Instructor's Solutions Manual
to accompany

INTRODUCTORY CIRCUIT ANALYSIS

Tenth Edition

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CHAPTER 1 (Odd)

5. $12\,\cancel{\text{mi}}\left[\dfrac{15\ \cancel{\text{min}}}{\cancel{\text{mi}}}\right]\left[\dfrac{1\ \text{h}}{60\ \cancel{\text{min}}}\right] = \mathbf{3\ h}$

7. CGS

9. MKS, CGS: $°\text{C} = \dfrac{5}{9}(°\text{F} - 32) = \dfrac{5}{9}(68 - 32) = \dfrac{5}{9}(36) = \mathbf{20°}$
K: $\text{K} = 273.15 + °\text{C} = 273.15 + 20 = \mathbf{293.15}$

11. $0.5\,\cancel{\text{yd}}\left[\dfrac{3\ \cancel{\text{ft}}}{1\ \cancel{\text{yd}}}\right]\left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right] = \mathbf{45.72\ cm}$

13. a. $\mathbf{15 \times 10^{3}}$ b. $\mathbf{30 \times 10^{-3}}$ c. $\mathbf{7.4 \times 10^{6}}$
d. $\mathbf{6.8 \times 10^{-6}}$ e. $\mathbf{402 \times 10^{-6}}$ f. $\mathbf{200 \times 10^{-12}}$

15. a. $(10^2)(10^2) = \mathbf{10^4}$ b. $(10^{-2})(10^3) = \mathbf{10}$ c. $\mathbf{10^9}$
d. $(10^3)(10^{-5}) = \mathbf{10^{-2}}$ e. $(10^{-6})(10 \times 10^6) = \mathbf{10}$ f. $(10^4)(10^{-8})(10^{35}) = \mathbf{10^{31}}$

17. a. $\dfrac{10^2}{10^3} = \mathbf{10^{-1}}$ b. $\dfrac{10^{-2}}{10^2} = \mathbf{10^{-4}}$ c. $\dfrac{10^4}{10^{-5}} = \mathbf{10^9}$

d. $\dfrac{10^{-7}}{10^2} = \mathbf{10^{-9}}$ e. $\dfrac{10^{38}}{10^{-4}} = \mathbf{1042}$ f. $\dfrac{(10^2)^{1/2}}{10^{-2}} = \dfrac{10^1}{10^{-2}} = \mathbf{10^3}$

19. a. $(10^2)^3 = \mathbf{10^6}$ b. $(10^{-4})^{1/2} = \mathbf{10^{-2}}$
c. $(10^4)^8 = \mathbf{10^{32}}$ d. $(10^{-7})^9 = \mathbf{10^{-63}}$

21. a. $(-10^{-3})^2 = 10-6$ b. $\dfrac{(10^2)(10^{-4})}{10} = \dfrac{10^{-2}}{10} = \mathbf{10^{-3}}$

c. $\dfrac{(10^{-3})^2(10^2)}{10^4} = \dfrac{(10^{-6})(10^2)}{10^4} = \dfrac{10^{-4}}{10^4} = \mathbf{10^{-8}}$ d. $\dfrac{(10^2)(10^4)}{10^{-3}} = \dfrac{10^6}{10^{-3}} = \mathbf{10^9}$

e. $\dfrac{(10^{-4})^3(10^2)}{10^6} = \dfrac{(10^{-12})(10^2)}{10^6} = \dfrac{10^{-10}}{10^6} = \mathbf{10^{-16}}$

f. $\dfrac{\left[(10^2)(10^{-2})\right]^{-3}}{\left[(10^2)^2\right]\left[10^{-3}\right]} = \dfrac{1}{(10^4)(10^{-3})} = \dfrac{1}{10} = \mathbf{10^{-1}}$

23. a. $6 \times 10^3 = \underline{0.006} \times 10^{+6}$ b. $4 \times 10^{-4} = \underline{400} \times 10^{-6}$

c. $50 \times 10^5 = \underline{5000} \times 10^3 = \underline{5} \times 10^6 = \underline{0.005} \times 10^9$

d. $30 \times 10^{-8} = \underline{0.0003} \times 10^{-3} = \underline{0.3} \times 10^{-6} = \underline{300} \times 10^{-9}$

25. a. $1.5\ \cancel{\text{min}} \left[\dfrac{60\ \text{s}}{1\ \cancel{\text{min}}}\right] = \mathbf{90\ s}$ b. $0.04\ \cancel{\text{h}} \left[\dfrac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\dfrac{60\ \text{s}}{1\ \cancel{\text{min}}}\right] = \mathbf{144\ s}$

c. $0.05\ \cancel{\text{s}} \left[\dfrac{1\ \mu\text{s}}{10^{-6}\ \cancel{\text{s}}}\right] = 0.05 \times 10^6\ \mu\text{s} = \mathbf{50 \times 10^3\ \mu s}$

d. $0.16\ \cancel{\text{m}} \left[\dfrac{1\ \text{mm}}{10^{-3}\ \cancel{\text{m}}}\right] = 0.16 \times 10^3\ \text{mm} = \mathbf{160\ mm}$

e. $1.2 \times 10^{-7}\ \cancel{\text{s}} \left[\dfrac{1\ \text{ns}}{10^{-9}\ \cancel{\text{s}}}\right] = 1.2 \times 10^2\ \text{ns} = \mathbf{120\ ns}$

f. $3.62 \times 10^6\ \cancel{\text{s}} \left[\dfrac{1\ \cancel{\text{min}}}{60\ \cancel{\text{s}}}\right]\left[\dfrac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right]\left[\dfrac{1\ \text{day}}{24\ \cancel{\text{h}}}\right] = \mathbf{41.898\ days}$

g. $1020\ \cancel{\text{mm}} \left[\dfrac{10^{-3}\ \text{m}}{1\ \cancel{\text{mm}}}\right] = \mathbf{1.02\ m}$

27. a. $100\ \cancel{\text{in.}} \left[\dfrac{1\ \text{m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{2.54\ m}$ b. $4\ \cancel{\text{ft}} \left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{1\ \text{m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{1.219\ m}$

c. $6\ \cancel{\text{lb}} \left[\dfrac{4.45\ \text{N}}{1\ \cancel{\text{lb}}}\right] = \mathbf{26.7\ N}$

d. $60 \times 10^3\ \cancel{\text{dynes}} \left[\dfrac{1\ \cancel{\text{N}}}{10^5\ \cancel{\text{dynes}}}\right]\left[\dfrac{1\ \text{lb}}{4.45\ \cancel{\text{N}}}\right] = \mathbf{0.1348\ lb}$

e. $150{,}000\ \cancel{\text{cm}} \left[\dfrac{1\ \cancel{\text{in.}}}{2.54\ \cancel{\text{cm}}}\right]\left[\dfrac{1\ \text{ft}}{12\ \cancel{\text{in.}}}\right] = \mathbf{4921.26\ ft}$

f. $0.002\,\cancel{\text{mi}}\left[\frac{5280\,\cancel{\text{ft}}}{1\,\cancel{\text{mi}}}\right]\left[\frac{12\,\cancel{\text{in.}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\text{ m}}{39.37\,\cancel{\text{in.}}}\right] = \mathbf{3.2187\ m}$

g. $7800\,\cancel{\text{m}}\left[\frac{39.37\,\cancel{\text{in.}}}{1\,\cancel{\text{m}}}\right]\left[\frac{1\,\cancel{\text{ft}}}{12\,\cancel{\text{in.}}}\right]\left[\frac{1\text{ yd}}{3\,\cancel{\text{ft}}}\right] = \mathbf{8530.17\ yds}$

29. $299{,}792{,}458\,\frac{\cancel{\text{m}}}{\cancel{\text{s}}}\left[\frac{39.37\,\cancel{\text{in.}}}{1\,\cancel{\text{m}}}\right]\left[\frac{1\,\cancel{\text{ft}}}{12\,\cancel{\text{in.}}}\right]\left[\frac{1\text{ mi}}{5280\,\cancel{\text{ft}}}\right]\left[\frac{60\,\cancel{\text{s}}}{1\,\cancel{\text{min}}}\right]\left[\frac{60\,\cancel{\text{min}}}{1\text{ h}}\right]$

$= 670{,}615{,}288.1\text{ mph} \cong \mathbf{670.62 \times 10^6\ mph}$

31. $100\,\cancel{\text{yds}}\left[\frac{3\,\cancel{\text{ft}}}{1\,\cancel{\text{yd}}}\right]\left[\frac{1\text{ mi}}{5280\,\cancel{\text{ft}}}\right] = 0.0568\text{ mi}$

$t = \frac{d}{v} = \frac{0.0568\,\cancel{\text{mi}}}{\frac{100\,\cancel{\text{mi}}}{\text{h}}} = 0.0568 \times 10^{-2}\,\cancel{\text{h}}\left[\frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{h}}}\right]\left[\frac{60\text{ s}}{1\,\cancel{\text{min}}}\right] = \mathbf{2.045\ s}$

33. $\frac{50\,\cancel{\text{m}}}{\cancel{\text{min}}}\left[\frac{60\,\cancel{\text{min}}}{1\text{ h}}\right]\left[\frac{39.37\,\cancel{\text{in.}}}{1\,\cancel{\text{m}}}\right]\left[\frac{1\,\cancel{\text{ft}}}{12\,\cancel{\text{in.}}}\right]\left[\frac{1\text{ mi}}{5280\,\cancel{\text{ft}}}\right] = 1.86\text{ mi/h}$

$t = \frac{d}{v} = \frac{3000\,\cancel{\text{mi}}}{1.86\,\frac{\cancel{\text{mi}}}{\text{h}}} = 1612.9\text{ h} = \mathbf{67.2\ days}$

35. $100\,\cancel{\text{yds}}\left[\frac{3\,\cancel{\text{ft}}}{1\,\cancel{\text{yd}}}\right]\left[\frac{12\text{ in.}}{1\,\cancel{\text{ft}}}\right] = 3600\text{ in.} \Rightarrow 3600\text{ quarters} = \mathbf{\$900}$

37. $d = vt = \left[600\frac{\cancel{\text{cm}}}{\cancel{\text{s}}}\right][0.016\,\cancel{\text{h}}]\left[\frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{h}}}\right]\left[\frac{60\,\cancel{\text{s}}}{1\,\cancel{\text{min}}}\right]\left[\frac{1\text{ m}}{100\,\cancel{\text{cm}}}\right] = \mathbf{345.6\ m}$

39. $d = (86\,\cancel{\text{stories}})\left[\frac{14\text{ ft}}{\cancel{\text{story}}}\right] = 1204\,\cancel{\text{ft}}\left[\frac{1\text{ mile}}{5{,}280\,\cancel{\text{ft}}}\right] = 0.228\text{ miles}$

$\frac{\text{min}}{\text{mile}} = \frac{10.7833\text{ min}}{0.228\text{ miles}} = \mathbf{47.30\ min/mile}$

41. a. $5\,\cancel{\text{J}}\left[\frac{1\text{ Btu}}{1054.35\,\cancel{\text{J}}}\right] = \mathbf{4.74 \times 10^{-3}\ Btu}$

b. $24\,\cancel{\text{ounces}}\left[\frac{1\,\cancel{\text{gallon}}}{128\,\cancel{\text{ounces}}}\right]\left[\frac{1\text{ m}^3}{264.172\,\cancel{\text{gallons}}}\right] = \mathbf{7.098 \times 10^{-4}\ m^3}$

c. $1.4\,\cancel{\text{days}}\left[\frac{86{,}400\text{ s}}{1\,\cancel{\text{day}}}\right] = \mathbf{1.2096 \times 10^5\ s}$

d. $1\,\cancel{\text{m}^3}\left[\frac{264.172\,\cancel{\text{gallons}}}{1\,\cancel{\text{m}^3}}\right]\left[\frac{8\text{ pints}}{1\,\cancel{\text{gallon}}}\right] = \mathbf{2113.38\ pints}$

43. $\boxed{\text{2nd F}}\ \boxed{\sqrt{\ }}\ \boxed{(}\ \boxed{3}\ \boxed{x^2}\ \boxed{+}\ \boxed{4}\ \boxed{x^2}\ \boxed{)}\ \boxed{\text{ENTER}} \Rightarrow \mathbf{5.000}$

45. $\boxed{\text{2nd F}}\ \boxed{\sqrt{\ }}\ \boxed{(}\ \boxed{4}\ \boxed{0}\ \boxed{0}\ \boxed{\div}\ \boxed{(}\ \boxed{6}\ \boxed{x^2}\ \boxed{+}\ \boxed{1}\ \boxed{0}\ \boxed{)}\ \boxed{)}\ \boxed{\text{ENTER}} \Rightarrow \mathbf{2.949}$

CHAPTER 1 (Even)

4. $50\dfrac{\cancel{mi}}{\cancel{h}}\left[\dfrac{5280\text{ ft}}{1\ \cancel{mi}}\right]\left[\dfrac{1\ \cancel{h}}{60\text{ min}}\right] = 4400\text{ ft/min}$

$d = vt = \left[\dfrac{4400\text{ ft}}{\cancel{min}}\right][1\ \cancel{min}] = \mathbf{4400\text{ ft}}$

8. MKS

10. $1000\,\cancel{J}\left[\dfrac{0.7378\text{ ft-lb}}{1\,\cancel{J}}\right] = \mathbf{737.8\text{ ft-lbs}}$

12. a. $\mathbf{10^4}$ b. 10^{-4} c. $\mathbf{10^3}$ d. $\mathbf{10^6}$ e. $\mathbf{10^{-7}}$ f. $\mathbf{10^{-5}}$

14. a. $4.2 \times 10^3 + 6{,}800 \times 10^3 = 6{,}804.2 \times 10^3 = \mathbf{6.8042 \times 10^6}$

b. $9 \times 10^4 + 0.36 \times 10^4 = \mathbf{9.36 \times 10^4}$

c. $50 \times 10^{-5} - 6 \times 10^{-5} = 44 \times 10^{-5} = \mathbf{4.4 \times 10^{-4}}$

d. $1.2 \times 10^3 + 0.05 \times 10^3 - 0.6 \times 10^3 = 0.65 \times 10^3 = \mathbf{6.5 \times 10^2}$

16. a. $(50 \times 10^3)(3 \times 10^{-4}) = 150 \times 10^{-1} = \mathbf{1.5 \times 10^1}$

b. $(2.2 \times 10^3)(8 \times 10^{-2}) = 17.6 \times 10^1 = \mathbf{1.76 \times 10^2}$

c. $(82 \times 10^{-6})(7 \times 10^{-5}) = 574 \times 10^{-11} = \mathbf{5.74 \times 10^{-9}}$

d. $(30 \times 10^{-4})(2 \times 10^{-4})(7 \times 10^8) = 420 \times 10^0 = \mathbf{4.2 \times 10^2}$

18. a. $\dfrac{2 \times 10^3}{8 \times 10^{-5}} = 0.25 \times 10^8 = \mathbf{2.5 \times 10^7}$

b. $\dfrac{4.08 \times 10^{-3}}{60 \times 10^3} = 0.068 \times 10^{-6} = \mathbf{6.8 \times 10^{-8}}$

c. $\dfrac{2.15 \times 10^{-4}}{5 \times 10^{-5}} = 0.43 \times 10^1 = \mathbf{4.3 \times 10^0}$

d. $\dfrac{78 \times 10^9}{4 \times 10^{-6}} = 19.5 \times 10^{15} = \mathbf{1.95 \times 10^{16}}$

20. a. $(2.2 \times 10^3)^3 = (2.2)^3 \times (10^3)^3 = 10.65 \times 10^9 = \mathbf{1.065 \times 10^{10}}$

b. $(6 \times 10^{-4} \times 10^2)^4 = (6 \times 10^{-2})^4 = (6)^4 \times (10^{-2})^4 = 1296 \times 10^{-8} = \mathbf{1.296 \times 10^{-5}}$

c. $(4 \times 10^{-3} \times 6 \times 10^2)^2 = (24 \times 10^{-1})^2 = (2.4)^2 = \mathbf{5.76}$

d. $((2 \times 10^{-3})(0.8 \times 10^4)(0.003 \times 10^5))^3 = (4.8 \times 10^3)^3 = (4.8)^3 \times 10^3)^3$
$= 110.6 \times 10^9 = \mathbf{1.106 \times 10^{11}}$

22. a. $\dfrac{(3 \times 10^2)^2(10^2)}{10^4} = \dfrac{(9 \times 10^4)(10^2)}{10^4} = \dfrac{9 \times 10^6}{10^4} = 9 \times 10^2 = \mathbf{900}$

b. $\dfrac{(4 \times 10^4)^2}{(20)^3} = \dfrac{16 \times 10^8}{8 \times 10^3} = \mathbf{9 \times 10^{12}}$

c. $\dfrac{(6 \times 10^4)^2}{(2 \times 10^{-2})^2} = \dfrac{36 \times 10^8}{4 \times 10^{-4}} = \mathbf{9 \times 10^{12}}$

d. $\dfrac{(27 \times 10^{-6})^{1/3}}{21 \times 10^4} = \dfrac{3 \times 10^{-2}}{21 \times 10^4} = \mathbf{\dfrac{1}{7} \times 10^{-6}}$

e. $\dfrac{[(4 \times 10^3)^2][300]}{2 \times 10^{-2}} = \dfrac{(16 \times 10^6)(3 \times 10^2)}{2 \times 10^{-2}} = \dfrac{48 \times 10^8}{2 \times 10^{-2}} = 24 \times 10^{10} = \mathbf{240 \times 10^9}$

f. $(16 \times 10^{-6})^{1/2}(10^5)^5(2 \times 10^{-2}) = (4 \times 10^{-3})(10^{25})(2 \times 10^{-2}) = \mathbf{8 \times 10^{20}}$
$= \mathbf{800 \times 10^{18}}$

g. $\dfrac{[(3 \times 10^{-3})^3][7 \times 10^{-5}]^2[8 \times 10^2]^2}{[(10^2)(9 \times 10^{-4})]^{1/2}} = \dfrac{(27 \times 10^{-9})(49 \times 10^{-10})(64 \times 10^4)}{(9 \times 10^{-2})^{1/2}}$

$= \dfrac{84{,}672 \times 10^{-15}}{3 \times 10^{-1}}$
$= 28{,}224 \times 10^{-14} = \mathbf{282.24 \times 10^{-12}}$

increase by (3)

24. a. $2000 \times 10^{-6}\ \mathrm{s} = \underline{2.0} \times 10^{-3}\ \mathrm{s} = \mathbf{2\ ms}$

decrease by (3)

b. $0.04 \times 10^{-3}\ \mathrm{s} \Rightarrow \underline{40} \times 10^{-6}\ \mathrm{s} = \mathbf{40\ \mu s}$

decrease by (3)

c. $0.06 \times 10^{-6}\ \mathrm{F} = \underline{60} \times 10^{-9}\ \mathrm{F} = \mathbf{60\ nF}$

increase by (6)

d. $8400 \times 10^{-12}\ \mathrm{s} \Rightarrow \underline{0.0084} \times 10^{-6}\ \mathrm{s} = \mathbf{0.0084\ \mu s}$

e. $0.006 \times 10^3\ \text{m} = \underline{6000} \times 10^{-3}\ \text{m} = \mathbf{6000\ m}$ (decrease by (6))

f. $260 \times \underbrace{10^3 \times 10^{-3}}_{10^0}\ \text{m} \Rightarrow \underline{0.26} \times 10^3\ \text{m} = \mathbf{0.26\ km}$ (increase by (3))

26. a. $0.1\,\cancel{\mu\text{F}}\left[\frac{10^{-6}\,\cancel{\text{F}}}{1\,\cancel{\mu\text{F}}}\right]\left[\frac{1\ \text{pF}}{10^{-12}\,\cancel{\text{F}}}\right] = 0.1 \times 10^{-6} \times 10^{12}\ \text{pF} = \mathbf{10^5\ pF}$

b. $0.467\,\cancel{\text{km}}\left[\frac{10^3\ \text{m}}{1\,\cancel{\text{km}}}\right] = \mathbf{467\ m}$

c. $63.9 \times 10^{-3}\,\cancel{\text{m}}\left[\frac{100\ \text{cm}}{1\,\cancel{\text{m}}}\right] = 63.9 \times 10^{-1}\ \text{cm} = \mathbf{6.39\ cm}$

d. $69\,\cancel{\text{cm}}\left[\frac{1\,\cancel{\text{m}}}{100\,\cancel{\text{cm}}}\right]\left[\frac{1\ \text{km}}{1000\,\cancel{\text{m}}}\right] = \mathbf{69 \times 10^{-5}\ km}$

e. $3.2\,\cancel{\text{h}}\left[\frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{h}}}\right]\left[\frac{60\,\cancel{\text{s}}}{1\,\cancel{\text{min}}}\right]\left[\frac{1\ \text{ms}}{10^{-3}\,\cancel{\text{s}}}\right] = \mathbf{11.52 \times 10^6\ ms}$

f. $0.016\,\cancel{\text{mm}}\left[\frac{10^{-3}\,\cancel{\text{m}}}{1\,\cancel{\text{mm}}}\right]\left[\frac{1\ \mu\text{m}}{10^{-6}\,\cancel{\text{m}}}\right] = 0.016 \times 10^3\ \mu\text{m} = \mathbf{16\ \mu m}$

g. $60\ \text{cm}^2 = 60(\cancel{\text{cm}})(\cancel{\text{cm}})\left[\frac{1\ \text{m}}{100\,\cancel{\text{cm}}}\right]\left[\frac{1\ \text{m}}{100\,\cancel{\text{cm}}}\right] = \mathbf{60 \times 10^{-4}\ m^2}$

28. **5280 ft**, $5280\,\cancel{\text{ft}}\left[\frac{1\ \text{yd}}{3\,\cancel{\text{ft}}}\right] = \mathbf{1760\ yds}$

$5280\,\cancel{\text{ft}}\left[\frac{12\,\cancel{\text{in.}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\ \text{m}}{39.37\,\cancel{\text{in.}}}\right] = \mathbf{1609.35\ m,\ 1.61\ km}$

30. $\frac{50\,\cancel{\text{ft}}}{20\,\cancel{\text{s}}}\left[\frac{1\ \text{mi}}{5280\,\cancel{\text{ft}}}\right]\left[\frac{60\,\cancel{\text{s}}}{1\,\cancel{\text{min}}}\right]\left[\frac{60\,\cancel{\text{min}}}{1\ \text{h}}\right] = \mathbf{1.7\ mph}$

32. $\frac{6\,\cancel{\text{mi}}}{\cancel{\text{h}}}\left[\frac{5280\,\cancel{\text{ft}}}{1\,\cancel{\text{mi}}}\right]\left[\frac{12\,\cancel{\text{in.}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\ \text{m}}{39.37\,\cancel{\text{in.}}}\right]\left[\frac{1\,\cancel{\text{h}}}{60\,\cancel{\text{min}}}\right]\left[\frac{1\,\cancel{\text{min}}}{60\ \text{s}}\right] = \mathbf{2.682\ m/s}$

34. $10\,\cancel{\text{km}}\left[\dfrac{1000\,\cancel{\text{m}}}{1\,\cancel{\text{km}}}\right]\left[\dfrac{39.37\,\cancel{\text{in.}}}{1\,\cancel{\text{m}}}\right]\left[\dfrac{1\,\cancel{\text{ft}}}{12\,\cancel{\text{in.}}}\right]\left[\dfrac{1\text{ mi}}{5280\,\cancel{\text{ft}}}\right] = 6.214\text{ mi}$

$$v = \frac{1\text{ mi}}{6.5\text{ min}},\ t = \frac{d}{v} = \frac{6.214\,\cancel{\text{mi}}}{\dfrac{1\,\cancel{\text{mi}}}{6.5\text{ min}}} = \mathbf{40.39\ min}$$

36. 55 mph: $t = \dfrac{d}{v} = \dfrac{3000\,\cancel{\text{mi}}}{\dfrac{55\,\cancel{\text{mi}}}{\text{h}}} = \mathbf{54.55\ h}$

65 mph: $t = \dfrac{d}{v} = \dfrac{3000\,\cancel{\text{mi}}}{\dfrac{65\,\cancel{\text{mi}}}{\text{h}}} = \mathbf{46.15\ h}$

38. $d = 86\,\cancel{\text{stories}}\left[\dfrac{14\,\cancel{\text{ft}}}{\cancel{\text{story}}}\right]\left[\dfrac{1\text{ step}}{\dfrac{9}{12}\,\cancel{\text{ft}}}\right] = 1605\text{ steps}$

$$v = \frac{d}{t} \Rightarrow t = \frac{d}{v} = \frac{1605\text{ steps}}{\dfrac{2\text{ steps}}{\text{second}}} = 802.5\,\cancel{\text{seconds}}\left[\frac{1\text{ minute}}{60\,\cancel{\text{seconds}}}\right] = \mathbf{13.38\ minutes}$$

40. $\dfrac{5\text{ min}}{\text{mile}} \Rightarrow \dfrac{1\,\cancel{\text{mile}}}{5\text{ min}}\left[\dfrac{5{,}280\text{ ft}}{1\,\cancel{\text{mile}}}\right] = \dfrac{1056\text{ ft}}{\text{minute}}$, distance $= 86\,\cancel{\text{stories}}\left[\dfrac{14\text{ ft}}{\cancel{\text{story}}}\right] = 1204\text{ ft}$

$$v = \frac{d}{t} \Rightarrow t = \frac{d}{v} = \frac{1204\text{ ft}}{1056\ \dfrac{\text{ft}}{\text{min}}} = \mathbf{1.14\ minutes}$$

42. $\boxed{6}\ \boxed{\times}\ \boxed{(}\ \boxed{4}\ \boxed{+}\ \boxed{8}\ \boxed{)}\ \boxed{\text{ENTER}} \Rightarrow \mathbf{72.000}$

44. $\boxed{\text{2nd}}\ \boxed{\tan^{-1}}\ \boxed{(}\ \boxed{4}\ \boxed{\div}\ \boxed{3}\ \boxed{)}\ \boxed{\text{ENTER}} \Rightarrow \mathbf{53.13}$

CHAPTER 2 (Odd)

3. a. $r = 1\text{ m}$: $F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{(9 \times 10^9)(1\ \mu\text{C})(2\ \mu\text{C})}{(1\text{ m})^2}$

$$= \frac{(9 \times 10^9)(2 \times 10^{-12})}{1} = \frac{18 \times 10^{-3}}{1} = \mathbf{18\ mN}$$

b. $r = 3\text{ m}$: $F = \dfrac{18 \times 10^{-3}}{(3)^2} = \dfrac{18 \times 10^{-3}}{9} = \mathbf{2\ mN}$

c. $r = 10\text{ m}$: $F = \dfrac{18 \times 10^{-3}}{(10)^2} = \dfrac{18 \times 10^{-3}}{100} = \mathbf{180\ \mu N}$

5. $F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{(9 \times 10^9)(2\text{ mC})(4\ \mu\text{C})}{r^2} = \dfrac{72}{r^2}$

$r = 0.5\text{ m}$, $F = \dfrac{72}{(0.5)^2} = \mathbf{288\ N}$

$r = 1\text{ m}$, $F = \dfrac{72}{(1)^2} = \mathbf{72\ N}$

$r = 5\text{ m}$, $F = \dfrac{72}{(5)^2} = \mathbf{2.88\ N}$

$r = 10\text{ m}$, $F = \dfrac{72}{(10)^2} = \mathbf{0.72\ N}$

7. $F = \dfrac{kQ_1Q_2}{r^2} \Rightarrow 1.8 = \dfrac{kQ_1Q_2}{(2\text{ m})^2} \Rightarrow kQ_1Q_2 = 4(1.8) = 7.2$

a. $F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{7.2}{(10)^2} = \mathbf{72\ mN}$

b. $Q_1/Q_2 = 1/2 \Rightarrow Q_2 = 2Q_1$

$7.2 = kQ_1Q_2 = (9 \times 10^9)(Q_1)(2Q_1) = 9 \times 10^9(2Q_1^2)$

$\dfrac{7.2}{18 \times 10^9} = Q_1^2 \Rightarrow Q_1 = \sqrt{\dfrac{7.2}{18 \times 10^9}} = \mathbf{20\ \mu C}$

$Q_2 = 2Q_1 = 2(2 \times 10^{-5}\text{ C}) = \mathbf{40\ \mu C}$

9. $I = \dfrac{Q}{t} = \dfrac{465\text{ C}}{(2.5)(60\text{ s})} = \mathbf{3.1\ A}$

11. $Q = It = (750 \times 10^{-3}\text{A})(120\text{ s}) = \mathbf{90\ C}$

13. $21.847 \times 10^{18} \text{ electrons}\left[\dfrac{1\text{ C}}{6.242 \times 10^{18}\text{ electrons}}\right] = 3.5\text{ C}$

$I = \dfrac{Q}{t} = \dfrac{3.5\text{ C}}{7\text{ s}} = \mathbf{0.5\ A}$

15. $I = \dfrac{Q}{t} = \dfrac{86\text{ C}}{(1.2)(60\text{ s})} = 1.194\text{ A} > 1\text{A (yes)}$

17. a. $Q = It = (2\text{ mA})(0.01\ \mu\text{s}) = 2 \times 10^{-11}\text{ C}$

$2 \times 10^{-11}\ \cancel{C}\left[\dfrac{6.242 \times 10^{18}\text{ electrons}}{1\ \cancel{C}}\right]\left[\dfrac{1\ ¢}{\text{electron}}\right]$

$= 1.248 \times 10^{8}\ ¢ = \$1.248 \times 10^{6} = \mathbf{1.248\ million}$

b. $Q = It = (100\ \mu\text{A})(1.5\text{ ns}) = 1.5 \times 10^{-13}\text{ C}$

$1.5 \times 10^{-13}\ \cancel{C}\left[\dfrac{6.242 \times 10^{18}\ \cancel{\text{electrons}}}{1\ \cancel{C}}\right]\left[\dfrac{\$1}{\cancel{\text{electron}}}\right] = \$936{,}300 = \mathbf{0.9363\ million}$

(a) > (b)

19. $W = VQ = (42\text{ V})(6\text{ C}) = \mathbf{252\ J}$

21. $Q = \dfrac{W}{V} = \dfrac{90\text{ J}}{22.5\text{ V}} = \mathbf{4\ C}$

23. $Q = It = \left(\dfrac{420\text{ C}}{\cancel{\text{min}}}\right)(0.5\ \cancel{\text{min}}) = 210\text{ C}$

$V = \dfrac{W}{Q} = \dfrac{742\text{ J}}{210\text{ C}} = \mathbf{3.53\ V}$

25. $I = \dfrac{\text{Ah rating}}{t(\text{hours})} = \dfrac{200\text{ Ah}}{40\text{ h}} = \mathbf{5\ A}$

27. $t(\text{hours}) = \dfrac{\text{Ah rating}}{I} = \dfrac{32\text{ Ah}}{1.28\text{ A}} = \mathbf{25\ h}$

29. From Fig. 2.18a ≅ 425 mAh

$t(\text{hours}) = \dfrac{\text{mAh rating}}{I(\text{mA})} = \dfrac{425\text{ mAh}}{550\text{ mA}} = \mathbf{0.773\ h}$

31. 1 h: $I_1 = \dfrac{40\text{ Ah}}{1\text{ h}} = 40\text{ A}$

$I_2 = \dfrac{60\text{ Ah}}{1\text{ h}} = 60\text{ A}$

60 A: 40 A ⇒ 1.5:1 (50% more)

33. $I = \dfrac{3\ \text{Ah}}{5.5\ \text{h}} = 545.45\ \text{mA}$

$Q = It = (545.45\ \text{mA})(5.5\ \cancel{\text{h}}) \left[\dfrac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\dfrac{60\ \text{s}}{1\ \cancel{\text{min}}}\right] = 10{,}799.91\ \text{C}$

$W = QV = (10{,}799.91\ \text{C})(12\ \text{V}) \cong \mathbf{129.6\ kJ}$

43. $4\ \cancel{\text{min}}\left[\dfrac{60\ \text{s}}{1\ \cancel{\text{min}}}\right] = 240\ \text{s}$

$Q = It = (2.5\ \text{A})(240\ \text{s}) = \mathbf{600\ C}$

CHAPTER 2 (Even)

2. $F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{(9 \times 10^9)(1.6 \times 10^{-19}\text{C})^2}{(5 \times 10^{-11}\text{ m})^2}$

$= \dfrac{23.04 \times 10^9 \times 10^{-38}}{25 \times 10^{-22}} = \dfrac{23.04}{25} \times 10^{-7} = \mathbf{0.092\ \mu N}$

4. a. $r = 1$ mi:

$1\ \cancel{\text{mi}}\left[\dfrac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}}\right]\left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 1609.35\text{ m}$

$F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{(9 \times 10^9)(8 \times 10^{-6}\text{ C})(40 \times 10^{-6}\text{ C})}{(1609.35\text{ m})^2} = \dfrac{2880 \times 10^{-3}}{2.59 \times 10^6}$

$= \mathbf{1.11\ \mu N}$

b. $r = 0.01$ m:

$F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{2880 \times 10^{-3}}{(10^{-2})^2} = \dfrac{2880 \times 10^{-3}}{10^{-4}} = 2880 \times 10^1 = \mathbf{28.8\ kN}$

c. $\dfrac{1\ \cancel{\text{in.}}}{16}\left[\dfrac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 1.59\text{ mm}$

$F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{2880 \times 10^{-3}}{(1.59 \times 10^{-3}\text{ m})^2} = \dfrac{2880 \times 10^{-3}}{2.53 \times 10^{-6}} = 1138.34 \times 10^3\text{ N}$

$= \mathbf{1138.34\ kN}$

6. $F = \dfrac{kQ_1Q_2}{r^2} \Rightarrow r = \sqrt{\dfrac{kQ_1Q_2}{F}} = \sqrt{\dfrac{(9 \times 10^9)(20 \times 10^{-6})^2}{3.6 \times 10^4}} = \mathbf{10\ mm}$

8. $I = \dfrac{Q}{t} = \dfrac{650\text{ C}}{50\text{ s}} = \mathbf{13\ A}$

10. $Q = It = (40\text{ A})(60\text{ s}) = \mathbf{2400\ C}$

12. $t = \dfrac{Q}{I} = \dfrac{4600 \times 10^{-6}\text{ C}}{2 \times 10^{-3}\text{ A}} = \mathbf{2.3\ s}$

14. $Q = It = (1\text{ A})(60\text{ s}) = 60\text{ C}$

$60\text{ C} = 60(6.242 \times 10^{18}\text{ electrons}) = \mathbf{374.52 \times 10^{18}\ electrons}$

16. $0.784 \times 10^{18}\ \cancel{\text{electrons}}\left[\dfrac{1\text{ C}}{6.242 \times 10^{18}\ \cancel{\text{electrons}}}\right] = 0.1256\text{ C}$

$I = \dfrac{Q}{t} = \dfrac{0.1256\text{ C}}{643 \times 10^{-3}\text{ s}} = \mathbf{195\ mA}$

18. $50 \times 10^{18} \cancel{\text{electrons}} \left[\dfrac{1\text{ C}}{6.242 \times 10^{18}\ \cancel{\text{electrons}}}\right] = 8.01\text{ C}$

$$V = \frac{W}{Q} = \frac{96 \times 10^{-3}\text{ J}}{8.01\text{ C}} = \mathbf{11.985\ mV}$$

20. $Q = \dfrac{W}{V} = \dfrac{96\text{ J}}{16\text{ V}} = \mathbf{6\ C}$

22. $Q = It = (200 \times 10^{-3}\text{ A})(30\text{ s}) = 6\text{ C}$

$$V = \frac{W}{Q} = \frac{40\text{ J}}{6\text{ C}} = \mathbf{6.67\ V}$$

24. $Q = \dfrac{W}{V} = \dfrac{0.4\text{ J}}{24\text{ V}} = 0.0167\text{ C}$

$$I = \frac{Q}{t} = \frac{0.0167\text{ C}}{5 \times 10^{-3}\text{ s}} = \mathbf{3.34\ A}$$

26. Ah = [0.8 A][76 h] = **60.8 Ah**

28. @ 100°F ≅ **475 mAh**
@ 0°C(32°F) ≅ **455 mAh**

30. From Fig. 2.19 ≅ 10.4 h @ 50 mA
≅ 3.4 h @ 150 mA
150 mA: 50 mA = 3:1
3.4 h: 10.4 h = 1:3

An increase in drain current by a factor of three decreases the time availability to about one-third.

32. For 1 hour, I = 500 mA

$$Q = It = (500\text{ mA})(1\ \cancel{\text{h}})\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = (500 \times 10^{-3}\text{ A})(3600\text{ s}) = 1800\text{ C}$$

$$W = VQ = (1.2\text{ V})(1800\text{ C}) = \mathbf{2160\ J}$$

44. $Q = It = (10 \times 10^{-3}\text{ A})(20\text{ s}) = \mathbf{200\ mC}$

$$W = VQ = (12.5\text{ V})(200 \times 10^{-3}\text{ C}) = \mathbf{2.5\ J}$$

CHAPTER 3 (Odd)

1. a. 0.5 in. = **500 mils** b. 0.01 in. = **10 mils**

   c. 0.004 in. = **4 mils** d. 1 in. = **1000 mils**

   e. $0.02\,\cancel{\text{ft}}\left[\frac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\frac{10^3\ \text{mils}}{1\ \cancel{\text{in.}}}\right] = \mathbf{240\ mils}$

   f. $0.01\ \cancel{\text{cm}}\left[\frac{1\ \text{in.}}{2.54\ \cancel{\text{cm}}}\right] = 0.003937\ \text{in.} = \mathbf{3.937\ mils}$

3. $A_{CM} = (d_{mils})^2 \Rightarrow d_{mils} = \sqrt{A_{CM}}$

   a. $d = \sqrt{1600\ \text{CM}} = 40\ \text{mils} = \mathbf{0.04\ in.}$ b. $d = \sqrt{900\ \text{CM}} = 30\ \text{mils} = \mathbf{0.03\ in.}$

   c. $d = \sqrt{40{,}000\ \text{CM}} = 200\ \text{mils} = \mathbf{0.2\ in.}$ d. $d = \sqrt{625\ \text{CM}} = 25\ \text{mils} = \mathbf{0.025\ in.}$

   e. $d = \sqrt{7.75\ \text{CM}} = 2.78\ \text{mils} = \mathbf{0.00278\ in.}$ f. $d = \sqrt{81\ \text{CM}} = 9\ \text{mils} = \mathbf{0.009\ in.}$

5. $R = \rho\frac{l}{A}$, $\rho = 9.9$, 50 yd = 150 ft
   0.0045 in. = 4.5 mils, $A_{CM} = (4.5\ \text{mils})^2 = 20.25\ \text{CM}$
   $R = \rho\frac{l}{A} = \frac{(9.9)(150\ \text{ft})}{(20.25\ \text{CM})} = \mathbf{73.33\ \Omega}$

7. $\frac{1}{32}" = 0.03125" = 31.25\ \text{mils}$, $A_{CM} = (31.25\ \text{mils})^2 = 976.56\ \text{CM}$
   $R = \rho\frac{l}{A} \Rightarrow l = \frac{RA}{\rho} = \frac{(2.2\ \Omega)(976.56\ \text{CM})}{600} = \mathbf{3.581\ ft}$

9. a. $R_{silver} > R_{copper} > R_{aluminum}$

   b. Silver: $R = \rho\frac{l}{A} = \frac{(9.9)(1\ \text{ft})}{1\ \text{CM}} = \mathbf{9.9\ \Omega}$ $\{A_{CM} = (1\ \text{mil})^2 = 1\ \text{CM}$
   Copper: $R = \rho\frac{l}{A} = \frac{(10.37)(10\ \text{ft})}{100\ \text{CM}} = \mathbf{1.037\ \Omega}$ $\{A_{CM} = (10\ \text{mils})^2 = 100\ \text{CM}$
   Aluminum: $R = \rho\frac{l}{A} = \frac{(17)(50\ \text{ft})}{2500\ \text{CM}} = \mathbf{0.34\ \Omega}$ $\{A_{CM} = (50\ \text{mils})^2 = 2500\ \text{CM}$

11. a. 3" = 3000 mils, 1/2" = 0.5 in. = 500 mils
   Area = $(3 \times 10^3\ \text{mils})(5 \times 10^2\ \text{mils} = 15 \times 10^5$ sq. mils
   $15 \times 10^5\ \text{sq}\ \cancel{\text{mils}}\left[\frac{4/\pi\ \text{CM}}{1\ \text{sq}\ \cancel{\text{mil}}}\right] = 19.108 \times 10^5\ \text{CM}$
   $R = \rho\frac{l}{A} = \frac{(10.37)(4')}{19.108 \times 10^5\ \text{CM}} = \mathbf{21.71\ \mu\Omega}$

b. $R = \rho\dfrac{l}{A} = \dfrac{(17)(4')}{19.108 \times 10^5\ \text{CM}} = \mathbf{35.59\ \mu\Omega}$

c. increases

d. decreases

13. $A = \dfrac{\pi d^2}{4} \Rightarrow d = \sqrt{\dfrac{4A}{\pi}} = \sqrt{\dfrac{4(0.04\ \text{in.}^2)}{\pi}} = 0.2257\ \text{in.}$

$d_{\text{mils}} = 225.7$ mils

$A_{\text{CM}} = (225.7\ \text{mils})^2 = 50{,}940.49$ CM

$$\frac{R_1}{R_2} = \frac{\rho_1\dfrac{l_1}{A_1}}{\rho_2\dfrac{l_2}{A_2}} = \frac{\cancel{\rho_1}l_1A_2}{\cancel{\rho_2}l_2A_1} = \frac{l_1A_2}{l_2A_1} \qquad (\rho_1 = \rho_2)$$

and $R_2 = \dfrac{R_1l_2A_1}{l_1A_2} = \dfrac{(800\ \text{m}\Omega)(300\ \text{ft})(40{,}000\ \text{CM})}{(200\ \text{ft})(50{,}940.49\ \text{CM})} = \mathbf{942.28\ m\Omega}$

15. a. #8: $R = 1800\,\cancel{\text{ft}}\left[\dfrac{0.6282\ \Omega}{1000\,\cancel{\text{ft}}}\right] = \mathbf{1.1308\ \Omega}$

#18: $R = 1800\,\cancel{\text{ft}}\left[\dfrac{6.385\ \Omega}{1000\,\cancel{\text{ft}}}\right] = \mathbf{11.493\ \Omega}$

b. #18:#8 = 11.493 Ω:1.1308 Ω = 10.164:1 ≅ **10:1**

c. #18:#8 = 1624.3 CM:16,509 CM = 1:10.164 ≅ **1:10**

17. a. A/CM = 230 A/211,600 CM = **1.087 mA/CM**

b. $\dfrac{1.087\ \text{mA}}{\cancel{\text{CM}}}\left[\dfrac{1\ \cancel{\text{CM}}}{\dfrac{\pi}{4}\ \cancel{\text{sq mils}}}\right]\left[\dfrac{1000\ \cancel{\text{mils}}}{1\ \text{in.}}\right]\left[\dfrac{1000\ \cancel{\text{mils}}}{1\ \text{in.}}\right] = \mathbf{1.384\ kA/in.^2}$

c. $5\ \cancel{\text{kA}}\left[\dfrac{1\ \text{in.}^2}{1.348\ \cancel{\text{kA}}}\right] = \mathbf{3.6127\ in.^2}$

19. a. $\dfrac{1}{2}''\left[\dfrac{2.54\ \text{cm}}{1''}\right] = 1.27\ \text{cm}, \quad 3\ \cancel{\text{in.}}\left[\dfrac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right] = 7.62\ \text{cm}$

$4\ \cancel{\text{ft}}\left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right] = 121.92\ \text{cm}$

$R = \rho\dfrac{l}{A}\ \dfrac{(1.724 \times 10^{-6})(121.92\ \text{cm})}{(1.27\ \text{cm})(7.62\ \text{cm})} = \mathbf{21.71\ \mu\Omega}$

b. $R = \rho\dfrac{l}{A} = \dfrac{(2.825 \times 10^{-6})(121.92\ \text{cm})}{(1.27\ \text{cm})(7.62\ \text{cm})} = \mathbf{35.59\ \mu\Omega}$

c. increases

d. decreases

21. $R = R_s \frac{l}{w} \Rightarrow w = \frac{R_s l}{R} = \frac{(150\ \Omega)(1/2\ \text{in.})}{500\ \Omega} = \mathbf{0.15\ in.}$

23. $\frac{234.5 + t_1}{R_1} = \frac{234.5 + t_2}{R_2} \Rightarrow \frac{234.5 + 10}{2\ \Omega} = \frac{234.5 + 60}{R_2}$

$R_2 = \frac{(294.5)(2\ \Omega)}{244.5} = \mathbf{2.409\ \Omega}$

25. $C = \frac{5}{9}(°F - 32) = \frac{5}{9}(32 - 32) = 0°\ (=32°F)$

$C = \frac{5}{9}(70 - 32) = 21.11°\ (=70°F)$

$\frac{234.5° + 21.11°}{4\ \Omega} = \frac{234.5° + 0°}{R_2}$

$R_2 = \frac{(234.5)(4\ \Omega)}{255.61} = \mathbf{3.67\ \Omega}$

27. $\frac{243 + (-30)}{0.04\ \Omega} = \frac{243 + 0}{R_2}$

$R_2 = \frac{(243)(40\ \text{m}\Omega)}{213} = \mathbf{46\ m\Omega}$

29. a. $\frac{238.5}{0.92\ \Omega} = \frac{234.5 + t_2}{1.06\ \Omega}$

$274.793 = 234.5 + t_2$

$t_2 = \mathbf{40.29°C}$

b. $\frac{238.5}{0.92\ \Omega} = \frac{234.5 + t_2}{0.15\ \Omega}$

$38.886 = 234.5 + t_2$

$t_2 = \mathbf{-195.61°C}$

31. a. $\alpha_{20} = \frac{1}{|T| + 20°C} = \frac{1}{234.5 + 20} = \frac{1}{254.5} = 0.003929 \cong \mathbf{0.00393}$

b. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$

$1\ \Omega = 0.8\ \Omega[1 + 0.00393(t - 20°)]$

$1.25 = 1 + 0.00393t - 0.0786$

$1.25 - 0.9214 = 0.00393t$

$0.3286 = 0.00393t$

$t = \frac{0.3286}{0.00393} = \mathbf{83.61°C}$

33. Table: 1000′ of #12 copper wire = 1.588Ω @ 20°C

$C° = \frac{5}{9}(F° - 32) = \frac{5}{9}(115 - 32) = 46.11°C$

$R = R_{20}[1 + \alpha_{20}(t - 20°C)]$

$= 1.588\Omega[1 + 0.00393(46.11 - 20)]$

$= \mathbf{1.751\ \Omega}$

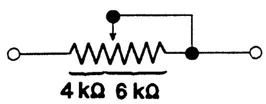
35. Fig. 3.21: At 90°C, +1% = 0.01(10,000) = 100 Ω, ∴ 10,100 Ω at 90°C
$\Delta R = R_2 - R_1 = 10{,}100\ \Omega - 10{,}000 = 100\ \Omega$
$\Delta T = 90° - 20°\text{C} = 70°\text{C}$

$$\text{PPM} = \frac{(\Delta R)(10^6)}{(R_{\text{nominal}})(\Delta T)} = \frac{(100\ \Omega)(10^6)}{(10\ \text{k}\Omega)(70)} = \mathbf{142.86}$$

41. $-30°\text{C} \Rightarrow +2\% = 200\ \Omega \Rightarrow$ **10.2 kΩ**
$100°\text{C} \Rightarrow 1.5\% = 150\ \Omega \Rightarrow$ **10.15 kΩ**

43. **6.5 kΩ**

45.



47. a. 220 Ω = Red, Red, Brown, Silver
b. 4700 Ω = Yellow, Violet, Red, Silver
c. 68 kΩ = Blue, Gray, Orange, Silver
d. 9.1 MΩ = White, Brown, Green, Silver

49. $\left.\begin{array}{l} 10\ \Omega \pm 10\% = 10\ \Omega \pm 1\ \Omega = 9\ \Omega - 11\ \Omega \\ 15\ \Omega \pm 10\% = 15\ \Omega \pm 1.5\ \Omega = 13.5\ \Omega - 16.5\ \Omega \end{array}\right\}$ No

51. a. Table 3.2, Ω/1000′ = 6.385 Ω

$$G = \frac{1}{R} = \frac{1}{6.385\ \Omega} = \mathbf{156.6\ mS}$$

$$\text{or } G = \frac{A}{\rho l} = \frac{1{,}624.3\ \text{CM (Table 3.2)}}{(10.37)(1000')} = \mathbf{156.6\ mS}$$

b. $G = \dfrac{1{,}624.3\ \text{CM}}{(17)(1000')} = \mathbf{95.54\ mS}$ (Al)

c. $G = \dfrac{1.624.3\ \text{CM}}{(74)(1000')} = \mathbf{21.95\ mS}$ (Fe)

53. Good: $R < 1\ \Omega$ (low)
Bad: $R = \infty\,\Omega$

55. Good: Some resistance (filament not open)
Bad: $R = \infty\,\Omega$ (filament open)

57. a. Log scale: 10 fc ⇒ 3 kΩ
100 fc ⇒ 0.4 kΩ

b. negative

c. no—log scales imply linearity

d. 1 kΩ ⇒ ≅30 fc
10 kΩ ⇒ ≅2 fc

$$\left|\frac{\Delta R}{\Delta fc}\right| = \frac{10\ \text{k}\Omega - 1\ \text{k}\Omega}{30\ \text{fc} - 2\ \text{fc}} = 321.43\ \Omega/\text{fc}$$

$$\text{and } \frac{\Delta R}{\Delta \text{fc}} = -321.43\ \Omega/\text{fc}$$

CHAPTER 3 (Even)

2. a. 0.050 in. = 50 mils, $A_{CM} = (50 \text{ mils})^2 = \mathbf{2500\ CM}$

b. 0.016 in. = 16 mils, $A_{CM} = (16 \text{ mils})^2 = \mathbf{256\ CM}$

c. 0.30 in. = 300 mils, $A_{CM} = (300 \text{ mils})^2 = \mathbf{90 \times 10^3\ CM}$

d. $[0.1\ \cancel{\text{cm}}]\left[\dfrac{1 \text{ in.}}{2.54\ \cancel{\text{cm}}}\right] = 0.0394 \text{ in.} = 39.4 \text{ mils}$

$A_{CM} = (39.4 \text{ mils})^2 = \mathbf{1552.36\ CM}$

e. $0.003\ \cancel{\text{ft}}\left[\dfrac{12 \text{ in.}}{1\ \cancel{\text{ft}}}\right] = 0.036 \text{ in.} = 36 \text{ mils}$

$A_{CM} = (36 \text{ mils})^2 = \mathbf{1296\ CM}$

f. $0.0042\ \cancel{\text{m}}\left[\dfrac{39.37 \text{ in.}}{1\ \cancel{\text{m}}}\right] = 0.1654 \text{ in.} = 165.4 \text{ mils}$

$A_{CM} = (165.4 \text{ mils})^2 = \mathbf{27{,}357.16\ CM}$

4. 0.01 in. = 10 mils, $A_{CM} = (10 \text{ mils})^2 = 100 \text{ CM}$

$R = \rho\dfrac{l}{A} = (10.37)\dfrac{(200')}{100 \text{ CM}} = \mathbf{20.74\ \Omega}$

6. a. $A = \rho\dfrac{l}{R} = \dfrac{(17)(80')}{2.5\ \Omega} = \mathbf{544\ CM}$

b. $d = \sqrt{A_{CM}} = \sqrt{544 \text{ CM}} = 23.32 \text{ mils} = \mathbf{0.0233\ in.}$

8. a. $A_{CM} = \rho\dfrac{l}{R} = \dfrac{(10.37)(300')}{2.5\ \Omega} = \mathbf{1244.40\ CM}$ b. **larger** c. **smaller**

10. $\rho = \dfrac{RA}{l} = \dfrac{(500\ \Omega)(94 \text{ CM})}{1000'} = 47 \Rightarrow$ **nickel**

12. $l_2 = 2l_1,\ A_2 = A_1/4,\ \rho_2 = \rho_1$

$$\frac{R_2}{R_1} = \frac{\dfrac{\rho_2 l_2}{A_2}}{\dfrac{\rho_1 l_1}{A_1}} = \frac{\cancel{\rho_2} l_2 A_1}{\cancel{\rho_1} l_1 A_2} = \frac{2l_1 A_1}{l_1 A_1/4} = 8$$

and $R_2 = 8R_1 = 8(0.2\ \Omega) = 1.6\ \Omega$

$\Delta R = 1.6\ \Omega - 0.2\ \Omega = \mathbf{1.4\ \Omega}$

14. a. #11: $450\ \cancel{\text{ft}}\left[\dfrac{1.260\ \Omega}{1000\ \cancel{\text{ft}}}\right] = \mathbf{0.567\ \Omega}$

#14: $450\ \cancel{\text{ft}}\left[\dfrac{2.525\ \Omega}{1000\ \cancel{\text{ft}}}\right] = \mathbf{1.136\ \Omega}$

b. Resistance: #14:#11 = 1.136 Ω:0.567 Ω ≅ **2:1**

c. Area: #14:#11 = 4106.8 CM:8234.0 CM ≅ **1:2**

16. a. $A = \rho\dfrac{l}{R} = \dfrac{(10.37)(30')}{6\ \text{m}\Omega} = \dfrac{311.1\ \text{CM}}{6 \times 10^{-3}} = 51{,}850\ \text{CM} \Rightarrow \#3$

but 110 A ⇒ **#2**

b. $A = \rho\dfrac{l}{R} = \dfrac{(10.37)(30')}{3\ \text{m}\Omega} = \dfrac{311.1\ \text{CM}}{3 \times 10^{-3}} = 103{,}700\ \text{CM} \Rightarrow \boldsymbol{\#0}$

18. $\dfrac{1}{10}\ \text{in.} = 0.1\ \text{in.}\left[\dfrac{2.54\ \text{cm}}{1\ \text{in.}}\right] = 0.254\ \text{cm}$

$$A = \frac{\pi d^2}{4} = \frac{(3.14)(0.254\ \text{cm})^2}{4} = 0.0506\ \text{cm}^2$$

$$l = \frac{RA}{\rho} = \frac{(2\ \Omega)(0.0506\ \text{cm}^2)}{1.724 \times 10^{-6}} = 58{,}700\ \text{cm} = \mathbf{58.7\ m}$$

20. $R_s = \dfrac{\rho}{d} = 100 \Rightarrow d = \dfrac{\rho}{100} = \dfrac{250 \times 10^{-6}}{100} = \mathbf{2.5\ \mu cm}$

22. a. $d = 1\ \text{in.} = 1000\ \text{mils}$

$A_{\text{CM}} = (10^3\ \text{mils})^2 = 10^6\ \text{CM}$

$$\rho_1 = \frac{RA}{l} = \frac{(1\ \text{m}\Omega)(10^6\ \text{CM})}{10^3\ \text{ft}} = \mathbf{1\ CM\text{-}\Omega/ft}$$

b. $1\ \text{in.} = 2.54\ \text{cm}$

$$A = \frac{\pi d^2}{4} = \frac{\pi(2.54\ \text{cm})^2}{4} = 5.067\ \text{cm}^2$$

$$l = 1000\ \text{ft}\left[\frac{12\ \text{in.}}{1\ \text{ft}}\right]\left[\frac{2.54\ \text{cm}}{1\ \text{in.}}\right] = 30{,}480\ \text{cm}$$

$$\rho_2 = \frac{RA}{l} = \frac{(1\ \text{m}\Omega)(5.067\ \text{cm}^2)}{30{,}480\ \text{cm}} = \mathbf{1.662 \times 10^{-7}\ \Omega\text{-cm}}$$

c. $k = \dfrac{\rho_2}{\rho_1} = \dfrac{1.662 \times 10^{-7}\ \Omega\text{-cm}}{1\ \text{CM-}\Omega/\text{ft}} = \mathbf{1.662 \times 10^{-7}}$

24. $\dfrac{236 + 0}{0.02\ \Omega} = \dfrac{236 + 100}{R_2}$

$$R_2 = \frac{(0.02\ \Omega)(336)}{236} = \mathbf{0.028\ \Omega}$$

26. $\dfrac{234.5 + 30}{0.76\ \Omega} = \dfrac{234.5 - 40}{R_2}$

$$R_2 = \frac{(194.5)(0.76\ \Omega)}{264.5} = \mathbf{0.5589\ \Omega}$$

28. a. $68°F = 20°C$, $32°F = 0°C$

$$\frac{234.5 + 20}{0.002} = \frac{234.5 + 0}{R_2}$$

$$R_2 = \frac{(234.5)(2\ m\Omega)}{254.5} = \mathbf{1.842\ m\Omega}$$

$212°F = 100\ °C$

$$\frac{234.5 + 20}{2\ m\Omega} = \frac{234.5 + 100}{R_2}$$

$$R_2 = \frac{(334.5)(2\ m\Omega)}{254.5} = \mathbf{2.628\ m\Omega}$$

b. $$\frac{\Delta R}{\Delta T} = \frac{2.628\ m\Omega - 2\ m\Omega}{100°C - 20°C} = \frac{0.628\ m\Omega}{80°C} = 7.85\ \mu\Omega/°C \text{ or } \mathbf{7.85 \times 10^{-5}\ \Omega/10°C}$$

30. a. $K = 273.15 + °C$

$50 = 273.15 + °C$

$°C = -223.15°$

$$\frac{234.5 + 20}{10\ \Omega} = \frac{234.5 - 223.15}{R_2}$$

$$R_2 = \frac{11.35}{254.5}(10\ \Omega) = \mathbf{0.446\ \Omega}$$

b. $K = 273.15 + °C$

$38.65 = 273.15 + °C$

$°C = -234.5°$

$$\frac{234.5 + 20}{10\ \Omega} = \frac{234.5 - 234.5}{R_2}$$

$$R_2 = \frac{(0)10\ \Omega}{254.5} = \mathbf{0\ \Omega}$$

Recall -234.5 = **Inferred**
Absolute zero ($R = 0\ \Omega$)

c. $$F = \frac{9}{5}°C + 32 = \frac{9}{5}(-273.15°) + 32 = \mathbf{-459.67°}$$

32. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$
$= 0.4\ \Omega[1 + 0.00393(16 - 20)] = 0.4\ \Omega[1 - 0.01572] = \mathbf{0.394\ \Omega}$

34. $$\Delta R = \frac{R_{\text{nominal}}}{10^6}(\text{PPM})(\Delta T) = \frac{(22\ \Omega)}{10^6}(200)(65° - 25°) = 0.176\ \Omega$$

$R = R_{\text{nominal}} + \Delta R = \mathbf{22.176\ \Omega}$

38. #12: Area = 6529 CM

$$d = \sqrt{6529\ \text{CM}} = 80.8\text{ mils} = 0.0808\text{ in.}\left[\frac{2.54\text{ cm}}{1\text{ in.}}\right] = 0.205\text{ cm}$$

$$A = \frac{\pi d^2}{4} = \frac{\pi(0.205\text{ cm})^2}{4} = 0.033\text{ cm}^2$$

$$I = \frac{1\text{ MA}}{\cancel{\text{cm}^2}}[0.033\ \cancel{\text{cm}^2}] = \mathbf{33\ kA} \gg 20\text{ A}$$

40. a. 2 times larger

b. 4 times larger

42. $120°F \Rightarrow C = \frac{5}{9}(°F - 32) = \frac{5}{9}(120 - 32) = \frac{5}{9}(88) = 48.89°$

Fig. 3.21 – no apparent change from 20° level
$\therefore$ **10 kΩ**

44. **6.25 kΩ and 18.75 kΩ**

46. a. $56{,}000 \pm 5\% = 56{,}000\ \Omega \pm 2800\ \Omega = \mathbf{53{,}200\ \Omega - 58{,}800\ \Omega}$

b. $220\ \Omega \pm 10\% = 220\ \Omega \pm 22\ \Omega = \mathbf{198\ \Omega - 242\ \Omega}$

c. $10\ \Omega \pm 20\% = 10\ \Omega \pm 2\ \Omega = \mathbf{8\ \Omega - 12\ \Omega}$

48. $\left.\begin{array}{l} 10\ \Omega \pm 20\% \Rightarrow 8\ \Omega \rightarrow 12\ \Omega \\ 15\ \Omega \pm 20\% \Rightarrow 12\ \Omega \rightarrow 18\ \Omega \end{array}\right\}$ Yes

50. a. $G = \dfrac{1}{0.086\ \Omega} = \mathbf{11.628\ S}$ b. $G = \dfrac{1}{4000\ \Omega} = \mathbf{0.25\ mS}$

c. $G = \dfrac{1}{2.2 \times 10^6\ \Omega} = \mathbf{0.4545\ \mu S}$

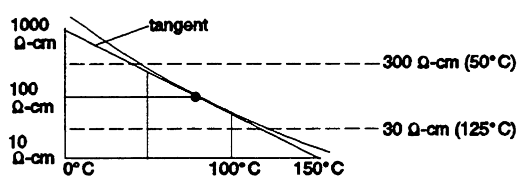
$G_a > G_b > G_c$ vs $R_c > R_b > R_a$

52. $A_2 = 1\frac{2}{3} A_1 = \frac{5}{3} A_1,\ l_2 = \left[1 - \frac{2}{3}\right] l_1 = \frac{l_1}{3},\ \rho_2 = \rho_1$

$$\frac{G_1}{G_2} = \frac{\rho_1 \frac{A_1}{l_1}}{\rho_2 \frac{A_2}{l_2}} = \frac{\cancel{\rho_2} l_2 A_1}{\cancel{\rho_1} l_1 A_2} = \frac{\left[\frac{l_1}{3}\right] A_1}{l_1 \left[\frac{5}{3} A_1\right]} = \frac{1}{5}$$

$G_2 = 5G_1 = 5(100\ \text{S}) = \mathbf{500\ S}$

56. a. $-50°$C specific resistance $\cong 10^5\ \Omega$-cm
$50°$C specific resistance $\cong 500\ \Omega$-cm
$200°$C specific resistance $\cong 7\ \Omega$-cm



b. negative

c. No

d. $\rho = \dfrac{\Delta\ \Omega\text{-cm}}{\Delta T} = \dfrac{300 - 30}{125 - 50} = \dfrac{270\ \Omega\text{-cm}}{75°\text{C}} \cong \mathbf{3.6\ \Omega\text{-cm}/°C}$

58. @ 0.5 mA, V $\cong$ **195 V**
@ 1 mA, V $\cong$ **200 V**
@ 5 mA, V $\cong$ **215 V**
$\Delta V_{\text{total}} = 215\ \text{V} - 195\ \text{V} = 20\ \text{V}$
5 mA:0.5 mA = 10:1
compared to
215 V:200 V = 1.075:1

CHAPTER 4 (Odd)

1. $V = IR = (2.5\text{ A})(6\ \Omega) = \mathbf{15\ V}$

3. $R = \dfrac{V}{I} = \dfrac{6\text{ V}}{1.5\text{ mA}} = \mathbf{4\ k\Omega}$

5. $V = IR = (3.6\ \mu\text{A})(0.02\text{ M}\Omega) = 0.072\text{ V} = \mathbf{72\ mV}$

7. $R = \dfrac{V}{I} = \dfrac{120\text{ V}}{2.2\text{ A}} = \mathbf{54.55\ \Omega}$

9. $R = \dfrac{V}{I} = \dfrac{120\text{ V}}{4.2\text{ A}} = \mathbf{28.571\ \Omega}$

11. $R = \dfrac{V}{I} = \dfrac{24\text{ mV}}{20\ \mu\text{A}} = \mathbf{1.2\ k\Omega}$

13. a. $R = \dfrac{V}{I} = \dfrac{120\text{ V}}{9.5\text{ A}} = \mathbf{12.632\ \Omega}$

b. $t = 1\cancel{\text{h}}\left[\dfrac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\dfrac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = 3600\text{ s}$

$$\begin{aligned} W &= Pt = VIt \\ &= (120\text{ V})(9.5\text{ A})(3600\text{ s}) \\ &= \mathbf{4.1 \times 10^6\ J} \end{aligned}$$

17. $R = \dfrac{\Delta V}{\Delta I} \Rightarrow \Delta V = R(\Delta I) = (2 \times 10^3)(400 \times 10^{-3}) = \mathbf{800\ V}$

19. $P = \dfrac{W}{t} = \dfrac{420\text{ J}}{7\ \cancel{\text{min}}\left[\dfrac{60\text{ s}}{1\ \cancel{\text{min}}}\right]} = \dfrac{420\text{ J}}{420\text{ s}} = \mathbf{1\ W}$

21. a. $8\cancel{\text{h}}\left[\dfrac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\dfrac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = 28{,}800\text{ s}$

$W = Pt = (2\text{ W})(28{,}000\text{ s}) = \mathbf{57.6\ kJ}$

b. $\text{kWh} = \dfrac{(2\text{ W})(8\text{ h})}{1000} = \mathbf{16 \times 10^{-3}\ kWh}$

23. $P = VI = (3\text{ V})(2\text{ A}) = 6\text{ W}$

$t = \dfrac{W}{P} = \dfrac{12\text{ J}}{6\text{ W}} = \mathbf{2\ s}$

25. $P = I^2R = (7 \times 10^{-3}\text{A})^2(4\ \Omega) = \mathbf{196\ \mu W}$

27. $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{64\text{ W}}{4\ \Omega}} = \sqrt{16} = \mathbf{4\ A}$

29. $V = \sqrt{PR} = \sqrt{(42\text{ mW})(2.2\text{ k}\Omega)} = \sqrt{92.40} = \mathbf{9.61\text{ V}}$

31. $P = VI, I = \dfrac{P}{V} = \dfrac{100\text{ W}}{120\text{ V}} = \mathbf{0.833\text{ A}}$

$R = \dfrac{V}{I} = \dfrac{120\text{ V}}{0.833\text{ A}} = \mathbf{144.06\ \Omega}$

33. a. $P = EI$ and $I = \dfrac{P}{E} = \dfrac{0.4 \times 10^{-3}\text{ W}}{3\text{ V}} = \mathbf{0.133\text{ mA}}$

b. Ah rating = (0.133 mA)(500 h) = **66.5 mAh**

35. c. $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{500\text{ mW}}{100\ \Omega}}\ \sqrt{5 \times 10^{-3}} \cong \mathbf{70.7\text{ mA}}$

37. a. $P = EI = (120\text{ V})(100\text{ A}) = \mathbf{12\text{ kW}}$

b. $P_T = 5\ \cancel{\text{hp}}\left[\dfrac{746\text{ W}}{\cancel{\text{hp}}}\right] + 3000\text{ W} + 2400\text{ W} + 1000\text{ W}$

$= 10{,}130 < 12{,}000\text{ W}$ **(Yes)**

39. $\eta = \dfrac{P_o}{P_i}, P_i = \dfrac{P_o}{\eta} = \dfrac{(1.8\ \cancel{\text{hp}})(746\text{ W}/\cancel{\text{hp}})}{0.685} = 1960.29\text{ W}$

$P_i = EI, I = \dfrac{P_i}{E} = \dfrac{1960.29\text{ W}}{120\text{ V}} = \mathbf{16.34\text{ A}}$

41. a. $P_i = EI = (120\text{ V})(2.4\text{ A}) = 288\text{ W}$

$P_i = P_o + P_{\text{lost}},\ P_{\text{lost}} = P_i - P_o = 288\text{ W} - 50\text{ W} = \mathbf{238\text{ W}}$

b. $\eta\% = \dfrac{P_o}{P_i} \times 100\% = \dfrac{50\text{ W}}{288\text{ W}} \times 100\% = \mathbf{17.36\%}$

43. a. $P_i = \dfrac{P_o}{\eta} = \dfrac{(2\text{ hp})(746\text{ W/hp})}{0.9} = \mathbf{1657.78\text{ W}}$

b. $P_i = EI = 1657.78\text{ W}$

$(110\text{ V})I = 1657.78\text{ W}$

$I = \dfrac{1657.78\text{ W}}{110\text{ V}} = \mathbf{15.07\text{ A}}$

c. $P_i = \dfrac{P_o}{\eta} = \dfrac{(2\ \cancel{\text{hp}})(746\text{ W}/\cancel{\text{hp}})}{0.7} = 2131.43\text{ W}$

$P_i = EI = 2131.43\text{ W}$

$(110\text{ V})I = 2131.43\text{ W}$

$I = \dfrac{2131.43\text{ W}}{110\text{ V}} = \mathbf{19.38\text{ A}}$

45. $\eta_T = \eta_1 \cdot \eta_2 = (0.87)(0.75) = 0.6525 \Rightarrow \mathbf{65.25\%}$

47. $\eta_T = \eta_1 \cdot \eta_2 = 0.72 = 0.9\eta_2$

$$\eta_2 = \frac{0.72}{0.9} = 0.8 \Rightarrow \mathbf{80\%}$$

49. a. $\eta_T = \eta_1 \cdot \eta_2 \cdot \eta_3 = (0.98)(0.87)(0.21) = 0.1790 \Rightarrow \mathbf{17.9\%}$

b. $\eta_T = \eta_1 \cdot \eta_2 \cdot \eta_3 = (0.98)(0.87)(0.90) = 0.7673 \Rightarrow \mathbf{76.73\%}$

$$\frac{76.73\% - 17.9\%}{17.9\%} \times 100\% \Rightarrow \mathbf{328.66\%}$$

51. a. $W = Pt = \left[\frac{V^2}{R}\right]t = \left[\frac{15\text{ V}}{10\ \Omega}\right]^2 60\text{ s} = \mathbf{1350\ J}$

b. Energy doubles, power the same

53. $\text{kWh} = \frac{Pt}{1000} \Rightarrow t = \frac{(1000)(\text{kWh})}{P} = \frac{(1000)(10\text{ kWh})}{1500\text{ W}} \doteq \mathbf{6.67\ h}$

55. a. $\text{kWh} = \frac{Pt}{1000} \Rightarrow P = \frac{(1000)(\text{kWh})}{t} = \frac{(1000)(500\text{ kWh})}{10\text{ s}} = \mathbf{50\ kW}$

b. $I = \frac{P}{E} = \frac{50 \times 10^3\text{ W}}{208\text{ V}} = \mathbf{240.38\ A}$

c. $P_{\text{lost}} = P_i - P_o = P_i - \eta P_i = P_i(1 - \eta) = 50\text{ kW}(1 - 0.82) = \mathbf{9\ kW}$

$$\text{kWh}_{\text{lost}} = \frac{Pt}{1000} = \frac{(9\text{ kW})(10\text{ h})}{1000} = \mathbf{90\ kWh}$$

57. $\text{kWh} = \frac{(860\text{ W})(24\text{ h}) + (4800\text{ W})(1/2\text{ h}) + (400\text{ W})(1\text{ h}) + (1200\text{ W})(0.75\text{ h})}{1000}$

$= \mathbf{24.34\ kWh}$

$24.34\ \cancel{\text{kWh}}[9¢/\cancel{\text{kWh}}] = \mathbf{\$2.19}$

CHAPTER 4 (Even)

2. $I = \dfrac{V}{R} = \dfrac{12\text{ V}}{72\ \Omega} = \mathbf{166.67\ mA}$

4. $I = \dfrac{V}{R} = \dfrac{12\text{ V}}{0.056\ \Omega} = \mathbf{214.29\ A}$

6. $I = \dfrac{V}{R} = \dfrac{62\text{ V}}{15\text{ k}\Omega} = \mathbf{4.133\ mA}$

8. $I = \dfrac{V}{R} = \dfrac{120\text{ V}}{7.5\text{ k}\Omega} = \mathbf{16\ mA}$

10. $R = \dfrac{V}{I} = \dfrac{120\text{ V}}{0.76\text{ A}} = \mathbf{157.89\ \Omega}$

12. $V = IR = (15\text{ A})(0.5\ \Omega) = \mathbf{7.5\ V}$

20. $t = \dfrac{W}{P} = \dfrac{640\text{ J}}{40\text{ W}} = \mathbf{16\ s}$

22. $I = \dfrac{Q}{t} = \dfrac{300\text{ C}}{1\ \cancel{\text{min}}}\left[\dfrac{1\ \cancel{\text{min}}}{60\text{ s}}\right] = 5\text{ C/s} = 5\text{ A}$

$P = I^2R = (5\text{ A})^2\ 10\ \Omega = \mathbf{250\ W}$

24. $I = \dfrac{48\text{ C}}{\cancel{\text{min}}}\left[\dfrac{1\ \cancel{\text{min}}}{60\text{ s}}\right] = 0.8\text{ A}$

$P = EI = (6\text{ V})(0.8\text{ A}) = \mathbf{4.8\ W}$

26. $P = \dfrac{V^2}{R} = \dfrac{(9 \times 10^{-3}\text{ V})^2}{3\ \Omega} = \mathbf{27\ \mu W}$

28. $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{0.5\text{ W}}{1\text{ k}\Omega}} = \mathbf{22.36\ mA}$

30. $P = EI = (9\text{ V})(45\text{ mA}) = \mathbf{405\ mW}$

32. $V = \dfrac{P}{I} = \dfrac{450\text{ W}}{3.75\text{ A}} = \mathbf{120\ V}$

$R = \dfrac{V}{I} = \dfrac{120\text{ V}}{3.75\text{ A}} = \mathbf{32\ \Omega}$

34. $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{100\text{ W}}{20\text{ k}\Omega}} = \sqrt{5 \times 10^{-3}} = \mathbf{70.71\ mA}$

$V = \sqrt{PR} = \sqrt{(100\text{ W})(20\text{ k}\Omega)} = \mathbf{1.414\ kV}$

36. a. $P = EI = (9\text{ V})(0.455\text{ A}) = \mathbf{4.095\ W}$ b. $R = \dfrac{E}{I} = \dfrac{9\text{ V}}{0.455\text{ A}} = \mathbf{19.78\ \Omega}$

c. $W = Pt = (4.095\text{ W})(21{,}600\text{ s}) = \mathbf{88.45\ kJ}$

$$6\,\cancel{\text{h}}\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = 21{,}600\text{ s}$$

38. $$\eta = \frac{P_o}{P_i} \times 100\% = \frac{(0.5\ \cancel{\text{hp}})\left[\dfrac{746\text{ W}}{\cancel{\text{hp}}}\right]}{450\text{ W}} \times 100\% = \frac{373}{450} \times 100\% = \mathbf{82.89\%}$$

40. $$\eta = \frac{P_o}{P_i} \times 100\% = \frac{746\text{ W}}{(4\text{ A})(220\text{ V})} \times 100\% = \frac{746}{880} \times 100\% = \mathbf{84.77\%}$$

42. $$P_i = EI = \frac{P_o}{\eta} \Rightarrow I = \frac{P_o}{\eta E} = \frac{(3.6\ \cancel{\text{hp}})(746\text{ W}/\cancel{\text{hp}})}{(0.87)(220\text{ V})} = \mathbf{14.03\ A}$$

44. $$P_i = \frac{P_o}{\eta} = \frac{(15\ \cancel{\text{hp}})(746\text{ W}/\cancel{\text{hp}})}{0.9} = 12{,}433.33\text{ W}$$

$$I = \frac{P_i}{E} = \frac{12{,}433.33\text{ W}}{220\text{ V}} = \mathbf{56.52\ A}$$

46. $\eta_1 = \eta_2 = 0.8$

$\eta_T = (\eta_1)(\eta_2) = (0.8)(0.8) = 0.64$

$$\eta_T = \frac{W_o}{W_i} \Rightarrow W_o = \eta_T W_i = (0.64)(60\text{ J}) = \mathbf{38.4\ J}$$

48. $$\eta_T = \frac{P_o}{P_i} = \eta_1 \cdot \eta_2 = \eta_1 \cdot 2\eta_1 = 2\eta_1^2$$

$$\eta_1^2 = \frac{P_o}{2P_i} \Rightarrow \eta_1 = \sqrt{\frac{P_o}{2P_i}} = \sqrt{\frac{128\ W}{2(400\ W)}} = 0.4$$

$\eta_2 = 2\eta_1 = 2(0.4) = 0.8$

$\therefore\ \eta_1 = \mathbf{40\%},\ \eta_2 = \mathbf{80\%}$

50. a. $$1\text{ watt}\cdot\cancel{\text{hour}}\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right]\left[\frac{1\text{ J}}{1\text{ watt}\cdot\cancel{\text{sec}}}\right] = \mathbf{3600\ J}$$

$$1\ \cancel{\text{kWh}}\left[\frac{1000\ \cancel{\text{Wh}}}{1\ \cancel{\text{kWh}}}\right]\left[\frac{3600\text{ J}}{1\ \cancel{\text{Wh}}}\right] = \mathbf{3.6 \times 10^6\ J}$$

b. For large energy applications the numbers would be enormous if joules were employed. For low levels of energy consumption the use of joules can be appropriate.

52. $\dfrac{12\text{ h}}{\cancel{\text{week}}}\left[\dfrac{4\frac{1}{3}\ \cancel{\text{weeks}}}{1\ \cancel{\text{month}}}\right][5\ \cancel{\text{months}}] = 260\text{ h}$

$$\text{kWh} = \frac{(230\text{ W})(260\text{ h})}{1000} = \mathbf{59.80\ kWh}$$

54. $\text{kWh} = \dfrac{(30\text{ W})(3\text{ h})}{1000} = \mathbf{0.09\ kWh}$

$$(0.09\ \cancel{\text{kWh}})(9¢/\cancel{\text{kWh}}) = \mathbf{0.81¢}$$

56. a. $\#\text{kWh} = \dfrac{\$1.00}{9¢} = 11.11$

$$\text{kWh} = \frac{Pt}{1000} \Rightarrow t = \frac{(\text{kWh})(1000)}{P} = \frac{(11.11)(1000)}{250} = \mathbf{44.44\ h}$$

b. $t = \dfrac{(\text{kWh})(1000)}{P} = \dfrac{(11.11)(1000)}{4800} = \mathbf{2.32\ h}$

58. $\text{kWh} = \dfrac{(110\text{ W})(4\text{ h}) + (1200\text{ W})(1/3\text{ h}) + (60\text{ W})(1.5\text{ h}) + (150\text{ W})(3\ 3/4\text{ h})}{1000}$

$$= \frac{440\text{ Wh} + 400\text{ Wh} + 90\text{ Wh} + 562.5\text{ Wh}}{1000} = 1.4925\text{ kWh}$$

$1.4925\ \cancel{\text{kWh}}[9¢/\cancel{\text{kWh}}] = \mathbf{13.43¢}$

CHAPTER 5 (Odd)

1. a. $R_T = 2\ \Omega + 6\ \Omega + 12\ \Omega = \mathbf{20\ \Omega}$, $I = \dfrac{E}{R_T} = \dfrac{60\ \text{V}}{20\ \Omega} = \mathbf{3\ A}$

   b. $R_T = 0.2\ \text{M}\Omega + 1\ \text{M}\Omega + 0.33\ \text{M}\Omega + 0.1\ \text{M}\Omega = \mathbf{1.63\ M\Omega}$
   $I = \dfrac{E}{R_T} = \dfrac{10\ \text{V}}{1.63\ \text{M}\Omega} = \mathbf{6.135\ \mu A}$

   c. $R_T = 15\ \Omega + 10\ \Omega + 25\ \Omega + 25\ \Omega + 10\ \Omega + 25\ \Omega = \mathbf{110\ \Omega}$
   $I = \dfrac{E}{R_T} = \dfrac{35\ \text{V}}{110\ \Omega} = \mathbf{318.2\ mA}$

   d. $R_T = 1.2\ \text{k}\Omega + 4.5\ \text{k}\Omega + 1.3\ \text{k}\Omega + 3\ \text{k}\Omega = \mathbf{10\ k\Omega}$
   $I = \dfrac{E}{R_T} = \dfrac{120\ \text{V}}{10\ \text{k}\Omega} = \mathbf{12\ mA}$

3. a. $R_T = 60\ \Omega + 1200\ \Omega + 2740\ \Omega = 4\ \text{k}\Omega$
   $E = IR_T = (4\ \text{mA})(4\ \text{k}\Omega) = \mathbf{16\ V}$

   b. $R_T = 1.2\ \Omega + 8.2\ \Omega + 4.7\ \Omega + 2.7\ \Omega = \mathbf{16.8\ \Omega}$
   $E = IR_T = (250\ \text{mA})(16.8\ \Omega) = \mathbf{4.2\ V}$

5. a. $R_T = 4.7\ \Omega + 5.6\ \Omega = 10.3\ \Omega$
   $I = \dfrac{16\ \text{V} - 8\ \text{V} - 4\ \text{V}}{10.3\ \Omega} = \dfrac{4\ \text{V}}{10.3\ \Omega} = \mathbf{0.388\ A}$ (clockwise)

   b. $R_T = 4.7\ \Omega + 1.2\ \Omega + 5.6\ \Omega = 11.5\ \Omega$
   $I = \dfrac{18\ \text{V} + 10\ \text{V} - 4\ \text{V}}{11.5\ \Omega} = \mathbf{2.087\ A}$ (counterclockwise)

7. a. $+10\ \text{V} - 2\ \text{V} - 3\ \text{V} - V_{\underset{+-}{ab}} = 0$

   $V_{\underset{+-}{ab}} = 10\ \text{V} - 5\ \text{V} = \mathbf{5\ V}$

   b. $60\ \text{V} + 20\ \text{V} - V_{\underset{+-}{ab}} - 10\ \text{V} = 0$

   $V_{\underset{+-}{ab}} = 80\ \text{V} - 10\ \text{V} = \mathbf{70\ V}$

9. $I = \dfrac{27\ \text{V} - 9\ \text{V} - 5\ \text{V}}{2.2\ \text{k}\Omega + 1.2\ \text{k}\Omega + 0.56\ \text{k}\Omega} = \dfrac{13\ \text{V}}{3.96\ \text{k}\Omega} = \mathbf{3.28\ mA}$
   $V_1 = IR = (3.28\ \text{mA})(2.2\ \text{k}\Omega) = \mathbf{7.22\ V}$

11. a. $R_T = 22\ \Omega + 10\ \Omega + 5.6\ \Omega + 33\ \Omega = \mathbf{70.6\ \Omega}$
   $I = \dfrac{E}{R_T} = \dfrac{6\ \text{V}}{70.6\ \Omega} = 0.085\ \text{A} = \mathbf{85\ mA}$ (CCW)
   $V_1 = IR = (85\ \text{mA})(33\ \Omega) = \mathbf{2.805\ V}$
   $V_2 = IR = (85\ \text{mA})(5.6\ \Omega) = \mathbf{0.476\ V}$
   $V_3 = IR = (85\ \text{mA})(10\ \Omega) = \mathbf{0.850\ V}$
   $V_4 = IR = (85\ \text{mA})(22\ \Omega) = \mathbf{1.870\ V}$

b. $E = V_1 + V_2 + V_3 + V_4$
$6\text{ V} = 2.805\text{ V} + 0.476\text{ V} + 0.850\text{ V} + 1.870\text{ V}$
$6\text{ V} \overset{\checkmark}{=} 6\text{ V}$

c. $33\ \Omega$: $P = I^2R = (85\text{ mA})^2\, 33\ \Omega = \mathbf{238.4\ mW}$
$5.6\ \Omega$: $P = I^2R = (85\text{ mA})^2\, 5.6\ \Omega = \mathbf{40.5\ mW}$
$10\ \Omega$: $P = I^2R = (85\text{ mA})^2\, 10\ \Omega = \mathbf{72.3\ mW}$
$22\ \Omega$: $P = I^2R = (85\text{ mA})^2\, 22\ \Omega = \mathbf{159\ mW}$

$P_{\text{del}} = EI = (6\text{ V})(85\text{ mA}) = 510\text{ mW}$
$P_{\text{del}} = 238.4\text{ mW} + 40.5\text{ mW} + 72.3\text{ mW} + 159\text{ mW}$
$510\text{ mW} \overset{\checkmark}{=} 510\text{ mW}$

d. All $\mathbf{\frac{1}{2}}$ **W.**

13. a. $R_T = NR_1 = 8\left[28\frac{1}{8}\ \Omega\right] = \mathbf{225\ \Omega}$

$I = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{225\ \Omega} = \mathbf{0.533\ A} = \dfrac{8}{15}\text{ A}$

b. $P = I^2R = \left[\dfrac{8}{15}\text{ A}\right]^2\left[28\frac{1}{8}\ \Omega\right] = \left[\dfrac{64}{\cancel{225}}\right]\left[\dfrac{\cancel{225}}{8}\right] = \mathbf{8\ W}$

c. $V = IR = \left[\dfrac{\cancel{8}}{15}\text{ A}\right]\left[\dfrac{225}{\cancel{8}}\ \Omega\right] = \mathbf{15\ V}$

d. All go out!

15. a. $V_{\underset{+-}{ab}} = \dfrac{50\ \Omega(100\text{ V})}{50\ \Omega + 25\ \Omega} = \mathbf{66.67\ V}$

b. $V_{\underset{+-}{ab}} = \dfrac{-4\ \Omega(80\text{ V})}{4\ \Omega + 6\ \Omega + 10\ \Omega + 20\ \Omega} = \dfrac{-320\text{ V}}{40} = \mathbf{-8\ V}$

c. $V_{\underset{+-}{ab}} = \dfrac{(2\text{ k}\Omega + 3\text{ k}\Omega)(40\text{ V})}{(4\text{ k}\Omega + 1\text{ k}\Omega + 2\text{ k}\Omega + 3\text{ k}\Omega)} = \dfrac{5(40\text{ V})}{10} = \mathbf{20\ V}$

d. $V_{\underset{+-}{ab}} = \dfrac{(1.5\ \Omega + 0.6\ \Omega + 0.9\ \Omega)(0.36\text{ V})}{2.5\ \Omega + 1.5\ \Omega + 0.6\ \Omega + 0.9\ \Omega + 0.5\ \Omega}$
$= \dfrac{(3\ \Omega)(0.36\text{ V})}{6\ \Omega} = \mathbf{0.18\ V}$

17. a. 12 V

b. $V_3 = E - V_1 - V_2 = 40\text{ V} - 4\text{ V} - 12\text{ V} = \mathbf{24\ V}$

c. $\dfrac{V_3}{V_1} = \dfrac{R_3}{R_1}$ and $R_3 = \dfrac{V_3}{V_1}R_1 = \dfrac{24\text{ V}}{4\text{ V}} \cdot 10\ \Omega = (6)(10\ \Omega) = \mathbf{60\ \Omega}$

d. $I = \dfrac{E}{R_T} = \dfrac{40\text{ V}}{10\ \Omega + 30\ \Omega + 60\ \Omega} = \dfrac{40\text{ V}}{100\ \Omega} = \mathbf{0.4\ A}$

e. $R_3 = \dfrac{V_3}{I} = \dfrac{24\text{ V}}{0.4\text{ A}} = \mathbf{60\ \Omega}$ (checks)

19. a. $R_{\text{bulb}} = \dfrac{V}{I} = \dfrac{8\text{ V}}{50\text{ mA}} = 160\ \Omega$

$$V_{R_s} = 12\text{ V} - 8\text{ V} = 4\text{ V} = \frac{R_s\,12\text{ V}}{R_s + 160\ \Omega}$$
$$(R_s + 160\ \Omega)4\text{ V} = R_s\,12\text{ V}$$
$$4R_s + 640\ \Omega = 12R_s$$
$$8R_s = 640\ \Omega$$
$$R_s = \frac{640\ \Omega}{8} = \mathbf{80\ \Omega}$$

b. $P = I^2R = (50\text{ mA})^2\,80\ \Omega = 0.2\text{ W} < \dfrac{1}{4}\text{ W}$

21. $R_T = \dfrac{V}{I} = \dfrac{72\text{ V}}{4\text{ mA}} = 18\text{ k}\Omega$
$V_{R_1} = 0.2V_{R_2}$
$IR_1 = 0.2IR_2$
and $R_1 = 0.2R_2$
but $R_T = R_1 + R_2 = 18\text{ k}\Omega$
and $0.2R_2 + R_2 = 18\text{ k}\Omega$
or $R_2 = \dfrac{18\text{ k}\Omega}{1.2} = \mathbf{15\ k\Omega}$
with $R_1 = 0.2R_2 = 0.2(15\text{ k}\Omega) = \mathbf{3\ k\Omega}$

23. a. $E = V_{R_1} + V_{R_2} + V_{R_3}$
$= V_{R_1} + 3V_{R_1} + 4V_{R_2} = V_{R_1} + 3V_{R_1} + 4(3V_{R_1}) = V_{R_1} + 3V_{R_1} + 12V_{R_1}$
with $E = 16V_{R_1}$
and $V_{R_1} = \dfrac{E}{16} = \dfrac{64\text{ V}}{16} = 4\text{ V}$
$V_{R_2} = 3V_{R_1} = 3(4\text{ V}) = 12\text{ V}$
$V_{R_3} = 4V_{R_2} = 4(12\text{ V}) = 48\text{ V}$
$R_1 = \dfrac{V_{R_1}}{I} = \dfrac{4\text{ V}}{10\text{ mA}} = \mathbf{0.4\ k\Omega}$, $R_2 = \dfrac{V_{R_2}}{I} = \dfrac{12\text{ V}}{10\text{ mA}} = \mathbf{1.2\ k\Omega}$
$R_3 = \dfrac{V_{R_3}}{I} = \dfrac{48\text{ V}}{10\text{ mA}} = \mathbf{4.8\ k\Omega}$

b. Voltage levels remain the same
$R_1 = \mathbf{0.4\ M\Omega}$, $R_2 = \mathbf{1.2\ M\Omega}$, $R_3 = \mathbf{4.8\ M\Omega}$

25. a. $I(\text{CW}) = \dfrac{120\text{ V} - 60\text{ V}}{6\ \Omega + 3\ \Omega} = \dfrac{60\text{ V}}{9\ \Omega} = \mathbf{6.667\ A}$
$V = IR = (6.667\text{ A})(3\ \Omega) = \mathbf{20\ V}$

b. $I(\text{CW}) = \dfrac{70\text{ V} - 10\text{ V}}{10\ \Omega + 20\ \Omega + 30\ \Omega} = \dfrac{60\text{ V}}{60\ \Omega} = \mathbf{1\ A}$

$V = IR = (1\text{ A})(10\ \Omega) = \mathbf{10\ V}$

27. $I = \dfrac{47\text{ V} - 20\text{ V}}{2\text{ k}\Omega + 3\text{ k}\Omega + 4\text{ k}\Omega} = \dfrac{27\text{ V}}{9\text{ k}\Omega} = 3\text{ mA (CCW)}$

$V_{2\text{k}\Omega} = 6\text{ V},\ V_{3\text{k}\Omega} = 9\text{ V},\ V_{4\text{k}\Omega} = 12\text{ V}$

a. $V_a = \mathbf{20\ V},\ V_b = 20\text{ V} + 6\text{ V} = \mathbf{26\ V},\ V_c = 20\text{ V} + 6\text{ V} + 9\text{ V} = \mathbf{35\ V}$

$V_d = \mathbf{-12\ V},\ V_e = \mathbf{0\ V}$

b. $V_{ab} = \mathbf{-6\ V},\ V_{dc} = \mathbf{-47\ V},\ V_{cb} = \mathbf{9\ V}$

c. $V_{ac} = \mathbf{-15\ V},\ V_{db} = -47\text{ V} + 9\text{ V} = \mathbf{-38\ V}$

29. $V_0 = \mathbf{0\ V}$

$V_4 = -12\text{ V} + 2\text{ V} = 0,\ V_4 = \mathbf{+10\ V}$

$V_7 = \mathbf{4\ V}$

$V_{10} = \mathbf{20\ V}$

$V_{23} = \mathbf{+6\ V}$

$V_{30} = \mathbf{-8\ V}$

$V_{67} = \mathbf{0\ V}$

$V_{56} = \mathbf{-6\ V}$

$I = \dfrac{V_4}{4\ \Omega} = \dfrac{V_{23}}{4\ \Omega} = \dfrac{6\text{ V}}{4\ \Omega} = 1.5\text{ A}\uparrow$

31. $R_{\text{int}} = \dfrac{V_{NL}}{I} - R_L = \dfrac{60\text{ V}}{2\text{ A}} - 28\ \Omega = \mathbf{2\ \Omega}$

33. $R_{\text{int}} = \dfrac{V_{NL}}{I} - R_L = \dfrac{6\text{ V}}{10\text{ mA}} - 500\ \Omega = \mathbf{100\ \Omega}$

35. $VR\% = \dfrac{R_{\text{int}}}{R_L} \times 100\% = \dfrac{0.05\ \Omega}{3.3\ \Omega} \times 100\%$

$= \mathbf{1.52\%}$

CHAPTER 5 (Even)

2. a. $R_T = 30\ \Omega = 10\ \Omega + 12\ \Omega + R$
$R = \mathbf{8\ \Omega}$
$I = \dfrac{E}{R_T} = \dfrac{30\text{ V}}{30\ \Omega} = \mathbf{1\ A}$

b. $R_T = 60\text{ k}\Omega = 12.6\text{ k}\Omega + R + 0.4\text{ k}\Omega + 45\text{ k}\Omega$
$R = \mathbf{2\ k\Omega}$

c. $R_T = 220\ \Omega = 50\ \Omega + R_1 + 60\ \Omega + R_1 + 10\ \Omega$
$220\ \Omega = 120\ \Omega + 2R_1$
$R_1 = \mathbf{50\ \Omega} = R_2$
$I = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{220\ \Omega} = \mathbf{0.5455\ A}$

d. $R_T = 1600\text{ k}\Omega = 200\text{ k}\Omega + 56\text{ k}\Omega + 100\text{ k}\Omega + R$
$R = 1{,}224\text{ k}\Omega = 1.244\text{ M}\Omega$
$I = \dfrac{E}{R_T} = \dfrac{50\text{ V}}{1.6\text{ M}\Omega} = \mathbf{31.25\ \mu A}$

4. a. $I = \dfrac{12\text{ V}}{2\ \Omega} = \mathbf{6\ A}$
$R_T = 16\ \Omega = 5\ \Omega + 2\ \Omega + R$
$R = \mathbf{9\ \Omega}$
$V_{5\Omega} = (I)(5\ \Omega) = (6\text{ A})(5\ \Omega) = \mathbf{30\ V}$
$V_{9\Omega} = (I)(9\ \Omega) = (6\text{ A})(9\ \Omega) = \mathbf{54\ V}$
$E = 30\text{ V} + 12\text{ V} + 54\text{ V} = \mathbf{96\ V}$

b. $P = I^2R \Rightarrow I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{79.2\text{ mW}}{2.2\text{ k}\Omega}} = \sqrt{36 \times 10^{-6}}$
$= 6 \times 10^{-3}\text{A} = \mathbf{6\ mA}$
$R = \dfrac{V}{I} = \dfrac{9\text{ V}}{6\text{ mA}} = \mathbf{1.5\ k\Omega}$
$V_{3.3\text{k}\Omega} = IR = (6\text{ mA})(3.3\text{ k}\Omega) = \mathbf{19.8\ V}$
$V_{2.2\text{k}\Omega} = IR = (6\text{ mA})(2.2\text{ k}\Omega) = \mathbf{1.32\ V}$
$E = 1.32\text{ V} + 9\text{ V} + 19.8\text{ V} = \mathbf{30.12\ V}$

6. a. $P = I^2R \Rightarrow R = \dfrac{P}{I^2} = \dfrac{100\text{ mW}}{(5\text{ mA})^2} = \mathbf{4\ k\Omega}$
$I(\text{CW}) = 5\text{ mA} = \dfrac{E + 20\text{ V}}{5\text{ k}\Omega + 4\text{ k}\Omega}$
$E + 20\text{ V} = 5\text{ mA}(9\text{ k}\Omega) = 45\text{ V}$
$E = 45\text{ V} - 20\text{ V} = \mathbf{25\ V}$

b. $I = \dfrac{16\text{ V}}{2\text{ k}\Omega} = \mathbf{8\text{ mA}},\ R = \dfrac{12\text{ V}}{I} = \dfrac{12\text{ V}}{8\text{ mA}} = \mathbf{1.5\text{ k}\Omega}$

$I(\text{CCW}) = 8\text{ mA} = \dfrac{E - 8\text{ V} - 6\text{ V}}{2\text{ k}\Omega + 1.5\text{ k}\Omega}$

$E - 14\text{ V} = 8\text{ mA}(3.5\text{ k}\Omega) = 28\text{ V}$

$E = 28\text{ V} + 14\text{ V} = \mathbf{42\text{ V}}$

8. a. $V_2 = \mathbf{+10\text{ V}}$

KVL: $+10\text{ V} - 6\text{ V} - V_1 = 0$

$V_1 = \mathbf{4\text{ V}}$

b. KVL: $24\text{ V} - 10\text{ V} - V_1 = 0$

$V_1 = \mathbf{14\text{ V}}$

$10\text{ V} - V_2 + 6\text{ V} = 0$

$V_2 = 10\text{ V} + 6\text{ V} = \mathbf{16\text{ V}}$

10. a. $R_T = 3\text{ k}\Omega + 1\text{ k}\Omega + 2\text{ k}\Omega = \mathbf{6\text{ k}\Omega}$

$I = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{6\text{ k}\Omega} = \mathbf{20\text{ mA}}$

$V_1 = IR_1 = (20\text{ mA})(3\text{ k}\Omega) = \mathbf{60\text{ V}}$

$V_2 = IR_2 = (20\text{ mA})(1\text{ k}\Omega) = \mathbf{20\text{ V}}$

$V_3 = IR_3 = (20\text{ mA})(2\text{ k}\Omega) = \mathbf{40\text{ V}}$

b. $E = V_1 + V_2 + V_3$

$120\text{ V} \stackrel{\checkmark}{=} 60\text{ V} + 20\text{ V} + 40\text{ V} = 120\text{ V}$

c. $P_1 = V_1I = (60\text{ V})(20 \times 10^{-3}\text{ A}) = \mathbf{1.2\text{ W}}$

$P_2 = V_2I = (20\text{ V})(20\text{ mA}) = \mathbf{0.4\text{ W}}$

$P_3 = V_3I = (40\text{ V})(20\text{ mA}) = \mathbf{0.8\text{ W}}$

$P_{del} = EI = (120\text{ V})(20\text{ mA}) = \mathbf{2.4\text{ W}}$

$P_{del} = P_1 + P_2 + P_3$

$2.4\text{ W} \stackrel{\checkmark}{=} 1.2\text{ W} + 0.4\text{ W} + 0.8\text{ W} = 2.4\text{ W}$

d. $R_1 \Rightarrow 2\text{W},\ R_2 \Rightarrow \dfrac{1}{2}\text{ W},\ R_3 \Rightarrow 1\text{ W}$

12. a. $V = 120\text{ V} - 80\text{ V} = \mathbf{40\text{ V}}$

$I = \dfrac{40\text{ V}}{20\ \Omega} = \mathbf{2A}$

$R = \dfrac{V}{I} = \dfrac{80\text{ V}}{2\text{ A}} = \mathbf{40\ \Omega}$

b. $I = \dfrac{8\text{ V}}{2.2\ \Omega} = \mathbf{3.636\text{ A}}$

$V_1 = I(4.7\ \Omega) = \mathbf{17.09\text{ V}}$

$V_2 = I(6.8\ \Omega) = \mathbf{24.73\text{ V}}$

c. $P = I^2R \Rightarrow R = P/I^2 = 21\text{ W}/(1\text{ A})^2 = \mathbf{21\ \Omega}$

$V_1 = IR = (1\text{ A})(2\ \Omega) = \mathbf{2\text{ V}}$

$V_2 = IR = (1\text{ A})(1\ \Omega) = \mathbf{1\text{ V}}$

$V_3 = IR = (1\text{ A})(21\ \Omega) = \mathbf{21\text{ V}}$

$E = V_1 + V_2 + V_3 = 2\text{ V} + 1\text{ V} + 21\text{ V} = \mathbf{24\text{ V}}$

d. $P = I^2R \Rightarrow I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{4\ W}{1\ \Omega}} = \mathbf{2\ A}$

$R_1 = \dfrac{P}{I^2} = \dfrac{8\ W}{(2\ A)^2} = \dfrac{8}{4} = \mathbf{2\ \Omega}$

$R_T = 16\ \Omega = R_1 + R_2 + 1\ \Omega$
$= 2\ \Omega + R_2 + 1\ \Omega$
$R_2 = \mathbf{13\ \Omega}$
$E = IR_T = (2\ A)(16\ \Omega) = \mathbf{32\ V}$

14. $R_1 + R_2 = 6\ \Omega,\ P_{del} = P_1 + P_2$
$24\ V \cdot I = I^2 \cdot 6\ \Omega + 24\ W$
$I^2 - 4I + 4 = 0$

$$I = \frac{-(-4) \pm \sqrt{16 - 4(1)(4)}}{2(1)} = 2\ A$$

and $R = \dfrac{P}{I^2} = \dfrac{24\ W}{(2\ A)^2} = \dfrac{24\ W}{4\ A^2} = \mathbf{6\ \Omega}$

16. a. $V_R = 4\ V = \dfrac{R(20\ V)}{R + 2\ k\Omega + 6\ k\Omega}$
$4R + 32\ k\Omega = 20\ R$
$R = \mathbf{2\ k\Omega}$

b. $V = 140\ V = \dfrac{(R + 6\ \Omega)(200\ V)}{(R + 6\ \Omega) + 3\ \Omega}$
$140R + 9(140) = 200R + 1200$
$R = \mathbf{1\ \Omega}$

18. $I_{R_2} = \dfrac{8\ V}{8\ \Omega} = 1\ A,\ R_1 = \dfrac{V_{R_1}}{I} = \dfrac{8\ V}{1\ A} = \mathbf{8\ \Omega},\ R_3 = \dfrac{V_{R_3}}{I} = \dfrac{4\ V}{1\ A} = \mathbf{4\ \Omega}$

20. $V_{R_2} = 48\ V - 12\ V = 36\ V$

$R_2 = \dfrac{V_{R_2}}{I} = \dfrac{36\ V}{16\ mA} = \mathbf{2.25\ k\Omega}$

$V_{R_3} = 12\ V - 0\ V = 12\ V$

$R_3 = \dfrac{V_{R_3}}{I} = \dfrac{12\ V}{16\ mA} = \mathbf{0.75\ k\Omega}$

$V_{R_4} = 20\ V$

$R_4 = \dfrac{V_{R_4}}{I} = \dfrac{20\ V}{16\ mA} = \mathbf{1.25\ k\Omega}$

$V_{R_1} = E - V_{R_2} - V_{R_3} - V_{R_4}$

$= 100\ V - 36\ V - 12\ V - 20\ V = 32\ V$

$R_1 = \dfrac{V_{R_1}}{I} = \dfrac{32\ V}{16\ mA} = \mathbf{2\ k\Omega}$

22. $V_{R_3} = \dfrac{R_3(60\ V)}{R_3 + 2R_3 + 7R_3} = \dfrac{R_3(60\ V)}{10R_3} = \mathbf{6\ V}$

$V_{R_2} = 7V_{R_3} = 7(6\ V) = \mathbf{42\ V}$

$V_{R_1} = 2V_{R_3} = 2(6\ V) = \mathbf{12\ V}$

24. a. $V_a = +12\text{ V} - 8\text{ V} = \mathbf{4\ V}$
$V_b = \mathbf{-8\ V}$
$V_{ab} = V_a - V_b = 4\text{ V} - (-8\text{ V}) = \mathbf{12\ V}$

b. $V_a = 20\text{ V} - 6\text{ V} = \mathbf{14\ V}$
$V_b = \mathbf{+4\ V}$
$V_{ab} = V_a - V_b = 14\text{ V} - 4\text{ V} = \mathbf{10\ V}$

c. $V_a = +10\text{ V} + 3\text{ V} = \mathbf{13\ V}$
$V_b = \mathbf{-8\ V}$
$V_{ab} = \mathbf{21\ V}$

26. a. $I = \dfrac{16\text{ V} - 8\text{ V}}{10\ \Omega + 20\ \Omega} = \dfrac{8\text{ V}}{30\ \Omega} = 0.267\text{ A (CW)}$
$V_a = 16\text{ V} - I(10\ \Omega) = 16\text{ V} - (0.267\text{ A})(10\ \Omega) = 16\text{ V} - 2.67\text{ V} = \mathbf{13.33\ V}$
$V_1 = IR = (0.267\text{ A})(20\ \Omega) = \mathbf{5.34\ V}$

b. $I = \dfrac{12\text{ V} + 10\text{ V} + 8\text{ V}}{2.2\text{ k}\Omega + 3.3\text{ k}\Omega} = \dfrac{30\text{ V}}{5.5\text{ k}\Omega} = 5.455\text{ mA}$
$V_a = 12\text{ V} - I(2.2\text{ k}\Omega) + 10\text{ V}$
$= 12\text{ V} - (5.455\text{ mA})(2.2\text{ k}\Omega) + 10\text{ V}$
$= 12\text{ V} - 12\text{ V} + 10\text{ V} = \mathbf{10\ V}$
$V_1 = I(2.2\text{ k}\Omega) = (5.455\text{ mA})(2.2\text{ k}\Omega) = \mathbf{12\ V}$

28. $I = \dfrac{44\text{ V} - 20\text{ V}}{2\text{ k}\Omega + 4\text{ k}\Omega + 6\text{ k}\Omega} = \dfrac{24\text{ V}}{12\text{ k}\Omega} = 2\text{ mA (CW)}$
$V_{2\text{k}\Omega} = IR = (2\text{ mA})(2\text{ k}\Omega) = 4\text{ V}$
$V_{4\text{k}\Omega} = IR = (2\text{ mA})(4\text{ k}\Omega) = 8\text{ V}$
$V_{6\text{k}\Omega} = IR = (2\text{ mA})(6\text{ k}\Omega) = 12\text{ V}$

a. $V_a = \mathbf{44\ V}$, $V_b = 44\text{ V} - 4\text{ V} = \mathbf{40\ V}$, $V_c = 44\text{ V} - 4\text{ V} - 8\text{ V} = \mathbf{32\ V}$
$V_d = \mathbf{20\ V}$

b. $V_{ab} = V_{2\text{k}\Omega} = \mathbf{4\ V}$, $V_{cb} = -V_{4\text{k}\Omega} = \mathbf{-8\ V}$
$V_{cd} = V_{6\text{k}\Omega} = \mathbf{12\ V}$

c. $V_{ad} = V_a - V_d = 44\text{ V} - 20\text{ V} = \mathbf{24\ V}$
$V_{ca} = V_c - V_a = 32\text{ V} - 44\text{ V} = \mathbf{-12\ V}$

30. $V_0 = \mathbf{0\ V}$, $V_{03} = \mathbf{0\ V}$, $V_2 = (2\text{ mA})(3\text{ k}\Omega + 1\text{ k}\Omega) = (2\text{ mA})(4\text{ k}\Omega) = \mathbf{8\ V}$
$V_{23} = \mathbf{8\ V}$, $V_{12} = 20\text{ V} - 8\text{ V} = \mathbf{12\ V}$, $\sum I_i = \sum I_o \Rightarrow I_i = 2\text{ mA} + 5\text{ mA} + 10\text{ mA} = \mathbf{17\ mA}$

32. $V_L = \dfrac{3.3\ \Omega(12\text{ V})}{3.3\ \Omega + 0.05\ \Omega} = \mathbf{11.82\ V}$
$I = \dfrac{12\text{ V}}{3.35\ \Omega} = 3.58\text{ A}$
$P = I^2R = (3.58\text{ A})^2\, 0.05\ \Omega = \mathbf{0.64\ W}$

34. $VR\% = \dfrac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$
$V_{FL} = IR = (2\text{ A})(28\ \Omega) = 56\text{ V}$
$VR\% = \dfrac{60\text{ V} - 56\text{ V}}{56\text{ V}} \times 100\% = 7.14\%$

CHAPTER 6 (Odd)

1. a. 2, 3, 4 in parallel b. 2, 3 in parallel c. 2, 3 in series, 1, 4 in parallel

3. a. $R_T = 9\ \Omega \parallel 18\ \Omega = \dfrac{9 \cdot 18}{9 + 18} = \dfrac{162}{27} = \mathbf{6\ \Omega}$

$G_T = \dfrac{1}{R_T} = \dfrac{1}{6\ \Omega} = \mathbf{0.1667\ S}$

b. $G_T = \dfrac{1}{3\ k\Omega} + \dfrac{1}{2\ k\Omega} + \dfrac{1}{6\ k\Omega} = 0.333\ mS + 0.5\ mS + 0.167\ mS = \mathbf{1\ mS}$

$R_T = \dfrac{1}{G_T} = \dfrac{1}{1\ mS} = \mathbf{1\ k\Omega}$

or $6\ k\Omega \parallel 3\ k\Omega = 2\ k\Omega$, $2\ k\Omega \parallel 2\ k\Omega = \mathbf{1\ k\Omega}$

c. $R_T = 3.3\ k\Omega \parallel 5.6\ k\Omega = \dfrac{(3.3\ k\Omega)(5.6\ k\Omega)}{3.3\ k\Omega + 5.6\ k\Omega} = \mathbf{2.076\ k\Omega}$

$G_T = \dfrac{1}{R_T} = \dfrac{1}{2.076\ k\Omega} = \mathbf{0.4817\ mS}$

d. $4\ \Omega \parallel 4\ \Omega = 2\ \Omega$, $8\ \Omega \parallel 8\ \Omega = 4\ \Omega$

$R_T = 2\ \Omega \parallel 4\ \Omega = \dfrac{(2\ \Omega)(4\ \Omega)}{2\ \Omega + 4\ \Omega} = \mathbf{1.333\ \Omega}$

$G_T = \dfrac{1}{R_T} = \dfrac{1}{1.333\ \Omega} = \mathbf{0.75\ S}$

e. $G_T = \dfrac{1}{10\ \Omega} + \dfrac{1}{2\ k\Omega} + \dfrac{1}{40\ k\Omega} = 0.1\ S + 0.5\ mS + 0.025\ mS = \mathbf{100.525\ mS}$

$R_T = \dfrac{1}{G_T} = \dfrac{1}{100.525\ mS} = \mathbf{9.948\ \Omega}$

f. $R'_T = \dfrac{9.1\ \Omega}{3} = 3.033\ \Omega$, $R''_T = \dfrac{2.2\ \Omega}{2} = 1.1\ \Omega$

$G_T = \dfrac{1}{3.033\ \Omega} + \dfrac{1}{1.1\ \Omega} + \dfrac{1}{4.7\ \Omega} = 0.3297\ S + 0.9091\ S + 0.2128\ S = \mathbf{1.4516\ S}$

$R_T = \dfrac{1}{G_T} = \dfrac{1}{1.4516\ S} = \mathbf{0.6889\ \Omega}$

5. a. $G_T = NG_1 + G_2$

$\dfrac{1}{6\ \Omega} = 2\left(\dfrac{1}{18\ \Omega}\right) + \dfrac{1}{R} \Rightarrow R = \mathbf{18\ \Omega}$

b. $G_T = NG_1 + G_2 + G_3$

$\dfrac{1}{4\ \Omega} = 2\left[\dfrac{1}{R_1}\right] + \dfrac{1}{9\ \Omega} + \dfrac{1}{18\ \Omega}$

$0.25\ S = \dfrac{2}{R_1} = 0.111\ S + 0.0556\ S$

$R_1 = \mathbf{24\ \Omega} = R_2$

7. $24\ \Omega \parallel 24\ \Omega = 12\ \Omega$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{12\ \Omega} + \frac{1}{120\ \Omega}$$

$$0.1\ \text{S} = \frac{1}{R_1} + 0.08333\ \text{S} + 0.00833\ \text{S}$$

$$0.1\ \text{S} = \frac{1}{R_1} + 0.09167\ \text{S}$$

$$\frac{1}{R_1} = 0.1\ \text{S} - 0.09167\ \text{S} = 0.00833\ \text{S}$$

$$R_1 = \frac{1}{0.00833\ \text{S}} = \mathbf{120\ \Omega}$$

9. a. $G_T = \frac{1}{3\ \Omega} + \frac{1}{6\ \Omega} + \frac{1}{1.5\ \Omega} = 0.333\ \text{S} + 0.167\ \text{S} + 0.667\ \text{S} = \mathbf{1.167\ S}$

$R_T = \frac{1}{G_T} = \frac{1}{1.167\ \text{S}} = \mathbf{0.857\ \Omega}$

b. $I_s = EG_T = \frac{E}{R_T} = \frac{0.9\ \text{V}}{0.857\ \Omega} = \mathbf{1.05\ A}$

$I_1 = \frac{E}{R_1} = \frac{0.9\ \text{V}}{3\ \Omega} = \mathbf{0.3\ A}$

$I_2 = \frac{E}{R_2} = \frac{0.9\ \text{V}}{6\ \Omega} = \mathbf{0.15\ A}$

$I_3 = \frac{E}{R_3} = \frac{0.9\ \text{V}}{1.5\ \Omega} = \mathbf{0.6\ A}$

c. $I_s \stackrel{?}{=} I_1 + I_2 + I_3$

$1.05\ \text{A} = 0.3\ \text{A} + 0.15\ \text{A} + 0.6\ \text{A}$

$1.05\ \text{A} \stackrel{\checkmark}{=} 1.05\ \text{A}$

d. R_1: $P_1 = I_1^2 R_1 = (0.3\ \text{A})^2\ 3\ \Omega = \mathbf{0.27\ W}$

R_2: $P_2 = I_2^2 R_2 = (0.15\ \text{A})^2\ 6\ \Omega = \mathbf{0.135\ W}$

R_3: $P_3 = I_3^2 R_3 = (0.6\ \text{A})^2\ 1.5\ \Omega = \mathbf{0.54\ W}$

$P_{\text{del}} = EI_s = (0.9\ \text{V})(1.05\ \text{A}) = \mathbf{0.945\ W}$

$P_{\text{del}} \stackrel{?}{=} P_1 + P_2 + P_3$

$0.945\ \text{W} = 0.27\ \text{W} + 0.135\ \text{W} + 0.54\ \text{W}$

$0.945\ \text{W} \stackrel{\checkmark}{=} 0.945\ \text{W}$

e. $R_1, R_2 \Rightarrow 1/2\ \text{W}$, $R_3 \Rightarrow 1\ \text{W}$

11. a. $I = \frac{E}{R} = \frac{120\ \text{V}}{1.8\ \text{k}\Omega} = \mathbf{66.67\ mA}$

b. $R_T = \frac{R}{N} = \frac{1.8\ \text{k}\Omega}{8} = \mathbf{225\ \Omega}$

c. $P = EI = (120\ \text{V})(66.67\ \text{mA}) = \mathbf{8\ W}$

d. No effect!

13. a. $R_T = 20\ \Omega \parallel 5\ \Omega = 4\ \Omega$

$I_s = \frac{E}{R_T} = \frac{30\ \text{V}}{4\ \Omega} = \mathbf{7.5\ A}$

CDR: $I_1 = \frac{5\ \Omega\ I_s}{5\ \Omega + 20\ \Omega} = \frac{1}{5}(7.5\ \text{A}) = \mathbf{1.5\ A}$

b. $10\text{ k}\Omega \parallel 10\text{ k}\Omega = 5\text{ k}\Omega$
$R_T = 1\text{ k}\Omega \parallel 5\text{ k}\Omega = 0.833\text{ k}\Omega$
$$I_s = \frac{E}{R_T} = \frac{8\text{ V}}{0.833\text{ k}\Omega} = \mathbf{9.6\text{ mA}}$$
$R'_T = 10\text{ k}\Omega \parallel 1\text{ k}\Omega = 0.9091\text{ k}\Omega$
$$I_1 = \frac{R'_T I_s}{R'_T + 10\text{ k}\Omega} = \frac{(0.9091\text{ k}\Omega)(9.6\text{ mA})}{0.9091\text{ k}\Omega + 10\text{ k}\Omega} = \frac{8.727\text{ mA}}{10.9091} = \mathbf{0.8\text{ mA}}$$

15. $$\frac{1}{R_T} = \frac{1}{5\ \Omega} + \frac{1}{10\ \Omega} + \frac{1}{20\ \Omega} = 0.2\text{ S} + 0.1\text{ S} + 0.05\text{ S} = 0.35\text{ S}$$
$$R_T = \frac{1}{0.35\text{ S}} = 2.857\ \Omega$$
$$P_{\text{del}} = \frac{E^2}{R_T} = \frac{(60\text{ V})^2}{2.857\ \Omega} = \mathbf{1260\text{ W}}$$

17. a. $$I = \frac{24\text{ V} - 8\text{ V}}{4\text{ k}\Omega} = \frac{16\text{ V}}{4\text{ k}\Omega} = \mathbf{4\text{ mA}}$$
b. $V = \mathbf{24\text{ V}}$

c. $$I_s = \frac{24\text{ V}}{10\text{ k}\Omega} + 4\text{ mA} + \frac{24\text{ V}}{2\text{ k}\Omega} = 2.4\text{ mA} + 4\text{ mA} + 12\text{ mA} = \mathbf{18.4\text{ mA}}$$

19. a. $I_1 = 8\text{ mA} - 5\text{ mA} = \mathbf{3\text{ mA}}$
$I_2 = 5\text{ mA} - 4\text{ mA} = \mathbf{1\text{ mA}}$
$I_3 = I_1 - 1.5\text{ mA} = 3\text{ mA} - 1.5\text{ mA} = \mathbf{1.5\text{ mA}}$

b. $I_2 = 6\ \mu\text{A} - 2\ \mu\text{A} = \mathbf{4\ \mu A}$
$I_3 = 2\ \mu\text{A} - 0.5\ \mu\text{A} = \mathbf{1.5\ \mu A}$
$I_4 = I_2 + I_3 = 4\ \mu\text{A} + 1.5\ \mu\text{A} = \mathbf{5.5\ \mu A}$
$I_1 = I_4 + 0.5\ \mu\text{A} = 5.5\ \mu\text{A} + 0.5\ \mu\text{A} = \mathbf{6\ \mu A}$

21. a. $$R_1 = \frac{E}{I_1} = \frac{10\text{ V}}{2\text{ A}} = \mathbf{5\ \Omega}$$
$I_2 = I - I_1 = 3\text{ A} - 2\text{ A} = 1\text{ A}$
$$R_2 = \frac{E}{I_2} = \frac{10\text{ V}}{1\text{ A}} = \mathbf{10\ \Omega}$$

b. $E = I_1R_1 = (2\text{ A})(6\ \Omega) = \mathbf{12\text{ V}}$
$$I_2 = \frac{E}{R_2} = \frac{12\text{ V}}{9\ \Omega} = \mathbf{1.333\text{ A}}$$
$$I_3 = \frac{P}{V} = \frac{12\text{ W}}{12\text{ V}} = \mathbf{1\text{ A}}$$
$$R_3 = \frac{E}{I_3} = \frac{12\text{ V}}{1\text{ A}} = \mathbf{12\ \Omega}$$
$I = I_1 + I_2 + I_3 = 2\text{ A} + 1.333\text{ A} + 1\text{ A} = \mathbf{4.333\text{ A}}$

c. $I_1 = \dfrac{64\text{ V}}{1\text{ k}\Omega} = \mathbf{64\text{ mA}}$

$I_3 = \dfrac{64\text{ V}}{4\text{ k}\Omega} = \mathbf{16\text{ mA}}$

$I_3 = I_1 + I_2 + I_3$

$I_2 = I_s - I_1 - I_3 = 100\text{ mA} - 64\text{ mA} - 16\text{ mA} = 20\text{ mA}$

$R = \dfrac{E}{I_2} = \dfrac{64\text{ V}}{20\text{ mA}} = \mathbf{3.2\text{ k}\Omega}$

$I = I_2 + I_3 = 20\text{ mA} + 16\text{ mA} = \mathbf{36\text{ mA}}$

d. $P = \dfrac{V_1^2}{R_1} \Rightarrow V_1 = \sqrt{PR_1} = \sqrt{(30\text{ W})(30\text{ }\Omega)} = \mathbf{30\text{ V}}$

$E = V_1 = \mathbf{30\text{ V}}$

$I_1 = \dfrac{E}{R_1} = \dfrac{30\text{ V}}{30\text{ }\Omega} = \mathbf{1\text{ A}}$

$I_3 = I_2, \qquad I_s = I_1 + I_2 + I_3 = I_1 + 2I_2$

$2\text{ A} = 1\text{ A} + 2I_2$

$I_2 = \dfrac{1}{2}(1\text{ A}) = 0.5\text{ A}$

$I_3 = \mathbf{0.5\text{ A}}$

$R_2 = R_3 = \dfrac{E}{I_2} = \dfrac{30\text{ V}}{0.5\text{ A}} = \mathbf{60\text{ }\Omega}$

$P_{R_2} = I_2^2 R_2 = (0.5\text{ A})^2 \cdot 60\text{ }\Omega = \mathbf{15\text{ W}}$

23. a. $I_1 = \dfrac{3\text{ }\Omega(12\text{ A})}{3\text{ }\Omega + 6\text{ }\Omega} = \mathbf{4\text{ A}}, I_2 = \dfrac{6\text{ }\Omega(12\text{ A})}{3\text{ }\Omega + 6\text{ }\Omega} = \mathbf{8\text{ A}}$

b. $\dfrac{8\text{ }\Omega}{2} = 4\text{ }\Omega, \dfrac{6\text{ }\Omega}{3} = 2\text{ }\Omega$

$I_1 = \dfrac{2\text{ }\Omega(6\text{ A})}{2\text{ }\Omega + 4\text{ }\Omega} = \mathbf{2\text{ A}}, I_2 = \dfrac{4\text{ }\Omega(6\text{ A})}{4\text{ }\Omega + 2\text{ }\Omega} = \mathbf{4\text{ A}}$

$I_3 = \dfrac{I_1}{2} = \dfrac{2\text{ A}}{2} = \mathbf{1\text{ A}}$

$I_4 = \dfrac{I_2}{3} = \dfrac{4\text{ A}}{3} = \mathbf{1.333\text{ A}}$

c. $2\text{ }\Omega \parallel 3\text{ }\Omega = \dfrac{6}{5}\text{ }\Omega, I_1 = \dfrac{6/5\text{ }\Omega(500\text{ mA})}{6/5\text{ }\Omega + 1\text{ }\Omega} = \mathbf{272.73\text{ mA}}$

$I_2 = \dfrac{1\text{ }\Omega(500\text{ mA})}{1\text{ }\Omega + 6/5\text{ }\Omega} = \mathbf{227.27\text{ mA}}$

$I_3 = \dfrac{2\text{ }\Omega(I_2)}{2\text{ }\Omega + 3\text{ }\Omega} = \dfrac{2\text{ }\Omega(227.27\text{ mA})}{5\text{ }\Omega} = \mathbf{90.91\text{ mA}}$

$I_4 = \mathbf{500\text{ mA}}$

d. $V_{18\Omega} = I_1R = (4\text{ A})(18\ \Omega) = 72\text{ V}$

$$I_2 = \frac{V}{R_T} = \frac{72\text{ V}}{4\ \Omega + 12\ \Omega} = \frac{72\text{ V}}{16\ \Omega} = \mathbf{4.5\ A}$$

$I_3 = I_1 + I_2 = 4\text{ A} + 4.5\text{ A} = \mathbf{8.5\ A}$

$I_s = I_3 = \mathbf{8.5\ A}$

25. a. CDR: $I_{6\Omega} = \dfrac{2\ \Omega\, I}{2\ \Omega + 6\ \Omega} = 1\text{A}$

$$I = \frac{1\text{ A}(8\ \Omega)}{2\ \Omega} = \mathbf{4\ A} = I_2$$

$I_1 = I - 1\text{ A} = \mathbf{3\ A}$

b. KCL: $I_3 = I = \mathbf{6\ \mu A}$

By inspection: $I_2 = \mathbf{2\ \mu A}$

$I_1 = I - 2(2\ \mu\text{A}) = 6\ \mu\text{A} - 4\ \mu\text{A} = \mathbf{2\ \mu A}$

Since all currents are equal

$R = \mathbf{9\ \Omega}$

27. $68\text{ mA} = I_1 + I_2 + I_3 = I_1 + 4\,I_1 + 3I_2$

$68\text{ mA} = I_1 + 4\,I_1 + 3(4\,I_1)$

$68\text{ mA} = I_1 + 4\,I_1 + 12\,I_1$

$68\text{ mA} = 17\,I_1$

$$I_1 = \frac{68\text{ mA}}{17} = 4\text{ mA}$$

$I_2 = 4\,I_1 = 16\text{ mA}$

$I_3 = 3\,I_2 = 48\text{ mA}$

$$R_1 = \frac{V_{R_1}}{I_1} = \frac{E}{I_1} = \frac{24\text{ V}}{4\text{ mA}} = \mathbf{6\ k\Omega}$$

$$R_2 = \frac{E}{I_2} = \frac{24\text{ V}}{16\text{ mA}} = \mathbf{1.5\ k\Omega}$$

$$R_3 = \frac{E}{I_3} = \frac{24\text{ V}}{48\text{ mA}} = \mathbf{0.5\ k\Omega}$$

29. $I_{8\Omega} = \dfrac{16\text{ V}}{8\ \Omega} = 2\text{ A}$

$I = 5\text{ A} - 2\text{ A} = \mathbf{3\ A}$

$I_R = 5\text{ A} + I = 5\text{ A} + 3\text{ A} = 8\text{ A}$

$$R = \frac{V_R}{I_R} = \frac{16\text{ V}}{8\text{ A}} = \mathbf{2\ \Omega}$$

31. a. $V_L = \dfrac{4.7\text{ k}\Omega(9\text{ V})}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = \dfrac{42.3\text{ V}}{6.9} = \mathbf{6.13\ V}$

b. $V_L = E = \mathbf{9\ V}$

c. $V_L = E = \mathbf{9\ V}$

33. a. $V_2 = \dfrac{20\text{ k}\Omega(6\text{ V})}{20\text{ k}\Omega + 10\text{ k}\Omega} = \dfrac{120\text{ V}}{30} = \mathbf{4\ V}$

b. $20\text{ k}\Omega \parallel 11\text{ M}\Omega = 19.96\text{ k}\Omega$

$$V_2 = \frac{19.96\text{ k}\Omega(6\text{ V})}{19.96\text{ k}\Omega + 10\text{ k}\Omega} = \frac{119.76\text{ V}}{29.96} = \mathbf{3.997\text{ V}}$$

c. $R_m = (10\text{ V})(20{,}000\ \Omega/\text{V}) = 200\text{ k}\Omega$

$20\text{ k}\Omega \parallel 200\text{ k}\Omega = 18.18\text{ k}\Omega$

$$V_2 = \frac{18.18\text{ k}\Omega(6\text{ V})}{18.18\text{ k}\Omega + 10\text{ k}\Omega} = \mathbf{3.871\text{ V}}$$

(b) more accurate than (c) but both readings in the "neighborhood."

d. $R_2 \parallel R_m = 200\text{ k}\Omega \parallel 200\text{ k}\Omega = 100\text{ k}\Omega$

$$V_2 = \frac{(100\text{ k}\Omega)(6\text{ V})}{100\text{ k}\Omega + 100\text{ k}\Omega} = \mathbf{3\text{ V}}$$

e. R_m as large as possible (compared to load).

