) $270\,\Omega$.
6. Slopes: 1, $\frac{1}{2}$, 0. Break points 1V, 2V.
7. Breakpoints: (8 V, 0 A) and (16 V, 2 A).
   Slopes (i/v): 1/10, 1/4 and 7/20 corresponding to resistance of $10\,\Omega$, $4\,\Omega$, $2.85\,\Omega$.
8. 

9. $25.9/R$.
10. (a) 0.53 V; 2.3 mA; 1.2 mW. (b) 1.2 mW.


11. $R_1 = 1/3\,\text{k}\Omega$; $R_2 = 2/3\,\text{k}\Omega$; $R_3 = 3\,\text{k}\Omega$; $R_4 = 7/6\,\text{k}\Omega$; $R_5 = 1.46\,\text{k}\Omega$.
12. 0.712 A.
13. (a) 1.67 A; 1.87 V; 1.13 V. (b) 1.16 A; 1.58 V, 0.85 V; 0.58 V.
15. (a) $R_1 =$ MΩ; $R_2 = 28.6\,\Omega$. (b) 0.1 mA; 31 mA.
16. (c) 10 mA. (d) 1.2 ms.

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17. $v_c(t) = V(1-\cos\omega_0 t), \qquad 0 < t < \pi/2\omega_0$

$v_c(t) = V + \omega_0 rCV[e^{-\frac{r}{L}(t-\frac{\pi}{2\omega_0})} - e^{-\frac{1}{rC}(t-\frac{\pi}{2\omega_0})}],$

$t > \pi/2\omega_0.$

18. (a) 1.05 A. (b) $C = 0.1$ F.
19. (a) 56.3 mA. (b) 6.3%. (c) 0.73 A. (d) 0.187 A. (e) 3.2%. (f) 0.1%.
20. (a) 360 V; 9.6 V. (b) 262 V; 377 μF.
21. (a) 25 mV. (b) $V_d = \sqrt{2}[(V_r^2 + V_s^2 + 2V_rV_s\cos\phi)^{\frac{1}{2}} - (V_r^2 + V_s^2 + 2V_rV_s\cos\phi)^{\frac{1}{4}}]$
22. 90°; 16.9 kΩ

$i = 3.24\sin(\omega t - 17.4) - 18e^{-1000t}\text{A}(t \geqslant 2.5\text{ ms}).$ 107°; 197°

23. $f(t) = \frac{4A}{\pi}\sum_{n=2k+1}^{\infty}\frac{1}{n}\left[\frac{sin(n2\pi p/T)}{n2\pi p/T}\right]\sin\frac{n2\pi t}{T} \qquad k = 0, 1, 2, \ldots$

(c) $p = T/6$. (d) $p = T/10$, $T/5$.

24. 60°; 1.15.

Chapter 8

1. $h_{11} = 14/3\,\Omega$; $h_{12} = 1/3$; $h_{21} = -1/3$; $h_{22} = 1/12$ S.
3. $z_{11} = R_e + R_b$; $z_{12} = R_e$; $z_{21} = R_e - \beta R_d$; $z_{22} = R_d + R_e$.
4. $y_{11} = y_{22} = \frac{s(s+3)}{2s+1}$; $y_{12} = y_{21} = \frac{s(s+1)}{2s+1}$.
5. (a) $A = -\frac{1}{\mu}[1 + Y(Z + R_2)]; \qquad B = A/R_1$

$C = -\frac{1}{\mu}[2Z + Z^2Y + R_2(1 + ZY)]; \; D = C/R_1$

6. $y_{11} = y_{22} = \frac{R^2C^2s^2 + 4RCs + 1}{2R(RCs+1)}$; $y_{21} = y_{12} = \frac{-R^2s^2C^2 + 1}{2R(RCs+1)}$

Infinite attenuation when $\omega = 1/RC$.

7. (b) $y_{12} = y_{21} = \frac{R^2s^3C^3}{2(1+sRC)} = \frac{s^3CT^2}{2(1+sT)}$.
8. Iterative impedances: 21.3 Ω and 16.2 Ω.
Image impedances: 17.1 Ω and 20.5 Ω.
9. $\frac{V_{IN}}{V_{OUT}} = \frac{1}{sL}[R + sL + \sqrt{(R^2 + 2RsL)}]$; $z_I = \sqrt{(R^2 + 2RsL)}$

For given values: $V_{IN}/V_{OUT} = 1.79 - j2.28$; $z_I = 1270 + j790\,\Omega$.

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