35. $V_a = 8.8$ V is an incorrect reading.

$$V_{1\text{k}\Omega} = \frac{1\text{ k}\Omega(12\text{ V} - 4\text{ V})}{1\text{ k}\Omega + 4\text{ k}\Omega} = \frac{1}{5}(8\text{ V}) = 1.6\text{ V}$$

$V_a = 12\text{ V} - 1.6\text{ V} = 10.4\text{ V}$

4 V supply reversed!

$$V_{1\text{k}\Omega} = \frac{1\text{ k}\Omega(12\text{ V} + 4\text{ V})}{1\text{ k}\Omega + 4\text{ k}\Omega} = \frac{1}{5}(16\text{ V}) = 3.2\text{ V}$$

$V_a = 12\text{ V} - 3.2\text{ V} = 8.8\text{ V}$ as indicated

CHAPTER 6 (Even)

2. a. There are no single elements in parallel.

   b. R_6 & R_7, R_1 & R_3 and E are in series.

   c. $R_5 \parallel (R_6 + R_7), R_2 \parallel (R_1 + E + R_3)$

4. a. $G_T = 0.55 \text{ S} = \dfrac{1}{4\ \Omega} + \dfrac{1}{R} + \dfrac{1}{6\ \Omega}$

$$0.55 \text{ S} = 0.25 \text{ S} + \frac{1}{R} + 0.1667 \text{ S}$$

$$0.1333 \text{ S} = \frac{1}{R}$$

$$R = \frac{1}{0.1333 \text{ S}} = \mathbf{7.5\ \Omega}$$

   b. $G_T = 0.45 \text{ mS} = \dfrac{1}{5\text{ k}\Omega} + \dfrac{1}{8\text{ k}\Omega} + \dfrac{1}{R}$

$$0.45 \text{ mS} = 0.2 \text{ mS} + 0.125 \text{ mS} + \frac{1}{R}$$

$$R = \frac{1}{0.125 \text{ mS}} = \mathbf{8\text{ k}\Omega}$$

6. $\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

$$\frac{1}{20\ \Omega} = \frac{1}{R_1} + \frac{1}{5R_1} + \frac{1}{\frac{R_1}{2}} = 1\left[\frac{1}{R_1}\right] + \frac{1}{5}\left[\frac{1}{R_1}\right] + 2\left[\frac{1}{R_1}\right] = 3.2\left[\frac{1}{R_1}\right]$$

and $R_1 = 3.2(20\ \Omega) = \mathbf{64\ \Omega}$

$R_2 = 5R_1 = 5(64\ \Omega) = \mathbf{320\ \Omega}$

$R_3 = \frac{1}{2}R_1 = \dfrac{64\ \Omega}{2} = \mathbf{32\ \Omega}$

8. a. $R_T = 8\text{ k}\Omega \parallel 24\text{ k}\Omega = \mathbf{6\text{ k}\Omega}$

$$G_T = \frac{1}{R_T} = \frac{1}{6\text{ k}\Omega} = \mathbf{0.167\text{ mS}}$$

   b. $I_s = \dfrac{E}{R_T} = \dfrac{48\text{ V}}{6\text{ k}\Omega} = \mathbf{8\text{ mA}}$

$$I_1 = \frac{48\text{ V}}{8\text{ k}\Omega} = \mathbf{6\text{ mA}}$$

$$I_2 = \frac{48\text{ V}}{24\text{ k}\Omega} = \mathbf{2\text{ mA}}$$

   c. $I_s = I_1 + I_2$

$8\text{ mA} = 6\text{ mA} + 2\text{ mA}$

$8\text{ mA} \stackrel{\checkmark}{=} 8\text{ mA}$

d. $P_1 = I_1^2 R_1 = (6\text{ mA})^2\, 8\text{ k}\Omega = (36 \times 10^{-6})(8 \times 10^3) = \mathbf{0.288\ W}$

$P_2 = I_2^2 R_2 = (2\text{ mA})^2\, 24\text{ k}\Omega = (4 \times 10^{-6})(24 \times 10^3) = \mathbf{96\ mW}$

$P_{\text{del}} = EI_s = (48\text{ V})(8\text{ mA}) = \mathbf{384\ mW}$

$$P_{\text{del}} \stackrel{?}{=} P_1 + P_2$$
$$384\text{ mW} = 288\text{ mW} + 96\text{ mW}$$
$$384\text{ mW} \stackrel{\checkmark}{=} 384\text{ mW}$$

e. both 1/2 W

10. a. $G_T = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} = \dfrac{1}{2.2\text{ k}\Omega} + \dfrac{1}{4.7\text{ k}\Omega} + \dfrac{1}{6.8\text{ k}\Omega}$

$= 0.4545\text{ mS} + 0.2128\text{ mS} + 0.1471\text{ mS} = \mathbf{0.8144\ mS}$

$R_T = \dfrac{1}{G_T} = \dfrac{1}{0.8144\text{ mS}} = \mathbf{1.2279\ k\Omega}$

b. $I_s = \dfrac{E}{R_T} = \dfrac{12\text{ V}}{1.2279\text{ k}\Omega} = \mathbf{9.7728\ mA}$

$I_1 = \dfrac{E}{R_1} = \dfrac{12\text{ V}}{2.2\text{ k}\Omega} = \mathbf{5.4545\ mA}$

$I_2 = \dfrac{E}{R_2} = \dfrac{12\text{ V}}{4.7\text{ k}\Omega} = \mathbf{2.5532\ mA}$

$I_3 = \dfrac{E}{R_3} = \dfrac{12\text{ V}}{6.8\text{ k}\Omega} = \mathbf{1.7647\ mA}$

c. $$I_s = I_1 + I_2 + I_3$$
$$9.7728\text{ mA} = 5.4545\text{ mA} + 2.5532\text{ mA} + 1.7647\text{ mA}$$
$$9.7728\text{ mA} \stackrel{\checkmark}{=} 9.7724\text{ mA}$$

d. $P_1 = I_1^2 R_1 = (5.4545\text{ mA})^2\, 2.2\text{ k}\Omega = \mathbf{65\ mW}$

$P_2 = I_2^2 R_2 = (2.5532\text{ mA})^2\, 4.7\text{ k}\Omega = \mathbf{31\ mW}$

$P_3 = I_3^2 R_3 = (1.7647\text{ mA})^2\, 6.8\text{ k}\Omega = \mathbf{21\ mW}$

$P_{\text{del}} = EI_s = (12\text{ V})(9.7728\text{ mA}) = \mathbf{117.27\ mW}$

$$P_{\text{del}} = P_1 + P_2 + P_3$$
$$117.27\text{ mW} = 65\text{ mW} + 31\text{ mW} + 21\text{ mW}$$
$$117.27\text{ mW} \stackrel{\checkmark}{=} 117\text{ mW}$$

e. all 1/2 W

12. a. Branch 1: $I = \dfrac{P}{E} = \dfrac{10(60\text{ W})}{120\text{ V}} = \mathbf{5\text{ A}}$

Branch 2: $I = \dfrac{P}{E} = \dfrac{400\text{ W}}{120\text{ V}} = \mathbf{3\frac{1}{3}}\text{ A}$

Branch 3: $I = \dfrac{P}{E} = \dfrac{360\text{ W}}{120\text{ V}} = \mathbf{3A}$

b. $I_s = I_1 + I_2 + I_3 = 5\text{ A} + 3\frac{1}{3}\text{ A} + 3\text{ A} = \mathbf{11\frac{1}{3}\text{ A}}$ **No**

c. $R_T = \dfrac{E}{I_s} = \dfrac{120\text{ V}}{11\frac{1}{3}\text{ A}} = \mathbf{10.59\ \Omega}$

d. $P_{del} = EI_s = (120\text{ V})\left[11\frac{1}{3}\text{ A}\right] = \mathbf{1360\text{ W}}$

$P_{del} = P_1 + P_2 + P_3$

$1360\text{ W} = 600\text{ W} + 400\text{ W} + 360\text{ W}$

$1360\text{ W} \stackrel{\checkmark}{=} 1360\text{ W}$

14. $I_{R_2} = \dfrac{12\text{ V}}{6\ \Omega} = 2\text{ A},\ I_{R_1} = 6\text{ A} - 2\text{ A} = 4\text{ A}$

$R_1 = \dfrac{V_{R_1}}{I_{R_1}} = \dfrac{E}{I_{R_1}} = \dfrac{12\text{ V}}{4\text{ A}} = \mathbf{3\ \Omega}$

16. a. $8\ \Omega \parallel 12\ \Omega = 4.8\ \Omega,\ 4.8\ \Omega \parallel 4\ \Omega = 2.182\ \Omega$

$I_1 = \dfrac{24\text{ V} + 8\text{ V}}{2.182\ \Omega} = \mathbf{14.67\text{ A}}$

b. $P_4 = \dfrac{V^2}{R} = \dfrac{(24\text{ V} + 8\text{ V})^2}{4\ \Omega} = \mathbf{256\text{ W}}$

c. $I_2 = I_s = \mathbf{14.67\text{ A}}$

18. a. $12\text{ A} + 9\text{ A} + 4\text{ A} - I_1 = 0$

$I_1 = \mathbf{25\text{ A}} \rightarrow$

$I_1 + 4\text{ A} - 6\text{ A} - I_2 = 0$

$I_2 = 25\text{ A} + 4\text{ A} - 6\text{ A} = \mathbf{23\text{ A}} \searrow$

$I_2 - 3\text{ A} - I_3 = 0$

$I_3 = 23\text{ A} - 3\text{ A} = \mathbf{20\text{ A}} \swarrow$

b. $20\text{ A} - 9\text{ A} - I_1 = 0$

$I_1 = \mathbf{11\text{ A}} \rightarrow$

$I_1 - 5\text{ A} - I_2 = 0$

$I_2 = 11\text{ A} - 5\text{ A} = \mathbf{6\text{ A}} \rightarrow$

$I_2 + 8\text{ A} - I_3 = 0$

$I_3 = 6\text{ A} + 8\text{ A} = \mathbf{14\text{ A}} \downarrow$

$I_3 - 4\text{ A} - I_4 = 0$

$I_4 = 14\text{ A} - 4\text{ A} = \mathbf{10\text{ A}} \downarrow$

20. $I_{R_2} = 5\text{ mA} - 2\text{ mA} = 3\text{ mA}$

$E = V_{R_2} = (3\text{ mA})(4\text{ k}\Omega) = \mathbf{12\text{ V}}$

$$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{12\text{ V}}{(9\text{ mA} - 5\text{ mA})} = \frac{12\text{ V}}{4\text{ mA}} = \mathbf{3\text{ k}\Omega}$$

$$R_3 = \frac{V_{R_3}}{I_{R_3}} = \frac{12\text{ V}}{2\text{ mA}} = \mathbf{6\text{ k}\Omega}$$

$$R_T = \frac{E}{I_T} = \frac{12\text{ V}}{9\text{ mA}} = \mathbf{1.333\text{ k}\Omega}$$

22. $I_2 = \frac{4\ \Omega}{12\ \Omega}I_1 = \frac{1}{3}I_1 = \mathbf{2\text{ A}}$

$I_3 = \frac{4\ \Omega}{2\ \Omega}I_1 = 2I_1 = \mathbf{12\text{ A}}$

$I_4 = \frac{4\ \Omega}{40\ \Omega}I_1 = \frac{1}{10}I_1 = \mathbf{0.6\text{ A}}$

$I_T = I_1 + I_2 + I_3 + I_4 = 6\text{ A} + 2\text{ A} + 12\text{ A} + 0.6\text{ A} = \mathbf{20.6\text{ A}}$

24. a. $I_1 \cong \frac{9}{10}(10\text{ A}) = \mathbf{9\text{ A}}$

b. $I_1/I_2 = 10\ \Omega/1\ \Omega = \mathbf{10}$, $I_3/I_4 = 100\text{ k}\Omega/1\text{ k}\Omega = \mathbf{100}$

c. $I_2/I_3 = 1\text{ k}\Omega/10\text{ k}\Omega = \mathbf{100}$, $I_1/I_4 = 100\text{ k}\Omega/1\ \Omega = \mathbf{100{,}000}$

d. $$\frac{1}{R_T} = \frac{1}{1\ \Omega} + \frac{1}{10\ \Omega} + \frac{1}{1\text{ k}\Omega} + \frac{1}{100\text{ k}\Omega} = 1 + 0.1 + 0.001 + 10 \times 10^{-6}$$
$$= 1.10101\text{ S}$$

$$R_T = \frac{1}{1.10101\text{ S}} = 0.9083\ \Omega$$

$V = IR_T = (10\text{ A})(0.9083\ \Omega) = 9.083\text{ V}$

$$I_1 = \frac{V}{R_1} = \frac{9.083\text{ V}}{1\ \Omega} = \mathbf{9.083\text{ A}}\text{ vs. }9\text{ A}$$

e. $$I_4 = \frac{V}{R_4} = \frac{9.083\text{ V}}{100\text{ k}\Omega} = 90.83\ \mu\text{A}$$

$$\frac{I_1}{I_4} = \frac{9.083\text{ A}}{90.83\ \mu\text{A}} = \mathbf{100{,}000}\text{ as above}$$

26. $60\text{ mA} = I_1 + I_2 = 3I_2 + I_2 = 4I_2$

and $I_2 = \frac{60\text{ mA}}{4} = 15\text{ mA}$

$I_1 = 3I_2 = 3(15\text{ mA}) = 45\text{ mA}$

$V_1 = V_2$

$(45\text{ mA})(2.2\text{ k}\Omega) = (15\text{ mA})(R)$

$$R = \frac{45\text{ mA}}{15\text{ mA}}(2.2\text{ k}\Omega) = 3(2.2\text{ k}\Omega) = \mathbf{6.6\text{ k}\Omega}$$

or $\dfrac{I_1}{I_2} = \dfrac{R}{2.2\text{ k}\Omega}$

and $\dfrac{3I_2}{I_2} = \dfrac{R}{2.2\text{ k}\Omega} \Rightarrow R = 3(2.2\text{ k}\Omega) = \mathbf{6.6\ k\Omega}$

28. $I_{8\Omega} = \dfrac{12\text{ V}}{8\ \Omega} = 1.5\text{ A},\ I_{56\Omega} = \dfrac{12\text{ V}}{56\ \Omega} = 0.214\text{ A}$

$I_2 = I_{8\Omega} + I_{56\Omega} = 1.5\text{ A} + 0.214\text{ A} = \mathbf{1.714\ A}$

$I_1 = \dfrac{I_2}{2} = \mathbf{0.857\ A}$

30. a. $I_s = \dfrac{E}{R_T} = \dfrac{12\text{ V}}{0.1\text{ k}\Omega + 10\text{ k}\Omega} = \dfrac{12\text{ V}}{10.1\text{ k}\Omega} = \mathbf{1.188\ mA}$

$V_L = I_sR_L = (1.188\text{ mA})(10\text{ k}\Omega) = \mathbf{11.88\ V}$

b. $I_s = \dfrac{12\text{ V}}{100\ \Omega} = \mathbf{120\ mA}$

c. $V_L = E = \mathbf{12\ V}$

32. a. $I_1 = \dfrac{20\text{ V}}{4\ \Omega} = \mathbf{5\ A},\ I_2 = \mathbf{0\ A}$

b. $V_1 = \mathbf{0\ V},\ V_2 = \mathbf{20\ V}$

c. $I_s = I_1 = \mathbf{5\ A}$

34. Not operating properly!
6 kΩ resistor not part of configuration (open at one or both terminals)

$R_T = \dfrac{6\text{ V}}{3.5\text{ mA}} = 1.714\text{ k}\Omega$

$R_T = 3\text{ k}\Omega \parallel 4\text{ k}\Omega = 1.714\text{ k}\Omega$

36. a. Connection at either end or 1 kΩ resistor opened up.

b. −4 V source connected as +4 V

CHAPTER 7 (Odd)

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. $I_2 = I - I_1 = 5\text{ A} - 2\text{ A} = \mathbf{3\text{ A}}$

c. yes (KCL)

d. $V_2 = E - V_1 = 10\text{ V} - 6\text{ V} = \mathbf{4\text{ V}}$

e. $R_T = R_1 \parallel R_2 + R_3 \parallel R_4 = 2\ \Omega \parallel 3\ \Omega + 1\ \Omega \parallel 4\ \Omega = \frac{6}{5}\ \Omega + \frac{4}{5}\ \Omega = \frac{10}{5}\ \Omega = \mathbf{2\ \Omega}$

f. $I = \frac{E}{R_T} = \frac{10\text{ V}}{2\ \Omega} = \mathbf{5\text{ A}}$

g. $P_{\text{del}} = EI = (10\text{ V})(5\text{ A}) = \mathbf{50\text{ W}}$

$V_1 = I(R_1 \parallel R_2) = 5\text{ A}\left(\frac{6}{5}\ \Omega\right) = 6\text{ V}$

$P_1 = \frac{V_1^2}{R_1} = \frac{(6\text{ V})^2}{3\ \Omega} = \mathbf{12\text{ W}}$

$P_2 = \frac{V_1^2}{R_2} = \frac{(6\text{ V})^2}{2\ \Omega} = \mathbf{18\text{ W}}$

5. a. $R' = R_1 \parallel R_2 = 10\ \Omega \parallel 15\ \Omega = 6\ \Omega$

$R_T = R' \parallel (R_3 + R_4) = 6\ \Omega \parallel 12\ \Omega = \mathbf{4\ \Omega}$

b. $I_s = \frac{E}{R_T} = \frac{36\text{ V}}{4\ \Omega} = \mathbf{9\text{ A}}$, $I_1 = \frac{E}{R'} = \frac{36\text{ V}}{6\ \Omega} = \mathbf{6\text{ A}}$

$I_2 = \frac{E}{R_3 + R_4} = \frac{36\text{ V}}{12\ \Omega} = \mathbf{3\text{ A}}$

c. $V_a = I_2R_4 = (3\text{ A})(2\ \Omega) = \mathbf{6\text{ V}}$

7. a, b. $I_1 = \frac{24\text{ V}}{4\ \Omega} = \mathbf{6\text{ A}} \downarrow$, $I_3 = \frac{8\text{ V}}{10\ \Omega} = \mathbf{0.8\text{ A}} \uparrow$

$I_2 = \frac{24\text{ V} + 8\text{ V}}{2\ \Omega} = \frac{32\text{ V}}{2\ \Omega} = \mathbf{16\text{ A}}$

$I = I_1 + I_2 = 6\text{ A} + 16\text{ A} = \mathbf{22\text{ A}} \downarrow$

9. a. $I_1 = \frac{E}{R_1 + R_4 \| (R_2 + R_3 \| R_5)} = \frac{20\text{ V}}{3\ \Omega + 3\ \Omega \| (3\ \Omega + 6\ \Omega \| 6\ \Omega)}$

$= \frac{20\text{ V}}{3\ \Omega + 3\ \Omega \| (3\ \Omega + 3\ \Omega)} = \frac{20\text{ V}}{3\ \Omega + 3\ \Omega \| 6\ \Omega} = \frac{20\text{ V}}{3\ \Omega + 2\ \Omega}$

$= \mathbf{4\text{ A}}$

b. CDR: $I_2 = \dfrac{R_4(I_1)}{R_4 + R_2 + R_3 \| R_5} = \dfrac{3\ \Omega(4\ \text{A})}{3\ \Omega + 3\ \Omega + 6\ \Omega \| 6\ \Omega}$

$= \dfrac{12\ \text{A}}{6 + 3} = \mathbf{1.333\ A}$

$I_3 = \dfrac{I_2}{2} = \mathbf{0.6665\ A}$

c. $I_4 = I_1 - I_2 = 4\ \text{A} - 1.333\ \text{A} = 2.667\ \text{A}$

$V_a = I_4R_4 = (2.667\ \text{A})(3\ \Omega) = \mathbf{8\ V}$

$V_b = I_3R_3 = (0.6665\ \text{A})(6\ \Omega) = \mathbf{4\ V}$

11. a. $R' = R_6 \| R_5 \| (R_7 + R_8) = 4\ \Omega \| 8\ \Omega \| (6\ \Omega + 2\ \Omega) = 4\ \Omega \| 8\ \Omega \| 8\ \Omega$

$= 4\ \Omega \| 4\ \Omega = 2\ \Omega$

$R'' = (R_3 + R') \| (R_6 + R_9) = (8\ \Omega + 2\ \Omega) \| (6\ \Omega + 4\ \Omega)$

$= 10\ \Omega \| 10\ \Omega = 5\ \Omega$

$R_T = R_1 \| (R_2 + R'') = 10\ \Omega \| (5\ \Omega + 5\ \Omega) = 10\ \Omega \| 10\ \Omega = \mathbf{5\ \Omega}$

$I = \dfrac{E}{R_T} = \dfrac{80\ \text{V}}{5\ \Omega} = \mathbf{16\ A}$

b. $I_{R_2} = \dfrac{I}{2} = \dfrac{16\ \text{A}}{2} = \mathbf{8\ A}$

$I_3 = I_9 = \dfrac{8\ \text{A}}{2} = \mathbf{4\ A}$

c. $I_{8\Omega} = \dfrac{(R_6 \| R_5)(I_3)}{(R_6 \| R_5) + (R_7 + R_8)}$

$= \dfrac{(4\ \Omega \| 8\ \Omega)(4\ \text{A})}{(4\ \Omega \| 8\ \Omega) + (6\ \Omega + 2\ \Omega)}$

$= \dfrac{(2.67\ \Omega)(4\ \text{A})}{2.67\ \Omega + 8\ \Omega} = \mathbf{1\ A}$

d. $-I_8R_8 - \underset{+-}{V_{ab}} + I_9R_9 = 0$

$V_{ab} = I_9R_9 - I_8R_8 = (4\ \text{A})(4\ \Omega) - (1\ \text{A})(2\ \Omega) = 16\ \text{V} - 2\ \text{V} = \mathbf{14\ V}$

13. a. $I_G = 0 \therefore V_G = \dfrac{270\ \text{k}\Omega(16\ \text{V})}{270\ \text{k}\Omega + 2000\ \text{k}\Omega} = \mathbf{1.9\ V}$

$V_G - V_{GS} - V_S = 0$

$V_S = V_G - V_{GS} = 1.9\ \text{V} - (-1.75\ \text{V}) = \mathbf{3.65\ V}$

b. $I_1 = I_2 = \dfrac{16\ \text{V}}{270\ \text{k}\Omega + 2000\ \text{k}\Omega} = \mathbf{7.05\ \mu A}$

$I_D = I_S = \dfrac{V_S}{R_S} = \dfrac{3.65\ \text{V}}{1.5\ \text{k}\Omega} = \mathbf{2.433\ mA}$

c. $V_{DS} = V_{DD} - I_DR_D - I_SR_S = V_{DD} - I_D(R_D + R_S)$ since $I_D = I_S$

$= 16\ \text{V} - (2.433\ \text{mA})(4\ \text{k}\Omega) = 16\ \text{V} - 9.732\ \text{V} = \mathbf{6.268\ V}$

d. $V_{DD} - I_DR_D - V_{DG} - V_G = 0$

$V_{DG} = V_{DD} - I_DR_D - V_G$

$= 16\ \text{V} - (2.433\ \text{mA})(2.5\ \text{k}\Omega) - 1.9\ \text{V} = 16\ \text{V} - 6.083\ \text{V} - 1.9\ \text{V} = \mathbf{8.02\ V}$

15. a. $I = \dfrac{E}{R_2 + R_3} = \dfrac{9\text{ V}}{7\ \Omega + 8\ \Omega} = \mathbf{0.6\ A}$

b. $E_1 - V + E_2 = 0$
$V = E_1 + E_2 = 9\text{ V} + 19\text{ V} = \mathbf{28\ V}$

17. a. R_8 "shorted out"

$$\begin{aligned} R' &= R_3 + R_4 \parallel R_5 + R_6 \parallel R_7 \\ &= 10\ \Omega + 6\ \Omega \parallel 6\ \Omega + 6\ \Omega \parallel 3\ \Omega \\ &= 10\ \Omega + 3\ \Omega + 2\ \Omega \\ &= 15\ \Omega \end{aligned}$$

$$\begin{aligned} R_T &= R_1 + R_2 \parallel R' \\ &= 10\ \Omega + 30\ \Omega \parallel 15\ \Omega = 10\ \Omega + 10\ \Omega \\ &= 20\ \Omega \end{aligned}$$

$$I = \frac{E}{R_T} = \frac{100\text{ V}}{20\ \Omega} = 5\text{ A}$$

$$I_2 = \frac{R'(I)}{R' + R_2} = \frac{(15\ \Omega)(5\text{ A})}{15\ \Omega + 30\ \Omega} = \mathbf{1.667\ A}$$

$$I_3 = I - I_2 = 5\text{ A} - 1\frac{2}{3}\text{ A} = 3\frac{1}{3}\text{ A}$$

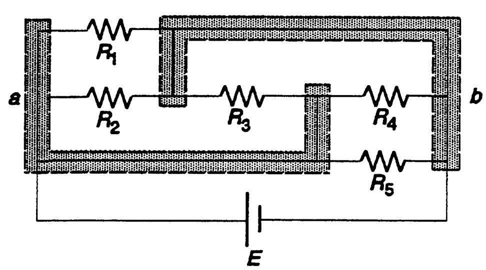
$$I_6 = \frac{R_7 I_3}{R_7 + R_6} = \frac{3\ \Omega\left(\frac{10}{3}\text{ A}\right)}{3\ \Omega + 6\ \Omega} = \mathbf{1.111\ A}$$

$I_8 = \mathbf{0\ A}$

b. $V_4 = I_3(R_4 \parallel R_5) = \left(\frac{10}{3}\text{ A}\right)(3\ \Omega) = \mathbf{10\ V}$

$V_8 = \mathbf{0\ V}$

19. a. All resistors in parallel (between terminals a & b)



$$R_T = \underbrace{16\ \Omega \parallel 16\ \Omega}_{} \parallel 8\ \Omega \parallel 4\ \Omega \parallel 32\ \Omega$$

$$\underbrace{8\ \Omega \parallel 8\ \Omega}_{} \parallel 4\ \Omega \parallel 32\ \Omega$$

$$\underbrace{4\ \Omega \parallel 4\ \Omega}_{} \parallel 32\ \Omega$$

$$2\ \Omega \parallel 32\ \Omega = \mathbf{1.882\ \Omega}$$

b. All in parallel. Therefore, $V_1 = V_4 = E = \mathbf{32\ V}$

c. $I_3 = V_3/R_3 = 32\text{ V}/4\ \Omega = \mathbf{8\ A} \leftarrow$

d. $I_s = I_1 + I_2 + I_3 + I_4 + I_5$

$$= \frac{32\text{ V}}{16\ \Omega} + \frac{32\text{ V}}{8\ \Omega} + \frac{32\text{ V}}{4\ \Omega} + \frac{32\text{ V}}{32\ \Omega} + \frac{32\text{ V}}{16\ \Omega}$$

$$= 2\text{ A} + 4\text{ A} + 8\text{ A} + 1\text{ A} + 2\text{ A}$$

$$= 17\text{ A}$$

$$R_T = \frac{E}{I_s} = \frac{32\text{ V}}{17\text{ A}} = \mathbf{1.882\ \Omega} \text{ as above}$$

21. a. Applying Kirchoff's voltage law in the CCW direction in the upper "window":

$$+18\text{ V} + 20\text{ V} - V_{8\Omega} = 0$$

$$V_{8\Omega} = 38\text{ V}$$

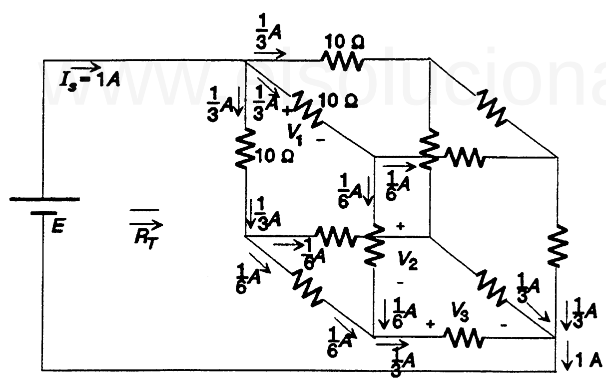
$$I_{8\Omega} = \frac{38\text{ V}}{8\ \Omega} = 4.75\text{ A}$$

$$I_{3\Omega} = \frac{18\text{ V}}{3\ \Omega + 6\ \Omega} = \frac{18\text{ V}}{9\ \Omega} = 2\text{ A}$$

$$\text{KCL: } I_{18\text{V}} = 4.75\text{ A} + 2\text{ A} = \mathbf{6.75\ A}$$

b. $V = (I_{3\Omega})(6\ \Omega) + 20\text{ V} = (2\text{ A})(6\ \Omega) + 20\text{ V} = 12\text{ V} + 20\text{ V} = \mathbf{32\ V}$

23. Assuming $I_s = 1$ A, the current I_s will divide as determined by the load appearing in each branch. Since balanced I_s will split equally between all three branches.



$$V_1 = \left[\frac{1}{3}\text{ A}\right](10\ \Omega) = \frac{10}{3}\text{ V}$$

$$V_2 = \left[\frac{1}{6}\text{ A}\right](10\ \Omega) = \frac{10}{6}\text{ V}$$

$$V_3 = \left[\frac{1}{3}\text{ A}\right](10\ \Omega) = \frac{10}{3}\text{ V}$$

$$E = V_1 + V_2 + V_3 = \frac{10}{3}\text{ V} + \frac{10}{6}\text{ V} + \frac{10}{3}\text{ V} = 8.333\text{ V}$$

$$R_T = \frac{E}{I} = \frac{8.333\text{ V}}{1\text{ A}} = \mathbf{8.333\ \Omega}$$

25. a. $R'_T = R_5 \parallel (R_6 + R_7) = 6\ \Omega \parallel 3\ \Omega = 2\ \Omega$
$R''_T = R_3 \parallel (R_4 + R'_T) = 4\ \Omega \parallel (2\ \Omega + 2\ \Omega) = 2\ \Omega$
$R_T = R_1 + R_2 + R''_T = 3\ \Omega + 5\ \Omega + 2\ \Omega = 10\ \Omega$
$I = \dfrac{240\text{ V}}{10\ \Omega} = \mathbf{24\ A}$

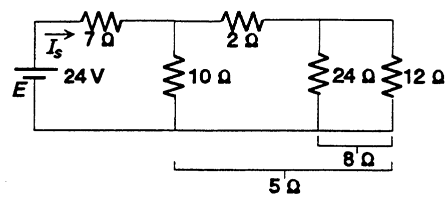
b. $I_4 = \dfrac{4\ \Omega(I)}{4\ \Omega + 4\ \Omega} = \dfrac{4\ \Omega(24\text{ A})}{8\ \Omega} = 12\text{ A}$
$I_7 = \dfrac{6\ \Omega(12\text{ A})}{6\ \Omega + 3\ \Omega} = \dfrac{72\text{ A}}{9} = \mathbf{8\ A}$

c. $V_3 = I_3R_3 = (I - I_4)R_3 = (24\text{ A} - 12\text{ A})4\ \Omega = \mathbf{48\ V}$
$V_5 = I_5R_5 = (I_4 - I_7)R_5 = (4\text{ A})6\ \Omega = \mathbf{24\ V}$
$V_7 = I_7R_7 = (8\text{ A})2\ \Omega = \mathbf{16\ V}$

d. $P = I_7^2R_7 = (8\text{ A})^2 2\ \Omega = \mathbf{128\ W}$
$P = EI = (240\text{ V})(24\text{ A}) = \mathbf{5760\ W}$

27. The 12 Ω resistors are in parallel.

Network redrawn:



$R_T = 12\ \Omega$
$I_s = \dfrac{E}{R_T} = \dfrac{24\text{ V}}{12\ \Omega} = 2\text{ A}$
$I_{2\Omega} = \dfrac{I_s}{2} = \dfrac{2\text{ A}}{2} = 1\text{ A}$
$I_{12\Omega} = \dfrac{24\ \Omega(I_{2\Omega})}{24\ \Omega + 12\ \Omega} = \dfrac{2}{3}\text{ A}$
$P_{10\Omega} = (I_{10\Omega})^2\, 10\ \Omega = \left[\dfrac{2}{3}\text{ A}\right]^2 \cdot 10\ \Omega = \mathbf{4.44\ W}$

29. a. $E = (40\text{ mA})(1.6\text{ k}\Omega) = \mathbf{64\ V}$

b. $R_{L_2} = \dfrac{48\text{ V}}{12\text{ mA}} = \mathbf{4\ k\Omega}$
$R_{L_3} = \dfrac{24\text{ V}}{8\text{ mA}} = \mathbf{3\ k\Omega}$

c. $I_{R_1} = 72\text{ mA} - 40\text{ mA} = 32\text{ mA}$
$I_{R_2} = 32\text{ mA} - 12\text{ mA} = 20\text{ mA}$
$I_{R_3} = 20\text{ mA} - 8\text{ mA} = 12\text{ mA}$
$R_1 = \dfrac{V_{R_1}}{I_{R_1}} = \dfrac{64\text{ V} - 48\text{ V}}{32\text{ mA}} = \dfrac{16\text{ V}}{32\text{ mA}} = \mathbf{0.5\ k\Omega}$
$R_2 = \dfrac{V_{R_2}}{I_{R_2}} = \dfrac{48\text{ V} - 24\text{ V}}{20\text{ mA}} = \dfrac{24\text{ V}}{20\text{ mA}} = \mathbf{1.2\ k\Omega}$
$R_3 = \dfrac{V_{R_3}}{I_{R_3}} = \dfrac{24\text{ V}}{12\text{ mA}} = \mathbf{2\ k\Omega}$

31. a. yes

b. VDR: $V_{R_2} = 3\text{ V} = \dfrac{R_2(12\text{ V})}{R_1 + R_2} = \dfrac{R_2(12\text{ V})}{1\text{ k}\Omega}$

$$R_2 = \frac{3\text{ V}(1\text{ k}\Omega)}{12\text{ V}} = 0.25\text{ k}\Omega = \mathbf{250\ \Omega}$$
$$R_1 = 1\text{ k}\Omega - 0.25\text{ k}\Omega = 0.75\text{ k}\Omega = \mathbf{750\ \Omega}$$

c. $V_{R_1} = E - V_L = 12\text{ V} - 3\text{ V} = 9\text{ V}$ (Chose V_{R_1} rather than $V_{R_2 \| R_L}$ since numerator of VDR equation "cleaner")

$$V_{R_1} = 9\text{ V} = \frac{R_1(12\text{ V})}{R_1 + (R_2 \| R_L)}$$
$$9R_1 + 9(R_2 \| R_L) = 12R_1$$
$$\left.\begin{aligned} \mathbf{R_1} &\mathbf{= 3(R_2 \| R_L)} \\ \mathbf{R_1 + R_2} &\mathbf{= 1\ k\Omega} \end{aligned}\right\} \text{2 eq. 2 unk}(R_L = 10\text{ k}\Omega)$$

$$R_1 = \frac{3R_2R_L}{R_2 + R_L} \Rightarrow \frac{3R_2\ 10\text{ k}\Omega}{R_2 + 10\text{ k}\Omega}$$
and $R_1(R_2 + 10\text{ k}\Omega) = 30\text{ k}\Omega\ R_2$
$$R_1R_2 + 10\text{ k}\Omega\ R_1 = 30\text{ k}\Omega\ R_2$$
$$R_1 + R_2 = 1\text{ k}\Omega:\ (1\text{ k}\Omega - R_2)R_2 + 10\text{ k}\Omega\ (1\text{ k}\Omega - R_2) = 30\text{ k}\Omega\ R_2$$
$$R_2^2 + 39\text{ k}\Omega\ R_2 - 10\text{ k}\Omega^2 = 0$$
$$R_2 = 0.255\text{ k}\Omega,\ \cancel{-39.255}\text{ k}\Omega$$
$$R_2 = \mathbf{255\ \Omega}$$
$$R_1 = 1\text{ k}\Omega - R_2 = \mathbf{745\ \Omega}$$

33. a. $I_{CS} = \mathbf{1\ mA}$

b. $R_{\text{shunt}} = \dfrac{R_m I_{CS}}{I_{\max} - I_{CS}} = \dfrac{(100\ \Omega)(1\text{ mA})}{20\text{ A} - 1\text{ mA}} \cong \dfrac{0.1}{20}\ \Omega = \mathbf{5\ m\Omega}$

35. a. $R_s = \dfrac{V_{\max} - V_{VS}}{I_{CS}} = \dfrac{15\text{ V} - (50\ \mu\text{A})(1\text{ k}\Omega)}{50\ \mu\text{A}} = \mathbf{300\ k\Omega}$

b. $\Omega/\text{V} = 1/I_{CS} = 1/50\ \mu\text{A} = \mathbf{20{,}000}$

37. $10\text{ M}\Omega = (0.5\text{ V})(\Omega/\text{V}) \Rightarrow \Omega/\text{V} = 20 \times 10^6$

$$I_{CS} = 1/(\Omega/\text{V}) = \frac{1}{20 \times 10^6} = \mathbf{0.05\ \mu A}$$

CHAPTER 7 (Even)

2. a. $R_T = 4\ \Omega + 4\ \Omega + 4\ \Omega = \mathbf{12\ \Omega}$

b. $R_T = 4\ \Omega + 4\ \Omega \parallel 4\Omega = 4\ \Omega + 2\ \Omega = \mathbf{6\ \Omega}$

c. $R_T = (4\ \Omega + 4\ \Omega) \parallel 4\Omega + 4\ \Omega = 8\ \Omega \parallel 4\ \Omega + 4\ \Omega$
$= 2.667\ \Omega + 4\ \Omega = \mathbf{6.667\ \Omega}$

d. $R_T = \mathbf{4\ \Omega}$

4. a. $R_T = R_1 \parallel R_2 + R_3 = 12\ \Omega \parallel 6\ \Omega + 12\ \Omega = 4\ \Omega + 12\ \Omega = \mathbf{16\ \Omega}$

b. $I = \dfrac{E}{R_T} = \dfrac{64\text{ V}}{16\ \Omega} = \mathbf{4\text{ A}}$ CDR: $I_1 = \dfrac{6\ \Omega(4\text{ A})}{6\ \Omega + 12\ \Omega} = \mathbf{1\frac{1}{3}}\text{ A}$

c. $V_3 = IR_3 = (4\text{ A})(12\ \Omega) = \mathbf{48\text{ V}}$

6. $I_1 = \dfrac{20\text{ V}}{5\ \Omega} = \mathbf{4\text{ A}}$
$R_T = 16\ \Omega \parallel 25\ \Omega = 9.756\ \Omega$
$I_2 = \dfrac{7\text{ V}}{9.756\ \Omega} = \mathbf{0.7175\text{ A}}$

8. a. $R' = R_4 + R_5 = 14\ \Omega + 6\ \Omega = 20\ \Omega$
$R'' = R_2 \parallel R' = 20\ \Omega \parallel 20\ \Omega = 10\ \Omega$
$R''' = R'' + R_1 = 10\ \Omega + 10\ \Omega = 20\ \Omega$
$R_T = R_3 \parallel R''' = 5\ \Omega \parallel 20\ \Omega = \mathbf{4\ \Omega}$

$$I_s = \frac{E}{R_T} = \frac{20\text{ V}}{4\ \Omega} = \mathbf{5\text{ A}}$$

$$I_1 = \frac{20\text{ V}}{R_1 + R''} = \frac{20\text{ V}}{10\ \Omega + 10\ \Omega} = \frac{20\text{ V}}{20\ \Omega} = \mathbf{1\text{ A}}$$

$$I_3 = \frac{20\text{ V}}{5\ \Omega} = \mathbf{4\text{ A}}$$

$$I_4 = \frac{I_1}{2} = (\text{since } R' = R_2) = \frac{1\text{ A}}{2} = \mathbf{0.5\text{ A}}$$

b. $V_a = I_3R_3 - I_4R_5 = (4\text{ A})(5\ \Omega) - (0.5\text{ A})(6\ \Omega) = 20\text{ V} - 3\text{ V} = \mathbf{17\text{ V}}$

$$V_{bc} = \left[\frac{I_1}{2}\right] R_2 = (0.5\text{ A})(20\ \Omega) = \mathbf{10\text{ V}}$$

10. a. $R_T = R_1 \parallel R_2 \parallel R_3 \parallel (R_6 + R_4 \parallel R_5)$
$= 12\text{ k}\Omega \parallel 12\text{ k}\Omega \parallel 3\text{ k}\Omega \parallel (10.4\text{ k}\Omega + 9\text{ k}\Omega \parallel 6\text{ k}\Omega)$
$= 6\text{ k}\Omega \parallel 3\text{ k}\Omega \parallel (10.4\text{ k}\Omega + 3.6\text{ k}\Omega)$
$= 2\text{ k}\Omega \parallel 14\text{ k}\Omega = \mathbf{1.75\text{ k}\Omega}$

$$I = \frac{E}{R_T} = \frac{28\text{ V}}{1.75\text{ k}\Omega} = \mathbf{16\text{ mA}}$$

$$R' = R_1 \parallel R_2 \parallel R_3 = 2\text{ k}\Omega$$
$$R'' = R_6 + R_4 \parallel R_5 = 14\text{ k}\Omega$$
$$I_6 = \frac{R'(I)}{R' + R''} = \frac{(2\text{ k}\Omega)(16\text{ mA})}{2\text{ k}\Omega + 14\text{ k}\Omega} = \mathbf{2\text{ mA}}$$

b. $V_1 = E = 28\text{ V}$
$V_5 = I_6(R_4 \parallel R_5) = (2\text{ mA})(3.6\text{ k}\Omega) = \mathbf{7.2\text{ V}}$

c. $P = \dfrac{V_5^2}{R_5} = \dfrac{(7.2\text{ V})^2}{6\text{ k}\Omega} = \mathbf{8.64\text{ mW}}$

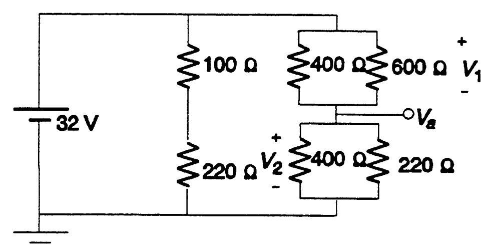
12. a. $I_E = \dfrac{V_E}{R_E} = \dfrac{2\text{ V}}{1\text{ k}\Omega} = \mathbf{2\text{ mA}}$
$I_C = I_E = \mathbf{2\text{ mA}}$

b. $I_B = \dfrac{V_{R_B}}{R_B} = \dfrac{V_{CC} - (V_{BE} + V_E)}{R_B} = \dfrac{8\text{V} - (0.7\text{ V} + 2\text{V})}{220\text{ k}\Omega}$
$= \dfrac{8\text{ V} - 2.7\text{ V}}{220\text{ k}\Omega} = \dfrac{5.3\text{ V}}{220\text{ k}\Omega} = \mathbf{24\ \mu A}$

c. $V_B = V_{BE} + V_E = \mathbf{2.7\text{ V}}$
$V_C = V_{CC} - I_C R_C = 8\text{ V} - (2\text{ mA})(2.2\text{ k}\Omega) = 8\text{ V} - 4.4\text{ V} = \mathbf{3.6\text{ V}}$

d. $V_{CE} = V_C - V_E = 3.6\text{ V} - 2\text{ V} = \mathbf{1.6\text{ V}}$
$V_{BC} = V_B - V_C = 2.7\text{ V} - 3.6\text{ V} = \mathbf{-0.9\text{ V}}$

14. a. Network redrawn:



$100\ \Omega + 220\ \Omega = 320\ \Omega$
$400\ \Omega \parallel 600\ \Omega = 240\ \Omega$
$400\ \Omega \parallel 220\ \Omega = 141.94\ \Omega$
$240\ \Omega + 141.94\ \Omega = 381.94\ \Omega$

$R_T = 320\ \Omega \parallel 381.94\ \Omega = \mathbf{174.12\ \Omega}$

b. $V_a = \dfrac{141.94\ \Omega(32\text{ V})}{141.94\ \Omega + 240\ \Omega} = \mathbf{11.892\text{ V}}$

c. $V_1 = 32\text{ V} - V_a = 32\text{ V} - 11.892\text{ V} = \mathbf{20.108\text{ V}}$

d. $V_2 = V_a = \mathbf{11.892\text{ V}}$

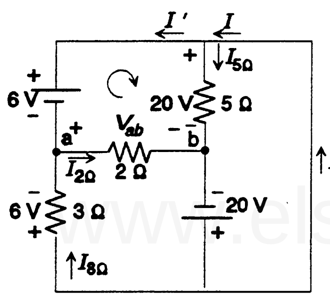
e. $I_{600\Omega} = \dfrac{20.108\text{ V}}{600\ \Omega} = 33.51\text{ mA}$
$I_{220\Omega} = \dfrac{11.892\text{ V}}{220\ \Omega} = 54.05\text{ mA}$
$I + I_{600\Omega} = I_{220\Omega}$
$I = I_{200\Omega} - I_{600\Omega}$
$= 54.05\text{ mA} - 33.5\text{ mA}$
$= \mathbf{20.54\text{ mA}} \rightarrow$

16. $R_T = 4\text{ k}\Omega + 2\text{ k}\Omega \parallel (1\text{ k}\Omega + 0.5\text{ k}\Omega + 1.5\text{ k}\Omega)$
$= 4\text{ k}\Omega + 2\text{ k}\Omega \parallel 3\text{ k}\Omega = 4\text{ k}\Omega + 1.2\text{ k}\Omega$
$= 5.2\text{ k}\Omega$

$$I_s = \frac{E}{R_T} = \frac{24\text{ V}}{5.2\text{ k}\Omega} = 4.615\text{ mA}$$
$$I = \frac{3\text{ k}\Omega(I_s)}{3\text{ k}\Omega + 2\text{ k}\Omega} = \frac{3\text{ k}\Omega(4.615\text{ mA})}{5\text{ k}\Omega} = \mathbf{2.769\text{ mA}}$$
$I_{R_3} = 4.615\text{ mA} - 2.769\text{ mA} = 1.846\text{ mA}$
$V_b = -I_{R_3}R_3 = -(1.846\text{ mA})(1\text{ k}\Omega) = \mathbf{-1.846\text{ V}}$
$V_a + 24\text{ V} - I_s\,4\text{ k}\Omega = 0$
$V_a = I_s\,4\text{ k}\Omega - 24\text{ V} = (4.615\text{ mA})(4\text{ k}\Omega) - 24\text{ V}$
$= 18.46\text{ V} - 24\text{ V} = \mathbf{-5.54\text{ V}}$
$V_{ab} = V_a - V_b = -5.54\text{ V} - (-1.846\text{ V}) = \mathbf{-3.694\text{ V}}$

18. $8\ \Omega \parallel 8\ \Omega = 4\ \Omega$
$$I = \frac{30\text{ V}}{4\ \Omega + 6\ \Omega} = \frac{30\text{ V}}{10\ \Omega} = 3\text{ A}$$
$V = I(8\ \Omega \parallel 8\ \Omega) = (3\text{ A})(4\ \Omega) = \mathbf{12\text{ V}}$

20. a.



KVL: $+6\text{ V} - 20\text{ V} + V_{ab} = 0$
$V_{ab} = +20\text{ V} - 6\text{ V} = \mathbf{14\text{ V}}$

b. $$I_{5\Omega} = \frac{20\text{ V}}{5\ \Omega} = 4\text{ A}$$
$$I_{2\Omega} = \frac{V_{ab}}{2\ \Omega} = \frac{14\text{ V}}{2\ \Omega} = 7\text{ A}$$
$$I_{3\Omega} = \frac{6\text{ V}}{3\ \Omega} = 2\text{ A}$$
$I' + I_{3\Omega} = I_{2\Omega}$
and $I' = I_{2\Omega} - I_{3\Omega} = 7\text{ A} - 2\text{ A} = 5\text{ A}$
$I = I' + I_{5\Omega} = 5\text{ A} + 4\text{ A} = \mathbf{9\text{ A}}$

22. $I_2R_2 = 2R_3 \Rightarrow I_2 = \dfrac{R_3}{10}$ (since the voltage across parallel elements is the same)

$$I_1 = I_2 + I_3 = \frac{R_3}{10} + 2$$

KVL: $120 = I_1 12 + I_3R_3 = \left[\dfrac{R_3}{10} + 2\right]12 + 2R_3$
and $R_3 = \mathbf{30\ \Omega}$

24. $36\text{ k}\Omega \parallel 6\text{ k}\Omega \parallel 12\text{ k}\Omega = 3.6\text{ k}\Omega$

$V = \dfrac{3.6\text{ k}\Omega(45\text{ V})}{3.6\text{ k}\Omega + 6\text{ k}\Omega} = 16.875\text{ V} \neq 27\text{ V}$. Therefore, not operating properly!

6 kΩ resistor "open"

$$V = \frac{9\text{ k}\Omega(45\text{ V})}{9\text{ k}\Omega + 6\text{ k}\Omega} = \mathbf{27\text{ V}}$$

26. a. $R'_T = R_4 \parallel (R_6 + R_7 + R_8) = 2\ \Omega \parallel 7\ \Omega = 1.556\ \Omega$
$R''_T = R_2 \parallel (R_3 + R_5 + R'_T) = 2\ \Omega \parallel (4\ \Omega + 1\ \Omega + 1.556\ \Omega) = 1.532\ \Omega$
$R_T = R_1 + R''_T = 4\ \Omega + 1.532\ \Omega = \mathbf{5.532\ \Omega}$

b. $I = 2\text{ V}/5.532\ \Omega = 0.3615\text{ A} = \mathbf{361.5\text{ mA}}$

c. $I_3 = \dfrac{2\ \Omega(I)}{2\ \Omega + 6.56\ \Omega} = \dfrac{2\ \Omega(361.5\text{ mA})}{2\ \Omega + 6.56\ \Omega} = \mathbf{84.5\text{ mA}}$

$I_8 = \dfrac{2\ \Omega(84.5\text{ mA})}{2\ \Omega + 7\ \Omega} = \mathbf{18.78\text{ mA}}$

28. a. $R_{10} + R_{11} \parallel R_{12} = 1\ \Omega + 2\ \Omega \parallel 2\ \Omega = 2\ \Omega$
$R_4 \parallel (R_5 + R_6) = 10\ \Omega \parallel 10\ \Omega = 5\ \Omega$
$R_1 + R_2 \parallel (R_3 + 5\ \Omega) = 3\ \Omega + 6\ \Omega \parallel 6\ \Omega = 6\ \Omega$
$R_T = 2\ \Omega \parallel 3\ \Omega \parallel 6\ \Omega = 2\ \Omega \parallel 2\ \Omega = 1\ \Omega$
$I = 12\text{ V}/1\ \Omega = \mathbf{12\text{ A}}$

b. $I_1 = 12\text{ V}/6\ \Omega = 2\text{ A}$

$I_3 = \dfrac{6\ \Omega(2\text{ A})}{6\ \Omega + 6\ \Omega} = 1\text{ A}$

$I_4 = \dfrac{1\text{ A}}{2} = \mathbf{0.5\text{ A}}$

c. $I_6 = I_4 = \mathbf{0.5\text{ A}}$

d. $I_{10} = \dfrac{12\text{ A}}{2} = \mathbf{6\text{ A}}$

30. $I_{R_1} = 40\text{ mA}$

$I_{R_2} = 40\text{ mA} - 10\text{ mA} = 30\text{ mA}$

$I_{R_3} = 30\text{ mA} - 20\text{ mA} = 10\text{ mA}$

$I_{R_5} = 40\text{ mA}$

$I_{R_4} = 40\text{ mA} - 4\text{ mA} = 36\text{ mA}$

$$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{120\text{ V} - 100\text{ V}}{40\text{ mA}} = \frac{20\text{ V}}{40\text{ mA}} = \mathbf{0.5\text{ k}\Omega}$$

$$R_2 = \frac{V_{R_2}}{I_{R_2}} = \frac{100\text{ V} - 40\text{ V}}{30\text{ mA}} = \frac{60\text{ V}}{30\text{ mA}} = \mathbf{2\text{ k}\Omega}$$

$$R_3 = \frac{V_{R_3}}{I_{R_3}} = \frac{40\text{ V}}{10\text{ mA}} = \mathbf{4\text{ k}\Omega}$$

$$R_4 = \frac{V_{R_4}}{I_{R_4}} = \frac{36\text{ V}}{36\text{ mA}} = \mathbf{1\text{ k}\Omega}$$

$$R_5 = \frac{V_{R_5}}{I_{R_5}} = \frac{60\text{ V} - 36\text{ V}}{40\text{ mA}} = \frac{24\text{ V}}{40\text{ mA}} = \mathbf{0.6\ k\Omega}$$

$P_1 = I_1^2R_1 = (40\text{ mA})^2 0.5\text{ k}\Omega = \mathbf{0.8\ W}$ (1 watt resistor)

$P_2 = I_2^2R_2 = (30\text{ mA})^2 2\text{ k}\Omega = \mathbf{1.8\ W}$ (2 watt resistor)

$P_3 = I_3^2R_3 = (10\text{ mA})^2 4\text{ k}\Omega = \mathbf{0.4\ W}$ (1/2 watt or 1 watt resistor)

$P_4 = I_4^2R_4 = (36\text{ mA})^2 1\text{ k}\Omega = \mathbf{1.296\ W}$ (2 watt resistor)

$P_5 = I_5^2R_5 = (40\text{ mA})^2 0.6\text{ k}\Omega = \mathbf{0.96\ W}$ (1 watt resistor)

All power levels less than **2 W**. Four less than **1 W**.

32. a. $V_{ab} = \dfrac{80\ \Omega(40\text{ V})}{100\ \Omega} = \mathbf{32\ V}$

$V_{bc} = 40\text{ V} - 32\text{ V} = \mathbf{8\ V}$

b. $80\ \Omega \parallel 1\text{ k}\Omega = 74.07\ \Omega$

$20\ \Omega \parallel 10\text{ k}\Omega = 19.96\ \Omega$

$V_{ab} = \dfrac{74.07\ \Omega(40\text{ V})}{74.07\ \Omega + 19.96\ \Omega} = \mathbf{31.51\ V}$

$V_{bc} = 40\text{ V} - 31.51\text{ V} = \mathbf{8.49\ V}$

c. $P = \dfrac{(31.51\text{ V})^2}{80\ \Omega} + \dfrac{(8.49\text{ V})^2}{20\ \Omega} = 12.411\text{ W} + 3.604\text{ W} = \mathbf{16.015\ W}$

d. $P = \dfrac{(32\text{ V})^2}{80\ \Omega} + \dfrac{(8\text{ V})^2}{20\ \Omega} = 12.8\text{ W} + 3.2\text{ W} = \mathbf{16\ W}$

34. 25 mA: $R_{\text{shunt}} = \dfrac{(1\text{ k}\Omega)(50\ \mu\text{A})}{25\text{ mA} - 0.05\text{ mA}} \cong \mathbf{2\ \Omega}$

50 mA: $R_{\text{shunt}} = \dfrac{(1\text{ k}\Omega)(50\ \mu\text{A})}{50\text{ mA} - 0.05\text{ mA}} = \mathbf{1\ \Omega}$

100 mA: $R_{\text{shunt}} \cong \mathbf{0.5\ \Omega}$

36. 5 V: $R_s = \dfrac{5\text{ V} - (1\text{ mA})(100\ \Omega)}{1\text{ mA}} = \mathbf{4.9\ k\Omega}$

50 V: $R_s = \dfrac{50\text{ V} - 0.1\text{ V}}{1\text{ mA}} = \mathbf{49.9\ k\Omega}$

500 V: $R_s = \dfrac{500\text{ V} - 0.1\text{ V}}{1\text{ mA}} = \mathbf{499.9\ k\Omega}$

38. a. $R_s = \dfrac{E}{I_m} - R_m - \dfrac{\text{zero adjust}}{2} = \dfrac{3\text{ V}}{100\ \mu\text{A}} - 1\text{ k}\Omega - \dfrac{2\text{ k}\Omega}{2} = \mathbf{28\ k\Omega}$

b. $$xI_m = \frac{E}{R_{\text{series}} + R_m + \frac{\text{zero adjust}}{2} + R_{\text{unk}}}$$

$$R_{\text{unk}} = \frac{E}{xI_m} - \left[R_{\text{series}} + R_m + \frac{\text{zero adjust}}{2}\right]$$

$$= \frac{3\text{ V}}{x100\ \mu\text{A}} - 30\text{ k}\Omega \Rightarrow \frac{30 \times 10^3}{x} - 30 \times 10^3$$

$$x = \frac{3}{4},\ R_{\text{unk}} = \mathbf{10\ k\Omega};\ x = \frac{1}{2},\ R_{\text{unk}} = \mathbf{30\ k\Omega};\ x = \frac{1}{4},\ R_{\text{unk}} = \mathbf{90\ k\Omega}$$

40. a. Carefully redrawing the network will reveal that all three resistors are in parallel and $R_T = \frac{R}{N} = \frac{12\ \Omega}{3} = \mathbf{4\ \Omega}$

b. Again, all three resistors are in parallel and $R_T = \frac{R}{N} = \frac{18\ \Omega}{3} = \mathbf{6\ \Omega}$

CHAPTER 8 (Odd)

1. $V_{ab} = E + IR = 10\text{ V} + (6\text{ A})(3\ \Omega) = \mathbf{28\ V}$

3. a. $I_1 = \dfrac{E}{R_1} = \dfrac{24\text{ V}}{2\ \Omega} = \mathbf{12\ A}$, $I_{R_2} = \dfrac{E}{R_2 + R_3} = \dfrac{24\text{ V}}{6\ \Omega + 2\ \Omega} = \dfrac{24\ \Omega}{8\ \Omega} = 3\text{A}$

   KCL: $I + I_s - I_1 - I_{R_2} = 0$

   $I_s = I_1 + I_{R_2} - I = 12\text{ A} + 3\text{ A} - 4\text{ A} = \mathbf{11\ A}$

   b. $V_s = E = 24\text{ V}$

   VDR: $V_3 = \dfrac{R_3E}{R_2 + R_3} = \dfrac{2\ \Omega(24\text{ V})}{6\ \Omega + 2\ \Omega} = \dfrac{48\text{ V}}{8} = \mathbf{6\ V}$

5. a. $I = \dfrac{E}{R_s} = \dfrac{18\text{ V}}{6\ \Omega} = \mathbf{3\ A}$, $R_p = R_s = \mathbf{6\ \Omega}$

   b. $I = \dfrac{E}{R_s} = \dfrac{9\text{ V}}{2.2\text{ k}\Omega} = \mathbf{4.091\ mA}$, $R_p = R_s = \mathbf{2.2\ k\Omega}$

7. a. CDR: $I_L = \dfrac{R_s(I)}{R_s + R_L} = \dfrac{4\ \Omega(12\text{ A})}{4\ \Omega + 2\ \Omega} = \mathbf{8\ A}$

   b. $E_s = IR = (12\text{ A})(4\ \Omega) = 48\text{ V}$

   $R_s = 4\ \Omega$

   $I = \dfrac{E_s}{R_s + R_L} = \dfrac{48\text{ V}}{4\ \Omega + 2\ \Omega} = \mathbf{8\ A}$

9. $I_T\uparrow = 7\text{ A} - 3\text{ A} = 4\text{ A}$

   CDR: $I_1 = \dfrac{R_2(I_T)}{R_1 + R_2} = \dfrac{6\ \Omega(4\text{ A})}{4\ \Omega + 6\ \Omega} = \mathbf{2.4\ A}$

   $V_2 = I_T(R_1 \| R_2) = 4\text{ A}(2.4\ \Omega) = \mathbf{9.6\ V}$

11. a. $I = \dfrac{E}{R_2} = \dfrac{12\text{ V}}{2.2\text{ k}\Omega} = \mathbf{5.4545\ mA}$, $R_p = \mathbf{2.2\ k\Omega}$

   b. $I_T\uparrow = 8\text{ mA} + 5.4545\text{ mA} - 3\text{ mA} = 10.4545\text{ mA}$

   $R' = 6.8\text{ k}\Omega \| 2.2\text{ k}\Omega = 1.662\text{ k}\Omega$

   $V_1 = I_TR' = (10.4545\text{ mA})(1.662\text{ k}\Omega)$

   $= \mathbf{17.375\ V}$

   c. $V_1 = V_2 + 12\text{ V} \Rightarrow V_2 = V_1 - 12\text{ V} = 17.375\text{ V} - 12\text{ V}$

   $= 5.375\text{ V}$

   d. $I_2 = \dfrac{V_2}{R_2} = \dfrac{5.375\text{ V}}{2.2\text{ k}\Omega} = \mathbf{2.443\ mA}$

13. (I): $I_1 \downarrow I_3 \; I_2$

$$10 - I_1\, 5.6\text{ k}\Omega - I_3\, 2.2\text{ k}\Omega + 20 = 0$$
$$-20 + I_3\, 2.2\text{ k}\Omega + I_2\, 3.3\text{ k}\Omega - 30 = 0$$
$$I_1 + I_2 = I_3$$

$I_1 = I_{R_1} = \mathbf{1.445\text{ mA}}$, $I_2 = I_{R_2} = \mathbf{8.513\text{ mA}}$, $I_3 = I_{R_3} = \mathbf{9.958\text{ mA}}$

(II): I_1, I_3, I_2

$$-1.2\text{ k}\Omega\, I_1 + 9 - 8.2\text{ k}\Omega\, I_3 = 0$$
$$-10.2\text{ k}\Omega\, I_2 + 8.2\text{ k}\Omega\, I_3 + 6 = 0$$
$$I_2 + I_3 = I_1$$

$I_1 = \mathbf{2.0316\text{ mA}}$, $I_2 = \mathbf{1.2316\text{ mA}}$, $I_3 = \mathbf{0.8\text{ mA}}$

$I_{R_1} = I_1 = \mathbf{2.0316\text{ mA}}$
$I_{R_2} = I_3 = \mathbf{0.8\text{ mA}}$
$I_{R_3} = I_{R_4} = I_2 = \mathbf{1.2316\text{ mA}}$

15. $I_1 = I_{R_1}$(CW), $I_2 = I_{R_2}$(down), $I_3 = I_{R_3}$(right), $I_4 = I_{R_4}$(down)
$I_5 = I_{R_5}$(CW)

a.
$$E_1 - I_1R_1 - I_2R_2 = 0$$
$$I_2R_2 - I_3R_3 - I_4R_4 = 0$$
$$I_4R_4 - I_5R_5 - E_2 = 0$$
$$I_1 = I_2 + I_3$$
$$I_3 = I_4 + I_5$$

b.
$$E_1 - I_2(R_1 + R_2) - I_3R_1 = 0$$
$$I_2R_2 - I_3(R_3 + R_4) + I_5R_4 = 0$$
$$I_3R_4 - I_5(R_4 + R_5) - E_2 = 0$$

c.
$$\begin{array}{lllll} I_2(R_1 + R_2) & + I_3R_1 & + 0 & = E_1 \\ I_2(R_2) & - I_3(R_3 + R_4) & + I_5R_4 & = 0 \\ 0 & + I_3R_4 & - I_5(R_4 + R_5) & = E_2 \end{array}$$

$$\begin{array}{l} 3I_2 + 2I_3 + 0 = 10 \\ 1I_2 - 9I_3 + 5I_5 = 0 \\ 0 + 5I_3 - 8I_5 = 6 \end{array}$$

d. $I_3 = I_{R_3} = \mathbf{-63.694\text{ mA}}$

17. a. $I_1 \; I_2$

$$4 - 4I_1 - 8(I_1 - I_2) = 0$$
$$-8(I_2 - I_1) - 2I_2 - 6 = 0$$

$I_1 = -\frac{1}{7}$ **A**, $I_2 = -\frac{5}{7}$ **A**

$I_{R_1} = I_1 = -\frac{1}{7}$ **A**

$I_{R_2} = I_2 = -\frac{5}{7}$ **A**

$I_{R_3} = I_1 - I_2 = \left[-\frac{1}{7}\text{ A}\right] - \left[-\frac{5}{7}\text{ A}\right] = \mathbf{\frac{4}{7}\text{ A}}$ (dir. of I_1)

b. $\circlearrowright I_1 \; \circlearrowright I_2$

$$-10 - 4I_1 - 3(I_1 - I_2) - 12 = 0$$
$$12 - 3(I_2 - I_1) - 12I_2 = 0$$

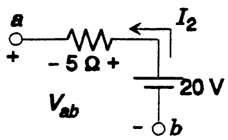
$$I_1 = \mathbf{-3.0625\ A},\ I_2 = \mathbf{0.1875\ A}$$

$$I_{R_1} = I_1 = \mathbf{-3.0625\ A}$$
$$I_{R_3} = I_2 = \mathbf{0.1875\ A}$$
$$I_{R_2} = I_1 - I_2 = (-3.0625\ \text{A}) - (0.1875\ \text{A}) = \mathbf{-3.25\ A}$$

19. (I): $\circlearrowright I_1 \; \circlearrowright I_2$

$$-25 - 2I_1 - 3(I_1 - I_2) + 60 = 0$$
$$-60 - 3(I_2 - I_1) + 6 - 5I_2 - 20 = 0$$

$$I_1 = \mathbf{1.8701\ A},\ I_2 = \mathbf{-8.5484\ A}$$



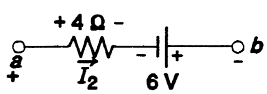
$$\underset{+-}{V_{ab}} = 20 - I_2 5 = 20 - (8.5484)(5) = 20\ \text{V} - 42.74\ \text{V}$$
$$= \mathbf{-22.74\ V}$$

(II): Source conversion: $E = 9$ V, $R = 3\ \Omega$

$\circlearrowright I_2 \; \circlearrowright I_3$

$$9 - 3I_2 - 4I_2 + 6 - 6(I_2 - I_3) = 0$$
$$-6(I_3 - I_2) - 8I_3 - 4 = 0$$

$I_2 = \mathbf{1.27}$[illegible] $I_3 = \mathbf{0.26\ A}$



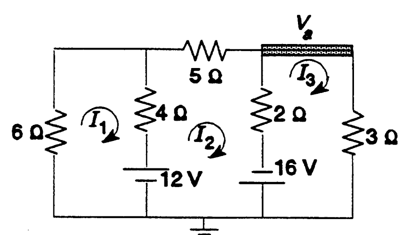
$$\underset{+-}{V_{ab}} = I_2 4 - 6 = (1.274\ \text{A})(4\ \Omega) - 6\ \text{V}$$
$$= 5.096\ \text{V} - 6\ \text{V}$$
$$= \mathbf{-0.904\ V}$$

21. a. $\circlearrowright I_1 \; \circlearrowright I_2$

$$-1I_1 - 4 - 5I_1 + 6 - 1(I_1 - I_2) = 0$$
$$-1(I_2 - I_1) - 6 - 3I_2 - 15 - 10I_2 = 0$$

$$I_1 = I_{5\Omega} = \mathbf{72.16\ mA}$$
$$V_a = -4 - (72.16\ \text{mA})(6\ \Omega)$$
$$= -4 - 0.433\ \text{V}$$
$$= \mathbf{-4.433\ V}$$

b. Network redrawn:



$$-6I_1 - 4(I_1 - I_2) - 12 = 0$$
$$12 - 4(I_2 - I_1) - 5I_2 - 2(I_2 - I_3) + 16 = 0$$
$$-16 - 2(I_3 - I_2) - 3I_3 = 0$$

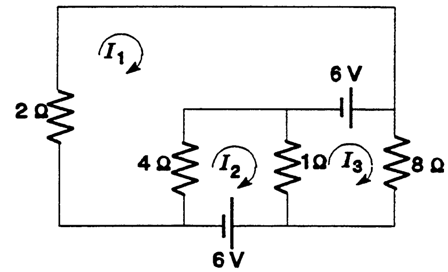
$$I_2 = I_{5\Omega} = \mathbf{1.953\ A}$$
$$V_a = (I_3)(3\ \Omega)$$
$$= (-2.419\ \text{mA})(3\ \Omega)$$
$$= \mathbf{-7.257\ V}$$

23. a. I_1 I_2 I_4 I_3

$$-6.8\text{ k}\Omega\, I_1 - 4.7\text{ k}\Omega(I_1 - I_2) + 6 - 2.2\text{ k}\Omega(I_1 - I_4) = 0$$
$$-6 - 4.7\text{ k}\Omega(I_2 - I_1) - 2.7\text{ k}\Omega\, I_2 - 8.2\text{ k}\Omega\,(I_2 - I_3) = 0$$
$$-1.1\text{ k}\Omega\, I_3 - 22\text{ k}\Omega(I_3 - I_4) - 8.2\text{ k}\Omega(I_3 - I_2) - 9 = 0$$
$$5 - 1.2\text{ k}\Omega\, I_4 - 2.2\text{ k}\Omega(I_4 - I_1) - 22\text{ k}\Omega(I_4 - I_3) = 0$$

I_1 = **0.0321 mA**, I_2 = **−0.8838 mA**, I_3 = **−0.968 mA**, I_4 = **−0.639 mA**

b. Network redrawn:



$$-2I_1 - 6 - 4I_1 + 4I_2 = 0$$
$$-4I_2 + 4I_1 - 1I_2 + 1I_3 - 6 = 0$$
$$-1I_3 + 1I_2 + 6 - 8I_3 = 0$$

I_1 = **−3.8 A**, I_2 = **−4.2 A**, I_3 = **0.2 A**,

25. a. I_1 I_2

$$(4 + 8)I_1 - 8I_2 = 4$$
$$(8 + 2)I_2 - 8I_1 = -6$$

$I_1 = -\frac{1}{7}$**A**, $I_2 = -\frac{5}{7}$**A**

b. I_1 I_2

$$(4 + 3)I_1 - 3I_2 = -10 - 12$$
$$(3 + 12)I_2 - 3I_1 = 12$$

I_1 = **−3.0625 A**, I_2 = **0.1875 A**

27. (I): a. I_1 I_2

$$(2 + 3)I_1 - 3I_2 = -25 + 60$$
$$(3 + 5)I_2 - 3I_1 = -60 + 6 - 20$$

b. I_1 = **1.871 A**, I_2 = **−8.548 A**

c. $I_{R_1} = I_1$ = **1.871 A**, $I_{R_2} = I_2$ = **−8.548 A**

$I_{R_3} = I_1 - I_2$ = 1.871 A − (−8.548 A) = **10.419A** (direction of I_1)

(II): a. I_2 I_3

$$(3 + 4 + 6)I_2 - 6I_3 = 9 + 6$$
$$(6 + 8)I_3 - 6I_2 = -4$$

b. I_2 = **1.274 A**, I_3 = **0.26 A**

c. $I_{R_2} = I_2$ = **1.274 A**, $I_{R_3} = I_3$ = **0.26 A**

$I_{R_4} = I_2 - I_3$ = 1.274 A − 0.26 A = **1.014 A**

I_{R_1} = 3 A − I_2 = 3 A − 1.274 A = **1.726 A**

29. From Sol. 21(b)

I_1 I_2 I_3

$$\begin{aligned} &I_1(6 + 4) - 4I_2 = -12 \\ &I_2(4 + 5 + 2) - 4I_1 - 2I_3 = 12 + 16 \\ &I_3(2 + 3) - 2I_2 = -16 \end{aligned}$$

$I_{5\Omega} = I_2 = \mathbf{1.953\ A}$

$I_3 = -2.4186\text{ A}, \therefore V_a = (I_3)(3\ \Omega) = (-2.4186\text{ A})(3\ \Omega) = \mathbf{-7.26\ V}$

31. a. I_1 I_2 I_4 I_3

$$\begin{aligned} &I_1(6.8\text{ k}\Omega + 4.7\text{ k}\Omega + 2.2\text{ k}\Omega) - 4.7\text{ k}\Omega\, I_2 - 2.2\text{ k}\Omega\, I_4 = 6 \\ &I_2(2.7\text{ k}\Omega + 8.2\text{ k}\Omega + 4.7\text{ k}\Omega) - 4.7\text{ k}\Omega\, I_1 - 8.2\text{ k}\Omega\, I_3 = -6 \\ &I_3(8.2\text{ k}\Omega + 1.1\text{ k}\Omega + 22\text{ k}\Omega) - 22\text{ k}\Omega\, I_4 - 8.2\text{ k}\Omega\, I_2 = -9 \\ &I_4(2.2\text{ k}\Omega + 22\text{ k}\Omega + 1.2\text{ k}\Omega) - 2.2\text{ k}\Omega\, I_1 - 22\text{ k}\Omega\, I_3 = 5 \end{aligned}$$

$I_1 = \mathbf{0.0321\ mA}$, $I_2 = \mathbf{-0.8838\ mA}$, $I_3 = \mathbf{-0.968\ mA}$, $I_4 = \mathbf{-0.639\ mA}$

b. From Sol. 23(b):

$$\begin{aligned} &I_1(2 + 4) - 4I_2 = -6 \\ &I_2(4 + 1) - 4I_1 - 1I_3 = -6 \\ &I_3(1 + 8) - 1I_2 = 6 \end{aligned}$$

$I_1 = \mathbf{3.8\ A}$, $I_2 = \mathbf{-4.2\ A}$, $I_3 = \mathbf{0.2\ A}$

33. (I): $\circ V_1$ $\circ V_2$

$$V_1\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{4}\right] - \frac{1}{4}V_2 = -5 - 3$$

$$V_2\left[\frac{1}{8} + \frac{1}{4}\right] - \frac{1}{4}V_1 = 3 - 4$$

$V_1 = \mathbf{-14.86\ V}$, $V_2 = \mathbf{-12.57\ V}$

$V_{R_1} = V_{R_4} = \mathbf{-14.86\ V}$

$V_{R_2} = \mathbf{-12.57\ V}$

${}^{+}V_{R_3}{}^{-} = 12\text{ V} + 12.57\text{ V} - 14.86\text{ V} = \mathbf{9.71\ V}$

(II): $\circ V_1$ $\circ V_2$

$$V_1\left[\frac{1}{5} + \frac{1}{3} + \frac{1}{2}\right] - \frac{1}{3}V_2 - \frac{1}{2}V_2 = -6$$

$$V_2\left[\frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{8}\right] - \frac{1}{3}V_1 - \frac{1}{2}V_1 = 7$$

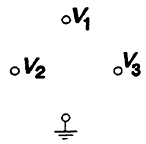
$V_1 = \mathbf{-2.556\ V}$, $V_2 = \mathbf{4.03\ V}$

$V_{R_1} = \mathbf{-2.556\ V}$

$V_{R_2} = V_{R_5} = \mathbf{4.03\ V}$

$V_{R_4} = V_{R_3} = 4.03\text{ V} + 2.556\text{ V} = \mathbf{6.586\ V}$

35. (I):



$$V_1\left[\frac{1}{3}+\frac{1}{6}+\frac{1}{6}\right]-\frac{1}{6}V_2-\frac{1}{6}V_3 = 5$$

$$V_2\left[\frac{1}{6}+\frac{1}{4}+\frac{1}{5}\right]-\frac{1}{6}V_1-\frac{1}{5}V_3 = -3$$

$$V_3\left[\frac{1}{6}+\frac{1}{5}+\frac{1}{7}\right]-\frac{1}{5}V_2-\frac{1}{6}V_1 = 0$$

V_1 = **7.238 V**, V_2 = **−2.453 V**, V_3 = **1.405 V**

(II): Source conversion: $I = 4$ A, $R = 4\ \Omega$

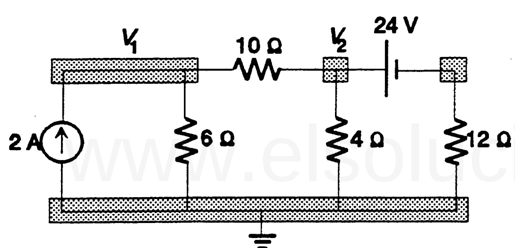
$$V_1\left[\frac{1}{9}+\frac{1}{20}+\frac{1}{20}\right]-\frac{1}{20}V_2-\frac{1}{20}V_3 = -2$$

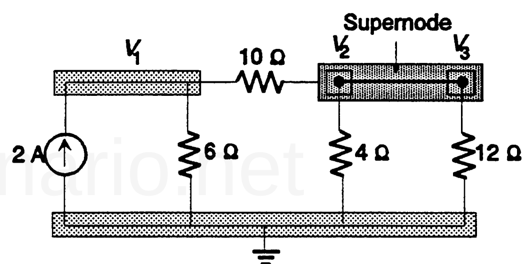
$$V_2\left[\frac{1}{20}+\frac{1}{20}+\frac{1}{18}\right]-\frac{1}{20}V_1-\frac{1}{20}V_3 = 0$$

$$V_3\left[\frac{1}{20}+\frac{1}{20}+\frac{1}{4}\right]-\frac{1}{20}V_2-\frac{1}{20}V_1 = 4$$

V_1 = **−6.642 V**, V_2 = **1.293 V**, V_3 = **10.664 V**

37. a.





$$\sum I_i = \sum I_o$$

Node V_1:

$$2\text{ A} = \frac{V_1}{6\ \Omega}+\frac{V_1 - V_2}{10\ \Omega}$$

Supernode V_2, V_3:

$$0 = \frac{V_2 - V_1}{10\ \Omega}+\frac{V_2}{4\ \Omega}+\frac{V_3}{12\ \Omega}$$

Independent source:

$$V_2 - V_3 = 24\text{ V or } V_3 = V_2 - 24\text{ V}$$

2 eq. 2 unknowns:

$$\frac{V_1}{6\ \Omega}+\frac{V_1 - V_2}{10\ \Omega} = 2\text{ A}$$

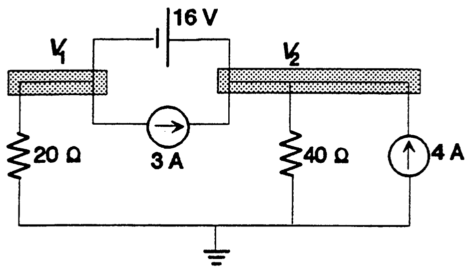
$$\frac{V_2 - V_1}{10\ \Omega}+\frac{V_2}{4\ \Omega}+\frac{V_2 - 24\text{ V}}{12\ \Omega} = 0$$

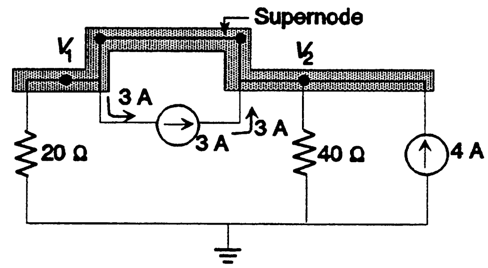
$$0.267V_1 - 0.1V_2 = 2$$
$$+0.1V_1 - 0.433V_2 = -2$$

V_1 = **10.083 V**, V_2 = **6.944 V**

$V_3 = V_2 - 24$ V = **−17.056 V**

b.





$\Sigma I_i = \Sigma I_o$

Supernode:

$$3\text{ A} + 4\text{ A} = 3\text{ A} + \frac{V_1}{20\ \Omega} + \frac{V_2}{40\ \Omega}$$

$$\text{2 eq. 2 unk.}\ \begin{cases} 4\text{ A} = \dfrac{V_1}{20\ \Omega} + \dfrac{V_2}{40\ \Omega} \\ V_2 - V_1 = 16\text{ V} \end{cases}$$

Subt. $V_2 = 16\text{ V} + V_1$

$$4\text{ A} = \frac{V_1}{20\ \Omega} + \frac{(16\text{ V} + V_1)}{40\ \Omega}$$

and $V_1 = \mathbf{48\ V}$

$V_2 = 16\text{ V} + V_1 = \mathbf{64\ V}$

39. (I): a. Note the solution to problem 33(I).

b. $V_1 = \mathbf{-14.86\ V}$, $V_2 = \mathbf{-12.57\ V}$

c. $V_{R_1} = V_{R_4} = V_1 = \mathbf{-14.86\ V}$, $V_{R_2} = V_2 = \mathbf{-12.57\ V}$

$+ V_{R_3} -$

R_3 $\quad V_{R_3} = V_1 - V_2 + 12\text{ V} = (-14.86\text{ V}) - (-12.57\text{ V}) + 12\text{ V} = \mathbf{9.71\ V}$

(II): a. Note the solution to problem 33(II).

b. $V_1 = \mathbf{-2.556\ V}$, $V_2 = \mathbf{4.03\ V}$

c. $V_{R_1} = V_1 = \mathbf{-2.556\ V}$, $V_{R_2} = V_{R_5} = V_2 = \mathbf{4.03\ V}$

$V_{R_3} = V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{6.586\ V}$

41. a. Note the solution to problem 36(I).

$V_1 = \mathbf{-5.311\ V}$, $V_2 = \mathbf{-0.6219\ V}$, $V_3 = \mathbf{3.751\ V}$

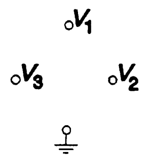
$V_{5\text{A}} = V_1 = \mathbf{-5.311\ V}$

b. Note the solution to problem 36(II).

$V_1 = \mathbf{-6.917\ V}$, $V_2 = \mathbf{12\ V}$, $V_3 = \mathbf{2.3\ V}$

$V_{2\text{A}} = \overset{(+)}{V_2} - \overset{(-)}{V_3} = \mathbf{9.7\ V}$, $V_{5\text{A}} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{18.917\ V}$

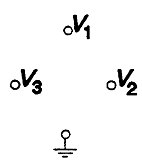
43. Source conversion: $I = 1$ A, $R = 6\ \Omega$



$$\left[\frac{1}{6} + \frac{1}{5} + \frac{1}{5}\right] V_1 - \frac{1}{5}V_2 - \frac{1}{5}V_3 = 1$$
$$\left[\frac{1}{5} + \frac{1}{5} + \frac{1}{20}\right] V_2 - \frac{1}{5}V_1 - \frac{1}{5}V_3 = 0$$
$$\left[\frac{1}{5} + \frac{1}{5} + \frac{1}{10}\right] V_3 - \frac{1}{5}V_1 - \frac{1}{5}V_2 = 0$$

V_{R_5} **= 0.1967 V, no**

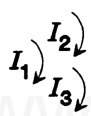
45. Source conversion: $I = 12$ A, $R = 2\ \text{k}\Omega$



$$\left[\frac{1}{2\ \text{k}\Omega} + \frac{1}{33\ \text{k}\Omega} + \frac{1}{56\ \text{k}\Omega}\right] V_1 - \frac{1}{56\ \text{k}\Omega}V_2 - \frac{1}{33\ \text{k}\Omega}V_3 = 12$$
$$\left[\frac{1}{56\ \text{k}\Omega} + \frac{1}{36\ \text{k}\Omega} + \frac{1}{5.6\ \text{k}\Omega}\right] V_2 - \frac{1}{56\ \text{k}\Omega}V_1 - \frac{1}{36\ \text{k}\Omega}V_3 = 0$$
$$\left[\frac{1}{33\ \text{k}\Omega} + \frac{1}{3.3\ \text{k}\Omega} + \frac{1}{36\ \text{k}\Omega}\right] V_3 - \frac{1}{33\ \text{k}\Omega}V_1 - \frac{1}{36\ \text{k}\Omega}V_2 = 0$$

I_{R_5} **= 0 A, yes**

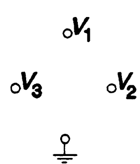
47. a.



$$(1\ \text{k}\Omega + 2\ \text{k}\Omega + 2\ \text{k}\Omega)I_1 - 2\ \text{k}\Omega\ I_2 - 2\ \text{k}\Omega\ I_3 = 10$$
$$(2\ \text{k}\Omega + 2\ \text{k}\Omega + 2\ \text{k}\Omega)I_2 - 2\ \text{k}\Omega\ I_1 - 2\ \text{k}\Omega\ I_3 = 0$$
$$(2\ \text{k}\Omega + 2\ \text{k}\Omega + 2\ \text{k}\Omega)I_3 - 2\ \text{k}\Omega\ I_1 - 2\ \text{k}\Omega\ I_2 = 0$$

$I_1 = I_{10\text{V}}$ **= 3.33 mA**

Source conversion: $I = 10\ \text{V}/1\ \text{k}\Omega = 10$ mA, $R = 1\ \text{k}\Omega$

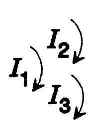


$$V_1\left[\frac{1}{1\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega}\right] - \frac{1}{2\ \text{k}\Omega}V_2 - \frac{1}{2\ \text{k}\Omega}V_3 = 10\ \text{mA}$$
$$V_2\left[\frac{1}{2\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega}\right] - \frac{1}{2\ \text{k}\Omega}V_1 - \frac{1}{2\ \text{k}\Omega}V_3 = 0$$
$$V_3\left[\frac{1}{2\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega} + \frac{1}{2\ \text{k}\Omega}\right] - \frac{1}{2\ \text{k}\Omega}V_2 - \frac{1}{2\ \text{k}\Omega}V_1 = 0$$

$V_1 = 6.67\ \text{V} = E - IR_s = 10\ \text{V} - I(1\ \text{k}\Omega)$

$$I = \frac{10 - 6.67\ \text{V}}{1\ \text{k}\Omega} = \mathbf{3.33\ mA}$$

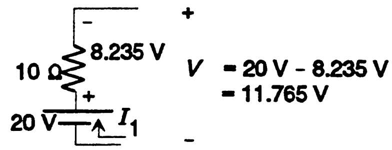
b.



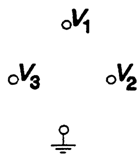
Source conversion: $E = 20$ V, $R = 10\ \Omega$

$$(10 + 10 + 20)I_1 - 10I_2 - 20I_3 = 20$$
$$(10 + 20 + 20)I_2 - 10I_1 - 20I_3 = 0$$
$$(20 + 20 + 10)I_3 - 20I_1 - 20I_2 = 0$$

$I_1 = I_{20\text{V}} = 0.8235$ A



$$I_s = \frac{V}{R_s} = \frac{11.765\ \text{V}}{10\ \Omega} = \mathbf{1.177A}$$



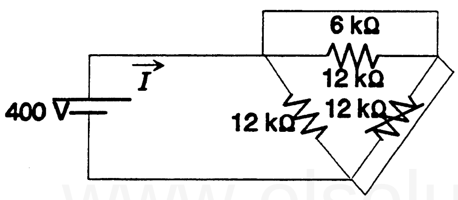
$$V_1\left[\frac{1}{10} + \frac{1}{10} + \frac{1}{20}\right] - \left[\frac{1}{20}\right]V_2 - \left[\frac{1}{10}\right]V_3 = 2$$

$$V_2\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{10}\right] - \left[\frac{1}{20}\right]V_1 - \left[\frac{1}{20}\right]V_3 = 0$$

$$V_3\left[\frac{1}{10} + \frac{1}{20} + \frac{1}{20}\right] - \left[\frac{1}{10}\right]V_1 - \left[\frac{1}{20}\right]V_2 = 0$$

$$I_{R_s} = \frac{V_1}{R_s} = \mathbf{1.177\ A}$$

49. a.



(Y−Δ conversion)

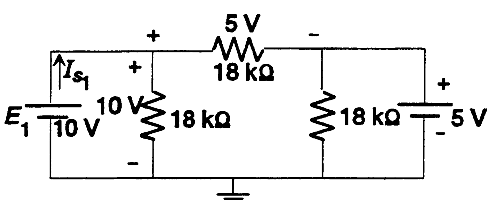
$$I = \frac{400\text{V}}{12\ \text{k}\Omega \| 12\ \text{k}\Omega \| 6\ \text{k}\Omega} = \frac{400\ \text{V}}{3\ \text{k}\Omega}$$

$$= \mathbf{133.33\ mA}$$

b. $$I = \frac{42\ \text{V}}{(18\ \Omega \| 18\ \Omega) \| [(18\ \Omega \| 18\ \Omega) + (18\ \Omega \| 18\ \Omega)]} = \frac{42\ \text{V}}{9\ \Omega \| [9\ \Omega + 9\ \Omega]}$$

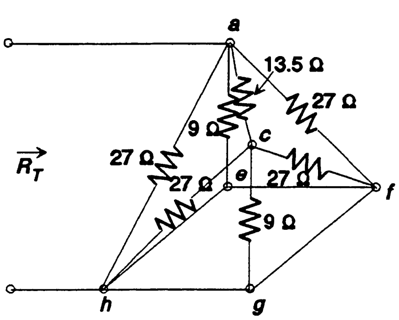
$= \mathbf{7\ A}$ (Y−Δ conversion)

51.



$$I_{s_1} = \frac{10\ \text{V}}{18\ \text{k}\Omega} + \frac{5\ \text{V}}{18\ \text{k}\Omega} = \frac{15\ \text{V}}{18\ \text{k}\Omega} = \mathbf{0.833\ mA}$$

53.



c − g: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

a − h: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

$$R_T = 5.4\ \Omega \| (13.5\ \Omega + 5.4\ \Omega)$$
$$= 5.4\ \Omega \| 18.9\ \Omega$$
$$= \mathbf{4.2\ \Omega}$$

CHAPTER 8 (Even)

2\. a. CDR: $I_{6\Omega} = \dfrac{10\text{ k}\Omega(4\text{ A})}{10\text{ k}\Omega + 8\ \Omega} = 3.997\text{ A}$

$V_{6\Omega} = I_{6\Omega}(6\ \Omega) = (3.997\text{ A})(6\ \Omega) = \mathbf{23.982\ V}$

b. $V_{6\Omega} = I_{6\Omega}(6\ \Omega) = (4\text{ A})(6\ \Omega) = \mathbf{24\ V}$. Yes, a good approximation.

4\. $V_1 = V_2 = V_s = IR_T = 0.6\text{ A}[6\ \Omega \| 24\ \Omega \| 24\ \Omega] = 0.6\text{ A}\ [6\ \Omega \| 12\ \Omega] = \mathbf{2.4\ V}$

$I_2 = \dfrac{V_2}{R_2} = \dfrac{2.4\text{ V}}{24\ \Omega} = \mathbf{0.1\ A}$

$V_3 = \dfrac{R_3 V_s}{R_3 + R_4} = \dfrac{16\Omega(2.4\text{ V})}{24\ \Omega} = \mathbf{1.6\ V}$

6\. a. $E = IR_s = (1.5\text{ A})(3\ \Omega) = \mathbf{4.5\ V}$, $R_s = \mathbf{3\ \Omega}$

b. $E = IR_s = (6\text{ mA})(4.7\text{ k}\Omega) = \mathbf{28.2\ V}$, $R_s = \mathbf{4.7\ k\Omega}$

8\. a. $E = IR_2 = (2\text{ A})(6.8\ \Omega) = \mathbf{13.6\ V}$, $R = \mathbf{6.8\ \Omega}$

b. $I_1 = (12\text{ V} + 13.6\text{ V})/(10\ \Omega + 6.8\ \Omega + 39\ \Omega) = \dfrac{25.6\text{ V}}{55.8\ \Omega} = \mathbf{458.78\ mA}$

c. $V_{\underset{+-}{ab}} = I_1R_3 = (458.78\text{ mA})(39\ \Omega) = \mathbf{17.89\ V}$

10\. a. Conversions: $I_1 = E_1/R_1 = 9\text{ V}/3\ \Omega = \mathbf{3\ A}$, $R_1 = \mathbf{3\ \Omega}$

$I_2 = E_2/R_2 = 20\text{ V}/2\ \Omega = \mathbf{10\ A}$, $R_2 = \mathbf{2\ \Omega}$

b. $I_T\downarrow = 10\text{ A} - 3\text{A} = 7\text{A}$, $R_T = 3\ \Omega \| 6\ \Omega \| 2\Omega \| 12\ \Omega$

$= 2\ \Omega \| 2\ \Omega \| 12\ \Omega$

$= 1\ \Omega \| 12\ \Omega$

$= 0.9231\ \Omega$

$V_{\underset{+-}{ab}} = -I_TR_T = -(7\text{ A})(0.9231\ \Omega) = \mathbf{-6.462\ V}$

c. $I\uparrow = \dfrac{6.462\text{ V}}{6\ \Omega} = \mathbf{1.077\ A}$

12\. a. $I_1 \downarrow I_3\ I_2$

$4 - 4I_1 - 8I_3 = 0$

$6 - 2I_2 - 8I_3 = 0$

$I_1 + I_2 = I_3$

$I_1 = -\dfrac{1}{7}\text{ A}$, $I_2 = \dfrac{5}{7}\text{ A}$, $I_3 = \dfrac{4}{7}\text{ A}$

$I_{R_1} = I_1 = -\dfrac{1}{7}\text{ A}$, $I_{R_2} = I_2 = \dfrac{5}{7}\text{ A}$, $I_{R_3} = I_3 = \dfrac{4}{7}\text{ A}$

b. $I_1 \uparrow I_3 \; I_2$

$$10 + 12 - 3I_3 - 4I_1 = 0$$
$$12 - 3I_3 - 12I_2 = 0$$
$$I_1 + I_2 = I_3$$

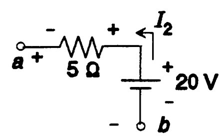
$I_1 = \mathbf{3.0625\ A}$
$I_2 = \mathbf{0.1875\ A}$
$I_3 = \mathbf{3.25\ A}$

$I_{R_1} = I_1 = \mathbf{3.0625\ A}$, $I_{R_2} = I_2 = \mathbf{3.25\ A}$
$I_{R_3} = I_3 = \mathbf{0.1875\ A}$

14. (I): $I_1 \downarrow I_3 \downarrow I_2$

$$-25 - 2I_1 - 3I_3 + 60 = 0$$
$$-60 + 3I_3 + 6 - 5I_2 - 20 = 0$$
$$I_1 = I_2 + I_3$$

$I_2 = \mathbf{-8.548\ A}$



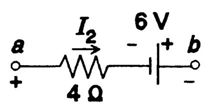
$$\underset{+\,-}{V_{ab}} = 20\text{ V} - I_2\, 5\ \Omega$$
$$= 20\text{ V} - (8.548\text{ A})(5\ \Omega)$$
$$= \mathbf{-22.75\ V}$$

(II): Source conversion: $E = IR_1 = (3\text{ A})(3\ \Omega) = 9\text{ V}$, $R_1 = 3\ \Omega$

$I_2 \downarrow I_4 \downarrow I_3$

$$9 + 6 - 3I_2 - 4I_2 - 6I_4 = 0$$
$$+ 6I_4 - 8I_3 - 4 = 0$$
$$I_2 = I_3 + I_4$$

$I_2 = \mathbf{1.274\ A}$



$$\underset{+\,-}{V_{ab}} = I_2\, 4\ \Omega - 6\text{V}$$
$$= (1.274\text{ A})4\ \Omega - 6\text{ V}$$
$$= \mathbf{-0.904\ V}$$

16. a. $20\text{ V} - I_B(270\text{ k}\Omega) - 0.7\text{ V} - I_E(0.51\text{ k}\Omega) = 0$
$I_E(0.51\text{ k}\Omega) + 8\text{ V} + I_C(2.2\text{ k}\Omega) - 20\text{ V} = 0$
$I_E = I_B + I_C$

$I_B = \mathbf{63.02\ \mu A}$, $I_C = \mathbf{4.416\ mA}$, $I_E = \mathbf{4.479\ mA}$

b. $V_B = \mathbf{2.985\ V}$, $V_E = \mathbf{2.285\ V}$, $V_C = \mathbf{10.285\ V}$

c. $\beta \cong \mathbf{70.07}$

18. (I): $I_1 \; I_2$

$$10 - I_1(5.6\ \text{k}\Omega) - 2.2\ \text{k}\Omega(I_1 - I_2) + 20 = 0$$
$$-20 - 2.2\ \text{k}\Omega(I_2 - I_1) - I_2\, 3.3\ \text{k}\Omega - 30 = 0$$

$I_1 = \mathbf{1.445\ mA}$, $I_2 = \mathbf{8.513\ mA}$

$I_{R_1} = I_1 = \mathbf{1.445\ mA}$, $I_{R_2} = I_2 = \mathbf{8.513\ mA}$

$I_{R_3} = I_2 - I_1 = \mathbf{7.068\ mA}$ (direction of I_2)

(II): I_1 I_2

$$-I_1(1.2\ \text{k}\Omega) + 9 - 8.2\ \text{k}\Omega(I_1 - I_2) = 0$$
$$-I_2(1.1\ \text{k}\Omega) + 6 - I_2\,(9.1\ \text{k}\Omega) - 8.2\ \text{k}\Omega(I_2 - I_1) = 0$$

$I_1 = \mathbf{2.0337\ mA}$, $I_2 = \mathbf{1.2316\ mA}$

$I_{R_1} = I_1 = \mathbf{2.0337\ mA}$, $I_{R_3} = I_{R_4} = I_2 = \mathbf{1.2316\ mA}$

$I_{R_2} = I_2 - I_1 = 2.0337\ \text{mA} - 1.2316\ \text{mA} = \mathbf{0.8021\ mA}$ (direction of I_1)

20. $I_1 \; I_2 \; I_3$

$$10 - I_1 2 - 1(I_1 - I_2) = 0$$
$$-1(I_2 - I_1) - I_2\, 4 - 5(I_2 - I_3) = 0$$
$$-5(I_3 - I_2) - I_3\, 3 - 6 = 0$$

$$\begin{aligned} 3I_1 - 1I_2 + 0 &= 10 \\ -1I_1 + 10I_2 - 5I_3 &= 0 \\ 0 - 5I_2 + 8I_3 &= -6 \end{aligned}$$

$I_2 = I_{R_3} = \mathbf{-63.694\ mA}$

22. (I): $I_1 \; I_2 \; I_3$

$$I_1(2.2\ \text{k}\Omega + 9.1\ \text{k}\Omega) - 9.1\ \text{k}\Omega\, I_2 = 18$$
$$I_2(9.1\ \text{k}\Omega + 7.5\ \text{k}\Omega + 6.8\ \text{k}\Omega) - 9.1\ \text{k}\Omega\, I_1 - 6.8\ \text{k}\Omega\, I_3 = -18$$
$$I_3(6.8\ \text{k}\Omega + 3.3\ \text{k}\Omega) - I_2\, 6.8\ \text{k}\Omega = -3$$

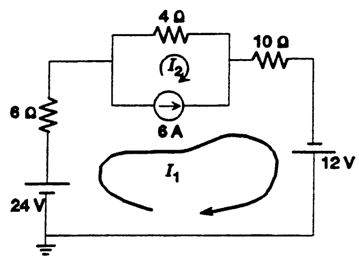
$I_1 = \mathbf{1.2059\ mA}$, $I_2 = \mathbf{-0.4806\ mA}$, $I_3 = \mathbf{-0.6206\ mA}$

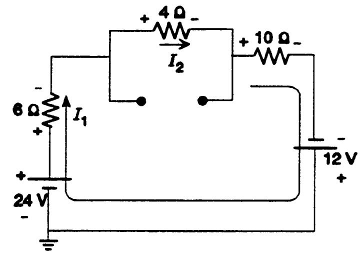
(II): I_1 I_3 I_2

$$16 - 4I_1 - 3(I_1 - I_2) - 12 - 4(I_1 - I_3) = 0$$
$$12 - 3(I_2 - I_1) - 10\, I_2 - 15 - 4(I_2 - I_3) = 0$$
$$-16 - 4(I_3 - I_1) - 4(I_3 - I_2) - 7I_3 = 0$$

$I_1 = \mathbf{-0.2385\ A}$, $I_2 = \mathbf{-0.5169\ A}$, $I_3 = \mathbf{-1.278\ A}$

24. a.





$$24\text{ V} - 6I_1 - 4I_2 - 10I_1 + 12\text{ V} = 0$$

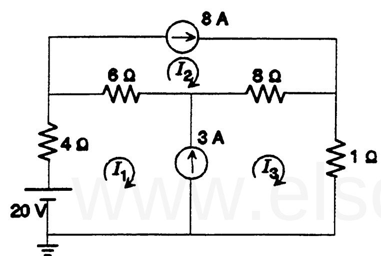
and $\quad 16I_1 + 4I_2 = 36$

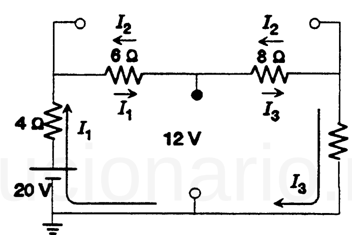
$$I_1 - I_2 = 6\text{ A}$$

$$I_1 = I_2 + 6\text{ A}$$
$$16[I_2 + 6\text{ A}] + 4I_2 = 36$$
$$16I_2 + 96 + 4I_2 = 36$$
$$20I_2 = -60$$
$$I_2 = \mathbf{-3\text{ A}}$$
$$I_1 = I_2 + 6\text{ A} = -3\text{ A} + 6\text{ A} = \mathbf{3\text{ A}}$$

$I_{24\text{V}} = I_{6\Omega} = I_{10\Omega} = I_{12\text{V}} = \mathbf{3\text{ A}}$ (CW)
$I_{4\Omega} = 3\text{ A}$ (CCW)

b.





$$20\text{ V} - 4I_1 - 6(I_1 - I_2) - 8(I_3 - I_2) - 1I_3 = 0$$
$$10I_1 - 14I_2 + 9I_3 = 20$$
$$I_3 - I_1 = 3\text{ A}$$
$$I_2 = 8\text{ A}$$

$$10I_1 - 14(8\text{ A}) + 9[I_1 + 3\text{ A}] = 20$$
$$19I_1 = 105$$
$$I_1 = 5.526\text{ A}$$
$$I_3 = I_1 + 3\text{ A} = 5.526\text{ A} + 3\text{ A} = 8.526\text{ A}$$
$$I_2 = 8$$

$I_{20\text{V}} = I_{4\Omega} = \mathbf{5.526\text{ A}}$ (dir. of I_1)
$I_{6\Omega} = I_2 - I_1 = \mathbf{2.474\text{ A}}$ (dir. of I_2)
$I_{8\Omega} = I_3 - I_2 = \mathbf{0.526\text{ A}}$ (dir. of I_3)
$I_{1\Omega} = \mathbf{8.526\text{ A}}$ (dir. of I_3)

26. (I): $I_1 \; I_2$

a. $I_1(5.6\text{ k}\Omega + 2.2\text{ k}\Omega) - 2.2\text{ k}\Omega\,(I_2) = 10 + 20$
$I_2(2.2\text{ k}\Omega + 3.3\text{ k}\Omega) - 2.2\text{ k}\Omega\,(I_1) = -20 - 30$

b. $I_1 = \mathbf{1.445\text{ mA}}$, $I_2 = \mathbf{-8.513\text{ mA}}$

c. $I_{R_1} = I_1 = \mathbf{1.445\ mA}$, $I_{R_2} = I_2 = \mathbf{-8.513\ mA}$
$I_{R_3} = I_1 + I_2 = 8.513\text{ mA} + 1.445\text{ mA} = \mathbf{9.958\ mA}$ (direction of I_1)

(II): $I_1 \circlearrowright$
$I_2 \circlearrowright$

a. $I_1(1.2\text{ k}\Omega + 8.2\text{ k}\Omega) - 8.2\text{ k}\Omega\, I_2 = 9$
$I_2(8.2\text{ k}\Omega + 1.1\text{ k}\Omega + 9.1\text{ k}\Omega) - 8.2\text{ k}\Omega\, I_1 = 6$

b. $I_1 = \mathbf{2.0316\ mA}$, $I_2 = \mathbf{1.2316\ mA}$

c. $I_{R_1} = I_1 = \mathbf{2.0316\ mA}$, $I_{R_3} = I_{R_4} = I_2 = \mathbf{1.2316\ mA}$
$I_{R_2} = I_1 - I_2 = 2.0316\text{ mA} - 1.2316\text{ mA} = \mathbf{0.8\ mA}$ (direction of I_1)

28. $I_1 \circlearrowright\ I_2 \circlearrowright\ I_3 \circlearrowright$

$I_1(2 + 1) - 1I_2 = 10$
$I_2(1 + 4 + 5) - 1I_1 - 5I_3 = 0$
$I_3(5 + 3) - 5I_2 = -6$

$I_2 = I_{R_3} = -63.694$ mA (exact match with problem 15)

30. (I): $I_1 \circlearrowright\ I_2 \circlearrowright\ I_3 \circlearrowright$

$(2.2\text{ k}\Omega + 9.1\text{ k}\Omega)I_1 - 9.1\text{ k}\Omega\, I_2 = 18$
$(9.1\text{ k}\Omega + 7.5\text{ k}\Omega + 6.8\text{ k}\Omega)I_2 - 9.1\text{ k}\Omega\, I_1 - 6.8\text{ k}\Omega\, I_3 = -18$
$(6.8\text{ k}\Omega + 3.3\text{ k}\Omega)I_3 - 6.8\text{ k}\Omega\, I_2 = -3$

$I_1 = \mathbf{1.2059\ mA}$, $I_2 = \mathbf{-0.4806\ mA}$, $I_3 = \mathbf{-0.6206\ mA}$

(II): $I_1 \circlearrowright$
$I_3 \circlearrowright\ I_2 \circlearrowright$

$(4\ \Omega + 4\ \Omega + 3\ \Omega)I_1 - 3\ \Omega\, I_2 - 4\ \Omega\, I_3 = 16 - 12$
$(4\ \Omega + 3\ \Omega + 10\ \Omega)I_2 - 3I_1 - 4\ \Omega\, I_3 = 12 - 15$
$(4\ \Omega + 4\ \Omega + 7\ \Omega)I_3 - 4I_1 - 4I_2 = -16$

$I_1 = \mathbf{-0.2385\ A}$, $I_2 = \mathbf{-0.5169\ A}$, $I_3 = \mathbf{-1.278\ A}$

32. a. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2} + \frac{1}{5} + \frac{1}{2}\right] - \frac{1}{2}V_2 = 5 \qquad V_1 = \mathbf{8.077\ V}$$
$$V_2 = \mathbf{9.385\ V}$$
$$V_2\left[\frac{1}{2} + \frac{1}{4}\right] - \frac{1}{2}V_1 = 3$$

Symmetry is present

b. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2}+\frac{1}{4}\right]-\frac{1}{4}V_2 = 4-2 \qquad V_1 = \mathbf{4.8\ V}$$

$$\qquad V_2 = \mathbf{6.4\ V}$$

$$V_2\left[\frac{1}{4}+\frac{1}{20}+\frac{1}{5}\right]-\frac{1}{4}V_1 = 2$$

Symmetry is present

34. (I): a. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2.2\ \text{k}\Omega}+\frac{1}{9.1\ \text{k}\Omega}+\frac{1}{7.5\ \text{k}\Omega}\right]-\frac{1}{7.5\ \text{k}\Omega}V_2 = -1.978\ \text{mA}$$

$$V_2\left[\frac{1}{7.5\ \text{k}\Omega}+\frac{1}{6.8\ \text{k}\Omega}+\frac{1}{3.3\ \text{k}\Omega}\right]-\frac{1}{7.5\ \text{k}\Omega}V_1 = 0.909\ \text{mA}$$

b. $V_1 = \mathbf{-2.653\ V}$, $V_2 = \mathbf{0.952\ V}$

c. $V_{R_3} = V_1 = \mathbf{-2.653\ V}$, $V_{R_5} = V_2 = \mathbf{0.952\ V}$, $V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{3.605\ V}$

R_1 (+ V_{R_1} −) $V_{R_1} = 18\ \text{V} - 2.653\ \text{V} = \mathbf{15.347\ V}$

R_2 (− V_{R_2} +) $V_{R_2} = 3\ \text{V} - 0.952\ \text{V} = \mathbf{2.048\ V}$

(II): a. $\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$V_1\left[\frac{1}{4}+\frac{1}{4}+\frac{1}{7}\right]-\frac{1}{4}V_2-\frac{1}{4}V_3 = 4$$

$$V_2\left[\frac{1}{4}+\frac{1}{3}+\frac{1}{10}\right]-\frac{1}{4}V_1-\frac{1}{3}V_3 = 4+1.5$$

$$V_3\left[\frac{1}{4}+\frac{1}{3}+\frac{1}{4}\right]-\frac{1}{4}V_1-\frac{1}{3}V_3 = -4-4$$

b. $V_1 = \mathbf{8.877\ V}$, $V_2 = \mathbf{9.831\ V}$, $V_3 = \mathbf{-3.005\ V}$

c. $V_{R_6} = V_1 = \mathbf{8.877\ V}$, $V_{R_4} = V_3 = \mathbf{-3.005\ V}$, $V_{R_5} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{0.954\ V}$

$-\,V_{R_1}+$, R_1: $V_{R_1} = 16\ \text{V} - V_1 + V_3 = \mathbf{4.118\ V}$

$-\,V_{R_2}+$, R_2: $V_{R_2} = V_2 - V_3 - 12\ \text{V} = \mathbf{0.836\ V}$

R_3 (− +): $V_{R_3} = 15\ \text{V} - V_2 = \mathbf{5.169\ V}$

36. (I) V_1 V_2 V_3

$$\left[\frac{1}{2}+\frac{1}{2}\right]V_1-\frac{1}{2}V_2+0=-5$$

$$\left[\frac{1}{2}+\frac{1}{9}+\frac{1}{7}+\frac{1}{2}\right]V_2-\frac{1}{2}V_1-\frac{1}{2}V_3=0$$

$$\left[\frac{1}{2}+\frac{1}{2}+\frac{1}{4}\right]V_3-\frac{1}{2}V_2=5$$

V_1 = **−5.311 V**, V_2 = **−0.6219 V**, V_3 = **3.751 V**

(II) V_1 V_2 V_3

$$V_1\left[\frac{1}{2}+\frac{1}{6}\right]-\frac{1}{6}V_3=-5$$

$$V_2\left[\frac{1}{4}\right]=5-2$$

$$V_3\left[\frac{1}{6}+\frac{1}{5}\right]-\frac{1}{6}V_1=2$$

V_1 = **−6.917 V**, V_2 = **12 V**, V_3 = **2.3 V**

38. a. V_1 V_2

$$V_1\left[\frac{1}{2}+\frac{1}{5}+\frac{1}{2}\right]-\frac{1}{2}V_2=5$$

$$V_2\left[\frac{1}{2}+\frac{1}{4}\right]-\frac{1}{2}V_1=3$$

V_1 = **8.077 V**, V_2 = **9.385 V**

Symmetry present

b. V_1 V_2

$$V_1\left[\frac{1}{2}+\frac{1}{4}\right]-\frac{1}{4}V_2=4-2$$

$$V_2\left[\frac{1}{4}+\frac{1}{20}+\frac{1}{5}\right]-\frac{1}{4}V_1=2$$

V_1 = **4.8 V**, V_2 = **6.4 V**

Symmetry present

40. (I): a. Source conversion: $I = 5$ A, $R = 3\ \Omega$

V_1 V_2 V_3

$$V_1\left[\frac{1}{3}+\frac{1}{6}+\frac{1}{6}\right]-\frac{1}{6}V_2-\frac{1}{6}V_3=5$$

$$V_2\left[\frac{1}{6}+\frac{1}{4}+\frac{1}{5}\right]-\frac{1}{6}V_1-\frac{1}{5}V_3=-3$$

$$V_3\left[\frac{1}{6}+\frac{1}{5}+\frac{1}{7}\right]-\frac{1}{5}V_2-\frac{1}{6}V_1=0$$

b. $V_1 = \mathbf{7.238\ V}$, $V_2 = \mathbf{-2.453\ V}$, $V_3 = \mathbf{1.405\ V}$

c. $R_1 \ V_{R_1} = 15\text{ V} - 7.238\text{ V} = \mathbf{7.762\ V}$

$V_{R_2} = V_2 = \mathbf{-2.453\ V}$, $V_{R_3} = V_3 = \mathbf{1.405\ V}$

$V_{R_4} = \overset{(+)}{V_3} - \overset{(-)}{V_2} = 1.405\text{ V} - (-2.453\text{ V}) = \mathbf{3.858\ V}$

$V_{R_5} = V_1 - V_2 = 7.238\text{ V} - (-2.453\text{ V}) = \mathbf{9.691\ V}$

$V_{R_6} = V_1 - V_3 = 7.238\text{ V} - 1.405\text{ V} = \mathbf{5.833\ V}$

(II): a. Source conversion: $I = 4$ A, $R = 4\ \Omega$

$\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$V_1\left[\frac{1}{9} + \frac{1}{20} + \frac{1}{20}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_3 = -2$$

$$V_2\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{18}\right] - \frac{1}{20}V_1 - \frac{1}{20}V_3 = 0$$

$$V_3\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{4}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_1 = 4$$

b. $V_1 = \mathbf{-6.642\ V}$, $V_2 = \mathbf{1.293\ V}$, $V_3 = \mathbf{10.664\ V}$

c. $V_{R_1} = V_1 = \mathbf{-6.737\ V}$, $R_2 \ V_{R_2} = 16\text{ V} - 10.676\text{ V} = \mathbf{5.324\ V}$

$V_{R_3} = V_2 = \mathbf{1.288\ V}$, $V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = 1.288\text{ V} - (-6.737\text{ V}) = \mathbf{8.025\ V}$

$V_{R_5} = \overset{(+)}{V_3} - \overset{(-)}{V_2} = 10.676\text{ V} - 1.288\text{ V} = \mathbf{9.388\ V}$

$V_{R_6} = \overset{(+)}{V_3} - \overset{(-)}{V_1} = 10.676\text{ V} - (-6.737\text{ V}) = \mathbf{17.413\ V}$

42. a. I_1, I_2, I_3

$$I_1(6 + 5 + 10) - 5I_2 - 10I_3 = 6$$
$$I_2(5 + 5 + 5) - 5I_1 - 5I_3 = 0$$
$$I_3(5 + 10 + 20) - 10I_1 - 5I_2 = 0$$

$I_1 = \mathbf{0.3934\ A}$, $I_2 = \mathbf{0.1770\ A}$, $I_3 = \mathbf{0.1377\ A}$

b. $I_5 = I_2 - I_3 = 39.34$ mA (direction of I_2)

c, d. no

44. a. I_1, I_2, I_3

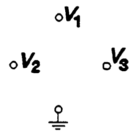
$$I_1(2\text{ k}\Omega + 33\text{ k}\Omega + 3.3\text{ k}\Omega) - 33\text{ k}\Omega\, I_2 - 3.3\text{ k}\Omega\, I_3 = 24$$
$$I_2(33\text{ k}\Omega + 56\text{ k}\Omega + 36\text{ k}\Omega) - 33\text{ k}\Omega\, I_1 - 36\text{ k}\Omega\, I_3 = 0$$
$$I_3(3.3\text{ k}\Omega + 36\text{ k}\Omega + 5.6\text{ k}\Omega) - 36\text{ k}\Omega\, I_2 - 3.3\text{ k}\Omega\, I_1 = 0$$

$I_1 = \mathbf{0.9662\ mA}$, $I_2 = I_3 = \mathbf{0.3583\ mA}$

b. $I_5 = I_2 - I_3 = 0.3583 \text{ mA} - 0.3583 \text{ mA} = \mathbf{0}$

c, d. yes

46. Source conversion: $I = 9$ mA, $R = 1$ kΩ

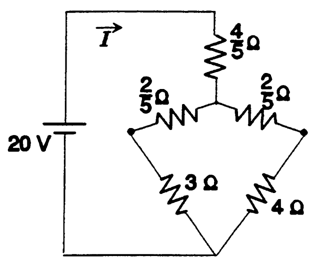


$$V_1\left[\frac{1}{1\text{ k}\Omega} + \frac{1}{100\text{ k}\Omega} + \frac{1}{200\text{ k}\Omega}\right] - \frac{1}{100\text{ k}\Omega}V_2 - \frac{1}{200\text{ k}\Omega}V_3 = 4\text{ mA}$$

$$V_2\left[\frac{1}{100\text{ k}\Omega} + \frac{1}{200\text{ k}\Omega} + \frac{1}{1\text{ k}\Omega}\right] - \frac{1}{100\text{ k}\Omega}V_1 - \frac{1}{1\text{ k}\Omega}V_3 = -9\text{ mA}$$

$$V_3\left[\frac{1}{200\text{ k}\Omega} + \frac{1}{100\text{ k}\Omega} + \frac{1}{1\text{ k}\Omega}\right] - \frac{1}{200\text{ k}\Omega}V_1 - \frac{1}{1\text{ k}\Omega}V_2 = 9\text{ mA}$$

48. a.

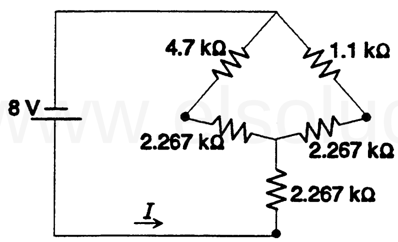


$$I = \frac{20\text{ V}}{\frac{4}{5}\,\Omega + \left[\frac{2}{5}\,\Omega + 3\,\Omega\right] \| \left[\frac{2}{5}\,\Omega + 4\,\Omega\right]}$$

$$= \frac{20\text{ V}}{\frac{4}{5}\,\Omega + (3.14\,\Omega) \| (4.4\,\Omega)}$$

$$= \mathbf{7.358\text{ A}}$$

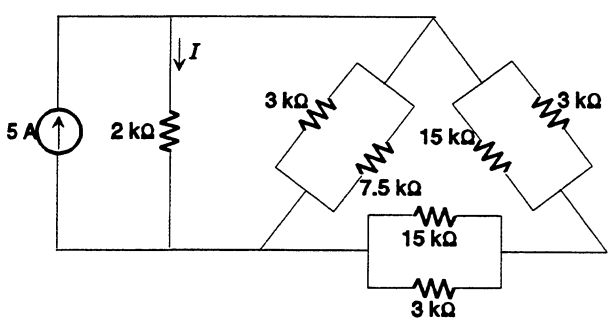
b.



$$\begin{aligned} R_T &= 2.267\text{ k}\Omega + [4.7\text{ k}\Omega + 2.267\text{ k}\Omega] \| [1.1\text{ k}\Omega + 2.267\text{ k}\Omega] \\ &= 2.267\text{ k}\Omega + [6.967\text{ k}\Omega] \| [3.367\text{ k}\Omega] \\ &= 2.267\text{ k}\Omega + 2.27\text{ k}\Omega \\ &= 4.537\text{ k}\Omega \end{aligned}$$

$$I = \frac{8\text{ V}}{4.537\text{ k}\Omega} = \mathbf{1.763\text{ mA}}$$

50.

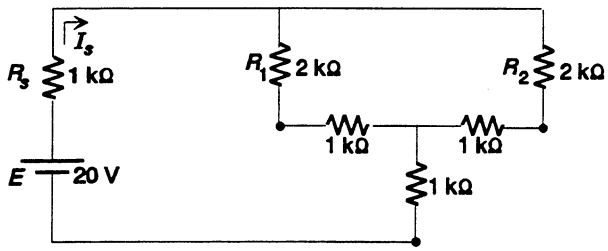


$3\text{ k}\Omega \| 7.5\text{ k}\Omega = 2.14\text{ k}\Omega$
$3\text{ k}\Omega \| 15\text{ k}\Omega = 2.5\text{ k}\Omega$

$$R'_T = 2.14\text{ k}\Omega \| (2.5\text{ k}\Omega + 2.5\text{ k}\Omega) = 1.499\text{ k}\Omega$$

CDR: $$I = \frac{(1.499\text{ k}\Omega)(5\text{ A})}{1.499\text{ k}\Omega + 2\text{ k}\Omega} = \mathbf{2.143\text{ A}}$$

52.



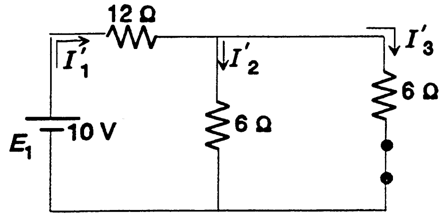
$R' = R_1 + 1\text{ k}\Omega = 3\text{ k}\Omega$
$R'' = R_2 + 1\text{ k}\Omega = 3\text{ k}\Omega$
$R'_T = \dfrac{3\text{ k}\Omega}{2} = 1.5\text{ k}\Omega$

$R_T = 1\text{ k}\Omega + 1.5\text{ k}\Omega + 1\text{ k}\Omega = 3.5\text{ k}\Omega$

$I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{3.5\text{ k}\Omega} = \mathbf{5.714\text{ mA}}$

CHAPTER 9 (Odd)

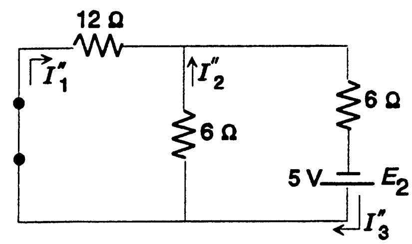
1. a. E_1:



$$I'_1 = \frac{10\text{ V}}{12\ \Omega + 6\ \Omega \| 6\ \Omega} = \frac{10\text{ V}}{12\ \Omega + 3\ \Omega} = \frac{2}{3}\text{ A}$$

$$I'_2 = I'_3 = \frac{I'_1}{2} = \frac{1}{3}\text{ A}$$

E_2:



$$I''_3 = \frac{5\text{ V}}{6\ \Omega + 6\ \Omega \| 12\ \Omega} = \frac{5\text{ V}}{6\ \Omega + 4\ \Omega} = \frac{1}{2}\text{ A}$$

$$I''_1 = \frac{6\ \Omega(I''_3)}{6\ \Omega + 12\ \Omega} = \frac{1}{6}\text{ A}$$

$$I''_2 = \frac{12\ \Omega(I''_3)}{12\ \Omega + 6\ \Omega} = \frac{1}{3}\text{ A}$$

$$I_1 = I'_1 + I''_1 = \frac{2}{3}\text{ A} + \frac{1}{6}\text{ A} = \mathbf{\frac{5}{6}\text{ A}}$$

$$I_2 = I'_2 - I''_2 = \frac{1}{3}\text{ A} - \frac{1}{3}\text{ A} = \mathbf{0\text{ A}}$$

$$I_3 = I'_3 + I''_3 = \frac{1}{3}\text{ A} + \frac{1}{2}\text{ A} = \mathbf{\frac{5}{6}\text{ A}}$$

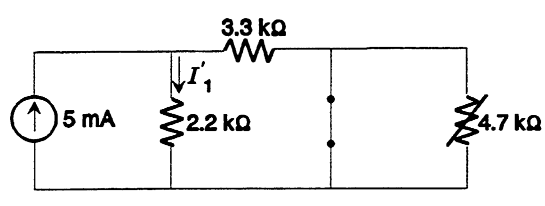
b. E_1: $P'_1 = I'^2_1 R_1 = \left(\frac{2}{3}\text{ A}\right)^2 12\ \Omega = \mathbf{5.333\text{ W}}$

E_2: $P''_1 = I''^2_1 R_1 = \left(\frac{1}{6}\text{ A}\right)^2 12\ \Omega = \mathbf{0.333\text{ W}}$

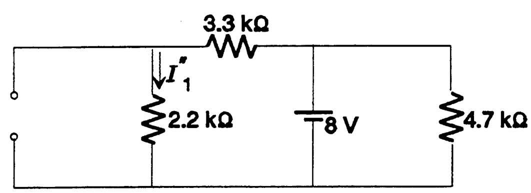
c. $P_1 = I_1^2 R_1 = \left(\frac{5}{6}\text{ A}\right)^2 12\ \Omega = \mathbf{8.333\text{ W}}$

d. $P'_1 + P''_1 = 5.333\text{ W} + 0.333\text{ W} = 5.666\text{ W} \neq 8.333\text{ W} = P_1$

3. a.



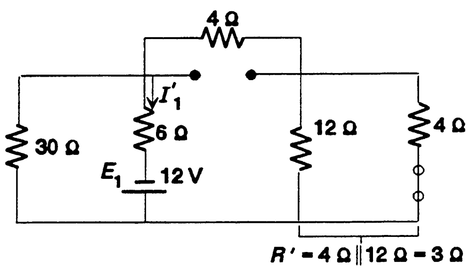
$$I_1 = \frac{3.3\text{ k}\Omega(5\text{ mA})}{2.2\text{ k}\Omega + 3.3\text{ k}\Omega} = \frac{16.5\text{ mA}}{5.5} = 3\text{ mA}$$

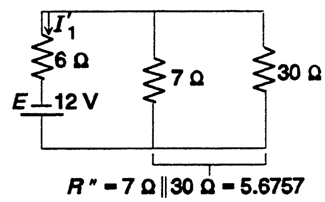


$$I''_1 = \frac{8\text{ V}}{3.3\text{ k}\Omega + 2.2\text{ k}\Omega} = \frac{8\text{ V}}{5.5\text{ k}\Omega} = 1.4545\text{ mA}$$

$$I_1 = I'_1 + I''_1 = 3\text{ mA} + 1.4545\text{ mA} = \mathbf{4.4545\text{ mA}}$$

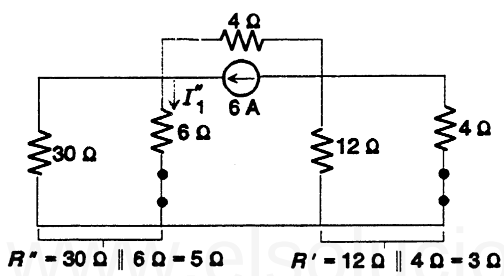
b. E_1:

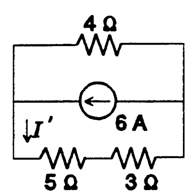




$$I'_1 = \frac{E_1}{R_T} = \frac{12\text{ V}}{6\ \Omega + 5.6757\ \Omega} = 1.0278\text{ A}$$

I:

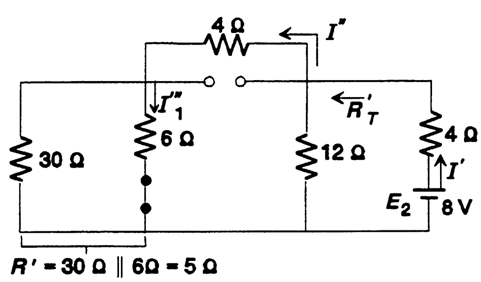




$$I' = \frac{4\ \Omega(6\text{ A})}{4\ \Omega + 8\ \Omega} = 2\text{ A}$$

$$I''_1 = \frac{30\ \Omega(2\text{ A})}{30\ \Omega + 6\ \Omega} = 1.667\text{ A}$$

E_2:



$$R'_T = 12\ \Omega \| (4\ \Omega + 5\ \Omega) = 12\ \Omega \| 9\ \Omega = 5.143\ \Omega$$

$$I' = \frac{E_2}{R_T} = \frac{8\text{ V}}{4\ \Omega + 5.143\ \Omega} = 0.875\text{ A}$$

$$I'' = \frac{12\ \Omega(I')}{12\ \Omega + 9\ \Omega} = \frac{12\ \Omega(0.875\text{ A})}{21\ \Omega} = 0.5\text{ A}$$

$$I'''_1 = \frac{30\ \Omega(I'')}{30\ \Omega + 6\ \Omega} = \frac{30\ \Omega(0.5\ \text{A})}{36\ \Omega} = 0.4167\ \text{A}$$

$$I_1 = I_{R_1} = I'_1 + I''_1 + I'''_1$$
$$= 1.0278\ \text{A} + 1.667\ \text{A} + 0.4167\ \text{A} = \mathbf{3.11\ A}$$

5. a. $R_{Th} = R_3 + R_1 \| R_2 = 4\ \Omega + 6\ \Omega \| 3\ \Omega = 4\ \Omega + 2\ \Omega = \mathbf{6\ \Omega}$

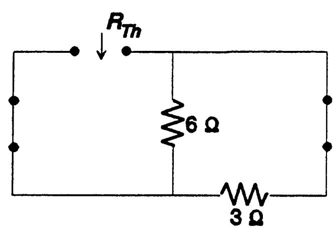
$$E_{Th} = \frac{R_2 E}{R_2 + R_1} = \frac{3\ \Omega(18\ \text{V})}{3\ \Omega + 6\ \Omega} = \mathbf{6\ V}$$

b. $I_1 = \dfrac{E_{Th}}{R_{Th} + R} = \dfrac{6\ \text{V}}{6\ \Omega + 2\ \Omega} = \mathbf{0.75\ A}$

$$I_2 = \frac{6\ \text{V}}{6\ \Omega + 30\ \Omega} = \mathbf{0.1667\ A}$$

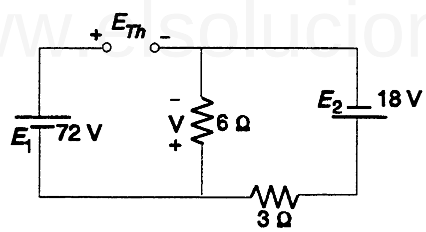
$$I_3 = \frac{6\ \text{V}}{6\ \Omega + 100\ \Omega} = \mathbf{0.0566\ A}$$

7. (I): R_{Th}:



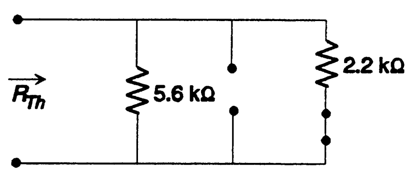
$R_{Th} = 6\ \Omega \| 3\ \Omega = \mathbf{2\ \Omega}$

E_{Th}:



$$V = \frac{6\ \Omega(18\ \text{V})}{6\ \Omega + 3\ \Omega} = 12\ \text{V}$$
$$E_{Th} = 72\ \text{V} + \text{V} = \mathbf{84\ V}$$

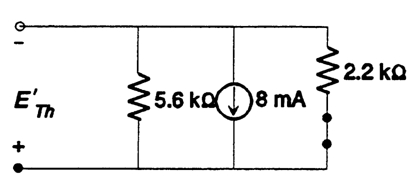
(II): R_{Th}:



$R_{Th} = 5.6\ \text{k}\Omega \| 2.2\ \text{k}\Omega = \mathbf{1.579\ k\Omega}$

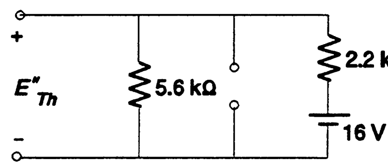
E_{Th}: Superposition:

I:



$$E'_{Th} = IR_T$$
$$= 8\ \text{mA}(5.6\ \text{k}\Omega \| 2.2\ \text{k}\Omega)$$
$$= 8\ \text{mA}(1.579\ \text{k}\Omega)$$
$$= 12.636\ \text{V}$$

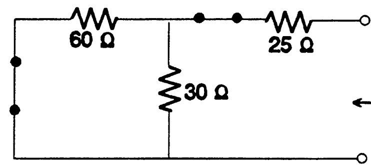
E:



$$E''_{Th} = \frac{5.6\text{ k}\Omega(16\text{ V})}{5.6\text{ k}\Omega + 2.2\text{ k}\Omega} = 11.487\text{ V}$$

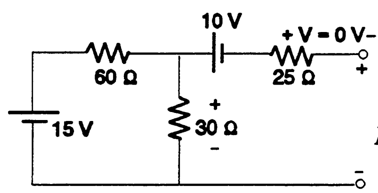
$$\overset{+}{\underset{-}{E_{Th}}} = 11.487\text{ V} - 12.636\text{ V} = \mathbf{-1.149\text{ V}}$$

9. (I): R_{Th}:



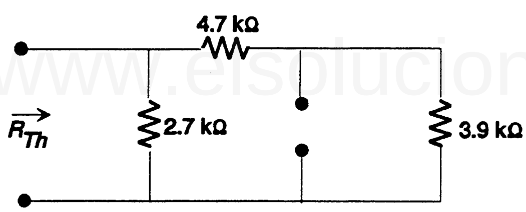
$$\leftarrow R_{Th} = 25\ \Omega + 60\ \Omega \| 30\ \Omega = 45\ \Omega$$

E_{Th}:



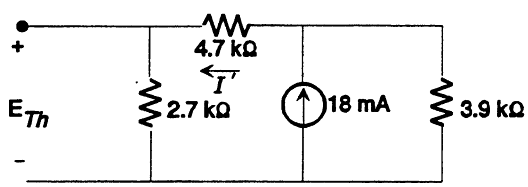
$$\begin{aligned} E_{Th} &= V_{30\Omega} - 10\text{ V} - 0 \\ &= \frac{30\ \Omega(15\text{ V})}{30\ \Omega + 60\ \Omega} - 10\text{ V} \\ &= 5\text{ V} - 10\text{ V} \\ &= -5\text{ V} \end{aligned}$$

(II): R_{Th}:



$$R_{Th} = 2.7\text{ k}\Omega \,\|\, (4.7\text{ k}\Omega + 3.9\text{ k}\Omega) = 2.7\text{ k}\Omega \,\|\, 8.6\text{ k}\Omega = \mathbf{2.055\text{ k}\Omega}$$

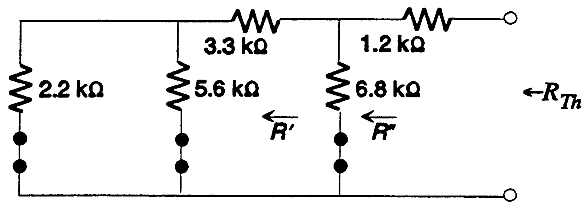
E_{Th}:



$$I' = \frac{3.9\text{ k}\Omega(18\text{ mA})}{3.9\text{ k}\Omega + 7.4\text{ k}\Omega} = 6.212\text{ mA}$$

$$E_{Th} = I'(2.7\text{ k}\Omega) = (6.212\text{ mA})(2.7\text{ k}\Omega) = \mathbf{16.772\text{ V}}$$

11. R_{Th}:



$2.2\ \text{k}\Omega \parallel 5.6\ \text{k}\Omega = 1.579\ \text{k}\Omega$
$R' = 1.579\ \text{k}\Omega + 3.3\ \text{k}\Omega$
$= 4.879\ \text{k}\Omega$

$R'' = 4.879\ \text{k}\Omega \parallel 6.8\ \text{k}\Omega = 2.841\ \text{k}\Omega$
$R_{Th} = 1.2\ \text{k}\Omega + R'' = 1.2\ \text{k}\Omega + 2.841\ \text{k}\Omega = \mathbf{4.041\ k\Omega}$

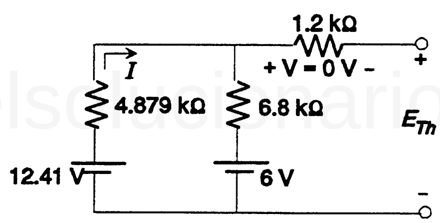
E_{Th}: Source conversions:

$$I_1 = \frac{22\ \text{V}}{2.2\ \text{k}\Omega} = 10\ \text{mA},\ R_s = 2.2\ \text{k}\Omega$$
$$I_2 = \frac{12\ \text{V}}{5.6\ \text{k}\Omega} = 2.143\ \text{mA},\ R_s = 5.6\ \text{k}\Omega$$

Combining parallel current sources: $I'_T = I_1 - I_2 = 10\ \text{mA} - 2.143\ \text{mA} = 7.857\ \text{mA}$

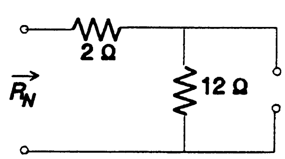
$2.2\ \text{k}\Omega \parallel 5.6\ \text{k}\Omega = 1.579\ \text{k}\Omega$

Source conversion:
$E = (7.857\ \text{mA})(1.579\ \text{k}\Omega) = 12.41\ \text{V}$
$R' = R_s + 3.3\ \text{k}\Omega = 1.579\ \text{k}\Omega + 3.3\ \text{k}\Omega = 4.879\ \text{k}\Omega$



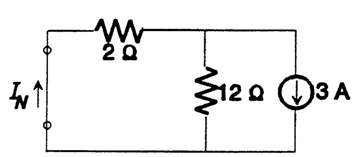
$$I = \frac{12.41\ \text{V} - 6\ \text{V}}{4.879\ \text{k}\Omega + 6.8\ \text{k}\Omega} = \frac{6.41\ \text{V}}{11.679\ \text{k}\Omega} = 0.549\ \text{mA}$$
$$V_{6.8\text{k}\Omega} = I(6.8\ \text{k}\Omega) = (0.549\ \text{mA})(6.8\ \text{k}\Omega) = 3.733\ \text{V}$$
$$E_{Th} = 6\ \text{V} + V_{6.8\text{k}\Omega} = 6\ \text{V} + 3.733\ \text{V} = \mathbf{9.733\ V}$$

13. (I) R_N:



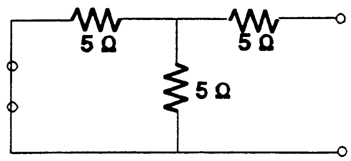
$R_N = 2\ \Omega + 12\ \Omega = \mathbf{14\ \Omega}$

I_N:



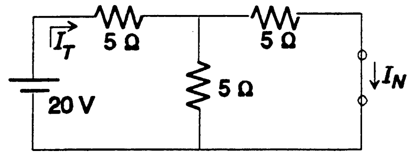
$$I_N = \frac{12\ \Omega(3\ \text{A})}{12\ \Omega + 2\ \Omega} = \mathbf{2.571\ A}$$

(II) R_N:



$\leftarrow R_N = 5\ \Omega + \dfrac{5\ \Omega}{2} = \mathbf{7.5\ \Omega}$

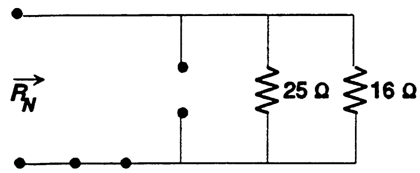
I_N:



$$I_T = \frac{20\ \text{V}}{5\ \Omega + \dfrac{5\ \Omega}{2}} = 2.667\ \text{A}$$

$$I_N = \frac{I_T}{2} = \mathbf{1.333\ A}$$

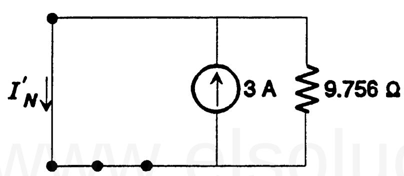
15. (a)



$R_N = 25\ \Omega \parallel 16\ \Omega = \mathbf{9.756\ \Omega}$

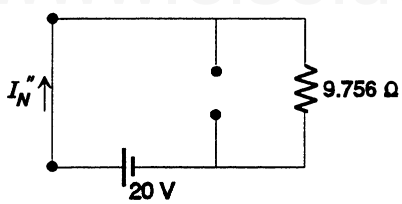
I_N: Superposition:

I:



$I'_N = 3\ \text{A}$

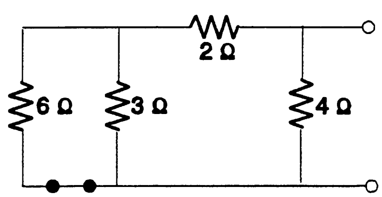
E:



$$I''_N = \frac{20\ \text{V}}{9.756\ \Omega} = 2.05\ \text{A}$$

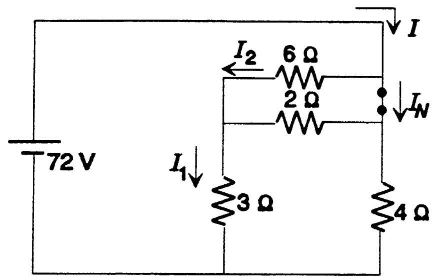
$I_N = I'_N - I''_N = 3\ \text{A} - 2.05\ \text{A} = \mathbf{0.95\ A}$ (direction of I'_N)

(b) R_N:



$\leftarrow R_N = 4\ \Omega \parallel (2\ \Omega + 2\ \Omega) = \mathbf{2\ \Omega}$

I_N:



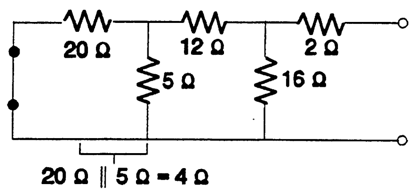
$$I = \frac{72\text{ V}}{4\ \Omega \| (3\ \Omega + 6\ \Omega \| 2\ \Omega)} = \frac{72\text{ V}}{2.118\ \Omega} \cong 34\text{ A}$$

$$I_1 = \frac{4\ \Omega(I)}{4\ \Omega + 4.5\ \Omega} = 16\text{ A}$$

$$I_2 = \frac{2\ \Omega(I_1)}{2\ \Omega + 6\ \Omega} = 4\text{ A}$$

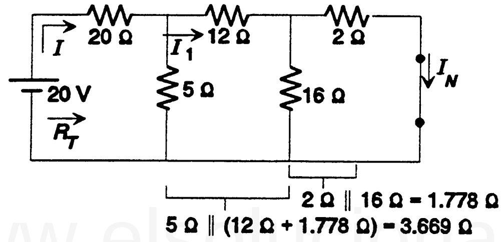
$$I_N = I - I_2 = 34\text{ A} - 4\text{ A} = \mathbf{30\text{ A}}$$

17. (a) R_N:



$$\leftarrow R_N = 2\ \Omega + 16\ \Omega \| (12\ \Omega + 4\ \Omega) = 2\ \Omega + 16\ \Omega \| 16\ \Omega = 2\ \Omega + 8\ \Omega = 10\ \Omega$$

I_N:

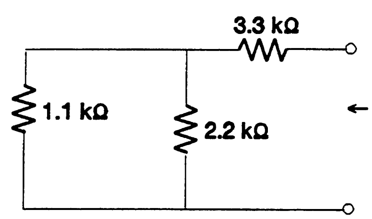


$$I = \frac{E}{R_T} = \frac{20\text{ V}}{20\ \Omega + 3.669\ \Omega} = 0.845\text{ A}$$

$$I_1 = \frac{5\ \Omega(0.845\text{ A})}{5\ \Omega + 13.778\ \Omega} = 0.225\text{ A}$$

$$I_N = \frac{16\ \Omega(0.225\text{ A})}{16\ \Omega + 2\ \Omega} = \mathbf{0.2\text{ A}}$$

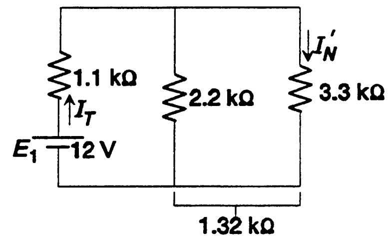
(b) R_N:



$$\leftarrow R_N = 3.3\text{ k}\Omega + 1.1\text{ k}\Omega \| 2.2\text{ k}\Omega = 3.3\text{ k}\Omega + 0.733\text{ k}\Omega = \mathbf{4.033\text{ k}\Omega}$$

I_N: Superposition:

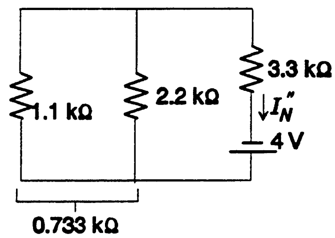
E_1:



$$I_T = \frac{12 \text{ V}}{1.1 \text{ k}\Omega + 1.32 \text{ k}\Omega} = 4.959 \text{ mA}$$

$$I'_N = \frac{2.2 \text{ k}\Omega(4.959 \text{ mA})}{2.2 \text{ k}\Omega + 3.3 \text{ k}\Omega} = 1.984 \text{ mA}$$

E_2:



$$I''_N = \frac{4 \text{ V}}{3.3 \text{ k}\Omega + 0.733 \text{ k}\Omega} = 0.9918 \text{ mA}$$

$$I_N = I'_N + I''_N = 1.984 \text{ mA} + 0.9918 \text{ mA} = \mathbf{2.9758 \text{ mA}}$$

19. a. (I) $R = R_{Th} = \mathbf{14\ \Omega}$
   (II) $R = R_{Th} = \mathbf{7.5\ \Omega}$

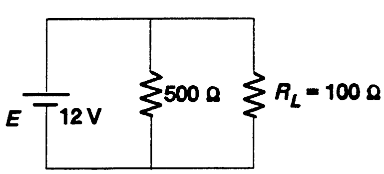
   b. (I) $P_{max} = E_{Th}^2/4R_{Th} = (36 \text{ V})^2/4(14\ \Omega) = \mathbf{23.14 \text{ W}}$
   (II) $P_{max} = E_{Th}^2/4R_{Th} = (10 \text{ V})^2/4(7.5\ \Omega) = \mathbf{3.33 \text{ W}}$

21. a. $R = R_{Th} = \mathbf{9.756\ \Omega}$
   b. $R = R_{Th} = \mathbf{2\ \Omega}$

   a. $P_{max} = E_{Th}^2/4R_{Th} = (9.268 \text{ V})^2/4(9.756\ \Omega) = \mathbf{2.20 \text{ W}}$
   b. $P_{max} = E_{Th}^2/4R_{Th} = (60 \text{ V})^2/4(2\ \Omega) = \mathbf{450 \text{ W}}$

23. $P_{max} = \left[\dfrac{E_{Th}}{R_{Th} + R_4}\right]^2 R_4$
   with $R_1 = \mathbf{0\ \Omega}$ $\quad E_{Th}$ is a maximum and R_{Th} a minimum
   $\therefore P_{max}$ **a maximum**

25.



Since R_L fixed, maximum power to R_L when V_{R_L} a maximum as defined by $P_L = \dfrac{V_{R_L}^2}{R_L}$

$$\therefore R = \mathbf{500\ \Omega} \text{ and } P_{max} = \frac{(12\text{V})^2}{100\ \Omega} = 1.44 \text{ W}$$

27. $E_{eq} = \dfrac{-5\text{ V}/2.2\text{ k}\Omega + 20\text{ V}/8.2\text{ k}\Omega}{1/2.2\text{ k}\Omega + 1/8.2\text{ k}\Omega} = 0.2879\text{ V}$

$R_{eq} = \dfrac{1}{1/2.2\text{ k}\Omega + 1/8.2\text{ k}\Omega} = 1.7346\text{ k}\Omega$

$I_L = \dfrac{E_{eq}}{R_{eq} + R_L} = \dfrac{0.2879\text{ V}}{1.7346\text{ k}\Omega + 5.6\text{ k}\Omega} = \mathbf{39.3\ \mu A}$

$V_L = I_L R_L = (39.3\ \mu\text{A})(5.6\text{ k}\Omega) = \mathbf{220\ mV}$

29. $I_{eq} = \dfrac{(4\text{ A})(4.7\ \Omega) + (1.6\text{ A})(3.3\ \Omega)}{4.7\ \Omega + 3.3\ \Omega} = \dfrac{18.8\text{ V} + 5.28\text{ V}}{8\ \Omega} = 3.01\text{ A}$

$R_{eq} = 4.7\ \Omega + 3.3\ \Omega = 8\ \Omega$

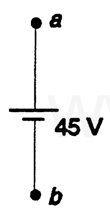
$I_L = \dfrac{R_{eq}(I_{eq})}{R_{eq} + R_L} = \dfrac{8\ \Omega(3.01\text{ A})}{8\ \Omega + 2.7\ \Omega} = \mathbf{2.25\ A}$

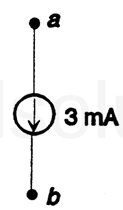
$V_L = I_L R_L = (2.25\text{ A})(2.7\ \Omega) = \mathbf{6.075\ V}$

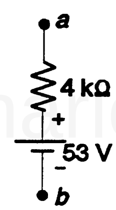
31. $15\text{ k}\Omega \parallel (8\text{ k}\Omega + 7\text{ k}\Omega) = 15\text{ k}\Omega \parallel 15\text{ k}\Omega = 7.5\text{ k}\Omega$

$V_{ab} = \dfrac{7.5\text{k}\Omega(60\text{ V})}{7.5\text{ k}\Omega + 2.5\text{ k}\Omega} = 45\text{ V}$

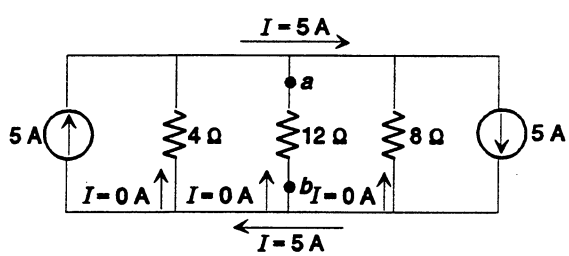
$I_{ab} = \dfrac{45\text{ V}}{15\text{ k}\Omega} = 3\text{ mA}$







33.

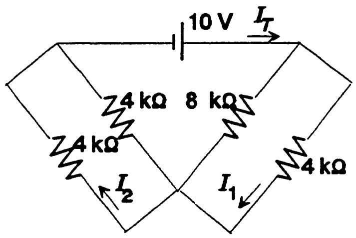


$V_{ab} = 0\text{ V}$ (short)
$I_{ab} = 0\text{ A}$ (open)

R_2 any resistive value

$\therefore R_2$ = short-circuit, open-circuit, any value

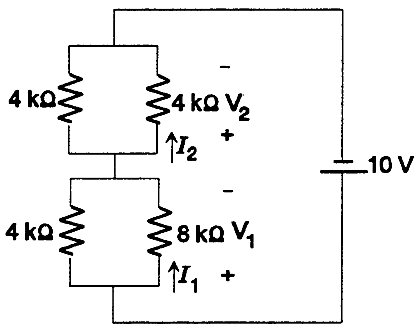
35. (a)



$$I_T = \frac{10\text{ V}}{4\text{ k}\Omega \| 8\text{ k}\Omega + 4\text{ k}\Omega \| 4\text{ k}\Omega}$$
$$= \frac{10\text{ V}}{2.667\text{ k}\Omega + 2\text{ k}\Omega}$$
$$= \frac{10\text{ V}}{4.667\text{ k}\Omega} = 2.143\text{ mA}$$

$$I_1 = \frac{8\ \Omega(I_T)}{8\ \Omega + 4\ \Omega} = 1.429\text{ mA},\ I_2 = I_T/2 = 1.0715\text{ mA}$$
$$I = I_1 - I_2 = 1.429\text{ mA} - 1.0715\text{ mA} = \mathbf{0.357\text{ mA}}$$

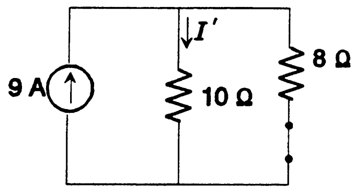
(b)



$$V_1 = \frac{(8\text{ k}\Omega \| 4\text{ k}\Omega)(10\text{ V})}{8\text{ k}\Omega \| 4\text{ k}\Omega + 4\text{ k}\Omega \| 4\text{ k}\Omega}$$
$$= 5.715\text{ V}$$
$$I_1 = \frac{V_1}{8\text{ k}\Omega} = 0.714\text{ mA}$$
$$V_2 = E - V_1 = 10\text{ V} - 5.715\text{ V}$$
$$= 4.285\text{ V}$$
$$I_2 = \frac{V_2}{4\text{ k}\Omega} = 1.071\text{ mA}$$
$$I = I_2 - I_1 = 1.071\text{ mA} - 0.714\text{ mA}$$
$$= \mathbf{0.357\text{ mA}}$$

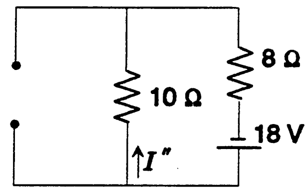
CHAPTER 9 (Even)

2. a. I:



$$I' = \frac{8\ \Omega(9\ \text{A})}{8\ \Omega + 10\ \Omega} = 4\ \text{A}$$

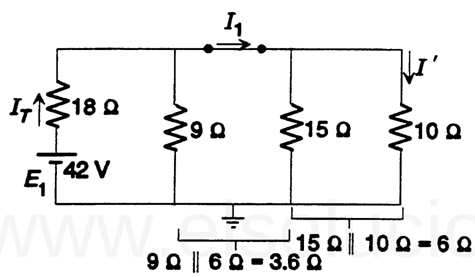
E:



$$I'' = \frac{18\ \text{V}}{10\ \Omega + 8\ \Omega} = 1\ \text{A}$$

$$I(\text{dir. of } I') = I' - I'' = 4\ \text{A} - 1\ \text{A} = \mathbf{3\ A}$$

b. E_1:

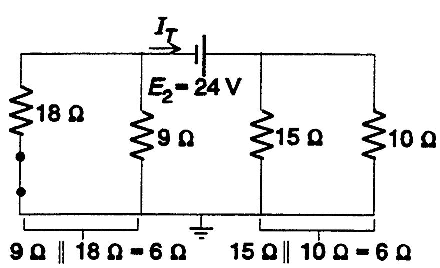


$$I_T = \frac{42\ \text{V}}{18\ \Omega + 3.6\ \Omega} = 1.944\ \text{A}$$

$$I_1 = \frac{9\ \Omega(I_T)}{9\ \Omega + 6\ \Omega} = \frac{9\ \Omega(1.944\ \text{A})}{15\ \Omega}$$
$$= 1.1664\ \text{A}$$

$$I' = \frac{15\ \Omega(I_1)}{15\ \Omega + 10\ \Omega} = \frac{15\ \Omega(1.1664\ \text{A})}{25\ \Omega}$$
$$= 0.7\ \text{A}$$

E_2:

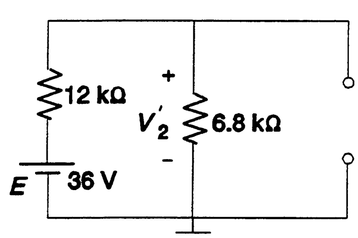


$$I_T = \frac{E_2}{R_T} = \frac{24\ \text{V}}{12\ \Omega} = 2\ \text{A}$$

$$I'' = \frac{15\ \Omega(I_T)}{15\ \Omega + 10\ \Omega} = 1.2\ \text{A}$$

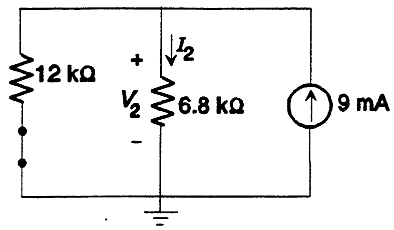
$$I_{10\Omega} = I' + I'' = 0.7\ \text{A} + 1.2\ \text{A} = \mathbf{1.9\ A}$$

4. E:



$$V'_2 = \frac{6.8\ \text{k}\Omega(36\ \text{V})}{6.8\ \text{k}\Omega + 12\ \text{k}\Omega} = 13.02\ \text{V}$$

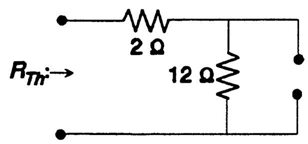
I:



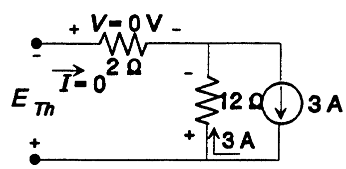
$$I_2 = \frac{12\text{ k}\Omega(9\text{ mA})}{12\text{ k}\Omega + 6.8\text{ k}\Omega} = 5.745\text{ mA}$$

$V''_2 = I_2R_2 = (5.745\text{ mA})(6.8\text{ k}\Omega) = 39.06\text{ V}$
$V_2 = V'_2 + V''_2 = 13.02\text{ V} + 39.06\text{ V} = \mathbf{52.08\text{ V}}$

6. (I) a.



$R_{Th} = 2\ \Omega + 12\ \Omega = 14\ \Omega$

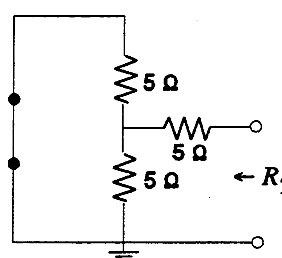


$E_{Th} = IR = (3\text{ A})(12\ \Omega) = 36\text{ V}$

b. $R = 2\ \Omega$: $P = \left[\dfrac{E_{Th}}{R_{Th} + R}\right]^2 R = \left[\dfrac{36\text{ V}}{14\ \Omega + 2\ \Omega}\right]^2 2\ \Omega = \mathbf{10.125\text{ W}}$

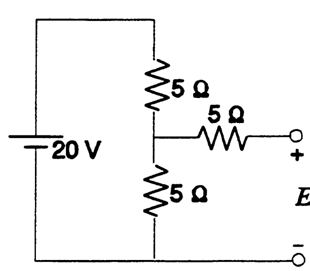
$R = 100\ \Omega$: $P = \left[\dfrac{36\text{ V}}{14\ \Omega + 100\ \Omega}\right]^2 100\ \Omega = \mathbf{9.9723\text{ W}}$

(II) a. R_{Th}:



$\leftarrow R_{Th} = 5\ \Omega + 5\ \Omega \parallel 5\ \Omega = 7.5\ \Omega$

E_{Th}:

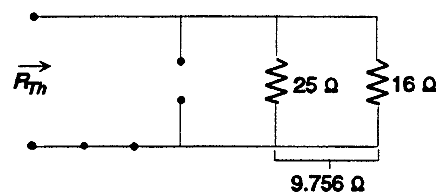


$E_{Th} = \dfrac{20\text{ V}}{2} = \mathbf{10\text{ V}}$

b. $R = 2\ \Omega$: $P = \left[\dfrac{E_{Th}}{R_{Th} + R}\right]^2 R = \left[\dfrac{10\ \text{V}}{7.5\ \Omega + 2\ \Omega}\right]^2 2\ \Omega = \mathbf{2.2161\ W}$

$R = 100\ \Omega$: $P = \left[\dfrac{10\ \text{V}}{7.5\ \Omega + 100\ \Omega}\right]^2 100\ \Omega = \mathbf{0.8653\ W}$

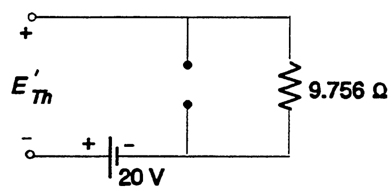
8. a. R_{Th}:



$R_{Th} = 25\ \Omega \parallel 16\ \Omega = \mathbf{9.756\ \Omega}$

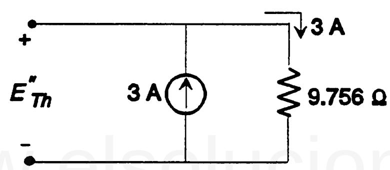
E_{Th}: Superposition:

E:



$E'_{Th} = -20$ V

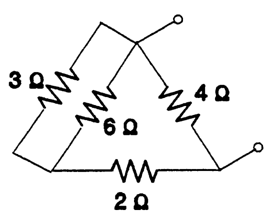
I:



$E''_{Th} = (3\ \text{A})(9.756\ \Omega) = 29.268$ V

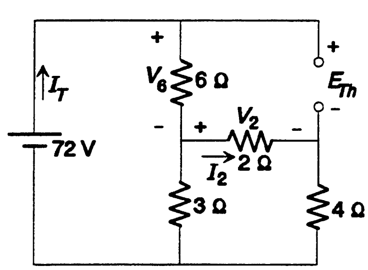
$E_{Th} = E''_{Th} - E'_{Th} = 29.268\ \text{V} - 20\ \text{V} = \mathbf{9.268\ V}$

b. R_{Th}:



$R_{Th} = 4\ \Omega \parallel (2\ \Omega + 6\ \Omega \parallel 3\ \Omega) = 2\ \Omega$

E_{Th}:

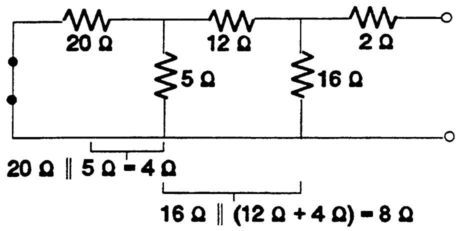


$I_T = \dfrac{72\ \text{V}}{6\ \Omega + 3\ \Omega \parallel (2\ \Omega + 4\ \Omega)} = 9$ A

$I_2 = \dfrac{3\ \Omega(I_T)}{3\ \Omega + 6\ \Omega} = \dfrac{3\ \Omega(9\ \text{A})}{9\ \Omega} = 3$ A

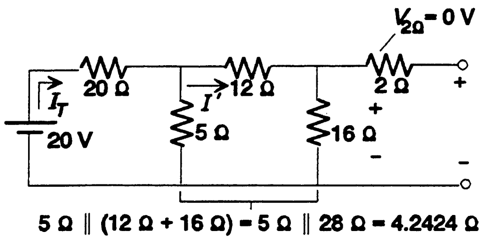
$E_{Th} = V_6 + V_2 = (I_T)(6\ \Omega) + I_2(2\ \Omega)$
$= (9\text{A})(6\ \Omega) + (3\ \text{A})(2\ \Omega) = \mathbf{60\ V}$

10. a. R_{Th}:



$\leftarrow R_{Th} = 2\ \Omega + 8\ \Omega = \mathbf{10\ \Omega}$

E_{Th}:



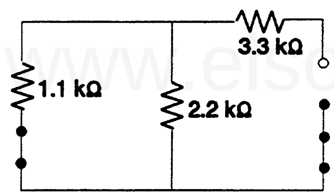
$E_{Th} = V_{16\Omega}$

$$I_T = \frac{20\ \text{V}}{20\ \Omega + 4.2424\ \Omega} = 0.825\ \text{A}$$

$$I' = \frac{5\ \Omega(I_T)}{5\ \Omega + 28\ \Omega} = \frac{5\ \Omega(0.825\ \text{A})}{33\ \Omega} = 0.125\ \text{A}$$

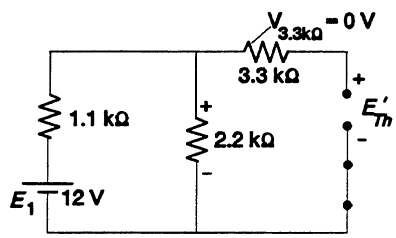
$$E_{Th} = V_{16\Omega} = (I')(16\ \Omega) = (0.125\ \text{A})(16\ \Omega) = \mathbf{2\ V}$$

b. R_{Th}:

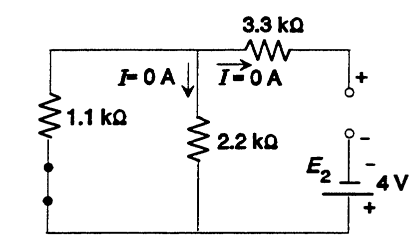


$\leftarrow R_{Th} = 3.3\ \text{k}\Omega + 2.2\ \text{k}\Omega \| 1.1\ \text{k}\Omega$
$= 3.3\ \text{k}\Omega + 0.733\ \text{k}\Omega$
$= \mathbf{4.033\ k\Omega}$

E_{Th}: Superposition:
E_1:



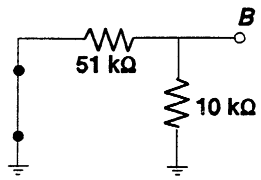
$$E'_{Th} = V_{2.2\text{k}\Omega} = \frac{2.2\ \text{k}\Omega(12\ \text{V})}{2.2\ \text{k}\Omega + 1.1\ \text{k}\Omega}$$
$$= 8\ \text{V}$$



$E_{Th}'' = E_2 = 4\ \text{V}$

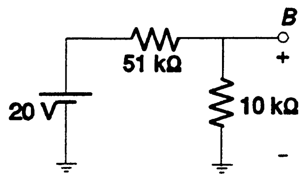
$$E_{Th} = E'_{Th} + E''_{Th} = 8\ \text{V} + 4\ \text{V} = \mathbf{12\ V}$$

12. a. R_{Th}:



$\leftarrow R_{Th} = 51\text{ k}\Omega \parallel 10\text{ k}\Omega = \mathbf{8.36\text{ k}\Omega}$

E_{Th}:



$$E_{Th} = \frac{10\text{ k}\Omega(20\text{ V})}{10\text{ k}\Omega + 51\text{ k}\Omega} = \mathbf{3.28\text{ V}}$$

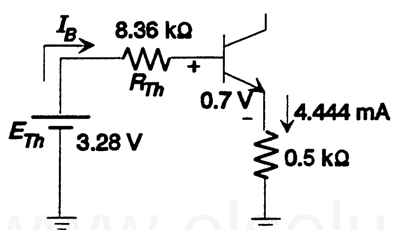
b. $I_E R_E + V_{CE} + I_C R_C = 20\text{ V}$

but $I_C = I_E$

and $I_E(R_C + R_E) + V_{CE} = 20\text{ V}$

$$\text{or } I_E = \frac{20\text{ V} - V_{CE}}{R_C + R_E} = \frac{20\text{ V} - 8\text{ V}}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega} = \frac{12\text{ V}}{2.7\text{ k}\Omega} = \mathbf{4.444\text{ mA}}$$

c.



$E_{Th} - I_B R_{Th} - V_{BE} - V_E = 0$

$$\text{and } I_B = \frac{E_{Th} - V_{BE} - V_E}{R_{Th}} = \frac{3.28\text{ V} - 0.7\text{ V} - (4.444\text{ mA})(0.5\text{ k}\Omega)}{8.36\text{ k}\Omega}$$

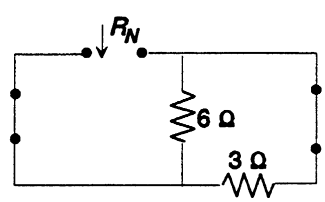
$$= \frac{2.58\text{ V} - 2.222\text{ V}}{8.36\text{ k}\Omega} = \frac{0.358\text{ V}}{8.36\text{ k}\Omega} = \mathbf{42.82\ \mu A}$$

d. $V_C = 20\text{ V} - I_C R_C = 20\text{ V} - (4.444\text{ mA})(2.2\text{ k}\Omega)$

$= 20\text{ V} - 9.777\text{ V}$

$= \mathbf{10.223\text{ V}}$

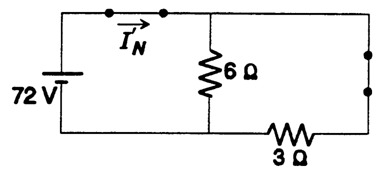
14. (I)(a) R_N:



$R_N = 6\ \Omega \parallel 3\ \Omega = \mathbf{2\ \Omega}$

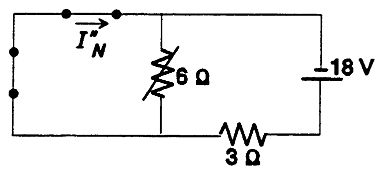
I_N:

E_1:



$$I'_N = \frac{72\ \text{V}}{6\ \Omega \parallel 3\ \Omega} = 36\ \text{A}$$

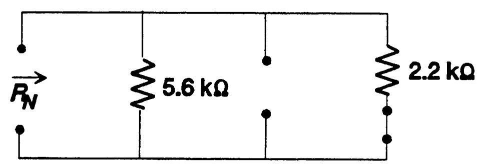
E_2:



$$I''_N = \frac{18\ \text{V}}{3\ \Omega} = 6\ \text{A}$$

$$I_N = I'_N + I''_N = 36\ \text{A} + 6\ \text{A} = \mathbf{42\ A}$$

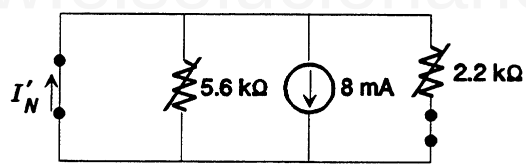
(II)(a) R_N:



$$R_N = 5.6\ \text{k}\Omega \parallel 2.2\ \text{k}\Omega = \mathbf{1.5795\ k\Omega}$$

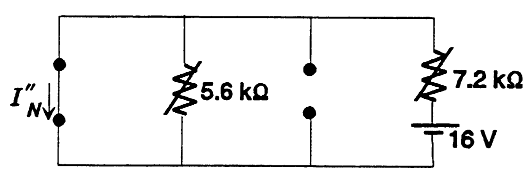
I_N:

I:



$$I'_N = 8\ \text{mA}$$

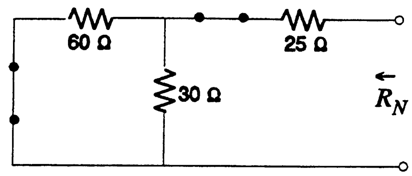
E:



$$I''_N = \frac{16\ \text{V}}{2.2\ \text{k}\Omega} = 7.2727\ \text{mA}$$

$$I_N\uparrow\ = 8\ \text{mA} - 7.2727\ \text{mA} = \mathbf{0.7273\ mA}$$

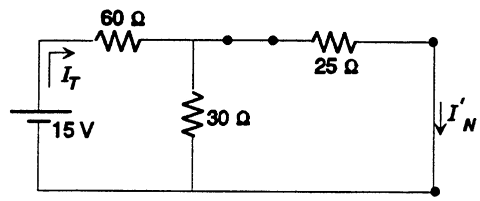
16. (I)(a) R_N:



$$\overleftarrow{R}_N = 25\ \Omega + 60\ \Omega \parallel 30\ \Omega$$
$$= 25\ \Omega + 20\ \Omega$$
$$= 45\ \Omega$$

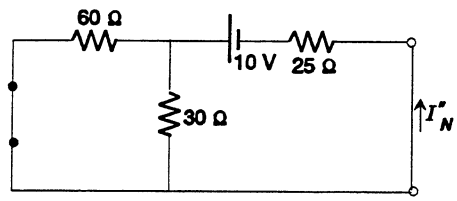
I_N:

$E = 15$ V:



$$I_T = \frac{15\text{ V}}{60\ \Omega + 30\ \Omega \parallel 25\ \Omega}$$
$$= 0.2037\text{ A}$$
$$I'_N = \frac{30\ \Omega(I_T)}{30\ \Omega + 25\ \Omega}$$
$$= 0.1111\text{ A}$$

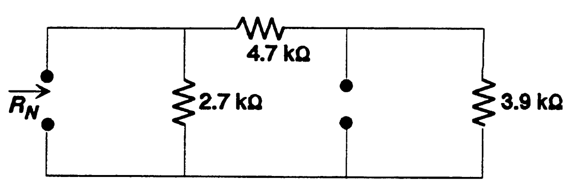
$E = 10$ V:



$$I''_N = \frac{10\text{ V}}{25\ \Omega + 60\ \Omega \parallel 30\ \Omega}$$
$$= \frac{10\text{ V}}{25\ \Omega + 20\ \Omega}$$
$$= 0.2222\text{ A}$$

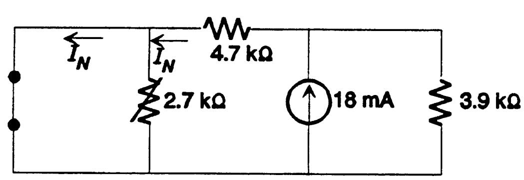
I_N (dir of I''_N) $= I''_N - I'_N = 0.2222\text{ A} - 0.1111\text{ A} = \mathbf{0.111\ A}$

(II)(a) R_N:



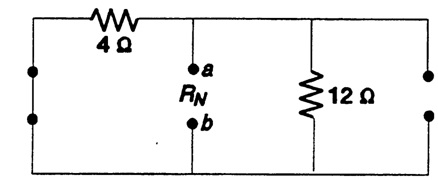
$$R_N = 2.7\text{ k}\Omega \parallel (4.7\text{ k}\Omega + 3.9\text{ k}\Omega) = \mathbf{2.055\ k\Omega}$$

I_N:



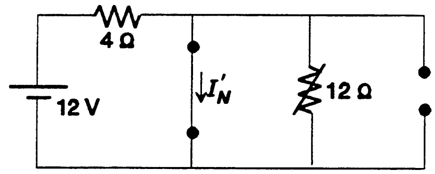
$$I_N = \frac{3.9\text{ k}\Omega(18\text{ mA})}{3.9\text{ k}\Omega + 4.7\text{ k}\Omega} = \mathbf{8.163\ mA}$$

18. a. R_N:



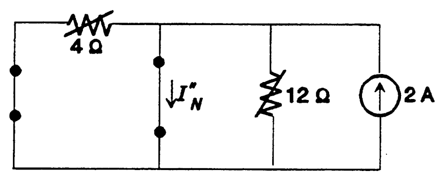
$R_N = 4\ \Omega \parallel 12\ \Omega = \mathbf{3\ \Omega}$

$E = 12$ V:



$$I'_N = \frac{12\text{ V}}{4\ \Omega} = 3\text{ A}$$

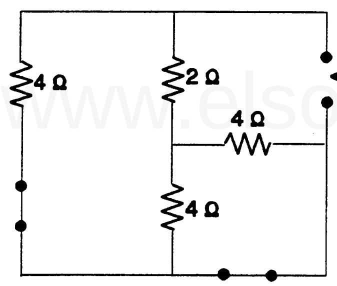
$I = 2$ A:



$I''_N = 2$ A

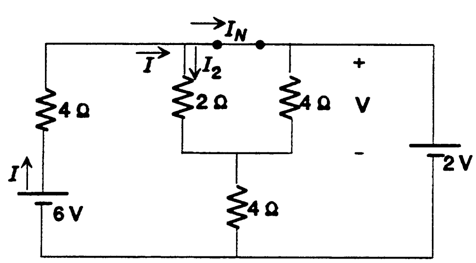
$$I_N = I'_N + I''_N = 3\text{ A} + 2\text{ A} = \mathbf{5\ A}$$

b. R_N:



$$\leftarrow R_N = (2\ \Omega + 4\ \Omega \parallel 4\ \Omega) \parallel 4\ \Omega$$
$$= (2\ \Omega + 2\ \Omega) \parallel 4\ \Omega$$
$$= \frac{4\ \Omega}{2} = \mathbf{2\ \Omega}$$

I_N:



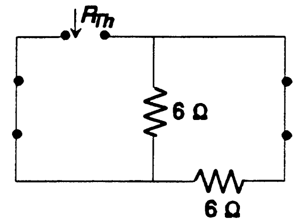
$$I = \frac{V_{4\Omega}}{4\ \Omega} = \frac{6\text{ V} - 2\text{ V}}{4\ \Omega} = \frac{4\text{ V}}{4\ \Omega}$$
$$= 1\text{ A}$$

$$V = \frac{(4\ \Omega \parallel 2\ \Omega)(2\text{ V})}{(4\ \Omega \parallel 2\ \Omega) + 4\ \Omega}$$
$$= 0.5\text{ V}$$

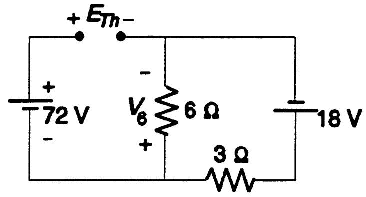
$$I_2 = \frac{V}{R} = \frac{0.5\text{ V}}{2\ \Omega} = 0.25\text{ A}$$

$$I_N = I - I_2 = 1\text{ A} - 0.25\text{ A} = \mathbf{0.75\ A}$$

20. (I) a.



$R_{Th} = R = 6\ \Omega \parallel 3\ \Omega = 2\ \Omega$

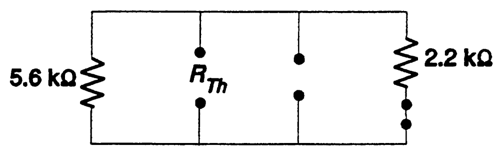


$$V_6 = \frac{6\ \Omega(18\ \text{V})}{6\ \Omega + 3\ \Omega} = 12\ \text{V}$$

$$E_{Th} = 72\ \text{V} + V_6$$
$$= 72\ \text{V} + 12\ \text{V} = \mathbf{84\ V}$$

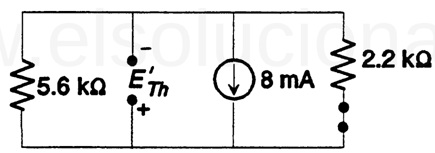
b. $P_{max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(84\ \text{V})^2}{4(2\ \Omega)} = \mathbf{882\ W}$

(II) a. R_{Th}:

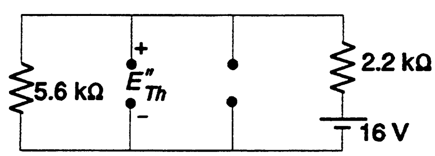


$$R_{Th} = 5.6\ \text{k}\Omega \parallel 2.2\ \text{k}\Omega$$
$$= \mathbf{1.5795\ k\Omega}$$

b. E_{Th}:



$$E'_{Th} = 8\ \text{mA}(2.2\ \text{k}\Omega \parallel 5.6\ \text{k}\Omega)$$
$$= 8\ \text{mA}(1.5795\ \text{k}\Omega)$$
$$= 12.636\ \text{V}$$

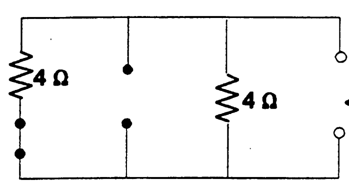


$$E''_{Th} = \frac{5.6\ \text{k}\Omega(16\ \text{V})}{5.6\ \text{k}\Omega + 2.2\ \text{k}\Omega}$$
$$= 11.487\ \text{V}$$

$$E_{Th}\ (\text{polarity of } E'_{Th}) = E'_{Th} - E''_{Th}$$
$$= 12.636\ \text{V} - 11.487\ \text{V} = \mathbf{1.149\ V}$$

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(1.149\ \text{V})^2}{4(1.5795\ \text{k}\Omega)} = \mathbf{0.21\ mW}$$

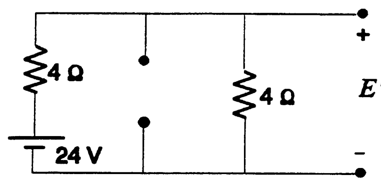
22. a.



$\leftarrow R = R_{Th} = 4\ \Omega \parallel 4\ \Omega = 2\ \Omega$

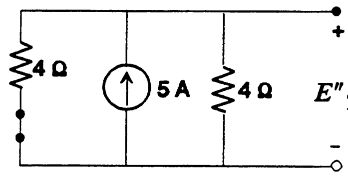
b. E_{Th}:

E:



$$E'_{Th} = \frac{24\text{ V}}{2} = 12\text{ V}$$

I:

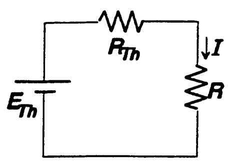


$$\begin{aligned} E''_{Th} &= IR_T = (5\text{ A})(4\ \Omega \parallel 4\ \Omega) \\ &= (5\text{ A})(2\ \Omega) \\ &= 10\text{ V} \end{aligned}$$

$$E_{Th} = E'_{Th} + E''_{Th} = 12\text{ V} + 10\text{ V} = \mathbf{22\text{ V}}$$

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(22\text{ V})^2}{4(2\ \Omega)} = \mathbf{60.5\text{ W}}$$

c.



$$P = I^2R = \left[\frac{E_{Th}}{R_{Th} + R}\right]^2 R$$

$R = \frac{1}{4}(2\ \Omega) = 0.5\ \Omega$, $P = \mathbf{38.72\text{ W}}$

$R = \frac{1}{2}(2\ \Omega) = 1\ \Omega$, $P = \mathbf{53.78\text{ W}}$

$R = \frac{3}{4}(2\ \Omega) = 1.5\ \Omega$, $P = \mathbf{59.27\text{ W}}$

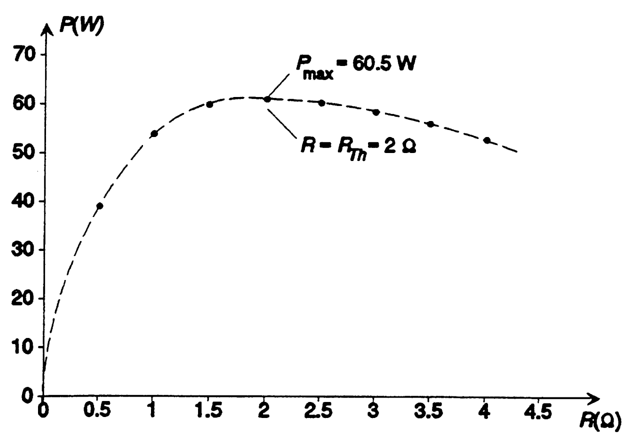
$\mathbf{R = 2\ \Omega, P = 60.5\text{ W}}$

$R = \frac{5}{4}(2\ \Omega) = 2.5\ \Omega$, $P = \mathbf{59.75\text{ W}}$

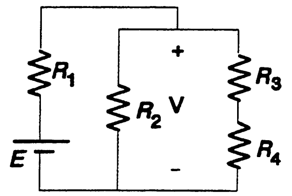
$R = \frac{3}{2}(2\ \Omega) = 3\ \Omega$, $P = \mathbf{58\text{ W}}$

$R = \frac{7}{4}(2\ \Omega) = 3.5\ \Omega$, $P = \mathbf{56\text{ W}}$

$R = 2(2\ \Omega) = 4\ \Omega$, $P = \mathbf{53.78\text{ W}}$



24. a.

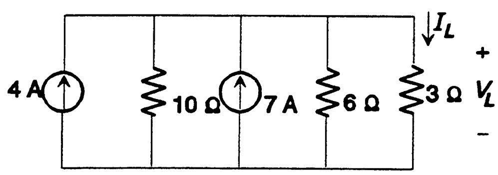


V, and therefore V_4, will be its largest value when R_2 is as large as possible. Therefore choose R_2 = open-circuit ($\infty\ \Omega$).

Then $P_4 = \dfrac{V_4^2}{R_4}$ will be a maximum.

b. No, examine each individually.

26.

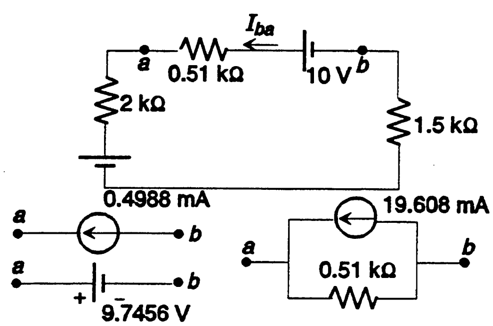


$I_T\uparrow = 4\text{ A} + 7\text{ A} = 11\text{ A}$
$R_T = 10\ \Omega \parallel 6\ \Omega \parallel 3\ \Omega = 1.667\ \Omega$
$V_L = I_T R_T = (11\text{ A})(1.667\ \Omega) = \mathbf{18.34\ V}$
$I_L = \dfrac{V_L}{R_L} = \dfrac{18.34\text{ V}}{3\ \Omega} = \mathbf{6.113\ A}$

28. $I_T\downarrow = 2\text{ A} - 0.2\text{ A} - 0.001\text{ A} = 1.799\text{ A}$
$R_T = 200\ \Omega \parallel 200\ \Omega \parallel 100\ \Omega \parallel 10\text{ k}\Omega = 49.751\ \Omega$
$V_L = I_T R_T = (1.799\text{ A})(49.751\ \Omega) = 89.5\text{ V}$
$I_L = \dfrac{V_L}{R_L} = \dfrac{89.5\text{ V}}{200\ \Omega} = \mathbf{0.448\ A}$

30. $\overleftarrow{I_{eq}} = \dfrac{(4\text{ mA})(8.2\text{ k}\Omega) + (8\text{ mA})(4.7\text{ k}\Omega) - (10\text{ mA})(2\text{ k}\Omega)}{8.2\text{ k}\Omega + 4.7\text{ k}\Omega + 2\text{ k}\Omega}$
$= \dfrac{32.8\text{ V} + 37.6\text{ V} - 20\text{ V}}{14.9\text{ k}\Omega} = 3.3826\text{ mA}$
$R_{eq} = 8.2\text{ k}\Omega + 4.7\text{ k}\Omega + 2\text{ k}\Omega = 14.9\text{ k}\Omega$
$I_L = \dfrac{R_{eq}I_{eq}}{R_{eq} + R_L} = \dfrac{(14.9\text{ k}\Omega)(3.3826\text{ mA})}{14.9\text{ k}\Omega + 6.8\text{ k}\Omega} = \mathbf{2.3226\ mA}$
$V_L = I_L R_L = (2.3226\text{ mA})(6.8\text{ k}\Omega) = \mathbf{15.7937\ V}$

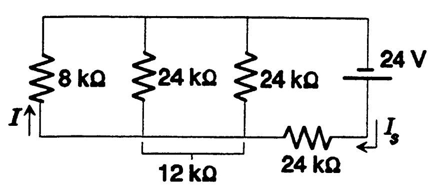
32.



$I_{ba} = \dfrac{10\text{ V} - 8\text{ V}}{2\text{ k}\Omega + 0.51\text{ k}\Omega + 1.5\text{ k}\Omega}$
$= \mathbf{0.4988\ mA}$
$V_{0.51\text{k}\Omega} = (0.4988\text{ mA})(0.51\text{ k}\Omega)$
$= 0.2544\text{ V}$
$V_{\underset{+\,-}{ab}} = 10\text{ V} - 0.2544\text{ V} = 9.7456\text{ V}$

34. a. $I_s = \dfrac{24\text{ V}}{8\text{ k}\Omega + \dfrac{24\text{ k}\Omega}{3}} = 1.5\text{ mA},\ I = \dfrac{I_s}{3} = \mathbf{0.5\ mA}$

b.



$$I_s = \frac{24\text{ V}}{24\text{ k}\Omega + 8\text{ k}\Omega \parallel 12\text{ k}\Omega} = 0.8333\text{ mA}$$

$$I = \frac{12\text{ k}\Omega(I_s)}{12\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{0.5\text{ mA}}$$

c. yes

36. a. $I_{R_2} = \dfrac{R_1(I)}{R_1 + R_2 + R_3} = \dfrac{3\Omega(6\text{ A})}{3\ \Omega + 2\ \Omega + 4\ \Omega} = 2\text{A}$

$V = I_{R_2}R_2 = (2\text{ A})(2\ \Omega) = \mathbf{4\text{ V}}$

b. $I_{R_1} = \dfrac{R_2(I)}{R_1 + R_2 + R_3} = \dfrac{2\ \Omega(6\text{ A})}{3\ \Omega + 2\ \Omega + 4\ \Omega} = 1.333\text{ A}$

$V = I_{R_1}R_1 = (1.333\text{ A})(3\ \Omega) = \mathbf{4\text{ V}}$

c. yes

CHAPTER 10 (Odd)

1. $\mathscr{E} = k\dfrac{Q_1}{r^2} = \dfrac{(9 \times 10^9)(4\ \mu C)}{(2\ m)^2} = \mathbf{9 \times 10^3\ N/C}$

3. $C = \dfrac{Q}{V} = \dfrac{1400\ \mu C}{20\ V} = \mathbf{70\ \mu F}$

5. $\mathscr{E} = \dfrac{V}{d} = \dfrac{100\ mV}{2\ mm} = \mathbf{50\ V/m}$

7. $V = \dfrac{Q}{C} = \dfrac{160\ \mu C}{4\ \mu F} = 40\ V$

   $\mathscr{E} = \dfrac{V}{d} = \dfrac{40\ V}{5\ mm} = \mathbf{8 \times 10^3\ V/m}$

9. $C = 8.85 \times 10^{-12}\,\epsilon_r \dfrac{A}{d} = 8.85 \times 10^{-12}(2.5)\dfrac{(75 \times 10^{-3} m^2)}{1.77\ mm} = \mathbf{937.5\ pF}$

11. $C = \epsilon_r C_o \Rightarrow \epsilon_r = \dfrac{C}{C_o} = \dfrac{0.006\ \mu F}{1200\ pF} = \mathbf{5\ (mica)}$

13. a. $\mathscr{E} = \dfrac{V}{d} = \dfrac{200\ V}{0.2\ mm} = \mathbf{10^6\ V/m}$

    b. $Q = \epsilon \mathscr{E} A = \epsilon_r \epsilon_o \mathscr{E} A = (7)(8.85 \times 10^{-12})(10^6\ V/m)(0.08\ m^2) = \mathbf{4.96\ \mu C}$

    c. $C = \dfrac{Q}{V} = \dfrac{4.96\ \mu C}{200\ V} = \mathbf{0.0248\ \mu F}$

15. $d = \dfrac{8.85 \times 10^{-12}\epsilon_r A}{C} = \dfrac{(8.85 \times 10^{-12})(5)(0.02\ m^2)}{0.006\ \mu F} = 0.1475\ mm = 147.5\ \mu m$

    $d = 0.1475\ \cancel{mm}\left[\dfrac{10^{-3}\ \cancel{m}}{1\ \cancel{mm}}\right]\left[\dfrac{39.37\ \cancel{in.}}{1\ \cancel{m}}\right]\left[\dfrac{1000\ mils}{1\ \cancel{in.}}\right] = 5.807\ mils$

    $5.807\ \cancel{mils}\left[\dfrac{5000\ V}{\cancel{mil}}\right] = \mathbf{29{,}035\ V}$

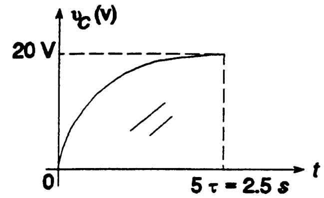
17. a. $\tau = RC = (10^5\ \Omega)(5\ \mu F) = \mathbf{0.5\ s}$

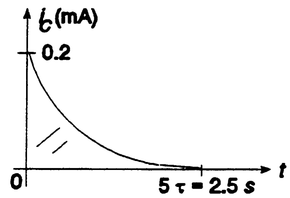
    b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20(1 - e^{-t/0.5})}$

    c. $1\tau = 0.632(20\ V) = \mathbf{12.64\ V}$, $3\tau = 0.95(20\ V) = \mathbf{19\ V}$
    $5\tau = 0.993(20\ V) = \mathbf{19.87\ V}$

    d. $i_C = \dfrac{20V}{100\ k\Omega}e^{-t/\tau} = \mathbf{0.2 \times 10^{-3}e^{-t/0.5}}$
    $v_R = Ee^{-t/\tau} = \mathbf{20e^{-t/0.5}}$

e.





19. a. $\tau = RC = (2.2\text{ k}\Omega + 3.3\text{ k}\Omega)1\ \mu\text{F} = (5.5\text{ k}\Omega)(1\ \mu\text{F}) = \mathbf{5.5\ ms}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{100(1 - e^{-t/5.5\times10^{-3}})}$

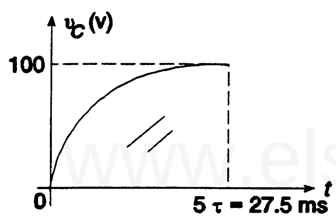
c. $1\tau = \mathbf{63.21\ V}$, $3\tau = \mathbf{95.02\ V}$, $5\tau = \mathbf{99.33\ V}$

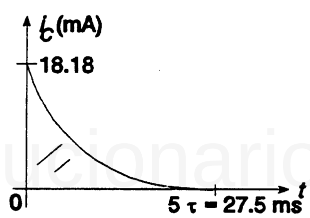
d. $i_C = \dfrac{E}{R_T}e^{-t/\tau} = \dfrac{100\text{ V}}{5.5\text{ k}\Omega}e^{-t/\tau} = \mathbf{18.18 \times 10^{-3} e^{-t/5.5\times10^{-3}}}$

$V_{R_2} = \dfrac{3.3\text{ k}\Omega(100\text{ V})}{3.3\text{ k}\Omega + 2.2\text{ k}\Omega} = 60\text{ V}$

$v_R = v_{R_2} = \mathbf{60e^{-t/5.5\times10^{-3}}}$

e.





21. a. $\tau = RC = (2\text{ k}\Omega + 3\text{ k}\Omega)2\ \mu\text{F} = (5\text{ k}\Omega)(2\ \mu\text{F}) = \mathbf{10\ ms}$

b. $v_C = \mathbf{50(1 - e^{-t/10\times10^{-3}})}$

c. $i_C = \dfrac{50\text{ V}}{5\text{ k}\Omega}e^{-t/\tau} = \mathbf{10 \times 10^{-3} e^{-t/10\times10^{-3}}}$

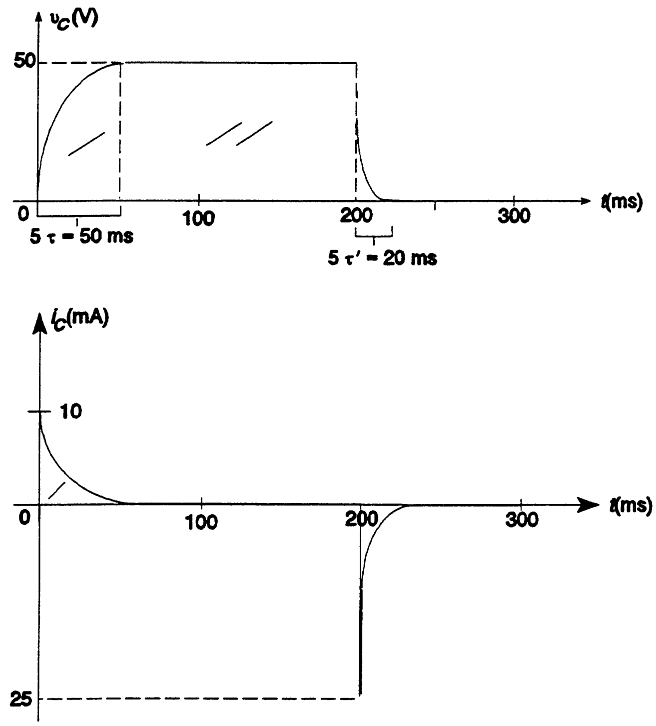
d. $t = 100$ ms: $v_C = 50(1 - e^{-t/\tau}) = 50(1 - e^{-10}) = 49.997\text{ V} \cong \mathbf{50\ V}$
$i_C \cong 0$ mA

e. $\tau' = R_2C = (2\text{ k}\Omega)(2\ \mu\text{F}) = 4$ ms

$v_C = 50e^{-t/\tau'} = \mathbf{50e^{-t/4\times10^{-3}}}$

$i_C = \dfrac{50\text{ V}}{2\text{ k}\Omega}e^{-t/\tau'} = \mathbf{25 \times 10^{-3} e^{-t/4\times10^{-3}}}$

f.



23. a. $\tau = R_1C = (10^5\ \Omega)(10\text{ pF}) = 1\ \mu\text{s}$

$$v_C = \mathbf{80(1 - e^{-t/1\times10^{-6}})}$$

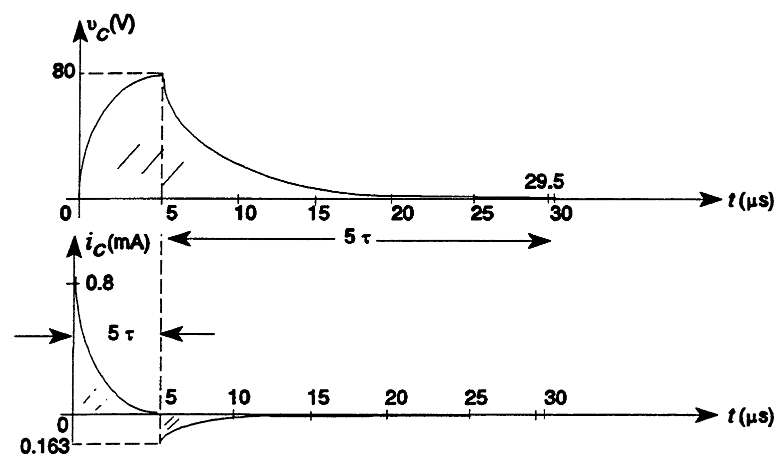
b. $i_C = \dfrac{80\text{ V}}{100\text{ k}\Omega}e^{-t/\tau} = \mathbf{0.8 \times 10^{-3}e^{-t/1\times10^{-6}}}$

c. $\tau' = R'C = (490\text{ k}\Omega)(10\text{ pF}) = 4.9\ \mu\text{s}$

$$v_C = 80e^{-t/\tau'} = \mathbf{80e^{-t/4.9\times10^{-6}}}$$

$$i_C = \frac{80\text{ V}}{490\text{ k}\Omega}e^{-t/\tau'} = \mathbf{0.163 \times 10^{-3}e^{-t/4.9\times10^{-6}}}$$

d.

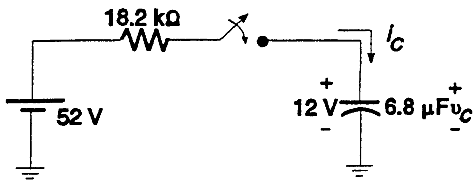


25. a. $\tau = RC = (2\ \text{m}\Omega)(1000\ \mu\text{F}) = 2\ \mu\text{s}$
$5\tau = \mathbf{10\ \mu s}$

b. $I_m = \dfrac{V}{R} = \dfrac{6\ \text{V}}{2\ \text{m}\Omega} = \mathbf{3\ kA}$

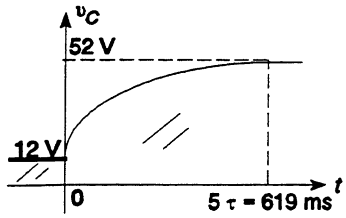
c. yes

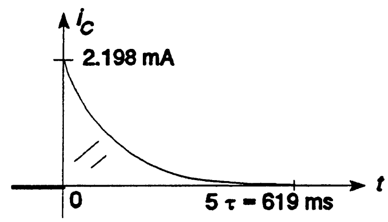
27. a.



$\tau = RC = (18.2\ \text{k}\Omega)(6.8\ \mu\text{F}) = 123.8\ \text{ms}$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 52\ \text{V} + (12\ \text{V} - 52\ \text{V})e^{-t/123.8\ \text{ms}}$
$v_C = \mathbf{52\ V - 40\ V}e^{-t/123.8\ \text{ms}}$
$v_R(0+) = 52\ \text{V} - 12\ \text{V} = 40\ \text{V}$
$i_C = \dfrac{40\ \text{V}}{18.2\ \text{k}\Omega}e^{-t/123.8\ \text{ms}}$
$= \mathbf{2.198\ mA}e^{-t/123.8\ \text{ms}}$

b.





29. $i_C = \underbrace{\dfrac{1}{2}\dfrac{E}{R}}_{\frac{1}{2}I_m} = \underbrace{\dfrac{E}{R}}_{I_m}e^{-t/\tau}$

$\dfrac{1}{2} = e^{-t/\tau} \Rightarrow \log_e \dfrac{1}{2} = -t/\tau \Rightarrow t = -\tau \log_e \dfrac{1}{2}$

$t = -2 \times 10^{-6} \log_e \dfrac{1}{2}$
$= -(2 \times 10^{-6})(-0.693)$
$= \mathbf{1.386\ \mu s}$

31. Eq. 10.23:

$$t = -\tau \log_e \left[1 - \frac{v_C}{E}\right]$$

$$10\ \text{s} = -\tau \underbrace{\log_e \underbrace{\left[1 - \frac{12\ \text{V}}{20\ \text{V}}\right]}_{.04}}_{-0.9163}$$

$$\tau = \frac{10\ \text{s}}{0.9163} = 10.913\ \text{s}$$

$$\tau = RC \Rightarrow R = \frac{\tau}{C} = \frac{10.913\ \text{s}}{200\ \mu\text{F}} = \mathbf{54.567\ k\Omega}$$

33. a. $\tau = RC = (1\ \text{M}\Omega)(0.2\ \mu\text{F}) = 0.2\ \text{s}$

$v_C = \mathbf{60(1 - e^{-t/0.2s})}$

$i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{60\ \text{V}}{1\ \text{M}\Omega}e^{-t/0.2\text{s}} = \mathbf{60 \times 10^{-6}e^{-t/0.2s}}$

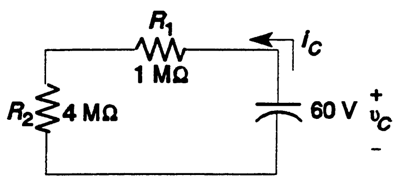
$v_{R_1} = Ee^{-t/\tau} = \mathbf{60e^{-t/0.2s}}$

v_C: 0.5 s = **55.07 V**
1 s = **59.576 V**

i_C: 0.5 s = **4.93 μA**
1 s = **0.404 μA**

v_{R_1}: 0.5 s = **4.93 V**
1 s = **0.404 V**

b.



$\tau' = RC = (1\ \text{M}\Omega + 4\ \text{M}\Omega)(0.2\ \mu\text{F})$
$= (5\ \text{M}\Omega)(0.2\ \mu\text{F})$
$= 1\ \text{s}$

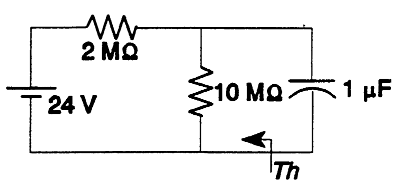
$i_C = \dfrac{60\ \text{V}}{5\ \text{M}\Omega}e^{-t} = 12 \times 10^{-6}e^{-t}$

$8 \times 10^{-6} = 12 \times 10^{-6}e^{-t}$
$0.667 = e^{-t}$
$\log_e 0.667 = -t$
$-0.405 = -t$
$t = \mathbf{0.405\ s}$

$v_C = 60e^{-t/\tau'}$
$10 = 60e^{-t}$
$0.1667 = e^{-t}$
$\log_e 0.1667 = -t$
$-1.792 = -t$
$t = 1.792\ \text{s}$

Longer = 1.792 s − 0.405 s = **1.387 s**

35. a.



$R_{Th} = 2\ \text{M}\Omega \parallel 10\ \text{M}\Omega = 1.667\ \text{M}\Omega$

$E_{Th} = \dfrac{10\ \text{M}\Omega(24\ \text{V})}{10\ \text{M}\Omega + 2\ \text{M}\Omega} = 20\ \text{V}$

$v_C = E_{Th}(1 - e^{-t/\tau})$
$= 20\ \text{V}(1 - e^{-4\tau/\tau})$
$= 20\ \text{V}(1 - e^{-4})$
$= 20\ \text{V}(1 - 0.0183)$
$= \mathbf{19.634\ V}$

$$\tau = R_{Th}C = (1.667\ \text{M}\Omega)(1\ \mu\text{F}) = 1.667\ \text{s}$$

$$i_C = \frac{E}{R}e^{-t/\tau}$$

$$3\ \mu\text{A} = \frac{20\ \text{V}}{1.667\ \text{M}\Omega}e^{-t/1.667\text{s}}$$

$$0.25 = e^{-t/1.667\text{s}}$$

$$\log_e 0.25 = -t/1.667\ \text{s}$$

$$t = -(1.667\ \text{s})(-1.386)$$

$$= \mathbf{2.31\ s}$$

c.

$$v_{\text{meter}} = v_C$$

$$v_C = E_{Th}(1 - e^{-t/\tau})$$

$$10\ \text{V} = 20\ \text{V}(1 - e^{-t/1.667\text{s}})$$

$$0.5 = 1 - e^{-t/1.667\text{s}}$$

$$-0.5 = -e^{-t/1.667\text{s}}$$

$$\log_e 0.5 = -t/1.667\ \text{s}$$

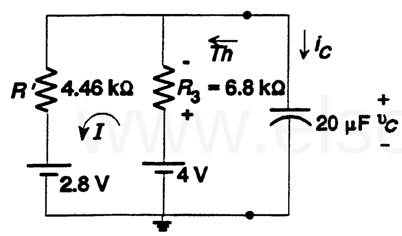
$$t = -(1.667\ \text{s})(-0.693)$$

$$= \mathbf{1.155\ s}$$

37. a. Source conversion:

$$E = IR_1 = (5\ \text{mA})(0.56\ \text{k}\Omega) = 2.8\ \text{V}$$

$$R' = R_1 + R_2 = 0.56\ \text{k}\Omega + 3.9\ \text{k}\Omega = 4.46\ \text{k}\Omega$$



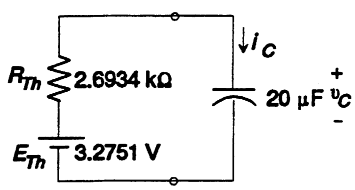
$$R_{Th} = 4.46\ \text{k}\Omega \parallel 6.8\ \text{k}\Omega = 2.6934\ \text{k}\Omega$$

$$I = \frac{4\text{V} - 2.8\ \text{V}}{6.8\ \text{k}\Omega + 4.46\ \text{k}\Omega} = \frac{1.2\ \text{V}}{11.26\ \text{k}\Omega} = 0.1066\ \text{mA}$$

$$E_{Th} = 4\ \text{V} - (0.1066\ \text{mA})(6.8\ \text{k}\Omega)$$

$$= 4\ \text{V} - 0.7249\ \text{V}$$

$$= 3.2751\ \text{V}$$



$$v_C = 3.2751(1 - e^{-t/\tau})$$

$$\tau = RC = (2.6934\ \text{k}\Omega)(20\ \mu\text{F})$$

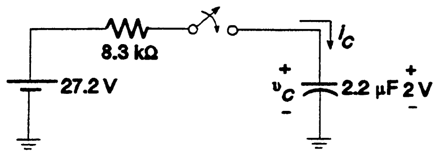
$$= 53.87\ \text{ms}$$

$$v_C = \mathbf{3.2751(1 - e^{-t/53.87\ ms})}$$

$$i_C = \frac{3.2751\ \text{V}}{2.6934\ \text{k}\Omega}e^{-t/\tau}$$

$$= \mathbf{1.216 \times 10^{-3}e^{-t/53.87\ ms}}$$

39. a. Source conversion:



$\tau = RC = (8.3\text{ k}\Omega)(2.2\ \mu\text{F}) = 18.26\text{ ms}$

$v_C = V_f + (V_i - V_f)e^{-t/\tau}$

$= 27.2\text{ V} + (2\text{ V} - 27.2\text{ V})e^{-t/18.26\text{ ms}}$

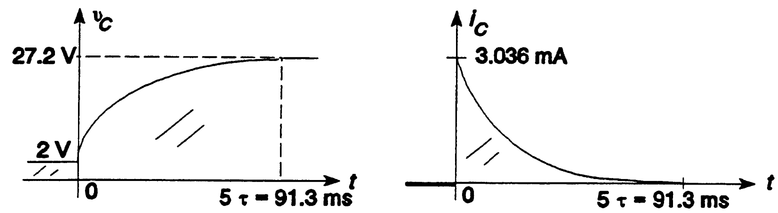
$v_C = \mathbf{27.2\ V - 25.2\ V}e^{-t/18.26\text{ ms}}$

$v_R(0+) = 27.2\text{ V} - 2\text{ V} = 25.2\text{ V}$

$i_C = \dfrac{25.2\text{ V}}{8.3\text{ k}\Omega}e^{-t/18.26\text{ ms}}$

$i_C = \mathbf{3.036\ mA}e^{-t/18.26\text{ ms}}$

b.



41. $i_C = C\dfrac{\Delta V}{\Delta t}$: $i_C = 0.06 \times 10^{-6}\dfrac{\Delta V}{\Delta t}$

0 – 4 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{20\text{ V}}{4\text{ ms}}\right] = 0.3\text{ mA}$

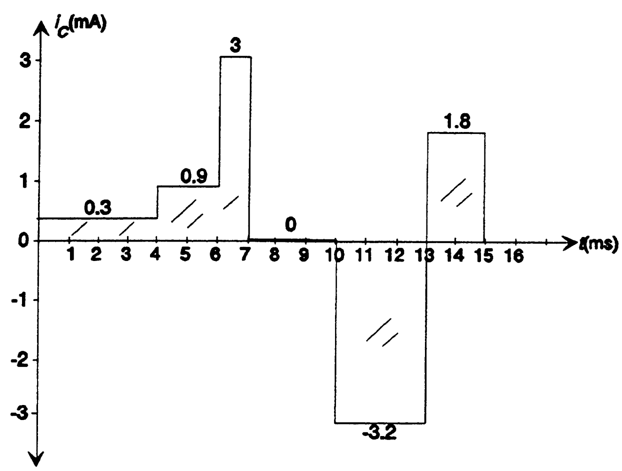
4 – 6 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{30\text{ V}}{2\text{ ms}}\right] = 0.9\text{ mA}$

6 – 7 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{50\text{ V}}{1\text{ ms}}\right] = 3\text{ mA}$

7 – 10 ms: $i_C = 0\text{ mA}$

10 – 13 ms: $i_C = -0.06 \times 10^{-6}\left[\dfrac{160\text{ V}}{3\text{ ms}}\right] = -3.2\text{ mA}$

13 – 15 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{60\text{ V}}{2\text{ ms}}\right] = 1.8\text{ mA}$



43. $i_C = C\dfrac{\Delta V_C}{\Delta t} \Rightarrow \Delta V_C = \dfrac{\Delta t}{C}(i_C)$

$0 - 4$ ms: $i_C = 0$ mA, $\Delta V_C = 0$ V

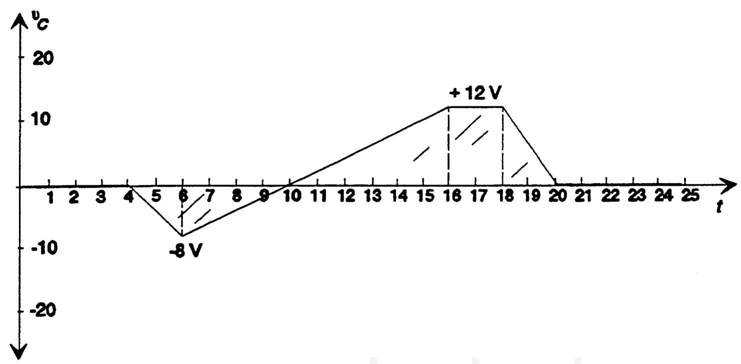
$4 - 6$ ms: $i_C = -80$ mA, $\Delta V_C = \dfrac{(2\text{ ms})}{20\ \mu\text{F}}(-80\text{ mA}) = -8$ V

$6 - 16$ ms: $i_C = +40$ mA, $\Delta V_C = \dfrac{(10\text{ ms})}{20\ \mu\text{F}}(40\text{ mA}) = +20$ V

$16 - 18$ ms: $i_C = 0$ mA, $\Delta V_C = 0$ V

$18 - 20$ ms: $i_C = -120$ mA, $\Delta V_C = \dfrac{(2\text{ ms})}{20\ \mu\text{F}}(-120\text{ mA}) = -12$ V

$20 - 25$ ms: $i_C = 0$ mA, $\Delta V_C = 0$ V



45. $V_1 = \mathbf{10}$ **V**, $Q_1 = C_1V_1 = (6\ \mu\text{F})(10\text{ V}) = \mathbf{60\ \mu C}$
$Q_2 = Q_3 = C_TV = (4\ \mu\text{F})(10\text{ V}) = \mathbf{40\ \mu C}$
$V_2 = Q_2/C_2 = 40\ \mu\text{C}/6\ \mu\text{F} = \mathbf{6.67\ V}$
$V_3 = Q_3/C_3 = 40\ \mu\text{C}/12\ \mu\text{F} = \mathbf{3.33\ V}$

47. a. $C_T = \dfrac{(8\ \mu\text{F})(24\ \mu\text{F})}{8\ \mu\text{F} + 24\ \mu\text{F}} = 6\ \mu\text{F}$

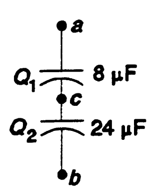
$\tau = RC = (20\text{ k}\Omega)(6\ \mu\text{F}) = 120$ ms

$v_{ab} = v_{C_T} = 100(1 - e^{-t/120\text{ms}})$

At $t = 100$ ms

$$v_{ab} = 100\left[1 - e^{-\frac{100\text{ms}}{120\text{ms}}}\right] = 100(1 - e^{-0.833})$$
$$= 100(.5654) = \mathbf{56.54\ V}$$

b, c.



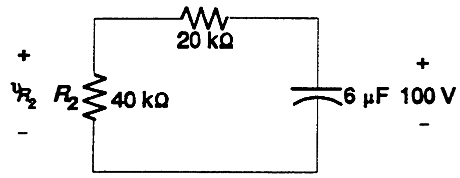
$Q_1 = Q_2 = C_TV_{ab} = (6\ \mu\text{F})(56.54\text{ V}) = 339.24\ \mu\text{C}$
$C_1V_1 = C_2V_2$
$8\ \mu\text{F}\ V_{ac} = 24\ \mu\text{F}\ V_{cb} = 339.24\ \mu\text{C}$

and $V_{ac} = \dfrac{339.24\ \mu\text{C}}{8\ \mu\text{F}} = \mathbf{42.405\ V}$

$V_{cb} = \dfrac{339.24\ \mu\text{C}}{24\ \mu\text{F}} = \mathbf{14.135\ V}$

d. $V_{da} = E - V_{ab} = 100\text{ V} - 56.54\text{ V} = \mathbf{43.46\text{ V}}$

e.



$$i_C = \frac{E}{R_T}e^{-t/\tau},\ \tau = RC = (60\text{ k}\Omega)(6\ \mu\text{F}) = 360\text{ ms}$$

$$i_C = \frac{100\text{ V}}{60\text{ k}\Omega}e^{-t/360\text{ms}} = 1.667 \times 10^{-3}e^{-t/360\text{ms}}$$

$$v_{R_2} = i_C R_2 = (1.667\text{ mA})(40\text{ k}\Omega)e^{-t/360\text{ms}}$$

$$= 66.67e^{-t/360\text{ms}}$$

$$20 = 66.67e^{-t/360\text{ms}} \Rightarrow\quad 0.3 = e^{-t/360\text{ms}}$$

$$\log_e 0.3 = -t/360\text{ ms}$$

$$-1.204 = -t/360\text{ ms}$$

$$t = 1.204(360\text{ ms})$$

$$= \mathbf{433.44\text{ ms}}$$

49. $W_C = \frac{1}{2}CV^2 = \frac{1}{2}(120\text{ pF})(12\text{ V})^2 = \mathbf{8{,}640\text{ pJ}}$

51. a. $W_C = \frac{1}{2}CV^2 = \frac{1}{2}(1000\ \mu\text{F})(100\text{ V})^2 = \mathbf{5\text{ J}}$

b. $Q = CV = (1000\ \mu\text{C})(100\text{ V}) = \mathbf{0.1\text{ C}}$

c. $I = Q/t = 0.1\text{ C}/(1/2000) = \mathbf{200\text{ A}}$

d. $P = V_{av}I_{av} = W/t = 5\text{ J}/(1/2000\text{ s}) = \mathbf{10{,}000\text{ W}}$

e. $t = Q/I = 0.1\text{ C}/10\text{ mA} = \mathbf{10\text{ s}}$

CHAPTER 10 (Even)

2. $\mathscr{E} = \dfrac{kQ}{r^2} \Rightarrow r = \sqrt{\dfrac{kQ}{\mathscr{E}}} = \sqrt{\dfrac{(9 \times 10^9)(0.064\ \mu\text{C})}{36\ \text{N/C}}} = \mathbf{4\ m}$

4. $Q = CV = (0.05\ \mu\text{F})(45\ \text{V}) = \mathbf{2.25\ \mu C}$

6. $d = 4\ \cancel{\text{mils}}\left[\dfrac{10^{-3}\ \cancel{\text{in.}}}{1\ \cancel{\text{mil}}}\right]\left[\dfrac{1\ \text{m}}{39.37\ \cancel{\text{in.}}}\right] = 0.102\ \text{mm}$

$\mathscr{E} = \dfrac{V}{d} = \dfrac{100\ \text{mV}}{0.102\ \text{mm}} = \mathbf{980.39\ V/m}$

8. $C = 8.85 \times 10{-}12\epsilon_r\dfrac{A}{d} = 8.85 \times 10^{-12}(1)\dfrac{(0.075\ \text{m}^2)}{1.77\ \text{mm}} = \mathbf{375\ pF}$

10. $C = 8.85 \times 10^{-12}\epsilon_r\dfrac{A}{d} \Rightarrow d = \dfrac{8.85 \times 10^{-12}(4)(0.09\ \text{m}^2)}{2\ \mu\text{F}} = \mathbf{1.593\ \mu m}$

12. a. $C = 8.85 \times 10^{-12}(1)\dfrac{(0.08\ \text{m}^2)}{0.2\ \text{mm}} = \mathbf{3.54\ nF}$

b. $\mathscr{E} = \dfrac{V}{d} = \dfrac{200\ \text{V}}{0.2\ \text{mm}} = 10^6\ \text{V/m}$

c. $Q = CV = (3.54\ \text{nF})(200\ \text{V}) = \mathbf{0.708\ \mu C}$

14. #12: $0.2 \times 10^{-3}\ \cancel{\text{m}}\left[\dfrac{39.37\ \cancel{\text{in.}}}{1\ \cancel{\text{m}}}\right]\left[\dfrac{1\ \text{mil}}{10^{-3}\ \cancel{\text{in.}}}\right] = 7.874\ \text{mils}$

$\dfrac{75\ \text{V}}{\cancel{\text{mil}}}[7.874\ \cancel{\text{mils}}] = \mathbf{590.55\ V}$

#13: $\dfrac{400\ \text{V}}{\cancel{\text{mil}}}[7.874\ \cancel{\text{mils}}] = \mathbf{3{,}149.60\ V}$

16. mica: $\dfrac{1250\ \text{V}}{\dfrac{5000\ \text{V}}{\text{mil}}} = 1250\ \cancel{\text{V}}\left[\dfrac{\text{mil}}{5000\ \cancel{\text{V}}}\right] = \mathbf{0.25\ mils}$

18. a. $\tau = RC = (10^6\ \Omega)(5\ \mu\text{F}) = 5\ \text{s}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20(1 - e^{-t/5})}$

c. $1\tau = \mathbf{12.64\ V}$, $3\tau = \mathbf{19\ V}$, $5\tau = \mathbf{19.87\ V}$

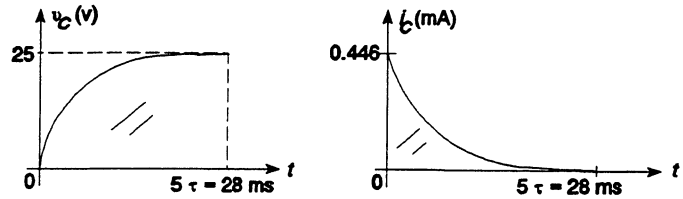
d. $i_C = \dfrac{20\ \text{V}}{1\ \text{M}\Omega}e^{-t/\tau} = \mathbf{20 \times 10^{-6}e^{-t/5}}$
$v_R = Ee^{-t/\tau} = \mathbf{20e^{-t/5}}$

e. Same as 17 with $5\tau = 25$ s and $I_m = 20\ \mu\text{A}$

20. a. $\tau = RC = (56\text{ k}\Omega)(0.1\ \mu\text{F}) = \mathbf{5.6\ ms}$ b. $v_C = E(1 - e^{-t/\tau}) = 25(1 - e^{-t/5.6\text{ms}})$

c. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{25\text{ V}}{56\text{ k}\Omega}e^{-t/\tau} = \mathbf{0.446 \times 10^{-3}e^{-t/5.6ms}}$

d.



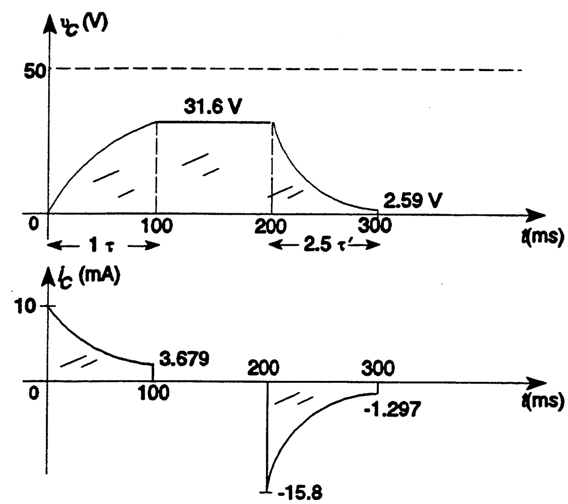
22. a. $\tau = RC = (5\text{ k}\Omega)(20\ \mu\text{F}) = \mathbf{100\ ms}$ b. $v_C = \mathbf{50(1 - e^{-t/100ms})}$

c. $i_C = \mathbf{10 \times 10^{-3}e^{-t/100ms}}$

d. $v_C = 50(1 - e^{-1}) = 50(1 - 0.3679) = 50(0.6321) = \mathbf{31.6\ V}$
$i_C = 10 \times 10^{-3}e^{-1} = 10 \times 10^{-3}(0.3679) = \mathbf{3.679\ mA}$

e. $\tau' = RC = (2\text{ k}\Omega)(20\ \mu\text{F}) = 40\text{ ms}$
$v_C = \mathbf{31.6e^{-t/40ms}}$
$i_C = \dfrac{31.6\text{ V}}{2\text{ k}\Omega}e^{-t/40\text{ms}} = \mathbf{15.8 \times 10^{-3}e^{-t/40ms}}$

f. At $t = 2.5\ \tau'$ (from 200 ms) → at 300 ms
$v_C = 31.6e^{-2.5} = 31.6(0.0821) = 2.59\text{ V}$
$i_C = 15.8 \times 10^{-3}e^{-2.5} = 1.297\text{ mA}$

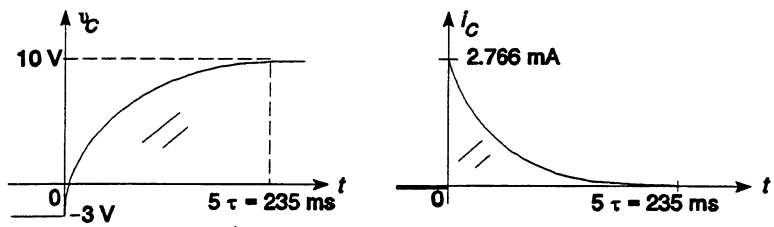


24. $\tau = RC = (2.2\text{ k}\Omega)(2000\ \mu\text{F}) = 4.4\text{ s}$
$v_C = V_C e^{-t/\tau} = \mathbf{40e^{-t/4.4}}$
$i_C = \dfrac{V_C}{R}e^{-t/\tau} = \dfrac{40\text{ V}}{2.2\text{ k}\Omega}e^{-t/4.4} = \mathbf{18.18 \times 10^{-3}e^{-t/4.4}}$
$v_R = v_C = \mathbf{40e^{-t/4.4}}$

26. a. $\tau = RC = (4.7\text{ k}\Omega)(10\ \mu\text{F}) = 47\text{ ms}$

$$v_C = V_f + (V_i - V_f)e^{-t/\tau}$$
$$= 10\text{ V} + (-3\text{ V} - 10\text{ V})e^{-t/47\text{ ms}}$$
$$v_C = \mathbf{10\ V - 13\ V}e^{-t/47\text{ ms}}$$
$$v_R(0+) = 10\text{ V} + 3\text{ V} = 13\text{ V}$$
$$i_C = \frac{13\text{ V}}{4.7\text{ k}\Omega}e^{-t/47\text{ ms}} = \mathbf{2.766\ mA}e^{-t/47\text{ ms}}$$

b.



28. a. $V_C = 8(1 - e^{-5\tau/\tau}) = 8(1 - e^{-5}) = 8(1 - 0.00674) = \mathbf{7.946\ V}$

b. $V_C = 8(1 - e^{-10}) = 8(1 - 0.0000454) = \mathbf{7.996\ V}$

c. $V_C = 8(1 - e^{-5\times10^{-6}/20\times10^{-6}}) = 8(1 - e^{-0.25}) = 8(1 - 0.7788) = \mathbf{1.7696\ V}$

30. $\tau = RC = (33\text{ k}\Omega)(20\ \mu\text{F}) = 0.66\text{ s}$

$$v_C = 12(1 - e^{-t/0.66})$$
$$8 = 12(1 - e^{-t/0.66})$$
$$8 = 12 - 12e^{-t/0.66}$$
$$-4 = -12e^{-t/0.66}$$
$$0.333 = e^{-t/0.66}$$
$$\log_e 0.333 = -t/0.66$$
$$-1.0996 = -t/0.66$$
$$t = 1.0996(0.66) = \mathbf{0.726\ s}$$

32. a. $\tau = (R_1 + R_2)C = (20\text{ k}\Omega)(6\ \mu\text{F}) = 0.12\text{ s}$

$$v_C = E(1 - e^{-t/\tau})$$
$$60\text{ V} = 80\text{ V}(1 - e^{-t/0.12\text{s}})$$
$$0.75 = 1 - e^{-t/0.12\text{s}}$$
$$0.25 = e^{-t/0.12\text{s}}$$
$$t = -(0.12\text{ s})(-1.386)$$
$$= \mathbf{0.166\ s}$$

b. $i_C = \dfrac{E}{R}e^{-t/\tau}$

$$i_C = \frac{80\text{ V}}{20\text{ k}\Omega}e^{-\frac{0.166\text{s}}{0.12\text{s}}} = 4\text{ mA }e^{-1.383}$$
$$= (4\text{ mA})(0.2508)$$
$$\cong \mathbf{1\ mA}$$

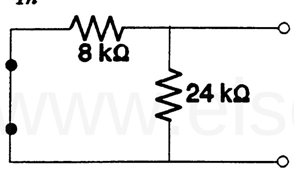
c. $i_s = i_C = 4 \text{ mA } e^{-t/\tau} = 4 \text{ mA } e^{-2\tau/\tau} = 4 \text{ mA } e^{-2}$
$= 4 \text{ mA}(0.1353)$
$= 0.541 \text{ mA}$
$P_s = EI_s = (80 \text{ V})(0.541 \text{ mA})$
$= \mathbf{43.28 \text{ mW}}$

34. a. $v_m = v_R = Ee^{-t/\tau} = 60 \text{ V } e^{-1\tau/\tau} = 60 \text{ V } e^{-1}$
$= 60 \text{ V}(0.3679)$
$= \mathbf{22.074 \text{ V}}$

b. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{60 \text{ V}}{10 \text{ M}\Omega}e^{-2\tau/\tau} = 6\ \mu\text{A } e^{-2}$
$= 6\ \mu\text{A}(0.1353)$
$= \mathbf{0.812\ \mu A}$

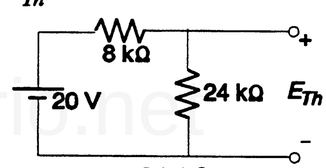
c. $v_C = E(1 - e^{-t/\tau})$ $\qquad \tau = RC = (10 \text{ M}\Omega)(0.2\ \mu\text{F}) = 2 \text{ s}$
$50 \text{ V} = 60 \text{ V}(1 - e^{-t/2s})$
$0.8333 = 1 - e^{-t/2s}$
$\log_e 0.1667 = -t/2s$
$t = -(2s)(-1.792)$
$= \mathbf{3.584 \text{ s}}$

36. a. Thevenin's theorem:
R_{Th}:

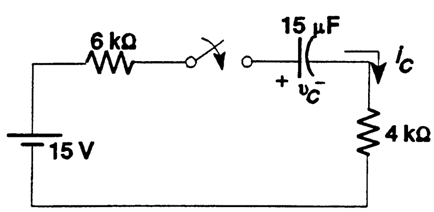


$\leftarrow R_{Th} = 8 \text{ k}\Omega \parallel 24 \text{ k}\Omega$
$= 6 \text{ k}\Omega$

E_{Th}:



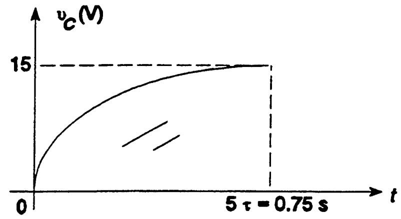
$E_{Th} = \dfrac{24 \text{ k}\Omega(20 \text{ V})}{24 \text{ k}\Omega + 8 \text{ k}\Omega} = 15 \text{ V}$

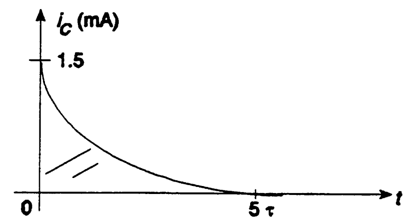


$\tau = RC = (10 \text{ k}\Omega)(15\ \mu\text{F}) = 0.15 \text{ s}$
$v_C = E(1 - e^{-t/\tau})$
$= \mathbf{15(1 - e^{-t/0.15})}$

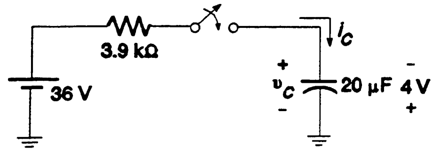
$i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{15 \text{ V}}{10 \text{ k}\Omega}e^{-t/0.15} = \mathbf{1.5 \times 10^{-3}e^{-t/0.15}}$

b.





38. a. $R_{Th} = 3.9\text{ k}\Omega + 0\ \Omega \parallel 1.8\text{ k}\Omega = 3.9\text{ k}\Omega$
$E_{Th} = 36\text{ V}$



$\tau = RC = (3.9\text{ k}\Omega)(20\ \mu\text{F}) = 78\text{ ms}$

$v_C = V_f + (V_i - V_f)e^{-t/\tau}$

$= 36\text{ V} + (-4\text{ V} - 36\text{ V})e^{-t/78\text{ ms}}$

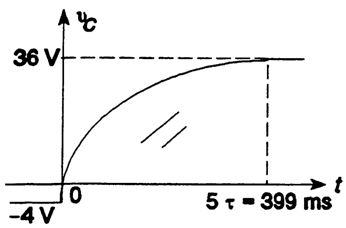
$\mathbf{v_C = 36\text{ V} - 40\text{ V}e^{-t/78\text{ ms}}}$

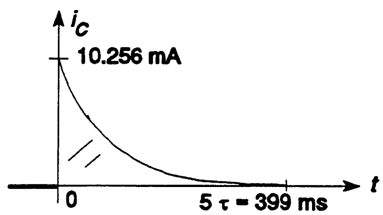
$v_R(0+) = 36\text{ V} + 4\text{ V} = 40\text{ V}$

$i_C = \dfrac{40\text{ V}}{3.9\text{ k}\Omega}e^{-t/78\text{ ms}}$

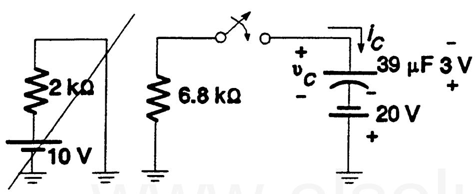
$\mathbf{i_C = 10.256\text{ mA}e^{-t/78\text{ ms}}}$

b.





40. a.



$\tau = RC = (6.8\text{ k}\Omega)(39\ \mu\text{F}) = 265.2\text{ ms}$

$v_C = V_f + (V_i - V_f)e^{-t/\tau}$

$= 20\text{ V} + (3\text{ V} - 20\text{ V})e^{-t/265.2\text{ ms}}$

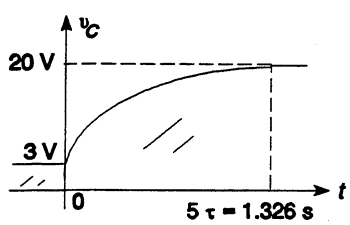
$\mathbf{v_C = 20\text{ V} - 17\text{ V}e^{-t/265.2\text{ ms}}}$

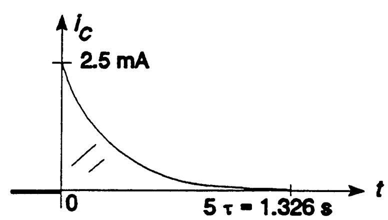
$v_R(0+) = 20\text{ V} - 3\text{ V} = 17\text{ V}$

$i_C = \dfrac{17\text{ V}}{6.8\text{ k}\Omega}e^{-t/265.2\text{ ms}}$

$\mathbf{i_C = 2.5\text{ mA}e^{-t/265.2\text{ ms}}}$

b.





42. $i_C = C\dfrac{\Delta V}{\Delta t} = 0.06 \times 10^{-6}\ \dfrac{\Delta V}{\Delta t}$

$0 \rightarrow 2\ \mu\text{s}$: $\quad i_C = 0.06 \times 10^{-6}\left[\dfrac{3\text{ V}}{2\ \mu\text{s}}\right] = 90\text{ mA}$

$2 \rightarrow 4\ \mu\text{s}$: $\quad i_C = -0.06 \times 10^{-6}\left[\dfrac{6\text{ V}}{2\ \mu\text{s}}\right] = -180\text{ mA}$

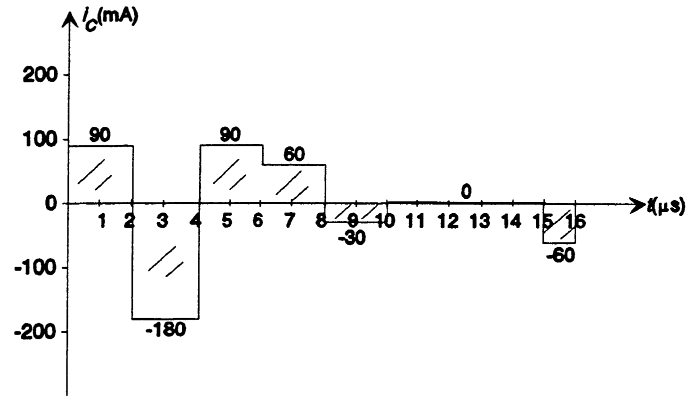
$4 \rightarrow 6\ \mu\text{s}$: $\quad i_C = 0.06 \times 10^{-6}\left[\dfrac{3\text{ V}}{2\ \mu\text{s}}\right] = 90\text{ mA}$

$6 \rightarrow 8\ \mu\text{s}$: $\quad i_C = 0.06 \times 10^{-6}\left[\dfrac{2\text{ V}}{2\ \mu\text{s}}\right] = 60\text{ mA}$

$8 \rightarrow 10\ \mu s$: $i_C = -0.06 \times 10^{-6}\left[\frac{1\ V}{2\ \mu s}\right] = -30\ mA$

$10 \rightarrow 15\ \mu s$: $i_C = 0\ mA$

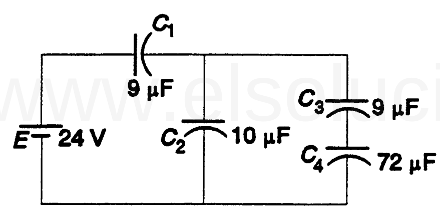
$15 \rightarrow 16\ \mu s$: $i_C = -0.06 \times 10^{-6}\left[\frac{1\ V}{1\ \mu s}\right] = -60\ mA$



44. a. $C_T = 0.2\ \mu F \parallel (2\ \mu F + 7\ \mu F) = \mathbf{0.1957\ \mu F}$

b. $C_T = 20\ pF + 60\ pF \parallel (10\ pF + 30\ pF) = \mathbf{44\ pF}$

46. a.

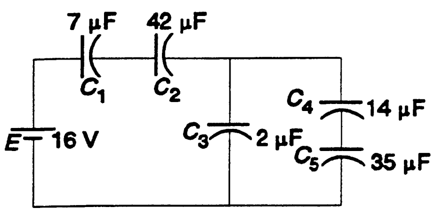


$$\frac{(9\ \mu F)(72\ \mu F)}{9\ \mu F + 72\ \mu F} = 8\ \mu F$$
$$8\ \mu F + 10\ \mu F = 18\ \mu F$$
$$\frac{(9\ \mu F)(18\ \mu F)}{9\ \mu F + 18\ \mu F} = 6\ \mu F$$

$$C_T = \frac{Q}{V} = \frac{Q}{E} \Rightarrow Q = C_T E = (6\ \mu F)(24\ V) = 144\ \mu C$$

$$Q_1 = \mathbf{144\ \mu C}$$
$$V_1 = \frac{Q_1}{C_1} = \frac{144\ \mu C}{9\ \mu F} = \mathbf{16\ V}$$
$$V_2 = E - V_1 = 24\ V - 16\ V = \mathbf{8\ V}$$
$$Q_2 = C_2V_2 = 10\ \mu F(8\ V) = \mathbf{80\ \mu C}$$
$$Q_{3-4} = C'V = (8\ \mu F)(8\ V) = 64\ \mu C$$
$$Q_3 = Q_4 = \mathbf{64\ \mu C}$$
$$V_3 = \frac{Q_3}{V_3} = \frac{64\ \mu C}{9\ \mu F} = \mathbf{7.111\ V}$$
$$V_4 = \frac{Q_4}{V_4} = \frac{64\ \mu C}{72\ \mu F} = \mathbf{0.889\ V}$$

b.



$$\frac{(14\ \mu F)(35\ \mu F)}{14\ \mu F + 35\ \mu F} = 10\ \mu F$$
$$2\ \mu F + 10\ \mu F = 12\ \mu F$$
$$\frac{(7\ \mu F)(42\ \mu F)}{7\ \mu F + 42\ \mu F} = 6\ \mu F$$
$$C_T = \frac{(6\ \mu F)(12\ \mu F)}{6\ \mu F + 12\ \mu F} = 4\ \mu F$$

$$Q = CV = (4\ \mu F)(16\ V) = 64\ \mu C$$
$$Q_1 = Q_2 = \mathbf{64\ \mu C}$$
$$V_1 = \frac{Q_1}{C_1} = \frac{64\ \mu C}{7\ \mu F} = \mathbf{9.143\ V}$$
$$V_2 = \frac{Q_2}{C_2} = \frac{64\ \mu C}{42\ \mu F} = \mathbf{1.524\ V}$$
$$V_3 = E - V_1 - V_2 = 16\ V - 9.143\ V - 1.524\ V = \mathbf{5.333\ V}$$
$$Q_3 = C_3V_3 = (2\ \mu F)(5.333\ V) = 10.667\ \mu C$$
$$Q' = CV = (10\ \mu F)(5.333\ V) = 53.33\ \mu C$$
$$Q_4 = Q_5 = \mathbf{53.33\ \mu C}$$
$$V_4 = \frac{Q_4}{C_4} = \frac{53.33\ \mu C}{14\ \mu F} = \mathbf{3.809\ V}$$
$$V_5 = \frac{Q_5}{C_5} = \frac{53.33\ \mu C}{35\ \mu F} = \mathbf{1.524\ V}$$

48. a. $V_{4k\Omega} = \dfrac{4\ k\Omega(48\ V)}{4\ k\Omega + 2\ k\Omega} = \mathbf{32\ V} = V_{0.08\mu F}$

$Q_{0.08\mu F} = (0.08\ \mu F)(32\ V) = \mathbf{2.56\ \mu C}$

$V_{0.04\mu F} = \mathbf{48\ V}$

$Q_{0.04\mu F} = (0.04\ \mu F)(48\ V) = \mathbf{1.92\ \mu C}$

b. $V_{6k\Omega} = \dfrac{6\ k\Omega(80\ V)}{6\ k\Omega + 4\ k\Omega} = \mathbf{48\ V} = V_{60\mu F}$

$Q_{60\mu F} = (60\ \mu F)(48\ V) = \mathbf{2880\ \mu C}$

$V_{40\mu F} = \mathbf{80\ V}$

$Q_{40\mu F} = (40\ \mu F)(80\ V) = \mathbf{3200\ \mu C}$

50. $W = \dfrac{Q^2}{2C} \Rightarrow Q = \sqrt{2CW} = \sqrt{2(6\ \mu F)(1200\ J)} = \mathbf{0.12\ C}$

52. a. $V_{6\mu F} = V_{12\mu F} = \dfrac{3\ k\Omega(24\ V)}{3\ k\Omega + 6\ k\Omega} = 8\ V$

$W_{6\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(6\ \mu F)(8\ V)^2 = \mathbf{0.192\ mJ}$

$W_{12\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(12\ \mu F)(8\ V)^2 = \mathbf{0.384\ mJ}$

b. $C_T = \dfrac{(6\ \mu F)(12\ \mu F)}{6\ \mu F + 12\ \mu F} = 4\ \mu F$

$Q_T = C_T V = (4\ \mu F)(8\ V) = 32\ \mu C$

$Q_{6\mu F} = Q_{12\mu F} = 32\ \mu C$

$V_{6\mu F} = \dfrac{Q}{C} = \dfrac{32\ \mu C}{6\ \mu F} = 5.333\ V$

$V_{12\mu F} = \dfrac{Q}{C} = \dfrac{32\ \mu C}{12\ \mu F} = 2.667\ V$

$W_{6\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(6\ \mu F)(5.333\ V)^2 = \mathbf{85.32\ \mu J}$

$W_{12\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(12\ \mu F)(2.667\ V)^2 = \mathbf{42.68\ \mu J}$

CHAPTER 11 (Odd)

1. Φ: CGS: **5 × 10⁴ Maxwells**, English: **5 × 10⁴ lines**
   B: CGS: **8 Gauss**, English: **51.616 lines/in.²**

3. $B = \dfrac{\Phi}{A} = \dfrac{4 \times 10^{-4}\text{ Wb}}{0.01\text{ m}^2} = \mathbf{0.04\text{ T}}$

5. $\Re = \dfrac{\mathscr{F}}{\Phi} = \dfrac{400\text{ At}}{4.2 \times 10^{-4}\text{ Wb}} = \mathbf{952.4 \times 10^3\text{ At/Wb}}$

7. $6\text{ in.}\left[\dfrac{1\text{ m}}{39.37\text{ in.}}\right] = 0.1524\text{ m}$

   $H = \dfrac{\mathscr{F}}{l} = \dfrac{400\text{ At}}{0.1524\text{ m}} = \mathbf{2624.67\text{ At/m}}$

9. $B = \dfrac{\Phi}{A} = \dfrac{10 \times 10^{-4}\text{ Wb}}{3 \times 10^{-3}\text{ m}^2} = 0.333\text{ T}$
   Fig. 11.23: $H \cong 800\text{ At/m}$
   $NI = Hl \Rightarrow I = Hl/N = (800\text{ At/m})(0.2\text{ m})/75\text{ t} = \mathbf{2.133\text{ A}}$

11. a. $N_1I_1 + N_2I_2 = Hl$

    $B = \dfrac{\Phi}{A} = \dfrac{12 \times 10^{-4}\text{ Wb}}{12 \times 10^{-4}\text{ m}^2} = 1\text{ T}$
    Fig. 11.23: $H \cong 750\text{ At/m}$
    $N_1(2\text{ A}) + 30\text{ At} = (750\text{ At/m})(0.2\text{ m})$
    $N_1 = \mathbf{60\text{ t}}$

    b. $\mu = \dfrac{B}{H} = \dfrac{1\text{ T}}{750\text{ At/m}} = \mathbf{13.34 \times 10^{-4}\text{ Wb/Am}}$

13. $N_1I + N_2I = \underbrace{Hl}_{\text{cast steel}} + \underbrace{Hl}_{\text{cast iron}}$

    $(20\text{ t})I + (30\text{ t})I = $ "
    $(50\text{ t})I = $ "

    $B = \dfrac{\Phi}{A}$ with $0.25\,\cancel{\text{in.}}^2\left[\dfrac{1\text{ m}}{39.37\,\cancel{\text{in.}}}\right]\left[\dfrac{1\text{ m}}{39.37\,\cancel{\text{in.}}}\right] = 1.6 \times 10^{-4}\text{ m}^2$

    $B = \dfrac{0.8 \times 10^{-4}\text{ Wb}}{1.6 \times 10^{-4}\text{ m}^2} = 0.5\text{ T}$
    Fig. 11.24: $H_{\text{cast steel}} \cong 280\text{ At/m}$
    Fig. 11.23: $H_{\text{cast iron}} \cong 1500\text{ At/m}$
    $l_{\text{cast steel}} = 5.5\,\cancel{\text{in.}}\left[\dfrac{1\text{ m}}{39.37\,\cancel{\text{in.}}}\right] = 0.1397\text{ m}$

$$l_{\text{cast iron}} = 2.5\ \cancel{\text{in.}} \left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 0.0635\text{ m}$$

$$(50\text{ t})I = (280\text{ At/m})(0.1397\text{ m}) + (1500\text{ At/m})(0.0635\text{ m})$$
$$50I = 39.12 + 95.25 = 134.37$$
$$I = \mathbf{2.687\ A}$$

15. $4\ \cancel{\text{cm}} \left[\frac{1\text{ m}}{100\ \cancel{\text{cm}}}\right] = 0.04\text{ m}$

$$f = \frac{1}{2}\,NI\frac{d\phi}{dx} = \frac{1}{2}(80\text{ t})(0.9\text{ A})\,\frac{(8\times10^{-4}\text{ Wb} - 0.5\times10^{-4}\text{ Wb})}{\frac{1}{2}(0.04\text{ m})} = \frac{36(7.5\times10^{-4})}{0.02}$$
$$= \mathbf{1.35\ N}$$

17. a. $0.2\ \cancel{\text{cm}} \left[\frac{1\text{ m}}{100\ \cancel{\text{cm}}}\right] = 2\times10^{-3}\text{ m}$

$$A = \frac{\pi d^2}{4} = \frac{(3.14)(0.01\text{ m})^2}{4} = 0.785\times10^{-4}\text{ m}^2$$
$$NI = H_g l_g,\ H_g = 7.96\times10^5\,B_g$$
$$(200\text{ t})I = \left[(7.96\times10^5)\left[\frac{0.2\times10^{-4}\text{ Wb}}{0.785\times10^{-4}\text{ m}^2}\right]\right]2\times10^{-3}\text{ m}$$
$$I = \mathbf{2.028\ A}$$

b. $F = \frac{1}{2}\frac{B_g^2 A}{\mu_o} = \frac{1}{2}\frac{(0.2548\text{ T})^2(0.785\times10^{-4}\text{ m}^2)}{4\pi\times10^{-7}}$

$\cong \mathbf{2\ N}$

19. $NI = Hl$

$l = 2\pi r = (6.28)(0.08\text{ m}) = 0.5024\text{ m}$

$(100\text{ t})(2\text{ A}) = H(0.5024\text{ m})$

$H = 398.09\text{ At/m}$

Fig. 11.24: $B \cong 0.675\text{ T}$

$\Phi = BA = (0.675\text{ T})(0.009\text{ m}^2) = 0.0061\text{ Wb}$

$\mathbf{\Phi = 6.1\times10^{-3}\ Wb}$

21. a. $1\tau = 0.632\ T_{max}$

$T_{max} \cong 1.5\text{ T}$ for cast steel

$0.632(1.5\text{ T}) = 0.945\text{ T}$

At 0.945 T, $H \cong 700\text{ At/m}$ (Fig. 11.21)

$\therefore\ \mathbf{B = 1.5(1 - e^{-H/700\text{ At/m}})}$

b. $H = 900\text{ At/m}$:

$$B = 1.5\left(1 - e^{-\frac{900\text{ At/m}}{700\text{ At/m}}}\right) = \mathbf{1.085\ T}$$

Graph: $\cong$ **1.1 T**

$H = 1800\text{ At/m}$:

$$B = 1.5\left(1 - e^{-\frac{1800\text{ At/m}}{700\text{ At/m}}}\right) = \mathbf{1.385\ T}$$

Graph: $\cong$ **1.38 T**
$H = 2700$ At/m:

$$B = 1.5\left[1 - e^{-\frac{2700\text{ At/m}}{700\text{ At/m}}}\right] = \mathbf{1.468\ T}$$

Graph: $\cong$ **1.47 T**
Excellent comparison!

c. $B = 1.5(1 - e^{-H/700\text{ At/m}}) = 1.5 - 1.5e^{-H/700\text{ At/m}}$

$B - 1.5 = -1.5e^{-H/700\text{ At/m}}$

$1.5 - B = 1.5e^{-H/700\text{ At/m}}$

$$\frac{1.5 - B}{1.5} = e^{-H/700\text{ At/m}}$$

$$\log_e\left[1 - \frac{B}{1.5}\right] = \frac{-H}{700\text{ At/m}}$$

and $H = -700 \log_e\left[1 - \dfrac{B}{1.5}\right]$

d. $B = 1$ T:

$$H = -700 \log_e\left[1 - \frac{1}{1.5}\right] = \mathbf{769.03\ At/m}$$

Graph: $\cong$ **750 At/m**

$B = 1.4$ T:

$$H = -700 \log_e\left[1 - \frac{1.4}{1.5}\right] = \mathbf{1895.64\ At/m}$$

Graph: $\cong$ **1920 At/m**

e. $H = -700 \log_e\left[1 - \dfrac{B}{1.5}\right]$

$= -700 \log_e\left[1 - \dfrac{0.2}{1.5}\right]$

$= 100.2$ At/m

$$I = \frac{Hl}{N} = \frac{(100.2\text{ At/m})(0.16\text{ m})}{400\text{ t}} = \mathbf{40.1\ mA}$$

vs 44 mA for Ex. 11.3

CHAPTER 11 (Even)

2. Φ: SI $\mathbf{6 \times 10^{-4}}$ **Wb**, English **60,000 lines**
   B: SI **0.465 T**, CGS $\mathbf{4.65 \times 10^3}$ **Gauss**, English **30,000 lines/in.^{2}**

4. a. $\Re = \dfrac{l}{\mu A} = \dfrac{0.06 \text{ m}}{\mu 2 \times 10^{-4} \text{ m}^2} = \dfrac{300}{\mu \text{m}}$

   b. $\Re = \dfrac{l}{\mu A} = \dfrac{0.0762 \text{ m}}{\mu 5 \times 10^{-4} \text{ m}^2} = \dfrac{152.4}{\mu \text{m}}$

   c. $\Re = \dfrac{l}{\mu A} = \dfrac{0.1 \text{ m}}{\mu 1 \times 10^{-4} \text{ m}^2} = \dfrac{1000}{\mu \text{m}}$

   from the above $\Re_{(c)} > \Re_{(a)} > \Re_{(b)}$

6. $\Re = \dfrac{\mathscr{F}}{\Phi} = \dfrac{120 \text{ gilberts}}{72{,}000 \text{ maxwells}} = \mathbf{1.667 \times 10^{-3}}$ **rels (CGS)**

8. $\mu = \dfrac{2B}{H} = \dfrac{2(1200 \times 10^{-4} \text{ T})}{600 \text{ At/m}} = \mathbf{4 \times 10^{-4}}$ **Wb/Am**

10. $B = \dfrac{\Phi}{A} = \dfrac{3 \times 10^{-4} \text{ Wb}}{5 \times 10^{-4} \text{ m}^2} = 0.6 \text{ T}$

    Fig. 11.23, $H_{\text{iron}} = 2500$ At/m
    Fig. 11.24, $H_{\text{steel}} = 70$ At/m

    $NI = Hl_{(\text{iron})} + Hl_{(\text{steel})}$

    $(100 \text{ t})I = (H_{\text{iron}} + H_{\text{steel}})l$

    $(100 \text{ t})I = (2500 \text{ At/m} + 70 \text{ At/m})0.3 \text{ m}$

    $I = \dfrac{771 \text{ A}}{100} = \mathbf{7.71 \text{ A}}$

12. a. $80{,}000 \text{ } \cancel{\text{lines}} \left[\dfrac{1 \text{ Wb}}{10^8 \text{ } \cancel{\text{lines}}}\right] = 8 \times 10^4 \times 10^{-8} \text{ Wb} = 8 \times 10^{-4} \text{ Wb}$

    $l_{(\text{cast steel})} = 5.5 \text{ } \cancel{\text{in.}} \left[\dfrac{1 \text{ m}}{39.37 \text{ } \cancel{\text{in.}}}\right] = 0.1397 \text{ m}$

    $l_{(\text{sheet steel})} = 0.5 \text{ } \cancel{\text{in.}} \left[\dfrac{1 \text{ m}}{39.37 \text{ } \cancel{\text{in.}}}\right] = 0.0127 \text{ m}$

    $\text{Area} = 1 \text{ } \cancel{\text{in.}^2} \left[\dfrac{1 \text{ m}}{39.37 \text{ } \cancel{\text{in.}}}\right]\left[\dfrac{1 \text{ m}}{39.37 \text{ } \cancel{\text{in.}}}\right] = 6.45 \times 10^{-4} \text{ m}^2$

    $B = \dfrac{\Phi}{A} = \dfrac{8 \times 10^{-4} \text{ Wb}}{6.45 \times 10^{-4} \text{ m}^2} = 1.24 \text{ T}$

Fig 11.24: $H_{\text{sheet steel}} \cong 460$ At/m, Fig. 11.23: $H_{\text{cast steel}} \cong 1275$ At/m

$$NI = Hl_{(\text{sheet steel})} + Hl_{(\text{cast iron})}$$
$$= (460\text{ At/m})(0.0127\text{ m}) + (1275\text{ At/m})(0.1397\text{ m})$$
$$= 5.842\text{ At} + 178.12\text{ At}$$
$$NI = \mathbf{183.96}$$

b. Cast steel: $\mu = \dfrac{B}{H} = \dfrac{1.24\text{ T}}{1275\text{ At/m}} = \mathbf{9.725 \times 10^{-4}\ Wb/Am}$

Sheet steel: $\mu = \dfrac{B}{H} = \dfrac{1.24\text{ T}}{460\text{ At/m}} = \mathbf{26.96 \times 10^{-4}\ Wb/Am}$

14. a. $l_{ab} = l_{ef} = 0.05\text{ m},\ l_{af} = 0.02\text{ m},\ l_{bc} = l_{de} = 0.0085\text{ m}$

$$NI = 2H_{ab}l_{ab} + 2H_{bc}l_{bc} + H_{fa}l_{fa} + H_gl_g$$
$$B = \frac{\Phi}{A} = \frac{2.4 \times 10^{-4}\text{ Wb}}{2 \times 10^{-4}\text{ m}^2} = 1.2\text{ T} \Rightarrow H \cong 360\text{ At/m} \quad (\text{Fig. 11.24})$$
$$100I = 2(360\text{ At/m})(0.05\text{ m}) + 2(360\text{ At/m})(0.0085\text{ m})$$
$$+ (360\text{ At/m})(0.02\text{ m}) + 7.97 \times 10^5(1.2\text{ T})(0.003\text{ m})$$
$$= 36\text{ At} + 6.12\text{ At} + 7.2\text{ At} + 2869\text{ At}$$
$$100I = 2918.32\text{ At}$$
$$I \cong \mathbf{29.18\ A}$$

b. air gap: metal = 2869 At:49.72 At = **58.17:1**

$$\mu_{\text{sheet steel}} = \frac{B}{H} = \frac{1.2\text{ T}}{360\text{ At/m}} = \mathbf{3.33 \times 10^{-3}\ Wb/Am}$$
$$\mu_{\text{air}} = \mathbf{4\pi \times 10^{-7}\ Wb/Am}$$
$$\mu_{\text{sheet steel}}:\mu_{\text{air}} = 3.33 \times 10^{-3}\text{ Wb/Am}:4\pi \times 10^{-7} \cong \mathbf{2627:1}$$

16. $C = 2\pi r = (6.28)(0.3\text{ m}) = 1.884\text{ m}$

$$B = \frac{\Phi}{A} = \frac{2 \times 10^{-4}\text{ Wb}}{1.3 \times 10^{-4}\text{ m}^2} = 1.538\text{ T}$$

Fig. 11.23: $H_{\text{sheet steel}} \cong 2100$ At/m

$$H_g = 7.97 \times 10^5 B_g = (7.97 \times 10^5)(1.538\text{ T}) = 12.26 \times 10^5\text{ At/m}$$
$$N_1I_1 + N_2I_2 = H_gl_g + Hl_{(\text{sheet steel})}$$
$$(200\text{ t})I_1 + (40\text{ t})(0.3\text{ A}) = (12.26 \times 10^5\text{ At/m})(2\text{ mm}) + (2100\text{ At/m})(1.884\text{ m})$$
$$I_1 = \mathbf{31.98\ A}$$

18. **Table:**

Section	Φ(Wb)	A(m^2)	B(T)	H	l(m)	Hl
a–b, g–h		5×10^{-4}			0.2	
b–c, f–g	2×10^{-4}	5×10^{-4}			0.1	
c–d, e–f	2×10^{-4}	5×10^{-4}			0.099	
a–h		5×10^{-4}			0.2	
b–g		2×10^{-4}			0.2	
d–e	2×10^{-4}	5×10^{-4}			0.002	

$$B_{bc} = B_{cd} = B_g = B_{ef} = B_{fg} = \frac{\Phi}{A} = \frac{2 \times 10^{-4}\ \text{Wb}}{5 \times 10^{-4}\ \text{m}^2} = 0.4\ \text{T}$$

Air gap: $H_g = 7.97 \times 10^5(0.4\ \text{T}) = 3.188 \times 10^5\ \text{At/m}$

$H_g l_g = (3.188 \times 10^5\ \text{At/m})(2\ \text{mm}) = 637.60\ \text{At}$

Fig 11.24: $H_{bc} = H_{cd} = H_{ef} = H_{fg} = 55\ \text{At/m}$

$H_{bc}l_{bc} = H_{fg}l_{fg} = (55\ \text{At/m})(0.1\ \text{m}) = 5.5\ \text{At}$

$H_{cd}l_{cd} = H_{ef}l_{ef} = (55\ \text{At/m})(0.099\ \text{m}) = 5.445\ \text{At}$

For loop 2: $\sum_{\circlearrowleft} \mathscr{F} = 0$

$H_{bc}l_{bc} + H_{cd}l_{cd} + H_g l_g + H_{ef}l_{ef} + H_{fg}l_{fg} - H_{gb}l_{gb} = 0$

$5.5\ \text{At} + 5.445\ \text{At} + 637.60\ \text{At} + 5.445\ \text{At} + 5.50\ \text{At} - H_{gb}l_{gb} = 0$

$H_{gb}l_{gb} = 659.49\ \text{At}$

and $H_{gb} = \dfrac{659.49\ \text{At}}{0.2\ \text{m}} = 3297.45\ \text{At/m}$

Fig 11.23: $B_{gb} \cong 1.55\ \text{T}$

with $\Phi_2 = B_{gb}A = (1.55\ \text{T})(2 \times 10^{-4}\ \text{m}^2) = 3.1 \times 10^{-4}\ \text{Wb}$

$\Phi_T = \Phi_1 + \Phi_2$

$= 2 \times 10^{-4}\ \text{Wb} + 3.1 \times 10^{-4}\ \text{Wb}$

$= 5.1 \times 10^{-4}\ \text{Wb} = \Phi_{ab} = \Phi_{ha} = \Phi_{gh}$

$$B_{ab} = B_{ha} = B_{gh} = \frac{\Phi_T}{A} = \frac{5.1 \times 10^{-4}\ \text{Wb}}{5 \times 10^{-4}\ \text{m}^2} = 1.02\ \text{T}$$

$B-H$ curve: (Fig 11.24):

$H_{ab} = H_{ha} = H_{gh} \cong 180\ \text{At/m}$

$H_{ab}l_{ab} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

$H_{ha}l_{ha} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

$H_{gh}l_{gh} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

which **completes** the table!

Loop #1: $\sum_{\circlearrowleft} \mathscr{F} = 0$

$NI = H_{ab}l_{ab} + H_{bg}l_{bg} + H_{gh}l_{gh} + H_{ah}l_{ah}$

$(200\ \text{t})I = 36\ \text{At} + 659.49\ \text{At} + 36\ \text{At} + 36\ \text{At}$

$(200\ \text{t})I = 767.49\ \text{At}$

$I \cong$ **3.84 A**

20. $NI = H_{ab}(l_{ab} + l_{bc} + l_{de} + l_{ef} + l_{fa}) + H_g l_g$

$300\ \text{At} = H_{ab}(0.7992\ \text{m}) + 7.97 \times 10^5 B_g(0.8\ \text{mm})$

$300\ \text{At} = H_{ab}(0.7992\ \text{m}) + 637.6\, B_g$

Assuming $637.6\, B_g >> H_{ab}(0.7992\ \text{m})$

then $300\ \text{At} = 637.6\, B_g$

and $B_g = 0.471\ \text{T}$

$\Phi = BA = (0.471\ \text{T})(2 \times 10^{-4}\ \text{m}^2) = 0.942 \times 10^{-4}\ \text{Wb}$

$B_{ab} = B_g = 0.471\ \text{T} \Rightarrow H \cong 270\ \text{At/m}$ (Fig. 11.24)

$300\ \text{At} = (270\ \text{At/m})(0.7992\ \text{m}) + 637.6(0.471\ \text{T})$

$300\ \text{At} \neq 516.09\ \text{At}$

$\therefore$ Poor approximation!

$$\frac{300 \text{ At}}{516.09 \text{ At}} \times 100\% \cong 58\%$$

Reduce Φ to 58%

$$0.58(0.942 \times 10^{-4} \text{ Wb}) = 0.546 \times 10^{-4} \text{ Wb}$$

$$B = \frac{\Phi}{A} = \frac{0.546 \times 10^{-4} \text{ Wb}}{2 \times 10^{-4} \text{ m}^2} = 0.273 \text{ T} \Rightarrow H \cong 190 \text{ At/m} \quad \text{(Fig. 11.24)}$$

$300 \text{ At} = (190 \text{ At/m})(0.7992) + 637.6(0.273 \text{ T})$

$300 \text{ At} \neq 325.91$

Reduce Φ another 10% $= 0.546 \times 10^{-4} \text{ Wb} - 0.1(546 \times 10^{-4} \text{ Wb})$
$= 0.491 \times 10^{-4} \text{ Wb}$

$$B = \frac{\Phi}{A} = \frac{0.491 \times 10^{-4} \text{ Wb}}{2 \times 10^{-4} \text{ m}^2} = 0.246 \text{ T} \Rightarrow H \cong 175 \text{ At/m} \quad \text{(Fig. 11.24)}$$

$300 \text{ At} = (175 \text{ At/m})(0.7992) + 637.6(0.273 \text{ T})$

$300 \text{ At} \neq 313.92$ At but within 5% $\therefore$ OK

$\mathbf{\Phi \cong 0.546 \times 10^{-4}}$ **Wb**

CHAPTER 12 (Odd)

1. $e = N\dfrac{d\phi}{dt} = (50\text{ t})(0.085\text{ Wb/s}) = \mathbf{4.25\ V}$

3. $N = \dfrac{e_{\text{ind}}}{\dfrac{d\phi}{dt}} = \dfrac{42\text{ mV}}{3 \times 10^{-3}\text{ Wb/s}} = \mathbf{14\ turns}$

5. $d = 0.25\ \cancel{\text{in.}}\left[\dfrac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{6.35\ mm}$

$A = \dfrac{\pi d^2}{4} = \dfrac{(3.14)(6.35 \times 10^{-3}\text{ m})^2}{4} = 31.65 \times 10^{-6}\text{ m}^2$

$\ell = 4\ \cancel{\text{in.}}\left[\dfrac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 0.1016\text{ m}$

$L = \dfrac{N^2\mu_r\mu_o A}{\ell} = \dfrac{(200\text{ t})^2(1)(4\pi \times 10^{-7})(31.65 \times 10^{-6}\text{ m}^2)}{0.1016\text{ m}} = \mathbf{15.65\ \mu H}$

7. a. $e_L = L\dfrac{di}{dt} = (5\text{ H})(0.5\text{ A/s}) = \mathbf{2.5\ V}$

b. $e_L = (5\text{ H})(60 \times 10^{-3}\text{ A/s}) = \mathbf{0.3\ V}$

c. $e_L = (5\text{ H})(0.04 \times 10^3\text{ A/s}) = \mathbf{200\ V}$

9. $e_L = L\dfrac{\Delta i}{\Delta t}$: $0 - 3$ ms, $e_L = \mathbf{0\ V}$

$3 - 8$ ms, $e_L = (200\text{ mH})\left(\dfrac{40 \times 10^{-3}\text{ A}}{5 \times 10^{-3}\text{ s}}\right) = \mathbf{1.6\ V}$

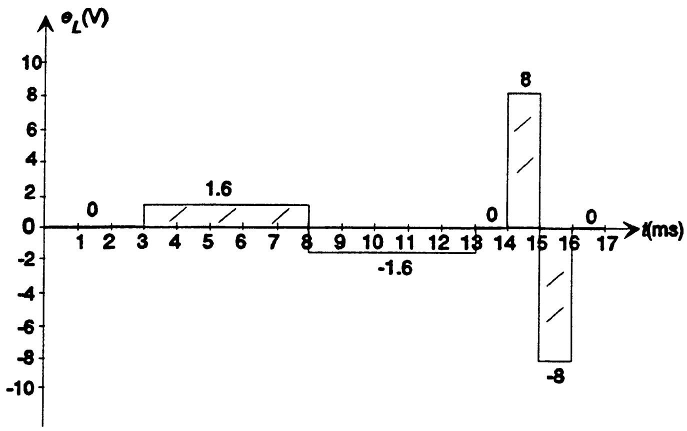
$8 - 13$ ms, $e_L = -(200\text{ mH})\left(\dfrac{40 \times 10^{-3}\text{ A}}{5 \times 10^{-3}\text{ s}}\right) = \mathbf{-1.6\ V}$

$13 - 14$ ms, $e_L = \mathbf{0\ V}$

$14 - 15$ ms, $e_L = (200\text{ mH})\left(\dfrac{40 \times 10^{-3}\text{ A}}{5 \times 10^{-3}\text{ s}}\right) = \mathbf{8\ V}$

$15 - 16$ ms, $e_L = \mathbf{-8\ V}$

$16 - 17$ ms, $e_L = \mathbf{0\ V}$



11. $L = 10$ mH, 4 mA at $t = 0$ s

$$v_L = L\frac{\Delta i}{\Delta t} \Rightarrow \Delta i = \frac{\Delta t}{L}v_L$$

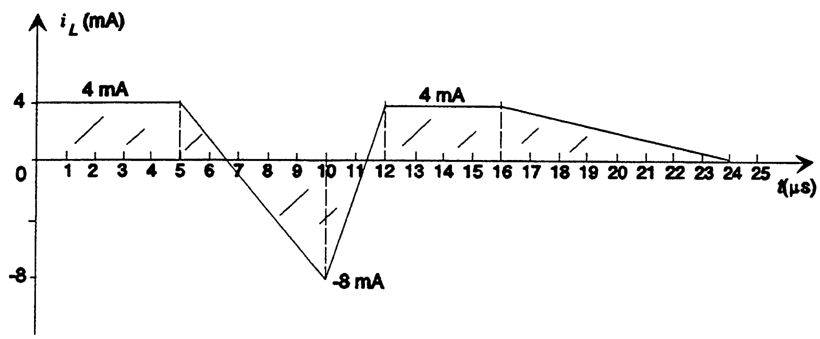
$0 - 5\ \mu s$: $v_L = 0$ V, $\Delta i_L = 0$ mA and $i_L = \mathbf{4\ mA}$

$5 - 10\ \mu s$: $\Delta i_L = \dfrac{5\ \mu s}{10\ mH}(-24\ V) = \mathbf{-12\ mA}$

$10 - 12\ \mu s$: $\Delta i_L = \dfrac{2\ \mu s}{10\ mH}(+60\ V) = \mathbf{+12\ mA}$

$12 - 16\ \mu s$: $v_L = 0$ V, $\Delta i_L = 0$ mA and $i_L = \mathbf{4\ mA}$

$16 - 24\ \mu s$: $\Delta i_L = \dfrac{8\ \mu s}{10\ mH}(-5\ V) = \mathbf{-4\ mA}$



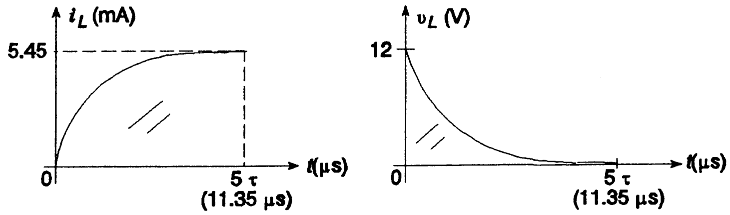
13. a. $\tau = \dfrac{L}{R} = \dfrac{5\ mH}{2.2\ k\Omega} = \mathbf{2.27\ \mu s}$

b. $i_L = \dfrac{E}{R}(1 - e^{-t/\tau}) = \dfrac{12\ V}{2.2\ k\Omega}(1 - e^{-t/\tau}) = \mathbf{5.45 \times 10^{-3}(1 - e^{-t/2.27\ \mu s})}$

c. $v_L = Ee^{-t/\tau} = \mathbf{12e^{-t/2.27\ \mu s}}$
$v_R = i_R R = i_L R = E(1 - e^{-t/\tau}) = \mathbf{12(1 - e^{-t/2.27\ \mu s})}$

d. i_L: $1\tau = \mathbf{3.45\ mA}$, $3\tau = \mathbf{5.179\ mA}$, $5\tau = \mathbf{5.413\ mA}$
v_L: $1\tau = \mathbf{4.415\ V}$, $3\tau = \mathbf{0.598\ V}$, $5\tau = \mathbf{0.081\ V}$

e.



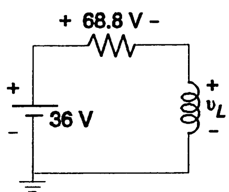
15. a. $\tau = \dfrac{L}{R} = \dfrac{120 \text{ mH}}{4.7 \text{ k}\Omega + 3.9 \text{ k}\Omega} = \dfrac{120 \text{ mH}}{8.6 \text{ k}\Omega} = 13.95\ \mu\text{s}$

$i_L = I_f + (I_i - I_f)e^{-t/\tau}$

$I_f = \dfrac{36 \text{ V}}{8.6 \text{ k}\Omega} = 4.186 \text{ mA}$

$i_L = 4.186 \text{ mA} + (8 \text{ mA} - 4.186 \text{ mA})e^{-t/13.95\ \mu\text{s}}$

$i_L = \mathbf{4.186 \text{ mA} - 3.814 \text{ mA}e^{-t/13.95\ \mu s}}$



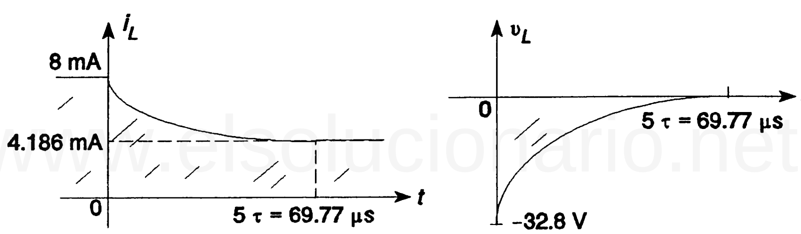
$v_{R_T}(0+) = 8 \text{ mA}(8.6 \text{ k}\Omega) = 68.8 \text{ V}$

KVL: $+36 \text{ V} - 68.8 \text{ V} - v_L = 0$,

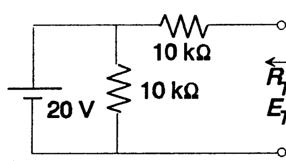
$v_L(0+) = 36 \text{ V} - 68.8 \text{ V} = -32.8 \text{ V}$

$v_L = \mathbf{-32.8 \text{ V}e^{-t/13.95\ \mu s}}$

b.



17. a.



$R_{Th} = 10 \text{ k}\Omega$

$E_{Th} = 20 \text{ V}$

$\tau = \dfrac{L}{R} = \dfrac{10 \text{ mH}}{10 \text{ k}\Omega} = 1\ \mu\text{s}$

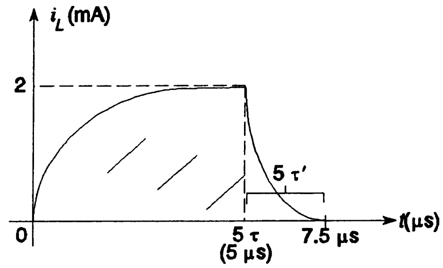
$v_L = \mathbf{20e^{-t/1\ \mu s}}$, $i_L = \dfrac{E}{R}(1 - e^{-t/\tau}) = \mathbf{2 \times 10^{-3}(1 - e^{-t/1\ \mu s})}$

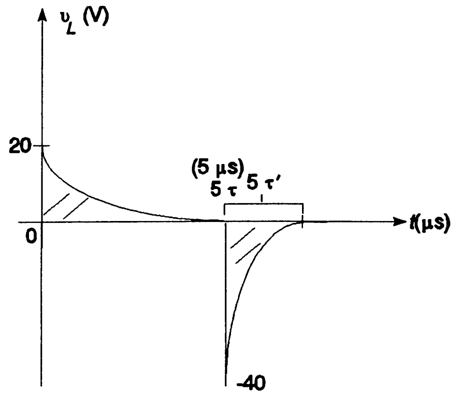
b. $5\tau \Rightarrow$ steady state

$\tau' = \dfrac{L}{R} = \dfrac{10 \text{ mH}}{20 \text{ k}\Omega} = 0.5\ \mu\text{s}$

$i_L = I_m e^{-t/\tau'} = \mathbf{2 \times 10^{-3} e^{-t/0.5\ \mu s}}$

$v_L = -(2 \text{ mA})(20 \text{ k}\Omega)e^{-t/\tau} = \mathbf{-40e^{-t/0.5\ \mu s}}$





19. a. $\tau = \dfrac{L}{R} = \dfrac{1\text{ mH}}{2\text{ k}\Omega} = 0.5\ \mu\text{s}$

$$i_L = \frac{E}{R}(1 - e^{-t/\tau}) = \frac{12\text{ V}}{2\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{6 \times 10^{-3}(1 - e^{-t/0.5\ \mu s})}$$

$$v_L = Ee^{-t/\tau} = \mathbf{12e^{-t/0.5\ \mu s}}$$

b. $i_L = 6 \times 10^{-3}(1 - e^{-t/0.5\ \mu s}) = 6 \times 10^{-3}(1 - e^{-1\ \mu s/0.5\ \mu s})$
$\quad = 6 \times 10^{-3}(1 - e^{-2}) = 5.188\text{ mA}$

$i_L = I'_m e^{-t/\tau'}$ $\qquad \tau' = \dfrac{L}{R} = \dfrac{1\text{ mH}}{12\text{ k}\Omega} = 0.0833\ \mu\text{s} = 83.3\text{ ns}$

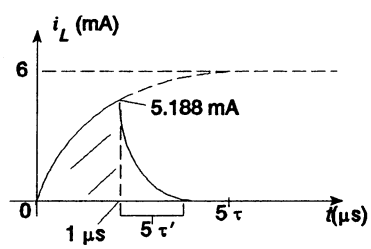
$i_L = \mathbf{5.188 \times 10^{-3}e^{-t/83.3\text{ ns}}}$

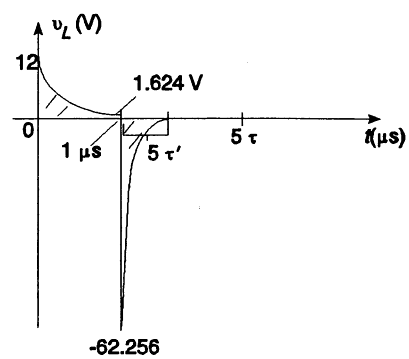
$t = 1\ \mu\text{s}$: $v_L = 12e^{-t/0.5\ \mu s} = 12e^{-2} = 12(0.1353) = 1.624\text{ V}$

$V'_L = (5.188\text{ mA})(12\text{ k}\Omega) = 62.256\text{ V}$

$v_L = \mathbf{-62.256e^{-t/83.3\text{ ns}}}$

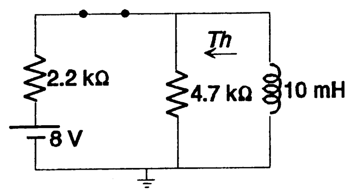
c.





21.
$$\begin{aligned}
2\text{ mA} &= 1.78\text{ mA} + 2.22\text{ mA}e^{-t/11.11\ \mu s}\\
0.22\text{ mA} &= 2.22\text{ mA}e^{-t/11.11\ \mu s}\\
99.1 \times 10^{-3} &= e^{-t/11.11\ \mu s}\\
\log_e 99.1 \times 10^{-3} &= \log_e(e^{-t/11.11\ \mu s})\\
-2.312 &= -t/11.11\ \mu s\\
t &= (11.11\ \mu s)(2.312)\\
t &= \mathbf{25.68\ \mu s}
\end{aligned}$$

23. a.



$R_{Th} = 2.2\text{ k}\Omega \| 4.7\text{ k}\Omega = 1.498\text{ k}\Omega$

$E_{Th} = \dfrac{4.7\text{ k}\Omega(8\text{ V})}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = 5.45\text{ V}$

$\tau = \dfrac{L}{R} = \dfrac{10\text{ mH}}{1.498\text{ k}\Omega} = 6.676\ \mu\text{s}$

$i_L = \dfrac{E}{R}(1 - e^{-t/\tau}) = \dfrac{5.45\text{ V}}{1.498\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{3.638 \times 10^{-3}(1 - e^{-t/6.676\ \mu s})}$

$v_L = Ee^{-t/\tau} = \mathbf{5.45e^{-t/6.676\ \mu s}}$

b. $t = 10\ \mu\text{s}$:

$i_L = 3.638 \times 10^{-3}(1 - e^{-10\ \mu s/6.676\ \mu s}) = 3.638 \times 10^{-3}(1 - \underbrace{e^{-1.4}}_{0.2236})$

$= \mathbf{2.825\ mA}$

$v_L = 5.45(0.2236) = \mathbf{1.2186\ V}$

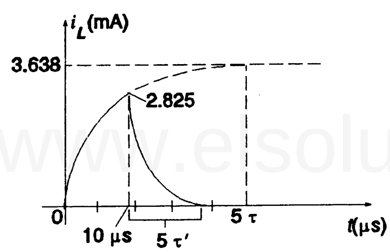
c. $\tau' = \dfrac{L}{R} = \dfrac{10\text{ mH}}{4.7\text{ k}\Omega} = 2.128\ \mu\text{s}$

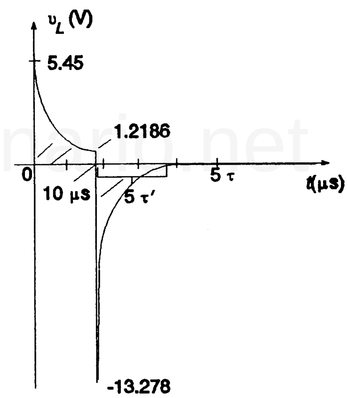
$i_L = \mathbf{2.825 \times 10^{-3}e^{-t/2.128\ \mu s}}$

At $t = 10\ \mu\text{s}$:

$V_L = (2.825\text{ mA})(4.7\text{ k}\Omega) = 13.278\text{ V}$

$v_L = \mathbf{-13.278e^{-t/2.128\ \mu s}}$





25. a. $v_L = Ee^{-t/\tau}$ $\quad \tau = \dfrac{L}{R_1 + R_3} = \dfrac{0.6\text{ H}}{100\ \Omega + 20\ \Omega} = \dfrac{0.6\text{ H}}{120\ \Omega} = 5\text{ ms}$

$v_L = 36\ e^{-t/5\text{ ms}}$

$v_L = 36\ e^{-25\text{ ms}/5\text{ ms}} = 36\ e^{-5} = 36(0.00674) = \mathbf{0.243\ V}$

b. $v_L = 36\ e^{-1\text{ ms}/5\text{ ms}} = 36\ e^{-0.2} = 36(0.819) = \mathbf{29.47\ V}$

c. $v_{R_1} = i_{R_1}R_1 = i_L R_1 = \left[\dfrac{E}{R_1 + R_3}(1 - e^{-t/\tau})\right] R_1$

$= \left[\dfrac{36\text{ V}}{120\ \Omega}(1 - e^{-t/5\text{ ms}})\right] 100\ \Omega$

$= (300\text{ mA}(1 - e^{-t/5\text{ ms}}))100\ \Omega$

$= 30\text{ V}(1 - e^{-5\text{ ms}/5\text{ ms}}) = 30\text{ V}(1 - e^{-1})$

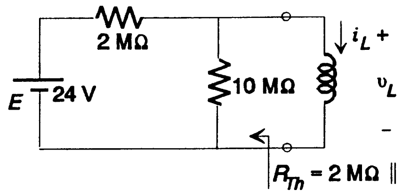
$= 30\text{ V}(1 - 0.368) = \mathbf{18.96\ V}$

d.
$$\begin{aligned} i_L &= 300\text{ mA}(1 - e^{-t/5\text{ ms}}) \\ 100\text{ mA} &= 300\text{ mA}(1 - e^{-t/5\text{ ms}}) \\ 0.333 &= 1 - e^{-t/5\text{ ms}} \\ 0.667 &= e^{-t/5\text{ ms}} \\ \log_e 0.667 &= -t/5\text{ ms} \\ 0.405 &= t/5\text{ ms} \\ t &= 0.405(5\text{ ms}) = \mathbf{2.025\text{ ms}} \end{aligned}$$

27. a. $L \Rightarrow$ open circuit equivalent

$$V_L = \frac{10\text{ M}\Omega(24\text{ V})}{10\text{ M}\Omega + 2\text{ M}\Omega} = \mathbf{20\text{ V}}$$

b.



$R_{Th} = 2\text{ M}\Omega \parallel 10\text{ M}\Omega = 1.667\text{ M}\Omega$

$E_{Th} = \dfrac{10\text{ M}\Omega(24\text{ V})}{10\text{ M}\Omega + 2\text{ M}\Omega} = 20\text{ V}$

$$I_{L_{\text{final}}} = \frac{E_{Th}}{R_{Th}} = \frac{20\text{ V}}{1.667\text{ M}\Omega} = \mathbf{12\ \mu A}$$

c.
$$\begin{aligned} i_L &= 12\ \mu\text{A}(1 - e^{-t/3\ \mu\text{s}}) \\ 10\ \mu\text{A} &= 12\ \mu\text{A}(1 - e^{-t/3\ \mu\text{s}}) \\ 0.8333 &= 1 - e^{-t/3\ \mu\text{s}} \\ 0.1667 &= e^{-t/3\ \mu\text{s}} \\ \log_e(0.1667) &= -t/3\ \mu\text{s} \\ 1.792 &= t/3\ \mu\text{s} \\ t &= 1.792(3\ \mu\text{s}) = \mathbf{5.376\ \mu s} \end{aligned}$$

$$\tau = \frac{L}{R} = \frac{5\text{ H}}{1.667\text{ M}\Omega} = 3\ \mu\text{s}$$

d.
$$\begin{aligned} v_L &= 20e^{-t/3\ \mu\text{s}} = 20e^{-12\ \mu\text{s}/3\ \mu\text{s}} = 20e^{-4} \\ &= 20(0.0183) = \mathbf{0.366\text{ V}} \end{aligned}$$

29. a. $I_i = -\dfrac{24\text{ V}}{2.2\text{ k}\Omega} = -10.91\text{ mA}$

Switch open: $I_f = -\dfrac{24\text{ V}}{2.2\text{ k}\Omega + 4.7\text{ k}\Omega} = -\dfrac{24\text{ V}}{6.9\text{ k}\Omega} = -3.478\text{ mA}$

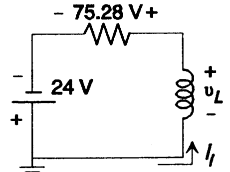
$i_L = I_f + (I_i - I_f)e^{-t/\tau}$

$\tau = \dfrac{L}{R} = \dfrac{1.2\text{ H}}{6.9\text{ k}\Omega} = 173.9\ \mu\text{s}$

$i_L = -3.478\text{ mA} + (-10.91\text{ mA} - (-3.478\text{ mA}))e^{-t/173.9\ \mu\text{s}}$

$\mathbf{i_L = -3.478\text{ mA} - 7.432\text{ mA}e^{-t/173.9\ \mu s}}$

$t = 0+$:



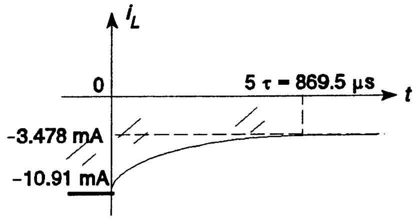
$v_R(0+) = (10.91\text{ mA})(6.9\text{ k}\Omega) = 75.28\text{ V}$

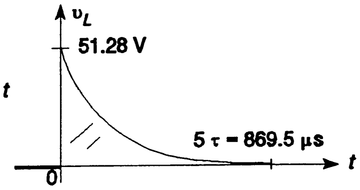
KVL: $-24\text{ V} + 75.28\text{ V} - v_L = 0$

$v_L = 51.28\text{ V}$

$\mathbf{v_L = 51.28\text{ V}e^{-t/173.9\ \mu s}}$

b.

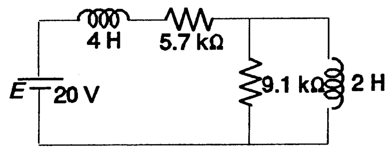




31. a. $L_T = 4\text{ H} + 2\text{ H} + 3\text{ H}\|6\text{ H} = \mathbf{8\text{ H}}$

b. $L_T = 12\text{ H}\|(3.6\text{ H} + 4\text{ H}\|6\text{ H}) = 12\text{ H}\|6\text{ H} = \mathbf{4\text{ H}}$

33. $L'_T = 6\text{ H}\|(1\text{ H} + 2\text{ H}) = 6\text{ H}\|3\text{ H} = 2\text{ H}$



35. $I_1 = \dfrac{16\text{ V}}{4\text{ k}\Omega + 0} = \mathbf{4\text{ mA}},\ V_1 = \mathbf{16\text{ V}},\ V_2 = \mathbf{0\text{ V}}$

37. $V_1 = \dfrac{(3\ \Omega + 3\Omega\|6\ \Omega)(50\text{ V})}{(3\ \Omega + 3\ \Omega\|6\Omega) + 20\ \Omega} = \dfrac{(3\ \Omega + 2\ \Omega)(50\text{ V})}{(3\ \Omega + 2\ \Omega) + 20\ \Omega} = \mathbf{10\text{ V}}$

$R_T = 20\ \Omega + 3\ \Omega + 3\ \Omega \parallel 6\ \Omega = 23\ \Omega + 2\ \Omega = 25\ \Omega$

$I_s = I_1 = \dfrac{50\text{ V}}{25\ \Omega} = \mathbf{2\text{ A}}$

$I_{5\Omega} = 0\text{ A},\ \therefore\ I_2 = \dfrac{6\ \Omega(I_s)}{6\ \Omega + 3\ \Omega} = \dfrac{6\ \Omega(2\text{ A})}{6\ \Omega + 3\ \Omega} = \mathbf{1.33\text{ A}}$

39. $W_{5\mu\text{F}} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(5\ \mu\text{F})(12\text{ V})^2 = \mathbf{360\ \mu J}$

$W_{6\text{H}} = \dfrac{1}{2}LI^2 = \dfrac{1}{2}(6\text{ H})(2\text{ A})^2 = \mathbf{12\text{ J}}$

CHAPTER 12 (Even)

2. $e = N\dfrac{d\phi}{dt} \Rightarrow \dfrac{d\phi}{dt} = \dfrac{e}{N} = \dfrac{20\text{ V}}{40\text{ t}} = \mathbf{0.5\ Wb/s}$

4. $A = \dfrac{\pi d^2}{4} = \dfrac{\pi(5\text{ mm})^2}{4} = 19.625 \times 10^{-6}\text{ m}^2$

$L = \dfrac{N^2\mu A}{\ell} = \dfrac{(200\text{ t})^2(4\pi \times 10^{-7})(19.625 \times 10^{-6}\text{ m}^2)}{0.075\text{ m}} = \mathbf{13.146\ \mu H}$

6. a. $L = \dfrac{N^2\mu A}{\ell} = \dfrac{(300\text{ t})^2(4\pi \times 10^{-7})(1.5 \times 10^{-4}\text{ m}^2)}{0.1\text{ m}} = \mathbf{169.56\ \mu H}$

b. $L = \mu_r L_o = (2 \times 10^3)(169.56\ \mu\text{H}) = \mathbf{339.12\ mH}$

8. $e_L = L\dfrac{di}{dt} = (50\text{ mH})\left[\dfrac{0.1 \times 10^{-3}\text{ A}}{10^{-6}\text{ s}}\right] = \mathbf{5\ V}$

10. $e = L\dfrac{\Delta i}{\Delta t} = (0.2\text{ H})\dfrac{\Delta i}{\Delta t}$

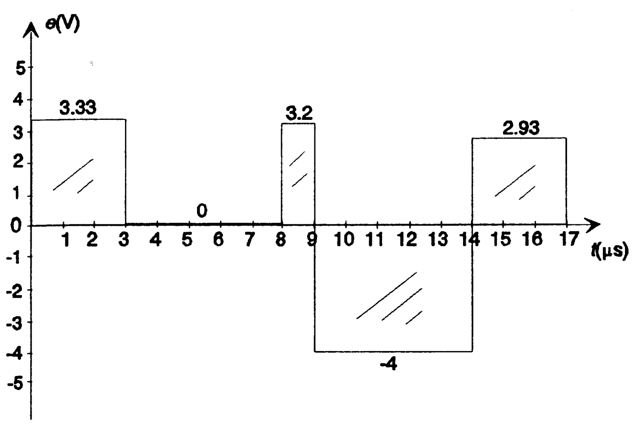
$0 - 3\ \mu\text{s}$: $e = (0.2\text{ H})\left[\dfrac{50\ \mu\text{A}}{3\ \mu\text{s}}\right] = 3.33\text{ V}$

$3 - 8\ \mu\text{s}$: $e = (0.2\text{ H})(0) = 0\text{ V}$

$8 - 9\ \mu\text{s}$: $e = (0.2\text{ H})\left[\dfrac{16\ \mu\text{A}}{1\ \mu\text{s}}\right] = 3.2\text{ V}$

$9 - 14\ \mu\text{s}$: $e = -(0.2\text{ H})\left[\dfrac{100\ \mu\text{A}}{5\ \mu\text{s}}\right] = -4\text{ V}$

$14 - 17\ \mu\text{s}$: $e = (0.2\text{ H})\left[\dfrac{44\ \mu\text{A}}{3\ \mu\text{s}}\right] = 2.93\text{ V}$



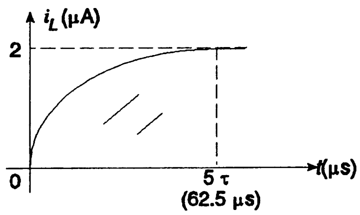
12. a. $\tau = \dfrac{L}{R} = \dfrac{250 \text{ mH}}{20 \text{ k}\Omega} = \mathbf{12.5\ \mu s}$

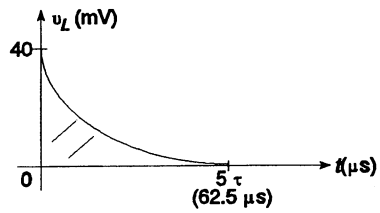
b. $i_L = \dfrac{E}{R}(1 - e^{-t/\tau}) = \dfrac{40 \text{ mV}}{20 \text{ k}\Omega}(1 - e^{-t/\tau})$
$= \mathbf{2 \times 10^{-6}(1 - e^{-t/12.5\ \mu s})}$

c. $v_L = Ee^{-t/\tau} = \mathbf{40 \times 10^{-3}e^{-t/12.5\ \mu s}}$
$v_R = i_R R = i_L R = E(1 - e^{-t/\tau}) = \mathbf{40 \times 10^{-3}(1 - e^{-t/12.5\ \mu s})}$

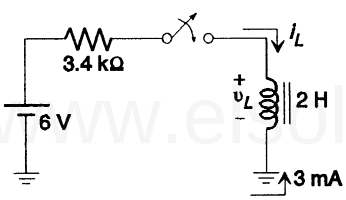
d. i_L: $1\tau = 1.264\ \mu$A, $3\tau = 1.9\ \mu$A, $5\tau = 1.987\ \mu$A
v_L: $1\tau = 14.72$ V, $3\tau = 1.99$ V, $5\tau = 0.2695$ V

e.

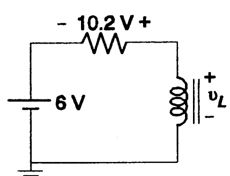




14. a. Source conversion:

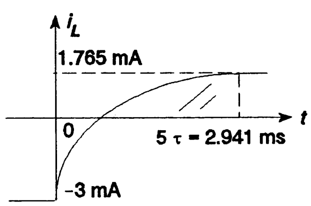


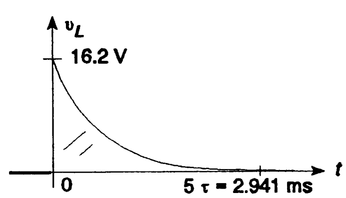
$\tau = \dfrac{L}{R} = \dfrac{2 \text{ H}}{3.4 \text{ k}\Omega} = 588.2\ \mu s$
$i_L = I_f + (I_i - I_f)e^{-t/\tau}$
$I_f = \dfrac{6 \text{ V}}{3.4 \text{ k}\Omega} = 1.765$ mA
$i_L = 1.765 \text{ mA} + (-3 \text{ mA} - 1.765 \text{ mA})e^{-t/588.2\ \mu s}$
$i_L = \mathbf{1.765 \text{ mA} + 4.765 \text{ mA}e^{-t/588.2\ \mu s}}$



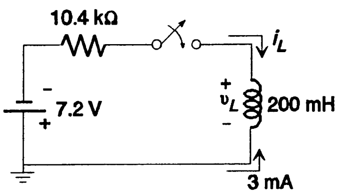
$v_R(0+) = 3 \text{ mA}(3.4 \text{ k}\Omega) = 10.2$ V
KVL: $+6 \text{ V} + 10.2 \text{ V} - v_L(0+) = 0$
$v_L(0+) = 16.2$ V
$v_L = \mathbf{16.2 \text{ V}e^{-t/588.2\ \mu s}}$

b.





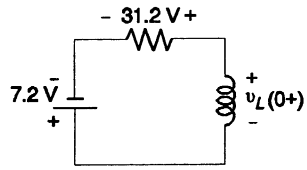
16. a.



$$I_f = -\frac{7.2\text{ V}}{10.4\text{ k}\Omega} = -0.692\text{ mA}$$

$$\tau = \frac{L}{R} = \frac{200\text{ mH}}{10.4\text{ k}\Omega} = 19.23\ \mu\text{s}$$

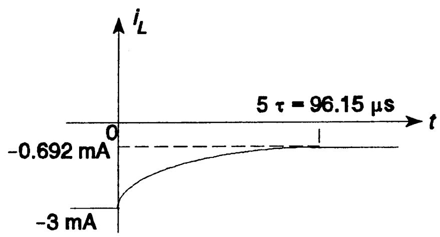
$$i_L = I_f + (I_i - I_f)e^{-t/\tau}$$
$$= -0.692\text{ mA} + (-3\text{ mA} - (-0.692\text{ mA}))e^{-t/19.23\ \mu\text{s}}$$
$$i_L = \mathbf{-0.692\ mA - 2.308\ mA}e^{-t/19.23\ \mu\text{s}}$$

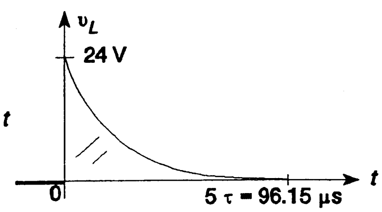


KVL: $-7.2\text{ V} + 31.2\text{ V} - v_L(0+) = 0$

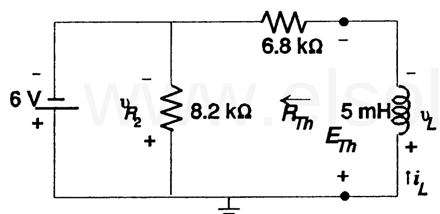
$$v_L(0+) = 24\text{ V}$$
$$v_L = \mathbf{24\ V}e^{-t/19.23\ \mu\text{s}}$$

b.

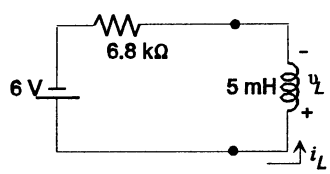




18. a.



$R_{Th} = 6.8\text{ k}\Omega$
$E_{Th} = 6\text{ V}$

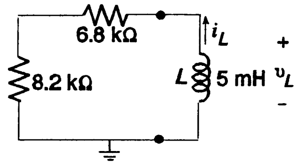


$$\tau = \frac{L}{R} = \frac{5\text{ mH}}{6.8\text{ k}\Omega} = 0.735\ \mu\text{s}$$

$$i_L = \frac{E}{R}(1 - e^{-t/\tau}) = \frac{6\text{ V}}{6.8\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{0.882 \times 10^{-3}(1 - e^{-t/0.735\ \mu s})}$$

$$v_L = Ee^{-t/\tau} = \mathbf{6}e^{-t/0.735\ \mu\text{s}}$$

b. Assume steady state and $I_L = 0.882$ mA



$$\tau' = \frac{L}{R} = \frac{5 \text{ mH}}{15 \text{ k}\Omega} = 0.333 \ \mu\text{s}$$

$i_L = I_m e^{-t/\tau'} = \mathbf{0.882 \times 10^{-3} e^{-t/0.333 \ \mu s}}$

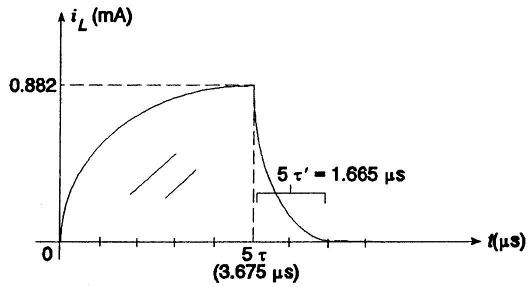
$v_L = -V_m e^{-t/\tau'}$

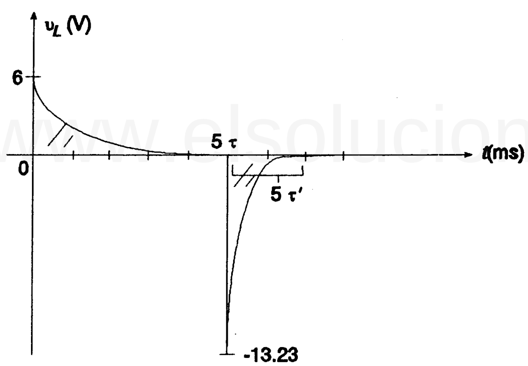
compared to defined polarity of Fig. 12.64.

$V_m = I_m R = (0.882 \text{ mA})(15 \text{ k}\Omega) = 13.23$ V

$v_L = \mathbf{-13.23 \ e^{-t/0.333 \ \mu s}}$

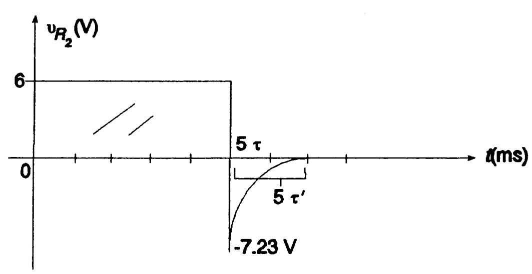
c.





d. For polarity of Fig. 12.64:

$V_{R_2 \max} = I_m R_2 = (0.882 \text{ mA})(8.2 \text{ k}\Omega) = 7.23$ V



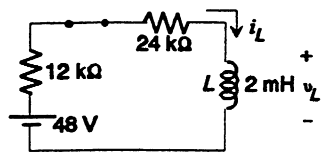
20. $i_L = 10$ mA: Eq. 12.21

$$t = \tau \log_e \left[\frac{I_m}{I_m - i_L}\right] = 2 \text{ ms} \log_e \left[\frac{25 \text{ mA}}{25 \text{ mA} - 10 \text{ mA}}\right]$$
$$= 2 \text{ ms} \log_e \left[\frac{25 \text{ mA}}{15 \text{ mA}}\right] = 2 \text{ ms} \log_e 1.667$$
$$= 2 \text{ ms } (0.511)$$
$$= \mathbf{1.02 \text{ ms}}$$

$v_L = 10$ V: Eq. 12.22

$$t = \tau \log_e \frac{E}{v_L} = 2 \text{ ms} \log_e \frac{50 \text{ V}}{10 \text{ V}}$$
$$= 2 \text{ ms} \log_e 5 = 2 \text{ ms}(1.609)$$
$$= \mathbf{3.219 \text{ ms}}$$

22. a. Source conversion: $E = IR = (4 \text{ mA})(12 \text{ k}\Omega) = 48$ V



$$\tau = \frac{L}{R} = \frac{2 \text{ mH}}{36 \text{ k}\Omega} = 55.56 \text{ ns}$$

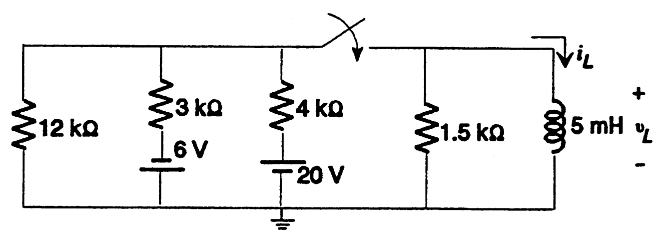
$$i_L = \frac{E}{R}(1 - e^{-t/\tau}) = \frac{48 \text{ V}}{36 \text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{1.33 \times 10^{-3}(1 - e^{-t/55.56 \text{ ns}})}$$
$$v_L = Ee^{-t/\tau} = \mathbf{48e^{-t/55.56 \text{ ns}}}$$

b. $t = 100$ ns:

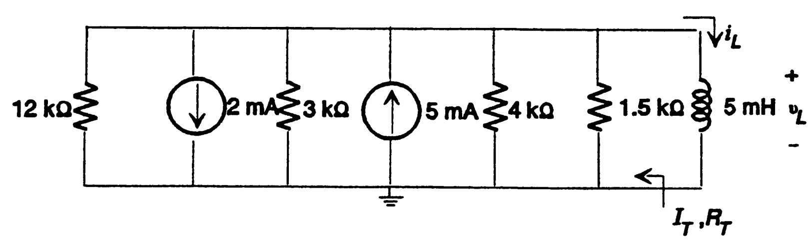
$$i_L = 1.33 \times 10^{-3}(1 - e^{-100 \text{ ns}/55.56 \text{ ns}}) = 1.33 \times 10^{-3}(1 - \underbrace{e^{-1.8}}_{0.1676}) = \mathbf{1.11 \text{ mA}}$$

$$v_L = 48e^{-1.8} = \mathbf{7.934 \text{ V}}$$

24. a. Redrawn:



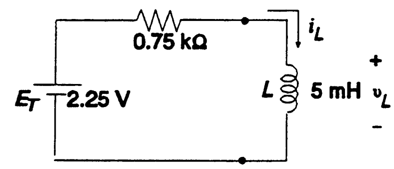
Source conversions:



$$I_T = 5 \text{ mA} - 2 \text{ mA} = 3 \text{ mA}\uparrow$$
$$\frac{1}{R_T} = \frac{1}{12 \text{ k}\Omega} + \frac{1}{3 \text{ k}\Omega} + \frac{1}{4 \text{ k}\Omega} + \frac{1}{1.5 \text{ k}\Omega} = 0.75 \text{ k}\Omega$$

Source conversion:

$$E_T = I_T R_T = (3\text{ mA})(0.75\text{ k}\Omega) = 2.25\text{ V}$$



$$\tau = \frac{L}{R} = \frac{5\text{ mH}}{0.75\text{ k}\Omega} = 6.67\ \mu\text{s}$$

$$i_L = \frac{2.25\text{ V}}{0.75\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{3 \times 10^{-3}(1 - e^{-t/6.67\ \mu s})}$$

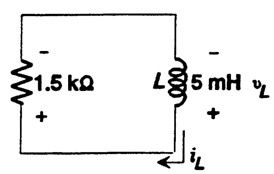
$$v_L = \mathbf{2.25\ e^{-t/6.67\ \mu s}}$$

b. 2τ: $0.865\ I_m$, $0.135\ V_m$

i_L: $0.865\ (3\text{ mA}) = \mathbf{2.595\ mA}$

v_L: $0.135(2.25\text{ V}) = \mathbf{0.304\ V}$

c.



$$\tau' = \frac{L}{R} = \frac{5\text{ mH}}{1.5\text{ k}\Omega} = 3.33\ \mu\text{s}$$

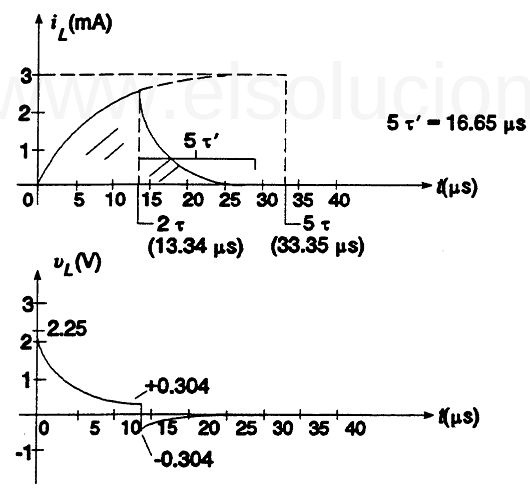
$$i_L = \mathbf{2.595 \times 10^{-3} e^{-t/3.33\ \mu s}}$$

$$i_L(0+) = 2.595\text{ mA}$$

$$v_R(0+) = (2.595\text{ mA})(1.5\text{ k}\Omega) = 3.893\text{ V}$$

$$v_L = \mathbf{-3.893\ V e^{-t/3.33\ \mu s}}$$

d.



26. a. $i_L = \dfrac{E}{R_1 + R_2}e^{-t/\tau}$ $\qquad \tau = \dfrac{L}{R_T} = \dfrac{L}{R_1 + R_2 + R_3} = \dfrac{0.6\text{ H}}{590\ \Omega} = 1.017\text{ms}$

$$= \frac{36\text{ V}}{100\ \Omega + 20\ \Omega}e^{-t/1.017\text{ ms}}$$

$$i_L = 300\text{ mA } e^{-t/1.017\text{ ms}}$$
$$1\text{ mA} = 300\text{ mA } e^{-t/1.017\text{ ms}}$$
$$3.333 \times 10^{-3} = e^{-t/1.017\text{ ms}}$$
$$\log_e (3.333 \times 10^{-3}) = -t/1.017\text{ ms}$$
$$-5.704 = -t/1.017\text{ ms}$$
$$t = 5.704(1.017\text{ ms}) = \mathbf{5.801\ ms}$$

b. $v_{L_{max}} = I_{L_{max}}(R_1 + R_2 + R_3) = (300\text{ mA})(590\ \Omega) = 177\text{ V}$

$v_L = -177e^{-t/\tau} = -177e^{-t/1.017\text{ ms}}$

$v_L = -177e^{-1\text{ ms}/1.017\text{ ms}} = -177e^{-0.983}$

$= -177(0.374) = \mathbf{-66.198\ V}$

c. $v_{R_3} = i_L R_3 = (300\text{ mA } e^{-t/1.017\text{ ms}})(20\ \Omega)$

$= 6e^{-t/1.017\text{ ms}} = 6e^{-5}$

$= 6(6.738 \times 10^{-3})$

$= \mathbf{40.428\ mV}$

28. a. $I_i = \dfrac{16\text{ V}}{4.7\text{ k}\Omega + 3.3\text{ k}\Omega} = 2\text{ mA}$

$t = 0\text{s}$: Thevenin:

$R_{Th} = 3.3\text{ k}\Omega + 1\text{ k}\Omega \| 4.7\text{ k}\Omega = 3.3\text{ k}\Omega + 0.825\text{ k}\Omega = 4.125\text{ k}\Omega$

$E_{Th} = \dfrac{1\text{ k}\Omega(16\text{ V})}{1\text{ k}\Omega + 4.7\text{ k}\Omega} = 2.807\text{ V}$

$i_L = I_f + (I_i - I_f)e^{-t/\tau}$

$I_f = \dfrac{2.807\text{ V}}{4.125\text{ k}\Omega} = 0.680\text{ mA},\ \tau = \dfrac{L}{R} = \dfrac{2\text{ H}}{4.125\text{ k}\Omega} = 484.9\ \mu\text{s}$

$i_L = 0.680\text{ mA} + (2\text{ mA} - 0.680\text{ mA})e^{-t/484.9\ \mu\text{s}}$

$i_L = \mathbf{0.680\ mA + 1.320\ mA}e^{-t/484.9\ \mu s}$

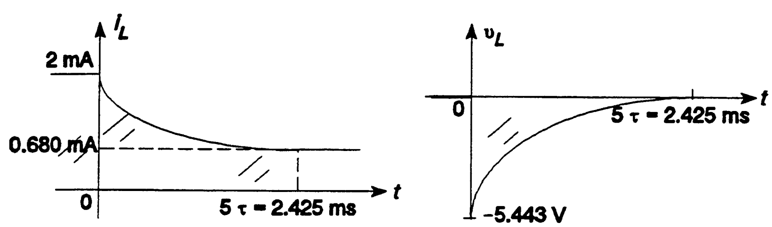
$v_R(0+) = 2\text{ mA}(4.125\text{ k}\Omega) = 8.25\text{ V}$

KVL(0+): $2.807\text{ V} - 8.25\text{ V} - v_L = 0$

$v_L = -5.443\text{ V}$

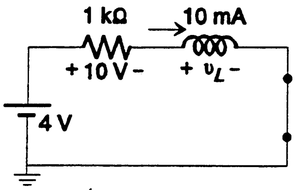
$v_L = \mathbf{-5.44\ V}e^{-t/484.9\ \mu s}$

b.



30. Source conversion: $I_i = \dfrac{18\text{ V} + 4\text{ V}}{1\text{ k}\Omega + 1.2\text{ k}\Omega} = \dfrac{22\text{ V}}{2.2\text{ k}\Omega} = 10\text{ mA}$

$t = 0+$:



$I_f = \dfrac{4\text{ V}}{1\text{ k}\Omega} = 4\text{ mA}$

$\tau = \dfrac{L}{R} = \dfrac{220\text{ mH}}{1\text{ k}\Omega} = 220\ \mu\text{s}$

$i_L = I_f + (I_i + I_f)e^{-t/\tau}$

$= 4\text{ mA} + (10\text{ mA} - 4\text{ mA})e^{-t/220\ \mu\text{s}}$

$\mathbf{i_L = 4\ mA + 6\ mA}e^{-t/220\ \mu s}$

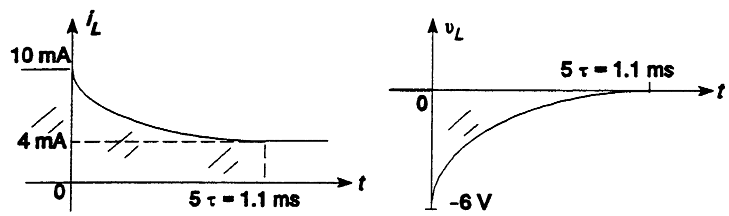
$v_R(0+) = (10\text{ mA})(1\text{ k}\Omega) = 10\text{ V}$

KVL: $+4\text{ V} - 10\text{ V} - v_L = 0$

$v_L(0+) = -6\text{ V}$

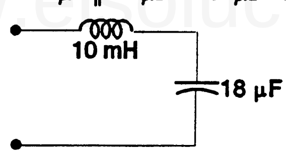
$v_L = \mathbf{-6\ V}e^{-t/220\ \mu s}$

b.



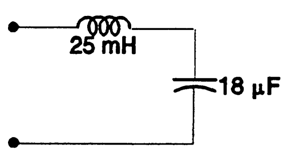
32. a. $L_T = 14\text{ mH} \| 35\text{ mH} = \mathbf{10\ mH}$

$C_T = 9\ \mu\text{F} + 10\ \mu\text{F} \| 90\ \mu\text{F} = 9\ \mu\text{F} + 9\ \mu\text{F} = \mathbf{18\ \mu F}$

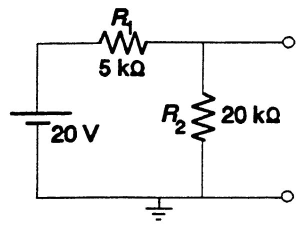


b. $C_T = 12\ \mu\text{F} + 7\ \mu\text{F} \| 42\ \mu\text{F} = 12\ \mu\text{F} + 6\ \mu\text{F} = \mathbf{18\ \mu F}$

$L_T = 5\text{ mH} + 20\text{ mH} = \mathbf{25\ mH}$



34. a.



$\overleftarrow{R_{Th}} = 5\text{ k}\Omega \parallel 20\text{ k}\Omega = 4\text{ k}\Omega$

$E_{Th} = \dfrac{20\text{ k}\Omega(20\text{ V})}{20\text{ k}\Omega + 5\text{ k}\Omega} = 16\text{ V}$

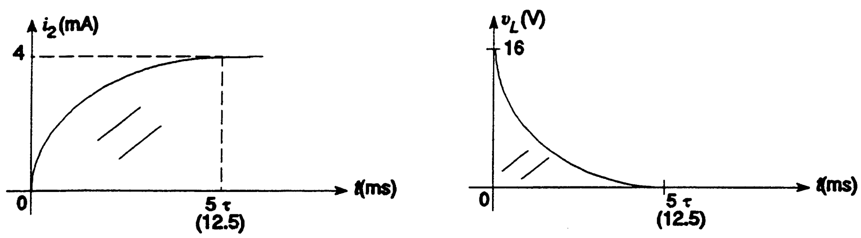
$$L_T = 5\text{ H} + 6\text{ H}\|30\text{ H} = 5\text{ H} + 5\text{ H} = \mathbf{10\text{ H}}$$

$$\tau = \frac{L_T}{R} = \frac{10\text{ H}}{4\text{ k}\Omega} = 2.5\text{ ms}$$

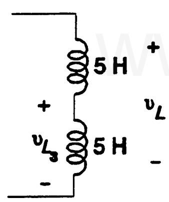
$$v_L = \mathbf{16e^{-t/2.5\text{ ms}}}$$

$$i_L = \frac{16\text{ V}}{4\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{4 \times 10^{-3}(1 - e^{-t/2.5\text{ ms}})}$$

b.



c.



$$v_{L_3} = \frac{v_L}{2} = \mathbf{8e^{-t/2.5\text{ ms}}}$$

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36. $I_1 = \dfrac{20\text{ V}}{4\ \Omega + 6\ \Omega} = 2\text{ A},\ V_1 = 20\text{ V} - I_1\, 4\ \Omega$

$$\begin{aligned} &= 20\text{ V} - (2\text{ A})(4\ \Omega) \\ &= 20\text{ V} - 8\text{ V} \\ &= \mathbf{12\text{ V}} \end{aligned}$$

38. $W_{2\text{H}} = \dfrac{1}{2}LI^2 = \dfrac{1}{2}(2\text{ H})(4\text{ mA})^2 = \mathbf{16\ \mu J}$

$W_{3\text{H}} = \dfrac{1}{2}(3\text{ H})(4\text{ mA})^2 = \mathbf{24\ \mu J}$

40. $W_{0.5\text{H}} = \dfrac{1}{2}(0.5\text{ H})(2\text{ A})^2 = \mathbf{1\text{ J}}$

$W_{4\text{H}} = \dfrac{1}{2}(4\text{ H})(4/3\text{ A})^2 = \mathbf{3.56\text{ J}}$

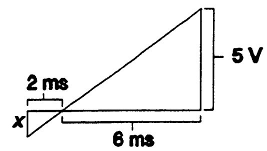
CHAPTER 13 (Odd)

1. a. $T = 18 \text{ ms} - 8 \text{ ms} = \mathbf{10 \text{ ms}}$

   b. **2 cycles**

   c. $f = \dfrac{1}{T} = \dfrac{1}{10 \times 10^{-3} \text{ s}} = 0.1 \times 10^3 \text{ Hz} = \mathbf{100 \text{ Hz}}$

   d. Amplitude = **5 V**



$$\frac{2 \text{ ms}}{x} = \frac{6 \text{ ms}}{5 \text{ V}}$$

$$x = \frac{5}{6}(2 \text{ V}) = 1.67 \text{ V}$$

$V_{p\text{-}p} = 5 \text{ V} + 1.67 \text{ V} = \mathbf{6.67 \text{ V}}$

3. $T = 26 \text{ ms} - 16 \text{ ms} = \mathbf{10 \text{ ms}}$

   $f = \dfrac{1}{T} = \dfrac{1}{10 \text{ ms}} = \mathbf{100 \text{ Hz}}$

5. a. $f = \dfrac{1}{T} = \dfrac{1}{1/60 \text{ s}} = \mathbf{60 \text{ Hz}}$

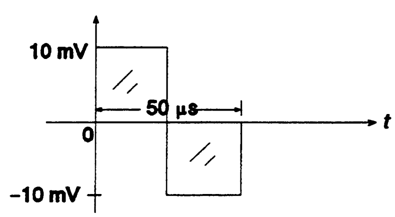
   b. $f = \dfrac{1}{T} = \dfrac{1}{0.01 \text{ s}} = \mathbf{100 \text{ Hz}}$

   c. $f = \dfrac{1}{34 \times 10^{-3} \text{ s}} = \mathbf{29.41 \text{ Hz}}$

   d. $f = \dfrac{1}{25 \times 10^{-6} \text{ s}} = \mathbf{40 \text{ kHz}}$

7. $T = \dfrac{1}{20 \text{ Hz}} = 0.05 \text{ s}, 5(0.05 \text{ s}) = \mathbf{0.25 \text{ s}}$

9. $T = \dfrac{1}{20 \text{ kHz}} = 50\ \mu\text{s}$



11. a. $(45°)\left[\dfrac{\pi}{180°}\right] = 0.25\pi = \dfrac{\pi}{4}$ **rad**

    b. $(60°)\left[\dfrac{\pi}{180°}\right] = \dfrac{\pi}{3}$ **rad**

    c. $(120°)\left[\dfrac{\pi}{180°}\right] = \dfrac{2}{3}\pi$ **rad**

    d. $(270°)\left[\dfrac{\pi}{180°}\right] = \dfrac{3}{2}\pi$ **rad**

    e. $(178°)\left[\dfrac{\pi}{180°}\right] = \mathbf{0.989\pi \text{ rad}}$

    f. $(221°)\left[\dfrac{\pi}{180°}\right] = \mathbf{1.228\pi \text{ rad}}$

13. a. $\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{2 \text{ s}} = \mathbf{3.14 \text{ rad/s}}$

    b. $\omega = \dfrac{2\pi}{0.3 \times 10^{-3} \text{ s}} = \mathbf{20.94 \times 10^3 \text{ rad/s}}$

c. $\omega = \dfrac{2\pi}{4 \times 10^{-6}\text{ s}} = \mathbf{1.57 \times 10^6\ rad/s}$ d. $\omega = \dfrac{2\pi}{1/25\text{ s}} = \mathbf{157.1\ rad/s}$

15. a. $\omega = 2\pi f = \dfrac{2\pi}{T} \Rightarrow f = \dfrac{\omega}{2\pi}$

$T = \dfrac{2\pi}{\omega} = \dfrac{1}{f}$

$f = \dfrac{\omega}{2\pi} = \dfrac{754\text{ rad/s}}{2\pi} = \mathbf{120\ Hz},\ \mathbf{T = 8.33\ ms}$

b. $f = \dfrac{\omega}{2\pi} = \dfrac{8.4\text{ rad/s}}{2\pi} = \mathbf{1.34\ Hz},\ \mathbf{T = 746.27\ ms}$

c. $f = \dfrac{\omega}{2\pi} = \dfrac{6000\text{ rad/s}}{2\pi} = \mathbf{954.93\ Hz},\ \mathbf{T = 1.05\ ms}$

d. $f = \dfrac{\omega}{2\pi} = \dfrac{1/16\text{ rad/s}}{2\pi} = \mathbf{9.95 \times 10^{-3}\ Hz},\ \mathbf{T = 100.5\ ms}$

17. $(30°)\left[\dfrac{\pi}{180°}\right] = \dfrac{\pi}{6},\ \alpha = \omega t \Rightarrow \omega = \dfrac{\alpha}{t} = \dfrac{\pi/6}{5 \times 10^{-3}\text{ s}} = \mathbf{104.7\ rad/s}$

23. $i = 0.5 \sin 72° = 0.5(0.9511) = \mathbf{0.4755\ A}$

25. $6 \times 10^{-3} = 30 \times 10^{-3} \sin \alpha$

$0.2 = \sin \alpha$

$\alpha = \sin^{-1} 0.2 = \mathbf{11.537°}$ and $180° - 11.537° = \mathbf{168.463°}$

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. $\left[\dfrac{\pi}{6}\right]\left[\dfrac{180°}{\pi}\right] = 30°,\ \omega = 2\pi f = 377\text{ rad/s}$

$\mathbf{v = 25 \sin(\omega t + 30°)}$

b. $\pi - \dfrac{2}{3}\pi = \dfrac{\pi}{3} = 60°,\ \omega = 2\pi f = 6.28 \times 10^3\text{ rad/s}$

$\mathbf{i = 3 \times 10^{-3} \sin(6.28 \times 10^3 t - 60°)}$

33. $T = \dfrac{1}{f} = \dfrac{1}{1000\text{ Hz}} = 1\text{ ms}$

$t_1 = \dfrac{120°}{180°}\left[\dfrac{T}{2}\right] = \dfrac{2}{3}\left[\dfrac{1\text{ ms}}{2}\right] = \mathbf{\dfrac{1}{3}\ ms}$

35. $\omega = \dfrac{2\pi}{T} \Rightarrow T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{1800} = 3.49\text{ ms}$

$t_1 = \dfrac{40°}{180°}\left[\dfrac{T}{2}\right] = 0.222\left[\dfrac{3.49\text{ ms}}{2}\right] = \mathbf{0.388\ ms}$

37. a. $T = (2\text{ div.})(0.2\text{ ms/div.}) = \mathbf{0.4\ ms}$

b. $f = \dfrac{1}{T} = \dfrac{1}{0.4\text{ ms}} = \mathbf{2.5\ kHz}$

c. Average $= (-2.5\text{ div.})(10\text{ mV/div.}) = \mathbf{-25\ mV}$

d. —

39. a.

$$G = \frac{\frac{1}{2}(3\text{ s})(10\text{ V}) + \frac{1}{2}(2\text{ s})(10\text{ V}) - \frac{1}{2}(2\text{ s})(10\text{ V})}{8\text{ s}}$$

$$= \frac{15\text{ V} + 10\text{ V} - 10\text{ V}}{8} = \mathbf{1.875\ V}$$

b.

$$G = \frac{\frac{1}{2}\left[\frac{\pi}{2}\right](10\text{ mA}) - 2(15\text{ mA}) - \frac{\pi}{2}(5\text{ mA})}{2\pi}$$

$$= \frac{2.5\pi\text{ mA} - 30\text{ mA} - 2.5\pi\text{ mA}}{2\pi}$$

$$= \frac{-30\text{ mA}}{2\pi} = \mathbf{-4.775\ mA}$$

41. a. $T = (4\text{ div.})(10\ \mu\text{s/div.}) = \mathbf{40\ \mu s}$

b. $f = \dfrac{1}{T} = \dfrac{1}{40\ \mu\text{s}} = \mathbf{25\ kHz}$

(c)

$$G = \frac{(2.5\text{ div.})(1.5\ \cancel{\text{div.}}) + (1\text{ div.})(0.5\ \cancel{\text{div.}}) + (1\text{ div.})(0.6\ \cancel{\text{div.}}) + (2.5\text{ div.})(0.4\ \cancel{\text{div.}}) + (1\text{ div.})(1\ \cancel{\text{div.}})}{4\ \cancel{\text{div.}}}$$

$$= \frac{3.75\text{ div.} + 0.5\text{ div.} + 0.6\text{ div.} + 1\text{ div.} + 1\text{ div.}}{4}$$

$$= \frac{6.85\text{ div.}}{4} = 1.713\text{ div.}$$

$1.713\text{ div.}(10\text{ mV/div.}) = \mathbf{17.13\ mV}$

43. a. $\mathbf{2\sin 377t}$ b. $\mathbf{100\sin 377t}$

c. $\mathbf{84.87 \times 10^{-3}\sin 377t}$ d. $\mathbf{33.95 \times 10^{-6}\sin 377t}$

45.

$$V_{\text{eff}} = \sqrt{\frac{(3\text{ V})^2(2\text{ s}) + (2\text{ V})^2(2\text{ s}) + (1\text{ V})^2(2\text{ s}) + (-1\text{ V})^2(2\text{ s}) + (-3\text{ V})^2(2\text{ s}) + (-2\text{ V}^2(2\text{ s})}{12\text{ s}}}$$

$$= \mathbf{+2.16\ V}$$

47.

$$G = \frac{(10\text{ V})(5\ \mu\text{s}) - (10\text{ V})(5\ \mu\text{s}) + 0}{15\ \mu\text{s}} = \frac{0 + 0}{15\ \mu\text{s}} = \mathbf{0\ V}$$

$$V_{\text{eff}} = \sqrt{\frac{(10\text{ V})^2\ 5\ \mu\text{s} + (-10\text{ V})^2\ 5\ \mu\text{s} + 0}{15\ \mu\text{s}}} = \mathbf{8.165\ V}$$

49. a. $T = (4 \text{ div.})(10\ \mu\text{s/div.}) = \mathbf{40\ \mu s}$

$$f = \frac{1}{T} = \frac{1}{40\ \mu\text{s}} = \mathbf{25\ kHz}$$

Av. = (1 div.)(20 mV/div.) = **20 mV**

Peak = (2 div.)(20 mV/div.) = 40 mV

$$\text{Effective} = \sqrt{V_0^2 + \frac{V_{\max}^2}{2}} = \sqrt{(20\ \text{mV})^2 + \frac{(40\ \text{mV})^2}{2}} = \mathbf{34.641\ mV}$$

b. $T = (2 \text{ div.})(50\ \mu\text{s}) = \mathbf{100\ \mu s}$

$$f = \frac{1}{T} = \frac{1}{100\ \mu\text{s}} = \mathbf{10\ kHz}$$

Av. = (−1.5 div.)(0.2 V/div.) = **−0.3 V**

Peak = (1.5 div.)(0.2 V/div.) = 0.3 V

$$\text{Effective} = \sqrt{V_0^2 + \frac{V_{\max}^2}{2}} = \sqrt{(.3\ \text{V})^2 + \frac{(.3\ \text{V})^2}{2}} = \mathbf{367.42\ mV}$$

CHAPTER 13 (Even)

2. a. $T = 15\ \mu s$

   b. $2\frac{1}{3}$ cycles

   c. $f = \frac{1}{T} = \frac{1}{15\ \mu s} = 66.7\ \text{kHz}$

   d. Positive amplitude = **10 V**, $V_{p\text{-}p}$ = **20 V**

4. a. $T = \frac{1}{25\ \text{Hz}} = 40\ \text{ms}$

   b. $T = \frac{1}{35 \times 10^6\ \text{Hz}} = 28.57\ \text{ns}$

   c. $T = \frac{1}{55 \times 10^3\ \text{Hz}} = 18.18\ \mu s$

   d. $T = \frac{1}{1\ \text{Hz}} = 1\ \text{s}$

6. $T = \frac{24\ \text{ms}}{80\ \text{cycles}} = 0.3\ \text{ms}$

8. $f = \frac{42\ \text{cycles}}{6\ \text{s}} = 7\ \text{Hz}$

10. a. V_{peak} = (3 boxes)(50 mV/box) = **150 mV**

    b. T = (4 boxes)(10 μs/box) = **40 μs**

    c. $f = \frac{1}{T} = \frac{1}{40\ \mu s} = 25\ \text{kHz}$

12. a. $\left[\frac{\cancel{\pi}}{4}\right]\left[\frac{180°}{\cancel{\pi}}\right] = 45°$

    b. $\left[\frac{\cancel{\pi}}{6}\right]\left[\frac{180°}{\cancel{\pi}}\right] = 30°$

    c. $\left[\frac{\cancel{\pi}}{10}\right]\left[\frac{180°}{\cancel{\pi}}\right] = 18°$

    d. $\left[\frac{7}{6}\cancel{\pi}\right]\left[\frac{180°}{\cancel{\pi}}\right] = 210°$

    e. $(3\cancel{\pi})\left[\frac{180°}{\cancel{\pi}}\right] = 540°$

    f. $(0.55\cancel{\pi})\left[\frac{180°}{\cancel{\pi}}\right] = 99°$

14. a. $\omega = 2\pi f = 2\pi(50\ \text{Hz}) = 314.16\ \text{rad/s}$

    b. $\omega = 2\pi f = 2\pi(600\ \text{Hz}) = 3769.91\ \text{rad/s}$

    c. $\omega = 2\pi f = 2\pi(2\ \text{kHz}) = 12.56 \times 10^3\ \text{rad/s}$

    d. $\omega = 2\pi f = 2\pi(0.004\ \text{MHz}) = 25.12 \times 10^3\ \text{rad/s}$

16. $(45°)\left[\frac{\pi}{180°}\right] = \frac{\pi}{4}$ radians

    $t = \frac{\theta}{\omega} = \frac{\pi/4\ \text{rad}}{2\pi f} = \frac{\pi/4\ \text{rad}}{2\pi(60\ \text{Hz})} = \frac{1}{(8)(60)} = \frac{1}{480} = 2.08\ \text{ms}$

18. a. Amplitude = **20**, $f = \dfrac{\omega}{2\pi} = \dfrac{377 \text{ rad/s}}{2\pi} = \mathbf{60\ Hz}$

b. Amplitude = **5**, $f = \dfrac{\omega}{2\pi} = \dfrac{754 \text{ rad/s}}{2\pi} = \mathbf{120\ Hz}$

c. Amplitude = $\mathbf{10^6}$, $f = \dfrac{\omega}{2\pi} = \dfrac{10{,}000 \text{ rad/s}}{2\pi} = \mathbf{1591.55\ Hz}$

d. Amplitude = **0.001**, $f = \dfrac{\omega}{2\pi} = \dfrac{942 \text{ rad/s}}{2\pi} = \mathbf{149.92\ Hz}$

e. Amplitude = **7.6**, $f = \dfrac{\omega}{2\pi} = \dfrac{43.6 \text{ rad/s}}{2\pi} = \mathbf{6.94\ Hz}$

f. Amplitude = **1/42**, $f = \dfrac{\omega}{2\pi} = \dfrac{6.28 \text{ rad/s}}{2\pi} = \mathbf{1\ Hz}$

22. $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{157} = 40 \text{ ms}, \ \dfrac{1}{2} \text{ cycle} = \mathbf{20\ ms}$

24. $1.2\pi\left[\dfrac{180°}{\pi}\right] = 216°$

$v = 20 \sin 216° = 20(-0.588) = \mathbf{-11.76\ V}$

26.
$$v = V_m \sin \alpha$$
$$40 = V_m \sin 30° = V_m(0.5)$$
$$\therefore V_m = \frac{40}{0.5} = \mathbf{80\ V}$$

$$\frac{30°}{360°} = \frac{1 \text{ ms}}{T}$$
$$T = 1 \text{ ms}\left[\frac{360}{30}\right] = \mathbf{12\ ms}$$
$$f = \frac{1}{T} = \frac{1}{12 \times 10^{-3} \text{ s}} = \mathbf{83.33\ Hz}$$
$$\omega = 2\pi f = (2\pi)(83.33 \text{ Hz}) = 523.58 \text{ rad/s}$$

and $\mathbf{v = 80 \sin 523.58t}$

30. a. $\left.\begin{array}{l} v = 2\sin(\omega t \underbrace{- 30° + 90°}_{+60°}) \\ i = 5\sin(\omega t + 60°) \end{array}\right\}$ **in phase**

b. $\left.\begin{array}{r} v = \sin(\omega t + 20° + 180°) = \sin(\omega t + 200°) \\ i = 10\sin(\omega t - 70°) \end{array}\right\}$ ***i* leads *v* by 90°**

c. $\left.\begin{array}{l} v = 4\sin(\omega t + 90° + 90° + 180°) = 4\sin \omega t \\ i = \sin(\omega t + 10° + 180°) = \sin(\omega t + 190°) \end{array}\right\}$ ***i* leads *v* by 190°**

32. a. $v = 0.01 \sin(2\pi(25)t + 11/18\pi) = \mathbf{0.01 \sin(157t - 110°)}$

b. $i = 2 \times 10^{-3} \sin(2\pi(10 \times 10^3)t + 135°) = \mathbf{2 \times 10^{-3} \sin(62.8 \times 10^3 t + 135°)}$

34. $\omega = 2\pi f = 50{,}000$ rad/s

$$f = \frac{50{,}000}{2\pi} = 7957.75 \text{ Hz}$$

$$T = \frac{1}{f} = 125.66\ \mu\text{s}$$

$$t_1 = \frac{40°}{180°}\left[\frac{T}{2}\right] = 0.222(125.66\ \mu\text{s}) = \mathbf{27.92\ \mu s}$$

36. a. $T = (8 \text{ div.})(1 \text{ ms/div.}) = \mathbf{8\ ms}$ (both waveforms)

b. $f = \dfrac{1}{T} = \dfrac{1}{8 \text{ ms}} = \mathbf{125\ Hz}$ (both)

c. Peak $= (2.5 \text{ div.})(0.5 \text{ V/div.}) = 1.25$ V
$V_{rms} = 0.707(1.25 \text{ V}) = \mathbf{0.884\ V}$

d. Phase shift $= 4.6$ div., $T = 8$ div.
$\theta = \dfrac{4.6 \text{ div.}}{8 \text{ div.}} \times 360° = \mathbf{207°}$ ***i* leads *e***
or ***e* leads *i* by 153°**

38. a. $G = \dfrac{(6\text{ V})(1\text{ s}) + (3\text{ V})(1\text{ s}) - (3\text{ V})(1\text{ s})}{3\text{ s}} = \dfrac{6\text{ V}}{3} = \mathbf{2\ V}$

b. $G = \dfrac{\left[\frac{1}{2}(4\text{ ms})(20\text{ mA})\right] - (2\text{ ms})(8\text{ mA})}{8\text{ ms}} = \dfrac{40\text{ mA} - 16\text{ mA}}{8} = \dfrac{24\text{ mA}}{8} = \mathbf{3\ mA}$

40. b. **0.5 V**

42. a. $V_{eff} = 0.707(20\text{ V}) = \mathbf{14.14\ V}$

b. $V_{eff} = 0.707(7.07\text{ V}) = \mathbf{5\ V}$

c. $I_{eff} = 0.707(6\text{ mA}) = \mathbf{4.242\ mA}$

d. $I_{eff} = 0.707(16\text{ mA}) = \mathbf{11.312\ mA}$

44. $V_{eff} = \sqrt{\dfrac{(2\text{ V})^2(4\text{ s}) + (-2\text{ V})^2(1\text{ s}) + (3\text{ V})^2\left(\frac{1}{2}\text{s}\right)}{12\text{ s}}} = \mathbf{1.43\ V}$

46. $G = \dfrac{(10\text{ V})(4\text{ ms}) - (10\text{ V})(4\text{ ms})}{8\text{ ms}} = \dfrac{0}{8\text{ ms}} = \mathbf{0\ V}$

$V_{eff} = \sqrt{\dfrac{(10\text{ V})^2(4\text{ ms}) + (-10\text{ V})^2(4\text{ ms})}{8\text{ ms}}} = \mathbf{10\ V}$

48. $G = \dfrac{\frac{1}{2}bh}{T} = \dfrac{\frac{1}{2}(10\text{ ms})(20\text{ V})}{10\text{ ms}} = \mathbf{10\ V}$

50. a. $V_{dc} = IR = (4\text{ mA})(2\text{ k}\Omega) = 8$ V
Meter indication $= 2.22(8\text{ V}) = \mathbf{17.76\ V}$

b. $V_{rms} = 0.707(16\text{ V}) = \mathbf{11.31\ V}$

CHAPTER 14 (Odd)

3. a. $(377)(10) \cos 377t = \mathbf{3770 \cos 377t}$

 b. $(754)(0.6) \cos(754t + 20°) = \mathbf{452.4 \cos(754t + 20°)}$

 c. $(\sqrt{2}\,20)(157) \cos(157t - 20°) = \mathbf{4440.63 \cos(157t - 20°)}$

 d. $(-200)(1) \cos(t + 180°) = -200 \cos(t + 180°) = \mathbf{200 \cos t}$

5. a. $V_m = I_mR = (0.03 \text{ A})(7 \times 10^3\ \Omega) = 210 \text{ V}$
 $\mathbf{v = 210 \sin 754t}$

 b. $V_m = I_mR = (2 \times 10^{-3} \text{ A})((7 \times 10^3\ \Omega) = 14.8 \text{ V}$
 $\mathbf{v = 14.8 \sin(400t - 120°)}$

 c. $i = 6 \times 10^{-6} \sin(\omega t - 2° + 90°) = 6 \times 10^{-6} \sin(\omega t + 88°)$
 $V_m = I_mR = (6 \times 10^{-6} \text{ A})((7 \times 10^3\ \Omega) = 42 \times 10^{-3} \text{ V}$
 $\mathbf{v = 42 \times 10^{-3} \sin(\omega t + 88°)}$

 d. $i = 0.004 \sin(\omega t - 90° + 90° + 180°) = 0.004 \sin(\omega t + 180°)$
 $V_m = I_mR = (4 \times 10^{-3} \text{ A})((7 \times 10^3\ \Omega) = 28 \text{ V}$
 $\mathbf{v = 28 \sin(\omega t + 180°)}$

7. a. $L = \dfrac{X_L}{2\pi f} = \dfrac{20\ \Omega}{2\pi(2 \text{ Hz})} = \mathbf{1.592 \text{ H}}$ b. $L = \dfrac{X_L}{2\pi f} = \dfrac{1000\ \Omega}{2\pi(60 \text{ Hz})} = \mathbf{2.654 \text{ H}}$

 c. $L = \dfrac{X_L}{2\pi f} = \dfrac{5280\ \Omega}{2\pi(1000 \text{ Hz})} = \mathbf{0.841 \text{ H}}$

9. a. $V_m = I_mX_L = (5 \text{ A})(20\ \Omega) = 100 \text{ V}$
 $\mathbf{v = 100 \sin(\omega t + 90°)}$

 b. $V_m = I_mX_L = (0.4 \text{ A})(20\ \Omega) = 8 \text{ V}$
 $\mathbf{v = 8 \sin(\omega t + 150°)}$

 c. $i = 6 \sin(\omega t + 150°)$, $V_m = I_mX_L = (6 \text{ A})(20\ \Omega) = 120 \text{ V}$
 $v = 120 \sin(\omega t + 240°) = \mathbf{120 \sin(\omega t - 120°)}$

 d. $i = 3 \sin(\omega t + 100°)$, $V_m = I_mX_L = (3 \text{ A})(20\ \Omega) = 60 \text{ V}$
 $\mathbf{v = 60 \sin(\omega t + 190°)}$

11. a. $I_m = \dfrac{V_m}{X_L} = \dfrac{50 \text{ V}}{50\ \Omega} = 1 \text{ A}$, $i = \mathbf{1 \sin(\omega t - 90°)}$

 b. $I_m = \dfrac{V_m}{X_L} = \dfrac{30 \text{ V}}{50\ \Omega} = 0.6 \text{ A}$, $i = \mathbf{0.6 \sin(\omega t - 70°)}$

 c. $v = 40 \sin(\omega t + 100°)$
 $I_m = \dfrac{V_m}{X_L} = \dfrac{40 \text{ V}}{50\ \Omega} = 0.8 \text{ A}$, $i = \mathbf{0.8 \sin(\omega t + 10°)}$

d. $v = 80 \sin(377t + 220°)$

$I_m = \dfrac{V_m}{X_L} = \dfrac{80\text{ V}}{50\ \Omega} = 1.6\text{ A},\ i = \mathbf{1.6 \sin(377t + 130°)}$

13. a. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(0\text{ Hz})(5 \times 10^{-6}\text{ F})} = \mathbf{\infty\ \Omega}$

b. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(60\text{ Hz})(5 \times 10^{-6}\text{ F})} = \mathbf{530.79\ \Omega}$

c. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(120\text{ Hz})(5 \times 10^{-6}\text{ F})} = \mathbf{265.39\ \Omega}$

d. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(1800\text{ Hz})(5 \times 10^{-6}\text{ F})} = \mathbf{17.693\ \Omega}$

e. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(24 \times 10^3\text{ Hz})(5 \times 10^{-6}\text{ F})} = \mathbf{1.327\ \Omega}$

15. a. $f = \dfrac{1}{2\pi CX_C} = \dfrac{1}{2\pi(50\times10^{-6}\text{ F})(342\ \Omega)} = \mathbf{9.31\text{ Hz}}$

b. $f = \dfrac{1}{2\pi CX_C} = \dfrac{1}{2\pi(50\times10^{-6}\text{ F})(684\ \Omega)} = \mathbf{4.66\text{ Hz}}$

c. $f = \dfrac{1}{2\pi CX_C} = \dfrac{1}{2\pi(50\times10^{-6}\text{ F})(171\ \Omega)} = \mathbf{18.62\text{ Hz}}$

d. $f = \dfrac{1}{2\pi CX_C} = \dfrac{1}{2\pi(50\times10^{-6}\text{ F})(2000\ \Omega)} = \mathbf{1.59\text{ Hz}}$

17. a. $v = 30 \sin 200t,\ X_C = \dfrac{1}{\omega C} = \dfrac{1}{(200)(1 \times 10^{-6})} = 5\text{ k}\Omega$

$I_m = \dfrac{V_m}{X_C} = \dfrac{30\text{ V}}{5\text{ k}\Omega} = 6\text{ mA},\ i = \mathbf{6 \times 10^{-3} \sin(200t + 90°)}$

b. $v = 90 \sin 377t,\ X_C = \dfrac{1}{\omega C} = \dfrac{1}{(377)(1 \times 10^{-6})} = 2.65\text{ k}\Omega$

$I_m = \dfrac{V_m}{X_C} = \dfrac{90\text{ V}}{2{,}650\ \Omega} = 33.96\text{ mA},\ i = \mathbf{33.96 \times 10^{-3} \sin(377t + 90°)}$

c. $v = 120 \sin(374t + 210°),\ X_C = \dfrac{1}{\omega C} = \dfrac{1}{(374)(1 \times 10^{-6})} = 2.67\text{ k}\Omega$

$I_m = \dfrac{V_m}{X_C} = \dfrac{120\text{ V}}{2{,}670\ \Omega} = 44.94\text{ mA},\ i = \mathbf{44.94 \times 10^{-3} \sin(374t + 300°)}$

d. $v = 70 \sin(800t + 70°)$, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(800)(1 \times 10^{-6})} = 1.25\ \text{k}\Omega$

$I_m = \dfrac{V_m}{X_C} = \dfrac{70\ \text{V}}{1250\ \Omega} = 56\ \text{mA}$, $i = \mathbf{56 \times 10^{-3} \sin(\omega t + 160°)}$

19. a. $i = 0.2 \sin 300t$, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(300)(0.5 \times 10^{-6})} = 6.67\ \text{k}\Omega$

$V_m = I_m X_C = (0.2\ \text{A})(6{,}670\ \Omega) = 1334\ \text{V}$, $v = \mathbf{1334 \sin(300t - 90°)}$

b. $i = 7 \times 10^{-3} \sin 377t$, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(377)(0.5 \times 10^{-6})} = 5.31\ \text{k}\Omega$

$V_m = I_m X_C = (7 \times 10^{-3}\ \text{A})(5.31 \times 10^3\ \Omega) = 37.17\ \text{V}$

$v = \mathbf{37.17 \sin(377t - 90°)}$

c. $i = 0.048 \sin(754t + 90°)$, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(754)(0.5 \times 10^{-6})} = 2.65\ \text{k}\Omega$

$V_m = I_m X_C = (48 \times 10^{-3}\ \text{A})(2.65 \times 10^3\ \Omega) = 127.2\ \text{V}$

$v = \mathbf{127.2 \sin 754t}$

d. $i = 80 \times 10^{-3} \sin(1600t - 80°)$, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(1600)(0.5 \times 10^{-6})} = 1.25\ \text{k}\Omega$

$V_m = I_m X_C = (80 \times 10^{-3}\ \text{A})(1.25 \times 10^3\ \Omega) = 100\ \text{V}$

$v = \mathbf{100 \sin(1600t - 170°)}$

21. a. $\left.\begin{array}{l} i = 5 \sin(\omega t + 90°) \\ v = 2000 \sin \omega t \end{array}\right\}$ i leads v by $90° \Rightarrow$ **C**

$X_C = \dfrac{V_m}{I_m} = \dfrac{2000\ \text{V}}{5\ \text{A}} = 400\ \Omega$

b. $\left.\begin{array}{l} i = 2 \sin(157t + 60°) \\ v = 80 \sin(157t + 150°) \end{array}\right\}$ v leads i by $90° \Rightarrow$ **L**

$X_L = \dfrac{V_m}{I_m} = \dfrac{80\ \text{V}}{2\ \text{A}} = 40\ \Omega$, $L = \dfrac{X_L}{\omega} = \dfrac{40\ \Omega}{157\ \text{rad/s}} = \mathbf{254.78\ mH}$

c. $\left.\begin{array}{l} v = 35 \sin(\omega t - 20°) \\ i = 7 \sin(\omega t - 20°) \end{array}\right\}$ in phase $\Rightarrow$ **R**

$R = \dfrac{V_m}{I_m} = \dfrac{35\ \text{V}}{7\ \text{A}} = \mathbf{5\ \Omega}$

25. $X_L = 2\pi f L = R$

$L = \dfrac{R}{2\pi f} = \dfrac{10{,}000\ \Omega}{2\pi(5 \times 10^3\ \text{Hz})} = \mathbf{318.47\ mH}$

27. $X_C = X_L$

$$\frac{1}{2\pi fC} = 2\pi fL \Rightarrow C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4(9.86)(2500 \times 10^6)(2 \times 10^{-3})} = \mathbf{5.067\ nF}$$

29. a. $P = \frac{V_m I_m}{2} \cos\theta = \frac{(5\text{ A})(2000\text{ V})}{2} \cos 90° = \mathbf{0\ W}$

b. $\cos\theta = 0 \Rightarrow \mathbf{0\ W}$

c. $P = \frac{(35\text{ V})(7\text{ A})}{2} \cos 0° = \mathbf{122.5\ W}$

31. $R = \frac{V_m}{I_m} = \frac{48\text{ V}}{8\text{ A}} = 6\ \Omega,\ P = I^2R = \left[\frac{8\text{ A}}{\sqrt{2}}\right]^2 6\ \Omega = \mathbf{192\ W}$

$$P = \frac{V_m I_m}{2} \cos\theta = \frac{(48\text{ V})(8\text{ A})}{2} \cos 0° = \mathbf{192\ W}$$

$$P = VI\cos\theta = \left[\frac{48\text{ V}}{\sqrt{2}}\right]\left[\frac{8\text{ A}}{\sqrt{2}}\right] \cos 0° = \mathbf{192\ W}$$

33. $P = \frac{V_m I_m}{2} \cos\theta$

$$500\text{ W} = \frac{(50\text{ V})I_m}{2}(0.5) \Rightarrow I_m = 40\text{ A}$$

$$\mathbf{i = 40 \sin(\omega t - 50°)}$$

35. a. $I_m = \frac{V_m}{X_L} = \frac{100\text{ V}}{50\ \Omega} = 2\text{ A},\ \mathbf{i = 2 \sin(157t - 60°)}$

b. $X_L = \frac{V_m}{I_m} = \frac{100\text{ V}}{2\text{ A}} = 50\ \Omega,\ L = \frac{X_L}{\omega} = \frac{50\ \Omega}{157\text{ rad/s}} = \mathbf{318.47\ mH}$

c. $L \Rightarrow \mathbf{0\ W}$

37. a. $X_{C_1} = \frac{1}{2\pi f C_1} = \frac{1}{\omega C_1} = \frac{1}{(10^4\text{ rad/s})(2\ \mu\text{F})} = 50\ \Omega$

$$X_{C_2} = \frac{1}{\omega C_2} = \frac{1}{(10^4)(8\ \mu\text{F})} = 12.5\ \Omega$$

$$\mathbf{E} = 100\text{ V} \angle 60° \quad \mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_{C_1}} = \frac{100\text{ V} \angle 60°}{50\ \Omega \angle -90°} = 2\text{ A} \angle 150°$$

$$\mathbf{I}_2 = \frac{\mathbf{E}}{\mathbf{Z}_{C_2}} = \frac{100\text{ V} \angle 60°}{12.5\ \Omega \angle -90°} = 8\text{ A} \angle 150°$$

$$i_1 = \sqrt{2}\ 2 \sin(10^4 t + 150°) = \mathbf{2.828 \sin(10^4 t + 150°)}$$

$$i_2 = \sqrt{2}\ 8 \sin(10^4 t + 150°) = \mathbf{11.312 \sin(10^4 t + 150°)}$$

b. $\mathbf{I}_s = \mathbf{I}_1 + \mathbf{I}_2 = 2\text{ A} \angle 150° + 8\text{ A} \angle 150° = 10\text{ A} \angle 150°$

$$i_s = \sqrt{2}\ 10 \sin(10^4 t + 150°) = \mathbf{14.14 \sin(10^4 t + 150°)}$$

39. a. **$5.0 \angle 36.87°$** b. **$2.83 \angle 45°$** c. **$16.38 \angle 77.66°$**

d. **$806.23 \angle 82.87°$** e. **$1077.03 \angle 21.80°$** f. **$0.00658 \angle 81.25°$**

g. **$11.78 \angle -49.82°$** h. **$8.94 \angle 153.43°$** i. **$61.85 \angle -104.04°$**

j. **$101.53 \angle -39.81°$** k. **$4{,}326.66 \angle 123.69°$** l. **$25.495 \times 10^{-3} \angle -78.69°$**

41. a. **$15.033 \angle 86.19°$** b. **$60.208 \angle 4.76°$** c. **$0.30 \angle 88.09°$**

d. **$2002.5 \angle -87.14°$** e. **$86.182 \angle 93.73°$** f. **$38.694 \angle -94.0°$**

43. a. **$11.8 + j7.0$** b. **$151.90 + j49.90$** c. **$4.72 \times 10^{-6} + j71$**

d. **$5.20 + j1.60$** e. **$209.30 + j311.0$** f. **$-21.20 + j12.0$**

g. $6 \angle 20° + 8 \angle 80° = (5.64 + j2.05) + (1.39 + j7.88) = \mathbf{7.03 + j9.93}$

h. $(29.698 + j29.698) + (31.0 + j53.69) - (-35 + j60.62) = \mathbf{95.698 + j22.768}$

45. a. **$6.0 \angle -50.0°$** b. **$0.2 \times 10^{-3} \angle 140°$** c. **$109.0 \angle -230.0°$**

d. **$76.471 \angle -80.0°$** e. $(11.314 \angle 45°)/(2.828 \angle 45°) = \mathbf{40 \angle 0°}$

f. $42.76 \angle 79.22°/60.30 \angle 95.71° = \mathbf{0.71 \angle -16.49°}$

g. $(0.05 + j0.25)/(8 - j60) = 0.255 \angle 78.69°/60.53 \angle -82.41° = \mathbf{4.21 \times 10^{-3} \angle 161.10°}$

h. $(7.5 \angle -126.87°)/(0.4123 \angle -75.96°) = \mathbf{18.191 \angle -50.91°}$

47. a.

$$x + j4 + 3x + jy - j7 = 16$$
$$(x + 3x) + j(4 + y - 7) = 16 + j0$$
$$x + 3x = 16 \qquad 4 + y - 7 = 0$$
$$4x = 16 \qquad y = +7 - 4$$
$$\mathbf{x = 4} \qquad \mathbf{y = 3}$$

b.

$$(10 \angle 20°)(x \angle -60°) = 30.64 - j25.72$$
$$10x \angle -40° = 40 \angle -40°$$
$$10\,x = 40$$
$$\mathbf{x = 4}$$

c. $\begin{array}{l} 5x + j10 \\ \underline{2 - jy} \end{array}$

$$10x + j20 - j5xy - j^2 10y = 90 - j70$$
$$(10x + 10y) + j(20 - 5xy) = 90 - j70$$
$$10x + 10y = 90 \qquad\qquad 20 - 5xy = -70$$
$$x + y = 9$$
$$x = 9 - y \Rightarrow \qquad 20 - 5(9 - y)y = -70$$
$$5y(9 - y) = 90$$
$$y^2 - 9y + 18 = 0$$
$$y = \frac{-(-9) \pm \sqrt{(-9)^2 - 4(1)(18)}}{2}$$
$$y = \frac{9 \pm 3}{2} = 6, 3$$

For $y = 6, x = 3$
$y = 3, x = 6$
($x = 3, y = 6$) or ($x = 6, y = 3$)

d. $\dfrac{80\ \angle 0°}{40\ \angle \theta} = 4\ \angle -\theta = 3.464 - j2 = 4\ \angle -30°$
$\boldsymbol{\theta = 30°}$

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

51. $i_s = i_1 + i_2 \Rightarrow i_1 = i_s - i_2$

(Using peak values) $= (20 \times 10^{-6}\text{ A } \angle 90°) - (6 \times 10^{-6}\text{ A } \angle -60°)$
and $i_1 = (0 + j2 \times 10^{-5}) - (3 \times 10^{-6} - j5.196 \times 10^{-6})$
$= -0.3 \times 10^{-5} + j2.5196 \times 10^{-5} = 2.537 \times 10^{-5}\ \angle 96.79°$
$= \mathbf{2.537 \times 10^{-5} \sin(\omega t + 96.79°)}$

53. (Using effective values)

$\mathbf{I}_s = \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3 = 4.240\text{ mA } \angle 180° + 5.656\text{ mA } \angle 0° + 11.312\text{ mA } \angle 0°$
$= -4.242\text{ mA} + 16.968\text{ mA} = 12.726\text{ mA } \angle 0°$
$i_s = \mathbf{18 \times 10^{-3} \sin 377t}$

CHAPTER 14 (Even)

4. a. $I_m = V_m/R = 150 \text{ V}/5\ \Omega = 30 \text{ A}$, $i = \mathbf{30 \sin 377}t$

b. $I_m = V_m/R = 30 \text{ V}/5\ \Omega = 6 \text{ A}$, $i = \mathbf{6 \sin(377}t \mathbf{+ 20°)}$

c. $I_m = V_m/R = 40 \text{ V}/5\ \Omega = 8 \text{ A}$, $i = \mathbf{8 \sin(\omega t + 100°)}$

d. $I_m = V_m/R = 80 \text{ V}/5\ \Omega = 16 \text{ A}$, $i = \mathbf{16 \sin(\omega t + 220°)}$

6. a. $\mathbf{0\ \Omega}$

b. $X_L = 2\pi fL = 2\pi Lf = (6.28)(2 \text{ H})f = 12.56f = 12.56(25 \text{ Hz}) = \mathbf{314\ \Omega}$

c. $X_L = 12.56f = 12.56(60 \text{ Hz}) = \mathbf{753.6\ \Omega}$

d. $X_L = 12.56f = 12.56(2000 \text{ Hz}) = \mathbf{25.13\ k\Omega}$

e. $X_L = 12.56f = 12.56(10^5 \text{ Hz}) = \mathbf{1.256\ M\Omega}$

8. a. $X_L = 2\pi fL \Rightarrow f = \dfrac{X_L}{2\pi L} = \dfrac{X_L}{(6.28)(10 \text{ H})} = \dfrac{X_L}{62.8}$

$f = \dfrac{50\ \Omega}{62.8} \cong \mathbf{0.796\ Hz}$

b. $f = \dfrac{X_L}{62.8} = \dfrac{3770\ \Omega}{62.8} = \mathbf{60.03\ Hz}$

c. $f = \dfrac{X_L}{62.8} = \dfrac{15{,}700\ \Omega}{62.8} = \mathbf{250\ Hz}$

d. $f = \dfrac{X_L}{62.8} = \dfrac{243\ \Omega}{62.8} = \mathbf{3.87\ Hz}$

10. a. $X_L = \omega L = (300 \text{ rad/s})(0.1 \text{ H}) = 3\ \Omega$
$V_m = I_m X_L = (30 \text{ A})(3\ \Omega) = 90 \text{ V}$
$v = \mathbf{90 \sin(30}t \mathbf{+ 90°)}$

b. $X_L = \omega L = (377 \text{ rad/s})(0.1 \text{ H}) = 37.7\ \Omega$
$V_m = I_m X_L = (6 \times 10^{-3} \text{ A})(37.7\ \Omega) = 226.2 \text{ mV}$
$v = \mathbf{226.2 \times 10^{-3} \sin(377}t \mathbf{+ 90°)}$

c. $X_L = \omega L = (400 \text{ rad/s})(0.1 \text{ H}) = 40\ \Omega$
$V_m = I_m X_L = (5 \times 10^{-6} \text{ A})(40\ \Omega) = 200\ \mu\text{V}$
$v = \mathbf{200 \times 10^{-6} \sin(400}t \mathbf{+ 110°)}$

d. $i = 4 \sin(20t + 200°)$
$X_L = \omega L = (20 \text{ rad/s})(0.1 \text{ H}) = 2\ \Omega$
$V_m = I_m X_L = (4 \text{ A})(2\ \Omega) = 8 \text{ V}$
$v = 8 \sin(20t + 290°) = \mathbf{8 \sin(20}t \mathbf{- 70°)}$

12. a. $X_L = \omega L = (60 \text{ rad/s})(0.2 \text{ H}) = 12\ \Omega$
$I_m = V_m/X_L = 1.5 \text{ V}/12\ \Omega = 0.125 \text{ A}$
$i = \mathbf{0.125 \sin(60}t \mathbf{- 90°)}$

b. $X_L = \omega L = (1 \text{ rad/s})(0.2 \text{ H}) = 0.2\ \Omega$
$I_m = V_m/X_L = 16 \text{ mV}/0.2\ \Omega = 80 \text{ mA}$
$i = 80 \times 10^{-3} \sin(t + 4° - 90°) = \mathbf{80 \times 10^{-3} \sin(}t \mathbf{- 86°)}$

c. $v = 4.8 \sin(0.05t + 230°)$
$X_L = \omega L = (0.05 \text{ rad/s})(0.2 \text{ H}) = 0.01\ \Omega$
$I_m = V_m/X_L = 4.8 \text{ V}/0.01\ \Omega = 480 \text{ A}$
$i = 480 \sin(0.05t + 230° - 90°) = \mathbf{480 \sin(0.05}t \mathbf{+ 140°)}$

d. $v = 9 \times 10^{-3} \sin(377t + 90°)$
$X_L = \omega L = (377 \text{ rad/s})(0.2 \text{ H}) = 75.4\ \Omega$
$I_m = V_m/X_L = 9 \text{ mV}/75.4\ \Omega = 0.119 \text{ mA}$
$i = \mathbf{0.119 \times 10^{-3} \sin 377}t$

14. a. $C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{6.28(60 \text{ Hz})(250\ \Omega)} = \mathbf{10.62\ \mu F}$

b. $C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{6.28(312 \text{ Hz})(55\ \Omega)} = \mathbf{9.28\ \mu F}$

c. $C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{6.28(25 \text{ Hz})(10\ \Omega)} = \mathbf{636.94\ \mu F}$

16. a. $I_m = V_m/X_C = 100 \text{ V}/2.5\ \Omega = 40 \text{ A}$
$i = \mathbf{40 \sin(\omega t + 90°)}$

b. $I_m = V_m/X_C = 0.4 \text{ V}/2.5\ \Omega = 0.16 \text{ A}$
$i = \mathbf{0.16 \sin(\omega t + 110°)}$

c. $v = 8 \sin(\omega t + 100°)$
$I_m = V_m/X_C = 8 \text{ V}/2.5\ \Omega = 3.2 \text{ A}$
$i = \mathbf{3.2 \sin(\omega t + 190°)}$

d. $v = -70 \sin(\omega t + 40°) = 70 \sin(\omega t + 220°)$
$I_m = V_m/X_C = 70 \text{ V}/2.5\ \Omega = 28 \text{ A}$
$i = 28 \sin(\omega t + 310°) = \mathbf{28 \sin(\omega t - 50°)}$

18. a. $V_m = I_m X_C = (50 \text{ A})(10\ \Omega) = 500 \text{ V}$
$v = \mathbf{500 \sin(\omega t - 90°)}$

b. $V_m = I_m X_C = (40 \text{ A})(10\ \Omega) = 400 \text{ V}$
$v = \mathbf{400 \sin(\omega t - 30°)}$

c. $i = -6 \sin(\omega t - 30°) = 6 \sin(\omega t + 150°)$
$V_m = I_m X_C = (6 \text{ A})(10\ \Omega) = 60 \text{ V}$
$v = \mathbf{60 \sin(\omega t + 60°)}$

d. $i = 3 \sin(\omega t + 100°)$
$V_m = I_m X_C = (3 \text{ A})(10\ \Omega) = 30 \text{ V}$
$v = \mathbf{30 \sin(\omega t + 10°)}$

20. a. v leads i by $90° \Rightarrow L$, $X_L = V_m/I_m = 550 \text{ V}/11 \text{ A} = 50\ \Omega$

$$L = \frac{X_L}{\omega} = \frac{50\ \Omega}{377 \text{ rad/s}} = \mathbf{132.63 \text{ mH}}$$

b. i leads v by 90° ⇒ C, $X_C = V_m/I_m = 36\text{ V}/4\text{ A} = 9\ \Omega$

$$C = \frac{1}{\omega X_C} = \frac{1}{(754\text{ rad/s})(9\ \Omega)} = \mathbf{147.36\ \mu F}$$

c. v and i are in phase ⇒ R

$$R = \frac{V_m}{I_m} = \frac{10.5\text{ V}}{1.5\text{ A}} = \mathbf{7\ \Omega}$$

24. $$X_C = \frac{1}{2\pi fC} = R \Rightarrow f = \frac{1}{2\pi RC} = \frac{1}{2\pi(2\times 10^3\ \Omega)(1\times 10^{-6}\text{ F})} = \frac{1}{12.56\times 10^{-3}}$$
$$\cong \mathbf{79.62\ Hz}$$

26. $$X_C = X_L$$
$$\frac{1}{2\pi fC} = 2\pi fL$$
$$f^2 = \frac{1}{4\pi^2 LC}$$
$$\text{and } f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(10\times 10^{-3}\text{ H})(1\times 10^{-6}\text{ F})}} = \mathbf{1.592\ kHz}$$

28. a. $$P = \frac{V_m I_m}{2}\cos\theta = \frac{(550\text{ V})(11\text{ A})}{2}\cos 90° = (\ )(0) = \mathbf{0\ W}$$

b. $$P = \frac{V_m I_m}{2}\cos\theta = \frac{(36\text{ V})(4\text{ A})}{2}\cos 90° = (\ )(0) = \mathbf{0\ W}$$

c. $$P = \frac{V_m I_m}{2}\cos\theta = \frac{(10.5\text{ V})(1.5\text{ A})}{2}\cos 0° = \mathbf{7.875\ W}$$

30. a. $$P = \frac{(60\text{ V})(15\text{ A})}{2}\cos 30° = \mathbf{389.7\ W},\ F_p = \mathbf{0.866}$$

b. $$P = \frac{(50\text{ V})(2\text{ A})}{2}\cos 60° = \mathbf{25\ W},\ F_p = \mathbf{0.5}$$

c. $$P = \frac{(50\text{ V})(3\text{ A})}{2}\cos 30° = \mathbf{64.95\ W},\ F_p = \mathbf{0.866}$$

d. $$P = \frac{(75\text{ V})(0.08\text{ A})}{2}\cos 30° = \mathbf{2.598\ W},\ F_p = \mathbf{0.866}$$

32. $P = 100\text{ W}$: $F_p = \cos\theta = P/VI = 100\text{ W}/(150\text{ V})(2\text{ A}) = \mathbf{0.333}$
$P = 0\text{ W}$: $F_p = \cos\theta = \mathbf{0}$
$P = 300\text{ W}$: $F_p = \dfrac{300}{300} = \mathbf{1}$

34. a. $I_m = E_m/R = 30\text{ V}/3\ \Omega = 10\text{ A}$, $i = \mathbf{10\sin(377t + 20°)}$

b. $P = I^2R = \left[\dfrac{10\text{ A}}{\sqrt{2}}\right]^2 3\ \Omega = \mathbf{150\ W}$

c. $T = \dfrac{2\pi}{\omega} = \dfrac{6.28}{377\text{ rad/s}} = \mathbf{16.67\ ms}$
$6(16.67\text{ ms}) = 100.02\text{ ms} \cong \mathbf{0.1\ s}$

36. a. $E_m = I_mX_C = (3\text{ A})(400\ \Omega) = 1200\text{ V}$
$e = 1200\sin(377t - 20° - 90°) = \mathbf{1200\sin(377t - 110°)}$

b. $C = \dfrac{1}{\omega X_C} = \dfrac{1}{(377\text{ rad/s})(400\ \Omega)} = \mathbf{6.63\ \mu F}$

c. $P = 0$ W

38. a. $L_1 \| L_2 = 4\text{ mH} \| 12\text{ mH} = 3\text{ mH}$
$X_{L_T} = 2\pi f L_T = 2\pi(10^3\text{ Hz})(3\text{ mH}) = 18.84\ \Omega$

$V_m = I_mX_{L_T} = (\sqrt{2}\ 6\text{ A})(18.84\ \Omega) = \sqrt{2}\ 113.04\text{ V}$

and $v_s = \sqrt{2}\,113.04\sin(10^3t + 30° + 90°)$

or $v_s = \mathbf{159.86\sin(10^3t + 120°)}$

b. $I_{m_1} = \dfrac{V_m}{X_{L_1}}$, $X_{L_1} = 2\pi f L_1 = 2\pi(10^3\text{ Hz})(4\text{ mH}) = 25.13\ \Omega$

$I_{m_1} = \dfrac{159.86\text{ V}}{25.13\ \Omega} = 6.36\text{ A}$

and $i_1 = \mathbf{6.36\sin(10^3t + 30°)}$
$X_{L_2} = 2\pi f L_2 = 2\pi(10^3\text{ Hz})(12\text{ mH}) = 75.398\ \Omega$

$I_{m_2} = \dfrac{159.86\text{ V}}{75.398\ \Omega} = 2.12\text{ A}$

and $i_2 = \mathbf{2.12\sin(10^3t + 30°)}$

40. a. **5.196 + *j*3.0** b. **6.946 + *j*39.392**

c. **2530.95 + *j*6953.73** d. $\mathbf{3.961 \times 10^{-4} + j5.567 \times 10^{-5}}$

e. **0.007 + *j*0.039** f. $\mathbf{8.561 \times 10^{-3} + j3.634 \times 10^{-3}}$

g. **−56.292 + *j*32.50** h. **−0.849 + *j*0.849**

i. **−469.846 − *j*171.01** j. **5177.04 − *j*3625.0**

k. **−4.313 − *j*6.160** l. **0.005142 − *j*0.006128**

42. a. **12.951 + *j*1.133** b. **8.374 + *j*159.781**

c. $\mathbf{6.996 \times 10^{-6} + j2.443 \times 10^{-7}}$ d. **−8.688 + *j*0.455**

e. **$75.815 - j5.301$** f. **$-34.514 - j394.493$**

44. a. **$-12.0 + j34.0$** b. $(29.2 + j19.6)(7 + j6) =$ **$86.80 + j312.40$**

c. **$-0.0160 - j0.008$**

d. $(447.214 \angle -26.565°)(0.5 \angle -91.146°)(3.162 \angle 108.435°) =$ **$707.045 \angle -9.276°$**

e. **$8.0 \angle 82.0°$** f. **$49.68 \angle -64.0°$**

g. **$0.040 \angle 260°$** h. **$-16{,}740 \angle 160°$**

46. a. $\dfrac{10 - j5}{1 + j0} =$ **$10.0 - j5.0$**

b. $\dfrac{8 \angle 60°}{102 + j100} = \dfrac{8 \angle 60°}{142.843 \angle 44.433°} =$ **$0.056 \angle 15.567°$**

c. $\dfrac{(6 \angle 20°)(120 \angle -40°)(5 \angle 53.13°)}{2 \angle -30°} = \dfrac{3600 \angle 33.13°}{2 \angle -30°} =$ **$1800 \angle 63.13°$**

d. $\dfrac{(0.16 \angle 120°)(300 \angle 40°)}{9.487 \angle 71.565°} = \dfrac{48 \angle 160°}{9.487 \angle 71.565°} =$ **$5.06 \angle 88.435°$**

e. $\left[\dfrac{1}{4 \times 10^{-4} \angle 20°}\right]\left[\dfrac{8}{j(j^2)}\right]\left[\dfrac{1}{36 - j30}\right]$

$(2500 \angle -20°)\left[\dfrac{8}{-j}\right]\left[\dfrac{1}{46.861 \angle -39.81°}\right]$

$(2500 \angle -20°)(8j)(0.0213 \angle 39.81°) =$ **$426 \angle 109.81°$**

48. a. **$100.0 \angle 30°$** b. **$0.250 \angle -40°$**

c. **$70.71 \angle -90°$** d. **$29.69 \angle 0°$**

e. **$4.242 \times 10^{-6} \angle 90°$** f. **$2.546 \times 10^{-6} \angle 70°$**

50. (Using peak values)

$$
\begin{aligned}
e_{in} = v_a + v_b \Rightarrow v_a &= e_{in} - v_b \\
&= 60\text{ V} \angle 20° - 20\text{ V} \angle 0° \\
&= (56.381 + j20.521) - (20 + j0) \\
&= 36.381 + j20.52 \\
&= 41.769\text{ V} \angle 29.43°
\end{aligned}
$$

and $e_{in} =$ **$41.769 \sin(377t + 29.43°)$**

52.

$$
\begin{aligned}
e &= v_a + v_b + v_c \\
&= 60\text{ V} \angle 30° + 30\text{ V} \angle -30° + 40\text{ V} \angle 120° \\
&= (51.96 + j30) + (25.98 - j15) + (-20 + j34.64) \\
&= 57.94 + j49.64 \\
&= 76.297\text{ V} \angle 40.59°
\end{aligned}
$$

and $e =$ **$76.297 \sin(\omega t + 40.59°)$**

CHAPTER 15 (Odd)

1. a. $R \angle 0° = \mathbf{6.8\ \Omega \angle 0° = 6.8\ \Omega}$

b. $X_L = \omega L = (377 \text{ rad/s})(2 \text{ H}) = 754\ \Omega$
$X_L \angle 90° = \mathbf{754\ \Omega \angle 90° = +j754\ \Omega}$

c. $X_L = 2\pi fL = (6.28)(50 \text{ Hz})(0.05 \text{ H}) = 15.7\ \Omega$
$X_L \angle 90° = \mathbf{15.7\ \Omega \angle 90° = +j15.7\ \Omega}$

d. $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(377 \text{ rad/s})(10 \times 10^{-6} \text{ F})} = 265.25\ \Omega$
$X_C \angle -90° = \mathbf{265.25\ \Omega \angle -90° = -j265.25\ \Omega}$

e. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(10 \times 10^3 \text{ Hz})(0.05 \times 10^{-6} \text{ F})} = 318.47\ \Omega$
$X_C \angle -90° = \mathbf{318.47\ \Omega \angle -90° = -j318.47\ \Omega}$

f. $R \angle 0° = 200\ \Omega \angle 0° = 200\ \Omega$

3. a. $\mathbf{I} = (0.707)(4 \text{ mA} \angle 0°) = 2.828 \text{ mA} \angle 0°$
$\mathbf{V} = (I \angle 0°)(R \angle 0°) = (2.828 \text{ mA} \angle 0°)(22\ \Omega \angle 0°) = 62.216 \text{ mV} \angle 0°$
$v = \mathbf{88 \times 10^{-3} \sin \omega t}$

b. $\mathbf{I} = (0.707)(1.5 \text{ A} \angle 60°) = 1.0605 \text{ A} \angle 60°$
$X_L = \omega L = (377 \text{ rad/s})(0.016 \text{ H}) = 6.032\ \Omega$

$\mathbf{V} = (I \angle \theta)(X_L \angle 90°) = (1.0605 \text{ A} \angle 60°)(6.032\ \Omega \angle 90°) = 6.397 \text{ V} \angle 150°$
$v = \mathbf{9.045 \sin(377t + 150°)}$

c. $\mathbf{I} = (0.707)(20 \text{ mA} \angle 40°) = 14.14 \text{ mA} \angle 40°$
$X_C = \dfrac{1}{\omega C} = \dfrac{1}{(157 \text{ rad/s})(0.05 \times 10^{-6} \text{ F})} = 127.39 \text{ k}\Omega$

$\mathbf{V} = (I \angle \theta)(X_C \angle -90°) = (14.14 \text{ mA} \angle 40°)(127.39 \text{ k}\Omega \angle -90°)$
$= 1801.3 \text{ V} \angle -50°$
$V_p = \sqrt{2}(1801.3 \text{ V}) = 2547.4 \text{ V}$
and $v = \mathbf{2547.4 \sin(157t - 50°)}$

5. a. $\mathbf{Z}_T = 3\ \Omega + j4\ \Omega - j7\ \Omega = \mathbf{3\ \Omega - j3\ \Omega = 4.24\ \Omega \angle -45°}$

b. $\mathbf{Z}_T = 0.5 \text{ k}\Omega + j7 \text{ k}\Omega - j4 \text{ k}\Omega = \mathbf{0.5 \text{ k}\Omega + j3 \text{ k}\Omega = 3.04 \text{ k}\Omega \angle 80.54°}$

c. $L_T = 0.26 \text{ H} = 260 \times 10^{-3} \text{ H} = 260 \text{ mH}$
$X_L = \omega L = 2\pi fL = 2\pi(10^3 \text{ Hz})(260 \times 10^{-3} \text{ H}) = 1632.8\ \Omega$
$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(10^3 \text{ Hz})(10 \times 10^{-6} \text{ F})} = 15.92\ \Omega$
$\mathbf{Z}_T = 47\ \Omega + j1632.8\ \Omega - j15.92\ \Omega$
$= \mathbf{47\ \Omega + j1616.88\ \Omega = 1617.56\ \Omega \angle 88.33°}$

7. a. $\mathbf{Z}_T = 8\ \Omega + j6\ \Omega = \mathbf{10\ \Omega\ \angle 36.87^\circ}$

c. $\mathbf{I} = \mathbf{E}/\mathbf{Z}_T = 100\text{ V}\ \angle 0^\circ/10\ \Omega\ \angle 36.87^\circ = \mathbf{10\text{ A}\ \angle -36.87^\circ}$
$\mathbf{V}_R = (I\ \angle\theta)(R\ \angle 0^\circ) = (10\text{ A}\ \angle -36.87^\circ)(8\ \Omega\ \angle 0^\circ) = \mathbf{80\text{ V}\ \angle -36.87^\circ}$
$\mathbf{V}_L = (I\ \angle\theta)(X_L\ \angle 90^\circ) = (10\text{ A}\ \angle -36.87^\circ)(6\ \Omega\ \angle 90^\circ) = \mathbf{60\text{ V}\ \angle 53.13^\circ}$

f. $P = I^2R = (10\text{ A})^2\ 8\ \Omega = \mathbf{800\text{ W}}$

g. $F_p = \cos\theta_T = R/Z_T = 8\ \Omega/10\ \Omega = \mathbf{0.8}$ **lagging**

9. a. $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(10^3\text{ Hz})(0.1\times 10^{-6}\text{ F})} = 1592.36\ \Omega$

$\mathbf{Z}_T = 470\ \Omega - j1592.36\ \Omega = \mathbf{1660.27\ \Omega\ \angle -73.56^\circ}$

b. $\mathbf{I} = \mathbf{E}/\mathbf{Z}_T = 14.14\text{ V}\ \angle 0^\circ/1660.27\ \Omega\ \angle -73.56^\circ = \mathbf{8.517\text{ mA}\ \angle 73.56^\circ}$

c. $\mathbf{V}_R = (I\ \angle\theta)(R\ \angle 0^\circ) = (8.517\text{ mA}\ \angle 73.56^\circ)(0.470\times 10^3\ \Omega\ \angle 0^\circ) = \mathbf{4\text{ V}\ \angle 73.56^\circ}$
$\mathbf{V}_L = (I\ \angle\theta)(X_C\ \angle -90^\circ) = (8.517\text{ mA}\ \angle 73.56^\circ)(1592.36\ \Omega\ \angle -90^\circ)$
$= \mathbf{13.562\text{ V}\ \angle -16.44^\circ}$

d. $P = I^2R = (8.517\text{ mA})^2\ 470\ \Omega = \mathbf{34.09\text{ mW}}$
$F_p = \cos\theta_T = \cos 73.56^\circ = \mathbf{0.283}$ **leading**

11. a. $\mathbf{Z}_T = 3\text{ k}\Omega + j2\text{ k}\Omega - j1\text{ k}\Omega = \mathbf{3\text{ k}\Omega + j1\text{ k}\Omega = 3.16\text{ k}\Omega\ \angle 18.43^\circ}$

c. $X_C = \dfrac{1}{\omega C} \Rightarrow C = \dfrac{1}{\omega X_C} = \dfrac{1}{(314\text{ rad/s})(10^3\ \Omega)} = \mathbf{3.18\ \mu F}$

$X_L = \omega L \Rightarrow L = \dfrac{X_L}{\omega} = \dfrac{2\times 10^3\ \Omega}{314\text{ rad/s}} = \mathbf{6.37\text{ H}}$

d. $\mathbf{I} = \mathbf{E}/\mathbf{Z}_T = 4.242\text{ V}\ \angle 60^\circ/3.16\text{ k}\Omega\ \angle 18.43^\circ = \mathbf{1.3424\text{ mA}\ \angle 41.57^\circ}$
$\mathbf{V}_R = (I\ \angle\theta)(R\ \angle 0^\circ) = (1.3424\text{ mA}\ \angle 41.57^\circ)(3\text{ k}\Omega\ \angle 0^\circ) = \mathbf{4.027\text{ V}\ \angle 41.57^\circ}$
$\mathbf{V}_L = (I\ \angle\theta)(X_L\ \angle 90^\circ) = (1.3424\text{ mA}\ \angle 41.57^\circ)(2\text{ k}\Omega\ \angle 90^\circ) = \mathbf{2.6848\text{ V}\ \angle 131.57^\circ}$
$\mathbf{V}_C = (I\ \angle\theta)(X_C\ \angle -90^\circ) = (1.3424\text{ mA}\ \angle 41.57^\circ)(1\text{ k}\Omega\ \angle -90^\circ)$
$= \mathbf{1.3424\text{ V}\ \angle -48.43^\circ}$

g. $P = I^2R = (1.3424\text{ mA})^2\ 3\text{ k}\Omega = \mathbf{5.406\text{ mW}}$

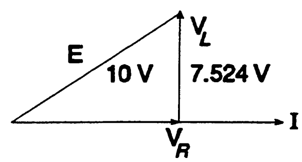
h. $F_p = \cos\theta_T = \cos 18.43^\circ = \mathbf{0.9487}$ **lagging**

i. $i = \mathbf{1.898\times 10^{-3}\sin(\omega t + 41.57^\circ)}$
$v_R = \mathbf{5.6942\sin(\omega t + 41.57^\circ)}$
$v_L = \mathbf{3.7963\sin(\omega t + 131.57^\circ)}$
$v_C = \mathbf{1.8982\sin(\omega t - 48.43^\circ)}$

13. a. $V_L(\text{rms}) = 0.7071\left[\dfrac{21.28\text{ V}}{2}\right] = 7.524\text{ V}$

$$X_L = \frac{V_L}{I_L} = \frac{7.524\text{ V}}{29.94\text{ mA}} = 251.303\ \Omega$$

$$X_L = 2\pi fL \Rightarrow L = \frac{X_L}{2\pi f} = \frac{251.303\ \Omega}{2\pi(1\text{ kHz})} = 39.996\text{ mH} \cong \mathbf{40\ mH}$$

b. 

$$E^2 = V_R^2 + V_L^2$$

$$V_R = \sqrt{E^2 - V_L^2}$$

$$= \sqrt{(100\text{ V}) - (56.611)} = \sqrt{43.389} = 6.587\text{ V}$$

$$R = \frac{V_R}{I_R} = \frac{6.587\text{ V}}{29.94\text{ mA}} = \mathbf{220\ \Omega}$$

15. a. $\mathbf{V}_1 = \dfrac{(2\text{ k}\Omega\ \angle 0°)(120\text{ V}\ \angle 20°)}{2\text{ k}\Omega + j6\text{ k}\Omega} = \dfrac{240\text{ V}\ \angle 20°}{6.32\ \angle 71.57°} = \mathbf{37.97\ V\ \angle -51.57°}$

$$\mathbf{V}_2 = \frac{(6\text{ k}\Omega\ \angle 90°)(120\text{ V}\ \angle 20°)}{6.32\text{ k}\Omega\ \angle 71.57°} = \mathbf{113.92\ V\ \angle 38.43°}$$

b. $\mathbf{V}_1 = \dfrac{(40\text{ k}\Omega\ \angle 90°)(60\text{ V}\ \angle 5°)}{6.8\ \Omega + j40\ \Omega + 9\ \Omega} = \dfrac{2400\text{ V}\ \angle 95°}{15.8 + j40} = \mathbf{55.80\ \angle 26.55°}$

$$\mathbf{V}_2 = \frac{(9\ \Omega\ \angle 0°)(60\text{ V}\ \angle 5°)}{43.01\ \Omega\ \angle 68.45°} = \frac{540\ V\ \angle 5°}{43.01\ \angle 68.45°} = \mathbf{12.56\ V\ \angle -63.45°}$$

17. a. $X_L = \omega L = (377\text{ rad/s})(0.4\text{ H}) = 150.8\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{(377\text{ rad/s})(4\ \mu\text{F})} = 663\ \Omega$$

$$\mathbf{Z}_T = 30\ \Omega + j150.8\ \Omega - j663\ \Omega = 30\ \Omega - j512.2\ \Omega = \mathbf{513.08\ \Omega\ \angle -86.65°}$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{20\text{ V}\ \angle 40°}{513.08\ \Omega\ \angle -86.65°} = \mathbf{39\ mA\ \angle 126.65°}$$

$$\mathbf{V}_R = (I\ \angle\theta)(R\ \angle 0°) = (39\text{ mA}\ \angle 126.65°)(30\ \Omega\ \angle 0°) = \mathbf{1.17\ V\ \angle 126.65°}$$

$$\mathbf{V}_C = (39\text{ mA}\ \angle 126.65°)(0.663\text{ k}\Omega\ \angle -90°) = \mathbf{25.86\ V\ \angle 36.65°}$$

b. $\cos\theta_T = \dfrac{R}{Z_T} = \dfrac{30\ \Omega}{513.08\ \Omega} = \mathbf{0.058\ leading}$

c. $P = I^2R = (39\text{ mA})^2\ 30\ \Omega = \mathbf{45.63\ mW}$

f. $\mathbf{V}_R = \dfrac{(30\ \Omega\ \angle 0°)(20\text{ V}\ \angle 40°)}{\mathbf{Z}_T} = \dfrac{600\text{ V}\ \angle 40°}{513.08\ \angle -86.65°} = \mathbf{1.17\ V\ \angle 126.65°}$

$$\mathbf{V}_C = \frac{(0.663\text{ k}\Omega\ \angle -90°)(20\text{ V}\ \angle 40°)}{513.08\ \Omega\ \angle -86.65°} = \mathbf{25.84\ V\ \angle 36.65°}$$

g. $\mathbf{Z}_T = \mathbf{30\ \Omega - \mathit{j}512.2\ \Omega} = R - jX_C$

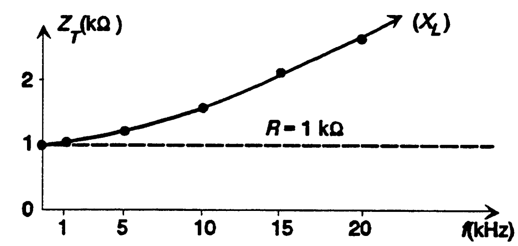
19. $P = VI\cos\theta \Rightarrow 8000\text{ W} = (200\text{ V})(I)(0.8)$

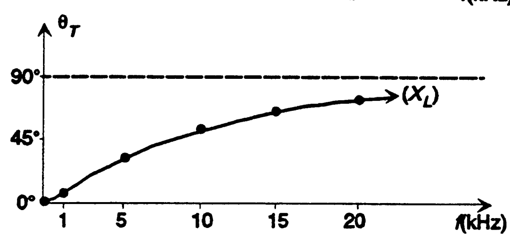
$$I = \frac{8000\text{ A}}{160} = 50\text{ A}$$

$$0.8 = \cos\theta$$
$$\theta = 36.87°$$
$$\mathbf{V} = 200\text{ V}\ \angle 0°,\ I = 50\text{ A}\ \angle -36.87°$$
$$\mathbf{Z}_T = \frac{\mathbf{V}}{\mathbf{I}} = \frac{200\ V\ \angle 0°}{50\text{ A}\ \angle -36.87°} = 4\ \Omega\ \angle 36.87° = \mathbf{3.2\ \Omega + j2.4\ \Omega}$$

21. a. $\mathbf{Z}_T = \sqrt{R^2 + X_L^2}\ \angle \tan^{-1} X_L/R$

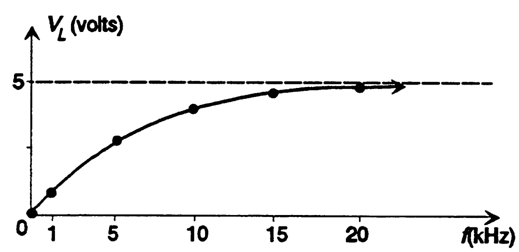
f	Z_T	θ_T
0 Hz	1.0 kΩ	0.0°
1 kHz	1.008 kΩ	7.16°
5 kHz	1.181 kΩ	32.14°
10 kHz	1.606 kΩ	51.49°
15 kHz	2.134 kΩ	62.05°
20 kHz	2.705 kΩ	68.3°





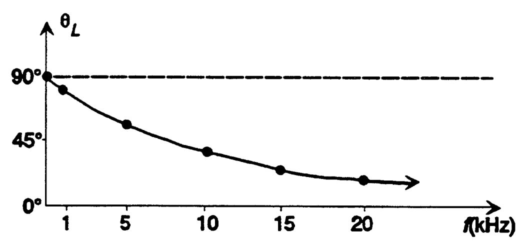
b. $V_L = \dfrac{X_L E}{Z_T}$

f	V_L
0 Hz	0.0 V
1 kHz	0.623 V
5 kHz	2.66 V
10 kHz	3.888 V
15 kHz	4.416 V
20 kHz	4.646 V



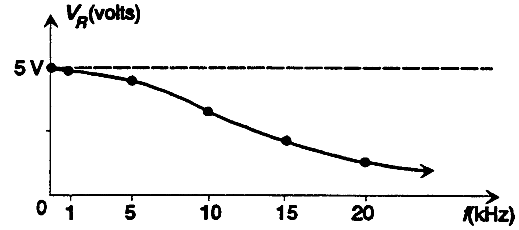
c.

f	$\theta_L = 90° - \tan^{-1} X_L/R$
0 Hz	90.0°
1 kHz	82.84°
5 kHz	57.85°
10 kHz	38.5°
15 kHz	27.96°
20 kHz	21.7°



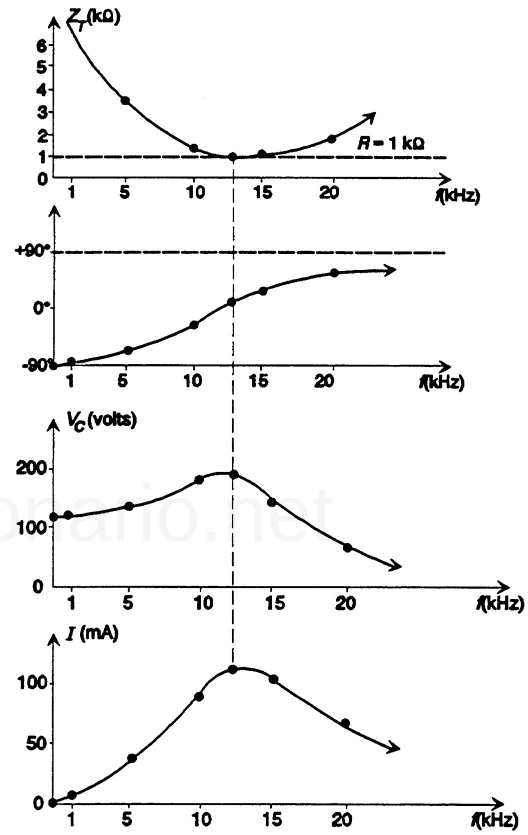
d.

f	$V_R = RE/Z_T$
0 Hz	5.0 V
1 kHz	4.96 V
5 kHz	4.23 V
10 kHz	3.11 V
15 kHz	2.34 V
20 kHz	1.848 V



23. a. $\mathbf{Z}_T = \sqrt{R^2 + (X_L - X_C)^2}\ \angle \tan^{-1}(X_L - X_C)/R$

f	Z_T	θ_T
0 Hz	∞ Ω	−90.0°
1 kHz	19,793.97 Ω	−87.1°
5 kHz	3,496.6 Ω	−73.38°
10 kHz	1,239.76 Ω	−36.23°
15 kHz	1,145.47 Ω	+29.19°
20 kHz	1,818.24 Ω	+56.63°



b. $|V_C| = \dfrac{X_C E}{Z_T}$

f	$\lvert V_C \rvert$
0 Hz	120.0 V
1 kHz	120.61 V
5 kHz	136.55 V
10 kHz	192.57 V
15 kHz	138.94 V
20 kHz	65.65 V

c. $|I| = \dfrac{E}{Z_T}$

f	I
0 Hz	0.0 mA
1 kHz	6.062 mA
5 kHz	34.32 mA
10 kHz	96.79 mA
15 kHz	104.76 mA
20 kHz	66.0 mA

25. a. $\mathbf{Z}_T = 3\ \Omega + j8\ \Omega = 8.544\ \Omega \angle 69.44°$, $\mathbf{Y}_T = 0.117\ \text{S} \angle -69.44$

$\mathbf{Y}_T = 41.1\ \text{mS} - j109.5\ \text{mS} = G - jB_L$

b. $\mathbf{Z}_T = 40\ \Omega + 20\ \Omega - j70\ \Omega = \mathbf{60\ \Omega - j70\ \Omega = 92.195\ \Omega\ \angle -49.40^\circ}$

$\mathbf{Y}_T = \mathbf{10.9\ mS\ \angle 49.40^\circ = 7.1\ mS + j8.3\ mS} = G + jB_C$

c. $\mathbf{Z}_T = 200\ \Omega + j500\ \Omega - j600\ \Omega = \mathbf{200\ \Omega - j100\ \Omega = 223.61\ \Omega\ \angle -26.57^\circ}$

$\mathbf{Y}_T = \mathbf{4.47\ mS\ \angle 26.57^\circ = 4\ mS + j2\ mS} = G + jB_C$

27. a. $\mathbf{Y}_T = \dfrac{1}{2\ \Omega\ \angle 0^\circ} + \dfrac{1}{5\ \Omega\ \angle 90^\circ} = 0.5\ \text{S} - j0.2\ \text{S} = \mathbf{538.52\ mS\ \angle -21.8^\circ}$

c. $\mathbf{E} = \mathbf{I}_s/\mathbf{Y}_T = 2\ \text{A}\ \angle 0^\circ/0.539\ \text{S}\ \angle -21.8^\circ = \mathbf{3.71\ V\ \angle 21.8^\circ}$

$\mathbf{I}_R = \dfrac{E\ \angle\theta}{R\ \angle 0^\circ} = 3.71\ \text{V}\ \angle 21.8^\circ/2\ \Omega\ \angle 0^\circ = \mathbf{1.855\ A\ \angle 21.8^\circ}$

$\mathbf{I}_L = \dfrac{E\ \angle\theta}{X_L\ \angle 90^\circ} = 3.71\ \text{V}\ \angle 21.8^\circ/5\ \Omega\ \angle 90^\circ = \mathbf{0.742\ A\ \angle -68.2^\circ}$

f. $P = I^2R = (1.855\ \text{A})^2\ 2\ \Omega = \mathbf{6.88\ W}$

g. $F_p = \dfrac{G}{Y_T} = \dfrac{0.5\ S}{0.539\ S} = \mathbf{0.928}$ **lagging**

h. $e = \mathbf{5.25\sin(377t + 21.8^\circ)}$
$i_R = \mathbf{2.62\sin(377t + 21.8^\circ)}$
$i_L = \mathbf{1.049\sin(377t - 68.2^\circ)}$
$i_s = \mathbf{2.828\sin 377t}$

29. a. $\mathbf{Y}_T = \dfrac{1}{12\ \Omega\ \angle 0^\circ} + \dfrac{1}{10\ \Omega\ \angle 90^\circ} = 0.083\ \text{S} - j0.1\ \text{S} = \mathbf{129.96\ mS\ \angle -50.31^\circ}$

c. $\mathbf{I}_s = \mathbf{E}\mathbf{Y}_T = (60\ \text{V}\ \angle 0^\circ)(0.13\ \text{S}\angle -50.31^\circ) = \mathbf{7.8\ A\ \angle -50.31^\circ}$

$\mathbf{I}_R = \dfrac{E\ \angle\theta}{R\ \angle\ 0^\circ} = 60\ \text{V}\ \angle 0^\circ/12\ \Omega\ \angle 0^\circ = \mathbf{5\ A\ \angle 0^\circ}$

$\mathbf{I}_L = \dfrac{E\ \angle\theta}{X_L\ \angle\ 90^\circ} = 60\ \text{V}\ \angle 0^\circ/10\ \Omega\ \angle 90^\circ = \mathbf{6\ A\ \angle -90^\circ}$

f. $P = I^2R = (5\ \text{A})^2\ 12\ \Omega = \mathbf{300\ W}$

g. $F_p = G/Y_T = 0.083\ \text{S}/0.13\ \text{S} = \mathbf{0.638}$ **lagging**

h. $e = \mathbf{84.84\sin 377t}$
$i_R = \mathbf{7.07\sin 377t}$
$i_L = \mathbf{8.484\sin(377t - 90^\circ)}$
$i_s = \mathbf{11.03\sin(377t - 50.31^\circ)}$

31. a. $\mathbf{Y}_T = \dfrac{1}{3\ \text{k}\Omega\ \angle 0^\circ} + \dfrac{1}{4\ \text{k}\Omega\ \angle 90^\circ} + \dfrac{1}{2\ \text{k}\Omega\ \angle -90^\circ}$
$= 0.333\ \text{mS}\ \angle 0^\circ + 0.25\ \text{mS}\ \angle -90^\circ + 0.5\ \text{mS}\ \angle 90^\circ$
$= \mathbf{0.333\ mS + j0.25\ mS = 0.416\ mS\ \angle 36.897^\circ}$

c. $X_L = \omega L \Rightarrow L = X_L/\omega = 4000\ \Omega/377\ \text{rad/s} = \mathbf{10.61\ H}$

$$X_C = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega X_C} = \frac{1}{(377\ \text{rad/s})(2000\ \Omega)} = \mathbf{1.326\ \mu F}$$

d. $\mathbf{E} = \mathbf{I}/\mathbf{Y}_T = 3.535\ \text{mA}\ \angle -20°/0.416\ \text{mS}\ \angle 36.897° = \mathbf{8.498\ V\ \angle -56.897°}$

$$\mathbf{I}_R = \frac{E\ \angle\theta}{R\ \angle 0°} = 8.498\ \text{V}\angle -56.897°/3\ \text{k}\Omega\ \angle 0° = \mathbf{2.833\ mA\ \angle -56.897°}$$

$$\mathbf{I}_L = \frac{E\ \angle\theta}{X_L\ \angle 90°} = 8.498\ \text{V}\angle -56.897°/4\ \text{k}\Omega\ \angle 90° = \mathbf{2.125\ mA\ \angle -146.897°}$$

$$\mathbf{I}_C = \frac{E\ \angle\theta}{X_C\ \angle -90°} = 8.498\ \text{V}\angle -56.897°/2\ \text{k}\Omega\ \angle -90° = \mathbf{4.249\ mA\ \angle 33.103°}$$

g. $P = I^2R = (2.833\ \text{mA})^2 \cdot 3\ \text{k}\Omega = \mathbf{24.078\ mW}$

h. $F_p = G/Y_T = 0.333\ \text{mS}/0.416\ \text{mS} = \mathbf{0.8\ leading}$

i. $e = \mathbf{12.016\ sin(377\mathit{t} - 56.897°)}$
$i_R \cong \mathbf{4\ sin(377\mathit{t} - 56.897°)}$
$i_L \cong \mathbf{3\ sin(377\mathit{t} - 146.897°)}$
$i_C = \mathbf{6\ sin(377\mathit{t} + 33.103°)}$

33. a. $$\mathbf{I}_1 = \frac{(70\ \Omega\ \angle 90°)(20\ \text{A}\ \angle 40°)}{33\ \Omega + j70\ \Omega} = \frac{1400\ \text{A}\ \angle 130°}{77.389\ \angle 64.759°} = \mathbf{18.09\ A\ \angle 65.241°}$$

$$\mathbf{I}_2 = \frac{(33\ \Omega\ \angle 0°)(20\ \text{A}\ \angle 40°)}{77.389\ \angle 64.759°} = \frac{660\ \text{A}\ \angle 40°}{77.389\ \angle 64.759°} = \mathbf{8.528\ A\ \angle -24.759°}$$

b. $$\mathbf{I}_1 = \frac{(3\ \Omega - j6\ \Omega)(6\ \text{A}\ \angle 30°)}{3\ \Omega - j6\ \Omega + j4\ \Omega} = \frac{(6.708\ \angle -63.435°)(6\ \text{A}\ \angle 30°)}{3 - j2}$$

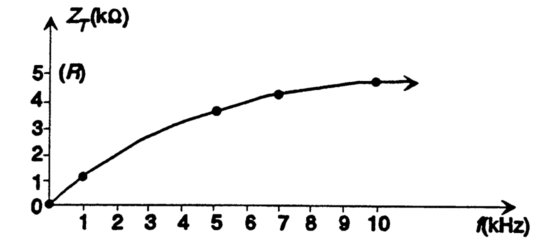
$$= \frac{40.248\ \text{A}\ \angle -33.435°}{3.606\ \angle -33.690°} = \mathbf{11.161\ A\ \angle 0.255°}$$

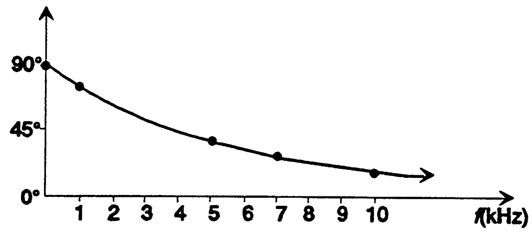
$$\mathbf{I}_2 = \frac{(4\ \Omega\ \angle 90°)(6\ \text{A}\ \angle 30°)}{3.606\ \Omega\angle -33.690°} = \frac{24\ \text{A}\ \angle 120°}{3.606\ \angle -33.690°} = \mathbf{6.656\ A\ \angle 153.690°}$$

35. a. $\mathbf{Z}_T = \dfrac{\mathbf{Z}_R\mathbf{Z}_L}{\mathbf{Z}_R + \mathbf{Z}_L} = \dfrac{(R\ \angle 0°)(X_L\ \angle 90°)}{R + jX_L} = \dfrac{RX_L}{\sqrt{R^2 + X_L^2}} \angle 90° - \tan^{-1} X_L/R$

$$|Z_T| = \frac{RX_L}{\sqrt{R^2 + X_L^2}} \qquad \theta_T = 90° - \tan^{-1} X_L/R$$

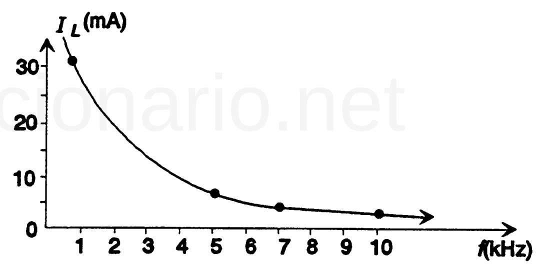
f	$\lvert\mathbf{Z}_T\rvert$	θ_T
0 Hz	0.0 kΩ	90.0°
1 kHz	1.22 kΩ	75.86°
5 kHz	3.91 kΩ	38.53°
7 kHz	4.35 kΩ	29.6°
10 kHz	4.65 kΩ	21.69°



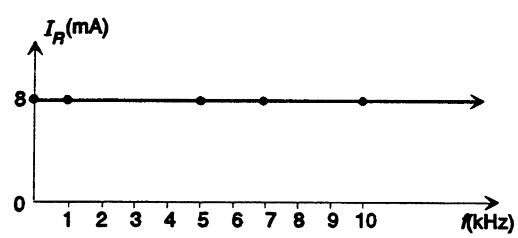


b. $|I_L| = \dfrac{E}{X_L}$

f	$\lvert I_L\rvert$
0 Hz	∞
1 kHz	31.75 mA
5 kHz	6.37 mA
7 kHz	4.55 mA
10 kHz	3.18 mA

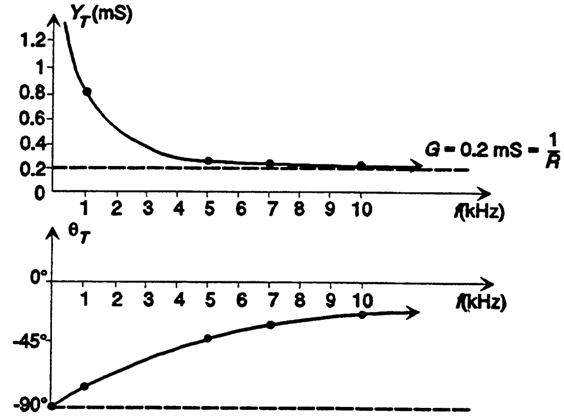


c. $I_R = \dfrac{E}{R} = \dfrac{40\text{ V}}{5\text{ k}\Omega} = 8\text{ mA (constant)}$



37. $Y_T = \dfrac{1}{Z_T}$(use data of Prob. 35), $\theta_{T_Y} = -\theta_{T_Z}$

f	Y_T	θ_T
0 Hz	∞	$-90.0°$
1 kHz	0.82 mS	$-75.86°$
5 kHz	0.256 mS	$-38.53°$
7 kHz	0.23 mS	$-29.6°$
10 kHz	0.215 mS	$-21.69°$



39. a. $R_p = \dfrac{R_s^2 + X_s^2}{R_s} = \dfrac{(22\ \Omega)^2 + (40\ \Omega)^2}{22\ \Omega} = \mathbf{94.73\ \Omega}\ (R)$

$X_p = \dfrac{R_s^2 + X_s^2}{X_s} = \dfrac{2084\ \Omega}{40} = \mathbf{52.1\ \Omega}\ (C)$

b. $R_p = \dfrac{R_s^2 + X_s^2}{R_s} = \dfrac{(2\ \text{k}\Omega)^2 + (2\ \text{k}\Omega)^2}{2\ \text{k}\Omega} = \mathbf{4\ k\Omega}\ (R)$

$X_p = \dfrac{R_s^2 + X_s^2}{X_s} = \dfrac{(2\ \text{k}\Omega)^2 + (2\ \text{k}\Omega)^2}{2\ \text{k}\Omega} = \mathbf{4\ k\Omega}\ (C)$

41. a. $C_T = 2\ \mu\text{F}$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi(10^3\ \text{Hz})(2\ \mu\text{F})} = 79.62\ \Omega$

$X_L = \omega L = 2\pi(10^3\ \text{Hz})(10\ \text{mH}) = 62.80\ \Omega$

$\mathbf{Y}_T = \dfrac{1}{220\ \Omega\ \angle 0°} + \dfrac{1}{79.62\ \Omega\ \angle -90°} + \dfrac{1}{62.8\ \Omega\ \angle 90°}$

$= 4.55\ \text{mS}\ \angle 0° + 12.56\ \text{mS}\ \angle 90° + 15.92\ \text{mS}\ \angle -90°$

$= \mathbf{4.55\ mS - \mathit{j}3.36\ mS = 5.66\ mS\ \angle -36.44°}$

$\mathbf{E} = \mathbf{I}/\mathbf{Y}_T = 1\ \text{A}\ \angle 0°/5.66\ \text{mS}\ \angle -36.44° = \mathbf{176.68\ V\ \angle 36.44°}$

$\mathbf{I}_R = \dfrac{E\ \angle\theta}{R\ \angle 0°} = 176.68\ \text{V}\ \angle 36.44°/220\ \Omega\ \angle 0° = \mathbf{0.803\ A\ \angle 36.44°}$

$\mathbf{I}_L = \dfrac{E\ \angle\theta}{X_L\ \angle 90°} = 176.68\ \text{V}\ \angle 36.44°/62.80\ \angle 90° = \mathbf{2.813\ A\ \angle -53.56°}$

b. $F_p = G/Y_T = 4.55\ \text{mS}/5.66\ \text{mS} = \mathbf{0.804}$ **lagging**

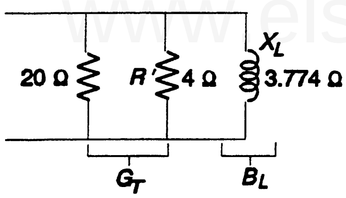
e. $P = I^2R = (0.803\ \text{A})^2\ 220\ \Omega = \mathbf{141.86\ W}$

f. $\mathbf{I}_s = \mathbf{I}_R + 2\mathbf{I}_C + \mathbf{I}_L$

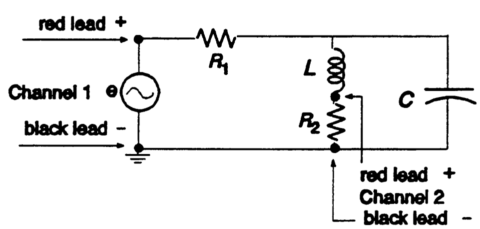
$$\text{and } \mathbf{I}_C = \frac{\mathbf{I}_s - \mathbf{I}_R - \mathbf{I}_L}{2}$$
$$= \frac{1\text{ A }\angle 0° - 0.803\text{ A }\angle 36.44° - 2.813\text{ A }\angle -53.56°}{2}$$
$$= \frac{1 - (0.646 + j0.477) - (1.671 - j2.263)}{2} = \frac{-1.317 + j1.786}{2}$$
$$\mathbf{I}_C = -0.657 + j0.893 = \mathbf{1.11\text{ A }\angle 126.43°}$$

g. $$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{5.66\text{ mS }\angle -36.44°} = 176.7\ \Omega\ \angle 36.44°$$
$$= \mathbf{142.15\ \Omega + j104.96\ \Omega} = R + jX_L$$

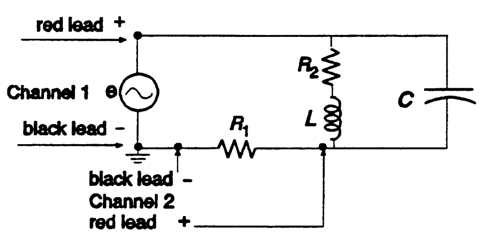
43. $P = VI\cos\theta = 3000\text{ W}$
$$\cos\theta = \frac{3000\text{ W}}{VI} = \frac{3000\text{ W}}{(100\text{ V})(40\text{ A})} = \frac{3000}{4000} = 0.75\text{ (lagging)}$$
$$\theta = \cos^{-1} 0.75 = 41.41°$$
$$\mathbf{Y}_T = \frac{\mathbf{I}}{\mathbf{E}} = \frac{40\text{ A }\angle -41.41°}{100\text{ V }\angle 0°} = 0.4\text{ S }\angle -41.41° = 0.3\text{ S} - j0.265\text{ S} = G_T - jB_L$$
$$G_T = 0.3\text{ S} = \frac{1}{20\ \Omega} + \frac{1}{R'} = 0.05\text{ S} + \frac{1}{R'}$$
$$\text{and } R' = \frac{1}{0.25\text{ S}} = \mathbf{4\ \Omega}$$
$$X_L = \frac{1}{B_L} = \frac{1}{0.265\text{ S}} = \mathbf{3.744\ \Omega}$$



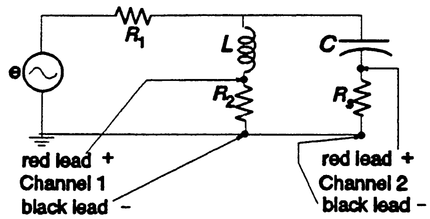
45. a. e and v_{R_2}



b. e and i_s



c. i_L and i_C


R1
L
C
e
R2
Rs
red lead +
Channel 1
black lead −
red lead +
Channel 2
black lead −

CHAPTER 15 (Even)

2. a. $\mathbf{V} = 14.847\text{ V} \angle 10°$, $\mathbf{I} = \dfrac{V\angle\theta}{R\angle 0°} = \dfrac{14.847\text{ V}\angle 10°}{3\ \Omega\angle 0°} = 4.949\text{ A}\angle 10°$
$i = \mathbf{7\sin(\omega t + 10°)}$

b. $\mathbf{V} = 34.643\text{ V}\angle 70°$, $\mathbf{I} = \dfrac{V\angle\theta}{X_L\angle 90°} = \dfrac{34.643\text{ V}\angle 70°}{7\ \Omega\angle 90°} = 4.949\text{ A}\angle -20°$
$i = \mathbf{7\sin(\omega t - 20°)}$

c. $\mathbf{V} = 17.675\text{ V}\angle -20°$, $\mathbf{I} = \dfrac{V\angle\theta}{X_C\angle -90°} = \dfrac{17.675\text{ V}\angle -20°}{100\ \Omega\angle -90°} = 0.1768\text{ A}\angle 70°$
$i = \mathbf{0.25\sin(\omega t + 70°)}$

d. $\mathbf{V} = 2.828\text{ mV}\angle -120°$, $\mathbf{I} = \dfrac{V\angle\theta}{R\angle 0°} = \dfrac{2.828\text{ mV}\angle -120°}{5.1\text{ k}\Omega\angle 0°} = 0.555\ \mu\text{A}\angle -120°$
$i = \mathbf{0.785 \times 10^{-6}\sin(\omega t - 120°)}$

e. $\mathbf{V} = 11.312\text{ V}\angle 60°$, $\mathbf{I} = \dfrac{V\angle\theta}{X_L\angle 90°} = \dfrac{11.312\text{ V}\angle 60°}{(377\text{ rad/s})(0.1\text{ H}\angle 90°} = 0.3\text{ A}\angle -30°$
$i = \mathbf{0.424\sin(377t - 30°)}$

f. $\mathbf{V} = 84.84\text{ V}\angle 0°$, $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(5\text{ k}\Omega)(2\ \mu\text{F})} = 15.924\ \Omega$
$\mathbf{I} = \dfrac{V\angle\theta}{X_C\angle -90°} = \dfrac{84.84\text{ V}\angle 0°}{15.924\ \Omega\angle -90°} = 5.328\text{ A}\angle 90°$
$i = \mathbf{7.534\sin(\omega t + 90°)}$

4. a. $\mathbf{Z}_T = 6.8\ \Omega + j6.8\ \Omega = \mathbf{9.167\ \Omega\angle 45°}$

b. $\mathbf{Z}_T = 2\ \Omega - j6\ \Omega + 8\ \Omega = \mathbf{10\ \Omega - j6\ \Omega = 11.66\ \Omega\angle -30.96°}$

c. $\mathbf{Z}_T = 1\text{ k}\Omega + j3\text{ k}\Omega + 4\text{ k}\Omega + j7\text{ k}\Omega = \mathbf{5\text{ k}\Omega + j10\text{ k}\Omega = 11.18\text{ k}\Omega\angle 63.435°}$

6. a. $\mathbf{Z}_T = \dfrac{\mathbf{E}}{\mathbf{I}} = \dfrac{120\text{ V}\angle 0°}{60\text{ A}\angle 70°} = 2\Omega\angle -70° = \mathbf{0.684\ \Omega - j1.879\ \Omega} = R - jX_C$

b. $\mathbf{Z}_T = \dfrac{\mathbf{E}}{\mathbf{I}} = \dfrac{80\text{ V}\angle 320°}{20\text{ mA}\angle 40°} = 4\text{ k}\Omega\angle 280° = 4\text{ k}\Omega\angle -80° = \mathbf{0.695\text{ k}\Omega - j3.939\text{ k}\Omega}$
$= R - jX_C$

c. $\mathbf{Z}_T = \dfrac{\mathbf{E}}{\mathbf{I}} = \dfrac{8\text{ kV}\angle 0°}{0.2\text{ A}\angle -60°} = 40\text{ k}\Omega\angle 60° = \mathbf{20\text{ k}\Omega + j34.64\text{ k}\Omega} = R + jX_L$

8. a. $\mathbf{Z}_T = 10\ \Omega - j30\ \Omega = \mathbf{31.62\ \Omega\angle -71.57°}$

c. $\mathbf{I} = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{120\text{ V} \angle 20°}{31.62\ \Omega \angle -71.57°} = \mathbf{3.795\ A \angle 91.57°}$

$\mathbf{V}_R = (I \angle \theta)(R \angle 0°) = (3.795\text{ A} \angle 91.57°)(10\ \Omega \angle 0°) = \mathbf{37.95\ V \angle 91.57°}$
$\mathbf{V}_C = (I \angle \theta)(X_C \angle -90°) = (3.795\text{ A} \angle 91.57°)(30\ \Omega \angle -90°) = \mathbf{113.85\ V \angle 1.57°}$

f. $P = I^2R = (3.795\text{ A})^2\ 10\ \Omega = \mathbf{144.02\ W}$

g. $F_p = R/Z_T = 10\ \Omega/31.62\ \Omega =$ **0.316 leading**

h. $i = \mathbf{5.37 \sin(377t + 91.57°)}$
$v_R = \mathbf{53.66 \sin(377t + 91.57°)}$
$v_C = \mathbf{160.98 \sin(377t + 1.57°)}$

10. a. $\mathbf{Z}_T = 2\ \Omega + j6\ \Omega - j10\ \Omega = 2\ \Omega - j4\ \Omega = \mathbf{4.47\ \Omega \angle -63.43°}$

c. $X_L = \omega L \Rightarrow L = \dfrac{X_L}{\omega} = \dfrac{6\ \Omega}{377\text{ rad/s}} = \mathbf{16\ mH}$

$X_C = \dfrac{1}{\omega C} \Rightarrow C = \dfrac{1}{\omega X_C} = \dfrac{1}{(377\text{ rad/s})(10\ \Omega)} = \mathbf{265\ \mu F}$

d. $\mathbf{I} = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{50\text{ V} \angle 0°}{4.47\ \Omega \angle -63.43°} = \mathbf{11.19\ A \angle 63.43°}$
$\mathbf{V}_R = (I \angle \theta)(R \angle 0°) = (11.19\text{ A} \angle 63.43°)(2\ \Omega \angle 0°) = \mathbf{22.38\ V \angle 63.43°}$
$\mathbf{V}_L = (I \angle \theta)(X_L \angle 90°) = (11.19\text{ A} \angle 63.43°)(6\ \Omega \angle 90°) = \mathbf{67.14\ V \angle 153.43°}$
$\mathbf{V}_C = (I \angle \theta)(X_C \angle -90°) = (11.19\text{ A} \angle 63.43°)(10\ \Omega \angle -90°) = \mathbf{111.9\ V \angle -26.57°}$

f. $\mathbf{E} = \mathbf{V}_R + \mathbf{V}_L + \mathbf{V}_C$
$50\text{ V} \angle 0° = 22.38\text{ V} \angle 63.43° + 67.14\text{ V} \angle 153.43° + 111.9\text{ V} \angle -26.57°$
$= (10 + j20) + (-60 + j30) + (100 - j50)$
$50\text{ V} \angle 0° \stackrel{\checkmark}{=} 50\text{ V} \angle 0°$

g. $P = I^2R = (11.19\text{ A})^2\ 2\ \Omega = \mathbf{250.43\ W}$

h. $F_p = \cos\theta_T = \dfrac{R}{Z_T} = 2\ \Omega/4.47\ \Omega =$ **0.447 leading**

i. $i = \mathbf{15.82 \sin(377t + 63.43°)}$
$e = \mathbf{70.7 \sin 377t}$
$v_R = \mathbf{31.65 \sin(377t + 62.43°)}$
$v_L = \mathbf{94.94 \sin(377t + 153.43°)}$
$v_C = \mathbf{158.227 \sin(377t - 26.57°)}$

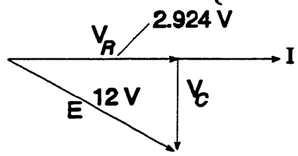
12. $V_{80\Omega}(\text{rms}) = 0.7071 \left[\dfrac{45.27\text{ V}}{2}\right] = 16\text{ V}$

$V_{\text{scope}} = \dfrac{80\ \Omega\,(20\text{ V})}{80\ \Omega + R} = 16\text{ V}$

$1600 = 1280 + 16R$

$R = \dfrac{320}{16} = \mathbf{20\ \Omega}$

14. $V_R(\text{rms}) = 0.7071\left[\dfrac{8.27\text{ V}}{2}\right] = 2.924\text{ V}$



$$V_C = \sqrt{E^2 - V_R^2}$$
$$= \sqrt{144 - 8.55} = \sqrt{135.45} = 11.638\text{ V}$$

$$I_C = I_R = \frac{2.924\text{ V}}{10\text{ k}\Omega} = 292.4\ \mu\text{A}$$
$$X_C = \frac{V_C}{I_C} = \frac{11.638\text{ V}}{292.4\ \mu\text{A}} = 39.802\text{ k}\Omega$$
$$X_C = \frac{1}{2\pi fC} \Rightarrow C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(40\text{ kHz})(39.802\text{ k}\Omega)} = 99.967\text{ pF} \cong \mathbf{100\ pF}$$

16. a. $\mathbf{V}_1 = \dfrac{(20\ \Omega\ \angle 90°)(20\text{ V}\ \angle 70°)}{20\ \Omega + j20\ \Omega - j60\ \Omega} = \mathbf{8.94\ V\ \angle 223.43°}$

$\mathbf{V}_2 = \dfrac{(60\ \Omega\ \angle -90°)(20\text{ V}\ \angle 70°)}{44.72\ \Omega\ \angle -63.43°} = \mathbf{26.83\ V\ \angle 43.43°}$

b. $\mathbf{Z}_T = 4.7\text{ k}\Omega + j30\text{ k}\Omega + 3.3\text{ k}\Omega - j10\text{ k}\Omega = 8\text{ k}\Omega + j20\text{ k}\Omega = 21.541\text{ k}\Omega\ \angle 68.199°$

$\mathbf{Z}'_T = 3.3\text{ k}\Omega + j30\text{ k}\Omega - j10\text{ k}\Omega = 3.3\text{ k}\Omega + j20\text{ k}\Omega = 20.27\text{ k}\Omega\ \angle 80.631°$

$\mathbf{V}_1 = \dfrac{\mathbf{Z}'_T\mathbf{E}}{\mathbf{Z}_T} = \dfrac{(20.27\text{ k}\Omega\ \angle 80.631°)(120\text{ V}\ \angle 0°)}{21.541\text{ k}\Omega\ \angle 68.199°} = \mathbf{112.92\ V\ \angle 12.432°}$

$\mathbf{V}_2 = \dfrac{\mathbf{Z}''_T\mathbf{E}}{\mathbf{Z}_T}$ $\quad\mathbf{Z}''_T = 3.3\text{ k}\Omega - j10\text{ k}\Omega = 10.53\text{ k}\Omega\ \angle -71.737°$

$= \dfrac{(10.53\text{ k}\Omega\ \angle -71.737°)(120\text{ V}\ \angle 0°)}{21.541\text{ k}\Omega\ \angle 68.199°} = \mathbf{58.66\ V\ \angle -139.936°}$

18. a. $X_L = \omega L = (377\text{ rad/s})(0.4\text{ H}) = 150.8\ \Omega$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{(377\text{ rad/s})(1 \times 10^{-3}\text{ F})} = 2.653\ \Omega$

$\mathbf{Z}_T = 30\ \Omega + j150.8\ \Omega - j2.653\ \Omega$
$= 30\ \Omega + j148.147\ \Omega = 151.154\ \Omega\ \angle 78.552°$

$\mathbf{I} = \mathbf{E}/\mathbf{Z}_T = 20\text{ V}\ \angle 40°/151.154\ \Omega\ \angle 78.552° = \mathbf{0.132\ A\ \angle -38.552°}$

$\mathbf{V}_R = (I\ \angle\theta)(R\ \angle 0°) = (0.132\text{ A}\ \angle -38.552°)(30\ \Omega\ \angle 0°) = \mathbf{3.96\ V\ \angle -38.552°}$

$\mathbf{V}_C = (I\ \angle\theta)(X_C\ \angle -90°) = (0.132\text{ A}\ \angle -38.552°)(2.653\ \Omega\ \angle -90°)$
$= \mathbf{0.35\ V\ \angle -128.552°}$

b. $F_p = \cos\theta_T = R/Z_T = 30\ \Omega/151.154\ \Omega = \mathbf{0.198\ lagging}$

c. $P = I^2R = (0.132\text{ A})^2\ 30\ \Omega = \mathbf{0.523\ W}$

f. $\mathbf{V}_R = \dfrac{(30\ \Omega\ \angle 0°)(20\text{ V}\angle 40°)}{151.154\ \Omega\ \angle 78.552°} = \mathbf{3.969\ V\ \angle -38.552°}$

$\mathbf{V}_C = \dfrac{(2.653\ \Omega\ \angle -90°)(20\text{ V}\angle 40°)}{151.154\ \Omega\ \angle 78.552°} = \mathbf{0.351\ V\ \angle 128.552°}$

g. $\mathbf{Z}_T = 30\ \Omega + j148.147\ \Omega = R + jX_L$

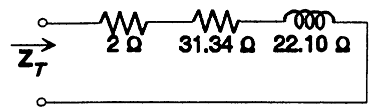
20. $P = VI\cos\theta \Rightarrow 300\text{ W} = (120\text{ V})(3\text{ A})\cos\theta$

$$\cos\theta = 0.833 \Rightarrow \theta = \mathbf{33.59°}$$

$$\mathbf{V} = 120\text{ V}\ \angle 0°,\ \mathbf{I} = 3\text{ A}\ \angle -33.59°$$

$$\mathbf{Z}_T = \frac{\mathbf{V}}{\mathbf{I}} = \frac{120\text{ V}\ \angle 0°}{3\text{ A}\ \angle -33.59°} = 40\ \Omega\ \angle 33.59° = \mathbf{33.34\ \Omega + \mathit{j}22.10\ \Omega}$$

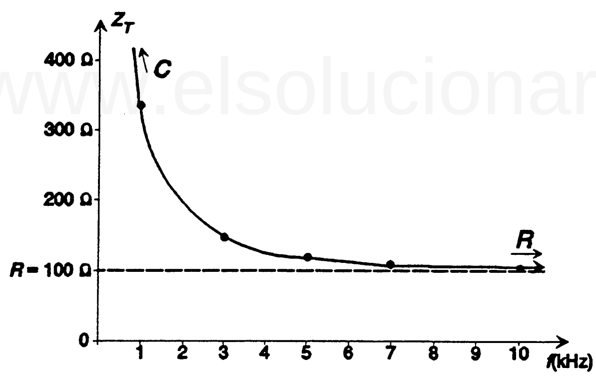
$$R_T = 33.34\ \Omega = 2\ \Omega + R \Rightarrow R = 31.34\ \Omega$$

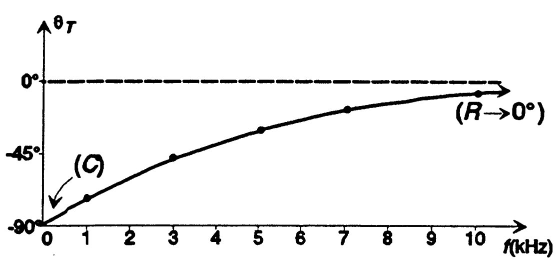


22. a. $\mathbf{Z}_T = \sqrt{R^2 + X_C^2}\ \angle\text{-}\tan^{-1}X_C/R$

$$|\mathbf{Z}_T| = \sqrt{R^2 + X_C^2},\ \theta_T = -\tan^{-1}X_C/R$$

f	$\lvert Z_T\rvert$	θ_T
0 kHz	∞ Ω	−90.0°
1 kHz	333.64 Ω	−72.56°
3 kHz	145.8 Ω	−46.7°
5 kHz	118.54 Ω	−32.48°
7 kHz	109.85 Ω	−24.45°
10 kHz	104.94 Ω	−17.66°

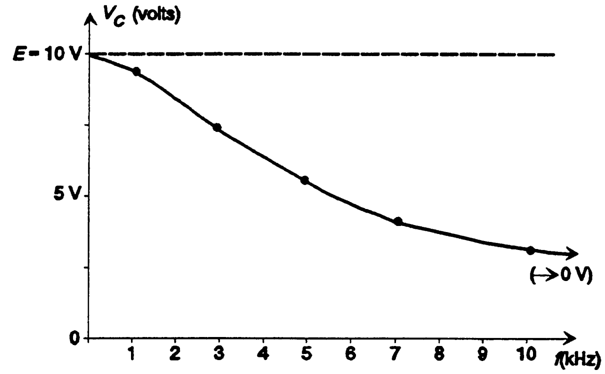




b. $\mathbf{V}_C = \dfrac{(X_C \angle -90°)(E \angle 0°)}{R - jX_C} = \dfrac{X_C E}{\sqrt{R^2 + X_C^2}} \angle -90° + \tan^{-1} X_C/R$

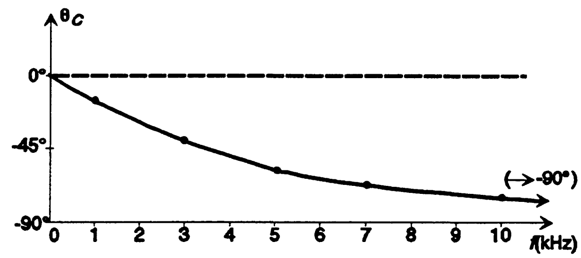
$|V_C| = \dfrac{X_C E}{\sqrt{R^2 + X_C^2}}$

f	$\lvert V_C \rvert$
0 Hz	10.0 V
1 kHz	9.54 V
3 kHz	7.28 V
5 kHz	5.37 V
7 kHz	4.14 V
10 kHz	3.03 V



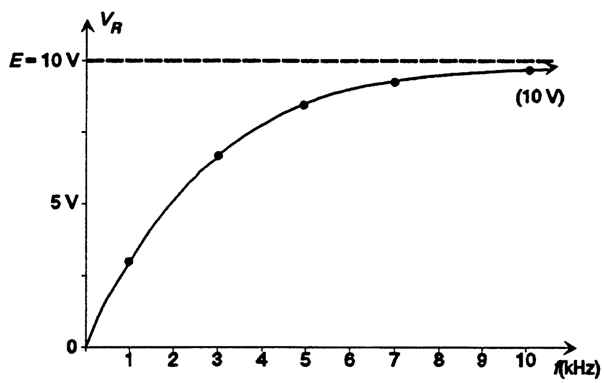
c. $\theta_C = -90° + \tan^{-1} X_C/R$

f	θ_C
0 Hz	0.0°
1 kHz	−17.44°
3 kHz	−43.3°
5 kHz	−57.52°
7 kHz	−65.55°
10 kHz	−72.34°



d. $|V_R| = \dfrac{RE}{\sqrt{R^2 + X_C^2}}$

f	$\lvert V_R \rvert$
0 Hz	0.0 V
1 kHz	3.0 V
3 kHz	6.86 V
5 kHz	8.44 V
7 kHz	9.10 V
10 kHz	9.53 V



24. a. $\mathbf{Z}_T = 47\ \Omega \angle 0° = R \angle 0°,\ \mathbf{Y}_T = 0.021\ \text{S} \angle 0° = G \angle 0°$

b. $\mathbf{Z}_T = 200\ \Omega \angle 90° = X_L \angle 90°,\ \mathbf{Y}_T = 5 \times 10^{-3}\ \text{S} \angle -90° = B_L \angle -90°$

c. $\mathbf{Z}_T = 0.6\ \Omega \angle -90° = X_C \angle -90°,\ \mathbf{Y}_T = 1.667\ \text{S} \angle 90° = B_C \angle 90°$

d. $\mathbf{Z}_T = \dfrac{(10\ \Omega \angle 0°)(60\ \Omega \angle 90°)}{10\ \Omega + j60\ \Omega} = 9.86\ \Omega \angle 9.46° = 9.726\ \Omega + j1.621\ \Omega = R + jX_L$

$$\mathbf{Y}_T = \mathbf{0.1014\ S\ \angle -9.46^\circ = 0.1\ S - j0.0167\ S} = G - jB_L$$

e. $$\mathbf{Z}_T = \frac{(11\ \Omega \angle 0^\circ)(6\ \Omega\ \angle -90^\circ)}{11\ \Omega - j6\ \Omega} = \frac{66\ \Omega\ \angle -90^\circ}{12.53\ \Omega\ \angle -28.61^\circ} = \mathbf{5.267\ \Omega\ \angle -61.39^\circ}$$
$$= \mathbf{2.522\ \Omega - j4.624\ \Omega} = R - jX_C$$
$$\mathbf{Y}_T = \mathbf{0.190\ S\ \angle 61.39^\circ = 0.091 + j0.167\ S} = G + jB_C$$

f. $$\mathbf{Y}_T = \frac{1}{3\ \text{k}\Omega\ \angle 0^\circ} + \frac{1}{6\ \text{k}\Omega\ \angle 90^\circ} + \frac{1}{9\ \text{k}\Omega\ \angle -90^\circ}$$
$$= 0.333 \times 10^{-3}\ \angle 0^\circ + 0.167 \times 10^{-3}\ \angle -90^\circ + 0.111 \times 10^{-3}\ \angle 90^\circ$$
$$= \mathbf{0.333 \times 10^{-3}\ S - j0.056 \times 10^{-3}\ S = 0.338 \times 10^{-3}\ S\ \angle -9.546^\circ}$$
$$= G - jB_L$$
$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \mathbf{2.959\ k\Omega\ \angle 9.546^\circ = 2.918\ k\Omega + j0.491\ k\Omega}$$

26. a. $$\mathbf{Y}_T = \frac{\mathbf{I}}{\mathbf{E}} = \frac{60\ \text{A}\ \angle 70^\circ}{120\ \text{V}\ \angle 0^\circ} = 0.5\ \text{S}\ \angle 70^\circ = 0.171 + j0.470 = G + jB_C$$
$$R = \frac{1}{G} = \mathbf{5.848\ \Omega},\ X_C = \frac{1}{B_C} = \mathbf{2.128\ \Omega}$$

b. $$\mathbf{Y}_T = \frac{\mathbf{I}}{\mathbf{E}} = \frac{20\ \text{mA}\ \angle 40^\circ}{80\ \text{V}\ \angle 320^\circ} = 0.25\ \text{mS}\ \angle -280^\circ = 0.25\ \text{mS}\ \angle 80^\circ$$
$$= 0.043\ \text{mS} + j0.246\ \text{mS} = G + jB_C$$
$$R = \frac{1}{G} = \mathbf{23.26\ k\Omega},\ X_C = \frac{1}{B_C} = \mathbf{4.065\ k\Omega}$$

c. $$\mathbf{Y}_T = \frac{\mathbf{I}}{\mathbf{E}} = \frac{0.2\ \text{A}\ \angle -60^\circ}{8\ \text{kV}\ \angle 0^\circ} = 0.25\ \text{mS}\ \angle -60^\circ = 0.0125\ \text{mS} - j0.02165 = G - jB_L$$
$$R = \frac{1}{G} = \mathbf{80\ k\Omega},\ X_L = \frac{1}{B_L} = \mathbf{46.19\ k\Omega}$$

28. a. $$\mathbf{Y}_T = \frac{1}{10\ \text{k}\Omega\ \angle 0^\circ} + \frac{1}{20\ \text{k}\Omega\ \angle -90^\circ} = 0.1\ \text{mS}\ \angle 0^\circ + 0.05\ \text{mS}\ \angle -90^\circ$$
$$= \mathbf{0.112\ mS\ \angle 26.57^\circ}$$

c. $$\mathbf{E} = \frac{\mathbf{I}_s}{\mathbf{Y}_T} = \frac{2\ \text{mA}\ \angle 20^\circ}{0.1118\ \text{mS}\ \angle 26.565^\circ} = \mathbf{17.89\ V\ \angle -6.565^\circ}$$
$$\mathbf{I}_R = \frac{\mathbf{E}}{\mathbf{Z}_R} = \frac{17.89\ \text{V}\ \angle -6.565^\circ}{10\ \text{k}\Omega\ \angle 0^\circ} = \mathbf{1.789\ mA\ \angle -6.565^\circ}$$
$$\mathbf{I}_C = \frac{\mathbf{E}}{\mathbf{Z}_C} = \frac{17.89\ \text{V}\ \angle -6.565^\circ}{20\ \text{k}\Omega\ \angle -90^\circ} = \mathbf{0.895\ mA\ \angle 83.435^\circ}$$

e. $$\mathbf{I}_s = \mathbf{I}_R + \mathbf{I}_C$$
$$2\ \text{mA}\ \angle 20^\circ = 1.789\ \text{mA}\ \angle -6.565^\circ + 0.895\ \text{mA}\ \angle 83.435^\circ$$
$$= (1.774\ \text{mA} - j0.204\ \text{mA}) + (0.102\ \text{mA} + j0.0887\ \text{mA})$$
$$= 1.876\ \text{mA} + j0.683\ \text{mA}$$
$$2\ \text{mA}\ \angle 20^\circ \stackrel{\checkmark}{=} 2\ \text{mA}\ \angle 20^\circ$$

f. $$P = I^2R = (1.789\ \text{mA})^2\ 10\ \text{k}\Omega = \mathbf{32\ mW}$$

g. $F_p = \dfrac{G}{Y_T} = \dfrac{0.1 \text{ mS}}{0.1118 \text{ mS}} = \mathbf{0.894 \text{ leading}}$

h. $\omega = 2\pi f = 377$ rad/s

$i_s = \mathbf{2.828 \times 10^{-3} \sin(\omega t + 20°)}$

$i_R = \mathbf{2.53 \times 10^{-3} \sin(\omega t - 6.565°)}$

$i_C = \mathbf{1.266 \times 10^{-3} \sin(\omega t + 83.435°)}$

$e = \mathbf{25.3 \sin(\omega t - 6.565°)}$

30. a. $\mathbf{Y}_T = \dfrac{1}{1.2\ \Omega\ \angle 0°} + \dfrac{1}{2\ \Omega\ \angle 90°} + \dfrac{1}{5\ \Omega\ \angle -90°}$

$= 0.833 \text{ S} \angle 0° + 0.5 \text{ S} \angle -90° + 0.2 \text{ S} \angle 90°$

$= 0.833 \text{ S} - j0.3 \text{ S} = \mathbf{0.885 \text{ S} \angle -19.81°}$

b. $X_C = \dfrac{1}{\omega_C} \Rightarrow C = \dfrac{1}{\omega X_C} = \dfrac{1}{(377 \text{ rad/s})(5\ \Omega)} = \mathbf{531\ \mu F}$

$X_L = \omega L \Rightarrow L = \dfrac{X_L}{\omega} = \dfrac{2\ \Omega}{377 \text{ rad/s}} = \mathbf{5.31 \text{ mH}}$

d. $\mathbf{E} = \dfrac{\mathbf{I}_s}{\mathbf{Y}_T} = \dfrac{(0.707)(3 \text{ A}) \angle 60°}{0.885 \text{ S} \angle -19.81°} = \dfrac{2.121 \text{ A} \angle 60°}{0.885 \text{ S} \angle -19.81°} = \mathbf{2.397 \text{ V} \angle 79.81°}$

$\mathbf{I}_R = \dfrac{E \angle \theta}{R \angle 0°} = \dfrac{2.397 \text{ V} \angle 79.81°}{1.2\ \Omega\ \angle 0°} = \mathbf{1.998 \text{ A} \angle 79.81°}$

$\mathbf{I}_L = \dfrac{E \angle \theta}{X_L \angle 90°} = \dfrac{2.397 \text{ V} \angle 79.81°}{2\ \Omega\ \angle 90°} = \mathbf{1.199 \text{ A} \angle -10.19°}$

$\mathbf{I}_C = \dfrac{E \angle \theta}{X_C \angle -90°} = \dfrac{2.397 \text{ V} \angle 79.81°}{5\ \Omega\ \angle -90°} = \mathbf{0.479 \text{ A} \angle 169.81°}$

f. $\mathbf{I}_s = \mathbf{I}_R + \mathbf{I}_L + \mathbf{I}_C$

$2.121 \text{ A} \angle 60° = 1.998 \text{ A} \angle 79.81° + 1.199 \text{ A} \angle -10.19° + 0.479 \text{ A} \angle 169.81°$

$= (0.353 + j1.966) + (1.18 - j0.212) + (-0.471 + j0.086)$

$2.121 \text{ A} \angle 60° \overset{\checkmark}{=} 1.062 + j1.84 = 2.124 \angle 60°$

g. $P = I^2R = (1.998 \text{ A})^2\, 1.2\ \Omega = \mathbf{4.79 \text{ W}}$

h. $F_p = \dfrac{G}{Y_T} = \dfrac{0.833 \text{ S}}{0.885 \text{ S}} = \mathbf{0.941 \text{ lagging}}$

i. $e = \mathbf{1.975 \sin(377t + 79.81°)}$

$i_R = \mathbf{2.825 \sin(377t + 79.81°)}$

$i_L = \mathbf{1.695 \sin(377t - 10.19°)}$

$i_C = \mathbf{0.677 \sin(377t + 169.81°)}$

32. a. $\mathbf{Y}_T = \dfrac{1}{5\Omega\ \angle -90°} + \dfrac{1}{22\Omega\ \angle 0°} + \dfrac{1}{10\ \Omega\ \angle 90°}$

$= 0.2 \text{ S} \angle 90° + 0.045 \text{ S} \angle 0° + 0.1 \text{ S} \angle -90°$

$= 0.045 \text{ S} + j0.1 \text{ S} = \mathbf{0.110 \text{ S} \angle 65.77°}$

c. $C = \dfrac{1}{\omega X_C} = \dfrac{1}{(377 \text{ rad/s})(5\ \Omega)} = \mathbf{636.9\ \mu F}$

$$L = \frac{X_L}{\omega} = \frac{10\ \Omega}{314\ \text{rad/s}} = \mathbf{31.8\ mH}$$

d. $\mathbf{E} = (0.707)(35.4\ \text{V})\ \angle 60° = \mathbf{25.03\ V\ \angle 60°}$

$\mathbf{I}_s = \mathbf{E}\mathbf{Y}_T = (25.03\ \text{V}\ \angle 60°)(0.11\ \text{S}\ \angle 65.77°) = \mathbf{2.75\ A\ \angle 125.77°}$

$$\mathbf{I}_C = \frac{E\ \angle\theta}{X_C\ \angle -90°} = \frac{25.03\ \text{V}\ \angle 60°}{5\ \angle -90°} = \mathbf{5\ A\ \angle 150°}$$

$$\mathbf{I}_R = \frac{E\ \angle\theta}{R\ \angle 0°} = \frac{25.03\ \text{V}\ \angle 60°}{22\ \Omega\ \angle 0°} = \mathbf{1.14\ A\ \angle 60°}$$

$$\mathbf{I}_L = \frac{E\ \angle\theta}{X_L\ \angle 90°} = \frac{25.03\ \text{V}\ \angle 60°}{10\ \Omega\ \angle 90°} = \mathbf{2.503\ A\ \angle -30°}$$

f. $\mathbf{I}_s = \mathbf{I}_C + \mathbf{I}_R + \mathbf{I}_L$

$$\begin{aligned} 2.75\ \text{A}\ \angle 125.77° &= 5\ \text{A}\ \angle 150° = 1.14\ \text{A}\ \angle 60° + 2.503\ \text{A}\ \angle -30° \\ &= (-4.33 + j2.5) + (0.57 + j0.9) + (2.17 - j1.25) \\ &= -1.59 + j2.24 = 2.75\ \angle 125.4° \end{aligned}$$

g. $P = I^2R = (1.14\ \text{A})^2\ 22\ \Omega = \mathbf{28.59\ W}$

h. $F_p = \dfrac{G}{Y_T} = \dfrac{0.045\ \text{S}}{0.110\ \text{S}} = \mathbf{0.4091\ leading}$

i. $e = \mathbf{35.4\ sin(314}t\ \mathbf{+\ 60°)}$

$i_s = \mathbf{3.89\ sin(314}t\ \mathbf{+\ 125.77°)}$

$i_C = \mathbf{7.07\ sin(314}t\ \mathbf{+\ 150°)}$

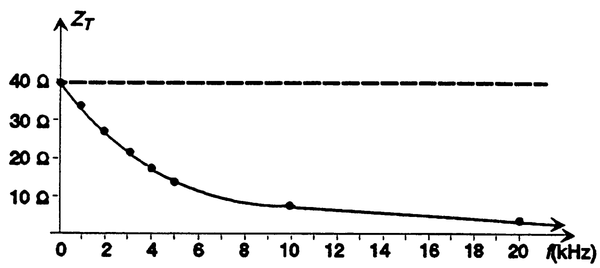
$i_R = \mathbf{1.61\ sin(314}t\ \mathbf{+\ 60°)}$

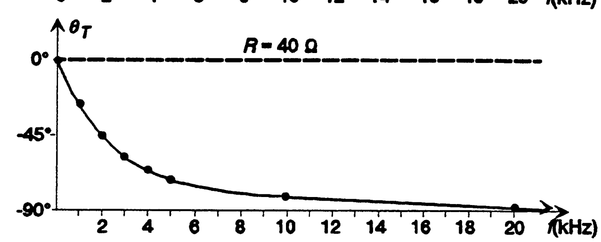
$i_L = \mathbf{3.54\ sin(314}t\ \mathbf{-\ 30°)}$

34. a. $$\mathbf{Z}_T = \frac{(R\ \angle 0°)(X_C\ \angle -90°)}{R - jX_C} = \frac{RX_C}{\sqrt{R^2 + X_C^2}}\ \angle -90° + \tan^{-1}X_C/R$$

$$|Z_T| = \frac{RX_C}{\sqrt{R^2 + X_C^2}} \qquad \theta_T = -90° + \tan^{-1}X_C/\text{R}$$

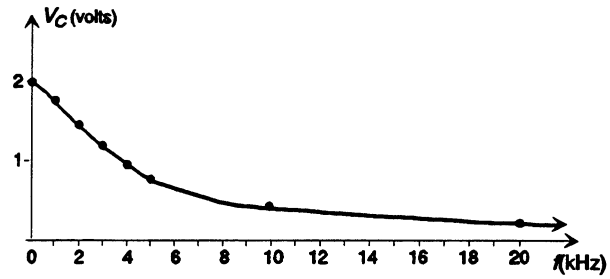
f	$\lvert Z_T\rvert$	θ_T
0 Hz	40.0 Ω	0.0°
1 kHz	35.74 Ω	−26.67°
2 kHz	28.22 Ω	−45.14°
3 kHz	22.11 Ω	−56.44°
4 kHz	17.82 Ω	−63.55°
5 kHz	14.79 Ω	−68.30°
10 kHz	7.81 Ω	−78.75°
20 kHz	3.959 Ω	−89.86°





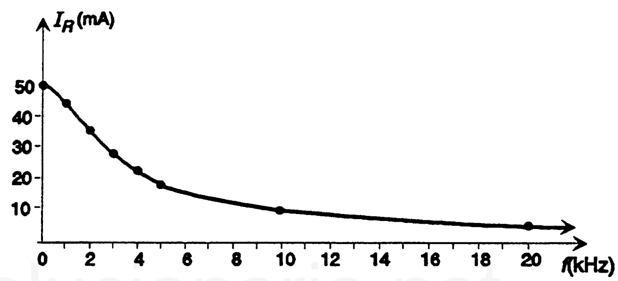
b. $|V_C| = \dfrac{IRX_C}{\sqrt{R^2 + X_C^2}} = I[Z_T(f)]$

f	$\lvert V_C \rvert$
0 kHz	2.0 V
1 kHz	1.787 V
2 kHz	1.411 V
3 kHz	1.105 V
4 kHz	0.891 V
5 kHz	0.740 V
10 kHz	0.391 V
20 kHz	0.198 V



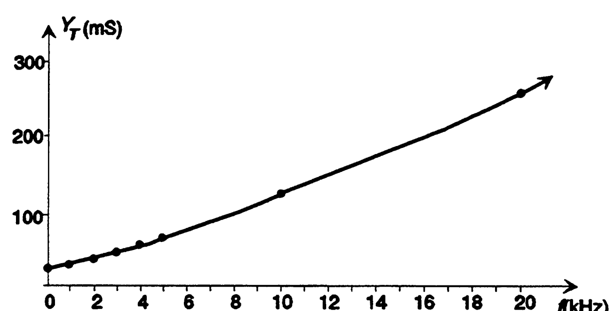
c. $|I_R| = \left|\dfrac{V_C}{R}\right|$

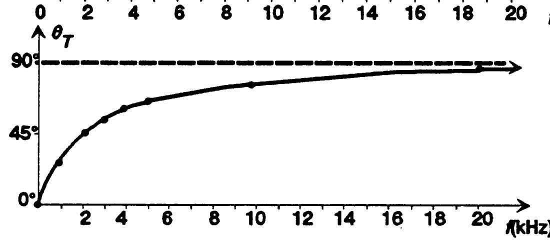
f	$\lvert I_R \rvert$
0 kHz	50.0 mA
1 kHz	44.7 mA
2 kHz	35.3 mA
3 kHz	27.64 mA
4 kHz	22.28 mA
5 kHz	18.50 mA
10 kHz	9.78 mA
20 kHz	4.95 mA



36. a. $Y_T = \dfrac{\sqrt{R^2 + X_C^2}}{RX_C} \angle 90° - \tan^{-1} X_C/R$

f	$\lvert Y_T \rvert$	θ_T
0 Hz	25.0 mS	0.0°
1 kHz	27.98 mS	26.67°
2 kHz	35.44 mS	45.14°
3 kHz	45.23 mS	56.44°
4 kHz	56.12 mS	63.55°
5 kHz	67.61 mS	68.30°
10 kHz	128.04 mS	78.75°
20 kHz	252.59 mS	89.86°

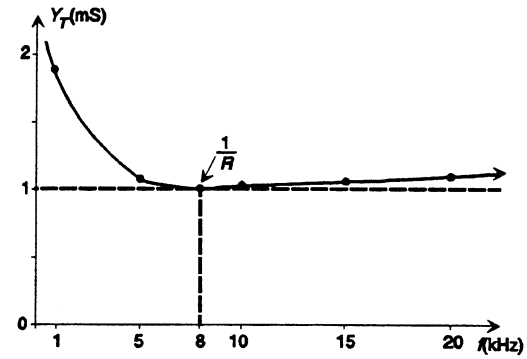




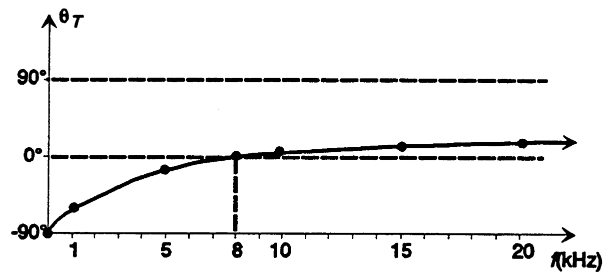
38. a. $\mathbf{Y}_T = G\ \angle 0° + B_L\ \angle -90° + B_C\ \angle 90°$

$$= \sqrt{G^2 + (B_C - B_L)^2}\ \angle \tan^{-1}\frac{B_C - B_L}{G}$$

f	$\lvert Y_T\rvert$
0 Hz	$X_L \Rightarrow 0\ \Omega$, $Z_T = 0\ \Omega$, $Y_T = \infty\ \Omega$
1 kHz	1.857 mS
5 kHz	1.018 mS
10 kHz	1.004 mS
15 kHz	1.036 mS
20 kHz	1.086 mS

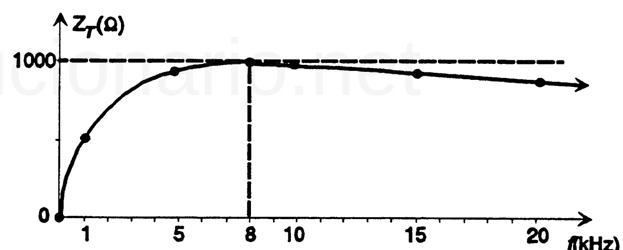


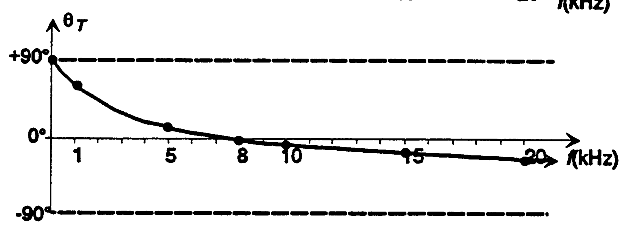
f	$\lvert\theta_T\rvert$
0 Hz	−90.0°
1 kHz	−57.42°
5 kHz	−10.87°
10 kHz	+5.26°
15 kHz	+15.16°
20 kHz	+22.95°



b. $Z_T = \dfrac{1}{Y_T}$, $\theta_{T_Z} = -\theta_{T_Y}$

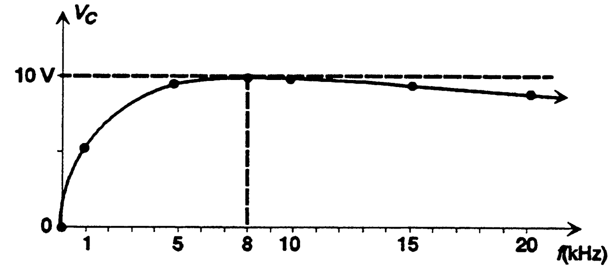
f	Z_T	θ_T
0 kHz	0.0 Ω	90.0°
1 kHz	538.5 Ω	57.42°
5 kHz	982.32 Ω	10.87°
10 kHz	996.02 Ω	−5.26°
15 kHz	965.25 Ω	−15.16°
20 kHz	921.66 Ω	−22.95°





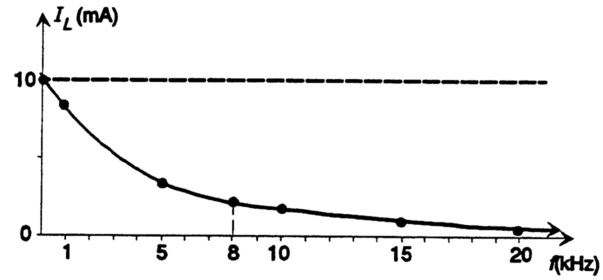
c. $V_C(f) = I[Z_T(f)]$

f	$\lvert V_C\rvert$
0 kHz	0.0 V
1 kHz	5.39 V
5 kHz	9.82 V
10 kHz	9.96 V
15 kHz	9.65 V
20 kHz	9.22 V



d. $I_L = \dfrac{V_C(f)}{X_L}$

f	I_L
0 kHz	10.0 mA
1 kHz	8.57 mA
5 kHz	3.13 mA
10 kHz	1.59 mA
15 kHz	1.02 mA
20 kHz	0.733 mA



40. a. $R_s = \dfrac{R_p X_p^2}{X_p^2 + R_p^2} = \dfrac{(4.7\ \text{k}\Omega)(20\ \text{k}\Omega)^2}{(20\ \text{k}\Omega)^2 + (4.7\ \text{k}\Omega)^2} = \dfrac{1880\ \text{k}\Omega}{422.09} = \mathbf{4.454\ k\Omega}$

$X_s = \dfrac{R_p^2 X_p}{X_p^2 + R_p^2} = \dfrac{(4.7\ \text{k}\Omega)^2(20\ \text{k}\Omega)}{422.09\ \text{k}\Omega} = \dfrac{441.8\ \text{k}\Omega}{422.09} = \mathbf{1.047\ k\Omega}$

$\mathbf{Z}_T = \mathbf{4.454\ k\Omega - \mathit{j}1.047\ k\Omega}$

b. $R_s = \dfrac{R_p X_p^2}{X_p^2 + R_p^2} = \dfrac{(68\ \Omega)(40\ \Omega)^2}{(40\ \Omega)^2 + (68\ \Omega)^2} = \mathbf{17.481\ \Omega}$

$X_s = \dfrac{R_p^2 X_p}{X_p^2 + R_p^2} = \dfrac{(68\ \Omega)^2(40\ \Omega)}{6224\ \Omega^2} = \mathbf{29.717\ \Omega}$

$\mathbf{Z}_T = \mathbf{17.481\ \Omega + \mathit{j}29.717\ \Omega}$

42. a. $(R = 220\ \Omega) \| (L = 1\ \text{H}) \| (C = 2\ \mu\text{F})$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi(10^3\ \text{Hz})(2\ \mu\text{F})} = 79.62\ \Omega$

$X_L = \omega L = 2\pi(10^3\ \text{Hz})(1\ \text{H}) = 6.28\ \text{k}\Omega$

$\mathbf{Y}_T = \dfrac{1}{220\ \Omega\ \angle 0^\circ} + \dfrac{1}{6.28 \times 10^3\ \Omega\ \angle 90^\circ} + \dfrac{1}{79.62\ \Omega\ \angle -90^\circ}$

$= 0.0045 - j0.1592 \times 10^{-3} + j0.0126$

$= 4.5 \times 10^{-3} - j0.1592 \times 10^{-3} + j12.6 \times 10^{-3}$

$= \mathbf{4.5\ mS + \mathit{j}12.44\ mS = 13.23\ mS\ \angle 70.11^\circ}$

$\mathbf{E} = \mathbf{I}/\mathbf{Y}_T = 1\ \text{A}\ \angle 0^\circ / 13.23\ \text{mS}\ \angle 70.11^\circ = \mathbf{75.6\ V\ \angle -70.11^\circ}$

$\mathbf{I}_R = \dfrac{E\ \angle\theta}{R\ \angle 0^\circ} = 75.6\ \text{V}\ \angle -70.11^\circ / 220\ \Omega\ \angle 0^\circ = \mathbf{0.3436\ A\ \angle -70.11^\circ}$

$\mathbf{I}_L = \dfrac{E\ \angle\theta}{X_L\ \angle 90^\circ} = 75.6\ \text{V}\ \angle -70.11^\circ / 6.28\ \text{k}\Omega\ \angle 90^\circ = \mathbf{12.04\ mA\ \angle -160.11^\circ}$

b. $F_p = \dfrac{G}{Y_T} = \dfrac{4.5\ \text{mS}}{13.23\ \text{mS}} =$ **0.3401 leading**

c. $P = I^2 R = (0.3436\text{A})^2\ 220\ \Omega = \mathbf{25.973\ W}$

f. $2\mathbf{I}_C = \mathbf{I}_s - \mathbf{I}_R - \mathbf{I}_L$

$$\mathbf{I}_C = \frac{\mathbf{I}_s - \mathbf{I}_R - \mathbf{I}_L}{2} = \frac{1\text{ A }\angle 0° - 0.3436\text{ A }\angle -70.11° - 12.04\text{ mA }\angle -160.11°}{2}$$

$$= \frac{1 - (0.1169 - j0.3231) - (-11.322 \times 10^{-3} - j4.0962 \times 10^{-3})}{2}$$

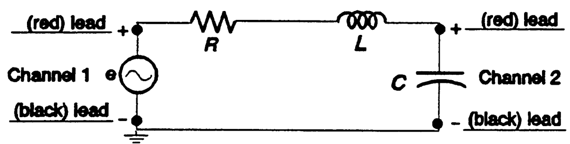
$$= \frac{0.8944 + j0.319}{2}$$

$\mathbf{I}_C = 0.4472 + j0.1595 = \mathbf{0.4748\ A\ \angle 19.63°}$

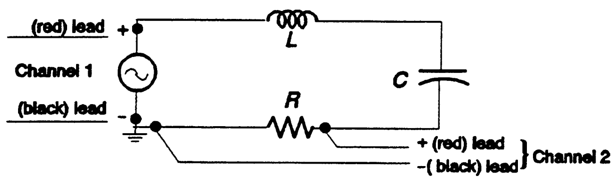
g. $\mathbf{Z}_T = \dfrac{1}{\mathbf{Y}_T} = \dfrac{1}{13.23\text{ mS }\angle 70.11°} = 75.59\ \Omega\ \angle -70.11° = \mathbf{25.72 - j71.08}$

$R = \mathbf{25.72\ \Omega}$, $X_C = \mathbf{71.08\ \Omega}$

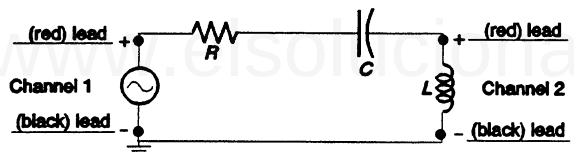
44. a.



b.



c.



46. (I): (a) $\theta_{\text{div.}} = 0.8$ div., $\theta_T = 4$ div.

$$\theta = \frac{0.8\text{ div.}}{4\text{ div.}} \times 360° = 72°$$

v_1 leads v_2 by 72°

(b) v_1: peak-to-peak = (5 div.)(0.5 V/div.) = 2.5 V

$$V_1(\text{rms}) = 0.7071\left[\frac{2.5\text{ V}}{2}\right] = \mathbf{0.884\ V}$$

v_2: peak-to-peak = (2.4 div.)(0.5 V/div.) = 1.2 V

$$V_2(\text{rms}) = 0.7071\left[\frac{1.2\text{ V}}{2}\right] = \mathbf{0.424\ V}$$

(c) $T = (4\text{ div.})(0.2\text{ ms/div.}) = 0.8\text{ ms}$

$$f = \frac{1}{T} = \frac{1}{0.8\text{ ms}} = \mathbf{1.25\ kHz}\text{ (both)}$$

(II): (a) $\theta_{div.} = 2.2 \text{ div.}, \theta_T = 6 \text{ div.}$

$$\theta = \frac{2.2 \text{ div.}}{6 \text{ div.}} \times 360° = 132°$$

v_1 leads v_2 by 132°

(b) v_1: peak-to-peak = (2.8 div.)(2 V/div.) = 5.6 V

$$V_1(\text{rms}) = 0.7071\left[\frac{5.6 \text{ V}}{2}\right] = \mathbf{1.98 \text{ V}}$$

v_2: peak-to-peak = (4 div.)(2 V/div.) = 8 V

$$V_2(\text{rms}) = 0.7071\left[\frac{8 \text{ V}}{2}\right] = \mathbf{2.828 \text{ V}}$$

(c) $T = (6 \text{ div.})(10 \text{ ms/div.}) = 60\ \mu s$

$$f = \frac{1}{T} = \frac{1}{60\ \mu s} = \mathbf{16.67 \text{ kHz}}$$

CHAPTER 16 (Odd)

1. a. $\mathbf{Z}_T = j6\ \Omega + 8\ \Omega\ \angle -90° \parallel 12\ \Omega\ \angle -90°$

$= j6\ \Omega + \dfrac{(8\ \Omega\ \angle -90°)(12\ \Omega\ \angle -90°)}{-j8\Omega - j12\Omega} = j6\ \Omega + \dfrac{96\ \Omega\ \angle -180°}{20\ \angle -90°}$

$= j6\ \Omega + 4.8\ \Omega\ \angle -90° = j6\ \Omega - j4.8\ \Omega$

$\mathbf{Z}_T = j1.2\ \Omega = \mathbf{1.2\ \Omega\ \angle 90°}$

b. $\mathbf{I} = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{12\ \text{V}\ \angle 0°}{1.2\ \Omega\ \angle 90°} = \mathbf{10\ A\ \angle -90°}$

c. $\mathbf{I}_1 = \mathbf{I} = \mathbf{10\ A\ \angle -90°}$

d. (CDR) $\mathbf{I}_2 = \dfrac{(12\ \Omega\ \angle -90°)(10\ \text{A}\ \angle -90°)}{-j12\ \Omega - j8\Omega} = \dfrac{120\ \text{A}\ \angle -180°}{20\ \angle -90°} = \mathbf{6\ A\ \angle -90°}$

$\mathbf{I}_3 = \dfrac{(8\ \Omega\ \angle -90°)(10\ \text{A}\ \angle -90°)}{20\ \Omega\ \angle -90°} = \dfrac{80\ \text{A}\ \angle -180°}{20\ \angle -90°} = \mathbf{4\ A\ \angle -90°}$

e. $\mathbf{V}_L = (I\ \angle\theta)(X_L\ \angle 90°) = (10\ \text{A}\ \angle -90°)(6\ \Omega\ \angle 90°) = \mathbf{60\ V\ \angle 0°}$

3. a. $\mathbf{Z}_T = 4.7\ \Omega \parallel (9.1\ \Omega - j12\ \Omega) = 4.7\ \Omega\ \angle 0° \parallel 15.06\ \Omega\ \angle -52.826°$

$= \dfrac{70.782\ \Omega\ \angle -52.826°}{4.7 + 9.1 - j12} = \dfrac{70.782\ \Omega\ \angle -52.826°}{13.8 - j12}$

$= \dfrac{70.782\ \Omega\ \angle -52.826°}{18.288\ \angle -41.009°} = \mathbf{3.87\ \Omega\ \angle -11.817°}$

$\mathbf{Y}_T = \dfrac{1}{\mathbf{Z}_T} = \dfrac{1}{3.87\ \Omega\ \angle -11.817°} = \mathbf{0.258\ S\ \angle 11.817°}$

b. $\mathbf{I}_s = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{60\ \text{V}\ \angle 30°}{3.87\ \Omega\ \angle -11.817°} = \mathbf{15.504\ A\ \angle 41.871°}$

c. (CDR) $\mathbf{I}_2 = \dfrac{(4.7\ \Omega\ \angle 0°)(15.504\ \text{A}\ \angle 41.817°)}{4.7\ \Omega + 9.1\ \Omega - j12\ \Omega} = \dfrac{72.869\ \text{A}\ \angle 41.817°}{18.288\ \angle -41.009°}$

$= \mathbf{3.985\ A\ \angle 82.826°}$

d. (VDR) $\mathbf{V}_C = \dfrac{(12\ \Omega\ \angle -90°)(60\ \text{V}\ \angle 30°)}{9.1\ \Omega - j12\ \Omega} = \dfrac{720\ \text{V}\ \angle -60°}{15.06\ \angle -52.826°}$

$= \mathbf{47.809\ V\ \angle -7.174°}$

e. $P = EI\cos\theta = (60\ \text{V})(15.504\ \text{A})\cos(41.87° - 30°)$

$= 930.24(0.979) = \mathbf{910.71\ W}$

5. a. $400\ \Omega\ \angle -90° \parallel 400\ \Omega\ \angle -90° = \dfrac{400\ \Omega\ \angle -90°}{2} = 200\ \Omega\ \angle -90°$

$\mathbf{Z}' = 200\ \Omega - j200\ \Omega = 282.843\ \Omega\ \angle -45°$

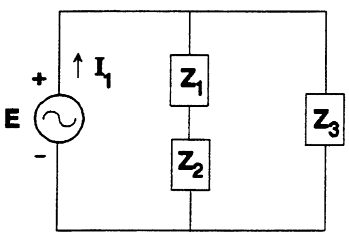
$\mathbf{Z}'' = 560\ \Omega + j560\ \Omega = 791.960\ \Omega\ \angle 45°$

$$\mathbf{Z}_T = \mathbf{Z}' \| \mathbf{Z}'' = \frac{(282.843\ \Omega\ \angle -45°)(791.960\ \Omega\ \angle 45°)}{(200\ \Omega - j200\ \Omega) + (560\ \Omega + j560\ \Omega)}$$
$$= \frac{224{,}000.34\ \Omega\ \angle 0°}{840.952\ \angle 25.346°} = \mathbf{266.365\ \Omega\ \angle -25.346°}$$
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{100\ \text{V}\ \angle 0°}{266.365\ \Omega\ \angle -25.346°} = \mathbf{0.375\ A\ \angle 25.346°}$$

b. $$\mathbf{V}_C = \frac{(200\ \Omega\ \angle -90°)(100\ \text{V}\ \angle 0°)}{200\ \Omega - j200\ \Omega} = \frac{20{,}000\ \text{V}\ \angle -90°}{282.843\ \angle -45°} = \mathbf{70.711\ V\ \angle -45°}$$

c. $$P = EI\cos\theta = (100\ \text{V})(0.375\ \text{A})\cos 25.346°$$
$$= (37.5)(0.904) = \mathbf{33.9\ W}$$

7. a.



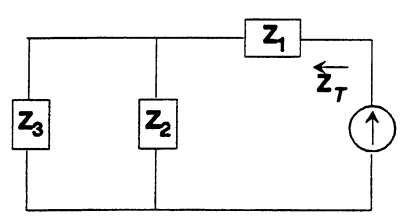
$$\mathbf{Z}_1 = 10\ \Omega\ \angle 0°$$
$$\mathbf{Z}_2 = 80\ \Omega\ \angle 90° \| 20\ \Omega\ \angle 0°$$
$$= \frac{1600\ \Omega\ \angle 90°}{20 + j80} = \frac{1600\ \Omega\ \angle 90°}{82.462\ \angle 75.964°}$$
$$= 19.403\ \Omega\ \angle 14.036°$$
$$\mathbf{Z}_3 = 60\ \Omega\ \angle -90°$$

$$\mathbf{Z}_T = (\mathbf{Z}_1 + \mathbf{Z}_2) \| \mathbf{Z}_3$$
$$= (10\ \Omega + 18.824\ \Omega + j4.706\ \Omega) \| 60\ \Omega\ \angle -90°$$
$$= 29.206\ \Omega\ \angle 9.273° \| 6\Omega\ \angle -90° = \frac{1752.36\ \Omega\ \angle -80.727°}{28.824 + j4.706 - j60}$$
$$= \frac{1752.36\ \Omega\ \angle -80.727°}{62.356\ \angle -62.468°} = \mathbf{28.103\ \Omega\ \angle -18.259°}$$
$$\mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{40\ \text{V}\ \angle 0°}{28.103\ \Omega\ \angle -18.259°} = \mathbf{1.423\ A\ \angle 18.259°}$$

b. $$\mathbf{V}_1 = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(19.403\ \Omega\ \angle 14.036°)(40\ \text{V}\ \angle 0°)}{29.206\ \Omega\ \angle 9.273°} = \frac{776.12\ \text{V}\ \angle 14.036°}{29.206\ \angle 9.273°}$$
$$= \mathbf{26.574\ V\ \angle 4.763°}$$

c. $$P = EI\cos\theta = (40\ \text{V})(1.423\ \text{A})\cos 18.259°$$
$$= \mathbf{54.074\ W}$$

9. a.



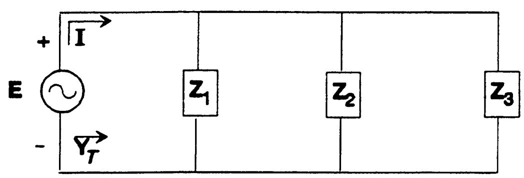
$$\mathbf{Z}' = 3\ \Omega\ \angle 0° \| 4\ \Omega\ \angle -90° = \frac{12\ \Omega\ \angle -90°}{3 - j4}$$
$$= \frac{12\ \Omega\ \angle -90°}{5\ \angle -53.13°} = 2.4\ \Omega\ \angle -36.87°$$
$$\mathbf{Z}_3 = 2\ \mathbf{Z}' + j7\ \Omega$$
$$= 4.8\ \Omega\ \angle -36.87° + j7\ \Omega$$
$$= 3.84\ \Omega - j2.88\ \Omega + j7\ \Omega$$
$$= 3.84\ \Omega + j4.12\ \Omega$$
$$= 5.632\ \Omega\ \angle 47.015°$$

$$\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 = 6.8\ \Omega + 8.2\ \Omega\ \angle 0° \| 5.632\ \Omega\ \angle 47.015°$$
$$= 6.8\ \Omega + \frac{46.182\ \Omega\ \angle 47.015°}{8.2 + 3.84 + j4.12} = 6.8\ \Omega + \frac{46.182\ \Omega\ \angle 47.015°}{12.725\ \angle 18.891°}$$
$$= 6.8\ \Omega + 3.629\ \Omega\ \angle 28.124° = 6.8\ \Omega + 3.201\ \Omega + j1.711\ \Omega$$
$$= 10\ \Omega + j1.711\ \Omega = \mathbf{10.145\ \Omega\ \angle 9.709°}$$
$$\mathbf{Y}_T = \frac{1}{\mathbf{Z}_T} = \mathbf{0.099\ S\ \angle -9.709°}$$

b. $\mathbf{V}_1 = \mathbf{I}\mathbf{Z}_1 = (3\ \text{A}\ \angle 30°)(6.8\ \Omega\ \angle 0°) = \mathbf{20.4\ V\ \angle 30°}$
$\mathbf{V}_2 = \mathbf{I}(\mathbf{Z}_2 \| \mathbf{Z}_3) = (3\ \text{A}\ \angle 30°)(3.629\ \Omega\ \angle 28.124°)$
$= \mathbf{10.887\ V\ \angle 58.124°}$

c. $\mathbf{I}_3 = \dfrac{\mathbf{V}_2}{\mathbf{Z}_3} = \dfrac{10.877\ \text{V}\ \angle 58.124°}{5.632\ \Omega\ \angle 47.015°} = \mathbf{1.933\ A\ \angle 11.109°}$

11.



$\mathbf{Z}_1 = 2\ \Omega - j2\ \Omega = 2.828\ \Omega\ \angle -45°$
$\mathbf{Z}_2 = 3\ \Omega - j9\ \Omega + j6\ \Omega$
$= 3\ \Omega - j3\ \Omega = 4.243\ \Omega\ \angle -45°$
$\mathbf{Z}_3 = 10\ \Omega\ \angle 0°$

$$\mathbf{Y}_T = \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3} = \frac{1}{2.828\ \Omega\ \angle -45°} + \frac{1}{4.243\ \Omega\ \angle -45°} + \frac{1}{10\ \Omega\ \angle 0°}$$
$$= 0.354\ \text{S}\ \angle 45° + 0.236\ \text{S}\ \angle 45° + 0.1\ \text{S}\ \angle 0° = 0.59\ \text{S}\ \angle 45° + 0.1\ \text{S}\ \angle 0°$$
$$= 0.417\ \text{S} + j0.417\ \text{S} + 0.1\ \text{S}$$
$$\mathbf{Y}_T = 0.517\ \text{S} + j\,0.417\ \text{S} = \mathbf{0.664\ S\ \angle 38.889°}$$
$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.664\ \text{S}\ \angle 38.889°} = \mathbf{1.506\ \Omega\ \angle -38.889°}$$
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\ \text{V}\ \angle 0°}{1.506\ \Omega\ \angle -38.889°} = \mathbf{33.201\ A\ \angle 38.889°}$$

13. $R_3 + R_4 = 2.7\ \text{k}\Omega + 4.3\ \text{k}\Omega = 7\ \text{k}\Omega$
$R' = 3\ \text{k}\Omega \| 7\ \text{k}\Omega = 2.1\ \text{k}\Omega$
$\mathbf{Z}' = 2.1\ \text{k}\Omega - j10\ \Omega$

(CDR) $\quad \mathbf{I}'$ (of 10 Ω cap.) $= \dfrac{(40\ \text{k}\Omega\ \angle 0°)(20\ \text{mA}\ \angle 0°)}{40\ \text{k}\Omega + 2.1\ \text{k}\Omega - j10\ \Omega}$
$= 19\ \text{mA}\ \angle +0.014°$ as expected since $R_1 \gg \mathbf{Z}'$

(CDR) $\quad \mathbf{I}_4 = \dfrac{(3\ \text{k}\Omega\ \angle 0°)(19\ \text{mA}\ \angle 0.014°)}{3\ \text{k}\Omega + 7\ \text{k}\Omega} = \dfrac{57\ \text{mA}\ \angle 0.014°}{10}$
$= 5.7\ \text{mA}\ \angle 0.014°$
$P = I^2R = (5.7\ \text{mA})^2\ 4.3\ \text{k}\Omega = \mathbf{139.71\ mW}$

CHAPTER 16 (Even)

2. a. $\mathbf{Z}_T = 3\ \Omega + j6\ \Omega + 2\ \Omega\ \angle 0° \parallel 8\ \Omega\ \angle -90°$
$= 3\ \Omega + j6\ \Omega + 1.94\ \Omega\ \angle -14.04°$
$= 3\ \Omega + j6\ \Omega + 1.882\ \Omega - j0.471\ \Omega$
$= 4.882\ \Omega + j5.529\ \Omega = \mathbf{7.376\ \Omega\ \angle 48.556°}$

b. $\mathbf{I}_s = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{30\text{ V}\ \angle 0°}{7.376\ \Omega\ \angle 48.556°} = \mathbf{4.067\ A\ \angle -48.556°}$

c. $\mathbf{I}_C = \dfrac{\mathbf{Z}_{R_2}\mathbf{I}_s}{\mathbf{Z}_{R_2} + \mathbf{Z}_C} = \dfrac{(2\ \Omega\ \angle 0°)(4.067\text{ A}\ \angle -48.556°)}{2\ \Omega - j8\ \Omega}$
$= \dfrac{8.134\text{ A}\ \angle -48.556°}{8.246\ \angle -75.964°} = \mathbf{0.986\ A\ \angle 27.408°}$

d. $\mathbf{V}_L = \dfrac{\mathbf{Z}_L\mathbf{E}}{\mathbf{Z}_T} = \dfrac{(6\ \Omega\ \angle 90°)(30\text{ V}\ \angle 0°)}{7.376\ \Omega\ \angle 48.556°} = \dfrac{180\text{ V}\ \angle 90°}{7.376\ \angle 48.556°}$
$= \mathbf{24.403\ V\ \angle 41.44°}$

4. a. $\mathbf{Z}_T = 2\ \Omega + \dfrac{(4\ \Omega\ \angle -90°)(6\Omega\ \angle 90°)}{-j4\ \Omega + j6\ \Omega} + \dfrac{4\ \Omega\ \angle 0°)(3\ \Omega\ \angle 90°)}{4\ \Omega + j3\ \Omega}$
$= 2\ \Omega + \dfrac{24\ \Omega\ \angle 0°}{2\ \angle 90°} + \dfrac{12\ \Omega\ \angle 90°}{5\ \angle 36.87°}$
$= 2\ \Omega + 12\ \Omega\ \angle -90° + 2.4\ \angle 53.13°$
$= 2\ \Omega - j12\ \Omega + 1.44\ \Omega + j1.92\ \Omega$
$= \mathbf{3.44\ \Omega - j10.08\ \Omega = 10.65\ \Omega\ \angle -71.16°}$

b. $\mathbf{V}_2 = \mathbf{I}(2.4\ \Omega\ \angle 53.13°) = (5\text{ A}\ \angle 0°)(2.4\ \Omega\ \angle 53.13°) = \mathbf{12\ V\ \angle 53.13°}$
$\mathbf{I}_L = \dfrac{(4\ \Omega\ \angle 0°)(\mathbf{I})}{4\ \Omega + j3\ \Omega} = \dfrac{(4\ \Omega\ \angle 0°)(5\text{ A}\ \angle 0°)}{5\ \Omega\ \angle 36.87°} = \dfrac{20\text{ A}\ \angle 0°}{5\ \angle 36.87°} = 4\text{ A}\ \angle -36.87°$

c. $F_p = \dfrac{R}{Z_T} = \dfrac{3.44\ \Omega}{10.65\ \Omega} = \mathbf{0.323\ (leading)}$

6. a. $\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$
$\mathbf{I}_1 = \dfrac{\mathbf{E}}{\mathbf{Z}_1} = \dfrac{120\text{ V}\ \angle 60°}{5\ \Omega\ \angle 53.13°} = 24\text{ A}\ \angle 6.87°$

b. $\mathbf{V}_C = \dfrac{(13\ \Omega\ \angle -90°)(120\text{ V}\ \angle 60°)}{-j13\ \Omega + j7\ \Omega} = \dfrac{1560\text{ V}\ \angle -30°}{6\ \angle -90°} = 260\text{ V}\ \angle 60°$

c. $\mathbf{V}_{R_1} = (I_1\ \angle\theta)R\ \angle 0° = (24\text{ A}\ \angle 6.87°)(3\ \Omega\ \angle 0°) = 72\text{ V}\ \angle 6.87°$
$\mathbf{V}_{\underset{+-}{ab}} + \mathbf{V}_{R_1} - \mathbf{V}_C = 0$
$\mathbf{V}_{\underset{+-}{ab}} = \mathbf{V}_C - \mathbf{V}_{R_1} = 260\text{ V}\ \angle 60° - 72\text{ V}\ \angle 6.87°$
$= (130\text{ V} + j225.167\text{ V}) - (71.483\text{ V} + j8.612\text{ V})$
$= \mathbf{58.517\ V + j216.555\ V = 224.32\ V\ \angle 74.88°}$

8. a. $\mathbf{Z}_1 = 2\ \Omega + j1\ \Omega = 2.236\ \Omega\ \angle 26.565°, \mathbf{Z}_2 = 3\ \Omega\ \angle 0°$

$\mathbf{Z}_3 = 16\ \Omega + j15\ \Omega - j7\ \Omega = 16\ \Omega + j8\ \Omega = 17.889\ \Omega\ \angle 26.565°$

$$\mathbf{Y}_T = \frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3} = \frac{1}{2.236\ \Omega\ \angle 26.565°} + \frac{1}{3\ \Omega\ \angle 0°} + \frac{1}{17.889\ \Omega\ \angle 26.565°}$$
$$= 0.447\ \text{S}\ \angle -26.565° + 0.333\ \text{S}\ \angle\ 0° + 0.056\ \text{S}\ \angle -26.565°$$
$$= (0.4\ \text{S} - j0.2\ \text{S}) + (0.333\ \text{S}) + (0.05\ \text{S} - j0.025\ \text{S})$$
$$= 0.783\ \text{S} - j0.225\ \text{S} = \mathbf{0.815\ S\ \angle -16.032°}$$

$$\mathbf{Z}_T = \frac{1}{\mathbf{Y}_T} = \frac{1}{0.815\ \text{S}\ \angle -16.032°} = \mathbf{1.227\ \Omega\ \angle 16.032°}$$

b. $$\mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{60\ \text{V}\ \angle 0°}{2.236\ \Omega\ \angle 26.565°} = \mathbf{26.834\ A\ \angle -26.565°}$$

$$\mathbf{I}_2 = \frac{\mathbf{E}}{\mathbf{Z}_2} = \frac{60\ \text{V}\ \angle 0°}{3\ \Omega\ \angle 0°} = 20\ \text{A}\ \angle 0°$$

$$\mathbf{I}_3 = \frac{\mathbf{E}}{\mathbf{Z}_3} = \frac{60\ \text{V}\ \angle 0°}{17.889\ \Omega\ \angle 26.565°} = \mathbf{3.354\ A\ \angle -26.565°}$$

c. $$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{60\ \text{V}\ \angle 0°}{1.227\ \Omega\ \angle 16.032°} = \mathbf{48.9\ A\ \angle -16.032°}$$

$$\mathbf{I}_s \stackrel{?}{=} \mathbf{I}_1 + \mathbf{I}_2 + \mathbf{I}_3$$

$$48.9\ \text{A}\ \angle -16.032° \stackrel{?}{=} 26.834\ \text{A}\ \angle -26.565° + 20\ \text{A}\ \angle 0° + 3.354\ \text{A}\ \angle -26.565°$$
$$= (24\ \text{A} - j12\ \text{A}) + (20\ \text{A}) + (3\ \text{A} - j1.5\ \text{A})$$
$$\stackrel{\checkmark}{=} 47\ \text{A} + j13.5\ \text{A} = \mathbf{48.9\ A\ \angle -16.026°}\ \text{(checks)}$$

d. $$F_p = \frac{G}{Y_T} = \frac{0.783\ \text{A}}{0.815\ \text{S}} = \mathbf{0.961\ (lagging)}$$

10. a. $X_{L_1} = \omega L_1 = 2\pi(10^3\ \text{Hz})(0.1\ \text{H}) = 628\ \Omega$

$X_{L_2} = \omega L_2 = 2\pi(10^3\ \text{Hz})(0.2\ \text{H}) = 1.256\ \text{k}\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(10^3\ \text{Hz})(1\ \mu\text{F})} = 0.159\ \text{k}\Omega$$

$$\mathbf{Z}_T = R\ \angle 0° + X_{L_1}\ \angle 90° + X_C\ \angle -90° \parallel X_{L_2}\ \angle 90°$$
$$= 300\ \Omega + j628\ \Omega + 0.159\ \text{k}\Omega\ \angle -90° \parallel 1.256\ \text{k}\Omega\ \angle 90°$$
$$= 300\ \Omega + j628\ \Omega - j182\ \Omega$$
$$= \mathbf{300\ \Omega + j446\ \Omega = 537.51\ \Omega\ \angle 56.07°}$$

$$\mathbf{Y}_T = \frac{1}{\mathbf{Z}_T} = \frac{1}{537.51\ \Omega\ \angle 56.07°} = \mathbf{1.86\ mS\ \angle -56.07°}$$

b. $$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\ \text{V}\ \angle 0°}{537.51\ \Omega\ \angle 56.07°} = \mathbf{93\ mA\ \angle -56.07°}$$

c. (CDR): $\mathbf{I}_1 = \dfrac{\mathbf{Z}_{L_2}\mathbf{I}_s}{\mathbf{Z}_{L_2} + \mathbf{Z}_C} = \dfrac{(1.256 \text{ k}\Omega \angle 90°)(93 \text{ mA} \angle -56.07°)}{+j1.256 \text{ k}\Omega - j0.159 \text{ k}\Omega}$

$= \dfrac{116.81 \text{ mA} \angle 33.93°}{1.097 \angle 90°} = \mathbf{106.48 \text{ mA} \angle -56.07°}$

$\mathbf{I}_2 = \dfrac{\mathbf{Z}_C\mathbf{I}_s}{\mathbf{Z}_{L_2} + \mathbf{Z}_C} = \dfrac{(0.159 \text{ k}\Omega \angle -90°)(93 \text{ mA} \angle -56.07°)}{1.097 \text{ k}\Omega \angle 90°}$

$= \dfrac{14.79 \text{ mA} \angle -146.07°}{1.097 \angle 90°} = 13.48 \text{ mA} \angle -236.07°$

$= \mathbf{13.48 \text{ mA} \angle 123.93°}$

d. $\mathbf{V}_1 = (I_2 \angle \theta)(X_{L_2} \angle 90°) = (13.48 \text{ mA} \angle 123.92°)(1.256 \text{ k}\Omega \angle 90°)$

$= \mathbf{16.931 \text{ V} \angle 213.93°}$

$V_{\underset{+-}{ab}} = \mathbf{E} - (I_s \angle \theta)(R \angle 0°) = 50 \text{ V} \angle 0° - (93 \text{ mA} \angle -56.07°)(300 \ \Omega \angle 0°)$

$= 50 \text{ V} - 27.9 \text{ V} \angle -56.07°$

$= 50 \text{ V} - (15.573 \text{ V} - j23.149 \text{ V})$

$= 34.43 \text{ V} + j23.149 \text{ V} = \mathbf{41.49 \text{ V} \angle 33.92°}$

e. $P = I_s^2 R = (93 \text{ mA})^2 300 \ \Omega = \mathbf{2.595 \text{ W}}$

f. $F_p = \dfrac{R}{Z_T} = \dfrac{300 \ \Omega}{537.51 \ \Omega} = \mathbf{0.558 \text{ (lagging)}}$

12. $\mathbf{Z}' = 12 \ \Omega - j20 \ \Omega = 23.324 \ \Omega \angle -59.036°$

$R_4 \angle 0° \| \mathbf{Z}' = 20 \ \Omega \angle 0° \| 23.324 \ \Omega \angle -59.036° = 12.362 \ \Omega \angle -27.031°$

$Z'' = R_3 \angle 0° + R_4 \angle 0° \| \mathbf{Z}' = 12 \ \Omega + 12.362 \ \Omega \angle -27.031°$

$= 12 \ \Omega + (11.012 \ \Omega - j5.618 \ \Omega)$

$= 23.012 \ \Omega - j5.618 \ \Omega = 23.688 \ \Omega \angle -13.719°$

$R_2 \angle 0° \| \mathbf{Z}'' = 20 \ \Omega \angle 0° \| 23.688 \ \Omega \angle -13.719° = 10.922 \ \Omega \angle -6.277°$

$\mathbf{Z}_T = R_1 \angle 0° + R_2 \angle 0° \| \mathbf{Z}'' = 12 \ \Omega + 10.922 \ \Omega \angle -6.277°$

$= 12 \ \Omega + (10.857 \ \Omega - j1.194 \ \Omega)$

$= 22.857 \ \Omega - j1.194 \ \Omega = \mathbf{22.888 \ \Omega \angle -2.99°}$

$\mathbf{I}_s = \dfrac{\mathbf{E}}{\mathbf{Z}_T} = \dfrac{100 \text{ V} \angle 0°}{22.888 \ \Omega \angle -2.99°} = \mathbf{4.371 \text{ A} \angle 2.99°}$

$\mathbf{I}_{R_1} = \mathbf{I}$

$\mathbf{I}_{R_3} = \dfrac{R_2 \angle 0° \mathbf{I}_s}{R_2 \angle 0° + \mathbf{Z}''} = \dfrac{(20 \ \Omega \angle 0°)(4.371 \text{ A} \angle 2.99°)}{\underbrace{20 \ \Omega + 23.012 \ \Omega}_{43.012 \ \Omega} - j5.618 \ \Omega} = \dfrac{87.42 \text{ A} \angle 2.99°}{43.377 \angle -7.442°}$

$= \mathbf{2.015 \text{ A} \angle 10.432°}$

$\mathbf{I}_5 = \dfrac{R_4 \angle 0° \mathbf{I}_{R_3}}{R_4 \angle 0° + \mathbf{Z}'} = \dfrac{(20 \ \Omega \angle 0°)(2.015 \text{ A} \angle 10.432°)}{\underbrace{20 \ \Omega + 12 \ \Omega}_{32 \ \Omega} - j20 \ \Omega} = \dfrac{40.3 \text{ A} \angle 10.432°}{37.736 \angle -32.005°}$

$= \mathbf{1.068 \text{ A} \angle 42.437°}$

14. $\mathbf{Z}' = X_{C_2} \angle -90° \| R_1 \angle 0° = 2\ \Omega \angle -90° \| 1\ \Omega \angle 0°$

$$= \frac{2\ \Omega \angle -90°}{1 - j2} = \frac{2\ \Omega \angle -90°}{2.236 \angle -63.435°}$$

$$= 0.894\ \Omega \angle -26.565°$$

$$\mathbf{Z}'' = X_{L_2} \angle 90° + \mathbf{Z}' = +j8\ \Omega + 0.894\ \Omega \angle -26.565°$$

$$= +j8\ \Omega + (0.8\ \Omega - j4\ \Omega)$$

$$= 0.8\ \Omega + j4 = 4.079\ \Omega \angle 78.69°$$

$$\mathbf{I}_{X_{L_2}} = \frac{X_{C_1} \angle -90° \mathbf{I}}{X_{C_1} \angle -90° + \mathbf{Z}''} = \frac{2\ \Omega(\angle -90°)(0.5\ \text{A} \angle 0°)}{-j2\ \Omega + (0.8\ \Omega + j4\ \Omega)} = \frac{1\text{A} \angle -90°}{0.8 + j2}$$

$$= \frac{1\ \text{A} \angle -90°}{2.154 \angle 68.199°} = 0.464\ \text{A} \angle -158.99°$$

$$\mathbf{I}_1 = \frac{X_{C_2} \angle -90° \mathbf{I}_{X_{L_2}}}{X_{C_2} \angle -90° + R_1} = \frac{(2\ \Omega \angle -90°)(0.464\ \text{A} \angle -158.99°)}{-j2\ \Omega + 1\ \Omega} = \frac{0.928\ \text{A} \angle -248.99°}{2.236 \angle -63.435°}$$

$$= \mathbf{0.415\ A \angle 174.45°}$$

CHAPTER 17 (Odd)

3. a. $\mathbf{Z} = 15\ \Omega - j16\ \Omega = \mathbf{21.93\ \Omega \angle -46.85^\circ}$
$\mathbf{E} = \mathbf{IZ} = (0.5\text{ A} \angle 60^\circ)(21.93\ \Omega \angle -46.85^\circ)$
$= \mathbf{10.97\text{ V} \angle 13.15^\circ}$

b. $\mathbf{Z} = 10\ \Omega \angle 0^\circ \| 6\ \Omega \angle 90^\circ = \mathbf{5.15\ \Omega \angle 59.04^\circ}$
$\mathbf{E} = \mathbf{IZ} = (2\text{ A} \angle 120^\circ)(5.15\ \Omega \angle 59.04^\circ)$
$= \mathbf{10.30\text{ V} \angle 179.04^\circ}$

5. a. Clockwise mesh currents:

$$\mathbf{E} - \mathbf{I}_1\mathbf{Z}_1 - \mathbf{I}_1\mathbf{Z}_2 + \mathbf{I}_2\mathbf{Z}_2 = 0$$
$$-\mathbf{I}_2\mathbf{Z}_2 + \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}_2\mathbf{Z}_3 - \mathbf{E}_2 = 0$$

$$[\mathbf{Z}_1 + \mathbf{Z}_2]\mathbf{I}_1 - \mathbf{Z}_2\mathbf{I}_2 = \mathbf{E}_1$$
$$-\mathbf{Z}_2\mathbf{I}_1 + [\mathbf{Z}_2 + \mathbf{Z}_3]\mathbf{I}_2 = -\mathbf{E}_2$$

$\mathbf{Z}_1 = R_1 \angle 0^\circ = 4\ \Omega \angle 0^\circ$
$\mathbf{Z}_2 = X_L \angle 90^\circ = 6\ \Omega \angle 90^\circ$
$\mathbf{Z}_3 = X_C \angle -90^\circ = 8\ \Omega \angle -90^\circ$
$\mathbf{E}_1 = 10\text{ V} \angle 0^\circ$, $\mathbf{E}_2 = 40\text{ V} \angle 60^\circ$

$$\mathbf{I}_{R_1} = \mathbf{I}_1 = \frac{\begin{vmatrix} \mathbf{E}_1 & -\mathbf{Z}_2 \\ -\mathbf{E}_2 & [\mathbf{Z}_2 + \mathbf{Z}_3] \end{vmatrix}}{\begin{vmatrix} [\mathbf{Z}_1 + \mathbf{Z}_2] & -\mathbf{Z}_2 \\ -\mathbf{Z}_2 & [\mathbf{Z}_2 + \mathbf{Z}_3] \end{vmatrix}} = \frac{[\mathbf{Z}_2 + \mathbf{Z}_3]\mathbf{E}_1 - \mathbf{Z}_2\mathbf{E}_2}{\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3} = \mathbf{5.15\text{ A} \angle -24.5^\circ}$$

b. By interchanging the right two branches, the general configuration of part (a) will result and

$$\mathbf{I}_{50\Omega} = \mathbf{I}_1 = \frac{[\mathbf{Z}_2 + \mathbf{Z}_3]\mathbf{E}_1 - \mathbf{Z}_2\mathbf{E}_2}{\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3} = \mathbf{0.442\text{ A} \angle 143.48^\circ}$$

$\mathbf{Z}_1 = R_1 = 50\ \Omega \angle 0^\circ$
$\mathbf{Z}_2 = X_C \angle -90^\circ = 60\ \Omega \angle -90^\circ$
$\mathbf{Z}_3 = X_L \angle 90^\circ = 20\ \Omega \angle 90^\circ$
$\mathbf{E}_1 = 5\text{ V} \angle 30^\circ$, $\mathbf{E}_2 = 20\text{ V} \angle 0^\circ$

7. a. Clockwise mesh currents:

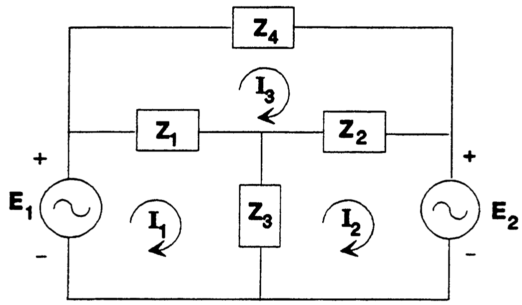
$$\mathbf{E}_1 - \mathbf{I}_1\mathbf{Z}_1 - \mathbf{I}_1\mathbf{Z}_2 + \mathbf{I}_2\mathbf{Z}_2 = 0$$
$$-\mathbf{I}_2\mathbf{Z}_2 + \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}_2\mathbf{Z}_3 - \mathbf{I}_2\mathbf{Z}_4 + \mathbf{I}_3\mathbf{Z}_4 = 0$$
$$-\mathbf{I}_3\mathbf{Z}_4 + \mathbf{I}_2\mathbf{Z}_4 - \mathbf{I}_3\mathbf{Z}_5 - \mathbf{E}_2 = 0$$

$\mathbf{Z}_1 = 4\ \Omega + j3\ \Omega$, $\mathbf{Z}_2 = -j1\ \Omega$
$\mathbf{Z}_3 = +j6\ \Omega$, $\mathbf{Z}_4 = -j2\ \Omega$
$\mathbf{Z}_5 = 8\ \Omega$
$\mathbf{E}_1 = 60\text{ V} \angle 0^\circ$, $\mathbf{E}_2 = 120\text{ V} \angle 120^\circ$

$$\begin{aligned} &[\mathbf{Z}_1 + \mathbf{Z}_2]\mathbf{I}_1 && - \mathbf{Z}_2\mathbf{I}_2 && + 0 = \mathbf{E}_1 \\ &-\mathbf{Z}_2\mathbf{I}_1 && + [\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_4]\mathbf{I}_2 && - \mathbf{Z}_4\mathbf{I}_3 = 0 \\ &0 && - \mathbf{Z}_4\mathbf{I}_2 && + [\mathbf{Z}_4 + \mathbf{Z}_5]\mathbf{I}_3 = -\mathbf{E}_2 \end{aligned}$$

$$\mathbf{I}_{R_1} = \mathbf{I}_3 = \frac{[\mathbf{Z}_2\mathbf{Z}_4]\mathbf{E}_1 + \left[\mathbf{Z}_2^2 - [\mathbf{Z}_1 + \mathbf{Z}_2][\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_4]\right]\mathbf{E}_2}{[\mathbf{Z}_1 + \mathbf{Z}_2][\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_4][\mathbf{Z}_4 + \mathbf{Z}_5] - [\mathbf{Z}_1 + \mathbf{Z}_2]\mathbf{Z}_4^2 - [\mathbf{Z}_4 + \mathbf{Z}_5]\mathbf{Z}_2^2}$$
$$= \mathbf{13.07\text{ A} \angle -33.71^\circ}$$

b.



$Z_1 = 15\ \Omega\ \angle 0°$, $Z_2 = 15\ \Omega\ \angle 0°$
$Z_3 = -j10\ \Omega = 10\ \Omega\ \angle -90°$
$Z_4 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$
$E_1 = 220\ \text{V}\ \angle 0°$
$E_2 = 100\ \text{V}\ \angle 90°$

$$I_1(Z_1 + Z_3) - I_2Z_3 - I_3Z_1 = E_1$$
$$I_2(Z_2 + Z_3) - I_1Z_3 - I_3Z_2 = -E_2$$
$$I_3(Z_1 + Z_2 + Z_4) - I_1Z_1 - I_2Z_2 = 0$$

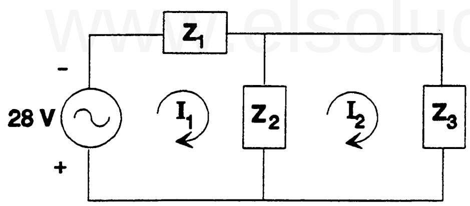
$$\begin{aligned} I_1(Z_1 + Z_3) - I_2Z_3 \quad - I_3Z_1 &= E_1 \\ -I_1Z_3 + I_2(Z_2 + Z_3) - I_3Z_2 &= -E_2 \\ -I_1Z_1 - I_2Z_2 + I_3(Z_1 + Z_2 + Z_4) &= 0 \end{aligned}$$

Applying determinants:

$$I_3 = \frac{-(Z_1 + Z_3)(Z_2)E_2 - Z_1Z_3E_2 + E_1[Z_2Z_3 + Z_1(Z_2 + Z_3)]}{(Z_1 + Z_3)\left[(Z_2 + Z_3)(Z_1 + Z_2 + Z_4) - Z_2^2\right] + Z_3[Z_3(Z_1 + Z_2 + Z_4) - Z_1Z_2] - Z_1[-Z_2Z_3 - Z_1(Z_2 + Z_3)]}$$
$$= \mathbf{48.33\ A\ \angle -77.57°}$$

or $I_3 = \dfrac{E_1 - E_2}{Z_4}$ if one carefully examines the network!

9.



$Z_1 = 5\ \text{k}\Omega\ \angle 0°$
$Z_2 = 10\ \text{k}\Omega\ \angle 0°$
$Z_3 = 1\ \text{k}\Omega + j4\ \text{k}\Omega = 4.123\ \text{k}\Omega\ \angle 75.96°$

$$I_1(Z_1 + Z_2) - Z_2I_2 = -28\ \text{V}$$
$$I_2(Z_2 + Z_3) - Z_2I_1 = 0$$

$$(Z_1 + Z_2)I_1 - Z_2I_2 = -28\ \text{V}$$
$$-Z_2I_1 + (Z_2 + Z_3)I_2 = 0$$

$$I_L = I_2 = \frac{-Z_2\ 28\ \text{V}}{Z_1Z_2 + Z_1Z_3 + Z_2Z_3} = \mathbf{-3.165 \times 10^{-3}\ V\ \angle 137.29°}$$

11. $6V_x - I_1\ 1\ \text{k}\Omega - 10\ \text{V}\ \angle 0° = 0$
$10\ \text{V}\angle 0° - I_2\ 4\ \text{k}\Omega - I_2\ 2\ \text{k}\Omega = 0$

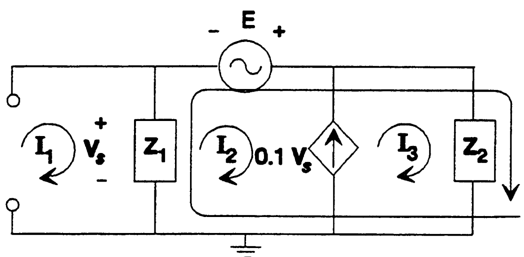
$V_x = I_2\ 2\ \text{k}\Omega$

$-I_1\ 1\ \text{k}\Omega + I_2\ 12\ \text{k}\Omega = 10\ \text{V}\ \angle 0°$
$-I_2\ 6\ \text{k}\Omega = -10\ \text{V}\ \angle 0°$

$$I_2 = \frac{10 \text{ V } \angle 0°}{6 \text{ k}\Omega} = 1.667 \text{ mA } \angle 0° = I_{2k\Omega}$$

$$-I_1\, 1 \text{ k}\Omega + (1.667 \text{ mA } \angle 0°)(12 \text{ k}\Omega) = 10 \text{ V } \angle 0°$$
$$-I_1\, 1 \text{ k}\Omega + 20 \text{ V } \angle 0° = 10 \text{ V } \angle 0°$$
$$-I_1\, 1 \text{ k}\Omega = -10 \text{ V } \angle 0°$$
$$I_1 = \frac{10 \text{ V } \angle 0°}{1 \text{ k}\Omega} = 10 \text{ mA } \angle 0°$$

13.



$Z_1 = 1 \text{ k}\Omega \angle 0°$
$Z_2 = 4 \text{ k}\Omega + j6 \text{ k}\Omega$
$E = 10 \text{ V } \angle 0°$

$$-Z_1(I_2 - I_1) + E - I_3Z_3 = 0$$
$$I_1 = 6 \text{ mA } \angle 0°,\ 0.1\, V_s = I_3 - I_2,\ V_s = (I_1 - I_2)Z_1$$

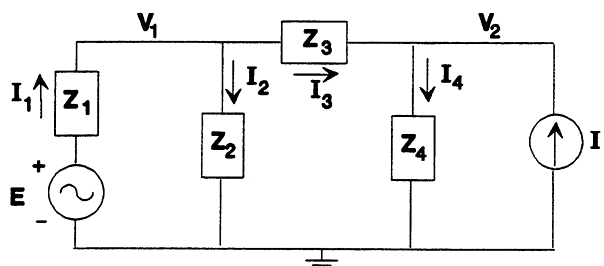
Substituting:

$$(1 \text{ k}\Omega)I_2 + (4 \text{ k}\Omega + j6 \text{ k}\Omega)I_3 = 16 \text{ V } \angle 0°$$
$$(99\ \Omega)I_2 + \qquad I_3 = 0.6 \text{ V } \angle 0°$$

Determinants:

$$I_3 = I_{6\text{ k}\Omega(2)} = 1.378 \text{ mA } \angle -56.31°$$

15. a.



$Z_1 = 5\ \Omega \angle 0°$
$Z_2 = 6\ \Omega \angle 90°$
$Z_3 = 4\ \Omega \angle -90°$
$Z_4 = 2\ \Omega \angle 0°$
$E = 30 \text{ V } \angle 50°$
$I = 0.04 \text{ A } \angle 90°$

$$I_1 = I_2 + I_3$$

$$\frac{E_1 - V_1}{Z_1} = \frac{V_1}{Z_2} + \frac{(V_1 - V_2)}{Z_3} \Rightarrow V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right] - \frac{V_2}{Z_3} = \frac{E_1}{Z_1}$$

or $V_1[Y_1 + Y_2 + Y_3] - Y_3V_2 = E_1Y_1$

$$I_3 + I = I_4$$

$$\frac{V_1 - V_2}{Z_3} + I = \frac{V_2}{Z_4} \Rightarrow V_2\left[\frac{1}{Z_3} + \frac{1}{Z_4}\right] - \frac{V_1}{Z_3} = I$$

or $V_2[Y_3 + Y_4] - V_1Y_3 = I$

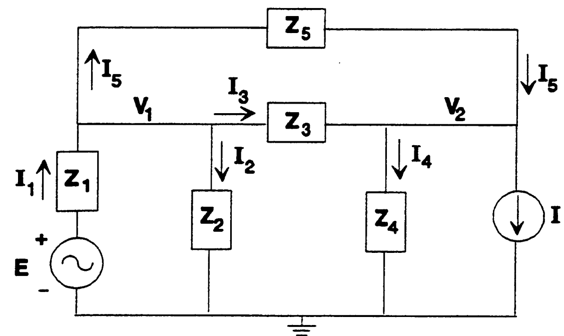
resulting in

$$\begin{aligned} V_1[Y_1 + Y_2 + Y_3] - V_2Y_3 &= E_1Y_1 \\ -V_1[Y_3] + V_2[Y_3 + Y_4] &= +I \end{aligned}$$

Using determinants:

$$V_1 = 19.86\text{ V } \angle 43.8^\circ \text{ and } V_2 = 8.94\text{ V } \angle 106.9^\circ$$

b.



$Z_1 = 10\ \Omega\ \angle 0^\circ$
$Z_2 = 10\ \Omega\ \angle 0^\circ$
$Z_3 = 4\ \Omega\ \angle 90^\circ$
$Z_4 = 2\ \Omega\ \angle 0^\circ$
$Z_5 = 8\ \Omega\ \angle -90^\circ$
$E = 50\text{ V } \angle 120^\circ$
$I = 0.8\text{ A } \angle 70^\circ$

$I_1 = I_2 + I_5$

$$\frac{E - V_1}{Z_1} = \frac{V_1}{Z_2} + \frac{(V_1 - V_2)}{Z_5} + \frac{V_1 - V_2}{Z_3} \Rightarrow V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \frac{1}{Z_5}\right] - V_2\left[\frac{1}{Z_3} + \frac{1}{Z_5}\right] = \frac{E}{Z_1}$$

or $V_1[Y_1 + Y_2 + Y_3 + Y_5] - V_2[Y_3 + Y_5] = E_1Y_1$

$I_3 + I_5 = I_4 + I$

$$\frac{V_1 - V_2}{Z_3} + \frac{V_1 - V_2}{Z_5} = \frac{V_2}{Z_4} + I \Rightarrow V_2\left[\frac{1}{Z_3} + \frac{1}{Z_4} + \frac{1}{Z_5}\right] - V_1\left[\frac{1}{Z_3} + \frac{1}{Z_5}\right] = -I$$

or $V_2[Y_3 + Y_4 + Y_5] - V_1[Y_3 + Y_5] = -I$

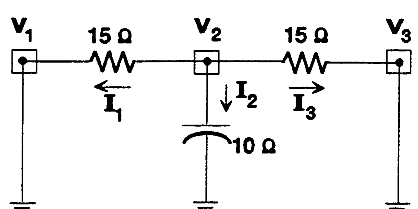
resulting in

$$\begin{aligned} V_1[Y_1 + Y_2 + Y_3 + Y_5] - V_2[Y_3 + Y_5] &= E_1Y_1 \\ -V_1[Y_3 + Y_5] + V_2[Y_3 + Y_4 + Y_5] &= -I \end{aligned}$$

Applying determinants:

$$V_1 = 19.78\text{ V } \angle 132.48^\circ \text{ and } V_2 = 13.37\text{ V } \angle 98.78^\circ$$

17.



(Note that 3 + j4 branch has no effect on nodal voltages)

$$\sum I_i = \sum I_o$$
$$0 = I_1 + I_2 + I_3$$
$$= \frac{V_2 - V_1}{15\ \Omega} + \frac{V_2}{10\ \Omega\ \angle -90^\circ} + \frac{V_2 - V_3}{15\ \Omega}$$

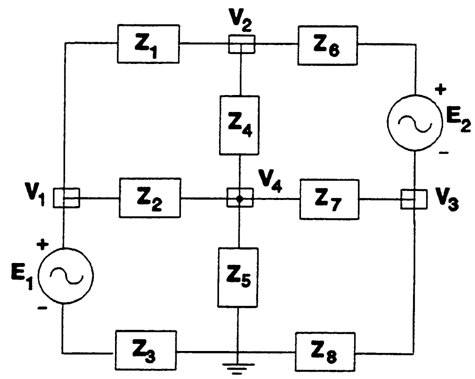
Through manipulation:

$$V_2[2 + j1.5] - V_1 - V_3 = 0$$

but $V_1 = 220\text{ V } \angle 0^\circ$ and $V_3 = 100\text{ V } \angle 90^\circ$

and $V_2 = \dfrac{220 + j100}{2 + j1.5} = 96.664\text{ V} \angle -12.426^\circ$

19.



$E_1 = 25\text{ V} \angle 0°$
$E_2 = 75\text{ V} \angle 20°$

$Z_1 = 10\ \Omega + j20\ \Omega$
$Z_2 = 6\ \Omega \angle 0°$
$Z_3 = 5\ \Omega \angle 0°$
$Z_4 = 20\ \Omega \angle -90°$
$Z_5 = 10\ \Omega \angle 0°$
$Z_6 = 80\ \Omega \angle 0°$
$Z_7 = 15\ \Omega \angle 90°$
$Z_8 = 5\ \Omega - j20\ \Omega$

$$V_1:\ \frac{V_1 - V_2}{Z_1} + \frac{V_1 - V_4}{Z_2} + \frac{V_1 - E_1}{Z_3} = 0$$

$$V_2:\ \frac{V_2 - V_1}{Z_1} + \frac{V_2 - V_4}{Z_4} + \frac{V_2 - E_2 - V_3}{Z_6} = 0$$

$$V_3:\ \frac{V_3 + E_2 - V_2}{Z_6} + \frac{V_3 - V_4}{Z_7} + \frac{V_3}{Z_8} = 0$$

$$V_4:\ \frac{V_4 - V_1}{Z_2} + \frac{V_4 - V_2}{Z_4} + \frac{V_4 - V_3}{Z_7} + \frac{V_4}{Z_5} = 0$$

Rearranging:

$$V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right] - \frac{V_2}{Z_1} - \frac{V_4}{Z_2} = \frac{E_1}{Z_3}$$

$$V_2\left[\frac{1}{Z_1} + \frac{1}{Z_4} + \frac{1}{Z_6}\right] - \frac{V_1}{Z_1} - \frac{V_4}{Z_4} - \frac{Z_3}{Z_6} = \frac{E_2}{Z_6}$$

$$V_3\left[\frac{1}{Z_6} + \frac{1}{Z_7} + \frac{1}{Z_8}\right] - \frac{V_2}{Z_6} - \frac{V_4}{Z_7} = -\frac{E_2}{Z_6}$$

$$V_4\left[\frac{1}{Z_2} + \frac{1}{Z_4} + \frac{1}{Z_7} + \frac{1}{Z_5}\right] - \frac{V_1}{Z_2} - \frac{V_2}{Z_4} - \frac{Z_3}{Z_7} = 0$$

Setting up and then using determinants:

$V_1 = 14.62\text{ V} \angle -5.861°$, $V_2 = 35.03\text{ V} \angle -37.69°$
$V_3 = 32.4\text{ V} \angle -73.34°$, $V_4 = 5.667\text{ V} \angle 23.53°$

21. Left node: V_1

$$\Sigma I_i = \Sigma I_o$$

$$4I_x = I_x + 5\text{ mA} \angle 0° + \frac{V_1 - V_2}{2\text{ k}\Omega}$$

Right node: V_2

$$\Sigma I_i = \Sigma I_o$$

$$8\text{ mA} \angle 0° = \frac{V_2}{1\text{ k}\Omega} + \frac{V_2 - V_1}{2\text{ k}\Omega} + 4I_x$$

Insert $I_x = \dfrac{V_1}{4\text{ k}\Omega \angle -90°}$

Rearrange, reduce and 2 equations with 2 unknowns result:

$$\mathbf{V}_1[1.803\ \angle 123.69°] + \mathbf{V}_2 = 10$$
$$\mathbf{V}_1[2.236\ \angle 116.57°] + 3\ \mathbf{V}_2 = 16$$

Determinants: $\mathbf{V}_1 = \mathbf{4.372\ V\ \angle -128.655°}$
$\mathbf{V}_2 = \mathbf{2.253\ V\ \angle 17.628°}$

23. Left node: $\mathbf{V}_1$

$$\Sigma \mathbf{I}_i = \Sigma \mathbf{I}_o$$
$$2\text{ mA } \angle 0° = 12\text{ mA } \angle 0° + \frac{\mathbf{V}_1}{2\text{ k}\Omega} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{1\text{ k}\Omega}$$

and $1.5\ \mathbf{V}_1 - \mathbf{V}_2 = -10$

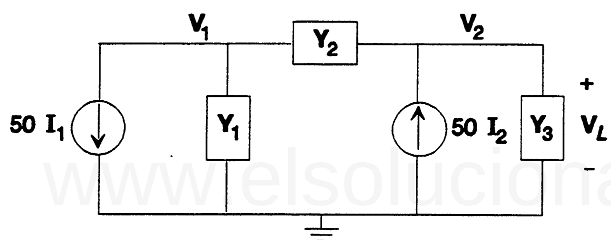
Right node: $\mathbf{V}_2$

$$\Sigma \mathbf{I}_i = \Sigma \mathbf{I}_o$$
$$0 = 2\text{ mA } \angle 0° + \frac{\mathbf{V}_2 - \mathbf{V}_1}{1\text{ k}\Omega} - \frac{\mathbf{V}_2 - 6\ \mathbf{V}_x}{3.3\text{ k}\Omega}$$

and $2.7\ \mathbf{V}_1 - 3.7\ \mathbf{V}_2 = -6.6$

Using determinants: $\mathbf{V}_1 = \mathbf{-10.667\ V\ \angle 0° = 10.667\ V\ \angle 180°}$
$\mathbf{V}_2 = \mathbf{-6\ V\ \angle 0° = 6\ V\ \angle 180°}$

25.



$$\mathbf{I}_1 = \frac{E_i\ \angle\theta}{R_1\ \angle 0°} = 1 \times 10^{-3}\ \mathbf{E}_i$$
$$\mathbf{Y}_1 = \frac{1}{50\text{ k}\Omega} = 0.02\text{ mS } \angle 0°$$
$$\mathbf{Y}_2 = \frac{1}{1\text{ k}\Omega} = 1\text{ mS } \angle 0°$$
$$\mathbf{Y}_3 = 0.02\text{ mS } \angle 0°$$
$$\mathbf{I}_2 = (\mathbf{V}_1 - \mathbf{V}_2)\mathbf{Y}_2$$

$$\mathbf{V}_1(\mathbf{Y}_1 + \mathbf{Y}_2) - \mathbf{Y}_2\mathbf{V}_2 = -50\mathbf{I}_1$$
$$\mathbf{V}_2(\mathbf{Y}_2 + \mathbf{Y}_3) - \mathbf{Y}_2\mathbf{V}_1 = 50\mathbf{I}_2 = 50(\mathbf{V}_1 - \mathbf{V}_2)\mathbf{Y}_2 = 50\mathbf{Y}_2\mathbf{V}_1 - 50\mathbf{Y}_2\mathbf{V}_2$$

$$(\mathbf{Y}_1 + \mathbf{Y}_2)\mathbf{V}_1 - \mathbf{Y}_2\mathbf{V}_2 = -50\mathbf{I}_1$$
$$-51\mathbf{Y}_2\mathbf{V}_1 + (51\mathbf{Y}_2 + \mathbf{Y}_3)\mathbf{V}_2 = 0$$

$$\mathbf{V}_L = \mathbf{V}_2 = \frac{-(50)(51)\mathbf{Y}_2\mathbf{I}_1}{(\mathbf{Y}_1 + \mathbf{Y}_2)(51\mathbf{Y}_2 + \mathbf{Y}_3) - 51\mathbf{Y}_2^2} = \mathbf{-2451.92\ E}_i$$

27. a.

$$\frac{\mathbf{Z}_1}{\mathbf{Z}_3} = \frac{\mathbf{Z}_2}{\mathbf{Z}_4}$$
$$\frac{4 \times 10^3\ \angle 0°}{4 \times 10^3\ \angle 90°} \stackrel{?}{=} \frac{4 \times 10^3\ \angle 0°}{4 \times 10^3\ \angle -90°}$$
$$1\ \angle -90° \neq 1\ \angle 90°\ \textbf{(not balanced)}$$

b. The solution to 26(b) resulted in

$$\mathbf{I}_3 = \mathbf{I}_{X_C} = \frac{\mathbf{E}(\mathbf{Z}_1\mathbf{Z}_5 + \mathbf{Z}_3(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5))}{\mathbf{Z}_\Delta}$$

where $\mathbf{Z}_\Delta = (\mathbf{Z}_1 + \mathbf{Z}_3 + \mathbf{Z}_6)[(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5)(\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5) - \mathbf{Z}_5^2]$
$\quad - \mathbf{Z}_1[\mathbf{Z}_1(\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5) - \mathbf{Z}_3\mathbf{Z}_5] - \mathbf{Z}_3[\mathbf{Z}_1\mathbf{Z}_5 + \mathbf{Z}_3(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5)]$

and $\mathbf{Z}_1 = 5\text{ k}\Omega \angle 0°, \mathbf{Z}_2 = 8\text{ k}\Omega \angle 0°, \mathbf{Z}_3 = 2.5\text{ k}\Omega \angle 90°$
$\mathbf{Z}_4 = 4\text{ k}\Omega \angle 90°, \mathbf{Z}_5 = 5\text{ k}\Omega \angle -90°, \mathbf{Z}_6 = 1\text{ k}\Omega \angle 0°$

and $\mathbf{I}_{X_C} = \mathbf{1.76\text{ mA} \angle -71.54°}$

c. The solution to 26(c) resulted in

$$\mathbf{V}_3 = \mathbf{V}_{X_C} = \frac{\mathbf{I}[\mathbf{Y}_1\mathbf{Y}_5 + \mathbf{Y}_2(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)]}{\mathbf{Y}_\Delta}$$

where $\mathbf{Y}_\Delta = (\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_6)[(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)(\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5) - \mathbf{Y}_5^2]$
$\quad - \mathbf{Y}_1[\mathbf{Y}_1(\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5) + \mathbf{Y}_2\mathbf{Y}_5]$
$\quad - \mathbf{Y}_2[\mathbf{Y}_1\mathbf{Y}_5 + \mathbf{Y}_2(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)]$

with $\mathbf{Y}_1 = 0.2\text{ mS} \angle 0°, \mathbf{Y}_2 = 0.125\text{ mS} \angle 0°, \mathbf{Y}_3 = 0.4\text{ mS} \angle -90°$
$\mathbf{Y}_4 = 0.25\text{ mS} \angle -90°, \mathbf{Y}_5 = 0.2\text{ mS} \angle 90°$

Source conversion: $\mathbf{Y}_6 = 1\text{ mS} \angle 0°, \mathbf{I} = 10\text{ mA} \angle 0°$
and $\mathbf{V}_3 = \mathbf{7.03\text{ V} \angle -18.46°}$

29. $X_{C_1} = \dfrac{1}{\omega C} = \dfrac{1}{(1000\text{ rad/s})(3\ \mu\text{F})} = \dfrac{1}{3}\text{k}\Omega$

$\mathbf{Z}_1 = R_1 \| X_{C_1} \angle -90° = (2\text{ k}\Omega \angle 0°) \| \dfrac{1}{3}\text{ k}\Omega \angle -90° = 328.8\ \Omega \angle -80.54°$

$\mathbf{Z}_2 = R_2 \angle 0° = 0.5\text{ k}\Omega \angle 0°, \mathbf{Z}_3 = R_3 \angle 0° = 4\text{ k}\Omega \angle 0°$

$\mathbf{Z}_4 = R_x + jX_{L_x} = 1\text{ k}\Omega + j6\text{ k}\Omega$

$$\frac{\mathbf{Z}_1}{\mathbf{Z}_3} = \frac{\mathbf{Z}_2}{\mathbf{Z}_4}$$

$$\frac{328.8\ \Omega \angle -80.54°}{4\text{ k}\Omega \angle 0°} \stackrel{?}{=} \frac{0.5\text{ k}\Omega \angle 0°}{6.083\ \Omega \angle 80.54°}$$

$$82.2 \angle -80.54° \stackrel{\checkmark}{=} 82.2 \angle -80.54° \ \textbf{(balanced)}$$

31. For balance:

$$R_1(R_x + jX_{L_x}) = R_2(R_3 + jX_{L_3})$$

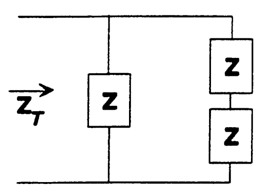
$$R_1R_x + jR_1X_{L_x} = R_2R_3 + jR_2X_{L_3}$$

$$\therefore\ R_1R_x = R_2R_3 \text{ and } R_x = \frac{R_2R_3}{R_1}$$

$$R_1X_{L_x} = R_2X_{L_3} \text{ and } R_1\omega L_x = R_2\omega L_3$$

$$\text{so that } L_x = \frac{R_2L_3}{R_1}$$

33. a.

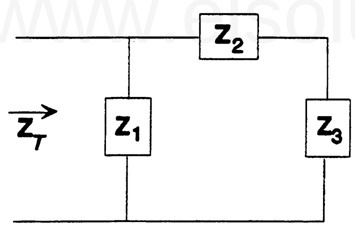


$$\mathbf{Z}_\Delta = 3\mathbf{Z}_Y = 3(3\ \Omega\ \angle 90°) = 9\ \Omega\ \angle 90°$$
$$\mathbf{Z} = 9\ \Omega\ \angle 90° \parallel (12\ \Omega - j16\ \Omega)$$
$$= 9\ \Omega\ \angle 90° \parallel 20\ \Omega\ \angle 53.13°$$
$$= 12.96\ \Omega\ \angle 67.13°$$

$$\mathbf{Z}_T = \mathbf{Z} \parallel 2\mathbf{Z} = \frac{2\mathbf{Z}^2}{\mathbf{Z} + 2\mathbf{Z}} = \frac{2}{3}\mathbf{Z} = \frac{2}{3}[12.96\ \Omega\ \angle 67.13°] = 8.64\ \Omega\ \angle 67.13°$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{100\ \text{V}\ \angle 0°}{8.64\ \Omega\ \angle 67.13°} = \mathbf{11.57\ A\ \angle -67.13°}$$

b. $\mathbf{Z}_\Delta = 3\mathbf{Z}_Y = 3(5\ \Omega) = 15\ \Omega$



$$\mathbf{Z}_1 = 15\ \Omega\ \angle 0° \parallel 5\ \Omega\ \angle -90°$$
$$= 4.74\ \Omega\ \angle -71.57°$$
$$\mathbf{Z}_2 = 15\ \Omega\ \angle 0° \parallel 6\ \Omega\ \angle 90°$$
$$= 5.57\ \Omega\ \angle 68.2° = 2.07\ \Omega + j5.17\ \Omega$$
$$\mathbf{Z}_3 = \mathbf{Z}_1 = 4.74\ \Omega\ \angle -71.57°$$
$$= 1.5\ \Omega - j4.5\ \Omega$$

$$\mathbf{Z}_T = \mathbf{Z}_1 \parallel (\mathbf{Z}_2 + \mathbf{Z}_3) = (4.74\ \Omega\ \angle -71.57°) \parallel (2.07\ \Omega + j5.17\ \Omega + 1.5\ \Omega - j4.5\ \Omega)$$
$$= (4.74\ \Omega\ \angle -7.57°) \parallel (3.63\ \Omega\ \angle 10.63°)$$
$$= 2.71\ \Omega\ \angle -23.87°$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{100\ \text{V}\ \angle 0°}{2.71\ \Omega\ \angle -23.87°} = \mathbf{36.9\ A\ \angle 23.87°}$$

CHAPTER 17 (Even)

2. a. $\mathbf{Z} = 5.6\ \Omega + j8.2\ \Omega = \mathbf{9.93\ \Omega\ \angle 55.67^\circ}$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{20\text{ V }\angle 20^\circ}{9.93\ \Omega\ \angle 55.67^\circ} = \mathbf{2.014\ A\ \angle -35.67^\circ}$$

b. $\mathbf{Z} = 2\ \Omega\ \angle 0^\circ \parallel 5\ \Omega\ \angle 90^\circ = \mathbf{1.86\ \Omega\ \angle 21.8^\circ}$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{60\text{ V }\angle 30^\circ}{1.86\ \Omega\ \angle 21.8^\circ} = 32.26\text{ A }\angle 8.2^\circ$$

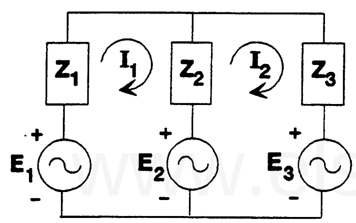
4. a. $\mathbf{I} = \frac{\mu\mathbf{V}}{R} = \frac{16\text{ V}}{4\times 10^3} = \mathbf{4\times 10^{-3}\ V}$

$\mathbf{Z} = \mathbf{4\ k\Omega\ \angle 0^\circ}$

b. $\mathbf{V} = (h\mathbf{I})(R) = (50\ \mathbf{I})(50\text{ k}\Omega) = \mathbf{2.5\times 10^6\ I}$

$\mathbf{Z} = \mathbf{50\ k\Omega\ \angle 0^\circ}$

6. a.



$\mathbf{Z}_1 = 12\ \Omega + j12\ \Omega = 16.971\ \Omega\ \angle 45^\circ$
$\mathbf{Z}_2 = 3\ \Omega\ \angle 0^\circ$
$\mathbf{Z}_3 = -j1\ \Omega$
$\mathbf{E}_1 = 20\text{ V }\angle 50^\circ$
$\mathbf{E}_2 = 60\text{ V }\angle 70^\circ$
$\mathbf{E}_3 = 40\text{ V }\angle 0^\circ$

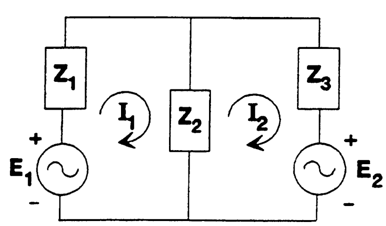
$$\mathbf{I}_1[\mathbf{Z}_1 + \mathbf{Z}_2] - \mathbf{Z}_2\mathbf{I}_2 = \mathbf{E}_1 - \mathbf{E}_2$$
$$\mathbf{I}_2[\mathbf{Z}_2 + \mathbf{Z}_3] - \mathbf{Z}_2\mathbf{I}_1 = \mathbf{E}_2 - \mathbf{E}_3$$

$$(\mathbf{Z}_1 + \mathbf{Z}_2)\mathbf{I}_1 - \mathbf{Z}_2\mathbf{I}_2 = \mathbf{E}_1 - \mathbf{E}_2$$
$$-\mathbf{Z}_2\mathbf{I}_1 + (\mathbf{Z}_2 + \mathbf{Z}_3)\mathbf{I}_2 = \mathbf{E}_2 - \mathbf{E}_3$$

Using determinants:

$$\mathbf{I}_{R_1} = \mathbf{I}_1 = \frac{(\mathbf{E}_1 - \mathbf{E}_2)(\mathbf{Z}_2 + \mathbf{Z}_3) + \mathbf{Z}_2(\mathbf{E}_2 - \mathbf{E}_3)}{\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3} = \mathbf{2.552\ A\ \angle 132.72^\circ}$$

b.



Source conversion:

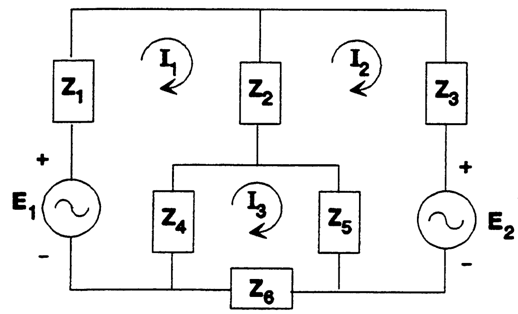
$\mathbf{E}_1 = \mathbf{IZ} = (6\text{ A }\angle 0^\circ)(2\ \Omega\ \angle 0^\circ)$
$= 12\text{ V }\angle 0^\circ$
$\mathbf{Z}_1 = 2\ \Omega + 20\ \Omega + j20\ \Omega = 22\ \Omega + j20\ \Omega$
$= 29.732\ \Omega\ \angle 42.274^\circ$
$\mathbf{Z}_2 = -j10\ \Omega = 10\ \Omega\ \angle -90^\circ$
$\mathbf{Z}_3 = 10\ \Omega\ \angle 0^\circ$

$$\begin{array}{l} \mathbf{I}_1[\mathbf{Z}_1 + \mathbf{Z}_2] - \mathbf{Z}_2\mathbf{I}_2 = \mathbf{E}_1 \\ \mathbf{I}_2[\mathbf{Z}_2 + \mathbf{Z}_3] - \mathbf{Z}_2\mathbf{I}_1 = -\mathbf{E}_2 \end{array}$$

$$\begin{array}{l} (\mathbf{Z}_1 + \mathbf{Z}_2)\mathbf{I}_1 - \mathbf{Z}_2\mathbf{I}_2 = \mathbf{E}_1 \\ -\mathbf{Z}_2\mathbf{I}_1 + (\mathbf{Z}_2 + \mathbf{Z}_3)\mathbf{I}_2 = -\mathbf{E}_2 \end{array}$$

$$\mathbf{I}_{R_1} = \mathbf{I}_1 = \frac{\mathbf{E}_1(\mathbf{Z}_2 + \mathbf{Z}_3) - \mathbf{Z}_2\mathbf{E}_2}{\mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3} = 0.495 \text{ A } \angle 72.255°$$

8. a.



$\mathbf{Z}_1 = 5\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 5\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 4\ \Omega\ \angle 0°$, $\mathbf{Z}_4 = 6\ \Omega\ \angle -90°$
$\mathbf{Z}_5 = 4\ \Omega\ \angle 0°$, $\mathbf{Z}_6 = 6\ \Omega + j8\ \Omega$
$\mathbf{E}_1 = 20\text{ V }\angle 0°$, $\mathbf{E}_2 = 40\text{ V }\angle 60°$

$$\begin{array}{l} \mathbf{I}_1(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_4) - \mathbf{I}_2\mathbf{Z}_2 - \mathbf{I}_3\mathbf{Z}_4 = \mathbf{E}_1 \\ \mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_5) - \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}_3\mathbf{Z}_5 = -\mathbf{E}_2 \\ \mathbf{I}_3(\mathbf{Z}_4 + \mathbf{Z}_5 + \mathbf{Z}_6) - \mathbf{I}_1\mathbf{Z}_4 - \mathbf{I}_2\mathbf{Z}_5 = 0 \end{array}$$

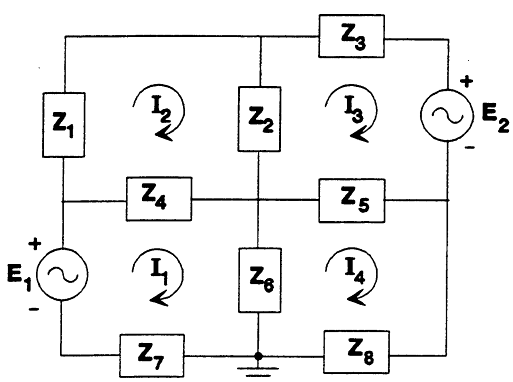
$$\begin{array}{llll} (\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_4)\mathbf{I}_1 & - \mathbf{Z}_2\mathbf{I}_2 & - \mathbf{Z}_4\mathbf{I}_3 & = \mathbf{E}_1 \\ -\mathbf{Z}_2\mathbf{I}_1 & + (\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_5)\mathbf{I}_2 & - \mathbf{Z}_5\mathbf{I}_3 & = -\mathbf{E}_2 \\ -\mathbf{Z}_4\mathbf{I}_1 & - \mathbf{Z}_5\mathbf{I}_2 & + (\mathbf{Z}_4 + \mathbf{Z}_5 + \mathbf{Z}_6)\mathbf{I}_3 & = 0 \end{array}$$

Using $\mathbf{Z}' = \mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_4$, $\mathbf{Z}'' = \mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_5$, $\mathbf{Z}''' = \mathbf{Z}_4 + \mathbf{Z}_5 + \mathbf{Z}_6$ and determinants:

$$\mathbf{I}_{R_1} = \mathbf{I}_1 = \frac{\mathbf{E}_1(\mathbf{Z}''\mathbf{Z}''' - \mathbf{Z}_5^2) - \mathbf{E}_2(\mathbf{Z}_2\mathbf{Z}''' + \mathbf{Z}_4\mathbf{Z}_5)}{\mathbf{Z}'(\mathbf{Z}''\mathbf{Z}''' - \mathbf{Z}_5^2) - \mathbf{Z}_2(\mathbf{Z}_2\mathbf{Z}''' + \mathbf{Z}_4\mathbf{Z}_5) - \mathbf{Z}_4(\mathbf{Z}_2\mathbf{Z}_5 + \mathbf{Z}_4\mathbf{Z}'')}$$

$$= 3.04 \text{ A } \angle 169.12°$$

b.



$\mathbf{Z}_1 = 10\ \Omega + j20\ \Omega$ $\quad$ $\mathbf{Z}_2 = -j20\ \Omega$
$\mathbf{Z}_3 = 80\ \Omega\ \angle 0°$ $\quad$ $\mathbf{Z}_4 = 6\ \Omega\ \angle 0°$
$\mathbf{Z}_5 = 15\ \Omega\ \angle 90°$ $\quad$ $\mathbf{Z}_6 = 10\ \Omega\ \angle 0°$
$\mathbf{Z}_7 = 5\ \Omega\ \angle 0°$ $\quad$ $\mathbf{Z}_8 = 5\ \Omega - j20\ \Omega$
$\mathbf{E}_1 = 25\text{ V }\angle 0°$ $\quad$ $\mathbf{E}_2 = 75\text{ V }\angle 20°$

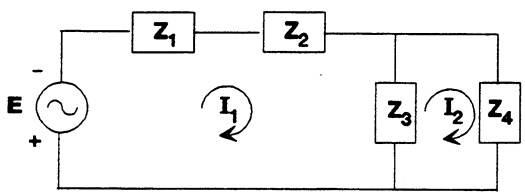
$$
\begin{aligned}
&I_1(Z_4 + Z_6 + Z_7) - I_2Z_4 - I_4Z_6 = E_1\\
&I_2(Z_1 + Z_2 + Z_4) - I_1Z_4 - I_3Z_2 = 0\\
&I_3(Z_2 + Z_3 + Z_5) - I_2Z_2 - I_4Z_5 = -E_2\\
&I_4(Z_5 + Z_6 + Z_8) - I_1Z_6 - I_3Z_5 = 0
\end{aligned}
$$

$$
\begin{array}{lllll}
(Z_4 + Z_6 + Z_7)I_1 & - Z_4I_2 & + 0 & - Z_6I_4 & = E_1\\
-Z_4I_1 & + (Z_1 + Z_2 + Z_4)I_2 & - Z_2I_3 & + 0 & = 0\\
0 & - Z_2I_2 & + (Z_2 + Z_3 + Z_5)I_3 & - Z_5I_4 & = -E_2\\
-Z_6I_1 & + 0 & - Z_5I_3 & + (Z_5 + Z_6 + Z_7)I_4 & = 0
\end{array}
$$

Applying determinants:

$$I_{R_1} = I_{80\Omega} = 0.681\text{ A} \angle -162.9°$$

10.



Source Conversion:

$$
\begin{aligned}
E &= (I \angle\theta)(R_p \angle 0°)\\
&= (50\ I)(40\text{ k}\Omega \angle 0°)\\
&= 2 \times 10^6\ I \angle 0°
\end{aligned}
$$

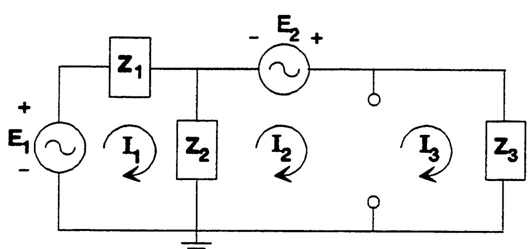
$Z_1 = R_s = R_p = 40\text{ k}\Omega \angle 0°$
$Z_2 = -j0.2\text{ k}\Omega$
$Z_3 = 8\text{ k}\Omega \angle 0°$
$Z_4 = 4\text{ k}\Omega \angle 90°$

$$
\begin{aligned}
&I_1(Z_1 + Z_2 + Z_3) - Z_3I_2 = -E\\
&I_2(Z_3 + Z_4) - Z_3I_1 = 0
\end{aligned}
$$

$$
\begin{aligned}
&(Z_1 + Z_2 + Z_3)I_1 - Z_3I_2 = -E\\
&-Z_3I_1 + (Z_3 + Z_4)I_2 = 0
\end{aligned}
$$

$$I_L = I_2 = \frac{-Z_3E}{(Z_1 + Z_2 + Z_3)(Z_3 + Z_4) - Z_3^2} = 42.91\ I \angle 149.31°$$

12.



$E_1 = 5\text{ V} \angle 0°$
$E_2 = 20\text{ V} \angle 0°$
$Z_1 = 2.2\text{ k}\Omega \angle 0°$
$Z_2 = 5\text{ k}\Omega \angle 90°$
$Z_3 = 10\text{ k}\Omega \angle 0°$
$I = 4\text{ mA} \angle 0°$

$$
\begin{aligned}
&E_1 - I_1Z_1 - Z_2(I_1 - I_2) = 0\\
&-Z_2(I_2 - I_1) + E_2 - I_3Z_3 = 0
\end{aligned}
$$

$$I_3 - I_2 = I$$

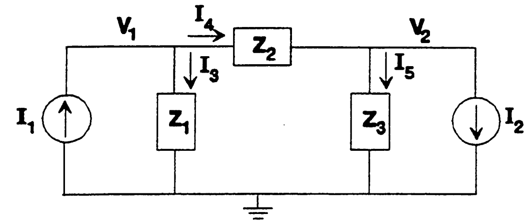
Substituting, we obtain:

$$
\begin{aligned}
&I_1(Z_1 + Z_2) - I_2Z_2 = E_1\\
&I_1Z_2 - I_2(Z_2 + Z_3) = IZ_3 - E_2
\end{aligned}
$$

Determinants:

$I_1 = 1.39\text{ mA} \angle -126.48°$, $I_2 = 1.341\text{ mA} \angle -10.56°$, $I_3 = 2.693\text{ mA} \angle -174.8°$
$I_{10k\Omega} = I_3 = 2.693\text{ mA} \angle -174.8°$

14. a.



$Z_1 = 4\ \Omega\ \angle 0°$
$Z_2 = 5\ \Omega\ \angle 90°$
$Z_3 = 2\ \Omega\ \angle -90°$
$I_1 = 3\text{ A}\ \angle 0°$
$I_2 = 5\text{ A}\ \angle 30°$

$$I_1 = I_3 + I_4$$

$$I_1 = \frac{V_1}{Z_1} + \frac{V_1 - V_2}{Z_2} \Rightarrow V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2}\right] - V_2\left[\frac{1}{Z_2}\right] = I_1$$

or $V_1[Y_1 + Y_2] - V_2[Y_2] = I_1$

$$I_4 = I_5 + I_2$$

$$\frac{V_1 - V_2}{Z_2} = \frac{V_2}{Z_3} + I_2 \Rightarrow V_2\left[\frac{1}{Z_2} + \frac{1}{Z_3}\right] - V_1\left[\frac{1}{Z_2}\right] = -I_2$$

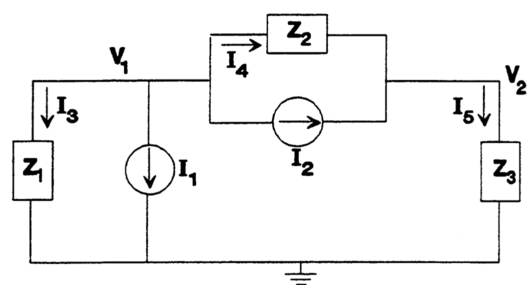
or $V_2[Y_2 + Y_3] - V_1[Y_2] = -I_2$

$$[Y_1 + Y_2]V_1 - Y_2V_2 = I_1$$
$$-Y_2V_1 + [Y_2 + Y_3]V_2 = -I_2$$

$$V_1 = \frac{[Y_2 + Y_3]I_1 - Y_2I_2}{Y_1Y_2 + Y_1Y_3 + Y_2Y_3} = 14.68\text{ V}\ \angle 68.89°$$

$$V_2 = \frac{-[Y_2 + Y_2]I_2 + Y_2I_1}{Y_1Y_2 + Y_1Y_3 + Y_2Y_3} = 12.97\text{ V}\ \angle 155.88°$$

b.



$Z_1 = 3\ \Omega + j4\ \Omega = 5\ \angle 53.13°$
$Z_2 = 2\ \Omega\ \angle 0°$
$Z_3 = 6\ \Omega\ \angle 0° \| 8\ \Omega\ \angle -90°$
$\quad = 4.8\ \Omega\ \angle -36.87°$
$I_1 = 0.6\text{ A}\ \angle 20°$
$I_2 = 4\text{ A}\ \angle 80°$

$$0 = I_1 + I_3 + I_4 + I_2$$

$$0 = I_1 + \frac{V_1}{Z_1} + \frac{V_1 - V_2}{Z_2} + I_2$$

$$V_1\left[\frac{1}{Z_1} + \frac{1}{Z_2}\right] - V_2\left[\frac{1}{Z_2}\right] = -I_1 - I_2$$

or $\underline{V_1[Y_1 + Y_2] - V_2[Y_2] = -I_1 - I_2}$

$$\mathbf{I}_2 + \mathbf{I}_4 = \mathbf{I}_5$$

$$\mathbf{I}_2 + \frac{\mathbf{V}_1 - \mathbf{V}_2}{\mathbf{Z}_2} = \frac{\mathbf{V}_2}{\mathbf{Z}_3}$$

$$\mathbf{V}_2\left[\frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_3}\right] - \mathbf{V}_1\left[\frac{1}{\mathbf{Z}_2}\right] = +\mathbf{I}_2$$

or $\quad \mathbf{V}_2[\mathbf{Y}_2 + \mathbf{Y}_3] - \mathbf{V}_1[\mathbf{Y}_2] = \mathbf{I}_2$

and $\quad [\mathbf{Y}_1 + \mathbf{Y}_2]\mathbf{V}_1 - \mathbf{Y}_2\mathbf{V}_2 = -\mathbf{I}_1 - \mathbf{I}_2$

$\quad -\mathbf{Y}_2\mathbf{V}_1 + [\mathbf{Y}_2 + \mathbf{Y}_3]\mathbf{V}_2 = \mathbf{I}_2$

Applying determinants:

$$\mathbf{V}_1 = \frac{-[\mathbf{Y}_2 + \mathbf{Y}_3][\mathbf{I}_1 + \mathbf{I}_2] + \mathbf{Y}_2\mathbf{I}_2}{\mathbf{Y}_1\mathbf{Y}_2 + \mathbf{Y}_1\mathbf{Y}_3 + \mathbf{Y}_2\mathbf{Y}_3} = \mathbf{5.12\ V\ \angle -79.36^\circ}$$

$$\mathbf{V}_2 = \frac{\mathbf{Y}_1\mathbf{I}_2 - \mathbf{I}_1\mathbf{Y}_2}{\mathbf{Y}_1\mathbf{Y}_2 + \mathbf{Y}_1\mathbf{Y}_3 + \mathbf{Y}_2\mathbf{Y}_3} = \mathbf{2.71\ V\ \angle 39.96^\circ}$$

16. $$\mathbf{I} = \frac{\mathbf{V}_1}{\mathbf{Z}_1} + \frac{\mathbf{V}_1 - \mathbf{V}_2}{\mathbf{Z}_2}$$

$$0 = \frac{\mathbf{V}_2 - \mathbf{V}_1}{\mathbf{Z}_2} + \frac{\mathbf{V}_2}{\mathbf{Z}_3} + \frac{\mathbf{V}_2 - \mathbf{E}}{\mathbf{Z}_4}$$

$\mathbf{Z}_1 = 2\ \Omega\ \angle 0^\circ$
$\mathbf{Z}_2 = 20\ \Omega + j\,20\ \Omega$
$\mathbf{Z}_3 = 10\Omega\ \angle -90^\circ$
$\mathbf{Z}_4 = 10\ \Omega\ \angle 0^\circ$
$\mathbf{I} = 6\ \text{A}\ \angle 0^\circ$
$\mathbf{E} = 30\ \text{V}\ \angle 0^\circ$

Rearranging:

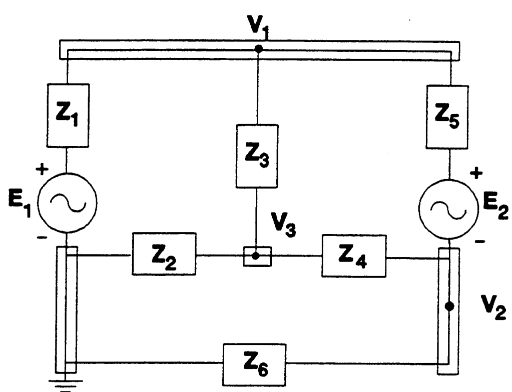
$$\mathbf{V}_1\left[\frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_2}\right] - \frac{1}{\mathbf{Z}_2}\mathbf{V}_2 = \mathbf{I}$$

$$\frac{-\mathbf{V}_1}{\mathbf{Z}_2} + \mathbf{V}_2\left[\frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_2} + \frac{1}{\mathbf{Z}_4}\right] = \frac{\mathbf{E}}{\mathbf{Z}_4}$$

Determinants and substituting:

$$\mathbf{V}_1 = \mathbf{11.74\ V\ \angle -4.611^\circ},\ \mathbf{V}_2 = \mathbf{22.53\ V\ \angle -36.48^\circ}$$

18.



$\mathbf{Z}_1 = 5\ \Omega\ \angle 0^\circ$
$\mathbf{Z}_2 = 6\ \Omega\ \angle -90^\circ$
$\mathbf{Z}_3 = 5\ \Omega\ \angle 90^\circ$
$\mathbf{Z}_4 = 4\ \Omega\ \angle 0^\circ$
$\mathbf{Z}_5 = 4\ \Omega\ \angle 0^\circ$
$\mathbf{Z}_6 = 6\ \Omega + j8\ \Omega$
$\mathbf{E}_1 = 20\ \text{V}\ \angle 0^\circ$
$\mathbf{E}_2 = 40\ \text{V}\ \angle 60^\circ$

node V_1: $\dfrac{V_1 - E_1}{Z_1} + \dfrac{V_1 - V_3}{Z_3} + \dfrac{V_1 - E_2 - V_2}{Z_5} = 0$

node V_2: $\dfrac{V_2 + E_2 - V_1}{Z_5} + \dfrac{V_2 - V_3}{Z_4} + \dfrac{V_2}{Z_6} = 0$

node V_3: $\dfrac{V_3}{Z_2} + \dfrac{V_3 - V_1}{Z_3} + \dfrac{V_3 - V_2}{Z_4} = 0$

Rearranging:

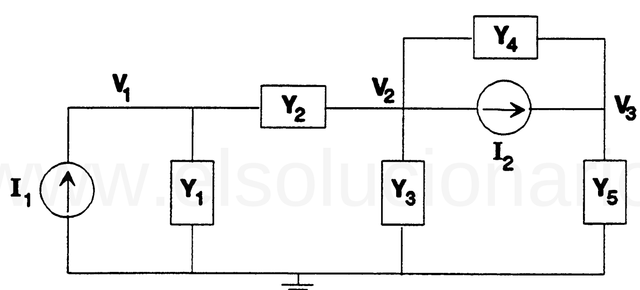
$$V_1\left[\frac{1}{Z_1} + \frac{1}{Z_3} + \frac{1}{Z_5}\right] - \frac{V_2}{Z_5} - \frac{V_3}{Z_3} = \frac{E_1}{Z_1} + \frac{E_2}{Z_5}$$

$$V_2\left[\frac{1}{Z_5} + \frac{1}{Z_4} + \frac{1}{Z_6}\right] - \frac{V_1}{Z_5} - \frac{V_3}{Z_4} = -\frac{E_2}{Z_5}$$

$$V_3\left[\frac{1}{Z_2} + \frac{1}{Z_3} + \frac{1}{Z_4}\right] - \frac{V_1}{Z_3} - \frac{V_2}{Z_4} = 0$$

Determinants: $V_1 = 5.839\text{ V} \angle 29.4°$, $V_2 = 28.06\text{ V} \angle -89.15°$, $V_3 = 31.96\text{ V} \angle -77.6$

20. a.



$Y_1 = \dfrac{1}{4\ \Omega \angle 0°} = 0.25\text{ S} \angle 0°$

$Y_2 = \dfrac{1}{1\ \Omega \angle 90°} = 1\text{ S} \angle -90°$

$Y_3 = \dfrac{1}{5\ \Omega \angle 0°} = 0.2\text{ S} \angle 0°$

$Y_4 = \dfrac{1}{4\ \Omega \angle -90°} = 0.25\text{ S} \angle 90°$

$Y_5 = \dfrac{1}{8\ \Omega \angle 90°} = 0.125\text{ S} \angle -90°$

$I_1 = 2\text{ A} \angle 30°$

$I_2 = 3\text{ A} \angle 150°$

$V_1[Y_1 + Y_2] - Y_2V_2 = I_1$
$V_2[Y_2 + Y_3 + Y_4] - Y_2V_1 - Y_4V_3 = -I_2$
$V_3[Y_4 + Y_5] - Y_4V_2 = I_2$

$$\begin{aligned}
[Y_1 + Y_2]V_1 &\quad - Y_2V_2 &\quad + 0 &= I_1\\
-Y_2V_1 &\quad + [Y_2 + Y_3 + Y_4]V_2 &\quad - Y_4V_3 &= -I_2\\
0 &\quad - Y_4V_2 &\quad + [Y_4 + Y_5]V_3 &= I_2
\end{aligned}$$

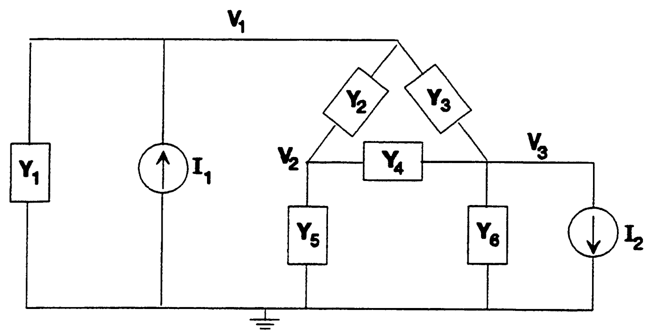
$$V_1 = \frac{I_1\left[(Y_2 + Y_3 + Y_4)(Y_4 + Y_5) - Y_4^2\right] - I_2[Y_2Y_5]}{[Y_1 + Y_2]\left[(Y_2 + Y_3 + Y_4)(Y_4 + Y_5) - Y_4^2\right] - Y_2^2(Y_4 + Y_5) = Y_\Delta}$$

$= 5.74\text{ V} \angle 122.76°$

$$V_2 = \frac{I_1Y_2(Y_4 + Y_5) - I_2Y_5(Y_1 + Y_2)}{Y_\Delta} = 4.04\ \text{V}\ \angle 145.03^\circ$$

$$V_3 = \frac{I_2\left[(Y_1 + Y_2)(Y_3 + Y_4) - Y_2^2\right] - Y_2Y_4I_1}{Y_\Delta} = 25.94\ \text{V}\ \angle 78.07^\circ$$

b.



$Y_1 = \dfrac{1}{4\ \Omega\ \angle 0^\circ} = 0.25\ \text{S}\ \angle 0^\circ$

$Y_2 = \dfrac{1}{6\ \Omega\ \angle 0^\circ} = 0.167\ \text{S}\ \angle 0^\circ$

$Y_3 = \dfrac{1}{8\ \Omega\ \angle 0^\circ} = 0.125\ \text{S}\ \angle 0^\circ$

$Y_4 = \dfrac{1}{2\ \Omega\ \angle -90^\circ} = 0.5\ \text{S}\ \angle 90^\circ$

$Y_5 = \dfrac{1}{5\ \Omega\ \angle 90^\circ} = 0.2\ \text{S}\ \angle -90^\circ$

$Y_6 = \dfrac{1}{4\ \Omega\ \angle 90^\circ} = 0.25\ \text{S}\ \angle -90^\circ$

$I_1 = 4\ \text{A}\ \angle 0^\circ$

$I_2 = 6\ \text{A}\ \angle 90^\circ$

$$V_1[Y_1 + Y_2 + Y_3] - Y_2V_2 - Y_3V_3 = I_1$$
$$V_2[Y_2 + Y_4 + Y_5] - Y_2V_1 - Y_4V_3 = 0$$
$$V_3[Y_3 + Y_4 + Y_6] - Y_3V_1 - Y_4V_2 = -I_2$$

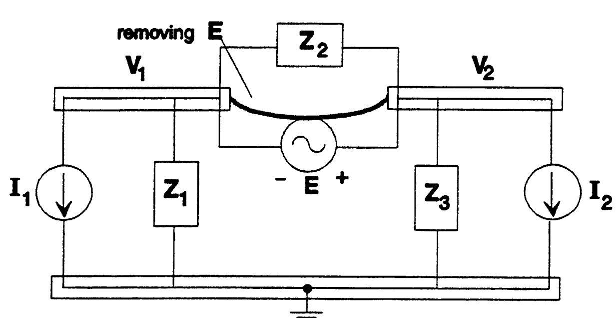
$$\begin{aligned}
&[Y_1 + Y_2 + Y_3]V_1 && - Y_2V_2 && - Y_3V_3 = I_1\\
&-Y_2V_1 && + [Y_2 + Y_4 + Y_5]V_2 && - Y_4V_3 = 0\\
&-Y_3V_1 && - Y_4V_2 && + [Y_3 + Y_4 + Y_6]V_3 = -I_2
\end{aligned}$$

$$V_1 = \frac{I_1\left[(Y_2 + Y_4 + Y_5)(Y_3 + Y_4 + Y_6) - Y_4^2\right] - I_2\left[Y_2Y_4 + Y_3(Y_3 + Y_4 + Y_5)\right]}{Y_\Delta = (Y_1 + Y_2 + Y_3)\left[(Y_2 + Y_4 + Y_5)(Y_3 + Y_4 + Y_6) - Y_4^2\right] - Y_2\left[Y_2(Y_3 + Y_4 + Y_6) + Y_3Y_4\right] - Y_3\left[Y_2Y_4 + Y_3(Y_2 + Y_4 + Y_5)\right]}$$
$$= 15.13\ \text{V}\ \angle 1.29^\circ$$

$$V_2 = \frac{I_1\left[(Y_2)(Y_3 + Y_4 + Y_6) + Y_3Y_4\right] + I_2\left[Y_4(Y_1 + Y_2 + Y_3) - Y_2Y_3\right]}{Y_\Delta} = 17.24\ \text{V}\ \angle 3.73^\circ$$

$$V_3 = \frac{I_1\left[(Y_3)(Y_2 + Y_4 + Y_5) + Y_2Y_4\right] + I_2\left[Y_2^2 - (Y_1 + Y_2 + Y_3)(Y_2 + Y_4 + Y_5)\right]}{Y_\Delta}$$
$$= 10.59\ \text{V}\ \angle -0.11^\circ$$

22.



$Z_1 = 1\ \text{k}\Omega\ \angle 0^\circ$
$Z_2 = 2\ \text{k}\Omega\ \angle 90^\circ$
$Z_3 = 3\ \text{k}\Omega\ \angle -90^\circ$
$I_1 = 12\ \text{mA}\ \angle 0^\circ$
$I_2 = 4\ \text{mA}\ \angle 0^\circ$
$E = 10\ \text{V}\ \angle 0^\circ$

$$\Sigma \mathbf{I}_i = \Sigma \mathbf{I}_o$$

$$0 = \mathbf{I}_1 + \frac{\mathbf{V}_1}{\mathbf{Z}_1} + \frac{\mathbf{V}_2}{\mathbf{Z}_3} + \mathbf{I}_2$$

and $\dfrac{\mathbf{V}_1}{\mathbf{Z}_1} + \dfrac{\mathbf{V}_2}{\mathbf{Z}_3} = -\mathbf{I}_1 - \mathbf{I}_2$

with $\mathbf{V}_2 - \mathbf{V}_1 = \mathbf{E}$

Substituting and rearranging:

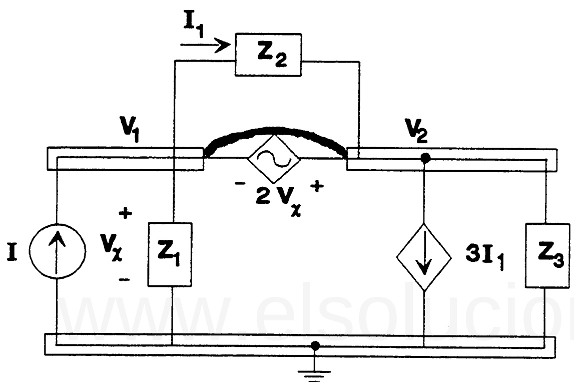
$$\mathbf{V}_1\left[\frac{1}{\mathbf{Z}_1} + \frac{1}{\mathbf{Z}_3}\right] = -\mathbf{I}_1 - \mathbf{I}_2 - \frac{\mathbf{E}}{\mathbf{Z}_3}$$

and solving for $\mathbf{V}_1$:

$\mathbf{V}_1 = \mathbf{15.4\ V \angle 178.2°}$

with $\mathbf{V}_2 = \mathbf{5.414\ V \angle 174.87°}$

24.



$\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 1\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = 1\ \text{k}\Omega\ \angle 0°$
$\mathbf{I} = 5\ \text{mA}\ \angle 0°$

$\mathbf{V}_1$: $\mathbf{I} = \dfrac{\mathbf{V}_1}{\mathbf{Z}_1} + 3\mathbf{I}_1 + \dfrac{\mathbf{V}_2}{\mathbf{Z}_3}$

with $\mathbf{I}_1 = \dfrac{\mathbf{V}_1 - \mathbf{V}_2}{\mathbf{Z}_2}$

and $\mathbf{V}_2 - \mathbf{V}_1 = 2\mathbf{V}_x = 2\mathbf{V}_1$ or $\mathbf{V}_2 = 3\mathbf{V}_1$

Substituting with result in:

$$\mathbf{V}_1\left[\frac{1}{\mathbf{Z}_1} + \frac{3}{\mathbf{Z}_2}\right] + 3\ \mathbf{V}_1\left[\frac{1}{\mathbf{Z}_3} - \frac{3}{\mathbf{Z}_2}\right] = \mathbf{I}$$

or $$\mathbf{V}_1\left[\frac{1}{\mathbf{Z}_1} - \frac{6}{\mathbf{Z}_2} + \frac{3}{\mathbf{Z}_3}\right] = \mathbf{I}$$

and $\mathbf{V}_1 = \mathbf{-2\ V \angle 0°}$

with $\mathbf{V}_2 = \mathbf{-6\ V \angle 0°}$

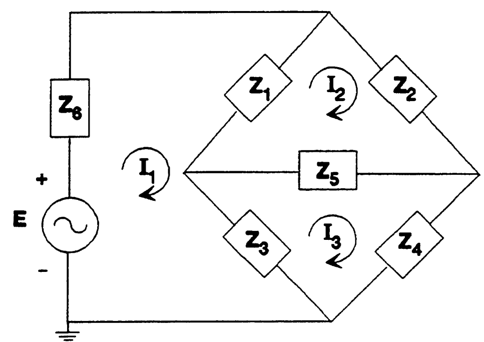
26. a. yes

$$\frac{\mathbf{Z}_1}{\mathbf{Z}_3} = \frac{\mathbf{Z}_2}{\mathbf{Z}_4}$$

$$\frac{5 \times 10^3 \angle 0°}{2.5 \times 10^3 \angle 90°} = \frac{8 \times 10^3 \angle 0°}{4 \times 10^3 \angle 90°}$$

$$2 \angle -90° = 2 \angle -90° \text{ (balanced)}✓$$

b. $\mathbf{Z}_1 = 5\text{ k}\Omega \angle 0°$, $\mathbf{Z}_2 = 8\text{ k}\Omega \angle 0°$
$\mathbf{Z}_3 = 2.5\text{ k}\Omega \angle 90°$, $\mathbf{Z}_4 = 4\text{ k}\Omega \angle 90°$
$\mathbf{Z}_5 = 5\text{ k}\Omega \angle -90°$, $\mathbf{Z}_6 = 1\text{ k}\Omega \angle 0°$



$$\mathbf{I}_1[\mathbf{Z}_1 + \mathbf{Z}_3 + \mathbf{Z}_6] - \mathbf{Z}_1\mathbf{I}_2 - \mathbf{Z}_3\mathbf{I}_3 = \mathbf{E}$$
$$\mathbf{I}_2[\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5] - \mathbf{Z}_1\mathbf{I}_1 - \mathbf{Z}_5\mathbf{I}_3 = 0$$
$$\mathbf{I}_3[\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5] - \mathbf{Z}_3\mathbf{I}_1 - \mathbf{Z}_5\mathbf{I}_2 = 0$$

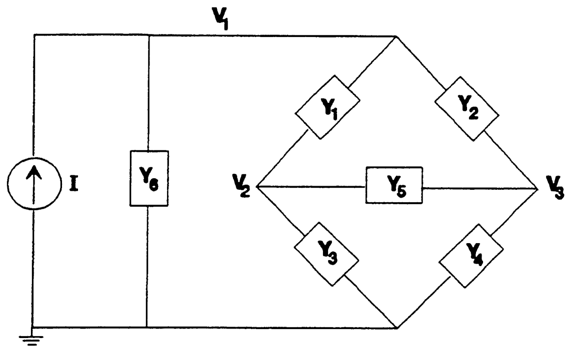
$$\begin{aligned}
&[\mathbf{Z}_1 + \mathbf{Z}_3 + \mathbf{Z}_6]\mathbf{I}_1 && - \mathbf{Z}_1\mathbf{I}_2 && - \mathbf{Z}_3\mathbf{I}_3 = \mathbf{E}\\
&-\mathbf{Z}_1\mathbf{I}_1 && + [\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5]\mathbf{I}_2 && - \mathbf{Z}_5\mathbf{I}_3 = 0\\
&-\mathbf{Z}_3\mathbf{I}_1 && - \mathbf{Z}_5\mathbf{I}_2 && + [\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5]\mathbf{I}_3 = 0
\end{aligned}$$

$$\mathbf{I}_2 = \frac{\mathbf{E}[\mathbf{Z}_1(\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5) + \mathbf{Z}_3\mathbf{Z}_5]}{\mathbf{Z}_\Delta = (\mathbf{Z}_1 + \mathbf{Z}_3 + \mathbf{Z}_6)[(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5)(\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5) - \mathbf{Z}_5^2] - \mathbf{Z}_1[\mathbf{Z}_1(\mathbf{Z}_3 + \mathbf{Z}_4 + \mathbf{Z}_5) - \mathbf{Z}_3\mathbf{Z}_5] - \mathbf{Z}_3[\mathbf{Z}_1\mathbf{Z}_5 + \mathbf{Z}_3(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5)]}$$

$$\mathbf{I}_3 = \frac{\mathbf{E}[\mathbf{Z}_1\mathbf{Z}_5 + \mathbf{Z}_3(\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5)]}{\mathbf{Z}_\Delta}$$

$$\mathbf{I}_{Z_5} = \mathbf{I}_2 - \mathbf{I}_3 = \frac{\mathbf{E}[\mathbf{Z}_1\mathbf{Z}_4 - \mathbf{Z}_3\mathbf{Z}_2]}{\mathbf{Z}_\Delta} = \frac{\mathbf{E}[20 \times 10^6 \angle 90° - 20 \times 10^6 \angle 90°]}{\mathbf{Z}_\Delta} = \mathbf{0\ A}$$

c.



$$\mathbf{I} = \frac{\mathbf{E}_s}{\mathbf{R}_s} = \frac{10\text{ V } \angle 0°}{1\text{ k}\Omega \angle 0°} = 10\text{ mA } \angle 0°$$

$$\mathbf{Y}_1 = \frac{1}{5\text{ k}\Omega \angle 0°} = 0.2\text{ mS } \angle 0°$$

$$\mathbf{Y}_2 = \frac{1}{8\text{ k}\Omega \angle 0°} = 0.125\text{ mS } \angle 0°$$

$$\mathbf{Y}_3 = \frac{1}{2.5\text{ k}\Omega \angle 90°} = 0.4\text{ mS } \angle -90°$$

$$\mathbf{Y}_4 = \frac{1}{4\text{ k}\Omega \angle 90°} = 0.25\text{ mS } \angle -90°$$

$$\mathbf{Y}_5 = \frac{1}{5\text{ k}\Omega \angle -90°} = 0.2\text{ mS } \angle 90°$$

$$\mathbf{Y}_6 = \frac{1}{1\text{ k}\Omega \angle 0°} = 1\text{ mS } \angle 0°$$

$$\begin{aligned}
\mathbf{V}_1[\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_6] - \mathbf{Y}_1\mathbf{V}_2 - \mathbf{Y}_2\mathbf{V}_3 &= \mathbf{I}\\
\mathbf{V}_2[\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5] - \mathbf{Y}_1\mathbf{V}_1 - \mathbf{Y}_5\mathbf{V}_3 &= 0\\
\mathbf{V}_3[\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5] - \mathbf{Y}_2\mathbf{V}_1 - \mathbf{Y}_5\mathbf{V}_2 &= 0
\end{aligned}$$

$$\begin{array}{rrrl}
[\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_6]\mathbf{V}_1 & - \mathbf{Y}_1\mathbf{V}_2 & - \mathbf{Y}_2\mathbf{V}_3 & = \mathbf{I}\\
-\mathbf{Y}_1\mathbf{V}_1 & + [\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5]\mathbf{V}_2 & - \mathbf{Y}_5\mathbf{V}_3 & = 0\\
-\mathbf{Y}_2\mathbf{V}_1 & - \mathbf{Y}_5\mathbf{V}_2 & + [\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5]\mathbf{V}_3 & = 0
\end{array}$$

$$\mathbf{V}_2 = \frac{\mathbf{I}[\mathbf{Y}_1(\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5) + \mathbf{Y}_2\mathbf{Y}_5]}{\mathbf{Y}_\Delta = (\mathbf{Y}_1 + \mathbf{Y}_2 + \mathbf{Y}_6)[(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)(\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5) - \mathbf{Y}_5^2] - \mathbf{Y}_1[\mathbf{Y}_1(\mathbf{Y}_2 + \mathbf{Y}_4 + \mathbf{Y}_5) + \mathbf{Y}_2\mathbf{Y}_5] - \mathbf{Y}_2[\mathbf{Y}_1\mathbf{Y}_5 + \mathbf{Y}_2(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)]}$$

$$\mathbf{V}_3 = \frac{\mathbf{I}[(\mathbf{Y}_1\mathbf{Y}_5 + \mathbf{Y}_2(\mathbf{Y}_1 + \mathbf{Y}_3 + \mathbf{Y}_5)]}{\mathbf{Y}_\Delta}$$

$$\mathbf{V}_{Z_5} = \mathbf{V}_2 - \mathbf{V}_3 = \frac{\mathbf{I}[\mathbf{Y}_1\mathbf{Y}_4 - \mathbf{Y}_2\mathbf{Y}_3]}{\mathbf{Y}_\Delta} = \frac{\mathbf{I}[0.05 \times 10^{-3} \angle -90° - 0.05 \times 10^{-3} \angle -90°]}{\mathbf{Y}_\Delta}$$
$$= \mathbf{0\ V}$$

28. $\mathbf{Z}_1\mathbf{Z}_4 = \mathbf{Z}_3\mathbf{Z}_2$

$$(R_1 - jX_C)(R_x + jX_{L_x}) = R_3R_2 \qquad X_C = \frac{1}{\omega C} = \frac{1}{(10^3\text{ rad/s})(1\ \mu\text{F})} = 1\text{ k}\Omega$$

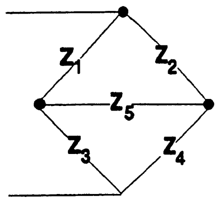
$$(1\text{ k}\Omega - j1\text{ k}\Omega)(R_x + jX_{L_x}) = (0.1\text{ k}\Omega)(0.1\text{ k}\Omega) = 10\text{ k}\Omega$$

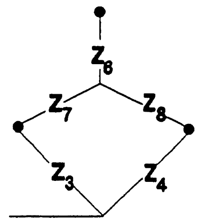
$$\text{and } R_x + jX_{L_x} = \frac{10 \times 10^3\ \Omega}{1 \times 10^3 - j1 \times 10^3} = \frac{10 \times 10^3}{1.414 \times 10^3 \angle -45°} = 5\ \Omega + j5\ \Omega$$

$$\therefore R_x = 5\ \Omega,\ L_x = \frac{X_{L_x}}{\omega} = \frac{5\ \Omega}{10^3\text{ rad/s}} = 5\text{ mH}$$

30. Apply Eq. **17.6.**

32. a.

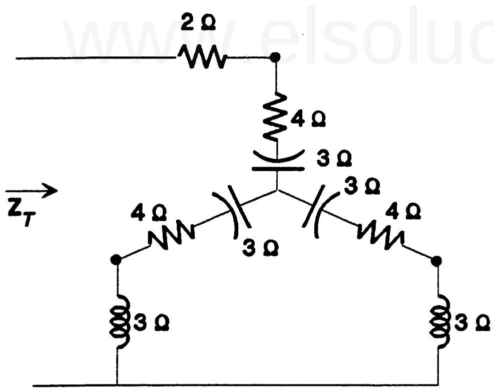




$\mathbf{Z}_1 = 8\ \Omega\ \angle -90° = -j8\ \Omega$
$\mathbf{Z}_2 = 4\ \Omega\ \angle 90° = +j4\ \Omega$
$\mathbf{Z}_3 = 8\ \Omega\ \angle 90° = +j8\ \Omega$
$\mathbf{Z}_4 = 6\ \Omega\ \angle -90° = -j6\ \Omega$
$\mathbf{Z}_5 = 5\ \Omega\ \angle 0°$

$$\mathbf{Z}_6 = \frac{\mathbf{Z}_1\mathbf{Z}_2}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5} = 5\ \Omega\ \angle 38.66°$$
$$\mathbf{Z}_7 = \frac{\mathbf{Z}_1\mathbf{Z}_5}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5} = 6.25\ \Omega\ \angle -51.34°$$
$$\mathbf{Z}_8 = \frac{\mathbf{Z}_2\mathbf{Z}_5}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_5} = 3.125\ \Omega\ \angle 128.66°$$
$$\mathbf{Z}' = \mathbf{Z}_7 + \mathbf{Z}_3 = 3.9\ \Omega + j3.12\ \Omega = 4.99\ \Omega\ \angle 38.66°$$
$$\mathbf{Z}'' = \mathbf{Z}_8 + \mathbf{Z}_4 = -1.95\ \Omega - j3.56\ \Omega = 4.06\ \Omega\ \angle -118.71°$$
$$\mathbf{Z}' \| \mathbf{Z}'' = 10.13\ \Omega\ \angle -67.33° = 3.90\ \Omega - j9.35\ \Omega$$
$$\mathbf{Z}_T = \mathbf{Z}_6 + \mathbf{Z}' \| \mathbf{Z}'' = 7.80\ \Omega - j6.23\ \Omega = 9.98\ \Omega\ \angle -38.61°$$
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{120\ \text{V}\ \angle 0°}{9.98\ \Omega\ \angle -38.61°} = \mathbf{12.02\ A\ \angle 38.61°}$$

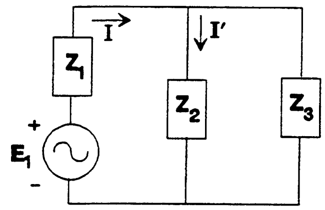
b. $$\mathbf{Z}_Y = \frac{\mathbf{Z}_\Delta}{3} = \frac{12\ \Omega - j9\ \Omega}{3} = 4\ \Omega - j3\ \Omega$$



$$\mathbf{Z}_T = 2\ \Omega + 4\ \Omega + j3\ \Omega + [4\ \Omega - j\cancel{3}\ \Omega + j\cancel{3}\ \Omega] \| [4\ \Omega - j\cancel{3}\ \Omega + j\cancel{3}\ \Omega]$$
$$= 6\ \Omega - j3\ \Omega + 2\ \Omega$$
$$= 8\ \Omega - j3\ \Omega = 8.544\ \Omega\ \angle -20.56°$$
$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{60\ \text{V}\ \angle 0°}{8.544\ \Omega\ \angle -20.56°} = \mathbf{7.02\ A\ \angle 20.56°}$$

CHAPTER 18 (Odd)

1. a.

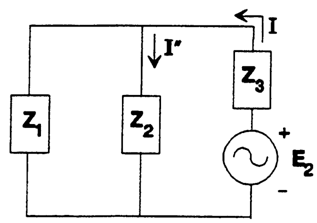


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°, \mathbf{Z}_2 = 8\ \Omega\ \angle 90°, \mathbf{Z}_3 = 6\ \Omega\ \angle -90°$

$\mathbf{Z}_2 \| \mathbf{Z}_3 = 8\ \Omega\ \angle 90° \| 6\ \Omega\ \angle -90° = 24\ \Omega\ \angle -90°$

$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2\|\mathbf{Z}_3} = \frac{30\text{ V } \angle 30°}{3\ \Omega - j24\ \Omega} = 1.24\text{ A } \angle 112.875°$$

$$\mathbf{I}' = \frac{\mathbf{Z}_3\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(6\ \Omega\ \angle -90°)(1.24\text{ A } \angle 112.875°)}{2\ \Omega\ \angle 90°} = 3.72\text{ A } \angle -67.125°$$



$\mathbf{Z}_1 \| \mathbf{Z}_2 = 3\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90° = 2.809\ \Omega\ \angle 20.556°$

$$\mathbf{I} = \frac{\mathbf{E}_2}{\mathbf{Z}_3 + \mathbf{Z}_1\|\mathbf{Z}_2} = \frac{60\text{ V } \angle 10°}{-j6\ \Omega + 2.630\ \Omega + j0.986\ \Omega}$$

$= 10.597\text{ A } \angle 72.322°$

$$\mathbf{I}'' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(3\ \Omega\ \angle 0°)(10.597\text{ A } \angle 72.322°)}{3\ \Omega + j8\ \Omega} = 3.721\text{ A } \angle 2.878°$$

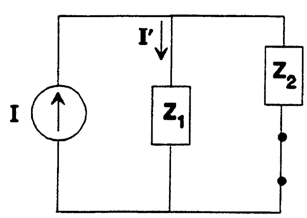
$\mathbf{I}_{L_1} = \mathbf{I}' + \mathbf{I}'' = 3.72\text{ A } \angle -67.125° + 3.721\text{ A } \angle 2.878°$

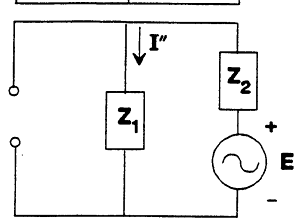
$= 1.446\text{ A} - j3.427\text{ A} + 3.716\text{ A} + j0.187\text{ A}$

$= 5.162\text{ A} - j3.24\text{ A}$

$= \mathbf{6.095\text{ A } \angle -32.115°}$

b.





$\mathbf{Z}_1 = 8\ \Omega\ \angle 90°, \mathbf{Z}_2 = 5\ \Omega\ \angle -90°$

$\mathbf{I} = 0.3\text{ A } \angle 60°, \mathbf{E} = 10\text{ V } \angle 0°$

$$\mathbf{I}' = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(5\ \Omega\ \angle -90°)(0.3\text{ A } \angle 60°)}{+j8\ \Omega - j5\ \Omega}$$

$= 0.5\text{A } \angle -120°$

$$\mathbf{I}'' = \frac{\mathbf{E}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{10\text{ V } \angle 0°}{3\ \Omega\ \angle 90°} = 3.33\text{ A } \angle -90°$$

$\mathbf{I}_{Z_1} = \mathbf{I}_{L_1} = \mathbf{I}' + \mathbf{I}''$

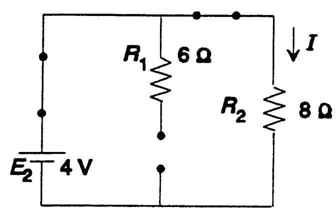
$= 0.5\text{ A } \angle -120° + 3.33\text{ A } \angle -90°$

$= -0.25\text{ A} - j0.433\text{ A} - j3.33\text{ A}$

$= -0.25\text{ A} - j3.763\text{ A}$

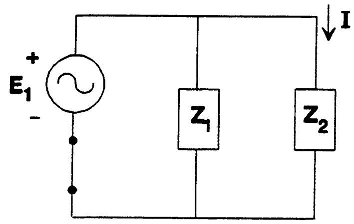
$= \mathbf{3.77\text{ A } \angle -93.8°}$

3. DC:



$$I_{DC} = \frac{4\ \text{V}}{8\ \Omega} = 0.5\ \text{A}$$

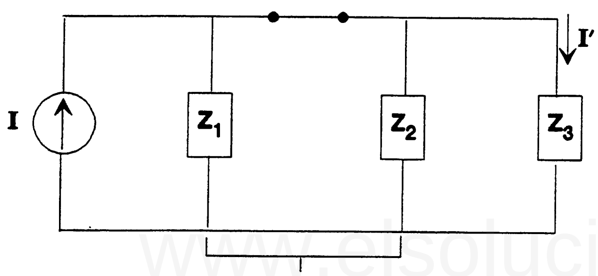
AC:



$$\mathbf{Z}_2 = R_2 + jX_L = 8\ \Omega + j4\ \Omega$$
$$= 8.944\ \Omega\ \angle 26.565^\circ$$
$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10\ \text{V}\ \angle 0^\circ}{8.944\ \Omega\ \angle 26.565^\circ}$$
$$= 1.118\ \text{A}\ \angle -26.565^\circ$$

$$\mathbf{I} = \mathbf{0.5\ A + 1.118\ A\ \angle -26.565^\circ}$$
$$\boldsymbol{i = 0.5\ \text{A} + 1.581\ \sin(\omega t - 26.565^\circ)}$$

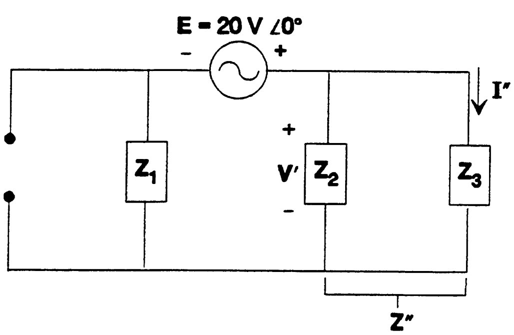
5.



$\mathbf{E} = 20\ \text{V}\ \angle 0^\circ$
$\mathbf{Z}_1 = 10\ \text{k}\Omega\ \angle 0^\circ$
$\mathbf{Z}_2 = 5\ \text{k}\Omega - j5\ \text{k}\Omega$
$= 7.071\ \text{k}\Omega\ \angle -45^\circ$
$\mathbf{Z}_3 = 5\ \text{k}\Omega\ \angle 90^\circ$
$\mathbf{I} = 5\ \text{mA}\ \angle 0^\circ$

$$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = 10\ \text{k}\Omega\ \angle 0^\circ \| 7.071\ \text{k}\Omega\ \angle -45^\circ = 4.472\ \text{k}\Omega\ \angle -26.57^\circ$$

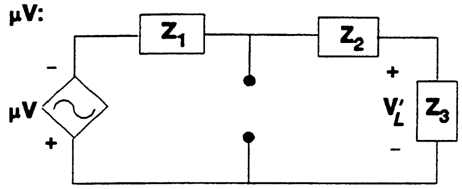
(CDR) $$\mathbf{I}' = \frac{\mathbf{Z}'\mathbf{I}}{\mathbf{Z}' + \mathbf{Z}_3} = \frac{(4.472\ \text{k}\Omega\ \angle -26.57^\circ)(5\ \text{mA}\ \angle 0^\circ)}{4\ \text{k}\Omega - j2\ \text{k}\Omega + j5\ \text{k}\Omega} = \frac{22.36\ \text{mA}\ \angle -26.57^\circ}{5\ \angle 36.87^\circ}$$
$$= 4.472\ \text{mA}\ \angle -63.44^\circ$$



$$\mathbf{Z}'' = \mathbf{Z}_2 \| \mathbf{Z}_3$$
$$= 7.071\ \text{k}\Omega\ \angle -45^\circ \| 5\ \text{k}\Omega\ \angle 90^\circ$$
$$= 7.071\ \text{k}\Omega\ \angle 45^\circ$$

(VDR) $$\mathbf{V}' = \frac{\mathbf{Z}''\mathbf{E}}{\mathbf{Z}'' + \mathbf{Z}_1} = \frac{(7.071\ \text{k}\Omega\ \angle 45^\circ)(20\ \text{V}\ \angle 0^\circ)}{(5\ \text{k}\Omega + j5\ \text{k}\Omega) + (10\ \text{k}\Omega)} = \frac{141.42\ \text{V}\ \angle 45^\circ}{15.81\ \angle 18.435^\circ}$$
$$= 8.945\ \text{V}\ \angle 26.565^\circ$$
$$\mathbf{I}'' = \frac{\mathbf{V}'}{\mathbf{Z}_3} = \frac{8.945\ \text{V}\ \angle 26.565^\circ}{5\ \text{k}\Omega\ \angle 90^\circ} = 1.789\ \text{mA}\ \angle -63.435^\circ = 0.8\ \text{mA} - j1.6\ \text{mA}$$
$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = (2\ \text{mA} - j4\ \text{mA}) + (0.8\ \text{mA} - j1.6\ \text{mA}) = 2.8\ \text{mA} - j5.6\ \text{mA}$$
$$= \mathbf{6.261\ mA\ \angle -63.43^\circ}$$

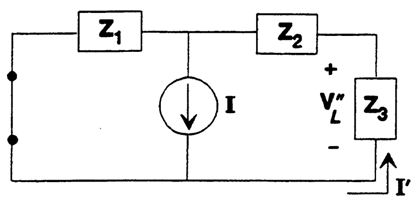
7. μV:



$\mathbf{Z}_1 = 5\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 1\text{ k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle 0°$
$\mathbf{V} = 2\text{ V}\ \angle 0°$, $\mu = 20$

$$\mathbf{V}'_L = \frac{-\mathbf{Z}_3(\mu\mathbf{V})}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{-(4\text{ k}\Omega\ \angle 0°)(20)(2\text{ V}\ \angle 0°)}{5\text{ k}\Omega - j1\text{ k}\Omega + 4\text{ k}\Omega} = -17.67\text{ V}\ \angle 6.34°$$

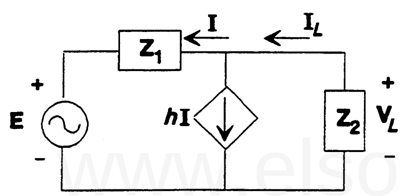
I:



$$\text{CDR: } \mathbf{I}' = \frac{\mathbf{Z}_1\mathbf{I}}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(5\text{ k}\Omega\ \angle 0°)(2\text{ mA}\ \angle 0°)}{9.056\text{ k}\Omega\ \angle -6.34°} = 1.104\text{ mA}\ \angle 6.34°$$

$$\mathbf{V}''_L = -\mathbf{I}'\mathbf{Z}_3 = -(1.104\text{ mA}\ \angle 6.34°)(4\text{ k}\Omega\ \angle 0°) = -4.416\text{ V}\ \angle 6.34°$$
$$\mathbf{V}_L = \mathbf{V}'_L + \mathbf{V}''_L = -17.67\text{ V}\ \angle 6.34° - 4.416\text{ V}\ \angle 6.34° = \mathbf{-22.09\text{ V}\ \angle 6.34°}$$

9.



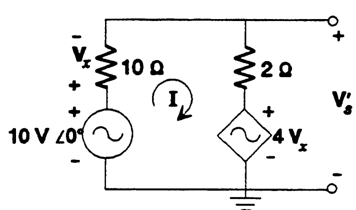
$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 2\text{ k}\Omega\ \angle 0°$
$\mathbf{V}_L = -\mathbf{I}_L\mathbf{Z}_2$
$\mathbf{I}_L = h\mathbf{I} + \mathbf{I} = (h+1)\mathbf{I}$
$\mathbf{V}_L = -(h+1)\mathbf{I}\mathbf{Z}_2$
and by KVL: $\mathbf{V}_L = \mathbf{I}\mathbf{Z}_1 + \mathbf{E}$
so that $\mathbf{I} = \dfrac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}$

$$\mathbf{V}_L = -(h+1)\mathbf{I}\mathbf{Z}_2 = -(h+1)\left[\frac{\mathbf{V}_L - \mathbf{E}}{\mathbf{Z}_1}\right]\mathbf{Z}_2$$

Subt. for $\mathbf{Z}_1$, $\mathbf{Z}_2$

$$\mathbf{V}_L = -(h+1)(\mathbf{V}_L - \mathbf{E})$$
$$\mathbf{V}_L(2+h) = \mathbf{E}(h+1)$$
$$\mathbf{V}_L = \frac{(h+1)}{(h+2)}\mathbf{E} = \frac{51}{52}(20\text{ V}\ \angle 53°) = \mathbf{19.62\text{ V}\ \angle 53°}$$

11. $\mathbf{E}_1$:

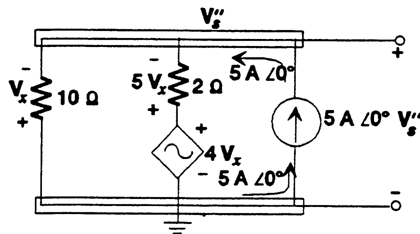


$$10\text{ V}\ \angle 0° - \mathbf{I}\ 10\ \Omega - \mathbf{I}\ 2\ \Omega - 4\ \mathbf{V}_x = 0$$
with $\mathbf{V}_x = \mathbf{I}\ 10\ \Omega$

Solving for **I**:

$$\mathbf{I} = \frac{10\text{ V}\ \angle 0°}{52\ \Omega} = 192.31\text{ mA}\ \angle 0°$$
$$\mathbf{V}'_s = 10\text{ V}\ \angle 0° - \mathbf{I}(10\ \Omega) = 10\text{ V} - (192.31\text{ mA}\ \angle 0°)(10\ \Omega\ \angle 0°) = 8.08\text{ V}\ \angle 0°$$

I:



$$\Sigma \mathbf{I}_i = \Sigma \mathbf{I}_o$$

$$5 \text{ A } \angle 0° + \frac{\mathbf{V}_x}{10\ \Omega} + \frac{5\ \mathbf{V}_x}{2\ \Omega} = 0$$

$$5 \text{ A} + 0.1\ \mathbf{V}_x + 2.5\ \mathbf{V}_x = 0$$

$$2.6\ \mathbf{V}_x = -5 \text{ A}$$

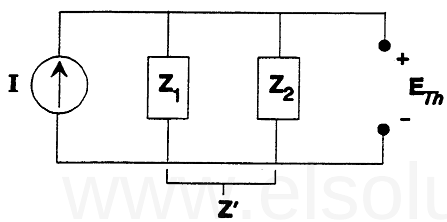
$$\mathbf{V}_x = -\frac{5}{2.6}\text{V} = -1.923 \text{ V}$$

$\mathbf{V}_s'' = -\mathbf{V}_x = -(-1.923 \text{ V}) = 1.923 \text{ V } \angle 0°$

$\mathbf{V}_s = \mathbf{V}_s' + \mathbf{V}_s'' = 8.08 \text{ V } \angle 0° + 1.923 \text{ V } \angle 0° = \mathbf{10\ V\ \angle 0°}$

13. a. From #27. $\mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2$

$\mathbf{Z}_{Th} = \mathbf{Z}_N = \mathbf{21.312\ \Omega\ \angle 32.196°}$

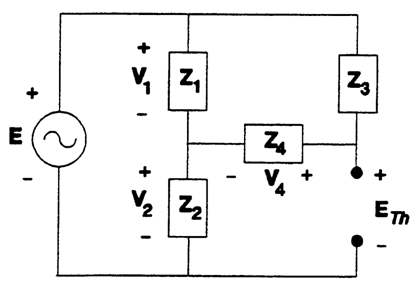


$\mathbf{E}_{Th} = \mathbf{IZ}' = \mathbf{IZ}_{Th}$

$= (0.1 \text{ A } \angle 0°)(21.312\ \Omega\ \angle 32.196°)$

$= \mathbf{2.131\ V \angle 32.196°}$

b. From #27. $\mathbf{Z}_{Th} = \mathbf{Z}_N = \mathbf{6.813\ \Omega\ \angle -54.228°} = 3.983\ \Omega - j5.528\ \Omega$



$\mathbf{Z}_1 = 2\ \Omega\ \angle 0°$, $\mathbf{Z}_3 = 8\ \Omega \angle -90°$

$\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_4 = 10\ \Omega\ \angle 0°$

$\mathbf{E} = 50 \text{ V } \angle 0°$

$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4$

$$\mathbf{V}_2 = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1 \| (\mathbf{Z}_3 + \mathbf{Z}_4)}$$

$$= \frac{(4\ \Omega\ \angle 90°)(50 \text{ V } \angle 0°)}{+j4\ \Omega + 2\ \Omega\ \angle 0° \| (10\ \Omega - j8\ \Omega)}$$

$$= 47.248 \text{ V } \angle 24.7°$$

$\mathbf{V}_1 = \mathbf{E} - \mathbf{V}_2 = 50 \text{ V } \angle 0° - 47.248 \text{ V } \angle 24.7° = 20.972 \text{ V } \angle -70.285°$

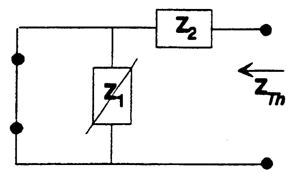
$$\mathbf{V}_4 = \frac{\mathbf{Z}_4\mathbf{V}_1}{\mathbf{Z}_4 + \mathbf{Z}_3} = \frac{(10\ \Omega\ \angle 0°)(20.972 \text{ V } \angle -70.285°)}{10\ \Omega - j8\ \Omega} = 16.377 \text{ V } \angle -31.625°$$

$\mathbf{E}_{Th} = \mathbf{V}_2 + \mathbf{V}_4 = 47.248 \text{ V } \angle 24.7° + 16.377 \text{ V } \angle -31.625°$

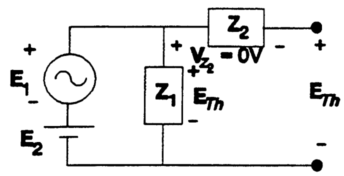
$= (42.925 \text{ V} + j19.743 \text{ V}) + (13.945 \text{ V} - j8.587 \text{ V})$

$= 56.870 \text{ V} + j11.156 \text{ V} = \mathbf{57.954\ V\ \angle 11.099°}$

15. a.



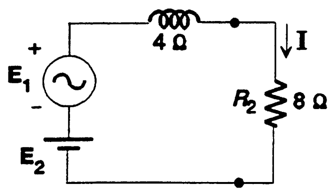
$Z_1 = 6\ \Omega - j2\ \Omega = 6.325\ \Omega\ \angle -18.435°$
$Z_2 = 4\ \Omega\ \angle 90°$
$\mathbf{Z_{Th} = Z_2 = 4\ \Omega\ \angle 90°}$



By inspection:

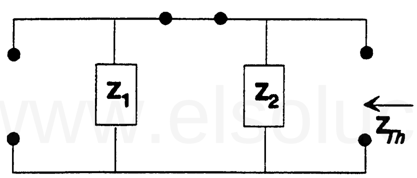
$E_{Th} = E_2 + E_1$
$= 4\ \underset{DC}{V} + 10\ \underset{AC}{V}\ \angle 0°$

b.



$$I = \frac{E_2}{R_2} + \frac{E_1}{R_2 + jX_L}$$
$$= \frac{4\ V}{8\ \Omega} + \frac{10\ V\ \angle 0°}{8\ \Omega + j4\ \Omega}$$
$$= 0.5\ A + \frac{10\ V\ \angle 0°}{8.944\ \Omega\ \angle 26.565°}$$
$$= \underset{(dc)}{0.5\ A} + \underset{(ac)}{1.118\ A\ \angle -26.565°}$$

17. a. Z_{Th}:

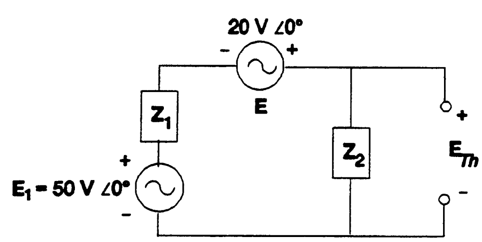


$Z_1 = 10\ k\Omega\ \angle 0°$
$Z_2 = 5\ k\Omega - j5\ k\Omega$
$= 7.071\ k\Omega\ \angle -45°$

$Z_{Th} = Z_1 \| Z_2 = (10\ k\Omega\ \angle 0°) \| (7.071\ k\Omega \angle -45°) = \mathbf{4.472\ k\Omega\ \angle -26.565°}$

Source conversion:

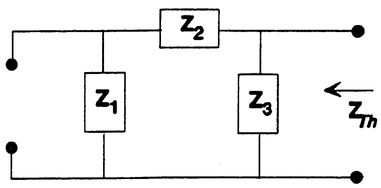
$E_1 = (I \angle \theta)(R_1 \angle 0°) = (5\ mA\ \angle 0°)(10\ k\Omega\ \angle 0°) = 50\ V\ \angle 0°$



$$E_{Th} = \frac{Z_2(E + E_1)}{Z_2 + Z_1}$$
$$= \frac{(7.071\ k\Omega\ \angle -45°)(20\ V\ \angle 0° + 50\ V\ \angle 0°)}{(5\ k\Omega - j5\ k\Omega) + (10\ k\Omega)}$$
$$= \frac{(7.071\ k\Omega\ \angle -45°)(70\ V\ \angle 0°)}{(15\ k\Omega - j5\ k\Omega)}$$
$$= \frac{494.97\ V\ \angle -45°}{15.811\ \angle -18.435°}$$
$$= \mathbf{31.31\ V\ \angle -26.565°}$$

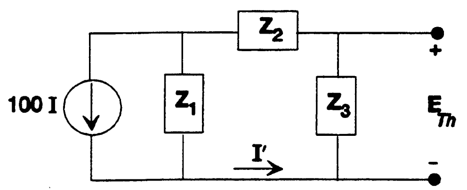
b.
$$I = \frac{E_{Th}}{Z_{Th} + Z_L} = \frac{31.31\ V\ \angle -26.565°}{4.472\ k\Omega\ \angle -26.565° + 5\ k\Omega\ \angle 90°}$$
$$= \frac{31.31\ V\ \angle -26.565°}{4\ k\Omega - j2\ k\Omega + j5\ k\Omega} = \frac{31.31\ V\ \angle -26.565°}{4\ k\Omega + j3\ k\Omega}$$
$$= \frac{31.31\ V\ \angle -26.565°}{5\ k\Omega\ \angle 36.87°} = \mathbf{6.26\ mA\ \angle 63.435°}$$

19. Z_{Th}:



$Z_1 = 40\ \text{k}\Omega\ \angle 0°$
$Z_2 = 0.2\ \text{k}\Omega\ \angle -90°$
$Z_3 = 5\ \text{k}\Omega\ \angle 0°$

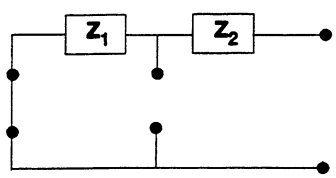
$$Z_{Th} = Z_3 \| (Z_1 + Z_2) = 5\ \text{k}\Omega\ \angle 0° \| (40\ \text{k}\Omega - j0.2\ \text{k}\Omega) = \mathbf{4.44\ k\Omega\ \angle -0.031°}$$



$$I' = \frac{Z_1(100\ I)}{Z_1 + Z_2 + Z_3} = \frac{(40\ \text{k}\Omega\ \angle 0°)(100\ I)}{45\ \text{k}\Omega\ \angle -0.255°} = 88.89\ I\ \angle 0.255°$$

$$E_{Th} = -I'Z_3 = -(88.89\ I\ \angle 0.255°)(5\ \text{k}\Omega\ \angle 0°) = \mathbf{-444.45 \times 10^3\ I\ \angle 0.255°}$$

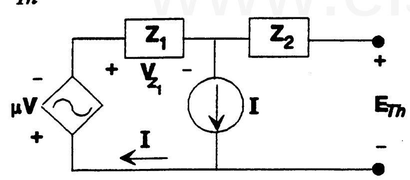
21. Z_{Th}:



$Z_1 = 5\ \text{k}\Omega\ \angle 0°$ $\quad$ $Z_2 = -j1\ \text{k}\Omega$

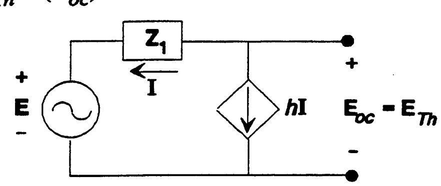
$$\leftarrow Z_{Th} = Z_1 + Z_2 = 5\ \text{k}\Omega - j1\ \text{k}\Omega = 5.099\ \text{k}\Omega\ \angle -11.31°$$

E_{Th}:



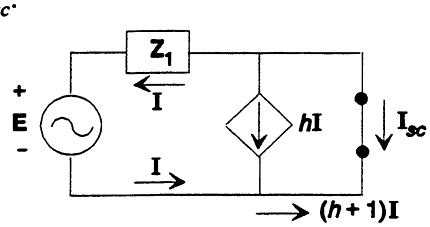
$$\begin{aligned} E_{Th} &= -[\mu V + V_{Z_1}] \\ &= -\mu V - IZ_1 \\ &= -(20)(2\ V\ \angle 0°) - (2\ \text{mA}\ \angle 0°)(5\ \text{k}\Omega\ \angle 0°) \\ &= \mathbf{-50\ V\ \angle 0°} \end{aligned}$$

23. E_{Th}: (E_{oc})



$hI = -I$ $\quad$ $Z_1 = 2\ \text{k}\Omega\ \angle 0°$
$\therefore$ $\quad I = 0$
and $\quad hI = 0$
with $\quad E_{oc} = E_{Th} = E = 20\ V\ \angle 53°$

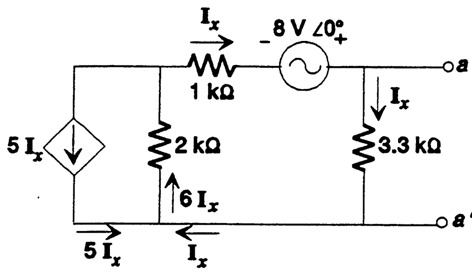
I_{sc}:



$$\begin{aligned} I_{sc} &= -(h + 1)I \\ &= -(h + 1)(10\ \text{mA}\ \angle 53°) \\ &= -510\ \text{mA}\ \angle 53° \end{aligned}$$

$$Z_{Th} = \frac{E_{oc}}{I_{sc}} = \frac{20\ V\ \angle 53°}{-510\ \text{mA}\ \angle 53°} = \mathbf{-39.215\ \Omega\ \angle 0°}$$

25. $\mathbf{E}_{oc}$:
($\mathbf{E}_{Th}$)

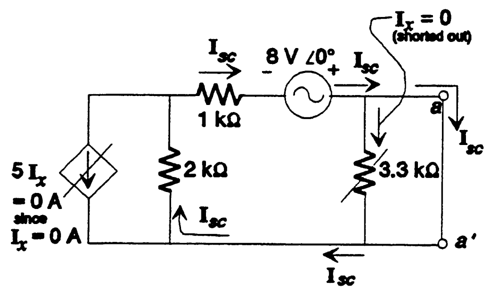


KVL: $-6\,\mathbf{I}_x(2\text{ k}\Omega) - \mathbf{I}_x(1\text{ k}\Omega) + 8\text{ V}\ \angle 0° - \mathbf{I}_x(3.3\text{ k}\Omega) = 0$

$$\mathbf{I}_x = \frac{8\text{ V}\ \angle 0°}{16.3\text{ k}\Omega} = 0.491\text{ mA}\ \angle 0°$$

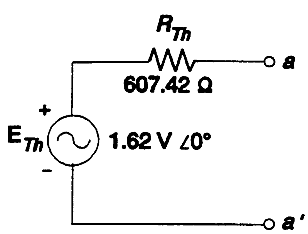
$$\mathbf{E}_{oc} = \mathbf{E}_{Th} = \mathbf{I}_x(3.3\text{ k}\Omega) = \mathbf{1.62\ V\ \angle 0°}$$

$\mathbf{I}_{sc}$:

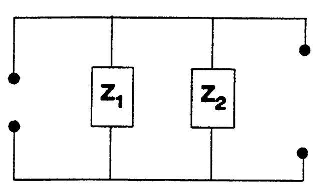


$$\mathbf{I}_{sc} = \frac{8\text{ V}}{3\text{ k}\Omega} = 2.667\text{ mA}\ \angle 0°$$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{1.62\text{ V}\ \angle 0°}{2.667\text{ mA}\ \angle 0°} = \mathbf{607.42\ \Omega}$$

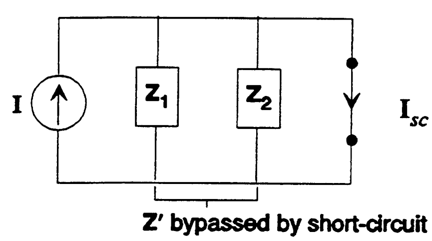


27. a.



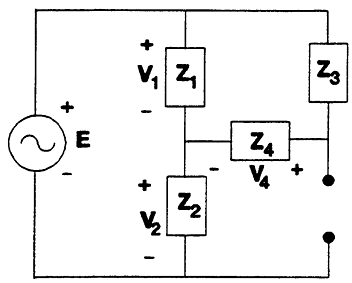
$\mathbf{Z}_1 = 20\ \Omega + j20\ \Omega = 28.284\ \Omega\ \angle 45°$
$\mathbf{Z}_2 = 68\ \Omega\ \angle 0°$

$\leftarrow \mathbf{Z}_N = \mathbf{Z}_1 \parallel \mathbf{Z}_2$
$= (28.284\ \Omega\ \angle 45°) \parallel (68\ \Omega\ \angle 0°)$
$= 21.312\ \Omega\ \angle 32.196°$



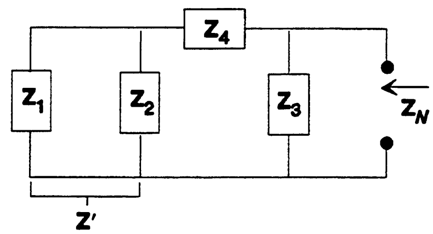
$\mathbf{I}_{sc} = \mathbf{I} = \mathbf{I}_N = 0.1\text{ A}\ \angle 0°$

b.

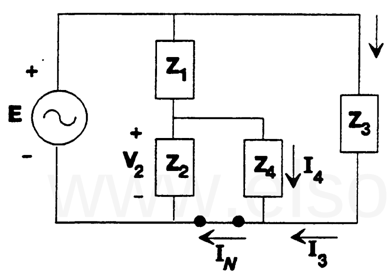


$Z_1 = 2\ \Omega\ \angle 0°$, $Z_2 = 4\ \Omega\ \angle 90°$
$Z_3 = 8\ \Omega\ \angle -90°$, $Z_4 = 10\ \Omega\ \angle 0°$
$E = 50\ V\ \angle 0°$

Z_N:



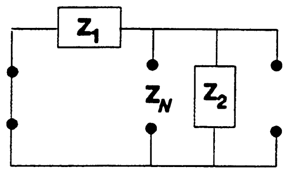
$$Z' = Z_1 \| Z_2 = 2\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90°$$
$$= 1.789\ \Omega\ \angle 26.565° = 1.6\ \Omega + j0.8\ \Omega$$
$$Z' + Z_4 = 1.6\ \Omega + j0.8\ \Omega + 10\ \Omega = 11.6\ \Omega + j0.8\ \Omega = 11.628\ \Omega\ \angle 3.945°$$
$$Z_N = Z_3 \| (Z' + Z_4) = (8\ \Omega\ \angle -90°) \| (11.628\ \Omega\ \angle 3.945°) = \mathbf{6.813\ \Omega\ \angle -54.228°}$$
$$= \mathbf{3.983\ \Omega - j5.528\ \Omega}$$



$$I_3 = \frac{E}{Z_3} = \frac{50\ V\ \angle 0°}{8\ \Omega\ \angle -90°} = 6.250\ A\ \angle 90°$$
$$Z' = Z_2 \| Z_4 = 4\ \Omega\ \angle 90° \| 10\ \Omega\ \angle 0°$$
$$= 3.714\ \Omega\ \angle 68.2°$$
$$V_2 = \frac{Z'E}{Z' + Z_1} = \frac{(3.714\ \Omega\ \angle 68.2°)(50\ V\ \angle 0°)}{1.378\ \Omega + j3.448\ \Omega + 2\ \Omega}$$
$$= \frac{185.7\ V\ \angle 68.2°}{4.827\ \angle 45.588°} = 38.471\ V\ \angle 22.612°$$

$$I_4 = \frac{V_2}{Z_4} = \frac{38.471\ V\ \angle 22.612°}{10\ \Omega\ \angle 0°} = 3.847\ A\ \angle 22.612°$$
$$I_N = I_3 + I_4 = 6.250\ A\ \angle 90° + 3.847\ A\ \angle 22.612°$$
$$= +j6.25\ A + 3.551\ A + j1.479\ A = 3.551\ A + j7.729\ A$$
$$= \mathbf{8.506\ A\ \angle 65.324°}$$

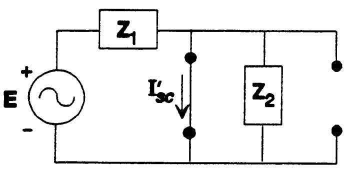
29. a. $\mathbf{Z}_N$:



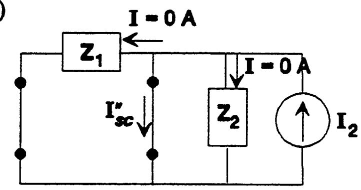
$\mathbf{E} = 20 \text{ V } \angle 0°,\ \mathbf{I}_2 = 0.4 \text{ A } \angle 20°$
$\mathbf{Z}_1 = 6\ \Omega + j8\ \Omega = 10\ \Omega \angle 53.13°$
$\mathbf{Z}_2 = 9\ \Omega - j12\ \Omega = 15\ \Omega \angle -53.13°$
$\mathbf{Z}_N = \mathbf{Z}_1 \| \mathbf{Z}_2 = (10\ \Omega \angle 53.13°) \| (15\ \Omega \angle -53.13°)$
$= \mathbf{9.66\ \Omega \angle 14.93°}$

$\mathbf{I}_N$:

(E)



($\mathbf{I}_2$)

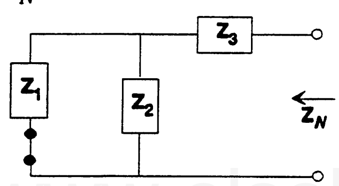


$\mathbf{I}'_{sc} = \mathbf{E}/\mathbf{Z}_1 = 20 \text{ V } \angle 0°/10\ \Omega \angle 53.13°$
$= 2 \text{ A } \angle -53.13°$

$\mathbf{I}''_{sc} = \mathbf{I}_2 = 0.4 \text{ A } \angle 20°$

$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 2\text{A } \angle -53.13° + 0.4 \text{ A } \angle 20°$
$= \mathbf{2.15\ A \angle -42.87°}$

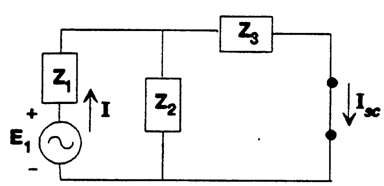
b. $\mathbf{Z}_N$:



$\mathbf{E}_1 = 120 \text{ V } \angle 30°,\ \mathbf{Z}_1 = 3\ \Omega \angle 0°$
$\mathbf{Z}_2 = 8\ \Omega - j8\ \Omega,\ \mathbf{Z}_3 = 4\ \Omega \angle 90°$

$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2$
$= 4\ \Omega \angle 90° + (3\ \Omega \angle 0°) \| (8\ \Omega - j8\ \Omega)$
$= \mathbf{4.37\ \Omega \angle 55.67° = 2.465\ \Omega + j3.61\ \Omega}$

$\mathbf{I}_N$:

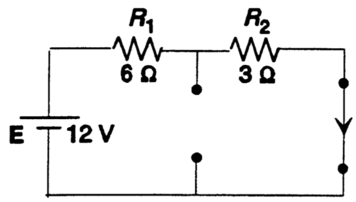


$$\mathbf{I} = \frac{\mathbf{E}_1}{\mathbf{Z}_T} = \frac{120 \text{ V } \angle 30°}{\mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3}$$
$$= \frac{120 \text{ V } \angle 30°}{3\ \Omega + (8\ \Omega - j8\ \Omega) \| 4\ \Omega \angle 90°}$$
$$= \frac{120 \text{ V } \angle 30°}{6.65\ \Omega \angle 46.22°}$$
$$= 18.05 \text{ A } \angle -16.22°$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2(\mathbf{I})}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(8\ \Omega - j8\ \Omega)(18.05 \text{ A } \angle -16.22°)}{8\ \Omega - j8\ \Omega + j4\ \Omega} = \mathbf{22.83\ A \angle -34.65°}$$

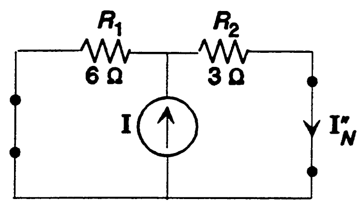
31. a. From #15 $\mathbf{Z}_N = \mathbf{Z}_{Th} = 9\ \Omega\ \angle 0°$

DC:



$$\mathbf{I}'_N = \frac{E}{R_T} = \frac{12\text{ V}}{9\ \Omega} = 1.333\text{ A}$$

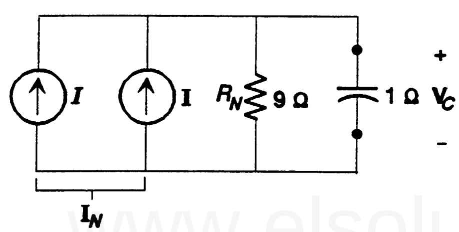
AC:



$$\mathbf{I}''_N = \frac{R_1\mathbf{I}}{R_1 + R_2} = \frac{(6\ \Omega\ \angle 0°)(4\text{ A}\ \angle 0°)}{9\ \Omega\ \angle 0°}$$
$$= \frac{24\text{ V}\ \angle 0°}{9\ \Omega\ \angle 0°} = 2.667\text{ A}\ \angle 0°$$

$\mathbf{I}_N = 1.333\text{ A} + 2.667\text{ A}\ \angle 0°$

b.

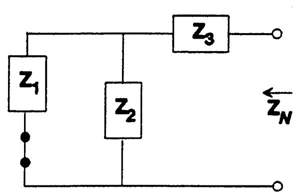


DC: $V_C = IR$
$= (1.333\text{ A})(9\ \Omega)$
$= 12\text{ V}$

AC: $\mathbf{Z}' = 9\ \Omega\ \angle 0° \| 1\ \Omega\ \angle -90°$
$= 0.994\ \Omega\ \angle -83.66°$

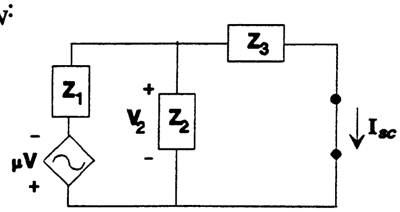
$$V_C = \mathbf{I}\mathbf{Z}' = (2.667\text{ A}\ \angle 0°)(0.994\ \Omega\ \angle -83.66°)$$
$$= 2.65\text{ V}\ \angle -83.66°$$
$$V_C = 12\text{ V} + 2.65\text{ V}\ \angle -83.66°$$

33. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = -j1\text{ k}\Omega$
$\mathbf{Z}_N = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega$
$= \mathbf{5.1\ k\Omega\ \angle -11.31°}$

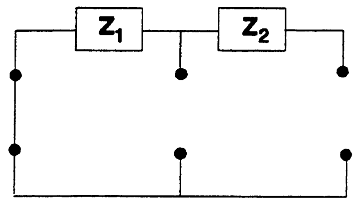
$\mathbf{I}_N$:



$$\mathbf{V}_2 = \frac{-(\mathbf{Z}_2 \| \mathbf{Z}_3)20\text{ V}}{(\mathbf{Z}_2 \| \mathbf{Z}_3) + \mathbf{Z}_1}$$
$$= \frac{-(0.995\text{ k}\Omega\ \angle -84.29°)(20\text{ V})}{0.1\text{ k}\Omega - j0.99\text{ k}\Omega + 10\text{ k}\Omega}$$
$$\mathbf{V}_2 = -1.961\text{ V}\ \angle -78.69°$$

$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{V}_2}{\mathbf{Z}_3} = \frac{-1.961\text{ V}\ \angle -78.69°}{1\text{ k}\Omega\ \angle -90°} = \mathbf{-1.961 \times 10^{-3}\ V\ \angle 11.31°}$$

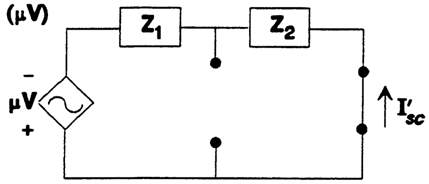
35. Z_N:



$Z_1 = 5\ \text{k}\Omega\ \angle 0°$, $Z_2 = 1\ \text{k}\Omega\ \angle -90°$

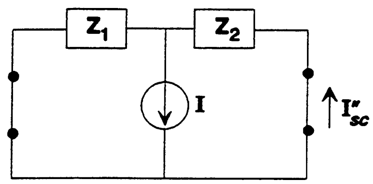
$\leftarrow Z_N = Z_1 + Z_2 = 5\ \text{k}\Omega - j1\ \text{k}\Omega$
$= 5.1\ \text{k}\Omega\ \angle -11.31°$

I_N: (μV)



$$I'_{sc} = \frac{\mu V}{Z_1 + Z_2} = \frac{(20)(2\ \text{V}\ \angle 0°)}{5.1\ \text{k}\Omega\ \angle -11.31°}$$
$$= 7.843\ \text{mA}\ \angle 11.31°$$

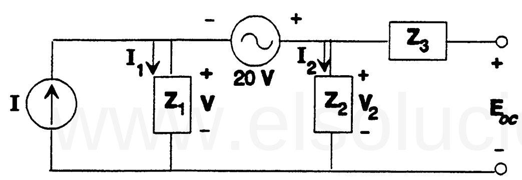
(I)



$$I''_{sc} = \frac{Z_1(I)}{Z_1 + Z_2}$$
$$= \frac{(5\ \text{k}\Omega\ \angle 0°)(2\ \text{mA}\ \angle 0°)}{5.1\ \text{k}\Omega\ \angle -11.31°}$$
$$= 1.96\ \text{mA}\ \angle 11.31°$$

$I_N = I'_{sc} + I''_{sc} = 7.843\ \text{mA}\ \angle 11.31° + 1.96\ \text{mA}\ \angle 11.31°$
$= \mathbf{9.81\ mA\ \angle 11.31°}$

37.



$Z_1 = 1\ \text{k}\Omega\ \angle 0°$
$Z_2 = 3\ \text{k}\Omega\ \angle 0°$
$Z_3 = 4\ \text{k}\Omega\ \angle 0°$

$$V_2 = 21\ V = E_{oc} \Rightarrow V = \frac{E_{oc}}{21}$$

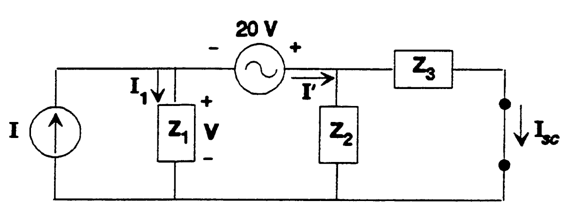
$$I = I_1 + I_2,\ I_1 = \frac{V}{Z_1} = \frac{E_{oc}}{21\ Z_1}$$

$$I_2 = \frac{E_{oc}}{Z_2},\quad I = I_1 + I_2 = \frac{E_{oc}}{21\ Z_1} + \frac{E_{oc}}{Z_2} = E_{oc}\left[\frac{1}{21\ Z_1} + \frac{1}{Z_2}\right]$$

$$I = E_{oc}\left[\frac{Z_2 + 21\ Z_1}{21\ Z_1 Z_2}\right]$$

and $$E_{oc} = \frac{21\ Z_1 Z_2 I}{Z_2 + 21\ Z_1} = \frac{(21)(1\ \text{k}\Omega\ \angle 0°)(3\ \text{k}\Omega\ \angle 0°)(2\ \text{mA}\ \angle 0°)}{3\ \text{k}\Omega + 21(1\ \text{k}\Omega\ \angle 0°)}$$

$E_{Th} = E_{oc} = 5.25\ \text{V}\ \angle 0°$



$$I_{sc} = \frac{V_3}{Z_3} = \frac{21\ V}{Z_3} \Rightarrow V = \frac{Z_3}{21} I_{sc}$$
$V = I_1 Z_1$
$I = I_1 + I'$

$$\mathbf{I}_{sc} = \frac{\mathbf{Z}_2\mathbf{I}'}{\mathbf{Z}_2 + \mathbf{Z}_3} \Rightarrow \mathbf{I}' = \left[\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

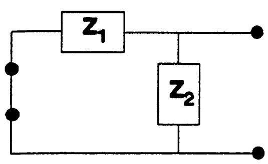
$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}' = \frac{\mathbf{V}}{\mathbf{Z}_1} + \left[\frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc} = \left[\frac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \frac{\mathbf{Z}_2 + \mathbf{Z}_3}{\mathbf{Z}_2}\right]\mathbf{I}_{sc}$$

$$\mathbf{I}_{sc} = \frac{\mathbf{I}}{\dfrac{\mathbf{Z}_3}{21\ \mathbf{Z}_1} + \dfrac{\mathbf{Z}_3 + \mathbf{Z}_2}{\mathbf{Z}_2}} = \frac{2\ \text{mA}\ \angle 0°}{\dfrac{4\ \text{k}\Omega}{21\ \text{k}\Omega} + \dfrac{7\ \text{k}\Omega}{3\ \text{k}\Omega}} = 0.792\ \text{mA}\ \angle 0°$$

$\therefore$ $\quad \mathbf{I}_N = \mathbf{0.792\ mA\ \angle 0°}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{5.25\ \text{V}\ \angle 0°}{0.792\ \text{mA}\ \angle 0°} = \mathbf{6.63\ k\Omega\ \angle 0°}$$

39. a.



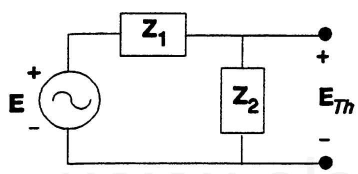
$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega$, $\mathbf{Z}_2 = -j6\ \Omega$

$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2$

$= 5\ \Omega\ \angle 53.13° \| 6\ \Omega\ \angle -9$

$= 8.32\ \Omega\ \angle -3.18°$

$\mathbf{Z}_L = 8.32\ \Omega\ \angle 3.18° = \mathbf{8.31\ \Omega - j0.462\ \Omega}$



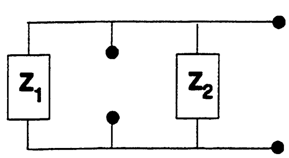
$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1}$$

$$= \frac{(6\ \Omega\ \angle -90°)(120\ \text{V}\ \angle 0°)}{3.61\ \Omega\ \angle -33.69°}$$

$= \mathbf{199.45\ V\ \angle -56.31°}$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(199.45\ \text{V})^2}{4(8.31\ \Omega)} = \mathbf{1198.2\ W}$$

b.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$

$\mathbf{Z}_2 = 2\ \Omega\ \angle 0°$

$\leftarrow \mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2$

$= 5\ \Omega\ \angle 53.13° \| 2\ \Omega\ \angle 0°$

$$= \frac{10\ \Omega\ \angle 53.13°}{2 + 3 + j4}$$

$$= \frac{10\ \Omega\ \angle 53.13°}{5 + j4}$$

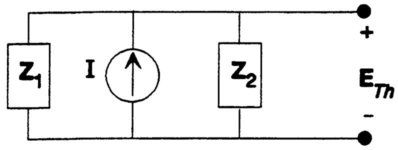
$$= \frac{10\ \Omega\ \angle 53.13°}{6.403\ \angle 38.66°}$$

$= \mathbf{1.562\ \Omega\ \angle 14.47°}$

$\mathbf{Z}_{Th} = 1.562\ \Omega\ \angle 14.47°$

$= 1.512\ \Omega + j0.39\ \Omega$

$\mathbf{Z}_L = \mathbf{1.512\ \Omega - j0.39\ \Omega}$



$\mathbf{E}_{Th} = \mathbf{I}(\mathbf{Z}_1 \| \mathbf{Z}_2)$

$= (2\ \text{A}\ \angle 30°)(1.562\ \Omega\ \angle 14.47°)$

$= \mathbf{3.124\ V\ \angle 44.47°}$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3.124\ \text{V})^2}{4(1.512\ \Omega)} = \mathbf{1.614\ W}$$

41. $\mathbf{I} = \dfrac{E\angle 0°}{R_1\angle 0°} = \dfrac{1\text{ V }\angle 0°}{1\text{ k}\Omega\ \angle 0°} = 1\text{ mA }\angle 0°$

$\mathbf{Z}_{Th} = 40\text{ k}\Omega\ \angle 0°$

$\mathbf{E}_{Th} = (50\ \mathbf{I})(40\text{ k}\Omega\ \angle 0°) = (50)(1\text{ mA }\angle 0°)(40\text{ k}\Omega\ \angle 0°) = 2000\text{ V }\angle 0°$

$P_{max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(2\text{ kV})^2}{4(40\text{ k}\Omega)} = \mathbf{25\ W}$

43. From #16, $\mathbf{Z}_{Th} = 9\ \Omega$, $\mathbf{E}_{Th} = 12\text{ V} + 24\text{ V }\angle 0°$

a. $\therefore Z_L = 9\ \Omega$

b. $P_{max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(12\text{ V})^2}{4(9\ \Omega)} + \dfrac{(24\text{ V})^2}{4(9\ \Omega)} = 4\text{ W} + 16\text{ W} = \mathbf{20\ W}$

or $E_{Th} = \sqrt{V_0^2 + {V_{1_{eff}}}^2} = 26.833\text{ V}$

and $P_{max} = \dfrac{E_{Th}^2}{4R_{Th}} = \dfrac{(26.833\text{ V})^2}{4(9\ \Omega)} = \mathbf{20\ W}$

45. a. $\mathbf{Z}_{Th} = 2\text{ k}\Omega\ \angle 0° \parallel 2\text{ k}\Omega\ \angle -90° = 1\text{ k}\Omega - j1\text{ k}\Omega$

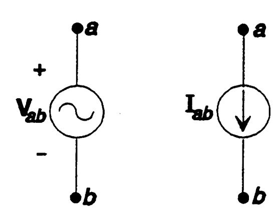
$$R_L = \sqrt{R_{Th}^2 + (X_{Th} + X_{Load})^2}$$
$$= \sqrt{(1\text{ k}\Omega)^2 + (-1\text{ k}\Omega + 2\text{ k}\Omega)^2}$$
$$= \sqrt{(1\text{ k}\Omega)^2 + (1\text{ k}\Omega)^2}$$
$$= \mathbf{1.414\ k\Omega}$$

b. $R_{av} = (R_{Th} + R_{Load})/2 = (1\text{ k}\Omega + 1.414\text{ k}\Omega)/2 = 1.207\text{ k}\Omega$

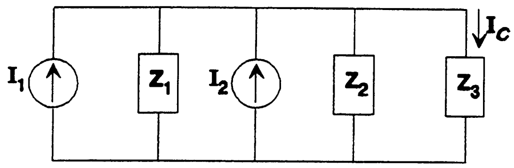
$P_{max} = \dfrac{E_{Th}^2}{4R_{av}} = \dfrac{(50\text{ V})^2}{4(1.207\text{ k}\Omega)} = \mathbf{0.518\ W}$

47. $\mathbf{I}_{ab} = \dfrac{(4\text{ k}\Omega\ \angle 0°)(4\text{ mA }\angle 0°)}{4\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{1.333\ mA\ \angle 0°}$

$\mathbf{V}_{ab} = (\mathbf{I}_{ab})(8\text{ k}\Omega\ \angle 0°) = \mathbf{10.67\ V\ \angle 0°}$



49.



$\mathbf{I}_1 = \dfrac{100\text{ V }\angle 0°}{2\text{ k}\Omega\ \angle 0°} = 50\text{ mA }\angle 0°$

$\mathbf{I}_2 = \dfrac{50\text{ V }\angle 0°}{4\text{ k}\Omega\ \angle 90°}$

$= 12.5\text{ mA }\angle -90°$

$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$

$\mathbf{Z}_2 = 4\text{ k}\Omega\ \angle 90°$

$\mathbf{Z}_3 = 4\text{ k}\Omega\ \angle -90°$

$\mathbf{I}_T = \mathbf{I}_1 - \mathbf{I}_2 = (50\text{ mA }\angle 0° - 12.5\text{ mA }\angle -90°) = 50\text{ mA} + j12.5\text{ mA}$

$= 51.54\text{ mA }\angle 14.04°$

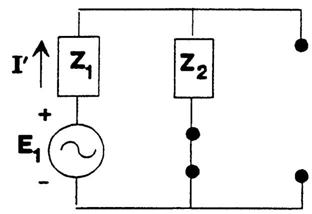
$\mathbf{Z}' = \mathbf{Z}_1 \| \mathbf{Z}_2 = (2\text{ k}\Omega\ \angle 0°) \| (4\text{ k}\Omega\ \angle 90°) = 1.79\text{ k}\Omega\ \angle 26.57°$

$\mathbf{I}_C = \dfrac{\mathbf{Z}'\mathbf{I}_T}{\mathbf{Z}' + \mathbf{Z}_3} = \dfrac{(1.79\text{ k}\Omega\ \angle 26.57°)(51.54\text{ mA }\angle 14.04°)}{1.6\text{ k}\Omega + j0.8\text{ k}\Omega - j4\text{ k}\Omega}$

$= \mathbf{25.77\text{ mA }\angle 104.04°}$

CHAPTER 18 (Even)

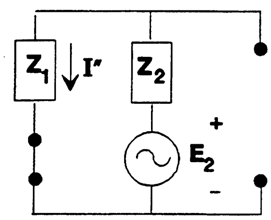
2. a. $\mathbf{E}_1$:



$\mathbf{E}_1 = 20\text{ V}\angle 0°,\quad \mathbf{Z}_1 = 4\ \Omega + j3\ \Omega = 5\ \Omega\angle 36.87°$
$\mathbf{Z}_2 = 1\ \Omega\angle 0°$

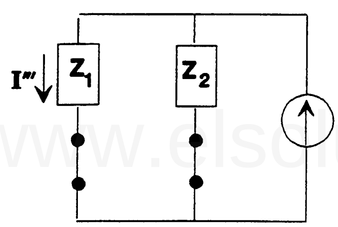
$$\mathbf{I}' = \frac{\mathbf{E}_1}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{20\text{ V}\angle 0°}{4\ \Omega + j3\ \Omega + 1\ \Omega} = 3.43\text{ A}\angle -30.96°$$

$\mathbf{E}_2$:



$$\mathbf{I}'' = \frac{\mathbf{E}_2}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{120\text{ V}\angle 0°}{5.83\ \Omega\angle 30.96°} = 20.58\text{ A}\angle -30.96°$$

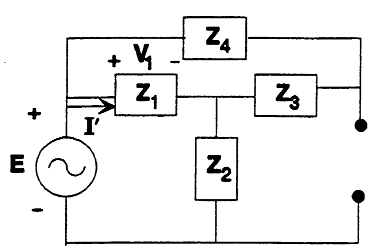
I:



$$\mathbf{I}''' = \frac{\mathbf{Z}_2\mathbf{I}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(1\ \Omega\angle 0°)(0.5\text{ A}\angle 60°)}{5.83\ \Omega\angle 30.96°} = 0.0858\text{ A}\angle 29.04°$$

$\uparrow\mathbf{I}_L = \mathbf{I}' - \mathbf{I}'' - \mathbf{I}'''$
$= (3.43\text{ A}\angle -30.96°) - (20.58\text{ A}\angle -30.96°) - (0.0858\text{ A}\angle 29.04°)$
$= \mathbf{17.20\text{ A}\angle 149.30°}$ or $\mathbf{17.20\text{ A}\angle -30.70°}\downarrow$

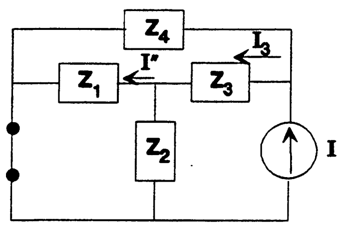
b. **E**:



$\mathbf{Z}_1 = 3\ \Omega\angle 90°,\ \mathbf{Z}_2 = 7\ \Omega\angle -90°$
$\mathbf{E} = 10\text{ V}\angle 90°$
$\mathbf{Z}_3 = 6\ \Omega\angle -90°,\ \mathbf{Z}_4 = 4\ \Omega\angle 0°$
$\mathbf{Z}' = \mathbf{Z}_1 \| (\mathbf{Z}_3 + \mathbf{Z}_4)$
$= 3\ \Omega\angle 90° \| (4\ \Omega - j6\ \Omega)$
$= 3\ \Omega\angle 90° \| 7.21\ \Omega\angle -56.31°$
$= 4.33\ \Omega\angle 70.56°$

$$\mathbf{V}_1 = \frac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_2}$$
$$= \frac{(4.33\ \Omega\ \angle 70.56°)(10\ \text{V}\ \angle 90°)}{(1.44\ \Omega + j4.08\ \Omega) - j7\Omega}$$
$$= \frac{43.3\ \text{V}\ \angle 160.56°}{3.26\ \angle -63.75°} = 13.28\ \text{V}\ \angle 224.31°$$
$$\mathbf{I}' = \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{13.28\ \text{V}\ \angle 224.31°}{3\ \Omega\ \angle 90°}$$
$$= 4.43\ \text{A}\ \angle 134.31°$$

I:

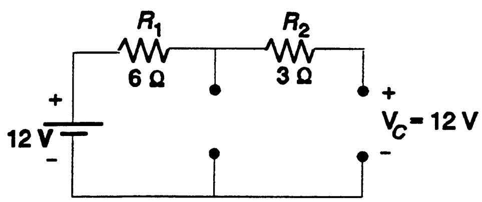


$$\mathbf{Z}'' = \mathbf{Z}_3 + \mathbf{Z}_1 \parallel \mathbf{Z}_2$$
$$= -j6\ \Omega + 3\ \Omega\ \angle 90° \parallel 7\ \Omega\ \angle -90°$$
$$= -j6\ \Omega + 5.25\ \Omega\ \angle 90°$$
$$= -j6\ \Omega + j5.25\ \Omega$$
$$= -j0.75\ \Omega = 0.75\ \Omega \angle -90°$$

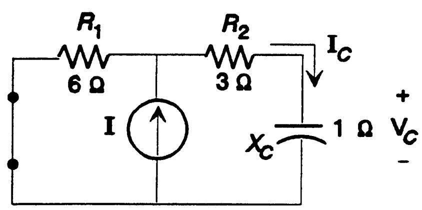
CDR:
$$\mathbf{I}_3 = \frac{\mathbf{Z}_4\mathbf{I}}{\mathbf{Z}_4 + \mathbf{Z}''} = \frac{(4\ \Omega\ \angle 0°)(0.6\ \text{A}\ \angle 120°)}{4\ \Omega - j0.75\ \Omega} = \frac{2.4\ \text{A}\ \angle 120°}{4.07\ \angle -10.62°}$$
$$= 0.59\ \text{A}\ \angle 130.62°$$
$$\mathbf{I}'' = \frac{\mathbf{Z}_2\mathbf{I}_3}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(7\ \Omega\ \angle -90°)(0.59\ \text{A}\ \angle 130.62°)}{-j7\ \Omega + j3\ \Omega} = \frac{4.13\ \text{A}\ \angle 40.62°}{4\ \angle -90°}$$
$$= 1.03\ \text{A}\ \angle 130.62°$$

$$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''\ \text{(direction of } \mathbf{I}'\text{)}$$
$$= 4.43\ \text{A}\ \angle 134.31° - 1.03\ \text{A}\ \angle 130.62°$$
$$= (-3.09\ \text{A} + j3.17\ \text{A}) - (-0.67\ \text{A} + j0.78\ \text{A}) = -2.42\ \text{A} + j2.39\ \text{A}$$
$$= \mathbf{3.40\ A\ \angle 135.36°}$$

4. DC:



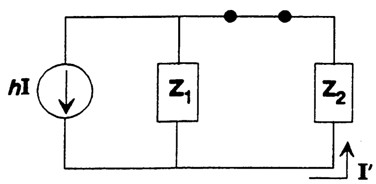
AC:



$$\mathbf{I}_C = \frac{(6\ \Omega\ \angle 0°)(\mathbf{I})}{6\ \Omega + 3\ \Omega - j1\ \Omega}$$
$$= \frac{(6\ \Omega\ \angle 0°)(4\ \text{A}\ \angle 0°)}{9\ \Omega - j1\ \Omega}$$
$$= \frac{24\ \text{A}\ \angle 0°}{9.055 \angle -6.34°}$$
$$= 2.65\ \text{A}\ \angle 6.34°$$

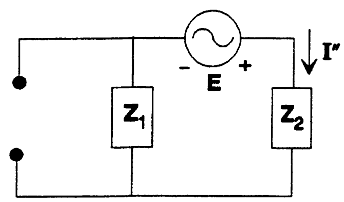
$$\mathbf{V}_C = \mathbf{I}_C\mathbf{X}_C = (2.65\ \text{A}\ \angle 6.34°)(1\ \Omega\ \angle -90°) = 2.65\ \text{V}\ \angle -83.66°$$
$$= \mathbf{12\ V + 2.65\ V\ \angle -83.66°}$$
$$v_C = \mathbf{12\ V + 3.747\ \sin(\omega t - 83.66°)}$$

6.



$\mathbf{Z}_1 = 20\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 90°$
$\mathbf{I} = 2\text{ mA}\ \angle 0°$
$\mathbf{E} = 10\text{ V}\ \angle 0°$

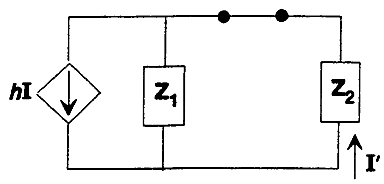
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\text{ k}\Omega\ \angle 0°)(100)(2\text{ mA}\ \angle 0°)}{20\text{ k}\Omega + j10\text{ k}\Omega} = 0.179\text{ A}\ \angle -26.57°$$



$$\mathbf{I}'' = \frac{\mathbf{E}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{10\text{ V}\ \angle 0°}{22.36\text{ k}\Omega\ \angle 26.57°}$$
$= 0.447\text{ mA}\ \angle -26.57°$

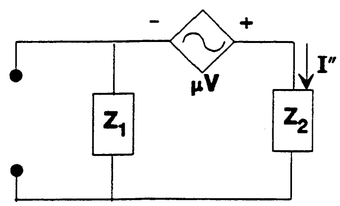
$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$= 179\text{ mA}\ \angle -26.57° - 0.447\text{ mA}\ \angle -26.57°$
$= \mathbf{178.55\text{ mA}\ \angle -26.57°}$

8.



$\mathbf{Z}_1 = 20\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega + j5\text{ k}\Omega$

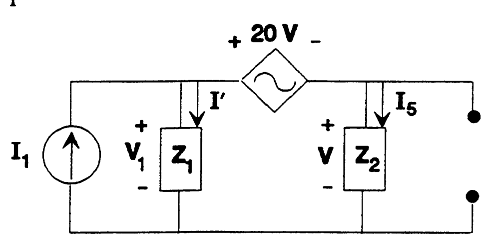
$$\mathbf{I}' = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20\text{ k}\Omega\ \angle 0°)(100)(1\text{ mA}\ \angle 0°)}{20\text{ k}\Omega + 5\text{ k}\Omega + j5\text{ k}\Omega} = 78.45\text{ mA}\ \angle -11.31°$$



$$\mathbf{I}'' = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(10\text{ V}\ \angle 0°)}{25.495\text{ k}\Omega\ \angle 11.31°}$$
$= 7.845\text{ mA}\ \angle -11.31°$

$\mathbf{I}_L = \mathbf{I}' - \mathbf{I}''$ (direction of $\mathbf{I}'$)
$= 78.45\text{ mA}\ \angle -11.31° - 7.845\text{ mA}\ \angle -11.31°$
$= \mathbf{70.61\text{ mA}\ \angle -11.31°}$

10. $\mathbf{I}_1$:



$\mathbf{I}_1 = 1\text{ mA}\ \angle 0°$
$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega\ \angle 0°$

KVL: $\mathbf{V}_1 - 20\text{ V} - \mathbf{V} = 0$ $\quad \mathbf{I}' = \dfrac{\mathbf{V}_1}{\mathbf{Z}_1}\ \therefore\ \mathbf{I}' = \dfrac{21\text{ V}}{\mathbf{Z}_1}$ or $\mathbf{V} = \dfrac{\mathbf{Z}_1}{21}\mathbf{I}'$

$\mathbf{V}_1 = 21\text{ V}$

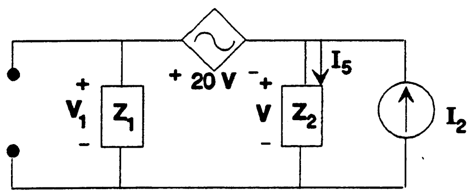
$$\mathbf{V} = \mathbf{I}_5\mathbf{Z}_2 = [\mathbf{I}_1 - \mathbf{I}']\mathbf{Z}_2$$

$$\frac{\mathbf{Z}_1}{21}\mathbf{I}' = \mathbf{I}_1\mathbf{Z}_2 - \mathbf{I}'\mathbf{Z}_2$$

$$\mathbf{I}'\left[\frac{\mathbf{Z}_1}{21} + \mathbf{Z}_2\right] = \mathbf{I}_1\mathbf{Z}_2$$

and $$\mathbf{I}' = \frac{\mathbf{Z}_2}{\frac{\mathbf{Z}_1}{21} + \mathbf{Z}_2}[\mathbf{I}_1] = \frac{(5\text{ k}\Omega\ \angle 0°)(1\text{ mA}\ \angle 0°)}{\left[\frac{2\text{ k}\Omega\ \angle 0°}{21}\right] + 5\text{ k}\Omega\ \angle 0°} = 0.981\text{ mA}\ \angle 0°$$

$\mathbf{I}_2$:



$$\mathbf{V}_1 = 20\text{ V} + \mathbf{V} = 21\text{ V}$$

$$\mathbf{I}'' = \frac{\mathbf{V}_1}{\mathbf{Z}_1} = \frac{21\text{ V}}{\mathbf{Z}_1} \Rightarrow \mathbf{V} = \frac{\mathbf{Z}_1}{21}\mathbf{I}''$$

$$\mathbf{I}_5 = \frac{\mathbf{V}}{\mathbf{Z}_2} = \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

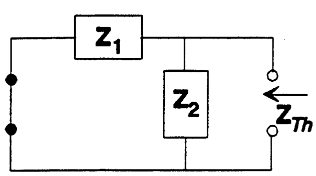
$$\mathbf{I}'' = \mathbf{I}_2 - \mathbf{I}_5 = \mathbf{I}_2 - \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\mathbf{I}''$$

$$\mathbf{I}''\left[1 + \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}\right] = \mathbf{I}_2$$

$$\mathbf{I}'' = \frac{\mathbf{I}_2}{1 + \frac{\mathbf{Z}_1}{21\ \mathbf{Z}_2}} = \frac{2\text{ mA}\ \angle 0°}{1 + \frac{2\text{ k}\Omega}{21(5\text{ k}\Omega)}} = 1.963\text{ mA}\ \angle 0°$$

$$\mathbf{I} = \mathbf{I}' + \mathbf{I}'' = 0.981\text{ mA}\ \angle 0° + 1.963\text{ mA}\ \angle 0°$$
$$= \mathbf{2.944\text{ mA}\ \angle 0°}$$

12. a. $\mathbf{Z}_{Th}$:

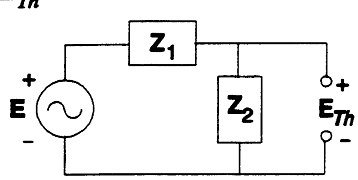


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$\mathbf{E} = 100\text{ V}\ \angle 0°$

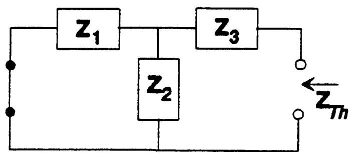
$$\mathbf{Z}_{Th} = \mathbf{Z}_1 \| \mathbf{Z}_2 = (3\ \Omega\ \angle 0° \| 4\ \Omega\ \angle 90°)$$
$$= 2.4\ \Omega\ \angle 36.87° = 1.92\ \Omega + j1.44\ \Omega$$

$\mathbf{E}_{Th}$:



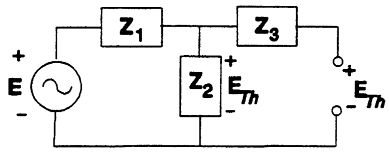
$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(4\ \Omega\ \angle 90°)(100\text{ V}\ \angle 0°)}{5\ \Omega\ \angle 53.13°}$$
$$= \mathbf{80\text{ V}\ \angle 36.87°}$$

b. $\mathbf{Z}_{Th}$:



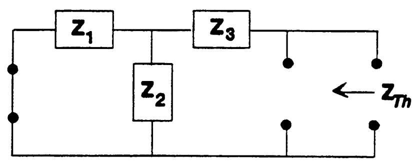
$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2\\ &= +j6\text{ k}\Omega + (2\text{ k}\Omega\ \angle 0° \| 3\text{ k}\Omega\ \angle -90°)\\ &= +j6\text{ k}\Omega + 1.664\text{ k}\Omega\ \angle -33.69°\\ &= +j6\text{ k}\Omega + 1.385\text{ k}\Omega - j0.923\text{ k}\Omega\\ &= 1.385\text{ k}\Omega + j5.077\text{ k}\Omega\\ &= \mathbf{5.263\text{ k}\Omega\ \angle 74.741°}\end{aligned}$$

$\mathbf{E}_{Th}$:



$$\mathbf{E}_{Th} = \frac{\mathbf{Z}_2\mathbf{E}}{\mathbf{Z}_2 + \mathbf{Z}_1} = \frac{(3\text{ k}\Omega\ \angle -90°)(20\text{ V}\ \angle 0°)}{2\text{ k}\Omega - j3\text{ k}\Omega}$$
$$= \frac{60\text{ V}\ \angle -90°}{3.606\ \angle -56.31°} = \mathbf{16.639\text{ V}\ \angle -33.69°}$$

14. a. $\mathbf{Z}_{Th}$:

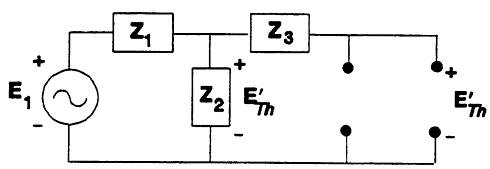


$\mathbf{Z}_1 = 10\ \Omega\ \angle 0°$, $\mathbf{Z}_2 = 8\ \Omega\ \angle 90°$
$\mathbf{Z}_3 = 8\ \Omega\ \angle -90°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2\\ &= -j8\ \Omega + 10\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90°\\ &= -j8\ \Omega + 6.247\ \Omega\ \angle 51.34°\\ &= -j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega\\ &= 3.902\ \Omega - j3.122\ \Omega\\ &= \mathbf{4.997\ \Omega\ \angle -38.663°}\end{aligned}$$

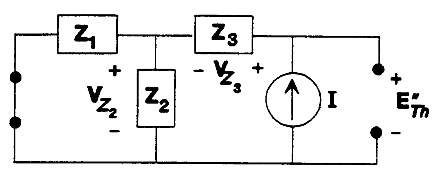
$\mathbf{E}_{Th}$: Superposition:

($\mathbf{E}_1$)



$$\mathbf{E}'_{Th} = \frac{(8\ \Omega\ \angle 90°)(120\text{ V}\ \angle 0°)}{10\ \Omega + j8\ \Omega}$$
$$= \frac{960\text{ V}\ \angle 90°}{12.806\ \angle 38.66°}$$
$$= 74.965\text{ V}\ \angle 51.34°$$

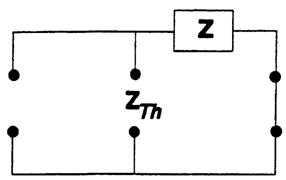
(I)



$$\begin{aligned}\mathbf{E}''_{Th} &= \mathbf{V}_{Z_2} + \mathbf{V}_{Z_3}\\ &= \mathbf{I}\mathbf{Z}_3 + \mathbf{I}(\mathbf{Z}_1 \| \mathbf{Z}_2)\\ &= \mathbf{I}(\mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2)\\ &= (0.5\text{ A}\ \angle 60°)(-j8\ \Omega + 10\ \Omega\ \angle 0° \| 8\ \Omega\ \angle 90°)\\ &= (0.5\text{ A}\ \angle 60°)(-j8\ \Omega + 3.902\ \Omega + j4.878\ \Omega)\\ &= (0.5\text{ A}\ \angle 60°)(3.902\ \Omega - j3.122\ \Omega)\\ &= (0.5\text{ A}\ \angle 60°)(4.997\ \Omega \angle -38.663°)\\ &= 2.499\text{ V}\ \angle 21.337°\end{aligned}$$

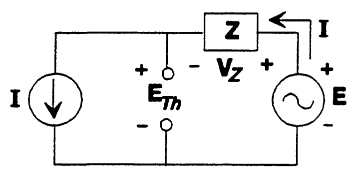
$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E}'_{Th} + \mathbf{E}''_{Th} \\ &= 74.965\text{ V } \angle 51.34° + 2.449\text{ V } \angle 21.337° \\ &= (46.83\text{ V} + j58.538\text{ V}) + (2.328\text{ V} + j0.909\text{ V}) \\ &= 49.158\text{ V} + j59.447\text{ V} = \mathbf{77.139\text{ V } \angle 50.412°}\end{aligned}$$

b. $\mathbf{Z}_{Th}$:



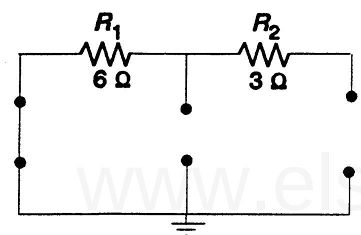
$\mathbf{Z}_{Th} = \mathbf{Z} = 10\ \Omega - j10\ \Omega = 14.142\ \Omega\ \angle -45°$

$\mathbf{E}_{Th}$:



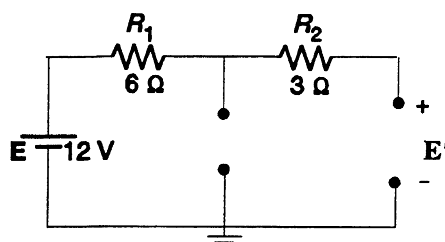
$$\begin{aligned}\mathbf{E}_{Th} &= \mathbf{E} - \mathbf{V}_Z \\ &= 20\text{ V } \angle 40° - \mathbf{IZ} \\ &= 20\text{ V } \angle 40° - (0.6\text{ A } \angle 90°)(14.142\ \Omega\ \angle -45°) \\ &= 20\text{ V } \angle 40° - 8.485\text{ V } \angle 45° \\ &= (15.321\text{ V} + j12.856\text{ V}) - (6\text{ V} + j6\text{ V}) \\ &= 9.321\text{ V} + j6.856\text{ V} \\ &= \mathbf{11.571\text{ V } \angle 36.336°}\end{aligned}$$

16. a. $\mathbf{Z}_{Th}$:



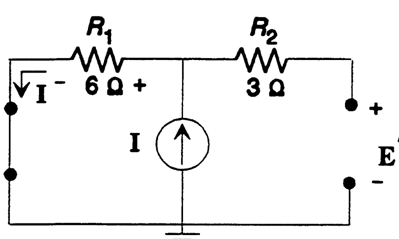
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_{R_1} + \mathbf{Z}_{R_2} = 6\ \Omega + 3\ \Omega = \mathbf{9\ \Omega}$

DC:



$\mathbf{E}'_{Th} = 12\text{ V}$

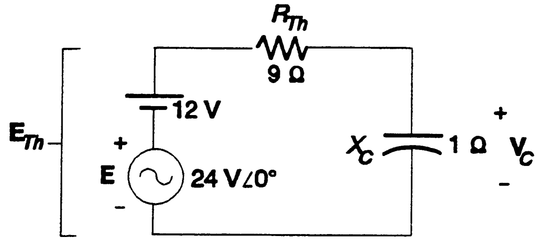
AC:



$\mathbf{E}''_{Th} = \mathbf{IZ}_{R_1} = (4\text{ A } \angle 0°)(6\ \Omega\ \angle 0°) = 24\text{ V } \angle 0°$

$$\mathbf{E}_{Th} = \underset{\text{(DC)}}{12\text{ V}} + \underset{\text{(AC)}}{24\text{ V } \angle 0°}$$

b.



DC: $\mathbf{V}_C = 12\text{ V}$

AC: $\mathbf{V}_C = \dfrac{\mathbf{Z}_C\mathbf{E}}{\mathbf{Z}_C + \mathbf{Z}_{R_{Th}}}$

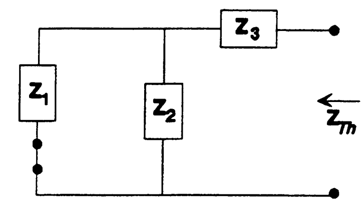
$= \dfrac{(1\ \Omega\ \angle -90°)(24\ \text{V}\ \angle 0°)}{-j1\ \Omega + 9\ \Omega}$

$= \dfrac{24\ \text{V} \angle -90°}{9.055\ \angle -6.34°}$

$\mathbf{V}_C = 2.65\ \text{V}\ \angle -83.66°$

$v_C = 12\text{ V} + 2.65\text{ V}\ \angle -83.66°$
$= \mathbf{12\ V + 3.747\ sin(\omega t - 83.66°)}$

18.

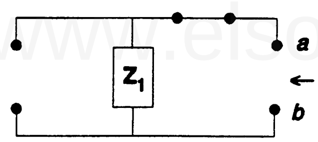


$\mathbf{Z}_1 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 10\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_3 = 1\text{ k}\Omega\ \angle -90°$

$\mathbf{Z}_{Th} = \mathbf{Z}_3 + \mathbf{Z}_1 \| \mathbf{Z}_2 = 5\text{ k}\Omega - j1\text{ k}\Omega \cong \mathbf{5.1\ k\Omega\ \angle -11.31°}$

$\mathbf{E}_{Th}$: (VDR) $\quad \mathbf{E}_{Th} = \dfrac{\mathbf{Z}_2(20\text{ V})}{\mathbf{Z}_2 + \mathbf{Z}_1} = \dfrac{(10\text{ k}\Omega\ \angle 0°)(20)\text{V}}{10\text{ k}\Omega + 10\text{ k}\Omega} = \mathbf{10\ V}$

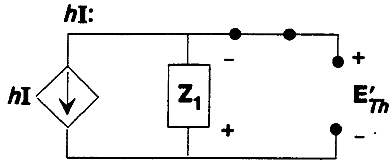
20. $\mathbf{Z}_{Th}$:



$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 = \mathbf{20\ k\Omega\ \angle 0°}$

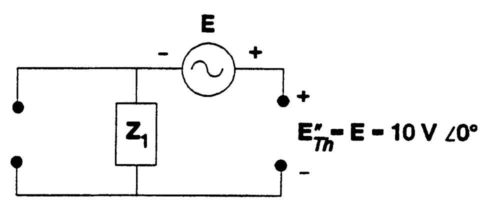
$\mathbf{E}_{Th}$:

$h\mathbf{I}$:



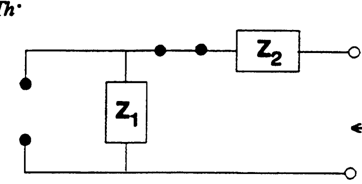
$\mathbf{E}'_{Th} = -(h\mathbf{I})(\mathbf{Z}_1)$
$= -(100)(2\text{ mA}\ \angle 0°)(20\text{ k}\Omega\ \angle 0°)$
$= -4\text{ kV}\ \angle 0°$

E:



$\mathbf{E}_{Th} = \mathbf{E}'_{Th} + \mathbf{E}''_{Th}$
$= -4\text{ kV}\ \angle 0° + 10\text{ V}\ \angle 0°$
$= \mathbf{-3990\ V\ \angle 0°}$

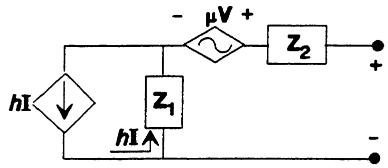
22. $\mathbf{Z}_{Th}$:



$\mathbf{Z}_1 = 20\text{ k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\text{ k}\Omega\ \angle 0°$

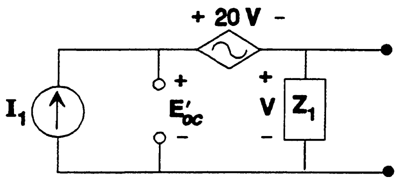
$\leftarrow \mathbf{Z}_{Th} = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\ k\Omega\ \angle 0°}$

$\mathbf{E}_{Th}$:



$$\begin{aligned}\mathbf{E}_{Th} &= \mu\mathbf{V} - (h\mathbf{I})(\mathbf{Z}_1)\\ &= (20)(10\text{ V }\angle 0°) - (100)(1\text{ mA }\angle 0°)(20\text{ k}\Omega\ \angle 0°)\\ &= \mathbf{-1800\text{ V }\angle 0°}\end{aligned}$$

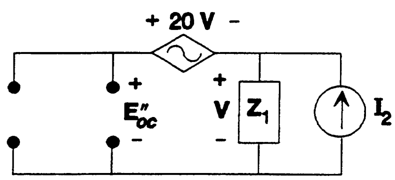
24. $\mathbf{E}_{Th}$:



$\mathbf{E}'_{oc} = 21\text{ V} \qquad \mathbf{Z}_1 = 5\text{ k}\Omega\ \angle 0°$

$$\begin{aligned}\mathbf{V} &= \mathbf{I}_1\mathbf{Z}_1 = (1\text{ mA }\angle 0°)(5\text{ k}\Omega\ \angle 0°)\\ &= 5\text{ V }\angle 0°\end{aligned}$$

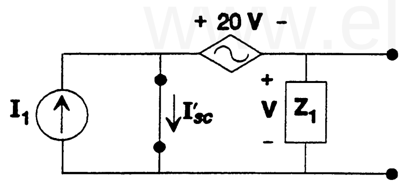
$$\begin{aligned}\mathbf{E}'_{oc} &= \mathbf{E}'_{Th} = 21(5\text{ V }\angle 0°)\\ &= 105\text{ V }\angle 0°\end{aligned}$$



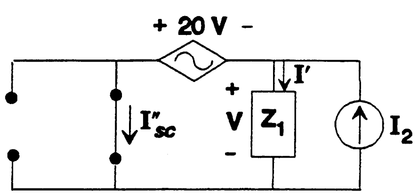
$$\begin{aligned}\mathbf{V} &= \mathbf{I}_2\mathbf{Z}_1\\ &= (2\text{ mA }\angle 0°)(5\text{ k}\Omega\ \angle 0°)\\ &= 10\text{ V }\angle 0°\end{aligned}$$

$\mathbf{E}''_{oc} = \mathbf{E}''_{Th} = 21\text{ V} = 210\ V\ \angle 0°$

$\mathbf{I}_{sc}$:



$\mathbf{I}'_{sc} = \mathbf{I}_1$



$20\text{ V} = \mathbf{V}\ \therefore\ \mathbf{V} = 0\text{ V}$
and $\mathbf{I}' = 0\text{ A}$
$\therefore\ \mathbf{I}''_{sc} = \mathbf{I}_2$

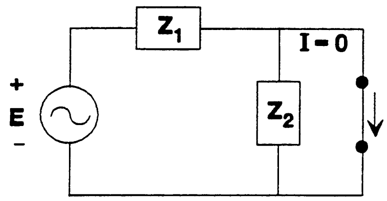
$\mathbf{I}_{sc} = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = 3\text{ mA }\angle 0°$

$\mathbf{E}_{oc} = \mathbf{E}'_{oc} + \mathbf{E}''_{oc} = 315\text{ V }\angle 0° = \mathbf{E}_{Th}$

$$\mathbf{Z}_{Th} = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{315\text{ V }\angle 0°}{3\text{ mA }\angle 0°} = \mathbf{105\text{ k}\Omega\ \angle 0°}$$

26. a. From Problem 12(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 1.92\ \Omega + j1.44\ \Omega = \mathbf{2.4\ \Omega\ \angle 36.87°}$

$\mathbf{I}_N$:

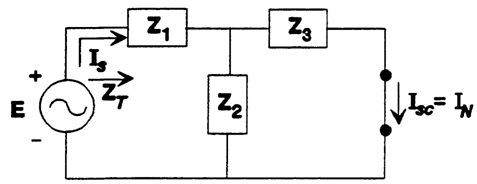


$\mathbf{Z}_1 = 3\ \Omega\ \angle 0°,\ \mathbf{Z}_2 = 4\ \Omega\ \angle 90°$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{100\text{ V}\ \angle 0°}{3\ \Omega\ \angle 0°} = \mathbf{33.33\text{ A}\ \angle 0°}$$

b. From Problem 12(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 5.263\text{ k}\Omega\ \angle 74.741° = \mathbf{1.385\text{ k}\Omega + j6.923\text{ k}\Omega}$

$\mathbf{I}_N$:



$\mathbf{Z}_1 = 2\text{ k}\Omega\ \angle 0°,\ \mathbf{Z}_2 = 3\text{ k}\Omega\ \angle -90°$
$\mathbf{Z}_3 = 6\text{ k}\Omega\angle 90°$

$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 2\text{ k}\Omega + 3\text{ k}\Omega\ \angle -90° \| 6\text{ k}\Omega\ \angle 90° \\ &= 2\text{ k}\Omega + 6\text{ k}\Omega\ \angle -90° \\ &= 2\text{ k}\Omega - j6\text{ k}\Omega \\ &= 6.325\text{ k}\Omega\ \angle -71.565°\end{aligned}$$

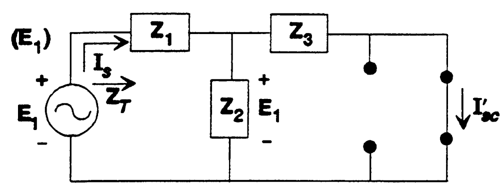
$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{20\text{ V}\ \angle 0°}{6.325\text{ k}\Omega\ \angle -71.565°} = 3.162\text{ mA}\ \angle 71.565°$$

$$\mathbf{I}_{sc} = \mathbf{I}_N = \frac{\mathbf{Z}_2\mathbf{I}_s}{\mathbf{Z}_2 + \mathbf{Z}_3} = \frac{(3\text{ k}\Omega\ \angle -90°)(3.162\text{mA}\ \angle 71.565°)}{-j3\text{ k}\Omega + j6\text{ k}\Omega}$$

$$= \frac{9.486\text{ mA}\ \angle -18.435°}{3\ \angle 90°} = \mathbf{3.162\text{ mA}\ \angle -108.435°}$$

28. a. From Problem 14(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.997\ \Omega\ \angle -38.663°}$

$\mathbf{I}_N$: Superposition:



$$\begin{aligned}\mathbf{Z}_T &= \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 \\ &= 10\ \Omega + 8\ \Omega\ \angle 90° \| 8\ \Omega\ \angle -90° \\ &= 10\ \Omega + \frac{64\ \Omega\ \angle 0°}{0} \\ &= \text{very large impedance}\end{aligned}$$

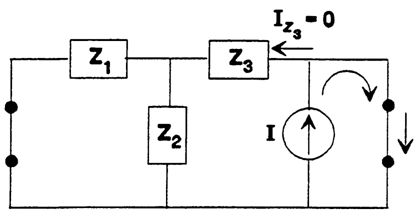
$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = 0\text{ A}$$

and $\mathbf{V}_{Z_1} = 0\text{ V}$

with $\mathbf{V}_{Z_2} = \mathbf{V}_{Z_3} = \mathbf{E}_1 = 120\text{ V}\ \angle 0°$

so that $$\mathbf{I}'_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_3} = \frac{120\text{ V}\ \angle 0°}{8\ \Omega\ \angle -90°} = 15\text{ A}\ \angle 90°$$

(I)

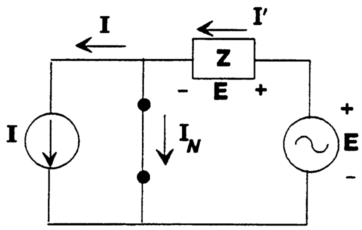


$\mathbf{I}''_{sc} = \mathbf{I} = 0.5 \text{ A } \angle 60°$

$$\mathbf{I}_N = \mathbf{I}'_{sc} + \mathbf{I}''_{sc} = +j15 \text{ A} + 0.5 \text{ A } \angle 60° = +j15 \text{ A} + 0.25 \text{ A} + j0.433 \text{ A}$$
$$= 0.25 \text{ A} + j15.433 \text{ A} = \mathbf{15.435 \text{ A } \angle 89.072°}$$

b. From Problem 14(b): $\mathbf{Z}_N = \mathbf{Z}_{Th} = 10\ \Omega - j10\ \Omega = \mathbf{14.142\ \Omega \angle -45°}$

$\mathbf{I}_N$:

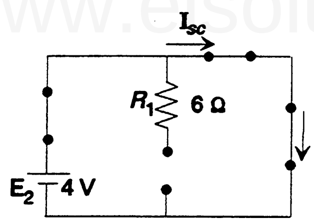


$$\mathbf{I}_N = \mathbf{I}' - \mathbf{I}$$
$$= \frac{\mathbf{E}}{\mathbf{Z}} - \mathbf{I}$$
$$= \frac{20 \text{ V } \angle 40°}{14.142\ \Omega \angle -45°} - 0.6 \text{ A } \angle 90°$$
$$= 1.414 \text{ A } \angle 85° - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j1.409 \text{ A} - j0.6 \text{ A}$$
$$= 0.123 \text{ A} + j0.809 \text{ A}$$
$$= \mathbf{0.818 \text{ A } \angle 81.355°}$$

30. a. Note Problem 15(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4\ \Omega \angle 90°}$

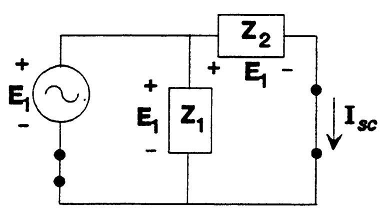
$\mathbf{I}_N$:

DC



$$\mathbf{I}_{sc} = \frac{E_2}{0\ \Omega} = \frac{4 \text{ V}}{0\ \Omega}$$

AC

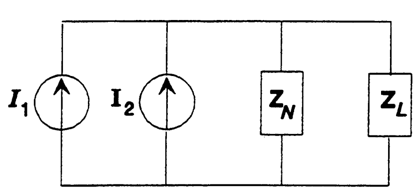


$Z_1 = 6\ \Omega - j2\ \Omega$
$Z_2 = 4\ \Omega \angle 90°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_1}{\mathbf{Z}_2} = \frac{10 \text{ V } \angle 0°}{4\ \Omega \angle 90°} = 2.5 \text{ A } \angle -90°$$

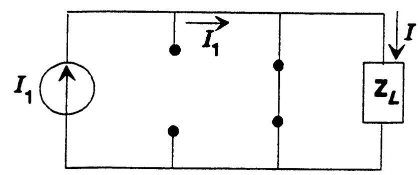
$$\mathbf{I}_N = \frac{4 \text{ V}}{0\ \Omega} + 2.5 \text{ A } \angle -90° \quad (\text{dc: } \mathbf{E}_{Th} = I_N Z_N = \frac{4 \text{ V}}{(0\ \Omega)}(0\ \Omega) = 4 \text{ V})$$

b.



$\mathbf{Z}_N = 4\ \Omega \angle 90°$
$\mathbf{Z}_L = 8\ \Omega \angle 0°$

DC:



(CDR)

$$I = \frac{(0\ \Omega)I_1}{0\ \Omega + 8\ \Omega}$$

$$= \frac{(0\ \Omega)\left[\dfrac{4\ V}{0\ \Omega}\right]}{0\ \Omega + 8\ \Omega} = \frac{4\ V}{8\ \Omega} = 0.5\ A$$

as obtained in Problem 15

AC:

$$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_2)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4\ \Omega\ \angle 90°)(2.5\ A\ \angle -90°)}{+j4\ \Omega + 8\ \Omega}$$

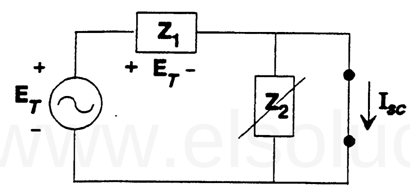
$$= \frac{10\ V\ \angle 0°}{8.944\ \Omega\ \angle 26.565°} = \mathbf{1.118\ A\ \angle -26.565°}$$ as obtained in Problem 15

$$I_{8\Omega} = \underset{\text{(dc)}}{0.5\ A} + \underset{\text{(ac)}}{1.118\ A\ \angle -26.565°}$$

32. a. Note Problem 17(a): $\mathbf{Z}_N = \mathbf{Z}_{Th} = \mathbf{4.472\ k\Omega\ \angle -26.565°}$

Using the same source conversion: $\mathbf{E}_1 = 50\ V\ \angle 0°$

Defining $\mathbf{E}_T = \mathbf{E}_1 + \mathbf{E} = 50\ V\ \angle 0° + 20\ V\ \angle 0° = 70\ V\ \angle 0°$



$\mathbf{Z}_1 = 10\ k\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\ k\Omega - j5\ k\Omega = 7.071\ k\Omega\ \angle -45°$

$$\mathbf{I}_{sc} = \frac{\mathbf{E}_T}{\mathbf{Z}_1} = \frac{70\ V\ \angle 0°}{10\ k\Omega\ \angle 0°} = 7\ mA\ \angle 0°$$

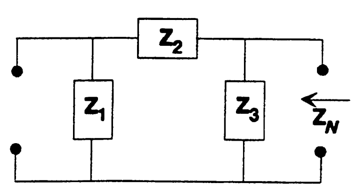
$\mathbf{I}_N = \mathbf{I}_{sc} = \mathbf{7\ mA\ \angle 0°}$

b. $$\mathbf{I} = \frac{\mathbf{Z}_N(\mathbf{I}_N)}{\mathbf{Z}_N + \mathbf{Z}_L} = \frac{(4.472\ k\Omega\ \angle -26.565°)(7\ mA\ \angle 0°)}{4.472\ k\Omega\ \angle -26.565° + 5\ k\Omega\ \angle 90°}$$

$$= \frac{31.30\ mA\ \angle -26.565°}{4 - j2 + j5} = \frac{31.30\ mA\ \angle -26.565°}{4 + j3}$$

$$= \frac{31.30\ mA\ \angle -26.565°}{5\ \angle 36.87°} = 6.26\ mA\ \angle 63.435°$$ as obtained in Problem 17.

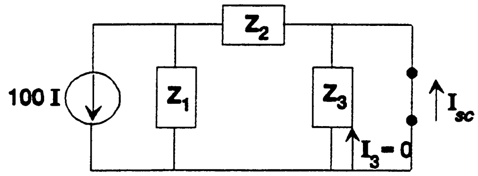
34. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 40\ k\Omega\ \angle 0°$, $\mathbf{Z}_2 = 0.2\ k\Omega\ \angle -90°$
$\mathbf{Z}_3 = 5\ k\Omega\ \angle 0°$

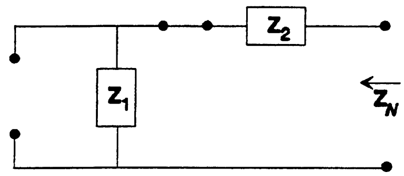
$$\mathbf{Z}_N = \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2)$$
$$= 5\ k\Omega\ \angle 0° \parallel (40\ k\Omega - j0.2\ k\Omega)$$
$$= \mathbf{4.44\ k\Omega\ \angle -0.031°}$$

I_N:



$$\mathbf{I}_N = \mathbf{I}_{sc} = \frac{\mathbf{Z}_1(100\ \mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$
$$= \frac{(40\ \text{k}\Omega\ \angle 0°)(100\ \mathbf{I})}{40\ \text{k}\Omega\ \angle -0.286°}$$
$$= \mathbf{100\ I\ \angle 0.286°}$$

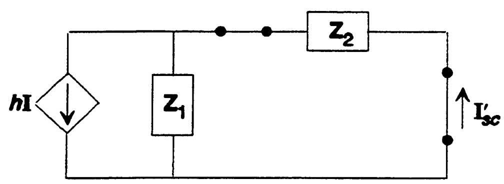
36. $\mathbf{Z}_N$:



$\mathbf{Z}_1 = 20\ \text{k}\Omega\ \angle 0°$, $\mathbf{Z}_2 = 5\ \text{k}\Omega\ \angle 0°$
$\mathbf{V} = 10\ \text{V}\ \angle 0°$, $\mu = 20$, $h = 100$
$\mathbf{I} = 1\ \text{mA}\ \angle 0°$

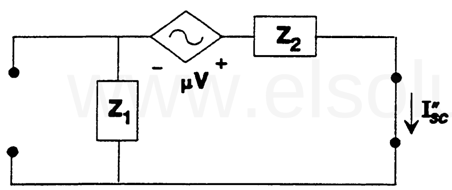
$$\mathbf{Z}_N = \mathbf{Z}_1 + \mathbf{Z}_2 = \mathbf{25\ k\Omega\ \angle 0°}$$

$\mathbf{I}_N$: ($h\mathbf{I}$)



$$\mathbf{I}'_{sc} = \frac{\mathbf{Z}_1(h\mathbf{I})}{\mathbf{Z}_1 + \mathbf{Z}_2}$$
$$= \frac{(20\ \text{k}\Omega\ \angle 0°)(h\mathbf{I})}{20\ \text{k}\Omega\ \angle 0° + 5\ \text{k}\Omega\ \angle 0°}$$
$$= 80\ \text{mA}\ \angle 0°$$

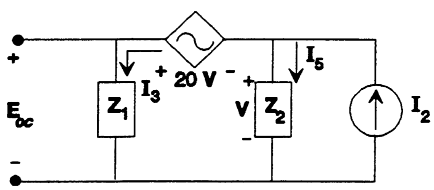
($\mu\mathbf{V}$)



$$\mathbf{I}''_{sc} = \frac{\mu\mathbf{V}}{\mathbf{Z}_1 + \mathbf{Z}_2} = \frac{(20)(10\ \text{V}\ \angle 0°)}{25\ \text{k}\Omega}$$
$$= 8\ \text{mA}\ \angle 0°$$

$\mathbf{I}_N$ (direction of $\mathbf{I}'_{sc}$) $= \mathbf{I}'_{sc} - \mathbf{I}''_{sc} = 80\ \text{mA}\ \angle 0° - 8\ \text{mA}\ \angle 0° = \mathbf{72\ mA\ \angle 0°}$

38.

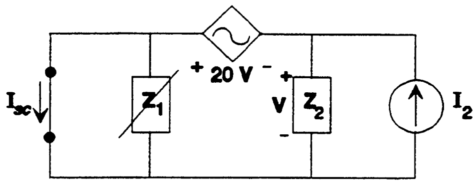


$\mathbf{Z}_1 = 2\ \text{k}\Omega\ \angle 0°$
$\mathbf{Z}_2 = 5\ \text{k}\Omega\ \angle 0°$

$$\mathbf{I}_2 = \mathbf{I}_3 + \mathbf{I}_5$$
$$\mathbf{V} = \mathbf{I}_5\mathbf{Z}_2 = (\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$$
$$\mathbf{E}_{oc} = \mathbf{E}_{Th} = 21\ \mathbf{V} = 21(\mathbf{I}_2 - \mathbf{I}_3)\mathbf{Z}_2$$
$$= 21\left[\mathbf{I}_2 - \frac{\mathbf{E}_{oc}}{\mathbf{Z}_1}\right]\mathbf{Z}_2$$
$$\mathbf{E}_{oc}\left[1 + 21\frac{\mathbf{Z}_2}{\mathbf{Z}_1}\right] = 21\ \mathbf{Z}_2\mathbf{I}_2$$

$$\mathbf{E}_{oc} = \frac{21\ \mathbf{Z}_2\mathbf{I}_2}{1 + 21\ \dfrac{\mathbf{Z}_2}{\mathbf{Z}_1}} = \frac{21(5\text{ k}\Omega\ \angle 0°)(2\text{ mA}\ \angle 0°)}{1 + 21\left[\dfrac{5\text{ k}\Omega\ \angle 0°}{2\text{ k}\Omega\ \angle 0°}\right]}$$

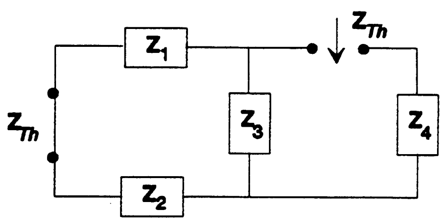
$$\mathbf{E}_{Th} = \mathbf{E}_{oc} = \mathbf{3.925\ V\ \angle 0°}$$



$20\text{ V} \neq -\text{V}\ \therefore\ \text{V} = 0$
and $\mathbf{I}_{sc} = \mathbf{I}_2 = \mathbf{I}_N = \mathbf{2\ mA\ \angle 0°}$

$$\mathbf{Z}_N = \frac{\mathbf{E}_{oc}}{\mathbf{I}_{sc}} = \frac{3.925\text{ V}\ \angle 0°}{2\text{ mA}\ \angle 0°} = \mathbf{1.9625\ k\Omega}$$

40. a. $\mathbf{Z}_{Th}$:

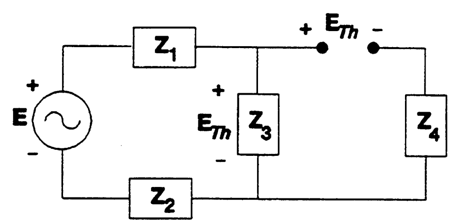


$\mathbf{Z}_1 = 4\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 10\ \Omega\ \angle 0°$
$\mathbf{Z}_3 = 5\ \Omega\ \angle -90°$, $\mathbf{Z}_4 = 6\ \Omega\ \angle -90°$
$\mathbf{E} = 60\text{ V}\ \angle 60°$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_4 + \mathbf{Z}_3 \parallel (\mathbf{Z}_1 + \mathbf{Z}_2) = -j6\ \Omega + (5\ \Omega\ \angle -90°) \parallel (10\ \Omega + j4\ \Omega)\\ &= 2.475\ \Omega - j4.754\ \Omega\\ &= 11.035\ \Omega\ \angle -77.03°\end{aligned}$$

$$\mathbf{Z}_L = \mathbf{11.035\ \Omega\ \angle 77.03°}$$

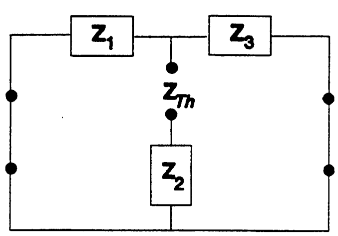
$\mathbf{E}_{Th}$:



$$\begin{aligned}\mathbf{E}_{Th} &= \frac{\mathbf{Z}_3(\mathbf{E})}{\mathbf{Z}_3 + \mathbf{Z}_1 + \mathbf{Z}_2}\\ &= \frac{(5\ \Omega\ \angle -90°)(60\text{ V}\ \angle 60°)}{-j5\ \Omega + j4\ \Omega + 10\ \Omega}\\ &= \mathbf{29.85\ V\ \angle -24.29°}\end{aligned}$$

$$P_{\max} = E_{Th}^2/4R_{Th} = (29.85\text{ V})^2/4(2.475\ \Omega) = \mathbf{90\ W}$$

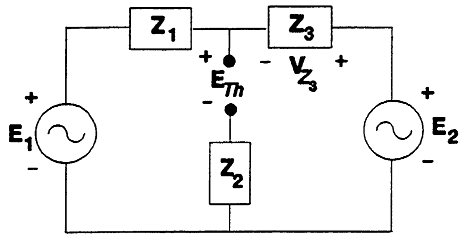
b.



$\mathbf{Z}_1 = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$
$\mathbf{Z}_2 = -j8\ \Omega$
$\mathbf{Z}_3 = 12\ \Omega + j9\ \Omega$

$$\begin{aligned}\mathbf{Z}_{Th} &= \mathbf{Z}_2 + \mathbf{Z}_1 \parallel \mathbf{Z}_3 = -j8\ \Omega + (5\ \Omega\ \angle 53.13°) \parallel (15\ \Omega\ \angle 36.87°)\\ &= 5.71\ \Omega\ \angle -64.30° = 2.475\ \Omega - j5.143\ \Omega\end{aligned}$$

$$\mathbf{Z}_L = \mathbf{5.71\ \Omega\ \angle 64.30° = 2.475\ \Omega + j5.143\ \Omega}$$



$$E_{Th} + V_{Z_3} - E_2 = 0$$
$$E_{Th} = E_2 - V_{Z_3}$$
$$V_{Z_3} = \frac{Z_3(E_2 - E_1)}{Z_3 + Z_1} = 168.97 \text{ V} \angle 112.53°$$

$$E_{Th} = E_2 - V_{Z_3} = 200 \text{ V} \angle 90° - 168.97 \text{ V} \angle 112.53° = \mathbf{78.24 \text{ V} \angle 34.16°}$$
$$P_{max} = E_{Th}^2/4R_{Th} = (78.24 \text{ V})^2/4(2.475\ \Omega) = \mathbf{618.33 \text{ W}}$$

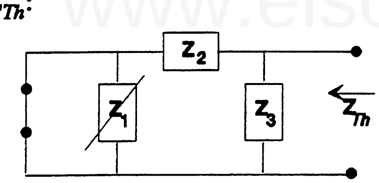
42. a. $Z_{Th} = 4\ \Omega \angle 90°$ (Problem 15(a))
$\mathbf{Z_L = 4 \text{ k}\Omega \angle -90°}$

b. Since load purely reactive P_{max} undefined ($P_{max} = \dfrac{E_{Th}^2}{4R_{Th}}$, $R_{Th} = 0\ \Omega$)

44. a. Problem 17(a):
$Z_{Th} = 4.472 \text{ k}\Omega \angle -26.565° = 4 \text{ k}\Omega - j2 \text{ k}\Omega$
$\mathbf{Z_L = 4 \text{ k}\Omega + j2 \text{ k}\Omega}$
$\mathbf{E_{Th} = 31.31 \text{ V} \angle -26.565°}$

b. $P_{max} = E_{Th}^2/4R_{Th} = (31.31 \text{ V})^2/4(4 \text{ k}\Omega) = \mathbf{61.27 \text{ mW}}$

46. a. Z_{Th}:



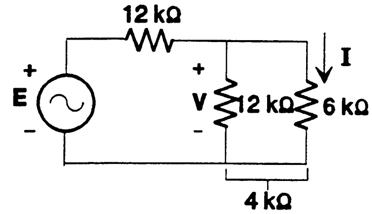
$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(10 \text{ kHz})(3.98 \text{ nF})} \cong 4 \text{ k}\Omega$$
$$X_L = 2\pi fL = 2\pi(10 \text{ kHz})(31.8 \text{ mH}) \cong 2 \text{ k}\Omega$$
$$Z_1 = 1 \text{ k}\Omega \angle 0°, Z_2 = 2 \text{ k}\Omega \angle 90°$$
$$Z_3 = 4 \text{ k}\Omega \angle -90°$$

$$Z_{Th} = Z_2 \| Z_3 = (2 \text{ k}\Omega \angle 90°) \| (4 \text{ k}\Omega \angle -90°) = \mathbf{4 \text{ k}\Omega \angle 90°}, \mathbf{Z_L = 4 \text{ k}\Omega \angle -90°}$$
$$X_C = \frac{1}{2\pi fC} = 4 \text{ k}\Omega, C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(10 \text{ kHz})(4 \text{ k}\Omega)} = \mathbf{3.97 \text{ nF}}$$

b. $R_{Th} = 0\ \Omega \therefore R_L = 0\ \Omega$

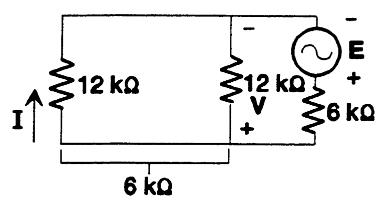
c. Undefined since $P_{max} = E_{Th}^2/4R_{Th}$ and $R_{Th} = 0\ \Omega$

48. a.



$$\mathbf{V} = \frac{4\ \text{k}\Omega(\mathbf{E})}{4\ \text{k}\Omega + 12\ \text{k}\Omega} = \frac{1}{4}(20\ \text{V}\ \angle 0°)$$
$$= 5\ \text{V}\ \angle 0°$$
$$\mathbf{I} = \frac{5\ \text{V}\ \angle 0°}{6\ \text{k}\Omega} = \mathbf{0.833\ mA\ \angle 0°}$$

b.



$$\mathbf{V} = \frac{6\ \text{k}\Omega(\mathbf{E})}{6\ \text{k}\Omega + 6\ \text{k}\Omega} = \frac{1}{2}(20\ \text{V}\ \angle 0°)$$
$$= 10\ \text{V}\ \angle 0°$$
$$\mathbf{I} = \frac{10\ \text{V}\ \angle 0°}{12\ \text{k}\Omega} = \mathbf{0.833\ mA\ \angle 0°}$$

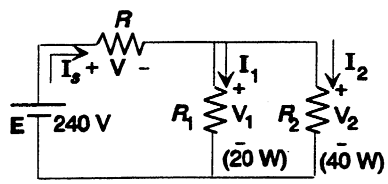
CHAPTER 19 (Odd)

1. a. $P_T = 60\text{ W} + 20\text{ W} + 40\text{ W} = \mathbf{120\text{ W}}$

b. $Q_T = \mathbf{0\text{ VARS}}$, $S_T = P_T = \mathbf{120\text{ VA}}$

c. $S_T = EI_s$, $I_s = \dfrac{S_T}{E} = \dfrac{120\text{ VA}}{240\text{ V}} = \mathbf{0.5\text{ A}}$

d.



$$P = I_s^2R,\ R = \frac{P}{I_s^2} = \frac{60\text{ W}}{(0.5\text{ A})^2} = 240\ \Omega$$
$$V = I_sR = (0.5\text{ A})(240\ \Omega) = 120\text{ V}$$
$$V_1 = V_2 = E - V = 240\text{ V} - 120\text{ V} = 120\text{ V}$$
$$P_1 = \frac{V_1^2}{R_1},\ R_1 = \frac{V_1^2}{P_1} = \frac{(120\text{ V})^2}{20\text{ W}} = \mathbf{720\ \Omega}$$
$$P_2 = \frac{V_2^2}{R_2},\ R_2 = \frac{V_2^2}{P_2} = \frac{(120\text{ V})^2}{40\text{ W}} = \mathbf{360\ \Omega}$$

e. $I_1 = \dfrac{V_1}{R_1} = \dfrac{120\text{ V}}{720\ \Omega} = \mathbf{\dfrac{1}{6}\text{ A}}$, $I_2 = \dfrac{V_2}{R_2} = \dfrac{120\text{ V}}{360\ \Omega} = \mathbf{\dfrac{1}{3}\text{ A}}$

3. a. $P_T = 0 + 100\text{ W} + 300\text{ W} = \mathbf{400\text{ W}}$
$Q_T = 200\text{ VAR}(L) - 600\text{ VAR}(C) + 0 = \mathbf{-400\text{ VAR}(C)}$
$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{565.69\text{ VA}}$
$F_p = \dfrac{P_T}{S_T} = \dfrac{400\text{ W}}{565.69\text{ VA}} = \mathbf{0.7071\ (leading)}$

b. —

c.
$$P_T = EI_s\cos\theta_T$$
$$400\text{ W} = (100\text{ V})I_s(0.7071)$$
$$I_s = \frac{400\text{ W}}{70.71\text{ V}} = 5.66\text{ A}$$
$$\mathbf{I}_s = 5.66\text{ A}\ \angle 135°$$

5. a. $P_T = 200\text{ W} + 200\text{ W} + 0 + 100\text{ W} = \mathbf{500\text{ W}}$
$Q_T = 100\text{ VAR}(L) + 100\text{ VAR}(L) - 200\text{ VAR}(C) - 200\text{ VAR}(C) = \mathbf{-200\text{ VAR}(C)}$
$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{538.52\text{ VA}}$

b. $F_p = \dfrac{P_T}{S_T} = \dfrac{500\text{ W}}{538.52\text{ VA}} = \mathbf{0.928\ (leading)}$

c. —

d. $P_T = EI_s \cos\theta_T$

$500\text{ W} = (50\text{ V})I_s(0.928)$

$I_s = \dfrac{500\text{ W}}{46.4\text{ V}} = 10.776\text{ A}$

$\mathbf{I}_s = \mathbf{10.776\ A\ \angle 21.875°}$

7. a. R: $P = \dfrac{E^2}{R} = \dfrac{(20\text{ V})^2}{2\ \Omega} = \mathbf{200\ W}$

$P_{L,C} = \mathbf{0\ W}$

b. R: $Q = \mathbf{0\ VAR}$

C: $Q_C = \dfrac{E^2}{X_C} = \dfrac{(20\text{ V})^2}{5\ \Omega} = \mathbf{80\ VAR(\mathit{C})}$

L: $Q_L = \dfrac{E^2}{X_L} = \dfrac{(20\text{ V})^2}{4\ \Omega} = \mathbf{100\ VAR(\mathit{L})}$

c. R: $S = \mathbf{200\ VA}$
C: $S = \mathbf{80\ VA}$
L: $S = \mathbf{100\ VA}$

d. $P_T = 200\text{ W} + 0 + 0 = \mathbf{200\ W}$

$Q_T = 0 + 80\text{ VAR}(C) + 100\text{ VAR}(L) = \mathbf{20\ VAR(\mathit{L})}$

$S_T = \sqrt{(200\text{ W})^2 + (20\text{ VAR})^2} = \mathbf{200.998\ VA}$

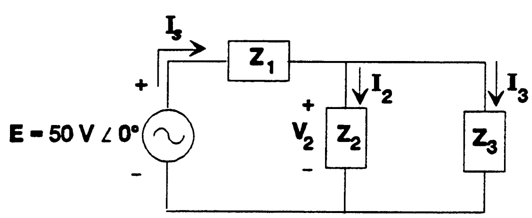
$F_p = \dfrac{P_T}{S_T} = \dfrac{200\text{ W}}{200.998\text{ VA}} = \mathbf{0.995\ (lagging)} \Rightarrow 5.73°$

e. —

f. $I_s = \dfrac{S_T}{E} = \dfrac{200.998\text{ VA}}{20\text{ V}} = 10.05\text{ A}$

$\mathbf{I}_s = 10.05\text{ A}\angle -5.73°$

9. a–c.



$X_L = \omega L = (400\text{ rad/s})(0.1\text{ H}) = 40\ \Omega$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{(400\text{ rad/s})(100\ \mu\text{F})} = 25\ \Omega$

$\mathbf{Z}_1 = 40\ \Omega\ \angle 90°$, $\mathbf{Z}_2 = 25\ \Omega\ \angle -90°$

$\mathbf{Z}_3 = 30\ \Omega\ \angle 0°$

$$\begin{aligned}\mathbf{Z}_T = \mathbf{Z}_1 + \mathbf{Z}_2 \| \mathbf{Z}_3 &= +j40\ \Omega + (25\ \Omega\ \angle -90°)\|(30\ \Omega\ \angle 0°)\\ &= +j40\ \Omega + 19.21\ \Omega\ \angle -50.19°\\ &= +j40\ \Omega + 12.3\ \Omega - j14.76\ \Omega\\ &= 12.3\ \Omega + j25.24\ \Omega\\ &= 28.08\ \Omega\ \angle 64.02°\end{aligned}$$

$$\mathbf{I}_s = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\text{ V}\ \angle 0°}{28.08\ \Omega\ \angle 64.02°} = 1.78\text{ A}\ \angle -64.02°$$

$$\begin{aligned}\mathbf{V}_2 &= \mathbf{I}_s(\mathbf{Z}_2\|\mathbf{Z}_3) = (1.78\text{ A}\ \angle -64.02°)(19.21\ \Omega\ \angle -50.19°)\\ &= 34.19\text{ V}\ \angle -114.21°\end{aligned}$$

$$\mathbf{I}_2 = \frac{\mathbf{V}_2}{\mathbf{Z}_2} = \frac{34.19 \text{ V} \angle -114.21^\circ}{25 \ \Omega \angle -90^\circ} = 1.37 \text{ A} \angle -24.21^\circ$$

$$\mathbf{I}_3 = \frac{\mathbf{V}_2}{\mathbf{Z}_3} = \frac{34.19 \text{ V} \angle -114.21^\circ}{30 \ \Omega \angle 0^\circ} = 1.14 \text{ A} \angle -114.21^\circ$$

$\mathbf{Z}_1$: $P = \mathbf{0\ W}$, $Q_L = I_s^2 X_L = (1.78 \text{ A})^2\, 40\ \Omega = \mathbf{126.74\ VAR}(\boldsymbol{L})$
$\mathbf{Z}_2$: $P = \mathbf{0\ W}$, $Q_C = I_2^2 X_C = (1.37 \text{ A})^2\, 25\ \Omega = \mathbf{46.92\ VAR}(\boldsymbol{C})$
$\mathbf{Z}_3$: $P = I_3^2 R = (1.14 \text{ A})^2\, 30\ \Omega = \mathbf{38.99\ W}$, $Q_R = \mathbf{0\ VAR}$

d. $P_T = 0 + 0 + 38.99 \text{ W} = \mathbf{38.99\ W}$
$Q_T = +126.74 \text{ VAR}(L) - 46.92 \text{ VAR}(C) + 0 = \mathbf{79.82\ VAR}(\boldsymbol{L})$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{88.83\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{38.99 \text{ W}}{88.83 \text{ VA}} = \mathbf{0.439\ (lagging)}$$

e. —

f. $$W_R = \frac{V_R I_R}{2 f_1} = \frac{V_2 I_3}{2 f_1} = \frac{(34.19 \text{ V})(1.14 \text{ A})}{2(63.69 \text{ Hz})} = \mathbf{0.31\ J}$$

$$f_1 = \frac{\omega_1}{2\pi} = \frac{400 \text{ rad/s}}{6.28} = 63.69 \text{ Hz}$$

g. $$W_L = \frac{V_L I_L}{\omega_1} = \frac{(I_s X_L) I_s}{\omega_1} = \frac{I_s^2 X_L}{\omega_1} = \frac{(1.78 \text{ A})^2\, 40\ \Omega}{400 \text{ rad/s}} = \mathbf{0.32\ J}$$

$$W_C = \frac{V_C I_C}{\omega_1} = \frac{V_2 I_2}{\omega_1} = \frac{(34.19 \text{ V})(1.37 \text{ A})}{400 \text{ rad/s}} = \mathbf{0.12\ J}$$

11. a. $$I = \frac{S_T}{E} = \frac{5000 \text{ VA}}{120 \text{ V}} = 41.67 \text{ A}$$
$F_p = 0.8 \Rightarrow 36.87^\circ$ (lagging)
$\mathbf{E} = 120 \text{ V} \angle 0^\circ$, $\mathbf{I} = 41.67 \text{ A} \angle -36.87^\circ$

$$\mathbf{Z} = \frac{\mathbf{E}}{\mathbf{I}} = \frac{120 \text{ V} \angle 0^\circ}{41.67 \text{ A} \angle -36.87^\circ} = 2.88\ \Omega \angle 36.87^\circ = \mathbf{2.30\ \Omega + \mathit{j}1.73\ \Omega} = R + jX_L$$

b. $P = S \cos\theta = (5000 \text{ VA})(0.8) = \mathbf{4000\ W}$

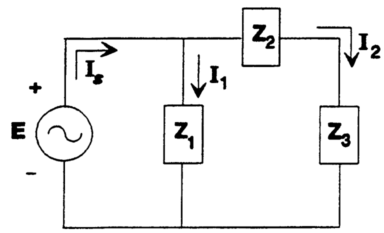
13. a. $P_T = 0 + 300 \text{ W} + 600 \text{ W} = \mathbf{900\ W}$
$Q_T = 500 \text{ VAR}(C) + 0 + 500 \text{ VAR}(L) = \mathbf{0\ VAR}$
$S_T = P_T = \mathbf{900\ VA}$

$$F_p = \frac{P_T}{S_T} = \mathbf{1}$$

b. $$I_s = \frac{S_T}{E} = \frac{900 \text{ VA}}{100 \text{ V}} = 9 \text{ A},\ \mathbf{I}_s = \mathbf{9\ A \angle 0^\circ}$$

c. —

d.



$$\mathbf{Z}_1\text{:}\quad Q_C = \frac{V^2}{X_C} \Rightarrow X_C = \frac{V^2}{Q_C} = \frac{10^4}{500} = \mathbf{20\ \Omega}$$

$$\mathbf{I}_1 = \frac{\mathbf{E}}{\mathbf{Z}_1} = \frac{100\text{ V }\angle 0°}{20\ \Omega\ \angle -90°} = 5\text{A }\angle 90°$$

$$\mathbf{I}_2 = \mathbf{I}_s - \mathbf{I}_1 = 9\text{ A} - j5\text{ A} = 10.296\text{ A }\angle -29.05°$$

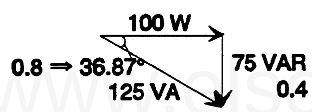
$$\mathbf{Z}_2\text{:}\quad R = \frac{P}{I^2} = \frac{300\text{ W}}{(10.296\text{ A})^2} = \frac{300}{106} = \mathbf{2.83\ \Omega}$$

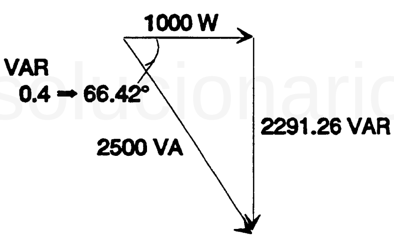
$$X_{L,C} = \mathbf{0\ \Omega}$$

$$\mathbf{Z}_3\text{:}\quad R = \frac{P}{I_2^2} = \frac{600\text{ W}}{(10.296\text{ A})^2} = \mathbf{5.66\ \Omega}$$

$$X_L = \frac{Q}{I_2^2} = \frac{500}{(10.296\text{ A})^2} = \mathbf{4.717\ \Omega},\ X_C = \mathbf{0\ \Omega}$$

15. a. $P_T = 100\text{ W} + 1000\text{ W} = \mathbf{1100\ W}$





$$Q_T = 75\text{ VAR}(C) + 2291.26\text{ VAR}(C) = \mathbf{2366.26\ VAR}(C)$$

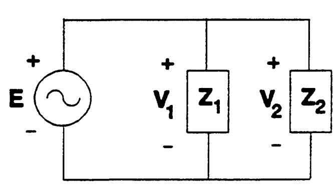
$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{2609.44\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{1100\text{ W}}{2609.44\text{ VA}} = \mathbf{0.4215\ (leading)} \Rightarrow 65.07°$$

b. $S_T = EI \Rightarrow E = \dfrac{S_T}{I} = \dfrac{2609.44\text{ VA}}{5\text{ A}} = 521.89\text{ V}$

$$\mathbf{E} = \mathbf{521.89\ V\ \angle -65.07°}$$

c.



$$I_{Z_1} = \frac{S}{V_1} = \frac{S}{E} = \frac{125\text{ VA}}{521.89\text{ V}} = 0.2395\text{ A}$$

$$I_{Z_2} = \frac{S}{V_2} = \frac{S}{E} = \frac{2500\text{ VA}}{521.89\text{ V}} = 4.79\text{ A}$$

$$\mathbf{Z}_1: \quad R = \frac{P}{I_{Z_1}^2} = \frac{100\text{ W}}{(0.2395)^2} = \mathbf{1743.38\ \Omega}$$

$$Q = I_{Z_1}^2 X_C \Rightarrow X_C = \frac{Q}{I_{Z_1}^2} = \frac{75\text{ VAR}}{(0.2395\text{ A})^2} = \mathbf{1307.53\ \Omega}$$

$$\mathbf{Z}_2: \quad R = \frac{P}{I_{Z_2}^2} = \frac{1000\text{ W}}{(4.790\text{ A})^2} = \mathbf{43.59\ \Omega}$$

$$X_C = \frac{Q}{I_{Z_2}^2} = \frac{2291.26\text{ VAR}}{(4.790\text{ A})^2} = \mathbf{99.88\ \Omega}$$

17. a. $P_T = 5\text{ kW},\ Q_T = 6\text{ kVAR}(L)$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{7.81\ kVA}$$

b. $$F_p = \frac{P_T}{S_T} = \frac{5\text{ kW}}{7.81\text{ kVA}} = \mathbf{0.640\ (lagging)}$$

c. $$I_s = \frac{S_T}{E} = \frac{7{,}810\text{ VA}}{120\text{ V}} = \mathbf{65.08\ A}$$

d. $$X_C = \frac{1}{2\pi fC},\ Q_C = I^2 X_C = \frac{E^2}{X_C} = \frac{(120\text{ V})^2}{X_C}$$

and $$X_C = \frac{(120\text{ V})^2}{Q_C} = \frac{14{,}400}{6000} = 2.4\ \Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{(2\pi)(60\text{ Hz})(2.4\ \Omega)} = \mathbf{1105\ \mu F}$$

e. $S_T = EI_s = P_T$

$$\therefore I_s = \frac{P_T}{E} = \frac{5000\text{ W}}{120\text{ V}} = \mathbf{41.67\ A}$$

19. a. $\mathbf{Z}_T = R_1 + R_2 + R_3 + jX_L - jX_C$
$= 2\ \Omega + 3\ \Omega + 1\ \Omega + j3\ \Omega - j12\ \Omega = 6\ \Omega - j9\ \Omega = 10.82\ \Omega\ \angle -56.31°$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\text{ V}\ \angle 0°}{10.82\ \Omega\ \angle -56.31°} = 4.62\text{ A}\ \angle 56.31°$$

$P = VI\cos\theta = (50\text{ V})(4.62\text{ A})\cos 56.31° = \mathbf{128.14\ W}$

b.
a-b: $P = I^2R = (4.62\text{ A})^2\, 2\ \Omega = \mathbf{42.69\ W}$
b-c: $P = I^2R = (4.62\text{ A})^2\, 3\ \Omega = \mathbf{64.03\ W}$
a-c: $42.69\text{ W} + 64.03\text{ W} = \mathbf{106.72\ W}$
a-d: **106.72 W**
c-d: **0 W**
d-e: **0 W**
f-e: $P = I^2R = (4.62\text{ A})^2\, 1\ \Omega = \mathbf{21.34\ W}$

21. a. $R = \dfrac{P}{I^2} = \dfrac{80\text{ W}}{(4\text{ A})^2} = 5\ \Omega,\ Z_T = \dfrac{E}{I} = \dfrac{200\text{ V}}{4\text{ A}} = 50\ \Omega$

$X_L = \sqrt{Z_T^2 - R^2} = \sqrt{(50\ \Omega)^2 - (5\ \Omega)^2} = 49.75\ \Omega$

$L = \dfrac{X_L}{2\pi f} = \dfrac{49.75\ \Omega}{(2\pi)(60\text{ Hz})} = \mathbf{132.03\ mH}$

b. $R = \dfrac{P}{I^2} = \dfrac{90\text{ W}}{(3\text{ A})^2} = \mathbf{10\ \Omega}$

c. $R = \dfrac{P}{I^2} = \dfrac{60\text{ W}}{(2\text{ A})^2} = \mathbf{15\ \Omega},\ Z_T = \dfrac{E}{I} = \dfrac{200\text{ V}}{2\text{ A}} = 100\ \Omega$

$X_L = \sqrt{Z_T^2 - R^2} = \sqrt{(100\ \Omega)^2 - (15\ \Omega)^2} = 98.87\ \Omega$

$L = \dfrac{X_L}{2\pi f} = \dfrac{98.87\ \Omega}{376.8} = \mathbf{262.39\ mH}$

CHAPTER 19 (Even)

2. a. $Z_T = 3\ \Omega - j5\ \Omega + j9\ \Omega = 3\ \Omega + j4\ \Omega = 5\ \Omega\ \angle 53.13°$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}_T} = \frac{50\ \text{V}\ \angle 0°}{5\ \Omega\ \angle 53.13°} = 10\ \text{A}\ \angle -53.13°$$

R: $P = I^2R = (10\ \text{A})^2\ 3\ \Omega = \mathbf{300\ W}$
L: $P = \mathbf{0\ W}$
C: $P = \mathbf{0\ W}$

b. R: $Q = \mathbf{0\ VAR}$
C: $Q_C = I^2X_C = (10\ \text{A})^2\ 5\ \Omega = \mathbf{500\ VAR}$
L: $Q_L = I^2X_L = (10\ \text{A})^2\ 9\ \Omega = \mathbf{900\ VAR}$

c. R: $S = \mathbf{300\ VA}$
C: $S = \mathbf{500\ VA}$
L: $S = \mathbf{900\ VA}$

d. $P_T = 300\ \text{W}$
$Q_T = Q_L - Q_C = \mathbf{400\ VAR}(L)$

$$S_T = \sqrt{P_T^2 + Q_T^2} = EI = (50\ \text{V})(10\ \text{A}) = \mathbf{500\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{300\ \text{W}}{500\ \text{VA}} = \mathbf{0.6\ lagging}$$

e. —

f. $$W_R = \frac{VI}{f_1}:\quad W_R = 2\left[\frac{VI}{f_2}\right] = 2\left[\frac{VI}{2f_1}\right] = \frac{VI}{f_1}$$

$V = IR = (10\ \text{A})(3\ \Omega) = 30\ \text{V}$

$$W_R = \frac{(30\ \text{V})(10\ \text{A})}{60\ \text{Hz}} = \mathbf{5\ J}$$

g. $V_C = IX_C = (10\ \text{A})(5\ \Omega) = 50\ \text{V}$

$$W_C = \frac{VI}{\omega_1} = \frac{(50\ \text{V})(10\ \text{A})}{(2\pi)(60\ \text{Hz})} = \mathbf{1.327\ J}$$

$V_L = IX_L = (10\ \text{A})(9\ \Omega) = 90\ \text{V}$

$$W_L = \frac{VI}{\omega_1} = \frac{(90\ \text{V})(10\ \text{A})}{376.8} = \mathbf{2.389\ J}$$

4. a. $P_T = 600\ \text{W} + 500\ \text{W} + 100\ \text{W} = \mathbf{1200\ W}$
$Q_T = 1200\ \text{VAR}(L) + 600\ \text{VAR}(L) - 600\ \text{VAR}(C) = \mathbf{1200\ VAR}(L)$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \sqrt{(1200\ \text{W})^2 + (1200\ \text{VAR})^2} = \mathbf{1697\ VA}$$

b. $$F_p = \frac{P_T}{S_T} = \frac{1200\ \text{W}}{1697\ \text{VA}} = \mathbf{0.7071\ (lagging)}$$

c. —

d. $I_s = \frac{S_T}{E} = \frac{1697\text{ VA}}{200\text{ V}} = 8.485\text{ A},\ 0.7071 \Rightarrow 45°\text{ (lagging)}$

$\mathbf{I}_s = \mathbf{8.485\ A\ \angle -45°}$

6. a. $\mathbf{I}_R = \frac{60\text{ V}\ \angle 30°}{20\ \Omega\ \angle 0°} = 3\text{ A}\ \angle 30°$

$P = I^2R = (3\text{ A})^2\ 20\ \Omega = \mathbf{180\ W}$

$Q_R = \mathbf{0\ VAR}$

$S = P = \mathbf{180\ VA}$

b. $\mathbf{I}_L = \frac{60\text{ V}\ \angle 30°}{10\ \Omega\ \angle 90°} = 6\text{ A}\ \angle -60°$

$P_L = \mathbf{0\ W}$

$Q_L = I^2X_L = (6\text{ A})^2\ 10\ \Omega = \mathbf{360\ VAR(\mathit{L})}$

$S = Q = \mathbf{360\ VA}$

c. $P_T = 180\text{ W} + 400\text{ W} = \mathbf{580\ W}$

$Q_T = 600\text{ VAR}(L) + 360\text{ VAR}(L) = \mathbf{960\ VAR(\mathit{L})}$

$S_T = \sqrt{(580\text{ W})^2 + (960\text{ VAR})^2} = \mathbf{1121.61\ VA}$

$F_p = \frac{P_T}{S_T} = \frac{580\text{ W}}{1121.61\text{ VA}} = \mathbf{0.517\ (lagging)}\quad \theta = 58.87°$

d. $S_T = EI_s$

$I_s = \frac{S_T}{E} = \frac{1121.61\text{ VA}}{60\text{ V}} = 18.69\text{ A}$

$\theta_{I_s} = 30° - 58.87° = -28.87°$

$\mathbf{I}_s = \mathbf{18.69\ A\ \angle -28.87°}$

8. a. $R - L$: $\quad \mathbf{I} = \frac{50\text{ V}\ \angle 60°}{5\ \Omega\ \angle 53.13°} = 10\text{ A}\ \angle 6.87°$

$P_R = I^2R = (10\text{ A})^2\ 3\ \Omega = \mathbf{300\ W}$

$P_L = \mathbf{0\ W}$

$P_C = \mathbf{0\ W}$

b. $Q_R = \mathbf{0\ VAR}$

$Q_L = I^2X_L = (10\text{ A})^2\ 4\ \Omega = \mathbf{400\ VAR}$

$\mathbf{I}_C = \frac{50\text{ V}\ \angle 60°}{10\ \Omega\ \angle -90°} = 5\text{ A}\ \angle 150°$

$Q_C = I^2X_C = (5\text{ A})^2\ 10\ \Omega = \mathbf{250\ VAR}$

c. $S_R = P = \mathbf{300\ VA}$

$S_L = Q_L = \mathbf{400\ VA}$

$S_C = Q_C = \mathbf{250\ VA}$

d. $P_T = P_R = \mathbf{300\ W}$

$Q_T = 400\text{ VAR}(L) - 250\text{ VAR}(C) = \mathbf{150\ VAR(\mathit{L})}$

$S_T = \sqrt{(300\text{ W})^2 + (150\text{ VAR})^2} = \mathbf{335.41\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{300 \text{ W}}{335.41 \text{ VA}} = \mathbf{0.894 \text{ (lagging)}}$$

e. —

f. $I_s = \dfrac{S_T}{E} = \dfrac{335.41 \text{ VA}}{50 \text{ V}} = 6.71 \text{ A}$

$0.894 \Rightarrow 26.62°$ lagging

$\theta = 60° - 26.62° = 33.38°$

$\mathbf{I}_s = \mathbf{6.71 \text{ A} \angle 33.38°}$

10. a. $I_s = \dfrac{S_T}{E} = \dfrac{10{,}000 \text{ VA}}{200 \text{ V}} = 50 \text{ A}$

$0.5 \Rightarrow 60°$ leading

$\therefore I_s$ leads $\mathbf{E}$ by $60°$

$$\mathbf{Z}_T = \frac{\mathbf{E}}{\mathbf{I}_s} = \frac{200 \text{ V} \angle 0°}{50 \text{ A} \angle 60°} = 4 \ \Omega \angle -60° = 2 \ \Omega - j3.464 \ \Omega = R - jX_C$$

b. $F_p = \dfrac{P_T}{S_T} \Rightarrow P_T = F_p S_T = (0.5)(10{,}000 \text{ VA}) = \mathbf{5000 \text{ W}}$

12. a. $P_T = 0 + 300 \text{ W} = \mathbf{300 \text{ W}}$

$Q_T = 600 \text{ VAR}(C) + 200(L) = \mathbf{400 \text{ VAR}(C)}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{500 \text{ VA}}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{300 \text{ W}}{500 \text{ VA}} = \mathbf{0.6 \text{ (leading)}}$

b. $I_s = \dfrac{S_T}{E} = \dfrac{500 \text{ VA}}{30 \text{ V}} = 16.67 \text{ A}$

$F_p = 0.6 \Rightarrow 53.13°$

$\mathbf{I}_s = \mathbf{16.67 \text{ A} \angle 53.13°}$

c. —

d. Load: 600 VAR(C), 0 W

$$R = 0, L = 0, Q_C = I^2 X_C \Rightarrow X_C = \frac{Q_C}{I^2} = \frac{600 \text{ VAR}}{(16.67 \text{ A})^2} = \mathbf{2.159 \ \Omega}$$

Load: 200 VAR(L), 300 W

$C = 0, R = P/I^2 = 300 \text{ W}/(16.67 \text{ A})^2 = \mathbf{1.079 \ \Omega}$

$X_L = \dfrac{Q_L}{I^2} = \dfrac{200 \text{ VAR}}{(16.67 \text{ A})^2} = \mathbf{0.7197 \ \Omega}$

$\mathbf{Z}_T = -j2.159 \ \Omega + 1.0796 \ \Omega + j0.7197 \ \Omega$

$= \mathbf{1.0796 \ \Omega - j1.4393 \ \Omega}$

14. a. $P_T = 200 \text{ W} + 30 \text{ W} + 0 = \mathbf{230 \text{ W}}$

$Q_T = 0 + 40 \text{ VAR}(L) + 100 \text{ VAR}(L) = \mathbf{140 \text{ VAR}(L)}$

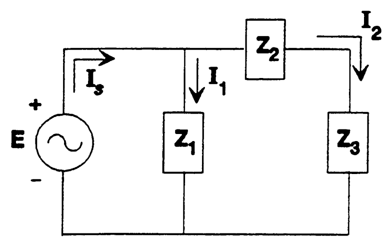
$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{269.26 \text{ VA}}$

$$F_p = \frac{P_T}{S_T} = \frac{230\text{ W}}{269.26\text{ VA}} = \mathbf{0.854\ (lagging)} \Rightarrow 31.35°$$

b. $I_s = \dfrac{S_T}{E} = \dfrac{269.26\text{ VA}}{100\text{ V}} = 2.6926\text{ A}$

$\mathbf{I}_s = 2.6926\text{ A}\ \angle -31.35°$

c.



$\mathbf{Z}_1$: $R = \dfrac{V^2}{P} = \dfrac{10^4}{200} = 50\ \Omega$

$X_L, X_C = 0\ \Omega$

$\mathbf{I}_1 = \dfrac{100\text{ V}\ \angle 0°}{50\ \Omega\ \angle 0°} = 2\text{ A}\ \angle 0°$

$\mathbf{I}_2 = \mathbf{I}_s - \mathbf{I}_1$
$= 2.6926\text{ A}\ \angle -31.35° - 2\text{ A}\ \angle 0°$
$= 2.299\text{ A} - j1.40\text{ A} - 2.0\text{ A}$
$= 0.299\text{ A} - j1.40\text{ A}$
$= 1.432\text{ A}\ \angle -77.94°$

$\mathbf{Z}_2$: $R = \dfrac{P}{I_2^2} = \dfrac{30\text{ W}}{(1.432\text{ A})^2} = \mathbf{14.63\ \Omega}$, $X_L = \dfrac{Q}{I_2^2} = \dfrac{40\text{ VAR}}{(1.432\text{ A})^2} = \mathbf{19.50\ \Omega}$

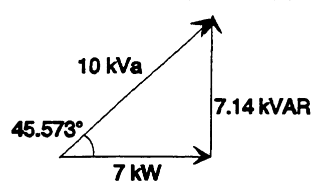
$X_C = \mathbf{0\ \Omega}$

$\mathbf{Z}_3$: $X_L = \dfrac{Q}{I_2^2} = \dfrac{100\text{ VAR}}{(1.432\text{ A})^2} = \mathbf{48.76\ \Omega}$, $R = \mathbf{0\ \Omega}$, $X_C = \mathbf{0\ \Omega}$

16. a. $0.7 \Rightarrow 45.573°$

$P = S\cos\theta = (10\text{ kVA})(0.7) = 7\text{ kW}$

$Q = S\sin\theta = (10\text{ kVA})(0.714) = 7.14\text{ kVAR}(L)$



b. $Q_C = 7.14\text{ kVAR} = \dfrac{V^2}{X_C}$

$$X_C = \frac{V^2}{Q_C} = \frac{(208\text{ V})^2}{7.14\text{ kVAR}} = 6.059\ \Omega$$

$$X_C = \frac{1}{2\pi fC} \Rightarrow C = \frac{1}{2\pi f X_C} = \frac{1}{(2\pi)(60\text{ Hz})(6.059\ \Omega)} = \mathbf{438\ \mu F}$$

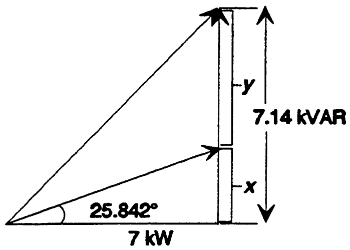
c. Uncompensated:

$$I_s = \frac{S_T}{E} = \frac{10{,}000\text{ VA}}{208\text{ V}} = \mathbf{48.08\ A}$$

Compensated:

$$I_s = \frac{S_T}{E} = \frac{P_T}{E} = \frac{7{,}000\text{ W}}{208\text{ V}} = \mathbf{33.65\ A}$$

d.



$$\cos\theta = 0.9$$
$$\theta = \cos^{-1}0.9 = 25.842°$$
$$\tan\theta = \frac{x}{7\text{ kW}}$$
$$\begin{aligned} x &= (7\text{ kW})(\tan 25.842°) \\ &= (7\text{ kW})(0.484) \\ &= 3.39\text{ kVAR} \\ y &= (7.14 - 3.39)\text{ kVAR} \\ &= 3.75\text{ kVAR} \end{aligned}$$

$$Q_C = 3.75\text{ kVAR} = \frac{V^2}{X_C}$$

$$X_C = \frac{V^2}{Q_C} = \frac{(208\text{ V})^2}{3.75\text{ kVAR}} = 11.537\ \Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{(2\pi)(60\text{ Hz})(11.537\ \Omega)} = \mathbf{230\ \mu F}$$

Uncompensated:

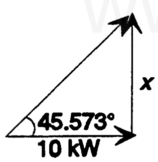
$$I_s = \mathbf{48.08\ A}$$

Compensated:

$$S_T = \sqrt{(7\text{ kW})^2 + (3.39\text{ kVAR})^2} = 7.778\text{ kVA}$$
$$I_s = \frac{S_T}{E} = \frac{7.778\text{ kVA}}{208\text{ V}} = \mathbf{37.39\ A}$$

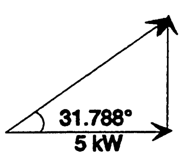
18. a. Load 1: $P = 20{,}000\text{ W},\ Q = 0\text{ VAR}$

Load 2: $\theta = \cos^{-1}0.7 = 45.573°$



$$\tan\theta = \frac{x}{10\text{ kW}}$$
$$\begin{aligned} x &= (10\text{ kW})\tan 45.573° \\ &= (10\text{ kW})(1.02) \\ &= \mathbf{10{,}202\ VAR(\mathit{L})} \end{aligned}$$

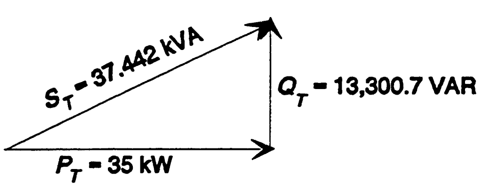
Load 3: $\theta = \cos^{-1}0.85 = 31.788°$



$$\tan\theta = \frac{x}{5\text{ kW}}$$
$$\begin{aligned} x &= (5\text{ kW})\tan 31.788° \\ &= (5\text{ kW})(0.62) \\ &= 3098.7\text{ VAR}(L) \end{aligned}$$

$$P_T = 20{,}000\text{ W} + 10{,}000\text{ W} + 5{,}000\text{ W} = \mathbf{35\ kW}$$
$$Q_T = 0 + 10{,}202\text{ VAR} + 3098.7\text{ VAR} = \mathbf{13{,}300.7\ VAR(\mathit{L})}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{37{,}442\ VA} = \mathbf{37.442\ kVA}$$



b. $Q_C = Q_L = 13{,}300.7\text{ VAR}$

$$X_C = \frac{E^2}{Q_C} = \frac{(10^3\text{ V})^2}{13{,}300.7\text{ VAR}} = 75.184\ \Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{(2\pi)(60\text{ Hz})(75.184\ \Omega)} = \mathbf{35.28\ \mu F}$$

c. Uncompensated:

$$I_s = \frac{S_T}{E} = \frac{37.442\text{ kVA}}{1\text{ kV}} = \mathbf{37.442\text{ A}}$$

Compensated:

$$S_T = P_T = 35\text{ kW}$$

$$I_s = \frac{S_T}{E} = \frac{35\text{ kW}}{1\text{ kV}} = \mathbf{35\text{ A}}$$

20. a. $S_T = 660\text{ VA} = EI_s$

$$I_s = \frac{660\text{ VA}}{120\text{ V}} = 5.5\text{ A}$$

$$\theta = \cos^{-1}0.6 = 53.13°$$

$$\therefore\ \mathbf{E} = 120\text{ V}\ \angle 0°,\ \mathbf{I}_s = 5.5\text{ A}\ \angle -53.13°$$

$$P = EI\cos\theta = (120\text{ V})(5.5\text{ A})(0.6) = \mathbf{396\text{ W}}$$

Wattmeter = **396 W**, Ammeter = **5.5 A**, Voltmeter = **120 V**

b. $$\mathbf{Z}_T = \frac{\mathbf{E}}{\mathbf{I}} = \frac{120\text{ V}\ \angle 0°}{5.5\text{ A}\ \angle -53.13°} = \mathbf{21.82\ \Omega\ \angle 53.13° = 13.09\ \Omega + j17.46\ \Omega} = R + jX_L$$

22. a. $X_L = 2\pi f L = (6.28)(50\text{ Hz})(0.08\text{ H}) = 25.12\ \Omega$

$$Z_T = \sqrt{R^2 + X_L^2} = \sqrt{(4\ \Omega)^2 + (25.12\ \Omega)^2} = 25.44\ \Omega$$

$$I = \frac{E}{Z_T} = \frac{60\text{ V}}{25.44\ \Omega} = 2.358\text{ A}$$

$$P = I^2R = (2.358\text{ A})^2\, 4\ \Omega = \mathbf{22.24\text{ W}}$$

b. $$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{30\text{ W}}{7\ \Omega}} = \mathbf{2.07\text{ A}}$$

$$Z_T = \frac{E}{I} = \frac{60\text{ V}}{2.07\text{ A}} = 28.99\ \Omega$$

$$X_L = \sqrt{(28.99\ \Omega)^2 - (7\ \Omega)^2} = 28.13\ \Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{28.13\ \Omega}{(2\pi)(50\text{ Hz})} = \mathbf{89.54\text{ mH}}$$

c. $P = I^2R = (1.7\text{ A})^2\, 10\ \Omega = \mathbf{28.9\text{ W}}$

$$Z_T = \frac{E}{I} = \frac{60\text{ V}}{1.7\text{ A}} = 35.29\ \Omega$$

$$X_L = \sqrt{(35.29\ \Omega)^2 - (10\ \Omega)^2} = 33.84\ \Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{38.84\ \Omega}{314} = \mathbf{107.77\text{ mH}}$$

CHAPTER 20 (Odd)

1. a. $\omega_s = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{1\text{ H})(16\ \mu\text{F})}} = \mathbf{250\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{250\text{ rad/s}}{2\pi} = \mathbf{39.79\ Hz}$

b. $\omega_s = \dfrac{1}{\sqrt{(0.5\text{ H})(0.16\ \mu\text{F})}} = \mathbf{3535.53\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{3535.53\text{ rad/s}}{2\pi} = \mathbf{562.7\ Hz}$

c. $\omega_s = \dfrac{1}{\sqrt{(0.28\text{ mH})(7.46\ \mu\text{F})}} = \mathbf{21{,}880\ rad/s}$

$f_s = \dfrac{\omega_s}{2\pi} = \dfrac{21{,}880\text{ rad/s}}{2\pi} = \mathbf{3482.31\ Hz}$

3. a. $X_L = \mathbf{40\ \Omega}$

b. $I = \dfrac{E}{Z_{T_s}} = \dfrac{20\text{ mV}}{2\ \Omega} = \mathbf{10\ mA}$

c. $V_R = IR = (10\text{ mA})(2\ \Omega) = \mathbf{20\ mV} = \text{E}$
$V_L = IX_L = (10\text{ mA})(40\ \Omega) = \mathbf{400\ mV}$
$V_C = IX_C = (10\text{ mA})(40\ \Omega) = \mathbf{400\ mV}$
$V_L = V_C = 20\ V_R$

d. $Q_s = \dfrac{X_L}{R} = \dfrac{40\ \Omega}{2\ \Omega} = \mathbf{20}$ (high Q)

e. $X_L = 2\pi fL,\ L = \dfrac{X_L}{2\pi f} = \dfrac{40\ \Omega}{2\pi(5\text{ kHz})} = \mathbf{1.27\ mH}$

$X_C = \dfrac{1}{2\pi fC},\ C = \dfrac{1}{2\pi fX_C} = \dfrac{1}{2\pi(5\text{ kHz})(40\ \Omega)} = \mathbf{0.796\ \mu F}$

f. $BW = \dfrac{f_s}{Q_s} = \dfrac{5\text{ kHz}}{20} = \mathbf{250\ Hz}$

g. $f_2 = f_s + \dfrac{BW}{2} = 5\text{ kHz} + \dfrac{0.25\text{ kHz}}{2} = \mathbf{5.125\ kHz}$

$f_1 = f_s - \dfrac{BW}{2} = 5\text{ kHz} - \dfrac{0.25\text{ kHz}}{2} = \mathbf{4.875\ kHz}$

5. a. $BW = f_s/Q_s = 6000\text{ Hz}/15 = \mathbf{400\ Hz}$

b. $f_2 = f_s + \dfrac{BW}{2} = 6000\text{ Hz} + 200\text{ Hz} = \mathbf{6200\ Hz}$

$f_1 = f_s - \dfrac{BW}{2} = 6000\text{ Hz} - 200\text{ Hz} = \mathbf{5800\ Hz}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = (15)(3\ \Omega) = \mathbf{45\ \Omega} = X_C$

d. $P_{HPF} = \dfrac{1}{2}P_{max} = \dfrac{1}{2}(I^2R) = \dfrac{1}{2}(0.5\text{ A})^2\, 3\Omega = \mathbf{375\ mW}$

7. a. $BW = \dfrac{f_s}{Q_s} \Rightarrow Q_s = f_s/BW = 2000\text{ Hz}/200\text{ Hz} = \mathbf{10}$

b. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = (10)(2\ \Omega) = \mathbf{20\ \Omega}$

c. $L = \dfrac{X_L}{2\pi f} = \dfrac{20\ \Omega}{(6.28)(2\text{ kHz})} = \mathbf{1.59\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(6.28)(2\text{ kHz})(20\ \Omega)} = \mathbf{3.98\ \mu F}$

d. $f_2 = f_s + BW/2 = 2000\text{ Hz} + 100\text{ Hz} = \mathbf{2100\ Hz}$

$f_1 = f_s - BW/2 = 2000\text{ Hz} - 100\text{ Hz} = \mathbf{1900\ Hz}$

9. $I_M = \dfrac{E}{R} \Rightarrow R = \dfrac{E}{I_M} = \dfrac{5\text{ V}}{500\text{ mA}} = \mathbf{10\ \Omega}$

$BW = f_s/Q_s \Rightarrow Q_s = f_s/BW = 8400\text{ Hz}/120\text{ Hz} = 70$

$Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = (70)(10\ \Omega) = \mathbf{700\ \Omega}$

$X_C = X_L = \mathbf{700\ \Omega}$

$L = \dfrac{X_L}{2\pi f} = \dfrac{700\ \Omega}{(2\pi)(8.4\text{ kHz})} = \mathbf{13.26\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{(2\pi)(8.4\text{ kHz})(0.7\text{ k}\Omega)} = \mathbf{27.07\ nF}$

$f_2 = f_s + BW/2 = 8400\text{ Hz} + 120\text{ Hz}/2 = \mathbf{8460\ Hz}$

$f_1 = f_s - BW/2 = 8400\text{ Hz} - 60\text{ Hz} = \mathbf{8340\ Hz}$

11. a. $f_s = \dfrac{\omega_s}{2\pi} = \dfrac{2\pi \times 10^6\text{ rad/s}}{2\pi} = \mathbf{1\ MHz}$

b. $\dfrac{f_2 - f_1}{f_s} = 0.16 \Rightarrow BW = f_2 - f_1 = 0.16 f_s = 0.16(1\text{ MHz}) = \mathbf{160\ kHz}$

c. $P = \dfrac{V_R^2}{R} \Rightarrow R = \dfrac{V_R^2}{P} = \dfrac{(120\text{ V})^2}{20\text{ W}} = \mathbf{720\ \Omega}$

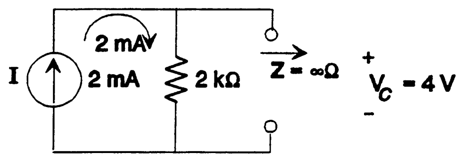
$BW = \dfrac{R}{2\pi L} \Rightarrow L = \dfrac{R}{2\pi BW} = \dfrac{720\ \Omega}{(6.28)(160\text{ kHz})} = \mathbf{0.7162\ mH}$

$f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow C = \dfrac{1}{4\pi^2 f_s^2 L} = \dfrac{1}{4\pi^2(10^6\text{ Hz})^2(0.7162\text{ mH})} = \mathbf{35.37\ pF}$

d. $Q_\ell = \dfrac{X_L}{R_\ell} = 80 \Rightarrow R_\ell = \dfrac{X_L}{80} = \dfrac{2\pi f_s L}{80} = \dfrac{2\pi(10^6\text{ Hz})(0.7162\text{ mH})}{80} = \mathbf{56.25\ \Omega}$

13. a. $f_p = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.1\text{ mH})(10\text{ nF})}} = \mathbf{159.155\ kHz}$

b.



c. $I_L = \dfrac{V_L}{X_L} = \dfrac{4\text{ V}}{2\pi f_p L} = \dfrac{4\text{ V}}{100\ \Omega} = \mathbf{40\ mA}$

$I_C = \dfrac{V_L}{X_C} = \dfrac{4\text{ V}}{1/2\pi f_p C} = \dfrac{4\text{ V}}{100\ \Omega} = \mathbf{40\ mA}$

d. $Q_p = \dfrac{R_s}{X_{L_p}} = \dfrac{2\text{ k}\Omega}{2\pi f_p L} = \dfrac{2\text{ k}\Omega}{100\ \Omega} = \mathbf{20}$

15. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.1\text{ mH})(2\ \mu\text{F})}} = \mathbf{11{,}253.95\ Hz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f_s L}{R_\ell} = \dfrac{2\pi(11{,}253.95\text{ Hz})(0.1\text{ mH})}{4\ \Omega} = \mathbf{1.77}$ (low Q_ℓ)

c. $f_p = f_s\sqrt{1 - \dfrac{R_\ell^2 C}{L}} = 11{,}253.95\text{ Hz}\sqrt{1 - \dfrac{(4\ \Omega)^2\ 2\ \mu\text{F}}{0.1\text{ mH}}} = 11{,}253.95\text{ Hz}(0.825)$

$= \mathbf{9{,}280.24\ Hz}$

$f_m = f_s\sqrt{1 - \dfrac{1}{4}\left[\dfrac{R_\ell^2 C}{L}\right]} = 11{,}253.95\text{ Hz}\sqrt{1 - \dfrac{1}{4}\left[\dfrac{(4\ \Omega)^2\ 2\ \mu\text{F}}{0.1\text{ mH}}\right]}$

$= 11{,}253.95\text{ Hz}(0.996) = \mathbf{10{,}794.41\ Hz}$

d. $X_L = 2\pi f_p L = 2\pi(9{,}280.24 \text{ Hz})(0.1 \text{ mH}) = \mathbf{5.83\ \Omega}$

$X_C = \dfrac{1}{2\pi f_p C} = \dfrac{1}{2\pi(9{,}280.24 \text{ Hz})(2\ \mu\text{F})} = \mathbf{8.57\ \Omega}$

$X_L \neq X_C,\ X_C > X_L$

e. $Z_{T_p} = R_s \| R_p = R_s \| \left[\dfrac{R_\ell^2 + X_L^2}{R_\ell}\right] = \dfrac{R_\ell^2 + X_L^2}{R_\ell} = \dfrac{(4\ \Omega)^2 + (5.83\ \Omega)^2}{4\ \Omega} = \mathbf{12.5\ \Omega}$

f. $V_C = IZ_{T_p} = (2 \text{ mA})(12.5\ \Omega) = \mathbf{25\ mV}$

g. Since $R_s = \infty\ \Omega$ $\quad Q_p = Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi f_p L}{R_\ell} = \dfrac{2\pi(9{,}280.24 \text{ Hz})(0.1 \text{ mH})}{4\ \Omega} = \mathbf{1.46}$

$BW = \dfrac{f_p}{Q_p} = \dfrac{9{,}280.24 \text{ Hz}}{1.46} = \mathbf{6.356\ kHz}$

h. $I_C = \dfrac{V_C}{X_C} = \dfrac{25 \text{ mV}}{8.57\ \Omega} = \mathbf{2.92\ mA}$

$I_L = \dfrac{V_L}{Z_{R\text{-}L}} = \dfrac{V_C}{R_\ell + jX_L} = \dfrac{25 \text{ mV}}{4\ \Omega + j5.83\ \Omega} = \dfrac{25 \text{ mV}}{7.07\ \Omega} = \mathbf{3.54\ mA}$

17. a. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{30\ \Omega}{2\ \Omega} = 15$ (use approximate approach): $X_C = X_L = \mathbf{30\ \Omega}$

b. $Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 450\ \Omega \| (15)^2\, 2\ \Omega = 450\ \Omega \| 450\ \Omega = \mathbf{225\ \Omega}$

c. $\mathbf{E} = \mathbf{I}\mathbf{Z}_{T_p} = (80 \text{ mA} \angle 0°)(225\ \Omega \angle 0°) = \mathbf{18\ V \angle 0°}$

$\mathbf{I}_C = \dfrac{\mathbf{E}}{X_C \angle -90°} = \dfrac{18 \text{ V} \angle 0°}{30\ \Omega \angle -90°} = \mathbf{0.6\ A \angle 90°}$

$\mathbf{I}_L = \dfrac{\mathbf{E}}{\mathbf{Z}_{R\text{-}L}} = \dfrac{18 \text{ V} \angle 0°}{2\ \Omega + j30\ \Omega} = \dfrac{18 \text{ V} \angle 0°}{30.07\ \Omega \angle 86.19°} \cong \mathbf{0.6\ A \angle -86.19°}$

d. $X_L = 2\pi f_p L,\ L = \dfrac{X_L}{2\pi f_p} = \dfrac{30\ \Omega}{2\pi(20 \times 10^3 \text{ Hz})} = \mathbf{0.239\ mH}$

$X_C = \dfrac{1}{2\pi f_p C},\ C = \dfrac{1}{2\pi f_p X_C} = \dfrac{1}{2\pi(20 \times 10^3 \text{ Hz})(30\ \Omega)} = \mathbf{265.26\ nF}$

e. $Q_p = \dfrac{Z_{T_p}}{X_L} = \dfrac{225\ \Omega}{30\ \Omega} = \mathbf{7.5},\ BW = \dfrac{f_p}{Q_p} = \dfrac{20{,}000 \text{ Hz}}{7.5} = \mathbf{2.67\ kHz}$

19. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\text{ mH})(1\ \mu\text{F})}} = \mathbf{7.118\ kHz}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 7.118\text{ kHz}\sqrt{1 - \frac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\text{ mH}}} = 7.118\text{ kHz}(0.9338) = \mathbf{6.647\ kHz}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 7.118\text{ kHz}\sqrt{1 - \frac{1}{4}\left[\frac{(8\ \Omega)^2(1\ \mu\text{F})}{0.5\text{ mH}}\right]} = 7.118\text{ kHz }(0.9839)$$
$$= \mathbf{7\ kHz}$$

b. $X_L = 2\pi f_p L = 2\pi(6.647\text{ kHz})(0.5\text{ mH}) = 20.88\ \Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(6.647\text{ kHz})(1\ \mu\text{F})} = 23.94\ \Omega$

$X_C > X_L$ (low Q)

c. $Z_{T_p} = R_s \| R_p = R_s \| \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 500\ \Omega \| \dfrac{(8\ \Omega)^2 + (20.88\ \Omega)^2}{8\ \Omega} = 500\ \Omega \| 62.5\ \Omega$

$= \mathbf{55.56\ \Omega}$

d. $Q_p = \dfrac{Z_{T_p}}{X_{L_p}} = \dfrac{55.56\ \Omega}{23.94\ \Omega} = \mathbf{2.32}$

$BW = \dfrac{f_p}{Q_p} = \dfrac{6.647\text{ kHz}}{2.32} = \mathbf{2.865\ kHz}$

e. One method: $V_C = IZ_{T_p} = (40\text{ mA})(55.56\ \Omega) = 2.22\text{ V}$

$I_C = \dfrac{V_C}{X_C} = \dfrac{2.22\text{ V}}{23.94\ \Omega} = \mathbf{92.73\ mA}$

$I_L = \dfrac{|V_C|}{|R_\ell + jX_L|} = \dfrac{2.22\text{ V}}{|8 + j20.88|} = \dfrac{2.22\text{ V}}{22.36\ \Omega} = \mathbf{99.28\ mA}$

f. $V_C = \mathbf{2.22\ V}$

21. a. $Q_\ell = 20 > 10 \therefore f_p = f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(200\text{ mH})(10\text{ nF})}} = \mathbf{3558.81\ Hz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi fL}{R_\ell} \Rightarrow R_\ell = \dfrac{2\pi fL}{Q_\ell} = \dfrac{2\pi(3558.81\text{ Hz})(0.2\text{ H})}{20} = 223.61\ \Omega$

$Z_{T_p} = R_s \| R_p = R_s \| Q_\ell^2 R_\ell = 40\text{ k}\Omega \| (20)^2\, 223.61\ \Omega$

$Z_{T_p} = 27.64\text{ k}\Omega$

$V_C = IZ_{T_p} = (5\text{ mA})(27.64\text{ k}\Omega) = \mathbf{138.2\ V}$

c. $P = I^2R = (5\text{ mA})^2 27.64\text{ k}\Omega = \mathbf{691\ mW}$

d. $$Q_p = \frac{R}{X_L} = \frac{R_s \| R_p}{X_L} = \frac{27.64\text{ k}\Omega}{2\pi(3558.81\text{ Hz})(0.2\text{ H})} = \mathbf{6.18}$$

$$BW = \frac{f_p}{Q_p} = \frac{3558.81\text{ Hz}}{6.18} = \mathbf{575.86\text{ Hz}}$$

23. a. $$X_C = \frac{R_\ell^2 + X_L^2}{X_L} \Rightarrow X_L^2 - X_L X_C + R_\ell^2 = 0$$

$$X_L^2 - 100\,X_L + 144 = 0$$

$$X_L = \frac{-(-100) \pm \sqrt{(100)^2 - 4(1)(144)}}{2}$$

$$= 50\ \Omega \pm \frac{\sqrt{10^4 - 576}}{2} = 50\ \Omega \pm 48.54\ \Omega$$

$$X_L = \mathbf{98.54\ \Omega}\text{ or } 1.46\ \Omega$$

b. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{98.54\ \Omega}{12\ \Omega} = \mathbf{8.21}$$

c. $$Q_p = \frac{R_s \| R_p}{X_{L_p}} = \frac{40\text{ k}\Omega \left\| \dfrac{R_\ell^2 + X_L^2}{R_\ell}\right.}{X_C} = \frac{40\text{ k}\Omega \left\| \dfrac{(12\ \Omega)^2 + (98.54\ \Omega)^2}{12\ \Omega}\right.}{100\ \Omega}$$

$$= \frac{40\text{ k}\Omega \| 821.18\ \Omega}{100\ \Omega} = \frac{804.66\ \Omega}{100\ \Omega} = \mathbf{8.05}$$

$$BW = f_p/Q_p \Rightarrow f_p = Q_p BW = (8.05)(1\text{ kHz}) = \mathbf{8.05\text{ kHz}}$$

d. $$V_{C_{max}} = IZ_{T_p} = (6\text{ mA})(804.66\ \Omega) = \mathbf{4.83\text{ V}}$$

e. $$f_2 = f_p + BW/2 = 8.05\text{ kHz} + \frac{1\text{ kHz}}{2} = \mathbf{8.55\text{ kHz}}$$

$$f_1 = f_p - BW/2 = 8.05\text{ kHz} - \frac{1\text{ kHz}}{2} = \mathbf{7.55\text{ kHz}}$$

25. $$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi f_p L}{R_\ell} \Rightarrow R_\ell = \frac{2\pi f_p L}{Q_\ell} = \frac{2\pi(20\text{ kHz})(2\text{ mH})}{80} = \mathbf{3.14\ \Omega}$$

$$BW = f_p/Q_p \Rightarrow Q_p = f_p/BW = 20\text{ kHz}/1.8\text{ kHz} = \mathbf{11.11}$$

High Q ∴ $$f_p \cong f_s = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{4\pi^2 f_p^2 L} = \frac{1}{4\pi^2(20\text{ kHz})^2\ 2\text{ mH}} = \mathbf{31.66\text{ nF}}$$

$$Q_p = \frac{R}{X_C} \Rightarrow R = Q_p X_C = \frac{Q_p}{2\pi f_p C} = \frac{11.11}{2\pi(20\text{ kHz})(31.66\text{ nF})} = \mathbf{2.793\text{ k}\Omega}$$

$$R_p = Q_\ell^2 R_\ell = (80)^2\ 3.14\ \Omega = 20.1\text{ k}\Omega$$

$$R = R_s \| R_p = \frac{R_s R_p}{R_s + R_p} \Rightarrow R_s = \frac{R_p R}{R_p - R} = \frac{(20.1 \text{ k}\Omega)(2.793 \text{ k}\Omega)}{20.1 \text{ k}\Omega - 2.793 \text{ k}\Omega} = \mathbf{3.244 \text{ k}\Omega}$$

27. a. $$f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(200 \ \mu\text{H})(2 \text{ nF})}} = 251.65 \text{ kHz}$$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65 \text{ kHz})(200 \ \mu\text{H})}{20 \ \Omega} = 15.81 \geq 10$$

$$\therefore f_p = f_s = \mathbf{251.65 \text{ kHz}}$$

b. $$Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 40 \text{ k}\Omega \| (15.81)^2 \, 20 \ \Omega = \mathbf{4.444 \text{ k}\Omega}$$

c. $$Q_p = \frac{R_s \| Q_\ell^2 R_\ell}{X_L} = \frac{4.444 \text{ k}\Omega}{316.23 \ \Omega} = \mathbf{14.05}$$

d. $$BW = \frac{f_p}{Q_p} = \frac{251.65 \text{ kHz}}{14.05} = \mathbf{17.91 \text{ kHz}}$$

e. **20 μH, 20 nF**

f_s the same since product LC the same

$f_s = 251.65$ kHz

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65 \text{ kHz})(20 \ \mu\text{H})}{20 \ \Omega} = 1.581$$

Low Q_ℓ:

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = (251.65 \text{ kHz})\sqrt{1 - \frac{(20 \ \Omega)^2(20 \text{ nF})}{20 \ \mu\text{H}}}$$

$$= (251.65 \text{ kHz})(0.775) = \mathbf{194.93 \text{ kHz}}$$

$$X_L = 2\pi f_p L = 2\pi(194.93 \text{ kHz})(20 \ \mu\text{H}) = 24.496 \ \Omega$$

$$R_p = \frac{R_\ell^2 + X_L^2}{R_\ell} = \frac{(20 \ \Omega)^2 + (24.496 \ \Omega)^2}{20 \ \Omega} = 50 \ \Omega$$

$$Z_{T_p} = R_s \| R_p = 40 \text{ k}\Omega \| 50 \ \Omega = \mathbf{49.94 \ \Omega}$$

$$Q_p = \frac{R}{X_L} = \frac{49.94 \ \Omega}{24.496 \ \Omega} = \mathbf{2.04}$$

$$BW = \frac{f_p}{Q_p} = \frac{194.93 \text{ kHz}}{2.04} = \mathbf{95.55 \text{ kHz}}$$

f. **0.4 mH, 1 nF**

$f_s = 251.65$ kHz since LC product the same

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi(251.65 \text{ kHz})(0.4 \text{ mH})}{20 \ \Omega} = 31.62 \geq 10$$

$$\therefore f_p = f_s = \mathbf{251.65 \text{ kHz}}$$

$$Z_{T_p} = R_s \| Q_\ell^2 R_\ell = 40 \text{ k}\Omega \| (31.62)^2 \, 20 \ \Omega = 40 \text{ k}\Omega \| (\cong 20 \text{ k}\Omega) \cong \mathbf{13.33 \text{ k}\Omega}$$

$$Q_p = \frac{R_s \| Q_l^2 R_l}{X_L} = \frac{13.33\ \text{k}\Omega}{632.47\ \Omega} = \mathbf{21.08}$$

$$BW = \frac{f_p}{Q_p} = \frac{251.65\ \text{kHz}}{21.08} = \mathbf{11.94\ kHz}$$

g. Network $\dfrac{L}{C} = \dfrac{200\ \mu\text{H}}{2\ \text{nF}} = \mathbf{100 \times 10^3}$

part (e) $\dfrac{L}{C} = \dfrac{20\ \mu\text{H}}{20\ \text{nF}} = \mathbf{1 \times 10^3}$

part (f) $\dfrac{L}{C} = \dfrac{0.4\ \text{mH}}{1\ \text{nF}} = \mathbf{400 \times 10^3}$

h. Yes, as $\dfrac{L}{C}$ ratio increased BW decreased.

Also, $V_p = IZ_{T_p}$, and for a fixed I, Z_{T_p} and therefore V_p will increase with increase in the L/C ratio.

CHAPTER 20 (Even)

2. a. $X_C = \mathbf{30\ \Omega}$ b. $Z_{T_s} = \mathbf{10\ \Omega}$ c. $I = \dfrac{E}{Z_{T_s}} = \dfrac{50\text{ mV}}{10\ \Omega} = \mathbf{5\ mA}$

d. $V_R = IR = (5\text{ mA})(10\ \Omega) = \mathbf{50\ mV} = \text{E}$
$V_L = IX_L = (5\text{ mA})(30\ \Omega) = \mathbf{150\ mV}$
$V_C = IX_C = (5\text{ mA})(30\ \Omega) = \mathbf{150\ mV}$
$V_L = V_C$

e. $Q_s = \dfrac{X_L}{R} = \dfrac{30\ \Omega}{10\ \Omega} = \mathbf{3}$ (low Q) f. $P = I^2R = (5\text{ mA})^2\ 10\ \Omega = \mathbf{0.25\ mW}$

4. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow L = \dfrac{1}{(2\pi f_s)^2 C} = \dfrac{1}{(2\pi\ 1.8\text{ kHz})^2\ 2\ \mu\text{F}} = \mathbf{3.91\ mH}$

b. $X_L = 2\pi fL = 2\pi(1.8\text{ kHz})(3.91\text{ mH}) = \mathbf{44.2\ \Omega}$
$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(1.8\text{ kHz})(2\ \mu\text{F})} = \mathbf{44.2\ \Omega}$
$X_L = X_C$

c. $E_{\text{rms}} = (0.707)(20\text{ mV}) = 14.14\text{ mV}$
$I_{\text{rms}} = \dfrac{E_{\text{rms}}}{R} = \dfrac{14.14\text{ mV}}{4.7\ \Omega} = \mathbf{3.01\ mA}$

d. $P = I^2R = (3.01\text{ mA})^2\ 4.7\ \Omega = \mathbf{42.58\ \mu W}$

e. $S_T = P_T = \mathbf{42.58\ \mu VA}$ f. $F_p = \mathbf{1}$

g. $Q_s = \dfrac{X_L}{R} = \dfrac{44.2\ \Omega}{4.7\ \Omega} = \mathbf{9.4}$
$BW = \dfrac{f_s}{Q_s} = \dfrac{1.8\text{ kHz}}{9.4} = \mathbf{191.49\ Hz}$

h. $$f_2 = \frac{1}{2\pi}\left[\frac{R}{2L} + \frac{1}{2}\sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}\right]$$
$$= \frac{1}{2\pi}\left[\frac{4.7\ \Omega}{2(3.91\text{ mH})} + \frac{1}{2}\sqrt{\left(\frac{4.7\ \Omega}{3.91\text{ mH}}\right)^2 + \frac{4}{(3.91\text{ mH})(2\ \mu\text{F})}}\right]$$
$$= \frac{1}{2\pi}[601.02 + 11.324 \times 10^3]$$
$$= \mathbf{1897.93\ Hz}$$

$$f_1 = \frac{1}{2\pi}\left[-\frac{R}{2L} + \frac{1}{2}\sqrt{\left(\frac{R}{L}\right)^2 + \frac{4}{LC}}\right]$$

$$= \frac{1}{2\pi}[-601.02 + 11.324 \times 10^3]$$

$$= \mathbf{1.707\ kHz}$$

$$P_{HPF} = \frac{1}{2}P_{max} = \frac{1}{2}(42.58\ \mu W) = \mathbf{21.29\ \mu W}$$

6. a. $L = \dfrac{X_L}{2\pi f} = \dfrac{200\ \Omega}{2\pi(10^4\ Hz)} = 3.185\ mH$

$BW = \dfrac{R}{2\pi L} = \dfrac{5\ \Omega}{2\pi(3.185\ mH)} \cong \mathbf{250\ Hz}$

or $Q_s = \dfrac{X_L}{R} = \dfrac{X_C}{R} = \dfrac{200\ \Omega}{5\ \Omega} = 40$, $BW = \dfrac{f_s}{Q_s} = \dfrac{10{,}000\ Hz}{40} = \mathbf{250\ Hz}$

b. $f_2 = f_s + BW/2 = 10{,}000\ Hz + 250\ Hz/2 = \mathbf{10{,}125\ Hz}$
$f_1 = f_s - BW/2 = 10{,}000\ Hz - 125\ Hz = \mathbf{9{,}875\ Hz}$

c. $Q_s = \dfrac{X_L}{R} = \dfrac{200\ \Omega}{5\ \Omega} = \mathbf{40}$

d. $\mathbf{I} = \dfrac{E\angle 0°}{R\angle 0°} = \dfrac{30\ V\ \angle 0°}{5\ \Omega\ \angle 0°} = 6\ A\ \angle 0°$, $\mathbf{V}_L = (I\ \angle 0°)(X_L\ \angle 90°)$

$= (6\ A\ \angle 0°)(200\ \Omega\ \angle 90°)$
$= \mathbf{1200\ V\ \angle 90°}$

$\mathbf{V}_C = (I\ \angle 0°)(X_C\ \angle -90°) = \mathbf{1200\ V\ \angle -90°}$

e. $P = I^2R = (6\ A)^2\ 5\ \Omega = \mathbf{180\ W}$

8. a. $BW = 6000\ Hz - 5400\ Hz = \mathbf{600\ Hz}$

b. $BW = f_s/Q_s \Rightarrow f_s = Q_sBW = (9.5)(600\ Hz) = \mathbf{5700\ Hz}$

c. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = X_C = Q_sR = (9.5)(2\ \Omega) = \mathbf{19\ \Omega}$

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{19\ \Omega}{2\pi(5700\ Hz)} = \mathbf{0.531\ mH}$

$C = \dfrac{1}{2\pi f X_C} = \dfrac{1}{2\pi(5.7\ kHz)(19\ \Omega)} = \mathbf{1.47\ \mu F}$

10. $Q_s = \dfrac{X_L}{R} \Rightarrow X_L = Q_sR = 20(2\ \Omega) = \mathbf{40\ \Omega} = X_C$

$BW = \dfrac{f_s}{Q_s} \Rightarrow f_s = Q_sBW = (20)(400\ Hz) = \mathbf{8\ kHz}$

$$L = \frac{X_L}{2\pi f} = \frac{40\ \Omega}{2\pi(8\ \text{kHz})} = \mathbf{0.796\ mH}$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(8\ \text{kHz})(40\ \Omega)} = \mathbf{0.497\ \mu F}$$

$$f_2 = f_s + BW/2 = 8000\ \text{Hz} + 400\ \text{Hz}/2 = \mathbf{8200\ Hz}$$

$$f_1 = f_s - BW/2 = 8000\ \text{Hz} - 200\ \text{Hz} = \mathbf{7800\ Hz}$$

12. a. $Q_\ell = \dfrac{X_L}{R_\ell}$

$$R_\ell = \frac{X_L}{Q_\ell} = \frac{2\pi fL}{Q_\ell} = \frac{2\pi(1\ \text{MHz})(100\ \mu\text{H})}{12.5} = 50.27\ \Omega$$

$$\frac{f_2 - f_1}{f_s} = \frac{1}{Q_s} = 0.2$$

$$Q_s = \frac{1}{0.2} = 5 = \frac{X_L}{R} = \frac{2\pi fL}{R} = \frac{2\pi(1\ \text{MHz})(100\ \mu\text{H})}{R} = \frac{628.32\ \Omega}{R}$$

$$R = \frac{628.32\ \Omega}{5} = 125.66$$

$$R = R_d + R_\ell$$

$$125.66\ \Omega = R_d + 50.27\ \Omega$$

and $R_d = 125.66\ \Omega - 50.27\ \Omega = \mathbf{75.39\ \Omega}$

c. $X_C = \dfrac{1}{2\pi fC} = X_L$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(1\ \text{MHz})(628.32\ \Omega)} = \mathbf{253.3\ pF}$$

14. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\ \text{mH})(30\ \text{nF})}} = \mathbf{41.09\ kHz}$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{2\pi fL}{R_\ell} = \dfrac{2\pi(41.09\ \text{kHz})(0.5\ \text{mH})}{8\ \Omega} = \mathbf{16.14} \geq 10$ (yes)

c. Since $Q_\ell \geq 10, f_p \cong f_s = \mathbf{41.09\ kHz}$

d. $X_L = 2\pi f_p L = 2\pi(41.09\ \text{kHz})(0.5\ \text{mH}) = \mathbf{129.1\ \Omega}$

$$X_C = \frac{1}{2\pi f_p C} = \frac{1}{2\pi(41.09\ \text{kHz})(30\ \text{nF})} = \mathbf{129.1\ \Omega}$$

$$X_L = X_C$$

e. $Z_{T_p} = Q_\ell^2 R\ell = (16.14)^2\ 8\ \Omega = \mathbf{2.084\ k\Omega}$

f. $V_C = IZ_{T_p} = (10\ \text{mA})(2.084\ \text{k}\Omega) = \mathbf{20.84\ V}$

g. $Q_\ell \geq 10,\ Q_p = Q_\ell = \mathbf{16.14}$

$$BW = \frac{f_p}{Q_p} = \frac{41.09\ \text{kHz}}{16.14} = \mathbf{2545.85\ Hz}$$

h. $I_L = I_C = Q_\ell I_T = (16.14)(10\text{ mA}) = \mathbf{161.4\ mA}$

16. a. $Q_\ell = \dfrac{X_L}{R_L} = \dfrac{100\ \Omega}{20\ \Omega} = 5 \le 10$

$$\therefore \frac{X_L}{R_\ell^2 + X_L^2} = \frac{1}{X_C} \Rightarrow X_C = \frac{R_\ell^2 + X_L^2}{X_L} = \frac{(20\ \Omega)^2 + (100\ \Omega)^2}{100\ \Omega} = \mathbf{104\ \Omega}$$

b. $Z_T = R_s \| R_p = R_s \| \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 1000\ \Omega \| \dfrac{10{,}400\ \Omega}{20} = \mathbf{342.11\ \Omega}$

c. $\mathbf{E} = \mathbf{I}\mathbf{Z}_{T_p} = (5\text{ mA}\ \angle 0°)(342.11\ \Omega\ \angle 0°) = 1.711\text{ V}\ \angle 0°$

$$\mathbf{I}_C = \frac{\mathbf{E}}{X_C\ \angle -90°} = \frac{1.711\text{ V}\ \angle 0°}{104\ \Omega\ \angle -90°} = \mathbf{16.45\ mA\ \angle 90°}$$

$$\mathbf{Z}_L = 20\ \Omega + j100\ \Omega = 101.98\ \Omega\ \angle 78.69°$$

$$\mathbf{I}_L = \frac{\mathbf{E}}{\mathbf{Z}_L} = \frac{1.711\text{ V}\ \angle 0°}{101.98\ \Omega\ \angle 78.69°} = \mathbf{16.78\ mA\ \angle -78.69°}$$

d. $L = \dfrac{X_L}{2\pi f} = \dfrac{100\ \Omega}{2\pi(20\text{ kHz})} = \mathbf{0.796\ mH}$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(20\text{ kHz})(104\ \Omega)} = \mathbf{76.52\ nF}$$

e. $Q_p = \dfrac{R}{X_C} = \dfrac{342.11\ \Omega}{104\ \Omega} = \mathbf{3.29}$

$$BW = f_p/Q_p = 20{,}000\text{ Hz}/3.29 = \mathbf{6079.03\ Hz}$$

18. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(80\ \mu\text{H})(0.03\ \mu\text{F})}} = \mathbf{102.73\ kHz}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 102.73\text{ kHz}\sqrt{1 - \frac{(1.5\ \Omega)^2\ 0.03\ \mu\text{F}}{80\ \mu\text{H}}} = 102.73\text{ kHz}(.99958)$$

$$= \mathbf{102.69\ kHz}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 102.73\text{ kHz}(0.99989) = \mathbf{102.72\ kHz}$$

Since $f_s \cong f_p \cong f_m \Rightarrow$ high Q_p

b. $X_L = 2\pi f_p L = 2\pi(102.69\text{ kHz})(80\ \mu\text{H}) = \mathbf{51.62\ \Omega}$

$$X_C = \frac{1}{2\pi f_p C} = \frac{1}{2\pi(102.69\text{ kHz})(0.03\ \mu\text{F})} = \mathbf{51.66\ \Omega}$$

$$X_L \cong X_C$$

c. $Z_{T_p} = R_s \| Q_\ell^2 R_\ell$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{51.62\ \Omega}{1.5\ \Omega} = 34.41$$

$$Z_{T_p} = 10\ \text{k}\Omega \| (34.41)^2 1.5\ \Omega = 10\ \text{k}\Omega \| 1.776\ \text{k}\Omega = \mathbf{1.51\ k\Omega}$$

d. $Q_p = \dfrac{R_s \| Q_\ell^2 R_\ell}{X_L} = \dfrac{Z_{T_p}}{X_L} = \dfrac{1.51\ \text{k}\Omega}{51.62\ \Omega} = \mathbf{29.25}$

$$BW = \frac{f_p}{Q_p} = \frac{102.69\ \text{kHz}}{29.25} = \mathbf{3.51\ kHz}$$

e. $I_T = \dfrac{R_s I_s}{R_s + Q_\ell^2 R_\ell} = \dfrac{10\ \text{k}\Omega(10\ \text{mA})}{10\ \text{k}\Omega + 1.78\ \text{k}\Omega} = 8.49\ \text{mA}$

$$I_C = I_L \cong Q_\ell I_T = (34.41)(8.49\ \text{mA}) = \mathbf{292.14\ mA}$$

f. $V_C = IZ_{T_p} = (10\ \text{mA})(1.51\ \text{k}\Omega) = \mathbf{15.1\ V}$

20. a. $Z_{T_p} = \dfrac{R_\ell^2 + X_L^2}{R_\ell} = 50\ \text{k}\Omega$

$$(50\ \Omega)^2 + X_L^2 = (50\ \text{k}\Omega)(50\ \Omega)$$

$$X_L = \sqrt{250 \times 10^4 - 2.5 \times 10^3} = \mathbf{1580.3\ \Omega}$$

b. $Q = \dfrac{X_L}{R_\ell} = \dfrac{1580.3}{50} = 31.61 \geq 10$

$$\therefore X_C = X_L = \mathbf{1580.3\ \Omega}$$

c. $X_L = 2\pi f_p L \Rightarrow f_p = \dfrac{X_L}{2\pi L} = \dfrac{1580.3\ \Omega}{2\pi(16\ \text{mH})} = \mathbf{15.72\ kHz}$

d. $X_C = \dfrac{1}{2\pi f_p C} \Rightarrow C = \dfrac{1}{2\pi f_s X_C} = \dfrac{1}{2\pi(15.72\ \text{kHz})(1580.3\ \Omega)} = \mathbf{6.4\ nF}$

22. a. Ratio of X_C to R_ℓ suggests high Q system.

$\therefore X_L = \mathbf{400\ \Omega} = X_C$

b. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{400\ \Omega}{8\ \Omega} = \mathbf{50}$

c. $Q_p = \dfrac{R}{X_L} = \dfrac{R_s \| R_p}{X_L} = \dfrac{R_s \| Q_\ell^2 R_\ell}{X_L} = \dfrac{20\ \text{k}\Omega \| (50)^2\ 8\ \Omega}{400\ \Omega} = \dfrac{10\ \text{k}\Omega}{400\ \Omega} = \mathbf{25}$

$$BW = \frac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (25)(1000\ \text{Hz}) = \mathbf{25\ kHz}$$

d. $V_{C_{max}} = IZ_{T_p} = (0.1\ \text{mA})(10\ \text{k}\Omega) = \mathbf{1\ V}$

e. $f_2 = f_p + BW/2 = 25\text{ kHz} + \dfrac{1\text{ kHz}}{2} = \mathbf{25.5\text{ kHz}}$

$f_1 = f_p - BW/2 = 25\text{ kHz} - \dfrac{1\text{ kHz}}{2} = \mathbf{24.5\text{ kHz}}$

24. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(0.5\text{ mH})(30\text{ nF})}} = \mathbf{41.09\text{ kHz}}$

$$f_p = f_s\sqrt{1 - \frac{R_\ell^2 C}{L}} = 41.09\text{ kHz}\sqrt{1 - \frac{(6\ \Omega)^2\ 30\text{ nF}}{0.5\text{ mH}}} = 41.09\text{ kHz}(0.9978) = \mathbf{41\text{ kHz}}$$

$$f_m = f_s\sqrt{1 - \frac{1}{4}\left[\frac{R_\ell^2 C}{L}\right]} = 41.09\text{ kHz}\sqrt{1 - \frac{1}{4}\left[\frac{(6\ \Omega)^2(30\text{ nF})}{0.5\text{ mH}}\right]} = 41.09\text{ kHz}(0.0995)$$
$$= \mathbf{41.07\text{ kHz}}$$

b. $\mathbf{I} = \dfrac{80\text{ V}\ \angle 0°}{20\text{ k}\Omega\ \angle 0°} = 4\text{ mA}\ \angle 0°,\ R_s = 20\text{ k}\Omega$

$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi f L}{R_\ell} = \frac{2\pi(41\text{ kHz})(0.5\text{ mH})}{6\ \Omega} = \mathbf{21.47}\text{ (high } Q \text{ coil)}$$

$$Q_p = \frac{R_s \| R_p}{X_{L_p}} = \frac{R_s \left\| \dfrac{R_\ell^2 + X_L^2}{R_\ell}\right.}{\dfrac{R_\ell^2 + X_L^2}{X_L}} = \frac{20\text{ k}\Omega \left\| \dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{6\ \Omega}\right.}{\dfrac{(6\ \Omega)^2 + (128.81\ \Omega)^2}{128.81\ \Omega}}$$

$$= \frac{20\text{ k}\Omega \| 2.771\text{ k}\Omega}{129.09\ \Omega} = \frac{2.434\text{ k}\Omega}{129.09\ \Omega} = \mathbf{18.86}\text{ (high } Q_p\text{)}$$

c. $Z_{T_p} = R_s \| R_p = 20\text{ k}\Omega \| 2.771\text{ k}\Omega = \mathbf{2.434\text{ k}\Omega}$

d. $V_C = IZ_{T_p} = (4\text{ mA})(2.434\text{ k}\Omega) = \mathbf{9.736\text{ V}}$

e. $BW = \dfrac{f_p}{Q_p} = \dfrac{41\text{ kHz}}{18.86} = \mathbf{2.174\text{ kHz}}$

f. $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi(41\text{ kHz})(30\text{ nF})} = \mathbf{129.39\ \Omega}$

$$I_C = \frac{V_C}{X_C} = \frac{9.736\text{ V}}{129.39\ \Omega} = \mathbf{75.25\text{ mA}}$$

$$I_L = \frac{V_C}{|R + jX_L|} = \frac{9.736\text{ V}}{6\ \Omega + j128.81\ \Omega} = \frac{9.736\text{ V}}{128.95\ \Omega} = \mathbf{75.50\text{ mA}}$$

26. $V_{C_{\max}} = IZ_{T_p} \Rightarrow Z_{T_p} = \dfrac{V_{C_{\max}}}{I} = \dfrac{1.8\text{ V}}{0.2\text{ mA}} = 9\text{ k}\Omega$

$$Q_p = \frac{R}{X_L} = \frac{R_s \| R_p}{X_L} = \frac{R_p}{X_L} \Rightarrow X_L = \frac{R_p}{Q_p} = \frac{9\text{ k}\Omega}{30} = \mathbf{300\ \Omega} = X_C$$

$$BW = \frac{f_p}{Q_p} \Rightarrow f_p = Q_p BW = (30)(500\text{ Hz}) = \mathbf{15\ kHz}$$

$$L = \frac{X_L}{2\pi f} = \frac{300\ \Omega}{2\pi(15\text{ kHz})} = \mathbf{3.18\ mH}$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(15\text{ kHz})(300\ \Omega)} = \mathbf{35.37\ nF}$$

$$Q_p = Q_\ell(R_s = \infty\ \Omega) = \frac{X_L}{R_\ell} \Rightarrow R_\ell = \frac{X_L}{Q_p} = \frac{300\ \Omega}{30} = \mathbf{10\ \Omega}$$

CHAPTER 21 (Odd)

1. a. $M = k\sqrt{L_pL_s} \Rightarrow L_s = \dfrac{M^2}{L_pk^2} = \dfrac{(80\text{ mH})^2}{(50\text{ mH})(0.8)^2} = \mathbf{0.2\ H}$

b. $e_p = N_p\dfrac{d\phi_p}{dt} = (20)(0.08\text{ Wb/s}) = \mathbf{1.6\ V}$

$e_s = kN_s\dfrac{d\phi_p}{dt} = (0.8)(80\text{ t})(0.08\text{ Wb/s}) = \mathbf{5.12\ V}$

c. $e_p = L_p\dfrac{di_p}{dt} = (50\text{ mH})(0.03 \times 10^3\text{ A/s}) = \mathbf{15\ V}$

$e_s = M\dfrac{di_p}{dt} = (80\text{ mH})(0.03 \times 10^3\text{ A/s}) = \mathbf{24\ V}$

3. a. $L_s = \dfrac{M^2}{L_pk^2} = \dfrac{(80\text{ mH})^2}{(50\text{ mH})(0.9)^2} = \mathbf{158.02\ mH}$

b. $e_p = N_p\dfrac{d\phi_p}{dt} = (300\text{ t})(0.08\text{ Wb/s}) = \mathbf{24\ V}$

$e_s = kN_s\dfrac{d\phi_p}{dt} = (0.9)(25\text{ t})(0.08\text{ Wb/s}) = \mathbf{1.8\ V}$

c. e_p and e_s the same as problem 1: $e_p = \mathbf{15\ V}$, $e_s = \mathbf{24\ V}$

5. a. $E_s = \dfrac{N_s}{N_p}E_p = \dfrac{30\text{ t}}{240\text{ t}}(25\text{ V}) = \mathbf{3.125\ V}$

b. $\Phi_{m(\max)} = \dfrac{E_p}{4.44\,fN_p} = \dfrac{25\text{ V}}{(4.44)(60\text{ Hz})(240\text{ t})} = \mathbf{391.02\ \mu Wb}$

7. $f = \dfrac{E_p}{(4.44)N_p\Phi_{m(\max)}} = \dfrac{25\text{ V}}{(4.44)(8\text{ t})(12.5\text{ mWb})} = \mathbf{56.31\ Hz}$

9. $Z_p = \dfrac{V_g}{I_p} = \dfrac{1600\text{ V}}{4\text{ A}} = \mathbf{400\ \Omega}$

11. $I_L = I_s = \dfrac{V_L}{Z_L} = \dfrac{240\text{ V}}{20\ \Omega} = 12\text{ A}$

$\dfrac{I_s}{I_p} = a = \dfrac{N_p}{N_s} \Rightarrow \dfrac{12\text{ A}}{0.05\text{ A}} = \dfrac{N_p}{50}$

$N_p = \dfrac{50(12)}{0.05} = \mathbf{12{,}000\ turns}$

13. a. $Z_p = a^2 Z_L \Rightarrow a = \sqrt{\dfrac{Z_p}{Z_L}}$

$$Z_p = \frac{V_p}{I_p} = \frac{10\text{ V}}{20\text{ V}/72\ \Omega} = 36\ \Omega$$

$$a = \sqrt{\frac{36\ \Omega}{4\ \Omega}} = \mathbf{3}$$

b. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p} = \dfrac{1}{3} \Rightarrow V_s = \dfrac{1}{3}V_p = \dfrac{1}{3}(10\text{ V}) = \mathbf{3\frac{1}{3}\ V}$

$$P = \frac{V_s^2}{Z_s} = \frac{(3.33\text{ V})^2}{4\ \Omega} = \mathbf{2.78\ W}$$

15. a. $a = \dfrac{N_p}{N_s} = \dfrac{4\text{t}}{1\text{t}} = 4$

$$R_e = R_p + a^2 R_s = 4\ \Omega + (4)^2\ 1\ \Omega = 20\ \Omega$$
$$X_e = X_p + a^2 X_s = 8\ \Omega + (4)^2\ 2\ \Omega = 40\ \Omega$$
$$\mathbf{Z}_p = \mathbf{Z}_{R_e} + \mathbf{Z}_{X_e} + a^2\mathbf{Z}_{X_L} = 20\ \Omega + j40\ \Omega + j(4)^2\ 20\ \Omega$$
$$= 20\ \Omega + j40\ \Omega + j320\ \Omega = 20\ \Omega + j360\ \Omega = \mathbf{360.56\ \Omega\ \angle 86.82^\circ}$$

b. $\mathbf{I}_p = \dfrac{\mathbf{V}_g}{\mathbf{Z}_p} = \dfrac{120\text{ V}\ \angle 0^\circ}{360.56\ \Omega\ \angle 86.82^\circ} = \mathbf{332.82\ mA\ \angle -86.82^\circ}$

c. $\mathbf{V}_{R_e} = (I\angle\theta)(R_e\angle 0^\circ) = (332.82\text{ mA}\ \angle -86.82^\circ)(20\ \Omega\ \angle 0^\circ)$
$= \mathbf{6.656\ V\ \angle -86.82^\circ}$

$\mathbf{V}_{X_e} = (I\angle\theta)(X_e\angle 90^\circ) = (332.82\text{ mA}\ \angle -86.32^\circ)(40\ \Omega\ \angle 90^\circ)$
$= \mathbf{13.313\ V\ \angle 3.18^\circ}$

$\mathbf{V}_{X_L} = \mathbf{I}(a^2\mathbf{Z}_{X_L}) = (332.82\text{ mA}\ \angle -86.82^\circ)(320\ \Omega\ \angle 90^\circ)$
$= \mathbf{106.50\ V\ \angle 3.18^\circ}$

17. —

19. $L_{T_{(+)}} = L_1 + L_2 + 2M_{12}$

$$M_{12} = k\sqrt{L_1 L_2} = (0.8)\sqrt{(200\text{ mH})(600\text{ mH})} = \mathbf{277\ mH}$$
$$L_{T_{(+)}} = 200\text{ mH} + 600\text{ mH} + 2(277\text{ mH}) = \mathbf{1.354\ H}$$

21. $\mathbf{E}_1 - \mathbf{I}_1[\mathbf{Z}_{R_1} + \mathbf{Z}_{L_1}] - \mathbf{I}_2[\mathbf{Z}_m] = 0$
$\mathbf{I}_2[\mathbf{Z}_{L_2} + \mathbf{Z}_{R_L}] + \mathbf{I}_1[\mathbf{Z}_m] = 0$

$\mathbf{I}_1(\mathbf{Z}_{R_1} + \mathbf{Z}_{L_1}) + \mathbf{I}_2(\mathbf{Z}_m) = \mathbf{E}_1$
$\mathbf{I}_1(\mathbf{Z}_m) + \mathbf{I}_2(\mathbf{Z}_{L_2} + \mathbf{Z}_{R_L}) = 0$ $\qquad X_m = -\omega M\ \angle 90^\circ$

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23. a. $a = \dfrac{N_p}{N_s} = \dfrac{V_p}{V_s} = \dfrac{2400\text{ V}}{120\text{ V}} = \mathbf{20}$

b. $10{,}000\text{ VA} = V_s I_s \Rightarrow I_s = \dfrac{10{,}000\text{ VA}}{V_s} = \dfrac{10{,}000\text{ VA}}{120\text{ V}} = \mathbf{83.33\text{ A}}$

c. $I_p = \dfrac{10{,}000\text{ VA}}{V_p} = \dfrac{10{,}000\text{ VA}}{2400\text{ V}} = \mathbf{4.167\text{ A}}$

d. $a = \dfrac{V_p}{V_s} = \dfrac{120\text{ V}}{2400\text{ V}} = 0.05 = \dfrac{1}{20}$

$I_s = \dfrac{10{,}000\text{ VA}}{2400\text{ V}} = \mathbf{4.167\text{ A}},\ I_p = \mathbf{83.33\text{ A}}$

25. a. $\mathbf{E}_s = \dfrac{N_s}{N_p}\mathbf{E}_p$

$= \dfrac{25\text{ t}}{100\text{ t}}(100\text{ V}\ \angle 0°) = 25\text{ V}\ \angle 0° = \mathbf{V}_L$

$\mathbf{I}_s = \dfrac{\mathbf{E}_s}{\mathbf{Z}_L} = \dfrac{25\text{ V}\ \angle 0°}{5\ \Omega\ \angle 0°} = \mathbf{5\text{ A}\ \angle\ 0°} = \mathbf{I}_L$

b. $\mathbf{Z}_i = a^2\mathbf{Z}_L = \left(\dfrac{N_p}{N_s}\right)^2\mathbf{Z}_L = \left(\dfrac{100\text{ t}}{25\text{ t}}\right)^2 5\ \Omega\ \angle 0° = (4)^2\ 5\ \Omega\ \angle 0° = \mathbf{80\ \Omega\ \angle 0°}$

c. $\mathbf{Z}_{1/2} = \dfrac{1}{4}\mathbf{Z}_i = \dfrac{1}{4}(80\ \Omega\ \angle 0°) = \mathbf{20\ \Omega\ \angle 0°}$

27. a. $\mathbf{E}_2 = \dfrac{N_2}{N_1}\mathbf{E}_1 = \left(\dfrac{40\text{ t}}{120\text{ t}}\right)(120\text{ V}\ \angle 60°) = \mathbf{40\text{ V}\ \angle 60°}$

$\mathbf{I}_2 = \dfrac{\mathbf{E}_2}{\mathbf{Z}_2} = \dfrac{40\text{ V}\ \angle 60°}{12\ \Omega\ \angle 0°} = \mathbf{3.33\text{ A}\ \angle 60°}$

$\mathbf{E}_3 = \dfrac{N_3}{N_1}\mathbf{E}_1 = \left(\dfrac{30\text{ t}}{120\text{ t}}\right)(120\text{ V}\ \angle 60°) = \mathbf{30\text{ V}\ \angle 60°}$

$\mathbf{I}_3 = \dfrac{\mathbf{E}_3}{\mathbf{Z}_3} = \dfrac{30\text{ V}\ \angle 60°}{10\ \Omega\ \angle 0°} = \mathbf{3\text{ A}\ \angle 60°}$

b. $\dfrac{1}{R_1} = \dfrac{1}{(N_1/N_2)^2 R_2} + \dfrac{1}{(N_1/N_3)^2 R_3}$

$= \dfrac{1}{(120\text{ t}/40\text{ t})^2 12\ \Omega} + \dfrac{1}{(120\text{ t}/30\text{ t})^2 10\ \Omega}$

$\dfrac{1}{R_1} = \dfrac{1}{108\ \Omega} + \dfrac{1}{160\ \Omega} = 0.0155\text{ S}$

$R_1 = \dfrac{1}{0.0155\text{ S}} = \mathbf{64.52\ \Omega}$

29. $\mathbf{E}_1 - \mathbf{I}_1\mathbf{Z}_1 - \mathbf{I}_1\mathbf{Z}_{L_1} - \mathbf{I}_2(-\mathbf{Z}_{M_{12}}) - \mathbf{I}_3(+\mathbf{Z}_{M_{13}}) = 0$

or $\mathbf{E}_1 - \mathbf{I}_1[\mathbf{Z}_1 + \mathbf{Z}_{L_1}] + \mathbf{I}_2\mathbf{Z}_{M_{12}} - \mathbf{I}_3\mathbf{Z}_{M_{13}} = 0$

$-\mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_{L_2}) + \mathbf{I}_3\mathbf{Z}_2 - \mathbf{I}_1(-\mathbf{Z}_{M_{12}}) = 0$

or $-\mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_{L_2}) + \mathbf{I}_3\mathbf{Z}_2 + \mathbf{I}_1\mathbf{Z}_{M_{12}} = 0$

$-\mathbf{I}_3(\mathbf{Z}_2 + \mathbf{Z}_4 + \mathbf{Z}_{L_3}) + \mathbf{I}_2\mathbf{Z}_2 - \mathbf{I}_1(+\mathbf{Z}_{M_{13}}) = 0$

or $-\mathbf{I}_3(\mathbf{Z}_2 + \mathbf{Z}_4 + \mathbf{Z}_{L_3}) + \mathbf{I}_2\mathbf{Z}_2 - \mathbf{I}_1\mathbf{Z}_{M_{13}} = 0$

$$\therefore \quad \begin{aligned} [\mathbf{Z}_1 + \mathbf{Z}_{L_1}]\mathbf{I}_1 - \mathbf{Z}_{M_{12}}\mathbf{I}_2 + \mathbf{Z}_{M_{13}}\mathbf{I}_3 &= \mathbf{E}_1 \\ \mathbf{Z}_{M_{12}}\mathbf{I}_1 - [\mathbf{Z}_2 + \mathbf{Z}_3 + \mathbf{Z}_{L_2}]\mathbf{I}_2 + \mathbf{Z}_2\mathbf{I}_3 &= 0 \\ \mathbf{Z}_{M_{13}}\mathbf{I}_1 \qquad \mathbf{Z}_2\mathbf{I}_2 + [\mathbf{Z}_2 + \mathbf{Z}_4 + \mathbf{Z}_{L_3}]\mathbf{I}_3 &= 0 \end{aligned}$$

CHAPTER 21 (Even)

2. a. $k = 1$

(a) $L_s = \dfrac{M^2}{L_p k^2} = \dfrac{(80 \text{ mH})^2}{(50 \text{ mH})(1)^2} = \mathbf{128\ mH}$

(b) $e_p = \mathbf{1.6\ V}$, $e_s = kN_s \dfrac{d\phi_p}{dt} = (1)(80 \text{ t})(0.08 \text{ Wb}/s) = \mathbf{6.4\ V}$

(c) $e_p = \mathbf{15\ V}$, $e_s = \mathbf{24\ V}$

b. $k = 0.2$

(a) $L_s = \dfrac{M^2}{L_p k^2} = \dfrac{(80 \text{ mH})^2}{(50 \text{ mH})(0.2)^2} = \mathbf{3.2\ H}$

(b) $e_p = \mathbf{1.6\ V}$, $e_s = kN_s \dfrac{d\phi_p}{dt} = (0.2)(80 \text{ t})(0.08 \text{ Wb/s}) = \mathbf{1.28\ V}$

(c) $e_p = \mathbf{15\ V}$, $e_s = \mathbf{24\ V}$

4. a. $E_s = \dfrac{N_s}{N_p} E_p = \dfrac{64 \text{ t}}{8 \text{ t}}(25 \text{ V}) = \mathbf{200\ V}$

b. $\Phi_{\max} = \dfrac{E_p}{4.4 f N_p} = \dfrac{25 \text{ V}}{4.44(60 \text{ Hz})(8 \text{ t})} = \mathbf{11.73\ mWb}$

6. $E_p = \dfrac{N_p}{N_s} E_s = \dfrac{60 \text{ t}}{720 \text{ t}}(240 \text{ V}) = \mathbf{20\ V}$

8. a. $I_L = aI_p = \left(\dfrac{1}{5}\right)(2 \text{ A}) = \mathbf{0.4\ A}$

$V_L = I_L Z_L = \left(\dfrac{2}{5} \text{ A}\right)(2\ \Omega) = \mathbf{0.8\ V}$

b. $Z_{\text{in}} = a^2 Z_L = \left(\dfrac{1}{5}\right)^2 2\ \Omega = \mathbf{0.08\ \Omega}$

10. $V_g = aV_L = \left(\dfrac{1}{4}\right)(1200 \text{ V}) = \mathbf{300\ V}$

$I_p = \dfrac{V_g}{Z_i} = \dfrac{300 \text{ V}}{4\ \Omega} = \mathbf{75\ A}$

12. a. $a = \dfrac{N_p}{N_s} = \dfrac{400 \text{ t}}{1200 \text{ t}} = \dfrac{1}{3}$

$Z_i = a^2 Z_L = \left(\dfrac{1}{3}\right)^2 [9\ \Omega + j12\ \Omega] = 1\ \Omega + j1.333\ \Omega = 1.667\ \Omega \angle 53.13°$

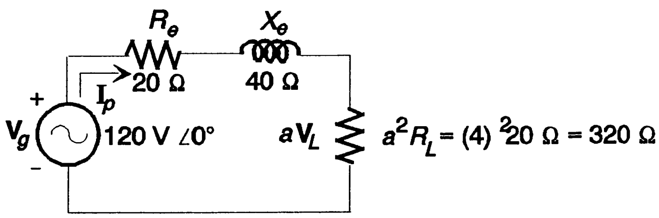
$I_p = V_g/Z_i = 100 \text{ V}/1.667\ \Omega = \mathbf{60\ A}$

b. $I_L = aI_p = \frac{1}{3}(60\text{ A}) = \mathbf{20\text{ A}},\ V_L = I_L Z_L = (20\text{ A})(15\ \Omega) = \mathbf{300\text{ V}}$

14. a. $R_e = R_p + a^2R_s = 4\ \Omega + (4)^2\ 1\ \Omega = \mathbf{20\ \Omega}$

b. $X_e = X_p + a^2X_s = 8\ \Omega + (4)^2\ 2\ \Omega = \mathbf{40\ \Omega}$

c.



d. $\mathbf{I}_p = \dfrac{\mathbf{V}_g}{\mathbf{Z}_p} = \dfrac{120\text{ V}\ \angle 0°}{20\ \Omega + 320\ \Omega + j40\ \Omega} = \dfrac{120\text{ V}\ \angle 0°}{340\ \Omega + j40\ \Omega} = \mathbf{0.351\text{ A}\ \angle -6.71°}$

e. $a\mathbf{V}_L = \dfrac{a^2R_L\mathbf{V}_g}{(R_e + a^2R_L) + jX_e} = \mathbf{I}_p a^2 R_L$

or $\mathbf{V}_L = a\mathbf{I}_p R_L \angle 0° = (4)(0.351\text{ A}\ \angle -6.71°)(20\ \Omega\ \angle 0°) = \mathbf{28.1\text{ V}\ \angle -6.71°}$

f. —

g. $V_L = \dfrac{N_s}{N_p}V_g = \dfrac{1}{4}(120\text{ V}) = \mathbf{30\text{ V}}$

16. a. $a = N_p/N_s = 4\text{ t}/1\text{ t} = 4,\ R_e = R_p + a^2R_s = 4\ \Omega + (4)^2\ 1\ \Omega = 20\ \Omega$

$X_e = X_p + a^2X_s = 8\ \Omega + (4)^2\ 2\ \Omega = 40\ \Omega$

$\mathbf{Z}_p = R_e + jX_e - ja^2X_C = 20\ \Omega + j40\ \Omega - j(4)^2\ 20\ \Omega$

$= 20\ \Omega - j280\ \Omega = \mathbf{280.71\ \Omega\ \angle -85.91°}$

b. $\mathbf{I}_p = \dfrac{\mathbf{V}_g}{\mathbf{Z}_p} = \dfrac{120\text{ V}\ \angle 0°}{280.71\ \Omega\ \angle -85.91°} = \mathbf{0.427\text{ A}\ \angle 85.91°}$

c. $\mathbf{V}_{R_e} = (I_p \angle \theta)(R_e \angle 0°) = (0.427\text{ A}\ \angle 85.91°)(20\ \Omega\ \angle 0°) = \mathbf{8.54\text{ V}\ \angle 85.91°}$

$\mathbf{V}_{X_e} = (I_p \angle \theta)(X_e \angle 90°) = (0.427\text{ A}\ \angle 85.91°)(40\ \Omega\ \angle 90°) = \mathbf{17.08\text{ V}\ \angle 175.91°}$

$\mathbf{V}_{X_C} = (I_p \angle \theta)(a^2X_C \angle -90°) = (0.427\text{ A}\ \angle 85.91°)(320\ \Omega\ \angle -90°) = \mathbf{136.64\text{ V}\ \angle -4.09°}$

18. Coil 1: $L_1 - M_{12}$

Coil 2: $L_2 - M_{12}$

$L_T = L_1 + L_2 - 2M_{12} = 4\text{ H} + 7\text{ H} - 2(1\text{ H}) = \mathbf{9\text{ H}}$

20. $M_{23} = k\sqrt{L_2L_3} = 1\sqrt{(1\text{ H})(4\text{ H})} = 2\text{ H}$

Coil 1: $L_1 + M_{12} - M_{13} = 2\text{ H} + 0.2\text{ H} - 0.1\text{ H} = 2.1\text{ H}$

Coil 2: $L_2 + M_{12} - M_{23} = 1\text{ H} + 0.2\text{ H} - 2\text{ H} = -0.8\text{ H}$

Coil 3: $L_3 - M_{23} - M_{13} = 4\text{ H} - 2\text{ H} - 0.1\text{ H} = 1.9\text{ H}$

$L_T = 2.1\text{ H} - 0.8\text{ H} + 1.9\text{ H} = \mathbf{3.2\text{ H}}$

22. $\mathbf{Z}_i = \mathbf{Z}_p + \dfrac{(\omega M)^2}{\mathbf{Z}_s + \mathbf{Z}_L} = R_p + jX_{L_p} + \dfrac{(\omega M)^2}{R_s + jX_{L_s} + R_L}$

$R_p = 2\ \Omega,\ X_{L_p} = \omega L_p = (10^3\text{ rad/s})(8\text{ H}) = 8\text{ k}\Omega$

$R_s = 1\ \Omega,\ X_{L_s} = \omega L_s = (10^3\text{ rad/s})(2\text{ H}) = 2\text{ k}\Omega$

$$M = k\sqrt{L_pL_s} = 0.05\sqrt{(8\text{ H})(2\text{ H})} = 0.2\text{ H}$$

$$\mathbf{Z}_i = 2\ \Omega + j8\text{ k}\Omega + \frac{(10^3\text{ rad/s}\cdot 0.2\text{ H})^2}{1\ \Omega + j2\text{ k}\Omega + 20\ \Omega}$$

$$= 2\ \Omega + j8\text{ k}\Omega + \frac{4\times 10^4\ \Omega}{21 + j2\times 10^3}$$

$$= 2\ \Omega + j8\text{ k}\Omega + 0.21\ \Omega - j19.99\ \Omega = 2.21\ \Omega + j7980\ \Omega$$

$\mathbf{Z}_i = \mathbf{7980\ \Omega\ \angle 89.98°}$

24. $I_s = I_1 = \mathbf{2\ A},\ E_p = V_L = \mathbf{40\ V}$

$V_gI_1 = V_LI_L \Rightarrow I_L = V_g/V_L\cdot I_1 = \dfrac{200\text{ V}}{40\text{ V}}(2\text{ A}) = \mathbf{10\ A}$

$I_p + I_1 = I_L \Rightarrow I_p = I_L - I_1 = 10\text{ A} - 2\text{A} = \mathbf{8\ A}$

26. a. $\mathbf{E}_2 = \dfrac{N_2}{N_1}\mathbf{E}_1 = \dfrac{15\text{ t}}{90\text{ t}}(60\text{ V}\angle 0°) = \mathbf{10\ V\ \angle 0°}$

$\mathbf{E}_3 = \dfrac{N_3}{N_1}\mathbf{E}_1 = \dfrac{45\text{ t}}{90\text{ t}}(60\text{ V}\angle 0°) = \mathbf{30\ V\ \angle 0°}$

$\mathbf{I}_2 = \dfrac{\mathbf{E}_2}{\mathbf{Z}_2} = \dfrac{10\text{ V}\angle 0°}{8\ \Omega\angle 0°} = \mathbf{1.25\ A\ \angle 0°}$

$\mathbf{I}_3 = \dfrac{\mathbf{E}_3}{\mathbf{Z}_3} = \dfrac{30\text{ V}\angle 0°}{5\ \Omega\angle 0°} = \mathbf{6\ A\ \angle 0°}$

b. $\dfrac{1}{R_1} = \dfrac{1}{(N_1/N_2)^2R_2} + \dfrac{1}{(N_1/N_3)^2R_3}$

$= \dfrac{1}{(90\text{ t}/15\text{ t})^2\ 8\ \Omega} + \dfrac{1}{(90\text{ t}/45\text{ t})^2\ 5\ \Omega}$

$\dfrac{1}{R_1} = \dfrac{1}{288\ \Omega} + \dfrac{1}{20\ \Omega} = 0.05347\text{ S}$

$R_1 = \mathbf{18.70\ \Omega}$

28. $\mathbf{Z}_M = \mathbf{Z}_{M_{12}} = \omega M_{12}\angle 90°$

$\mathbf{E} - \mathbf{I}_1\mathbf{Z}_1 - \mathbf{I}_1\mathbf{Z}_{L_1} - \mathbf{I}_1(-\mathbf{Z}_m) - \mathbf{I}_2(+\mathbf{Z}_m) - \mathbf{I}_1\mathbf{Z}_{L_2} + \mathbf{I}_2\mathbf{Z}_{L_2} - \mathbf{I}_1(-\mathbf{Z}_m) = 0$

$\mathbf{E} - \mathbf{I}_1(\mathbf{Z}_1 + \mathbf{Z}_{L_1} - \mathbf{Z}_m + \mathbf{Z}_{L_2} - \mathbf{Z}_m) - \mathbf{I}_2(\mathbf{Z}_m - \mathbf{Z}_{L_2}) = 0$

or $\mathbf{I}_1(\mathbf{Z}_1 + \mathbf{Z}_{L_1} + \mathbf{Z}_{L_2} - 2\mathbf{Z}_m) + \mathbf{I}_2(\mathbf{Z}_m - \mathbf{Z}_{L_2}) = \mathbf{E}$

$-\mathbf{I}_2\mathbf{Z}_2 - \mathbf{Z}_{L_2}(\mathbf{I}_2 - \mathbf{I}_1) - \mathbf{I}_1(+\mathbf{Z}_m) = 0$

or $\mathbf{I}_1(\mathbf{Z}_m - \mathbf{Z}_{L_2}) + \mathbf{I}_2(\mathbf{Z}_2 + \mathbf{Z}_{L_2}) = 0$

CHAPTER 22 (Odd)

1. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_\phi = \mathbf{120.1\ V}$

   c. $I_\phi = \dfrac{V_\phi}{R_\phi} = \dfrac{120.1\text{ V}}{10\ \Omega} = \mathbf{12.01\ A}$ d. $I_L = I_\phi = \mathbf{12.01\ A}$

3. a. $E_\phi = \mathbf{120.1\ V}$ b. $V_\phi = \mathbf{120.1\ V}$

   c. $Z_\phi = (10\ \Omega\ \angle 0°) \| (10\ \Omega\ \angle -90°) = 7.071\ \Omega\ \angle -45°$
   $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.1\text{ V}}{7.071\ \Omega} = \mathbf{16.98\ A}$

   d. $I_L = \mathbf{16.98\ A}$

5. a. $\theta_2 = \mathbf{-120°},\ \theta_3 = \mathbf{+120°}$

   b. $\mathbf{V}_{an} = \mathbf{120\ V\ \angle 0°},\ \mathbf{V}_{bn} = \mathbf{120\ V\ \angle -120°},\ \mathbf{V}_{cn} = \mathbf{120\ V\ \angle 120°}$

   c. $\mathbf{Z}_\phi = 9\ \Omega + j12\ \Omega = 15\ \Omega\ \angle 53.13°$
   $\mathbf{I}_{an} = \dfrac{120\text{ V}\ \angle 0°}{15\ \Omega\ \angle 53.13°} = \mathbf{8\ A\ \angle -53.13°},\ \mathbf{I}_{bn} = \dfrac{120\text{ V}\ \angle -120°}{15\ \Omega\ \angle 53.13°} = \mathbf{8\ A\ \angle -173.13°}$
   $\mathbf{I}_{cn} = \dfrac{120\text{ V}\ \angle 120°}{15\ \Omega\ \angle 53.13°} = \mathbf{8\ A\ \angle 66.87°}$

   e. $I_L = I_\phi = \mathbf{8\ A}$ f. $E_L = \sqrt{3}\,E_\phi = (1.732)(120\text{ V}) = \mathbf{207.85\ V}$

7. $V_\phi = V_{an} = V_{bn} = V_{cn} = \dfrac{V_L}{\sqrt{3}} = \dfrac{220\text{ V}}{1.732} = \mathbf{127.0\ V}$
   $\mathbf{Z}_\phi = 10\ \Omega - j10\ \Omega = 14.42\ \Omega\ \angle -45°$
   $I_\phi = I_{an} = I_{bn} = I_{cn} = \dfrac{V_\phi}{Z_\phi} = \dfrac{127\text{ V}}{14.142\ \Omega} = \mathbf{8.98\ A}$
   $I_L = I_{Aa} = I_{Bb} = I_{Cc} = I_\phi = \mathbf{8.98\ A}$

9. a. $\mathbf{E}_{AN} = \dfrac{22\text{ kV}}{\sqrt{3}}\ \angle -30° = \mathbf{12.7\ kV\ \angle -30°}$
   $\mathbf{E}_{BN} = \dfrac{22\text{ kV}}{\sqrt{3}}\ \angle -150° = \mathbf{12.7\ kV\ \angle -150°}$
   $\mathbf{E}_{CN} = \dfrac{22\text{ kV}}{\sqrt{3}}\ \angle 90° = \mathbf{12.7\ kV\ \angle 90°}$

b, c. $\mathbf{I}_{Aa} = \mathbf{I}_{an} = \dfrac{\mathbf{E}_{AN}}{\mathbf{Z}_{AN}} = \dfrac{12.7\text{ kV}\ \angle -30°}{(30\ \Omega + j40\ \Omega) + (0.4\text{ k}\Omega + j1\text{ k}\Omega)}$

$= \dfrac{12.7\text{ kV}\ \angle -30°}{430\ \Omega + j1040\ \Omega} = \dfrac{12.7\text{ kV}\ \angle -30°}{1125.39\ \Omega\ \angle 67.54°}$

$= \mathbf{11.285\ A\ \angle -97.54°}$

$\mathbf{I}_{Bb} = \mathbf{I}_{bn} = \dfrac{\mathbf{E}_{BN}}{\mathbf{Z}_{BN}} = \dfrac{12.7\text{ kV}\ \angle -150°}{1125.39\ \Omega\ \angle 67.54°} = \mathbf{11.285\ A\ \angle -217.54°}$

$\mathbf{I}_{Cc} = \mathbf{I}_{cn} = \dfrac{\mathbf{E}_{CN}}{\mathbf{Z}_{CN}} = \dfrac{12.7\text{ kV}\ \angle 90°}{1125.39\ \Omega\ \angle 67.54°} = \mathbf{11.285\ A\ \angle 22.46°}$

d. $\mathbf{V}_{an} = \mathbf{I}_{an}\mathbf{Z}_{an} = (11.285\text{ A}\ \angle -97.54°)(400 + j1000)$

$= (11.285\text{ A}\ \angle -97.54°)(1077.03\ \Omega\ \angle 68.2°)$

$= \mathbf{12{,}154.28\ V\ \angle -29.34°}$

$\mathbf{V}_{bn} = \mathbf{I}_{bn}\mathbf{Z}_{bn} = (11.285\text{ A}\ \angle -217.54°)(1077.03\ \angle 68.2°)$

$= \mathbf{12{,}154.28\ V\ \angle -149.34°}$

$\mathbf{V}_{cn} = \mathbf{I}_{cn}\mathbf{Z}_{cn} = (11.285\text{ A}\ \angle 22.46°)(1077.03\ \angle 68.2°)$

$= \mathbf{12{,}154.28\ V\ \angle 90.66°}$

11. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_L = \mathbf{208\ V}$

c. $\mathbf{Z}_\phi = 6.8\ \Omega + j14\ \Omega = 15.564\ \Omega\ \angle 64.09°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{208\text{ V}}{15.564\ \Omega} = \mathbf{13.364\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(13.364\text{ A}) = \mathbf{23.15\ A}$

13. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{208\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{208\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{208\ V\ \angle 120°}$

c. —

d. $\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{208\text{ V}\ \angle 0°}{22\ \Omega\ \angle 0°} = \mathbf{9.455\ A\ \angle 0°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{208\text{ V}\ \angle -120°}{22\ \Omega\ \angle 0°} = \mathbf{9.455\ A\ \angle -120°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{208\text{ V}\ \angle 120°}{22\ \Omega\ \angle 0°} = \mathbf{9.455\ A\ \angle 120°}$

e. $I_L = \sqrt{3}\,I_\phi = (1.732)(9.455\text{ A}) = \mathbf{16.376\ A}$

f. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$

15. a, b. The same as problem 12. c. —

d. $\mathbf{Z}_\phi = 3\ \Omega\ \angle 0° \parallel 4\ \Omega\ \angle 90° = 2.4\ \Omega\ \angle 36.87°$

$$\mathbf{I}_{ab} = \frac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \frac{208\ \text{V}\ \angle 0°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\ A\ \angle -36.87°}$$

$$\mathbf{I}_{bc} = \frac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \frac{208\ \text{V}\ \angle -120°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\ A\ \angle -156.87°}$$

$$\mathbf{I}_{ca} = \frac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \frac{208\ \text{V}\ \angle 120°}{2.4\ \Omega\ \angle 36.87°} = \mathbf{86.67\ A\ \angle 83.13°}$$

e. $\mathbf{I}_L = \sqrt{3}\, I_\phi = (1.732)(86.67\ \text{A}) = \mathbf{150.11\ A}$

f. $E_\phi = \mathbf{120.1\ V}$

17. a. $$\mathbf{I}_{ab} = \frac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \frac{16\ \text{kV}\ \angle 0°}{300\ \Omega + j1000\ \Omega} = \frac{16\ \text{kV}\ \angle 0°}{1044.03\ \Omega\ \angle 73.30°}$$

$\mathbf{I}_{ab} = \mathbf{15.325\ A\ \angle -73.30°}$

$$\mathbf{I}_{bc} = \frac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \frac{16\ \text{kV}\ \angle -120°}{1044.03\ \Omega\ \angle 73.30°} = \mathbf{15.325\ A\ \angle -193.30°}$$

$$\mathbf{I}_{ca} = \frac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \frac{16\ \text{kV}\ \angle 120°}{1044.03\ \Omega\ \angle 73.30°} = \mathbf{15.325\ A\ \angle 46.7°}$$

b. $\mathbf{I}_{Aa} - \mathbf{I}_{ab} + \mathbf{I}_{ca} = 0$

$\mathbf{I}_{Aa} = \mathbf{I}_{ab} - \mathbf{I}_{ca} = 15.325\ \text{A}\ \angle -73.30° - 15.325\ \text{A}\ \angle 46.7°$

$= (4.40\ \text{A} - j14.68\ \text{A}) - (10.51\ \text{A} + j11.153\ \text{A})$

$= 4.40\ \text{A} - 10.51\ \text{A} - j(14.68\ \text{A} + 11.153\ \text{A})$

$= -6.11\ \text{A} - j25.83\ \text{A} = \mathbf{26.54\ A\ \angle -103.31°}$

$\mathbf{I}_{Bb} + \mathbf{I}_{ab} = \mathbf{I}_{bc}$

$\mathbf{I}_{Bb} = \mathbf{I}_{bc} - \mathbf{I}_{ab} = 15.325\ \text{A}\ \angle -193.30° - 15.325\ \text{A}\ \angle -73.30°$

$= \mathbf{26.54\ A\ \angle 136.68°}$

$\mathbf{I}_{Cc} + \mathbf{I}_{bc} = \mathbf{I}_{ca}$

$\mathbf{I}_{Cc} = \mathbf{I}_{ca} - \mathbf{I}_{bc} = 15.325\ \text{A}\ \angle 46.7° - 15.325\ \text{A}\ \angle -193.30°$

$= \mathbf{26.54\ A\ \angle 16.69°}$

c. $\mathbf{E}_{AB} = \mathbf{I}_{Aa}(10\ \Omega + j20\ \Omega) + \mathbf{V}_{ab} - \mathbf{I}_{Bb}(22.361\ \Omega\ \angle 63.43°)$

$= (26.54\ \text{A}\ \angle -103.31°)(22.361\ \Omega\ \angle 63.43°) + 16\ \text{kV}\ \angle 0°$

$- (26.54\ \text{A}\ \angle 136.68°)(22.361\ \Omega\ \angle 63.43°)$

$= (455.41\ \text{V} - j380.52\ \text{V}) + 16{,}000\ \text{V} - (-557.28\ \text{V} - j204.04\ \text{V})$

$= 17{,}012.69\ \text{V} - j176.48\ \text{V}$

$= \mathbf{17{,}013.6\ V\ \angle -0.59°}$

$\mathbf{E}_{BC} = \mathbf{I}_{Bb}(22.361\ \Omega\ \angle 63.43°) + \mathbf{V}_{bc} - \mathbf{I}_{Cc}(22.361\ \Omega\ \angle 63.53°)$

$= (26.54\ \text{A}\ \angle 136.68°)(22.361\ \Omega\ \angle 63.53°) + 16\ \text{kV}\ \angle -120°$

$- (26.54\ \text{A}\ \angle 16.69°)(22.361\ \Omega\ \angle 63.53°)$

$= -8659.07\ \text{V} - j14{,}645.44\ \text{V}$

$= \mathbf{17{,}013.77\ V\ \angle -120.59°}$

$$\begin{aligned}\mathbf{E}_{CA} &= \mathbf{I}_{Cc}(22.361\ \Omega\ \angle 63.43°) + \mathbf{V}_{ca} - \mathbf{I}_{Aa}(22.361\ \Omega\ \angle 63.43°)\\ &= (26.54\text{ A}\ \angle 16.69°)(22.361\ \Omega\ \angle 63.43°) + 16{,}000\text{ V}\ \angle +120°\\ &\qquad - (26.54\text{ A}\ \angle -103.31°)(22.361\ \Omega\ \angle 63.53°)\\ &= -8355.27\text{ V} + j14{,}820.97\text{ V}\\ &= \mathbf{17{,}013.87\ V\ \angle 119.41°}\end{aligned}$$

19. a. $E_\phi = E_L = \mathbf{208\ V}$

b. $V_\phi = E_L\sqrt{3} = \mathbf{120.09\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.09\text{ V}}{16.971\ \Omega} = \mathbf{7.076\ A}$

d. $I_L = I_\phi = \mathbf{7.076\ A}$

21. $V_{an} = V_{bn} = V_{cn} = \dfrac{120\text{ V}}{\sqrt{3}} = \dfrac{120\text{ V}}{1.732} = \mathbf{69.28\ V}$

$I_{an} = I_{bn} = I_{cn} = \dfrac{69.28\text{ V}}{24\ \Omega} = \mathbf{2.89\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = \mathbf{2.89\ A}$

23. $V_{an} = V_{bn} = V_{cn} = \mathbf{69.28\ V}$

$\mathbf{Z}_\phi = 20\ \Omega\ \angle 0° \parallel 15\ \Omega\ \angle -90° = 12\ \Omega\ \angle -53.13°$

$I_{an} = I_{bn} = I_{cn} = \dfrac{69.28\text{ V}}{12\ \Omega} = \mathbf{5.77\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = \mathbf{5.77\ A}$

25. a. $E_\phi = E_L = \mathbf{440\ V}$

b. $V_\phi = E_L = \mathbf{440\ V}$

c. $\mathbf{Z}_\phi = 12\ \Omega - j9\ \Omega = 15\ \Omega\ \angle -36.87°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{15\ \Omega} = \mathbf{29.33\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(29.33\text{ A}) = \mathbf{50.8\ A}$

27. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{100\text{ V}\ \angle 0°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle 0°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{100\text{ V}\ \angle -120°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle -120°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{100\text{ V}\ \angle 120°}{20\ \Omega\ \angle 0°} = \mathbf{5\ A\ \angle 120°}$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \sqrt{3}\,(5\text{ A}) = \mathbf{8.66\ A}$

29. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 20\ \Omega\ \angle 0° \parallel 20\ \Omega\ \angle -90° = 14.14\ \Omega\ \angle -45°$

$$\mathbf{I}_{ab} = \frac{100\ \text{V}\ \angle 0°}{14.14\ \Omega\ \angle -45°} = \mathbf{7.072\ A\ \angle 45°}$$

$$\mathbf{I}_{bc} = \frac{100\ \text{V}\ \angle -120°}{14.14\ \Omega\ \angle -45°} = \mathbf{7.072\ A\ \angle -75°}$$

$$\mathbf{I}_{ca} = \frac{100\ \text{V}\ \angle 120°}{14.14\ \Omega\ \angle -45°} = \mathbf{7.072\ A\ \angle 165°}$$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \left(\sqrt{3}\right)(7.072\ \text{A}) = \mathbf{12.25\ A}$

31. $V_\phi = 120\ \text{V}$, $I_\phi = 120\ \text{V}/20\ \Omega = 6\text{A}$

$P_T = 3I_\phi^2R_\phi = 3(6\ \text{A})^2\ 20\ \Omega = \mathbf{2160\ W}$

$Q_T = \mathbf{0\ VAR}$

$S_T = P_T = \mathbf{2160\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2160\ \text{W}}{2160\ \text{VA}} = \mathbf{1}$$

33. $V_\phi = 208\ \text{V}$

$$P_T = 3\left[\frac{V_\phi^2}{R_\phi}\right] = 3 \cdot \frac{(208\ \text{V})^2}{18\ \Omega} = \mathbf{7210.67\ W}$$

$$Q_T = 3\left[\frac{V_\phi^2}{X_\phi}\right] = 3 \cdot \frac{(208\ \text{V})^2}{18\ \Omega} = \mathbf{7210.67\ VAR(\mathit{C})}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{10{,}197.42\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{7210.67\ \text{W}}{10{,}197.42\ \text{VA}} = \mathbf{0.707\ (leading)}$$

35. $P_T = 3I_\phi^2R_\phi = 3(15.56\ \text{A})^2\ 10\ \Omega = \mathbf{7.263\ kW}$

$Q_T = 3I_\phi^2X_\phi = 3(15.56\ \text{A})^2\ 10\ \Omega = \mathbf{7.263\ kVAR}$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{10.272\ kVA}$$

$$F_p = \frac{P_T}{S_T} = \frac{7.263\ \text{kW}}{10.272\ \text{kVA}} = \mathbf{0.7071\ (lagging)}$$

37. $\mathbf{Z}_\phi = 10\ \Omega + j20\ \Omega = 22.36\ \Omega\ \angle 63.43°$

$$V_\phi = \frac{V_L}{\sqrt{3}} = \frac{120\text{ V}}{1.732} = 69.28\text{ V}$$

$$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{69.28\text{ V}}{22.36\ \Omega} = 3.098\text{ A}$$

$$P_T = 3I_\phi^2 R_\phi = 3(3.098\text{ A})^2\ 10\ \Omega = \mathbf{287.93\ W}$$

$$Q_T = 3I_\phi^2 X_\phi = 3(3.098\text{ A})^2\ 20\ \Omega = \mathbf{575.86\ VAR}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{643.83\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{287.93\text{ W}}{643.83\text{ VA}} = \mathbf{0.4472\ (lagging)}$$

39. $Z_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega\ \angle 53.13°$

$$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{100\text{ V}}{20\ \Omega} = 5\text{ A}$$

$$P_T = 3I_\phi^2 R_\phi = 3(5\text{ A})^2\ 12\ \Omega = \mathbf{900\ W}$$

$$Q_T = 3I_\phi^2 X_\phi = 3(5\text{ A})^2\ 16\ \Omega = \mathbf{1200\ VAR(\mathit{L})}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{1500\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{900\text{ W}}{1500\text{ VA}} = \mathbf{0.6\ (lagging)}$$

41. $P_T = \sqrt{3}\, E_L I_L \cos\theta$

$$1200\text{ W} = \sqrt{3}\,(208\text{ V})I_L(0.6) \Rightarrow I_L = 5.55\text{ A}$$

$$V_\phi = \frac{V_L}{\sqrt{3}} = \frac{208\text{ V}}{1.732} = 120.1\text{ V}$$

$$\theta = \cos^{-1} 0.6 = 53.13°\text{ (leading)}$$

$$\mathbf{Z}_\phi = \frac{\mathbf{V}_\phi}{\mathbf{I}_\phi} = \frac{120.1\text{ V}\ \angle 0°}{5.55\text{ A}\ \angle 53.13°} = 21.64\ \Omega\ \angle -53.13° = \underbrace{12.98\ \Omega}_{R} - j\underbrace{17.31\ \Omega}_{X_C}$$

43. a. $E_\phi = \dfrac{16\text{ kV}}{\sqrt{3}} = \mathbf{9{,}237.6\ V}$ b. $I_L = I_\phi = \mathbf{80\ A}$

c. $P_{\phi_L} = \dfrac{1200\text{ kW}}{3} = 400\text{ kW}$

$$P_{4\Omega} = (80\text{ A})^2 4\ \Omega = 25.6\text{ kW}$$

$$P_T = 3P_\phi = 3(25.6\text{ kW} + 400\text{ kW}) = \mathbf{1276.8\ kW}$$

d. $F_p = \dfrac{P_T}{S_T},\ S_T = \sqrt{3}\, V_L I_L = \sqrt{3}\,(16\text{ kV})(80\text{ A}) = 2{,}217.025\text{ kVA}$

$$F_p = \frac{1{,}276.8\text{ kW}}{2{,}217.025\text{ kVA}} = \mathbf{0.576\ lagging}$$

e. $\theta_L = \cos^{-1} 0.576 = 54.83°$ (lagging)

$$\mathbf{I}_{Aa} = \frac{\mathbf{E}_{AN}\angle 0°}{\underset{\substack{\uparrow \\ \text{for entire load}}}{Z_T \angle 54.83°}} \Rightarrow \underbrace{80\text{ A}}_{\text{given}} \angle -54.83°$$

f.
$$\begin{aligned}\mathbf{V}_{an} &= \mathbf{E}_{AN} - \mathbf{I}_{Aa}(4\ \Omega + j20\ \Omega)\\ &= 9237.6\text{ V} \angle 0° - (80\text{ A} \angle -54.83°)(20.396\ \Omega \angle 78.69°)\\ &= 9237.6\text{ V} \angle 0° - 1631.68\text{ V} \angle 23.86°\\ &= 9237.6\text{ V} - (1492.22\text{ V} + j660\text{ V})\\ &= 7745.38\text{ V} - j660\text{ V}\\ &= \mathbf{7773.45\ V \angle -4.87°}\end{aligned}$$

g.
$$\mathbf{Z}_\phi = \frac{\mathbf{V}_{an}}{\mathbf{I}_{Aa}} = \frac{7773.45\text{ V} \angle -4.87°}{80\text{ A} \angle -54.83°} = 97.168\ \Omega \angle 49.95°$$
$$= \underbrace{62.52\ \Omega}_{R} + j\underbrace{74.38\ \Omega}_{X_L}$$

h. F_p(entire load) = **0.576 (lagging)**
F_p(load) = **0.643 (lagging)**

i.
$$\eta = \frac{P_o}{P_i} = \frac{P_i - P_{\text{lost}}}{P_i} = \frac{1276.8\text{ kW} - 3(25.6\text{ kW})}{1276.8\text{ kW}} = 0.9398 \Rightarrow \mathbf{93.98\%}$$

45. b. P_T = **5899.64 W**, P_{meter} = **1966.55 W**

49. a. $V_\phi = E_\phi = \dfrac{E_L}{\sqrt{3}} = \mathbf{120.09\ V}$

b.
$$I_{an} = \frac{V_{an}}{Z_{an}} = \frac{120.09\text{ V}}{14.142\ \Omega} = \mathbf{8.492\ A}$$
$$I_{bn} = \frac{V_{bn}}{Z_{bn}} = \frac{120.09\text{ V}}{16.971\ \Omega} = \mathbf{7.076\ A}$$
$$I_{cn} = \frac{V_{cn}}{Z_{cn}} = \frac{120.09\text{ V}}{2.828\ \Omega} = \mathbf{42.465\ A}$$

c.
$$\begin{aligned}P_T &= I_{\text{an}}^2\ 10\ \Omega + I_{\text{bn}}^2\ 12\ \Omega + I_{\text{cn}}^2\ 2\ \Omega\\ &= (8.492\text{ A})^2\ 10\ \Omega + (7.076\text{ A})^2\ 12\ \Omega + (42.465\text{ A})^2\ 2\ \Omega\\ &= 721.141\text{ W} + 600.837\text{ W} + 3606.552\text{ W}\\ &= \mathbf{4928.53\ W}\end{aligned}$$
$Q_T = P_T$ = **4928.53 VAR(L)**
$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{6969.99\ VA}$$
$$F_p = \frac{P_T}{S_T} = \mathbf{0.7071\ (lagging)}$$

d. $\mathbf{E}_{an} = 120.09\text{ V}\angle -30°$, $\mathbf{E}_{bn} = 120.09\text{ V}\angle -150°$, $\mathbf{E}_{cn} = 120.09\text{ V}\angle 90°$

$$\mathbf{I}_{an} = \frac{\mathbf{E}_{an}}{\mathbf{Z}_{an}} = \frac{120.09\text{ V}\ \angle -30°}{10\ \Omega + j10\ \Omega} = \frac{120.09\text{ V}\ \angle -30°}{14.142\ \Omega\ \angle 45°} = \mathbf{8.492\ A\ \angle -75°}$$

$$\mathbf{I}_{bn} = \frac{\mathbf{E}_{bn}}{\mathbf{Z}_{bn}} = \frac{120.09\text{ V}\ \angle -150°}{12\ \Omega + j12\ \Omega} = \frac{120.09\text{ V}\ \angle -150°}{16.971\ \Omega\ \angle 45°} = \mathbf{7.076\ A\ \angle -195°}$$

$$\mathbf{I}_{cn} = \frac{\mathbf{E}_{cn}}{\mathbf{Z}_{cn}} = \frac{120.09\text{ V}\ \angle 90°}{2\ \Omega + j2\ \Omega} = \frac{120.09\text{ V}\ \angle 90°}{2.828\ \Omega\ \angle 45°} = \mathbf{42.465\ A\ \angle 45°}$$

e. $\mathbf{I}_N = \mathbf{I}_{an} + \mathbf{I}_{bn} + \mathbf{I}_{cn}$

$= 8.492\text{ A}\ \angle -75° + 7.076\text{ A}\ \angle -195° + 42.465\text{ A}\angle 45°$

$= (2.198\text{ A} - j8.20\text{ A}) + (-6.83\text{ A} + j1.83\text{ A}) + (30.03\text{ A} + j30.03\text{ A})$

$= 25.398\text{ A} - j23.661\text{ A}$

$= \mathbf{34.712\ A\ \angle -42.972°}$

CHAPTER 22 (Even)

2. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_\phi = \mathbf{120.1\ V}$

c. $\mathbf{Z}_\phi = 12\ \Omega - j16\ \Omega = 20\ \Omega\ \angle -53.13°$ d. $I_L = I_\phi = \mathbf{6\ A}$

$$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{120.1\text{ V}}{20\ \Omega} \cong \mathbf{6\ A}$$

4. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{120°}$

b. $\mathbf{V}_{an} = \mathbf{120\ V\ \angle 0°}$, $\mathbf{V}_{bn} = \mathbf{120\ V\ \angle -120°}$, $\mathbf{V}_{cn} = \mathbf{120\ V\ \angle 120°}$

c. $$\mathbf{I}_{\text{an}} = \frac{\mathbf{V}_{an}}{\mathbf{Z}_{an}} = \frac{120\text{ V}\ \angle 0°}{20\ \Omega\ \angle 0°} = \mathbf{6\ A\ \angle 0°}$$

$$\mathbf{I}_{\text{bn}} = \frac{\mathbf{V}_{bn}}{\mathbf{Z}_{bn}} = \frac{120\text{ V}\ \angle -120°}{20\ \Omega\ \angle 0°} = \mathbf{6\ A\ \angle -120°}$$

$$\mathbf{I}_{\text{cn}} = \frac{\mathbf{V}_{cn}}{\mathbf{Z}_{cn}} = \frac{120\text{ V}\ \angle 120°}{20\ \Omega\ \angle 0°} = \mathbf{6\ A\ \angle 120°}$$

d. $I_L = I_\phi = \mathbf{6A}$ e. $V_L = \sqrt{3}\,V_\phi = \sqrt{3}\,(120\text{ V}) = \mathbf{207.8\ V}$

6. a, b. The same as problem 4.

c. $\mathbf{Z}_\phi = 6\ \Omega\ \angle 0° \parallel 8\ \Omega\ \angle -90° = 4.8\ \Omega\ \angle -36.87°$

$$\mathbf{I}_{an} = \frac{\mathbf{V}_{an}}{\mathbf{Z}_{an}} = \frac{120\text{ V}\ \angle 0°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\ A\ \angle 36.87°}$$

$$\mathbf{I}_{bn} = \frac{\mathbf{V}_{bn}}{\mathbf{Z}_{bn}} = \frac{120\text{ V}\ \angle -120°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\ A\ \angle -83.13°}$$

$$\mathbf{I}_{cn} = \frac{\mathbf{V}_{cn}}{\mathbf{Z}_{cn}} = \frac{120\text{ V}\ \angle 120°}{4.8\ \Omega\ \angle -36.87°} = \mathbf{25\ A\ \angle 156.87°}$$

d. $I_L = I_\phi = \mathbf{25\ A}$ e. $V_L = \sqrt{3}\,V_\phi = \sqrt{3}\,(120\text{ V}) = \mathbf{207.84\ V}$

8. $\mathbf{Z}_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega \angle 53.13°$

$$I_\phi = \frac{V_\phi}{Z_\phi} = \frac{50\text{ V}}{20\ \Omega} = \mathbf{2.5\ A}$$

$\mathbf{Z}_{T_\phi} = 13\ \Omega + j16\ \Omega = 20.62\ \Omega\ \angle 50.91°$

$V_\phi = I_\phi Z_{T_\phi} = (2.5\text{ A})(20.62\ \Omega) = 51.55\text{ V}$

$V_L = \sqrt{3}\,V_\phi = \left(\sqrt{3}\right)(51.55\text{ V}) = \mathbf{89.285\ V}$

10. a. $E_\phi = E_L/\sqrt{3} = 208\text{ V}/1.732 = \mathbf{120.1\ V}$ b. $V_\phi = E_L = \mathbf{208\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{208\text{ V}}{20\ \Omega} = \mathbf{10.4\ A}$ d. $I_L = \sqrt{3}\,I_\phi = (1.732)(10.4\text{ A}) = \mathbf{18\ A}$

12. $\mathbf{Z}_\phi = 18\ \Omega\ \angle 0° \parallel 18\ \Omega\ \angle -90° = 12.728\ \Omega\ \angle -45°$

a. $E_\phi = V_L/\sqrt{3} = 208\ \text{V}/\sqrt{3} = \mathbf{120.09\ V}$ b. $V_\phi = \mathbf{208\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{208\ \text{V}}{12.728\ \Omega} = \mathbf{16.342\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(16.342\ \text{A}) = \mathbf{28.304\ A}$

14. a. $\theta_2 = \mathbf{-120°},\ \theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{208\ V\ \angle 0°},\ \mathbf{V}_{bc} = \mathbf{208\ V\ \angle -120°},\ \mathbf{V}_{ca} = \mathbf{208\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 100\ \Omega - j100\ \Omega = 141.42\ \Omega \angle -45°$

$\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{208\ \text{V}\ \angle 0°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle 45°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{208\ \text{V}\ \angle -120°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle -75°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{208\ \text{V}\ \angle 120°}{141.42\ \Omega\ \angle -45°} = \mathbf{1.471\ A\ \angle 165°}$

e. $I_L = \sqrt{3}\,I_\phi = (1.732)(1.471\ \text{A}) = \mathbf{2.548\ A}$

f. $E_\phi = E_L/\sqrt{3} = 208\ \text{V}/1.732 = \mathbf{120.1\ V}$

16. $V_{ab} = V_{bc} = V_{ca} = \mathbf{220\ V}$

$\mathbf{Z}_\phi = 10\ \Omega + j10\ \Omega = 14.142\ \Omega \angle 45°$

$I_{ab} = I_{bc} = I_{ca} = \dfrac{V_\phi}{Z_\phi} = \dfrac{220\ \text{V}}{14.142\ \Omega} = \mathbf{15.56\ A}$

18. a. $E_\phi = E_L = \mathbf{208\ V}$ b. $V_\phi = \dfrac{E_L}{\sqrt{3}} = \dfrac{208\ \text{V}}{1.732} = \mathbf{120.1\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.1\ \text{V}}{30\ \Omega} = \mathbf{4.003\ A}$ d. $I_L = I_\phi \cong \mathbf{4\ A}$

20. a, b. The same as problem 18.

c. $\mathbf{Z}_\phi = 15\ \Omega\ \angle 0° \parallel 20\ \Omega\ \angle -90° = 12\ \Omega\ \angle -36.87°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{120.1\ \text{V}}{12\ \Omega} \cong \mathbf{10\ A}$

d. $I_L = I_\phi \cong \mathbf{10\ A}$

22. $V_{an} = V_{bn} = V_{cn} = \dfrac{120\text{ V}}{\sqrt{3}} = \mathbf{69.28\ V}$

$\mathbf{Z}_\phi = 10\ \Omega + j20\ \Omega = 22.36\ \Omega \angle 63.43°$

$I_{an} = I_{bn} = I_{cn} = \dfrac{\mathbf{V}_\phi}{\mathbf{Z}_\phi} = \dfrac{69.28\text{ V}}{22.36\ \Omega} = \mathbf{3.098\ A}$

$I_{Aa} = I_{Bb} = I_{Cc} = I_\phi = \mathbf{3.098\ A}$

24. a. $E_\phi = E_L = \mathbf{440\ V}$

b. $V_\phi = E_L = E_\phi = \mathbf{440\ V}$

c. $I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{220\ \Omega} = \mathbf{2\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(2\text{ A}) = \mathbf{3.464\ A}$

26. a, b. The same as problem 24.

c. $\mathbf{Z}_\phi = 22\ \Omega\ \angle 0° \parallel 22\ \Omega\ \angle 90° = 15.56\ \Omega\ \angle 45°$

$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{440\text{ V}}{15.56\ \Omega} = \mathbf{28.28\ A}$

d. $I_L = \sqrt{3}\,I_\phi = (1.732)(28.28\text{ A}) = \mathbf{48.98\ A}$

28. a. $\theta_2 = \mathbf{-120°}$, $\theta_3 = \mathbf{+120°}$

b. $\mathbf{V}_{ab} = \mathbf{100\ V\ \angle 0°}$, $\mathbf{V}_{bc} = \mathbf{100\ V\ \angle -120°}$, $\mathbf{V}_{ca} = \mathbf{100\ V\ \angle 120°}$

c. —

d. $\mathbf{Z}_\phi = 12\ \Omega + j16\ \Omega = 20\ \Omega\ \angle 53.13°$

$\mathbf{I}_{ab} = \dfrac{\mathbf{V}_{ab}}{\mathbf{Z}_{ab}} = \dfrac{100\text{ V}\ \angle 0°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle -53.13°}$

$\mathbf{I}_{bc} = \dfrac{\mathbf{V}_{bc}}{\mathbf{Z}_{bc}} = \dfrac{100\text{ V}\ \angle -120°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle -173.13°}$

$\mathbf{I}_{ca} = \dfrac{\mathbf{V}_{ca}}{\mathbf{Z}_{ca}} = \dfrac{100\text{ V}\ \angle 120°}{20\ \Omega\ \angle 53.13°} = \mathbf{5\ A\ \angle 66.87°}$

e. $I_{Aa} = I_{Bb} = I_{Cc} = \sqrt{3}\,I_\phi = (1.732)(5\text{ A}) = \mathbf{8.66\ A}$

30. $P_T = 3I_\phi^2 R_\phi = 3(6\text{ A})^2\ 12\ \Omega = \mathbf{1296\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(6\text{ A})^2\ 16\ \Omega = \mathbf{1728\ VAR(\mathit{C})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{2160\ VA}$

$F_p = \dfrac{P_T}{S_T} = \dfrac{1296\text{ W}}{2160\text{ VA}} = \mathbf{0.6\ (leading)}$

32. $P_T = 3I_\phi^2 R_\phi = 3(8.98\text{ A})^2\ 10\ \Omega = \mathbf{2419.21\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(8.98\text{ A})^2\ 10\ \Omega = \mathbf{2419.21\ VAR(\mathit{C})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3421.28\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2419.21\ \text{W}}{3421.28\ \text{VA}} = \mathbf{0.7071\ (leading)}$$

34. $P_T = 3I_\phi^2 R_\phi = 3(1.471\ \text{A})^2\ 100\ \Omega = \mathbf{649.15\ W}$

$Q_T = 3I_\phi^2 X_\phi = 3(1.471\ \text{A})^2\ 100\ \Omega = \mathbf{649.15\ VAR(\mathit{C})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{918.04\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{649.15\ \text{W}}{918.04\ \text{VA}} = \mathbf{0.7071\ (leading)}$$

36. $P_T = 3\dfrac{V_\phi^2}{R_\phi} = \dfrac{3(120.1\ \text{V})^2}{15\ \Omega} = \mathbf{2884.80\ W}$

$$Q_T = 3\frac{V_\phi^2}{X_\phi} = \frac{3(120.1\ \text{V})^2}{20\ \Omega} = \mathbf{2163.60\ VAR(\mathit{C})}$$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3605.97\ VA}$

$$F_p = \frac{P_T}{S_T} = \frac{2884.80\ \text{W}}{3605.97\ \text{VA}} = \mathbf{0.8\ (leading)}$$

38. $P_T = 3\dfrac{V_\phi^2}{R_\phi} = \dfrac{3(440\ \text{V})^2}{22\ \Omega} = \mathbf{26.4\ kW}$

$Q_T = P_T = \mathbf{26.4\ kVAR(\mathit{L})}$

$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{37.34\ kVA}$

$$F_p = \frac{P_T}{S_T} = \frac{26.4\ \text{kW}}{37.34\ \text{kVA}} = \mathbf{0.707\ (lagging)}$$

40. $P_T = \sqrt{3}\,E_L I_L \cos\theta$

$4800\ \text{W} = (1.732)(200\ \text{V})I_L\ (0.8)$

$I_L = 17.32\ \text{A}$

$$I_\phi = \frac{I_L}{\sqrt{3}} = \frac{17.32\ \text{A}}{1.732} = 10\ \text{A}$$

$\theta = \cos^{-1} 0.8 = 36.87°$

$$\mathbf{Z}_\phi = \frac{\mathbf{V}_\phi}{\mathbf{I}_\phi} = \frac{200\ \text{V}\ \angle 0°}{10\ \text{A}\ \angle -36.87°} = 20\ \Omega\ \angle 36.87° = \mathbf{16\ \Omega + \mathit{j}12\ \Omega}$$

42. Δ: $\mathbf{Z}_\phi = 15\ \Omega + j20\ \Omega = 25\ \Omega \angle 53.13°$

$$I_\phi = \frac{\mathbf{V}_\phi}{\mathbf{Z}_\phi} = \frac{125\ \text{V}}{25\ \Omega} = 5\ \text{A}$$

$P_T = 3I_\phi^2 R_\phi = 3(5\ \text{A})^2\ 15\ \Omega = \mathbf{1125\ W}$

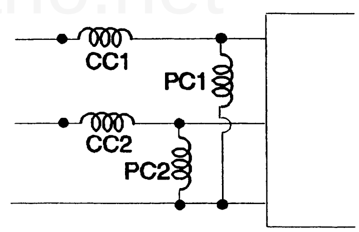
$Q_T = 3I_\phi^2 X_\phi = 3(5\ \text{A})^2\ 20\ \Omega = \mathbf{1500\ VAR(\mathit{L})}$

Y: $V_\phi = V_L/\sqrt{3} = 125\text{ V}/1.732 = \mathbf{72.17\text{ V}}$
$\mathbf{Z}_\phi = 3\ \Omega - j4\ \Omega = 5\ \Omega\angle -53.13°$
$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{72.17\text{ V}}{5\ \Omega} = \mathbf{14.43\text{ A}}$
$P_T = 3I_\phi^2 R_\phi = 3(14.43\text{ A})^2\, 3\ \Omega = \mathbf{1874.02\text{ W}}$
$Q_T = 3I_\phi^2 X_\phi = 3(14.43\text{ A})^2\, 4\ \Omega = \mathbf{2498.7\text{ VAR}}$
$P_T = 1125\text{ W} + 1874.02\text{ W} = \mathbf{2999.02\text{ W}}$
$Q_T = 1500\text{ VAR}(L) - 2498.7\text{ VAR}(C) = \mathbf{998.7\text{ VAR}(C)}$
$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3161\text{ VA}}$
$F_p = \dfrac{P_T}{S_T} = \dfrac{2999.02\text{ W}}{3161\text{ VA}} = \mathbf{0.949\ (leading)}$

44. a. —

b. $V_\phi = \dfrac{220\text{ V}}{\sqrt{3}} = 127.02\text{ V},\ \mathbf{Z}_\phi = 10\ \Omega - j10\ \Omega = 14.14\ \Omega\angle -45°$
$I_\phi = \dfrac{V_\phi}{Z_\phi} = \dfrac{127.02\text{ V}}{14.14\ \Omega} = 8.98\text{ A}$
$P_T = 3I_\phi^2 R_\phi = 3(8.98\text{ A})^2\, 10\ \Omega = \mathbf{2419.2\text{ W}}$
Each wattmeter: $\dfrac{2419.2\text{ W}}{3} = \mathbf{806.4\text{ W}}$

46. a. —



b. $P_T = P_\ell + P_h = 85\text{ W} + 200\text{ W} = \mathbf{285\text{ W}}$

c. $0.2 \Rightarrow \dfrac{P_\ell}{P_h} = 0.5$
$P_h = \dfrac{P_\ell}{0.5} = \dfrac{100\text{ W}}{0.5} = \mathbf{200\text{ W}}$
$P_T = P_h - P_\ell = 200\text{ W} - 100\text{ W} = \mathbf{100\text{ W}}$

48. a. $\mathbf{I}_{ab} = \dfrac{\mathbf{E}_{AB}}{R\angle 0°} = \dfrac{208\text{ V}\angle 0°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle 0°}$
$\mathbf{I}_{bc} = \dfrac{\mathbf{E}_{BC}}{R\angle 0°} = \dfrac{208\text{ V}\angle -120°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle -120°}$
$\mathbf{I}_{ca} = \dfrac{\mathbf{E}_{CA}}{R\angle 0°} = \dfrac{208\text{ V}\angle 120°}{10\ \Omega\ \angle 0°} = \mathbf{20.8\text{ A}\ \angle 120°}$

b. $\mathbf{I}_{Aa} + \mathbf{I}_{ca} - \mathbf{I}_{ab} = 0$
$\mathbf{I}_{Aa} = \mathbf{I}_{ab} - \mathbf{I}_{ca}$
$= 20.8\text{ A}\ \angle 0° - 20.8\text{ A}\ \angle 120°$
$= 20.8\text{ A} - (-10.4\text{ A} + j18.01\text{ A})$
$= 31.2\text{ A} - j18.01\text{ A}$
$= \mathbf{36.02\text{ A}\ \angle -30°}$
$\mathbf{I}_{Bb} + \mathbf{I}_{ab} - \mathbf{I}_{bc} = 0$

$$\begin{aligned}\mathbf{I}_{Bb} &= \mathbf{I}_{bc} - \mathbf{I}_{ab}\\ &= 20.8\text{ A} \angle -120° - 20.8\text{ A} \angle 0°\\ &= (-10.4\text{ A} - j18.01\text{ A}) - 20.8\text{ A}\\ &= -31.2\text{ A} - j18.01\text{ A}\\ &= \mathbf{36.02\text{ A} \angle -150°}\end{aligned}$$

$$\mathbf{I}_{Cc} + \mathbf{I}_{bc} - \mathbf{I}_{ca} = 0$$

$$\begin{aligned}\mathbf{I}_{Cc} &= \mathbf{I}_{ca} - \mathbf{I}_{bc}\\ &= 20.8\text{ A} \angle 120° - 20.8\text{ A} \angle -120°\\ &= (-10.4\text{ A} + j18.01\text{ A}) - (-10.4\text{ A} - j18.01\text{ A})\\ &= -10.4\text{ A} + 10.4\text{ A} + j18.01\text{ A} + j18.01\text{ A}\\ &= \mathbf{32.02\text{ A} \angle 90°}\end{aligned}$$

c. $P_1 = V_{ac} I_{Aa} \cos_{\mathbf{I}_{Aa}}^{\mathbf{V}_{ca}}$, $\quad \mathbf{V}_{ac} = V_{ca} \angle \theta - 180° = 208\text{ V} \angle 120° - 180°$

$$= 208\text{ V} \angle -60°$$

$$\mathbf{I}_{Aa} = 36.02\text{ A} \angle -30°$$

$$= (208\text{ V})(36.02\text{ A}) \cos 30°$$

$$= \mathbf{6488.4\text{ W}}$$

$P_2 = V_{bc} I_{Bb} \cos_{\mathbf{I}_{Bb}}^{\mathbf{V}_{bc}}$, $\quad \mathbf{V}_{bc} = 208\text{ V} \angle -120°$, $\mathbf{I}_{Bb} = 36.02\text{ A} \angle -150°$

$$= (208\text{ V})(36.02\text{ A}) \cos 30°$$

$$= \mathbf{6488.4\text{ W}}$$

d. $P_T = P_1 + P_2 = 6488.4\text{ W} + 6488.4\text{ W}$

$$= \mathbf{12{,}976.8\text{ W}}$$

50. $\mathbf{Z}_1 = 12\ \Omega - j16\ \Omega = 20\ \Omega \angle -53.13°$, $\mathbf{Z}_2 = 3\ \Omega + j4\ \Omega = 5\ \Omega \angle 53.13°$
$\mathbf{Z}_3 = 20\ \Omega \angle 0°$

$\mathbf{E}_{AB} = 200\text{ V} \angle 0°$, $\mathbf{E}_{BC} = 200\text{ V} \angle -120°$, $\mathbf{E}_{CA} = 200\text{ V} \angle 120°$

$$\begin{aligned}\mathbf{Z}_\Delta &= \mathbf{Z}_1\mathbf{Z}_2 + \mathbf{Z}_1\mathbf{Z}_3 + \mathbf{Z}_2\mathbf{Z}_3\\ &= (20\ \Omega \angle -53.13°)(5\ \Omega \angle 53.13°) + (20\ \Omega \angle -53.13°)(20\ \Omega \angle 0°)\\ &\quad + (5\ \Omega \angle 53.13°)(20\ \Omega \angle 0°)\\ &= 100\ \Omega \angle 0° + 400\ \Omega \angle -53.13° + 100\ \Omega \angle 53.13°\\ &= 100\ \Omega + (240\ \Omega - j320\ \Omega) + (60\ \Omega + j80\ \Omega)\\ &= 400\ \Omega - j240\ \Omega\\ &= 466.48\ \Omega \angle -30.96°\end{aligned}$$

$$\mathbf{I}_{an} = \frac{\mathbf{E}_{AB}\mathbf{Z}_3 - \mathbf{E}_{CA}\mathbf{Z}_2}{\mathbf{Z}_\Delta} = \frac{(200\text{ V} \angle 0°)(20\ \Omega \angle 0°) - (200\text{ V} \angle 120°)(5\ \Omega \angle 53.13°)}{\mathbf{Z}_\Delta}$$

$$= \frac{4000\text{ A} \angle 0° - 1000\text{ A} \angle 173.13°}{466.48 \angle -30.96°} = \mathbf{10.706\text{ A} \angle 29.59°}$$

$$\mathbf{I}_{bn} = \frac{\mathbf{E}_{BC}\mathbf{Z}_1 - \mathbf{E}_{AB}\mathbf{Z}_3}{\mathbf{Z}_\Delta} = \frac{(200\text{ V} \angle -120°)(20\ \Omega \angle -53.13°) - (200\text{ V} \angle 0°)(20\ \Omega \angle 0°)}{\mathbf{Z}_\Delta}$$

$$= \frac{4000\text{ A} \angle -173.13° - 4000\text{ A} \angle 0°}{466.48 \angle -30.96°} = \mathbf{17.12\text{ A} \angle -145.61°}$$

$$\mathbf{I}_{cn} = \frac{\mathbf{E}_{CA}\mathbf{Z}_2 - \mathbf{E}_{BC}\mathbf{Z}_1}{\mathbf{Z}_\Delta} = \frac{(200\text{ V} \angle 120°)(5\ \Omega \angle 53.13°) - (200\text{ V} \angle -120°)(20\ \Omega \angle -53.13°)}{\mathbf{Z}_\Delta}$$

$$= \frac{1000\text{ A} \angle 173.13° - 4000\text{ A} \angle -173.13°}{466.48 \angle -30.96°} = \mathbf{6.512\text{ A} \angle 42.32°}$$

$$\begin{aligned}
P_T &= I_{\text{an}}^2\ 12\ \Omega + I_{\text{bn}}^2\ 3\ \Omega + I_{\text{cn}}^2\ 20\ \Omega \\
&= (10.706\ \text{A})^2\ 12\ \Omega + (17.119\ \text{A})^2\ 3\ \Omega + (6.512\ \text{A})^2\ 20\ \Omega \\
&= 1375.42\ \text{W} + 879.18\ \text{W} + 848.12\ \text{W} = \mathbf{3102.72\ W}
\end{aligned}$$

$$\begin{aligned}
Q_T &= I_{\text{an}}^2 X_C + I_{\text{bn}}^2 X_L = (10.706\ \text{A})^2\ 16\ \Omega + (17.119\ \text{A})^2\ 4\ \Omega \\
&= \underset{(C)}{1833.9\ \text{VAR}} + \underset{(L)}{1172.24\ \text{VAR}} = \underset{(C)}{661.66\ \text{VAR}}
\end{aligned}$$

$$S_T = \sqrt{P_T^2 + Q_T^2} = \mathbf{3172.49\ VA}$$

$$F_p = \frac{P_T}{S_T} = \frac{3102.72\ \text{W}}{3172.49\ \text{VA}} = \mathbf{0.978\ (leading)}$$

CHAPTER 23 (Odd)

1. a. left: $d_1 = \frac{3}{16}'' = 0.1875''$, $d_2 = 1''$

$$\text{Value} = 10^3 \times 10^{0.1875''/1''} = 10^3 \times 1.54 = \mathbf{1.54\ kHz}$$

right: $d_1 = \frac{3}{4}'' = 0.75''$, $d_2 = 1''$

$$\text{Value} = 10^3 \times 10^{0.75''/1''} = 10^3 \times 5.623 = \mathbf{5.623\ kHz}$$

b. bottom: $d_1 = \frac{5}{16}'' = 0.3125''$, $d_2 = \frac{15}{16}'' = 0.9375''$

$$\text{Value} = 10^{-1} \times 10^{0.3125''/0.9375''} = 10^{-1} \times 10^{0.333} = 10^{-1} \times 2.153 = \mathbf{0.2153\ V}$$

top: $d_1 = \frac{11}{16}'' = 0.6875''$, $d_2 = 0.9375''$

$$\text{Value} = 10^{-1} \times 10^{0.6875''/0.9375''} = 10^{-1} \times 10^{0.720} = 10^{-1} \times 5.248 = \mathbf{0.5248\ V}$$

3. a. **1000** b. $\mathbf{10^{12}}$ c. **1.585** d. **1.096**

e. $\mathbf{10^{10}}$ f. **1513.56** g. **10.023** h. **1,258,925.41**

5. $\log_{10} 48 = \mathbf{1.681}$

$\log_{10} 8 + \log_{10} 6 = 0.903 + 0.778 = \mathbf{1.681}$

7. $\log_{10} 0.5 = \mathbf{-0.301}$

$-\log_{10} 2 = -(0.301) = \mathbf{-0.301}$

9. a. $\text{bels} = \log_{10} \frac{P_2}{P_1} = \log_{10} \frac{280\ \text{mW}}{4\ \text{mW}} = \log_{10} 70 = \mathbf{1.845}$

b. $\text{dB} = 10 \log_{10} \frac{P_2}{P_1} = 10(\log_{10} 70) = 10(1.845) = \mathbf{18.45}$

11. $\text{dB} = 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{40\ \text{W}}{2\ \text{W}} = 10 \log_{10} 20 = \mathbf{13.01}$

13. $\text{dB}_v = 20 \log_{10} \frac{V_2}{V_1} = 20 \log_{10} \frac{8.4\ \text{V}}{0.1\ \text{V}} = 20 \log_{10} 84 = \mathbf{38.49}$

15. $\text{dB}_s = 20 \log_{10} \frac{P}{0.0002\ \mu\text{bar}}$

$\text{dB}_s = 20 \log_{10} \frac{0.001\ \mu\text{bar}}{0.0002\ \mu\text{bar}} = \mathbf{13.98}$

$\text{dB}_s = 20 \log_{10} \dfrac{0.016\ \mu\text{bar}}{0.0002\ \mu\text{bar}} = \mathbf{38.06}$

Increase $= \mathbf{24.08\ dB_s}$

19. a. $A_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{X_C}{\sqrt{R^2 + X_C^2}} \angle -90° + \tan^{-1} X_C/R = \dfrac{1}{\sqrt{\left(\dfrac{R}{X_C}\right)^2 + 1}} \angle -\tan^{-1} R/X_C$

$f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(2.2\ \text{k}\Omega)(0.02\ \mu\text{F})} = \mathbf{3617.16\ Hz}$

$f = f_c$: $\quad A_v = \dfrac{V_o}{V_i} = 0.707$

$f = 0.1f_c$: At f_c, $X_C = R = 2.2\ \text{k}\Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi\, 0.1 f_c C} = \frac{1}{0.1}\left[\frac{1}{2\pi f_c C}\right] = 10[2.2\ \text{k}\Omega] = 22\ \text{k}\Omega$$

$$A_v = \frac{1}{\sqrt{\left(\dfrac{R}{X_C}\right)^2 + 1}} = \frac{1}{\sqrt{\left(\dfrac{2.2\ \text{k}\Omega}{22\ \text{k}\Omega}\right)^2 + 1}} = \frac{1}{\sqrt{(.1)^2 + 1}} = \mathbf{0.995}$$

$f = 0.5f_c = \frac{1}{2}f_c$: $\quad X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi\left(\dfrac{f_c}{2}\right)C} = 2\left[\dfrac{1}{2\pi f_c C}\right] = 2[2.2\ \text{k}\Omega] = 4.4\ \text{k}\Omega$

$$A_v = \frac{1}{\sqrt{\left(\dfrac{2.2\ \text{k}\Omega}{4.4\ \text{k}\Omega}\right)^2 + 1}} = \frac{1}{\sqrt{(0.5)^2 + 1}} = \mathbf{0.894}$$

$f = 2f_c$: $\quad X_C = \dfrac{1}{2\pi(2f_c)C} = \dfrac{1}{2}\left[\dfrac{1}{2\pi f_c C}\right] = \dfrac{1}{2}[2.2\ \text{k}\Omega] = 1.1\ \text{k}\Omega$

$$A_v = \frac{1}{\sqrt{\left(\dfrac{2.2\ \text{k}\Omega}{1.1\ \text{k}\Omega}\right)^2 + 1}} = \frac{1}{\sqrt{(2)^2 + 1}} = \mathbf{0.447}$$

$f = 10f_c$: $\quad X_C = \dfrac{1}{2\pi(10f_c)C} = \dfrac{1}{10}\left[\dfrac{1}{2\pi f_c C}\right] = \dfrac{1}{10}[2.2\ \text{k}\Omega] = 0.22\ \text{k}\Omega$

$$A_v = \frac{1}{\sqrt{\left(\dfrac{2.2\ \text{k}\Omega}{0.22\ \text{k}\Omega}\right)^2 + 1}} = \frac{1}{\sqrt{(10)^2 + 1}} = \mathbf{0.0995}$$

b. $\theta = -\tan^{-1} R/X_C$

$f = f_c$: $\theta = -\tan^{-1} = \mathbf{-45°}$

$f = 0.1f_c$: $\theta = -\tan^{-1} 2.2\text{ k}\Omega/22\text{ k}\Omega = -\tan^{-1}\dfrac{1}{10} = \mathbf{-5.71°}$

$f = 0.5f_c$: $\theta = -\tan^{-1} 2.2\text{ k}\Omega/4.4\text{ k}\Omega = -\tan^{-1}\dfrac{1}{2} = \mathbf{-26.57°}$

$f = \ 2f_c$: $\theta = -\tan^{-1} 2.2\text{ k}\Omega/1.1\text{ k}\Omega = -\tan^{-1} 2 = \mathbf{-63.43°}$

$f = 10f_c$: $\theta = -\tan^{-1} 2.2\text{ k}\Omega/0.22\text{ k}\Omega = -\tan^{-1} 10 = \mathbf{-84.29°}$

21. $f_c = 500\text{ Hz} = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(1.2\text{ k}\Omega)C}$

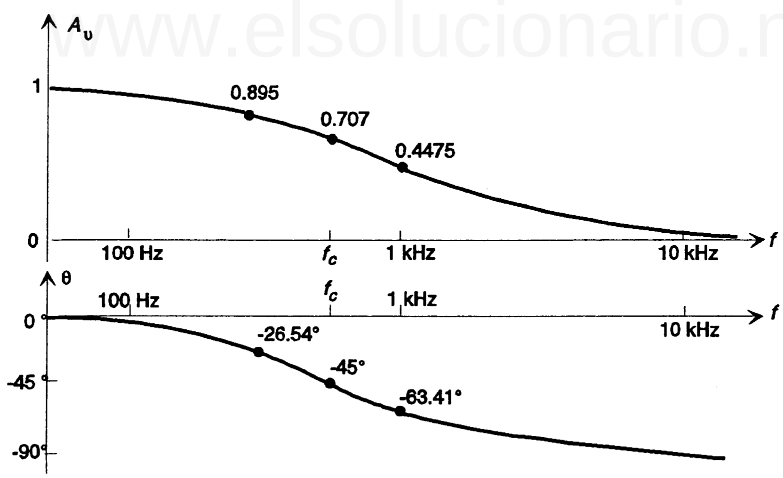
$$C = \frac{1}{2\pi R f_c} = \frac{1}{2\pi(1.2\text{ k}\Omega)(500\text{ Hz})} = \mathbf{0.265\ \mu F}$$

$$A_v = \frac{V_o}{V_i} = \frac{1}{\sqrt{\left[\dfrac{R}{X_C}\right]^2 + 1}}$$

At $f = 250$ Hz, $X_C = 2402.33\ \Omega$ and $A_v = 0.895$
At $f = 1000$ Hz, $X_C = 600.58\ \Omega$ and $A_v = 0.4475$
$\theta = -\tan^{-1}R/X_C$

At $f = 250\text{ Hz} = \frac{1}{2}f_c$, $\theta = -26.54°$

At $f = 1\text{ kHz} = 2f_c$, $\theta = -63.41°$



23. a. $A_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{R}{\sqrt{R^2 + X_C^2}} \angle \tan^{-1} X_C/R = \dfrac{1}{\sqrt{1 + \left(\dfrac{X_C}{R}\right)^2}} \angle \tan^{-1} X_C/R$

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(2.2\text{ k}\Omega)(20\text{ nF})} = \mathbf{3.617\ kHz}$$

$f = f_c$: $A_v = \dfrac{V_o}{V_i} = 0.707$

$f = 2f_c$: At f_c, $X_C = R = 2.2\text{ k}\Omega$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(2f_c)C} = \frac{1}{2}\left[\frac{1}{2\pi f_c C}\right] = \frac{1}{2}[2.2\text{ k}\Omega] = 1.1\text{ k}\Omega$$

$$A_v = \frac{1}{\sqrt{1 + \left[\dfrac{1.1\text{ k}\Omega}{2.2\text{ k}\Omega}\right]^2}} = \mathbf{0.894}$$

$f = \frac{1}{2}f_c$: $X_C = \dfrac{1}{2\pi\left[\dfrac{f_c}{2}\right]C} = 2\left[\dfrac{1}{2\pi f_c C}\right] = 2[2.2\text{ k}\Omega] = 4.4\text{ k}\Omega$

$$A_v = \frac{1}{\sqrt{1 + \left[\dfrac{4.4\text{ k}\Omega}{2.2\text{ k}\Omega}\right]^2}} = \mathbf{0.447}$$

$f = 10f_c$: $X_C = \dfrac{1}{2\pi(10f_c)C} = \dfrac{1}{10}\left[\dfrac{1}{2\pi f_c C}\right] = \dfrac{2.2\text{ k}\Omega}{10} = 0.22\text{ k}\Omega$

$$A_v = \frac{1}{\sqrt{1 + \left[\dfrac{0.22\text{ k}\Omega}{2.2\text{ k}\Omega}\right]^2}} = \mathbf{0.995}$$

$f = \frac{1}{10}f_c$: $X_C = \dfrac{1}{2\pi\left[\dfrac{f_c}{10}\right]C} = 10\left[\dfrac{1}{2\pi f_c C}\right] = 10[2.2\text{ k}\Omega] = 22\text{ k}\Omega$

$$A_v = \frac{1}{\sqrt{1 + \left[\dfrac{22\text{ k}\Omega}{2.2\text{ k}\Omega}\right]^2}} = \mathbf{0.0995}$$

b. $f = f_c$, $\theta = \mathbf{45^\circ}$

$f = 2f_c$, $\theta = \tan^{-1}(X_C/R) = \tan^{-1} 1.1\text{ k}\Omega/2.2\text{ k}\Omega = \tan^{-1}\dfrac{1}{2} = \mathbf{26.57^\circ}$

$f = \frac{1}{2}f_c$, $\theta = \tan^{-1}\dfrac{4.4\text{ k}\Omega}{2.2\text{ k}\Omega} = \tan^{-1} 2 = \mathbf{63.43^\circ}$

$f = 10f_c$, $\theta = \tan^{-1}\dfrac{0.22\text{ k}\Omega}{2.2\text{ k}\Omega} = \mathbf{5.71^\circ}$

$f = \frac{1}{10}f_c$, $\theta = \tan^{-1}\dfrac{22\text{ k}\Omega}{2.2\text{ k}\Omega} = \mathbf{84.29^\circ}$

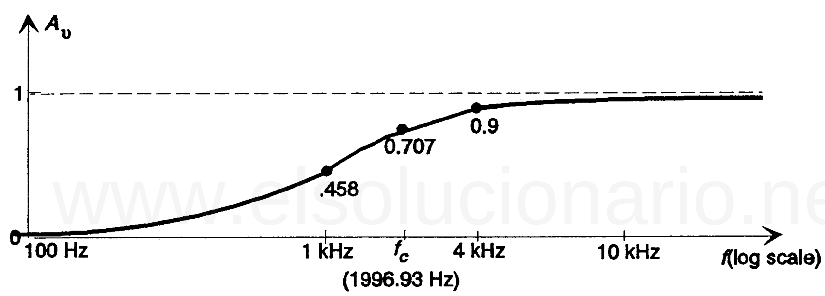
25. $\mathbf{A}_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{1}{\sqrt{1 + \left[\dfrac{X_C}{R}\right]^2}} \angle \tan^{-1} X_C/R$

$f_c = \dfrac{1}{2\pi RC} \Rightarrow R = \dfrac{1}{2\pi f_c C} = \dfrac{1}{2\pi(2 \text{ kHz})(0.1\ \mu\text{F})} = 795.77\ \Omega$

$R = 795.77\ \Omega \Rightarrow \underbrace{750\ \Omega + 47\ \Omega}_{\text{nominal values}} = 797\ \Omega$

$\therefore f_c = \dfrac{1}{2\pi(797\ \Omega)(0.1\ \mu\text{F})} = $ **1996.93 Hz** using nominal values

At $f = 1$ kHz, $A_v = 0.458$
$f = 4$ kHz, $A_v \cong 0.9$
$\theta = \tan^{-1} \dfrac{X_C}{R}$
$f = 1$ kHz, $\theta = 63.4°$
$f = 4$ kHz, $\theta = 26.53°$



27. a. low-pass section: $f_{c_1} = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(0.1\ \text{k}\Omega)(2\ \mu\text{F})} = $ **795.77 Hz**

high-pass section: $f_{c_2} = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(10\ \text{k}\Omega)(8\ \text{nF})} = $ **1989.44 Hz**

For the analysis to follow, it is assumed $(R_2 + jX_{C_2}) \| R_1 \cong R_1$ for all frequencies of interest.

At $f_{c_1} = 795.77$ Hz:

$V_{R_1} = 0.707\ V_i$

$X_{C_2} = \dfrac{1}{2\pi f C_2} = 25\ \text{k}\Omega$

$|V_o| = \dfrac{25\ \text{k}\Omega(V_{R_1})}{\sqrt{(10\ \text{k}\Omega)^2 + (25\ \text{k}\Omega)^2}} = 0.9285\ V_{R_1}$

$V_o = (0.9285)(0.707\ V_i) = \mathbf{0.656\ V_i}$

At $f_{c_2} = 1989.44$ Hz:

$$V_o = 0.707\ V_{R_1}$$

$$X_{C_1} = \frac{1}{2\pi f C_1} = 40\ \Omega$$

$$|V_{R_1}| = \frac{R_1 V_i}{\sqrt{R_1^2 + X_{C_1}^2}} = \frac{100\ \Omega(V_i)}{\sqrt{(100\ \Omega)^2 + (40\ \Omega)^2}} = 0.928\ V_i$$

$$|V_o| = (0.707)(0.928\ V_i) = \mathbf{0.656\ V_i}$$

$$\text{At } f = 795.77 \text{ Hz} + \frac{(1989.44 \text{ Hz} - 795.77 \text{ Hz})}{2} = 1392.60 \text{ Hz}$$

$$X_{C_1} = 57.14\ \Omega,\ X_{C_2} = 14.29\ \text{k}\Omega$$

$$V_{R_1} = \frac{100\ \Omega(V_i)}{\sqrt{(100\ \Omega)^2 + (57.14\ \Omega)^2}} = 0.868\ V_i$$

$$V_o = \frac{14.29\ \text{k}\Omega(V_{R_1})}{\sqrt{(10\ \text{k}\Omega)^2 + (14.29\ \text{k}\Omega)^2}} = 0.8193\ V_{R_1}$$

$$V_o = 0.8193(0.868\ V_i) = 0.711\ V_i$$

$$\text{and } A_v = \frac{V_o}{V_i} = 0.711\ (\cong \text{maximum value})$$

After plotting the points it was determined that the gain should also be determined at $f = 500$ Hz and 4 kHz:

$f = 500$ Hz: $X_{C_1} = 159.15\ \Omega$, $X_{C_2} = 39.8\ \text{k}\Omega$,
$V_{R_1} = 0.532\ V_i$, $V_o = 0.97\ V_{R_1}$
$V_o = \mathbf{0.516\ V_i}$

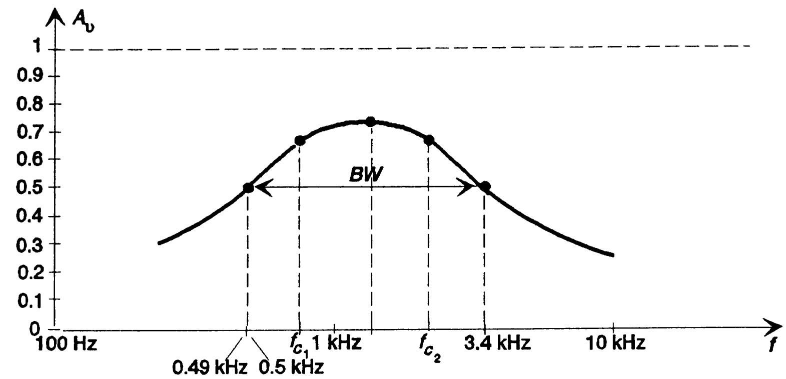
$f = 4$ kHz: $X_{C_1} = 19.89\ \Omega$, $X_{C_2} = 4.97\ \text{k}\Omega$,
$V_{R_1} = 0.981\ V_i$, $V_o = 0.445\ V_{R_1}$
$V_o = \mathbf{0.437\ V_i}$

b. Using $0.707(.711) = 0.5026 \cong 0.5$ to define the bandwidth

$$BW = 3.4 \text{ kHz} - 0.49 \text{ kHz} = 2.91 \text{ kHz}$$

and $BW \cong$ **2.9 kHz**

$$\text{with } f_{\text{center}} = 490 \text{ Hz} + \left[\frac{2.9 \text{ kHz}}{2}\right] = \mathbf{1940\ Hz}$$



29. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(5\text{ mH})(500\text{ pF})}} = \mathbf{100.658\ kHz}$

b. $Q_s = \dfrac{X_L}{R + R_\ell} = \dfrac{2\pi(100.658\text{ kHz})(5\text{ mH})}{160\ \Omega + 12\ \Omega} = \mathbf{18.39}$

$BW = \dfrac{f_s}{Q_s} = \dfrac{100.658\text{ kHz}}{18.39} = \mathbf{5{,}473.52\ Hz}$

c. At $f = f_s$: $V_{o_{\max}} = \dfrac{R}{R + R_\ell}V_i = \dfrac{160\ \Omega(1\text{ V})}{172\ \Omega} = 0.93\text{ V}$ and $A_v = \dfrac{V_o}{V_i} = \mathbf{0.93}$

Since $Q_s \geq 10$, $f_1 = f_s - \dfrac{BW}{2} = 100.658\text{ kHz} - \dfrac{5{,}473.52\text{ Hz}}{2} = 97{,}921.24\text{ Hz}$

$f_2 = f_s + \dfrac{BW}{2} = 103{,}394.76\text{ Hz}$

At $f = 95$ kHz: $X_L = 2\pi fL = 2\pi(95 \times 10^3\text{ Hz})(5\text{ mH}) = 2.98\text{ k}\Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(95 \times 10^3\text{ Hz})(500\text{ pF})} = 3.35\text{ k}\Omega$

$\mathbf{V}_o = \dfrac{160\ \Omega(1\text{ V}\angle 0°)}{172 + j2.98\text{ k}\Omega - j3.35\text{ k}\Omega} = \dfrac{160\text{ V}\angle 0°}{172 - j370}$

$= \dfrac{160\text{ V}\angle 0°}{480\ \angle -65.07°} = \mathbf{0.392\ V\angle 65.07°}$

At $f = 105$ kHz: $X_L = 2\pi fL = 2\pi(105\text{ kHz})(5\text{ mH}) = 3.3\text{ k}\Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(105\text{ kHz})(500\text{ pF})} = 3.03\text{ k}\Omega$

$\mathbf{V}_o = \dfrac{160\ (1\text{ V}\ \angle 0°)}{172 + j3.3\text{ k}\Omega - j3.03\text{ k}\Omega} = \dfrac{160\text{ V}\angle 0°}{172 + j270}$

$= \dfrac{160\text{ V}\angle 0°}{320\ \angle 57.50°} = \mathbf{0.5\angle -57.50°}$

d. $f = f_s$: $V_{o_{\max}} = \mathbf{0.93\ V}$
$f = f_1 = 97{,}921.24\text{ Hz}$, $V_o = 0.707(0.93\text{ V}) = \mathbf{0.658\ V}$
$f = f_2 = 103{,}394.76\text{ Hz}$, $V_o = 0.707(0.93\text{ V}) = \mathbf{0.658\ V}$

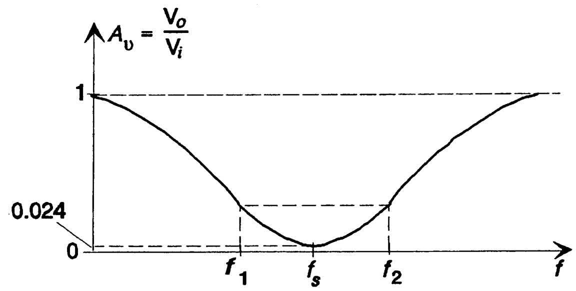
31. a. $Q_s = \dfrac{X_L}{R + R_\ell} = \dfrac{5000\ \Omega}{400\ \Omega + 10\ \Omega} = \dfrac{5000\ \Omega}{410\ \Omega} = \mathbf{12.195}$

b. $BW = \dfrac{f_s}{Q_s} = \dfrac{5000\text{ Hz}}{12.195} = \mathbf{410\ Hz}$

$f_1 = 5000\text{ Hz} - \dfrac{410\text{ Hz}}{2} = \mathbf{4795\ Hz}$

$f_2 = 5000\text{ Hz} + \dfrac{410\text{ Hz}}{2} = \mathbf{5205\ Hz}$

c.



At resonance

$V_o = \dfrac{10\ \Omega(V_i)}{10\ \Omega + 400\ \Omega}$
$= 0.024\ V_i$

d. At resonance, $10\ \Omega \| 2\text{ k}\Omega = 9.95\ \Omega$

$V_o = \dfrac{9.95\ \Omega(V_i)}{9.95\ \Omega + 400\ \Omega} \cong 0.024\ V_i$ as above!

33. a. $f_p = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{(400\ \mu\text{H})(120\text{ pF})}} = \mathbf{726.44\ kHz}$ (band-stop)

$X_{L_s}\ \angle 90° + (X_{L_p}\ \angle 90° \| X_C\ \angle -90°) = 0$

$$jX_{L_s} + \frac{(X_{L_p}\ \angle 90°)(X_C\ \angle -90°)}{jX_{L_p} - jX_C} = 0$$

$$jX_{L_s} + \frac{X_{L_p}X_C}{j(X_{L_p} - X_C)} = 0$$

$$jX_{L_s} - j\frac{X_{L_p}X_C}{(X_{L_p} - X_C)} = 0$$

$$X_{L_s} - \frac{X_{L_p}X_C}{X_{L_p} - X_C} = 0$$

$$X_{L_s}X_C - X_{L_s}X_{L_p} + X_{L_p}X_C = 0$$

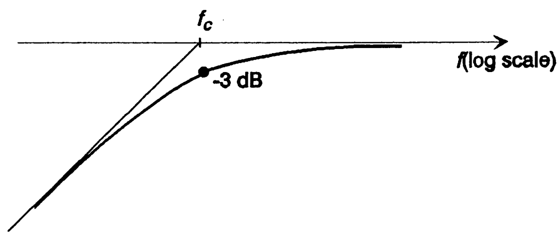
$$\frac{\omega L_s}{\omega C} - \omega L_s \omega L_p + \frac{\omega L_p}{\omega C} = 0$$

$$L_sL_p\omega^2 - \frac{1}{C}[L_s + L_p] = 0$$

$$\omega = \sqrt{\frac{L_s + L_p}{CL_sL_p}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{L_s + L_p}{CL_sL_p}} = \frac{1}{2\pi}\sqrt{\frac{460 \times 10^{-6}}{28.8 \times 10^{-19}}} = \mathbf{2.013\ MHz}\ \text{(pass-band)}$$

35. a, b. $f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(0.47\ \text{k}\Omega)(0.05\ \mu\text{F})} = \mathbf{772.55\ Hz}$



c. $f = \frac{1}{2}f_c$: $A_{v_{\text{dB}}} = 20\log_{10}\dfrac{1}{\sqrt{1 + (f_c/f)^2}} = 20\log_{10}\dfrac{1}{\sqrt{1 + (2)^2}} = \mathbf{-7\ dB}$

$f = 2f_c$: $A_{v_{\text{dB}}} = 20\log_{10}\dfrac{1}{\sqrt{1 + (0.5)^2}} = \mathbf{-0.969\ dB}$

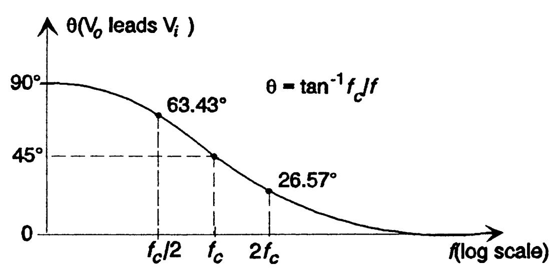
$f = \frac{1}{10}f_c$: $A_{v_{\text{dB}}} = 20\log_{10}\dfrac{1}{\sqrt{1 + (10)^2}} = \mathbf{-20.04\ dB}$

$f = 10f_c$: $A_{v_{\text{dB}}} = 20\log_{10}\dfrac{1}{\sqrt{1 + (0.1)^2}} = \mathbf{-0.043\ dB}$

d. $f = \frac{1}{2}f_c$: $A_v = \dfrac{1}{\sqrt{1 + (f_c/f)^2}} = \dfrac{1}{\sqrt{1 + (2)^2}} = \mathbf{0.4472}$

$f = 2f_c$: $A_v = \dfrac{1}{\sqrt{1 + (0.5)^2}} = \mathbf{0.894}$

e.



37. a, b. $\mathbf{A}_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = A_v \angle\theta = \dfrac{1}{\sqrt{1 + (f/f_c)^2}} \angle -\tan^{-1} f/f_c$

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(12\text{ k}\Omega)(1\text{ nF})} = 13.26\text{ kHz}$$

c. $f = f_c/2 = 6.63$ kHz

$$A_{v_{dB}} = 20\log_{10}\frac{1}{\sqrt{1 + (0.5)^2}} = \mathbf{-0.97\ dB}$$

$f = 2f_c = 26.52$ kHz

$$A_{v_{dB}} = 20\log_{10}\frac{1}{\sqrt{1 + (2)^2}} = \mathbf{-6.99\ dB}$$

$f = f_c/10 = 1.326$ kHz

$$A_{v_{dB}} = 20\log_{10}\frac{1}{\sqrt{1 + (0.1)^2}} = \mathbf{-0.043\ dB}$$

$f = 10f_c = 132.6$ kHz

$$A_{v_{dB}} = 20\log_{10}\frac{1}{\sqrt{1 + (10)^2}} = \mathbf{-20.04\ dB}$$

d. $f = f_c/2$: $\quad A_v = \dfrac{1}{\sqrt{1 + (0.5)^2}} = \mathbf{0.894}$

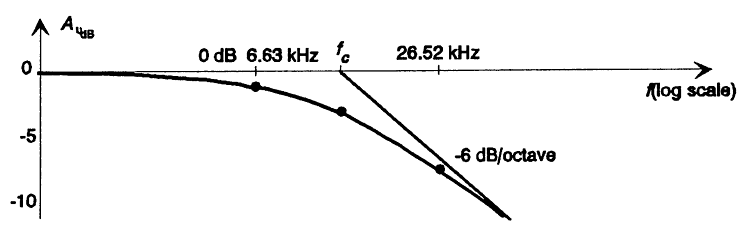
$f = 2f_c$: $\quad A_v = \dfrac{1}{\sqrt{1 + (2)^2}} = \mathbf{0.447}$

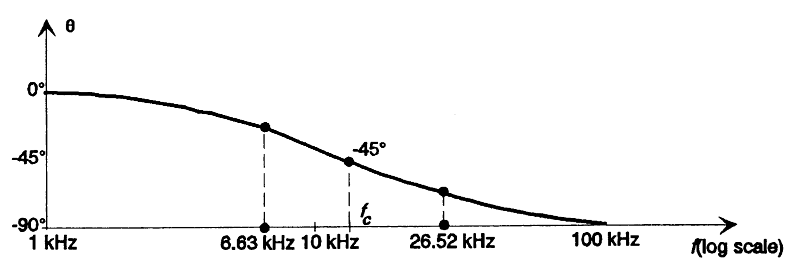
e. $\theta = \tan^{-1} f/f_c$

$f = f_c/2$: $\quad \theta = -\tan^{-1} 0.5 = -26.57°$

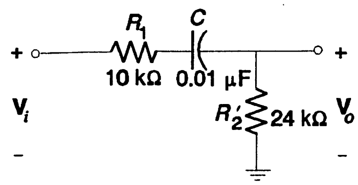
$f = f_c$: $\quad \theta = -\tan^{-1} 1 = -45°$

$f = 2f_c$: $\quad \theta = -\tan^{-1} 2 = -63.43°$





39.

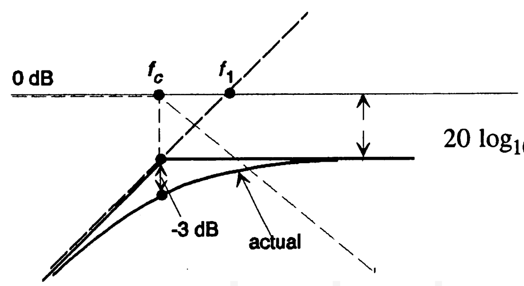


a. From Section 23.11,

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{jf/f_1}{1 + jf/f_c}$$

$$f_1 = \frac{1}{2\pi R_2' C} = \frac{1}{2\pi(24\ \text{k}\Omega)(0.01\ \mu\text{F})} = 663.15\ \text{Hz}$$

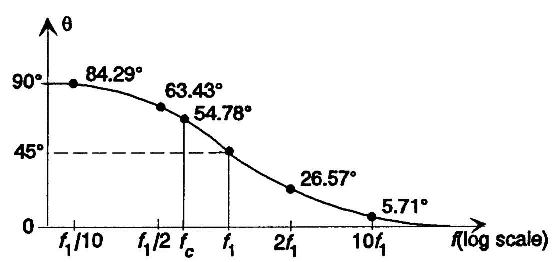
$$f_c = \frac{1}{2\pi(R_1 + R_2')C} = \frac{1}{2\pi(10\ \text{k}\Omega + 24\ \text{k}\Omega)(0.01\ \mu\text{F})} = 468.1\ \text{Hz}$$



$$20 \log_{10} \frac{f}{f_1} = 20 \log_{10} \frac{f_c}{f_1}$$
$$= 20 \log_{10} \frac{468.1\ \text{Hz}}{663.15\ \text{Hz}}$$
$$= \mathbf{-3.03\ dB}$$

b. $\theta = 90° - \tan^{-1} \dfrac{f}{f_1} = + \tan^{-1} \dfrac{f_1}{f}$

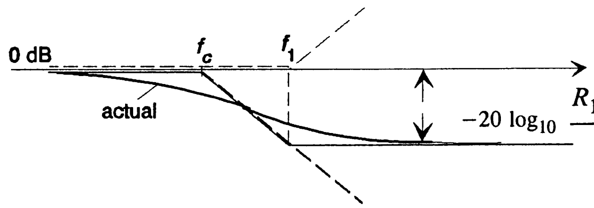
$f = f_1$: $\theta = 45°$
$f = f_c$: $\theta = 54.78°$
$f = \dfrac{1}{2} f_1 = 331.58\ \text{Hz},\ \theta = 63.43°$
$f = \dfrac{1}{10} f_1 = 66.31\ \text{Hz},\ \theta = 84.29°$
$f = 2f_1 = 1{,}326.3\ \text{Hz},\ \theta = 26.57°$
$f = 10f_1 = 6{,}631.5\ \text{Hz},\ \theta = 5.71°$



41. a. $\mathbf{A}_v = \dfrac{1 + j\dfrac{f}{f_1}}{1 + j\dfrac{f}{f_c}}$

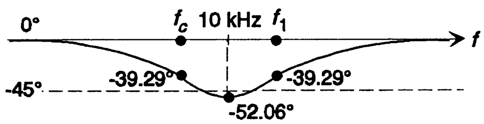
$f_1 = \dfrac{1}{2\pi R_2 C} = \dfrac{1}{2\pi(10\text{ k}\Omega)(800\text{ pF})} = 19{,}894.37\text{ Hz}$

$f_c = \dfrac{1}{2\pi(R_1 + R_2)C} = \dfrac{1}{2\pi(10\text{ k}\Omega + 90\text{ k}\Omega))(800\text{ pF})}$
$= 1{,}989.44\text{ Hz}$



$-20\log_{10}\dfrac{R_1 + R_2}{R_2} = -20\log_{10} 10$
$= \mathbf{-20\ dB}$

b.



$\theta = \tan^{-1} f/f_1 - \tan^{-1} f/f_c$

$f = 10\text{ kHz}$

$\theta = \tan^{-1}\dfrac{10\text{ kHz}}{19.89\text{ kHz}} - \tan^{-1}\dfrac{10\text{ kHz}}{1.989\text{ kHz}} = 26.69° - 78.75° = \mathbf{-52.06°}$

$f = f_c$: $(f_1 = 10\, f_c)$

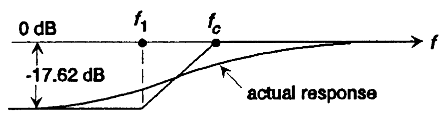
$\theta = \tan^{-1}\dfrac{f_c}{10\, f_c} - \tan^{-1}\dfrac{f_c}{f_c} = \tan^{-1} 0.1 - \tan^{-1} 1 = 5.71° - 45° = \mathbf{-39.29°}$

43. a. $\mathbf{A}_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{1 - j\, f_1/f}{1 - j\, f_c/f}$

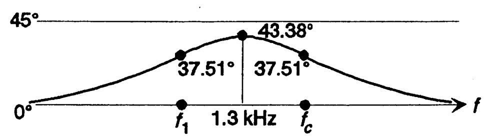
$f_1 = \dfrac{1}{2\pi R_1 C} = \dfrac{1}{2\pi(3.3\text{ k}\Omega)(0.05\ \mu\text{F})} = 964.58\text{ Hz}$

$f_c = \dfrac{1}{2\pi(R_1 \| R_2)C} = \dfrac{1}{2\pi(\underbrace{3.3\text{ k}\Omega \| 0.5\text{ k}\Omega}_{0.434\text{ k}\Omega})(0.05\ \mu\text{F})} = \mathbf{7{,}334.33\ Hz}$

$-20\log_{10}\dfrac{R_1 + R_2}{R_2} = -20\log_{10}\dfrac{3.3\text{ k}\Omega + 0.5\text{ k}\Omega}{0.5\text{ k}\Omega} = -20\log_{10} 7.6 = -17.62\text{ dB}$



b.

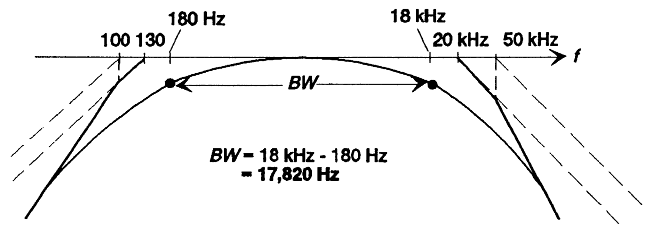


$$\theta = -\tan^{-1}\frac{f_1}{f} + \tan^{-1}\frac{f_c}{f}$$

$f = 1.3$ kHz: $\quad \theta = -\tan^{-1}\dfrac{964.58\text{ kHz}}{1.3\text{ kHz}} + \tan^{-1}\dfrac{7334.33\text{ Hz}}{1.3\text{ kHz}}$

$$= -36.57° + 79.95° = 43.38°$$

45. a. $$\frac{A_v}{A_{v_{\max}}} = \frac{1}{\left[1 - j\dfrac{100\text{ Hz}}{f}\right]\left[1 - j\dfrac{130\text{ Hz}}{f}\right]\left[1 + j\dfrac{f}{20\text{ kHz}}\right]\left[1 + j\dfrac{f}{50\text{ kHz}}\right]}$$



Proximity of 100 Hz to 130 Hz will raise lower cutoff frequency above 130 Hz:

Testing: $f = 180$ Hz: (with lower terms only)

$$A_{v_{\text{dB}}} = -20\log_{10}\sqrt{1 + \left[\frac{100}{f}\right]^2} - 20\log_{10}\sqrt{1 + \left[\frac{130}{f}\right]^2}$$

$$= -20\log_{10}\sqrt{1 + \left[\frac{100}{180}\right]^2} - 20\log_{10}\sqrt{1 + \left[\frac{130}{180}\right]^2}$$

$$= 1.17\text{ dB} - 1.82\text{ dB} = \mathbf{-2.99\text{ dB}} \cong -3\text{ dB}$$

Proximity of 50 kHz to 20 kHz will lower high cutoff frequency below 20 kHz:

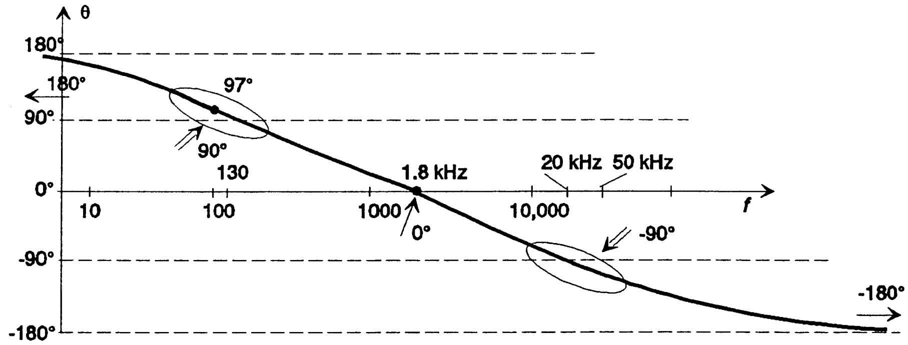
Testing: $f = 18$ kHz: (with upper terms only)

$$A_{v_{\text{dB}}} = -20\log_{10}\sqrt{1 + \left[\frac{f}{20\text{ kHz}}\right]^2} - 20\log_{10}\sqrt{1 + \left[\frac{f}{50\text{ kHz}}\right]^2}$$

$$= -20\log_{10}\sqrt{1 + \left[\frac{18\text{ kHz}}{20\text{ kHz}}\right]^2} - 20\log_{10}\sqrt{1 + \left[\frac{13\text{ kHz}}{20\text{ kHz}}\right]^2}$$

$$= -2.576\text{ dB} - 0.529\text{ dB} = \mathbf{-3.105\text{ dB}}$$

b.

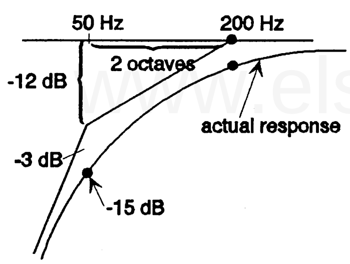


Testing: $\quad f = 1.8 \text{ kHz}$:

$$\theta = \tan^{-1}\frac{100}{1.8 \text{ kHz}} + \tan^{-1}\frac{130}{1.8 \text{ kHz}} - \tan^{-1}\frac{1.8 \text{ kHz}}{20 \text{ kHz}} - \tan^{-1}\frac{1.8 \text{ kHz}}{50 \text{ kHz}}$$
$$= 3.18° + 4.14° - 5.14° - 2.06°$$
$$= \mathbf{0.12° \cong 0°}$$

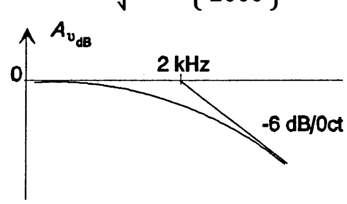
47. $f_{\text{low}} = f_{\text{high}} - BW = 36 \text{ kHz} - 35.8 \text{ kHz} = 0.2 \text{ kHz} = 200 \text{ Hz}$

$$A_v = \frac{-120}{\left(1 - j\dfrac{50}{f}\right)\left(1 - j\dfrac{200}{f}\right)\left(1 + j\dfrac{f}{36 \text{ kHz}}\right)}$$



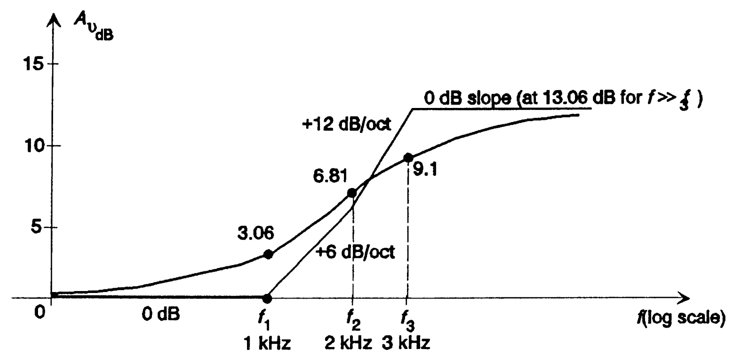
49. $$\mathbf{A}_v = \frac{200}{200 + j0.1f} = \frac{1}{1 + j\dfrac{0.1f}{200}} = \frac{1}{1 + j\dfrac{f}{2000}}$$

$$A_{v_{\text{dB}}} = 20 \log_{20}\frac{1}{\sqrt{1 + \left(\dfrac{f}{2000}\right)^2}}, \quad \frac{f}{2000} = 1 \text{ and } f = \mathbf{2 \text{ kHz}}$$



51. $$A_v = \frac{\left[1 + j\dfrac{f}{1000}\right]\left[1 + j\dfrac{f}{2000}\right]}{\left[1 + j\dfrac{f}{3000}\right]^2}$$

$$A_{v_{dB}} = 20\log_{10}\sqrt{1 + \left[\frac{f_1}{1000}\right]^2} + 20\log_{10}\sqrt{1 + \left[\frac{f_2}{2000}\right]^2} + 40\log_{10}\frac{1}{\sqrt{1 + \left[\dfrac{f_3}{3000}\right]^2}}$$



53. a. woofer - 400 Hz:

$$X_L = 2\pi fL = 2\pi(400 \text{ Hz})(4.7 \text{ mH}) = 11.81\ \Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(400 \text{ Hz})(39\ \mu\text{F})} = 10.20\ \Omega$$

$$R \| X_C = 8\ \Omega\ \angle 0° \| 10.20 \angle -90° = 6.3\ \Omega\ \angle -38.11°$$

$$\mathbf{V}_o = \frac{(R\|X_C)(\mathbf{V}_i)}{(R\|X_C) + jX_L} = \frac{(6.3\ \Omega\ \angle -38.11°)(\mathbf{V}_i)}{(6.3\ \Omega\ \angle -38.11°) + j11.81\ \Omega}$$

$$\mathbf{V}_o = 0.673\ \angle -96.11°\ \mathbf{V}_i$$

and $A_v = \dfrac{V_o}{V_i} =$ **0.673** vs desired 0.707 (off by less than 5%)

tweeter - 5 kHz:

$$X_L = 2\pi fL = 2\pi(5 \text{ kHz})(0.39 \text{ mH}) = 12.25\ \Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(5 \text{ kHz})(2.7\ \mu\text{F})} = 11.79\ \Omega$$

$$R \| X_L = 8\ \Omega\ \angle 0° \| 12.25\ \Omega\ \angle 90° = 6.7\ \Omega\ \angle 33.15°$$

$$\mathbf{V}_o = \frac{(6.7\ \Omega\ \angle 33.15°)(\mathbf{V}_i)}{(6.7\ \Omega\ \angle 33.15°) - j11.79\ \Omega}$$

$$\mathbf{V}_o = 0.678\ \angle 88.54°\ \mathbf{V}_i$$

and $A_v = \dfrac{V_o}{V_i} =$ **0.678** vs 0.707 (off by less than 5%)

b. woofer - 3 kHz:

$$X_L = 2\pi fL = 2\pi(3\text{ kHz})(4.7\text{ mH}) = 88.59\ \Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(3\text{ kHz})(39\ \mu\text{F})} = 1.36\ \Omega$$

$$R \| X_C = 8\ \Omega\ \angle 0° \| 1.36\ \Omega\ \angle -90° = 1.341\ \Omega\ \angle -80.35°$$

$$\mathbf{V}_o = \frac{(R\|X_C)(\mathbf{V}_i)}{(R\|X_C) + jX_L} = \frac{(1.341\ \Omega\ \angle -80.35°)(\mathbf{V}_i)}{(1.341\ \Omega\ \angle -80.35°) + j88.59\ \Omega}$$

$$\mathbf{V}_o = 0.015\ \angle -170.2°\ \mathbf{V}_i$$

and $A_v = \dfrac{V_o}{V_i} = \mathbf{0.015}$ vs desired 0 (excellent)

tweeter - 3 kHz:

$$X_L = 2\pi fL = 2\pi(3\text{ kHz})(0.39\text{ mH}) = 7.35\ \Omega$$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(3\text{ kHz})(2.7\ \mu\text{F})} = 19.65\ \Omega$$

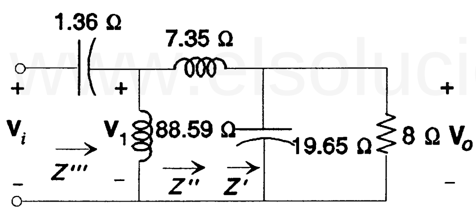
$$R \| X_L = 8\ \Omega\ \angle 0° \| 7.35\ \Omega\ \angle 90° = 5.42\ \Omega\ \angle 47.42°$$

$$\mathbf{V}_o = \frac{(R\|X_L)(\mathbf{V}_i)}{(R\|X_L) + jX_C} = \frac{(5.42\ \Omega\ \angle 47.42°)(\mathbf{V}_i)}{(5.42\ \Omega\ \angle 47.42°) - j19.65\ \Omega}$$

$$\mathbf{V}_o = 0.337\ \angle 124.24°\ \mathbf{V}_i$$

and $A_v = \dfrac{V_o}{V_i} = \mathbf{0.337}$ (acceptable since relatively close to cutoff frequency for tweeter)

c. mid-range speaker - 3 kHz:



$$\mathbf{Z}' = 7.41\ \Omega\ \angle -22.15°$$

$$\mathbf{Z}' = 8.24\ \Omega\ \angle 33.58°$$

$$\mathbf{Z}''' = 7.816\ \Omega\ \angle 37.79°$$

$$\mathbf{V}_1 = \frac{\mathbf{Z}'''\mathbf{V}_i}{\mathbf{Z}''' - jX_C} = \frac{(7.816\ \Omega\ \angle 37.79°)\mathbf{V}_i}{7.816\ \Omega\ \angle 37.79° - j1.36\ \Omega} = 1.11\ \angle 8.83°\ \mathbf{V}_i$$

$$\mathbf{V}_o = \frac{\mathbf{Z}'\mathbf{V}_1}{\mathbf{Z}' + jX_L} = \frac{(7.41\ \Omega\ \angle -22.15°)\mathbf{V}_i}{7.41\ \Omega\ \angle -22.15° + j7.35\ \Omega} = 0.998\ \angle -46.9°\ \mathbf{V}_i$$

and $A_v = \dfrac{V_o}{V_i} = \mathbf{0.998}$ kHz (excellent)

CHAPTER 23 (Even)

2. a. **5** b. **−4** c. **8** d. **−6**

   e. **1.301** f. **3.937** g. **4.748** h. **−0.498**

4. a. **11.513** b. **−9.21** c. **2.996** d. **9.065**

6. $\log_{10} 0.2 = \mathbf{-0.699}$
   $\log_{10} 18 - \log_{10} 90 = 1.255 - 1.954 = \mathbf{-0.699}$

8. $\log_{10} 27 = \mathbf{1.431}$
   $3 \log_{10} 3 = 3(0.4771) = \mathbf{1.431}$

10.
$$\begin{aligned}
\text{dB} &= 10 \log_{10} \frac{P_2}{P_1} \\
6\text{ dB} &= 10 \log_{10} \frac{100\text{ W}}{P_1} \\
0.6 &= \log_{10} x \\
x &= 3.981 = \frac{100\text{ W}}{P_1} \\
P_1 &= \frac{100\text{ W}}{3.981} = \mathbf{25.12\ W}
\end{aligned}$$

12.
$$\text{dB}_m = 10 \log_{10} \frac{P}{1\text{ mW}}$$
$$\text{dB}_m = 10 \log_{10} \frac{120\text{ mW}}{1\text{ mW}} = 10 \log_{10} 120 = \mathbf{20.792}$$

14.
$$\begin{aligned}
\text{dB}_v &= 20 \log_{10} \frac{V_2}{V_1} \\
22 &= 20 \log_{10} \frac{V_o}{20\text{ mV}} \\
1.1 &= \log_{10} x \\
x &= 12.589 = \frac{V_o}{20\text{ mV}} \\
V_o &= \mathbf{251.785\ mV}
\end{aligned}$$

16. $60\text{ dB}_s \Rightarrow 90\text{ dB}_s$
   quiet loud

$$\begin{aligned}
60\text{ dB}_s &= 20 \log_{10} \frac{P_1}{0.002\ \mu\text{bar}} = 20 \log_{10} x \\
3 &= \log_{10} x \\
x &= \mathbf{1000}
\end{aligned}$$

$$90\text{ dB}_s = 20\log_{10}\frac{P_2}{0.002\ \mu\text{bar}} = 20\log_{10}y$$
$$4.5 = \log_{10}y$$
$$y = \mathbf{31.623 \times 10^3}$$
$$\frac{x}{y} = \frac{\dfrac{P_1}{\cancel{0.002\ \mu\text{bar}}}}{\dfrac{P_2}{\cancel{0.002\ \mu\text{bar}}}} = \frac{P_1}{P_2} = \frac{\cancel{10^3}}{31.623 \times \cancel{10^3}}$$
and $P_2 = \mathbf{31.623\ P_1}$

18. a.
$$8\text{ dB} = 20\log_{10}\frac{V_2}{0.775\text{ V}}$$
$$0.4 = \log_{10}\frac{V_2}{0.775\text{ V}}$$
$$\frac{V_2}{0.775\text{ V}} = 2.512$$
$$V_2 = (2.512)(0.775\text{ V}) = 1.947\text{ V}$$
$$P = \frac{V^2}{R} = \frac{(1.947\text{ V})^2}{600\ \Omega} = \mathbf{6.318\ mW}$$

b.
$$-5\text{ dB} = 20\log_{10}\frac{V_2}{0.775\text{ V}}$$
$$-0.25 = \log_{10}\frac{V_2}{0.775\text{ V}}$$
$$\frac{V_2}{0.775\text{ V}} = 0.562$$
$$V_2 = (0.562)(0.775\text{ V}) = 0.436\text{ V}$$
$$P = \frac{V^2}{R} = \frac{(0.436\text{ V})^2}{600\ \Omega} = \mathbf{0.317\ mW}$$

20. a.
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(1\text{ k}\Omega)(0.01\ \mu\text{F})} = 15.915\text{ kHz}$$
$$f = 2f_c = 31.83\text{ kHz}$$
$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(31.83\text{ kHz})(0.01\ \mu\text{F})} = 500\ \Omega$$
$$A_v = \frac{V_o}{V_i} = \frac{X_C}{\sqrt{R^2 + X_C^2}} = \frac{500\ \Omega}{\sqrt{(1\text{ k}\Omega)^2 + (0.5\text{ k}\Omega)^2}} = 0.4472$$
$$V_o = 0.4472V_i = 0.4472(10\text{ mV}) = \mathbf{4.472\ mV}$$

b.
$$f = \frac{1}{10}f_c = \frac{1}{10}(15{,}915\text{ kHz}) = 1.5915\text{ kHz}$$
$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(1.5915\text{ kHz})(0.01\ \mu\text{F})} = 10\text{ k}\Omega$$
$$A_v = \frac{V_o}{V_i} = \frac{X_C}{\sqrt{R^2 + X_C^2}} = \frac{10\text{ k}\Omega}{\sqrt{(1\text{ k}\Omega)^2 + (10\text{ k}\Omega)^2}} = 0.995$$
$$V_o = 0.995V_i = 0.995(10\text{ mV}) = \mathbf{9.95\ mV}$$

c. Yes, at $f = f_c$, $V_o = 7.07$ mV

at $f = \frac{1}{10}f_c$, $V_o = 9.95$ mV (much higher)

at $f = 2f_c$, $V_o = 4.472$ mV (much lower)

22. a. $f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(4.7\text{ k}\Omega)(500\text{ pF})} = \mathbf{67.726\ kHz}$

b. $f = 0.1 f_c = 0.1(67.726\text{ kHz}) \cong 6.773\text{ kHz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(6.773\text{ kHz})(500\text{ pF})} = 46.997\text{ k}\Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{X_C}{\sqrt{R^2 + X_C^2}} = \frac{46.997\text{ k}\Omega}{\sqrt{(4.7\text{ k}\Omega)^2 + (46.997\text{ k}\Omega)^2}} = \mathbf{0.995} \cong 1$$

c. $f = 10f_c = 677.26\text{ kHz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(677.26\text{ kHz})(500\text{ pF})} \cong 470\ \Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{X_C}{\sqrt{R^2 + X_C^2}} = \frac{470\ \Omega}{\sqrt{(4.7\text{ k}\Omega)^2 + (470\ \Omega)^2}} = \mathbf{0.0995} \cong 0.1$$

d. $A_v = \dfrac{V_o}{V_i} = 0.01 = \dfrac{X_C}{\sqrt{R^2 + X_C^2}}$

$$\sqrt{R^2 + X_C^2} = \frac{X_C}{0.01} = 100\ X_C$$

$$R^2 + X_C^2 = 10^4 X_C^2$$

$$R^2 = 10^4 X_C^2 - X_C^2 = 9{,}999 X_C^2$$

$$X_C = \frac{R}{\sqrt{9{,}999}} = \frac{4.7\text{ k}\Omega}{99.995} \cong 47\ \Omega$$

$$X_C = \frac{1}{2\pi fC} \Rightarrow f = \frac{1}{2\pi X_C C} = \frac{1}{2\pi(47\ \Omega)(500\text{ pF})} = \mathbf{6.77\ MHz}$$

24. a. $f = f_c$: $A_v = \dfrac{V_o}{V_i} = \mathbf{0.707}$

b. $f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(10\text{ k}\Omega)(1000\text{ pF})} = 15.915\text{ kHz}$

$f = 4f_c = 4(15.915\text{ kHz}) = 63.66\text{ kHz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(63.66\text{ kHz})(1000\text{ pF})} = 2.5\text{ k}\Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{10\text{ k}\Omega}{\sqrt{(10\text{ k}\Omega)^2 + (2.5\text{ k}\Omega)^2}} = \mathbf{0.970} \text{ (significant rise)}$$

c. $f = 100f_c = 100(15.915\text{ kHz}) = 1591.5\text{ kHz} \cong 1.592\text{ MHz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(1.592\text{ MHz})(1000\text{ pF})} = 99.972\ \Omega$$

$$A_v = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{10\text{ k}\Omega}{\sqrt{(10\text{ k}\Omega)^2 + (99.972\ \Omega)^2}} = 0.99995 \cong 1$$

d. At $f = f_c$, $V_o = 0.707V_i = 0.707(10\text{ mV}) = 7.07\text{ mV}$

$$P_o = \frac{V_o^2}{R} = \frac{(7.07\text{ mV})^2}{10\text{ k}\Omega} \cong \mathbf{5\ nW}$$

26. a. $f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(100\text{ k}\Omega)(20\text{ pF})} = \mathbf{79.577\ kHz}$

b. $f = 0.01f_c = 0.01(79.577\text{ kHz}) = 0.7958\text{ kHz} \cong 796\text{ Hz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(796\text{ Hz})(20\text{ pF})} = 9.997\text{ M}\Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{100\text{ k}\Omega}{\sqrt{(100\text{ k}\Omega)^2 + (9.997\text{ M}\Omega)^2}} = \mathbf{0.01} \cong 0$$

c. $f = 100f_c = 100(79.577\text{ kHz}) \cong 7.96\text{ MHz}$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(7.96\text{ MHz})(20\text{ pF})} = 999.72\ \Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{100\text{ k}\Omega}{\sqrt{(100\text{ k}\Omega)^2 + (999.72\ \Omega)^2}} = \mathbf{0.99995} \cong 1$$

d. $A_v = \dfrac{V_o}{V_i} = 0.5 = \dfrac{R}{\sqrt{R^2 + X_C^2}}$

$$\sqrt{R^2 + X_C^2} = 2R$$

$$R^2 + X_C^2 = 4R^2$$

$$X_C^2 = 4R^2 - R^2 = 3R^2$$

$$X_C = \sqrt{3R^2} = \sqrt{3}\,R = \sqrt{3}\,(100\text{ k}\Omega) = 173.2\text{ k}\Omega$$

$$X_C = \frac{1}{2\pi fC} \Rightarrow f = \frac{1}{2\pi X_C C} = \frac{1}{2\pi(173.2\text{ k}\Omega)(20\text{ pF})}$$

$$f = \mathbf{45.95\ kHz}$$

28. $f_1 = \dfrac{1}{2\pi R_1 C_1} = 4\text{ kHz}$

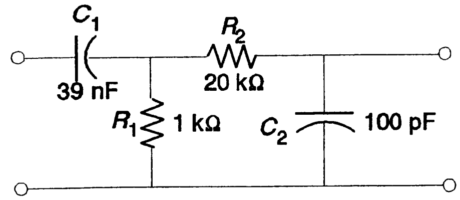
Choose $R_1 = 1\text{ k}\Omega$

$$C_1 = \frac{1}{2\pi f_1 R_1} = \frac{1}{2\pi(4\text{ kHz})(1\text{ k}\Omega)} = 39.8\text{ nF} \therefore \text{ Use } \mathbf{39\ nF}$$

$$f_2 = \frac{1}{2\pi R_2 C_2} = 80\text{ kHz}$$

Choose $R_2 = 20\text{ k}\Omega$

$$C_2 = \frac{1}{2\pi f_2 R_2} = \frac{1}{2\pi(80\text{ kHz})(20\text{ k}\Omega)} = 99.47\text{ pF} \therefore \text{ Use } 100\text{ pF}$$



$$\text{Center frequency} = 4\text{ kHz} + \frac{80\text{ kHz} - 4\text{ kHz}}{2} = 42\text{ kHz}$$

At $f = 42$ kHz, $X_{C_1} = 97.16\ \Omega$, $X_{C_2} = 37.89\text{ k}\Omega$

Assuming $\mathbf{Z}_2 \gg \mathbf{Z}_1$

$$|V_{R_1}| = \frac{R_1(V_i)}{\sqrt{R_1^2 + X_{C_1}^2}} = 0.995V_i$$

$$|V_o| = \frac{X_{C_2}(V_{R_1})}{\sqrt{R_2^2 + X_{C_2}^2}} = 0.884V_i$$

$V_o = 0.884V_{R_1} = 0.884(0.995V_i) = \mathbf{0.88\ V_i}$

as $f = f_1$: $V_{R_1} = 0.707V_i$, $X_{C_2} = 221.05\text{ k}\Omega$

and $V_o = 0.996V_{R_1}$

so that $V_o = 0.996V_{R_1} = 0.996(0.707V_i) = 0.704V_i$

Although $A_v = 0.88$ is less than the desired level of 1, f_1 and f_2 do define a band of frequencies for which $A_v \geq 0.7$ and the power to the load is significant.

30. a. $$f_p = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R_\ell^2 C}{L}} \cong \mathbf{159.15\text{ kHz}}$$

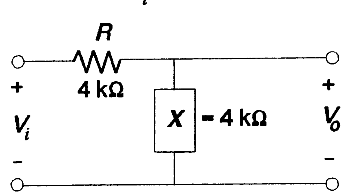
$$Q_\ell = \frac{X_L}{R_\ell} = \frac{2\pi f_p L}{R_\ell} = \frac{2\pi(159.15\text{ kHz})(1\text{ mH})}{16\ \Omega} = 62.5 \gg 10$$

$$\therefore Z_{T_p} = Q_\ell^2 R_\ell = (62.5)^2\, 16\ \Omega = 62.5\text{ k}\Omega \gg R = 4\text{ k}\Omega$$

and $V_o \cong V_i$ at resonance.

However, $R = 4\text{ k}\Omega$ affects the shape of the resonance curve and $BW = f_p/Q_\ell$ cannot be applied.

For $A_v = \dfrac{V_o}{V_i} = 0.707$, $|X| = R$ for the following configuration



For frequencies near f_p, $X_L >> R_\ell$ *and* $Z_L = R_\ell + jX_L \cong X_L$ and $X = X_L \| X_C$.

For frequencies near f_p but less than f_p

$$X = \frac{X_C X_L}{X_C - X_L}$$

and for $A_v = 0.707$

$$\frac{X_C X_L}{X_C - X_L} = R$$

Substituting $X_C = \dfrac{1}{2\pi f_1 C}$ and $X_L = 2\pi f_1 L$

the following equation can be derived:

$$f_1^2 + \frac{1}{2\pi RC} f_1 - \frac{1}{4\pi^2 LC} = 0$$

For this situation:

$$\frac{1}{2\pi RC} = \frac{1}{2\pi(4\text{ k}\Omega)(0.001\ \mu\text{F})} = 39.79 \times 10^3$$

$$\frac{1}{4\pi^2 LC} = \frac{1}{4\pi^2(1\text{ mH})(0.001\ \mu\text{F})} = 2.53 \times 10^{10}$$

and solving the quadratic equation, $f_1 = 140.4$ kHz

and $\dfrac{BW}{2} = 159.15\text{ kHz} - 140.4\text{ kHz} = 18.75\text{ kHz}$

with $BW = 2(18.75\text{ kHz}) = \mathbf{37.5\ kHz}$

b. $Q_p = \dfrac{f_p}{BW} = \dfrac{159.15\text{ kHz}}{37.5\text{ kHz}} = \mathbf{4.24}$

32. a. $Q_\ell = \dfrac{X_L}{R_\ell} = \dfrac{400\ \Omega}{10\ \Omega} = 40$

$Z_{T_p} = Q_\ell^2 R_\ell = (40)^2\ 20\ \Omega = 32\text{ k}\Omega >> 1\text{ k}\Omega$

At resonance, $V_o = \dfrac{32\text{ k}\Omega\ V_i}{32\text{ k}\Omega + 1\text{ k}\Omega} = 0.97V_i$

and $A_v = \dfrac{V_o}{V_i} = 0.97$

For the low cutoff frequency note solution to Problem 30:

$$f_1^2 + \frac{1}{2\pi f R_C} f_1 - \frac{1}{4\pi^2 LC} = 0$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(20\text{ kHz})(400\ \Omega)} = 19.9\text{ nF}$$

$$L = \frac{X_L}{2\pi f} = \frac{400\ \Omega}{2\pi(20\text{ kHz})} = 3.18\text{ mH}$$

Substituting into the above equation and solving

$f_1 = 16.4\text{ kHz}$

with $\dfrac{BW}{2} = 20\text{ kHz} - 16.4\text{ kHz} = 3.6\text{ kHz}$

and $BW = 2(3.6\text{ kHz}) = \mathbf{7.2\ kHz}$

$Q_p = \dfrac{f_p}{BW} = \dfrac{20\text{ kHz}}{7.2\text{ kHz}} = \mathbf{2.78}$

b. —

c. At resonance

$Z_{T_p} = 32\text{ k}\Omega \parallel 100\text{ k}\Omega = 24.24\text{ k}\Omega$

with $V_o = \dfrac{24.24\text{ k}\Omega\ V_i}{24.24\text{ k}\Omega + 1\text{ k}\Omega} = 0.96V_i$

and $A_v = \dfrac{V_o}{V_i} = 0.96$ vs 0.97 above

At frequencies to the right and left of f_p, the impedance Z_{T_p} will decrease and be affected less and less by the parallel 100 kΩ load. The characteristics, therefore, are only slightly affected by the 100 kΩ load.

d. At resonance

$Z_{T_p} = 32\text{ k}\Omega \parallel 20\text{ k}\Omega = 12.31\text{ k}\Omega$

with $V_o = \dfrac{12.31\text{ k}\Omega\ V_i}{12.31\text{ k}\Omega + 1\text{ k}\Omega} = 0.925V_i$ vs 0.97 above

At frequencies to the right and left of f_p, the impedance of each frequency will actually be less due to the parallel 20 kΩ load. The effect will be to narrow the resonance curve and decrease the bandwidth with an increase in Q_p.

34. a. $f_s = \dfrac{1}{2\pi\sqrt{LC}} \Rightarrow L_s = \dfrac{1}{4\pi^2 f_s^2 C} = \dfrac{1}{4\pi^2(100\text{ kHz})^2(200\text{ pF})} = 12.68\text{ mH}$

$X_L = 2\pi fL = 2\pi(30\text{ kHz})(12.68\text{ mH}) = 2388.91\ \Omega$

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(30\text{ kHz})(200\text{ pF})} = 26.54\text{ k}\Omega$

$X_C - X_L = 26.54\text{ k}\Omega - 2388.91\ \Omega = 24.15\text{ k}\Omega(C)$

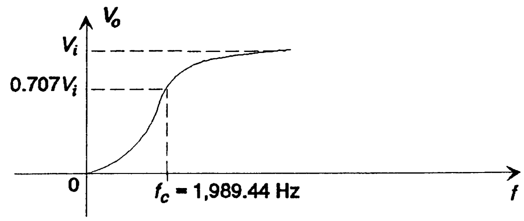
$X_{L_p} = X_{C_{(\text{net})}} = 24.15\text{ k}\Omega$

$L_p = \dfrac{X_L}{2\pi f} = \dfrac{24.15\text{ k}\Omega}{2\pi(30\text{ kHz})} = \mathbf{128.19\ mH}$

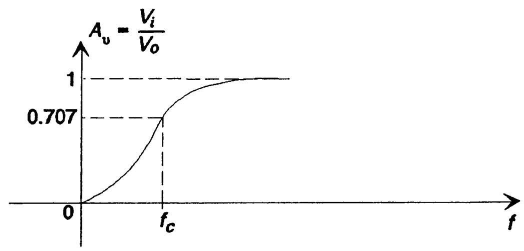
36. a. $f_c = \dfrac{1}{2\pi RC} = \dfrac{1}{2\pi(6\text{ k}\Omega \parallel 12\text{ k}\Omega)0.01\ \mu\text{F}} = \dfrac{1}{2\pi(4\text{ k}\Omega)(0.01\ \mu\text{F})} = \mathbf{1989.44\ Hz}$

$\dfrac{V_o}{V_i} = \dfrac{1}{\sqrt{1 + (f_c/f)^2}}$

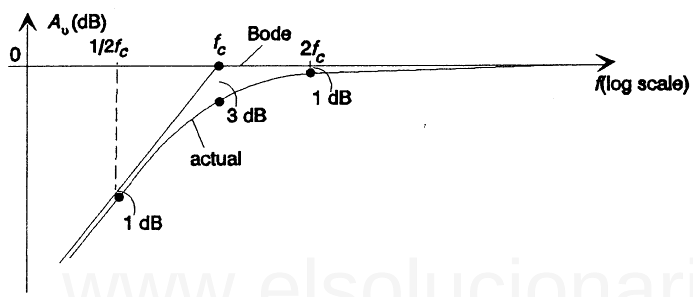
and $V_o = \left[\dfrac{1}{\sqrt{1 + (f_c/f)^2}}\right] V_i$



b.



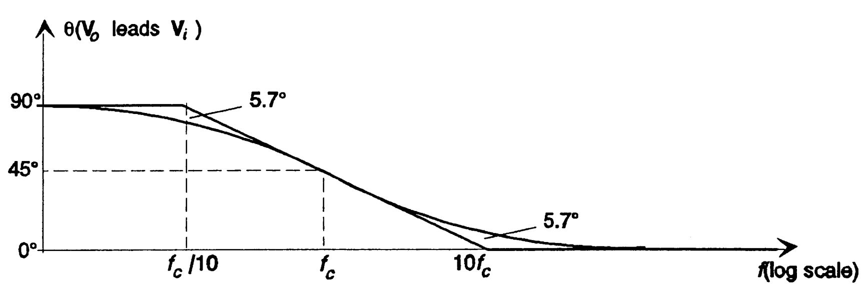
c. & d.



e. Remember the log scale! $1.5f_c$ not midway between f_c and $2f_c$

$$A_{v_{dB}} = 20 \log_{10} A_v$$
$$-1.5 = 20 \log_{10} A_v$$
$$-0.075 = \log_{10} A_v$$
$$A_v = \frac{V_o}{V_i} = \mathbf{0.841}$$

f. $\theta = \tan^{-1} f_c/f$



38. a. $R_2 \| X_C = \dfrac{(R_2)(-jX_C)}{R_2 - jX_C} = -j\dfrac{R_2X_C}{R_2 - jX_C}$

$$\mathbf{V}_o = \frac{\left(\dfrac{-jR_2X_C)}{R_2 - jX_C}\right)\mathbf{V}_i}{R_1 - j\dfrac{R_2X_C}{R_2 - jX_C}} = -j\frac{R_2X_C\mathbf{V}_i}{R_1(R_2 - jX_C) - jR_2X_C}$$

$$= \frac{-jR_2X_C\mathbf{V}_i}{R_1R_2 - jR_1X_C - jR_2X_C} = \frac{-jR_2X_C\mathbf{V}_i}{R_1R_2 - j(R_1 + R_2)X_C}$$

$$= \frac{R_2X_C\mathbf{V}_i}{jR_1R_2 + (R_1 + R_2)X_C} = \frac{R_2\mathbf{V}_i}{j\dfrac{R_1R_2}{X_C} + (R_1 + R_2)}$$

$$= \frac{R_2\mathbf{V}_i}{R_1 + R_2 + j\dfrac{R_1R_2}{X_C}} = \frac{\left(\dfrac{R_2}{R_1 + R_2}\right)\mathbf{V}_i}{1 + j\left(\dfrac{R_1R_2}{R_1 + R_2}\right)\dfrac{1}{X_C}}$$

and $\mathbf{A}_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{\dfrac{R_2}{R_1 + R_2}}{1 + j\omega\left(\dfrac{R_1R_2}{R_1 + R_2}\right)C}$

or $\mathbf{A}_v = \dfrac{R_2}{R_1 + R_2}\left[\dfrac{1}{1 + j2\pi f(R_1 \| R_2)C}\right]$

defining $f_c = \dfrac{1}{2\pi(R_1 \| R_2)C}$

$$\mathbf{A}_v = \frac{R_2}{R_1 + R_2}\left[\frac{1}{1 + j\,f/f_c}\right]$$

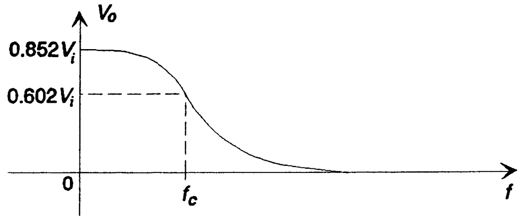
and $\mathbf{A}_v = \dfrac{R_2}{R_1 + R_2}\left[\dfrac{1}{\sqrt{1 + (f/f_c)^2}} \angle -\tan^{-1} f/f_c\right]$

with $|V_o| = \dfrac{R_2}{R_1 + R_2}\left[\dfrac{1}{\sqrt{1 + (f/f_c)^2}}\right]|V_i|$

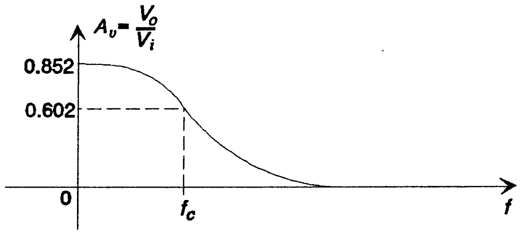
for $f \ll f_c$, $V_o = \dfrac{R_2}{R_1 + R_2}V_i = \dfrac{27\text{ k}\Omega}{4.7\text{ k}\Omega + 27\text{ k}\Omega}V_i = 0.852V_i$

at $f = f_c$: $V_o = 0.852[0.707]V_i = 0.602V_i$

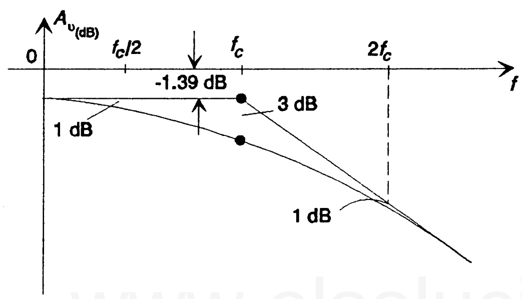
$f_c = \dfrac{1}{2\pi(R_1 \| R_2)C} =$ **994.72 Hz**



b.



c. & d.

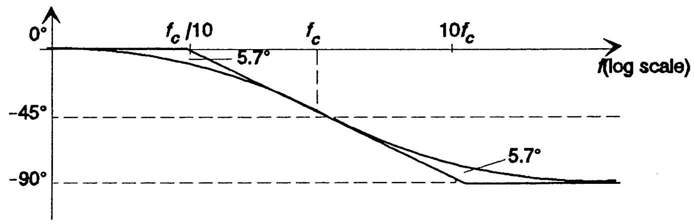


$$-20\log_{10}\frac{R_1 + R_2}{R_2} = -20\log_{10}\frac{4.7\text{ k}\Omega + 27\text{ k}\Omega}{27\text{ k}\Omega}$$
$$= -20\log_{10} 1.174 = -1.39\text{ dB}$$

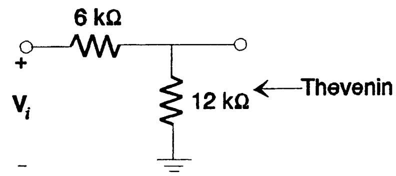
e. $A_{v_{\text{dB}}} \cong -1.39\text{ dB} - 0.5\text{ dB} = -1.89\text{ dB}$

$$A_{v_{\text{dB}}} = 20\log_{10} A_v$$
$$-1.89 = 20\log_{10} A_v$$
$$0.0945 = \log_{10} A_v$$
$$A_v = \frac{V_o}{V_i} = \mathbf{0.804}$$

f. $\theta = -\tan^{-1} f/f_c$

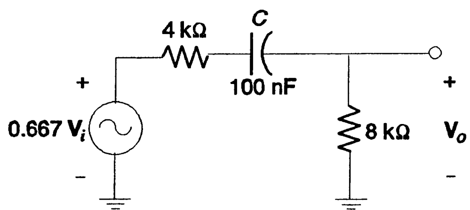


40. a.



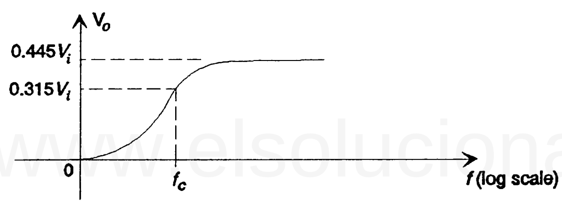
$$\mathbf{V}_{Th} = \frac{12\ \text{k}\Omega\ \mathbf{V}_i}{12\ \text{k}\Omega + 6\ \text{k}\Omega} = 0.667\ \mathbf{V}_i$$

$$R_{Th} = 6\ \text{k}\Omega \,\|\, 12\ \text{k}\Omega = 4\ \text{k}\Omega$$



$f = \infty$ Hz: ($C \Rightarrow$ short circuit)

$$\mathbf{V}_o = \frac{8\ \text{k}\Omega\ (0.667\ \mathbf{V}_i)}{8\ \text{k}\Omega + 4\ \text{k}\Omega} = 0.445\ \mathbf{V}_i$$

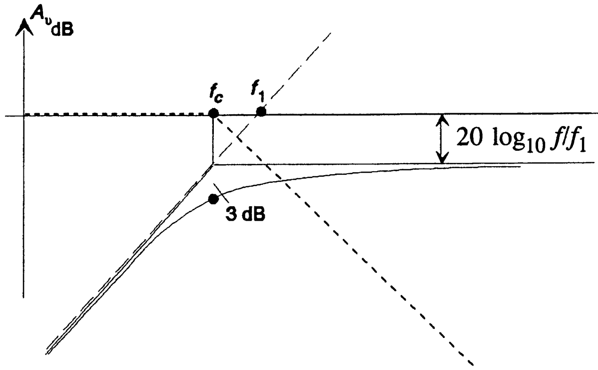


voltage-divider rule: $\mathbf{V}_o = \dfrac{R_2(0.667\ \mathbf{V}_i)}{R_1 + R_2 - jX_C} = \dfrac{0.667\ R_2\mathbf{V}_i}{R_1 + R_2 - jX_C}$

and $\mathbf{A}_v = \dfrac{\mathbf{V}_o}{\mathbf{V}_i} = \dfrac{0.667R_2}{R_1 + R_2 - jX_C} = \dfrac{j2\pi f(0.667R_2)C}{1 + j2\pi f(R_1 + R_2)C}$

so that $\mathbf{A}_v = \dfrac{jf/f_1}{1 + jf/f_c}$ with $f_1 = \dfrac{1}{2\pi 0.667R_2C} = \dfrac{1}{2\pi 0.667(8\ \text{k}\Omega)(100\ \text{nF})}$
$= 298.27$ Hz

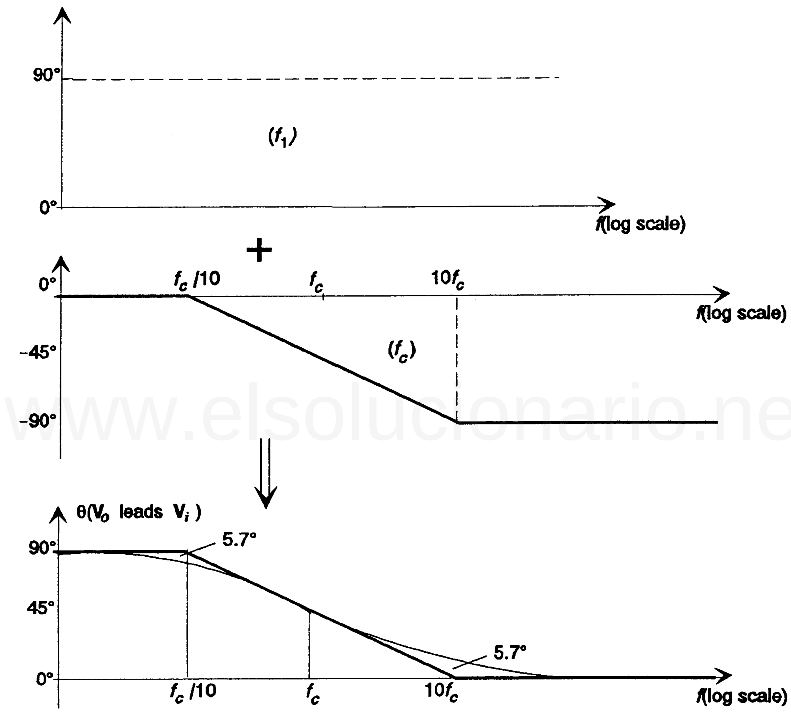
and $f_c = \dfrac{1}{2\pi(R_1 + R_2)C} = \dfrac{1}{2\pi(4\ \text{k}\Omega + 8\ \text{k}\Omega)(100\ \text{nF})}$
$= 132.63$ Hz



$$20 \log_{10} f/f_1 = 20 \log_{10} \frac{132.63 \text{ Hz}}{298.27 \text{ Hz}}$$
$$= 20 \log_{10} 0.445 = -7.04 \text{ dB}$$

b. $\theta = 90° - \tan^{-1} f/f_c = +\tan^{-1} f_c/f = \tan^{-1} 132.6 \text{ Hz}/f$

or



42. a. R_1 no effect!
Note Section 23.12.

$$\mathbf{A}_v = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1 + j\,(f/f_1)}{1 + j\,(f/f_c)}$$

$$f_1 = \frac{1}{2\pi(6 \text{ k}\Omega)(0.01\ \mu\text{F})} = 2652.58 \text{ Hz}$$

$$f_c = \frac{1}{2\pi(12 \text{ k}\Omega + 6 \text{ k}\Omega)(0.01\ \mu\text{F})} = 884.19 \text{ Hz}$$

Note Fig. 23.65.

Asymptote at 0 dB from $0 \rightarrow f_c$
-6 dB/octave from f_c to f_1
-9.54 dB from f_1 on $\left[-20 \log \dfrac{12\text{ k}\Omega + 6\text{ k}\Omega}{6\text{ k}\Omega} = -9.54\text{ dB}\right]$

(b) Note Fig. 23.67.

From 0° to $-26.50°$ at f_c and f_1
$\theta = \tan^{-1} f/f_1 - \tan^{-1} f/f_c$
At $f = 1500$ Hz (between f_c and f_1)
$\theta = \tan^{-1} 1500\text{ Hz}/2652.58\text{ Hz} - \tan^{-1} 1500\text{ Hz}/884.19\text{ Hz}$
$= 29.49° - 59.48° = -30°$

44. a. Note Section 23.13.

$$\mathbf{A}_v = \frac{1 - j(f_1/f)}{1 - j(f_c/f)}$$

$$f_1 = \frac{1}{2\pi R_1 C} = \frac{1}{2\pi(3.3\text{ k}\Omega)(0.05\text{ }\mu\text{F})} = \mathbf{964.58\text{ Hz}}$$

$$f_c = \frac{1}{2\pi(R_1 \| R_2)C} = \frac{1}{2\pi\underbrace{(3.3\text{ k}\Omega \| 0.5\text{ k}\Omega)}_{0.434\text{ k}\Omega}0.05\text{ }\mu\text{F}} = \mathbf{7334.33\text{ Hz}}$$

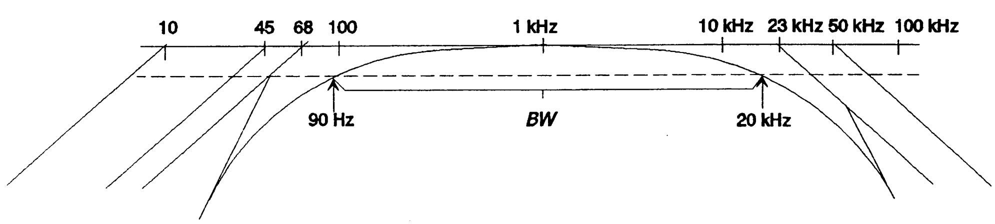
Note Fig. 23.72.

$$-20\log_{10}\frac{R_1 + R_2}{R_2} = -20\log_{10}\frac{3.3\text{ k}\Omega + 0.5\text{ k}\Omega}{0.5\text{ k}\Omega} = -17.62\text{ dB}$$

Asymptote at -17.62 dB from $0 \rightarrow f_1$
$+6$ dB/octave from f_1 to f_c
0 dB from f_c on

b. $\theta = -\tan^{-1} f_1/f + \tan^{-1} f_c/f$
Test at 3 kHz
$\theta = -\tan^{-1} 964.58\text{ Hz}/3.0\text{ kHz} + \tan^{-1} 7334.33\text{ Hz}/3.0\text{ kHz}$
$= -17.82° + 67.75° = 49.93° \cong 50°$

Therefore rising above 45° at and near the peak



50 kHz vs 23 kHz → drop about 1 dB at 23 kHz due to 50 kHz break.
Ignore effect of break frequency at 10 Hz.
Assume -2 dB drop at 68 Hz due to break frequency at 45 Hz.
Rough sketch suggests low cut-off frequency of 90 Hz.

Checking: Ignoring upper terms

$$A'_{v_{dB}} = -20\ \log_{10}\sqrt{1+\left(\frac{10\text{ Hz}}{f}\right)^2} - 20\log_{10}\sqrt{1+\left(\frac{45\text{ Hz}}{f}\right)^2} - 20\log_{10}\sqrt{1+\left(\frac{68\text{ Hz}}{f}\right)^2}$$

$$= -0.0532\text{ dB} - 0.969\text{ dB} - 1.96\text{ dB}$$

$$= -2.98\text{ dB}\quad\text{(excellent)}$$

High frequency cutoff: Try 20 kHz

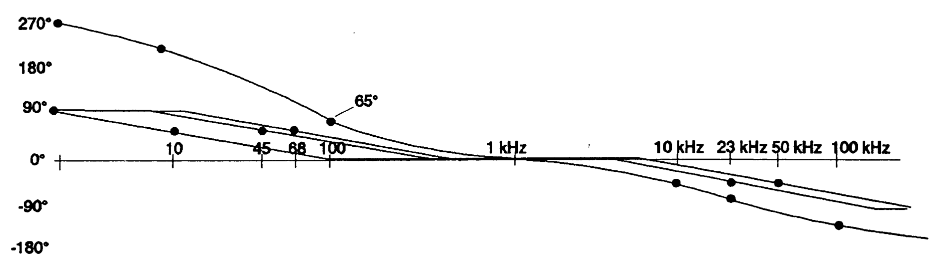
$$A'_{v_{dB}} = -20\log_{10}\sqrt{1+\left(\frac{f}{23\text{ kHz}}\right)^2} - 20\ \log_{10}\sqrt{1+\left(\frac{f}{50\text{ kHz}}\right)^2}$$

$$= -2.445\text{ dB} - 0.6445\text{ dB}$$

$$= -3.09\text{ dB}\quad\text{(excellent)}$$

$\therefore BW = 20\text{ kHz} - 90\text{ kHz} = \mathbf{19{,}910\ Hz} \cong 20\text{ kHz}$

$f_1 = \mathbf{90\ Hz}, f_2 = \mathbf{20\ kHz}$

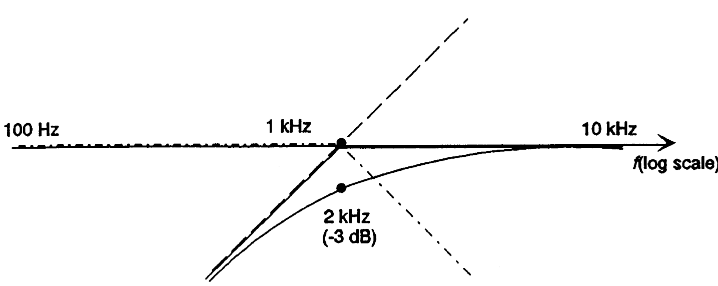


Testing: $f = 100$ Hz

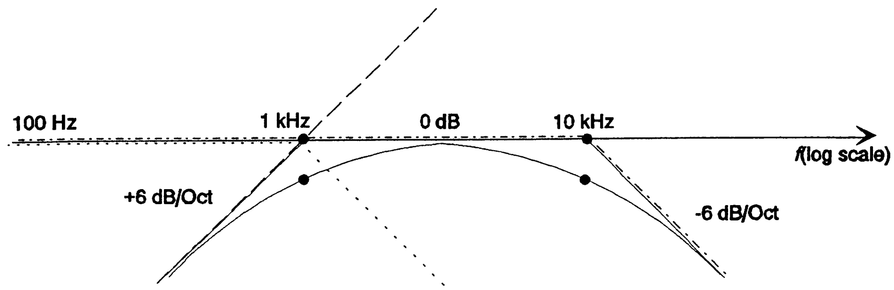
$$\theta = \tan^{-1}\frac{10\text{ Hz}}{f} + \tan^{-1}\frac{45\text{ Hz}}{f} + \tan^{-1}\frac{68\text{ Hz}}{f} - \tan^{-1}\frac{f}{23\text{ kHz}} - \tan^{-1}\frac{f}{50\text{ kHz}}$$
$$= \tan^{-1}0.1 + \tan^{-1}0.45 + \tan^{-1}0.68 - \tan^{-1}0.00435 - \tan^{-1}.002$$
$$= 5.71° + 24.23° + 34.22° - 0.249° - 0.115°$$
$$= \mathbf{63.8°}\text{ vs about }65°\text{ on the plot}$$

48. $$\mathbf{A}_v = \frac{0.05}{0.05 - j\dfrac{100}{f}} = \frac{1}{1 - j\dfrac{100}{0.05\,f}} = \frac{1}{1 - j\dfrac{2000}{f}} = \frac{+jf}{+jf + 2000}$$

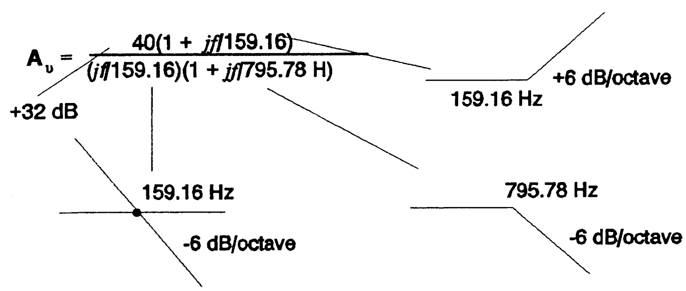
$$= \frac{+j\dfrac{f}{2000}}{1 + j\dfrac{f}{2000}}\quad\text{and } f_1 = 2000\text{ Hz}$$

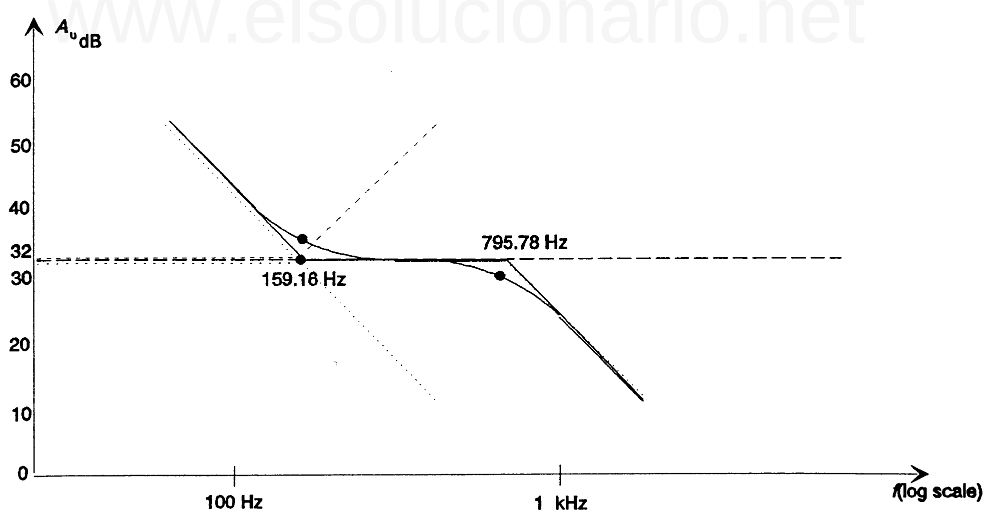


50. $\mathbf{A}_v = \dfrac{jf/1000}{(1 + jf/1000)(1 + jf/10{,}000)}$



52. $\dfrac{j\omega}{1000} = j\dfrac{2\pi f}{1000} = j\dfrac{f}{\dfrac{1000}{2\pi}} = j\dfrac{f}{159.16\text{ Hz}},\ \dfrac{j\omega}{5000} = j\dfrac{f}{795.78\text{ Hz}}$





CHAPTER 24 (Odd)

1. a. **positive-going** b. $V_b = \mathbf{2\ V}$ c. $t_p = \mathbf{0.2\ ms}$

d. Amplitude = 8 V − 2 V = **6 V**

e. $\%\ \text{tilt} = \dfrac{V_1 - V_2}{V} \times 100\%$

$$V = \frac{8\text{ V} + 7.5\text{ V}}{2} = 7.75\text{ V}$$

$$\%\ \text{tilt} = \frac{8\text{ V} - 7.5\text{ V}}{7.75\text{ V}} \times 100\% = \mathbf{6.5\%}$$

3. a. **positive-going** b. $V_b = \mathbf{10\ mV}$ c. $t_p = \left[\dfrac{8}{10}\right] 4\text{ ms} = \mathbf{3.2\ ms}$

d. Amplitude = (30 − 10)mV = **20 mV**

e. $\%\ \text{tilt} = \dfrac{V_1 - V_2}{V} \times 100\%$

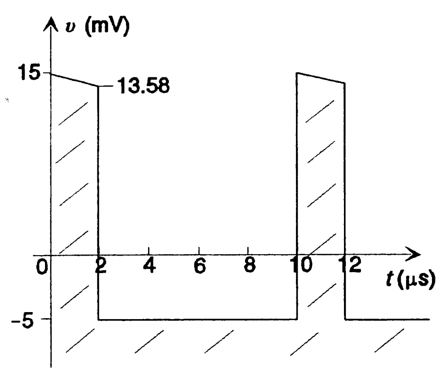
$$V = \frac{30\text{ mV} + 28\text{ mV}}{2} = 29\text{ mV}$$

$$\%\ \text{tilt} = \frac{30\text{ mV} - 28\text{ mV}}{29\text{ mV}} \times 100\% \cong \mathbf{6.9\%}$$

5. $\text{tilt} = \dfrac{V_1 - V_2}{V} = 0.1$ with $V = \dfrac{V_1 + V_2}{2}$

Substituting V into top equation,

$$\frac{V_1 - V_2}{\dfrac{V_1 + V_2}{2}} = 0.1 \text{ leading to } V_2 = \frac{0.95\ V_1}{1.05} \text{ or } V_2 = 0.905(15\text{ mV}) = 13.58\text{ mV}$$



7. a. $T = (4.8 - 2.4)\text{div.}[50\ \mu\text{s/div.}] = \mathbf{120\ \mu s}$ b. $f = \dfrac{1}{T} = \dfrac{1}{120\ \mu\text{s}} = 8.33\text{ kHz}$

c. Maximum Amplitude: (2.2 div.)(0.2 V/div.) = 0.44 V = **440 mV**
Minimum Amplitude: (0.4 div.)(0.2 V/div.) = 0.08 V = **80 mV**

9. $T = (15 - 7)\mu s = 8\ \mu s$

$\text{prf} = \dfrac{1}{T} = \dfrac{1}{8\ \mu s} = \mathbf{125\ kHz}$

$\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{(20 - 15)\mu s}{8\ \mu s} \times 100\% = \dfrac{5}{8} \times 100\% = \mathbf{62.5\%}$

11. a. $T = (9 - 1)\mu s = \mathbf{8\ \mu s}$ b. $t_p = (3 - 1)\mu s = \mathbf{2\ \mu s}$

c. $\text{prf} = \dfrac{1}{T} = \dfrac{1}{8\ \mu s} = \mathbf{125\ kHz}$

d. $V_{av} = (\text{Duty cycle})(\text{Peak value}) + (1 - \text{Duty cycle})(V_b)$

$\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{2\ \mu s}{8\ \mu s} = \times 100\% = 25\%$

$V_{av} = (0.25)(6\text{ mV}) + (1 - 0.25)(-2\text{ mV}\}$
$= 1.5\text{ mV} - 1.5\text{ mV} = \mathbf{0\ V}$

or

$V_{av} = \dfrac{(2\ \mu s)(6\text{ mV}) - (2\ \mu s)(6\text{ mV})}{8\ \mu s} = \mathbf{0\ V}$

e. $V_{eff} = \sqrt{\dfrac{(36 \times 10^{-6})(2\ \mu s) + (4 \times 10^{-6})(6\ \mu s)}{8\ \mu s}} = \mathbf{3.464\ mV}$

13. Ignoring tilt and using 20 mV level to define t_p
$t_p = (2.8\text{ div.} - 1.2\text{ div.})(2\text{ ms/div.}) = 3.2\text{ ms}$
$T = (\text{at }10\text{ mV level}) = (4.6\text{ div.} - 1\text{ div.})(2\text{ ms/div.}) = 7.2\text{ ms}$

$\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{3.2\text{ ms}}{7.2\text{ ms}} \times 100\% = 44.4\%$

$V_{av} = (\text{Duty cycle})(\text{peak value}) + (1 - \text{Duty cycle})(V_b)$
$= (0.444)(30\text{ mV}) + (1 - 0.444)(10\text{ mV})$
$= 13.320\text{ mV} + 5.560\text{ mV}$
$= \mathbf{18.88\ mV}$

15. Using methods of Section 13.8:

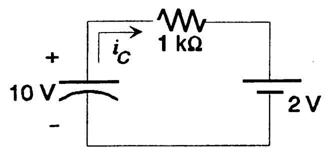
$A_1 = b_1h_1 = [(0.2\text{ div.})(50\ \mu s/\text{div.})][(2\text{ div.})(0.2\text{ V/div.})] = 4\ \mu sV$
$A_2 = b_2h_2 = [(0.2\text{ div.})(50\ \mu s/\text{div.})][(2.2\text{ div.})(0.2\text{ V/div.})] = 4.4\ \mu sV$
$A_3 = b_3h_3 = [(0.2\text{ div.})(50\ \mu s/\text{div.})][(1.4\text{ div.})(0.2\text{ V/div.})] = 2.8\ \mu sV$
$A_4 = b_4h_4 = [(0.2\text{ div.})(50\ \mu s/\text{div.})][(1\text{ div.})(0.2\text{ V/div.})] = 2.0\ \mu sV$
$A_5 = b_5h_5 = [(0.2\text{ div.})(50\ \mu s/\text{div.})][(0.4\text{ div.})(0.2\text{ V/div.})] = 0.8\ \mu sV$

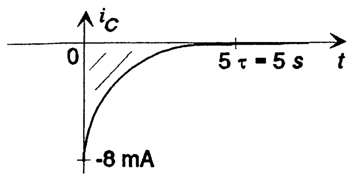
$V_{av} = \dfrac{(4 + 4.4 + 2.8 + 2.0 + 0.8)\mu sV}{120\ \mu s} = \mathbf{117\ mV}$

17. $v_C = V_i + (V_f - V_i)(1 - e^{-t/RC})$
$= 8 + (4 - 8)(1 - e^{-t/20\text{ ms}})$
$= 8 - 4(1 - e^{-t/20\text{ ms}})$
$= 8 - 4 + 4e^{-t/20\text{ ms}}$
$= 4 + 4e^{-t/20\text{ ms}}$
$v_C = \mathbf{4(1 + e^{-t/20\text{ ms}})}$

$\tau = RC = (2\text{ k}\Omega)(10\ \mu\text{F})$
$= 20\text{ ms}$

19. $V_i = 10\text{ V}, I_i = 0\text{ A}$





Using the defined direction of i_C

$$i_C = \frac{-(10\text{ V} - 2\text{ V})}{1\text{ k}\Omega}e^{-t/\tau}$$

$$\tau = RC = (1\text{ k}\Omega)(1000\ \mu\text{F}) = 1\text{ s}$$

$$i_C = -\frac{8\text{ V}}{1\text{ k}\Omega}e^{-t}$$

and $i_C = \mathbf{-8 \times 10^{-3}e^{-t}}$

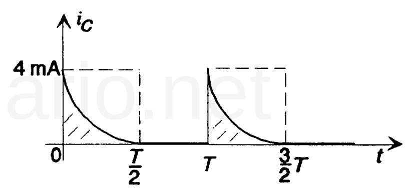
21. The mathematical expression for i_C is the same for each frequency!

$$\tau = RC = (5\text{ k}\Omega)(0.04\ \mu\text{F}) = 0.2\text{ ms}$$

and $i_C = \dfrac{20\text{ V}}{5\text{ k}\Omega}e^{-t/0.2\text{ ms}} = 4 \times 10^{-3}e^{-t/0.2\text{ ms}}$

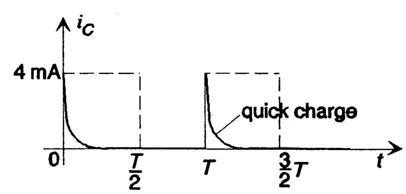
a. $T = \dfrac{1}{500\text{ Hz}} = 2\text{ ms},\ \dfrac{T}{2} = 1\text{ ms}$

$5\tau = 5(0.2\text{ ms}) = 1\text{ ms} = \dfrac{T}{2}$



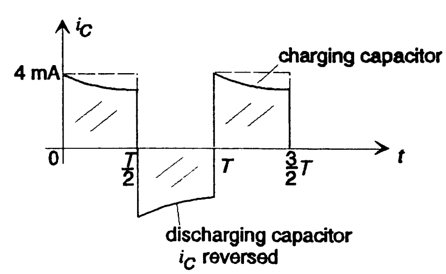
b. $T = \dfrac{1}{100\text{ Hz}} = 10\text{ ms},\ \dfrac{T}{2} = 5\text{ ms}$

$5\tau = 1\text{ ms} = \dfrac{1}{5}\left[\dfrac{T}{2}\right]$



c. $T = \dfrac{1}{5000\text{ Hz}} = 0.2\text{ ms},\ \dfrac{T}{2} = 0.1\text{ ms}$

$5\tau = 1\text{ ms} = 10\left[\dfrac{T}{2}\right]$



23. $v_C = V_i + (V_f - V_i)(1 - e^{-t/RC})$

$$V_i = 20\text{ V},\ V_f = 20\text{ V}$$
$$v_C = 20 + (20 - 20)(1 - e^{-t/RC})$$
$$= 20\text{ V (for } 0 \to \tfrac{T}{2})$$

For $\frac{T}{2} \to T$, $v_i = 0$ V and $v_C = 20e^{-t/\tau}$

$\tau = RC = 0.2$ ms

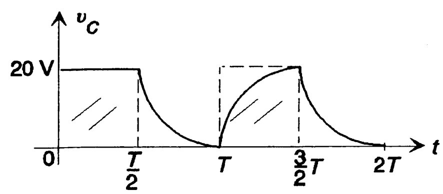
with $\frac{T}{2} = 1$ ms and $5\tau = \frac{T}{2}$

For $T \to \frac{3}{2}T$, $v_i = 20$ V

$$v_C = 20(1 - e^{-t/\tau})$$

For $\frac{3}{2}T \to 2T$, $v_i = 0$ V

$$v_C = 20e^{-t/\tau}$$



25. $\mathbf{Z}_p$: $X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi(10\text{ kHz})(3\text{ pF})} = 5.31\text{ M}\Omega$

$$\mathbf{Z}_p = \frac{(9\text{ M}\Omega\ \angle 0°)(5.31\text{ M}\Omega\ \angle -90°)}{9\text{ M}\Omega - j5.31\text{ M}\Omega} = 4.573\text{ M}\Omega\ \angle -59.5°$$

$\mathbf{Z}_s$: $C_T = 18\text{ pF} + 9\text{ pF} = 27\text{ pF}$

$$X_C = \frac{1}{2\pi fC_T} = \frac{1}{2\pi(10\text{ kHz})(27\text{ pF})} = 0.589\text{ M}\Omega$$

$$\mathbf{Z}_s = \frac{(1\text{ M}\Omega\ \angle 0°)(0.589\text{ M}\Omega\ \angle -90°)}{1\text{ M}\Omega - j0.589\text{ M}\Omega} = 0.507\text{ M}\Omega\ \angle -59.5°$$

$$\mathbf{V}_{\text{scope}} = \frac{\mathbf{Z}_s\mathbf{V}_i}{\mathbf{Z}_s + \mathbf{Z}_p} = \frac{(0.507\text{ M}\Omega\ \angle -59.5°)(100\text{ V}\angle 0°)}{(0.257\text{ M}\Omega - j0.437\text{ M}\Omega) + (2.324\text{ M}\Omega - j3.939\text{ M}\Omega)}$$

$$= \frac{50.7 \times 10^6\text{ V}\ \angle -59.5°}{5.07 \times 10^6\ \angle -59.5°} = \mathbf{10\text{ V}\ \angle 0°} = \frac{1}{10}(100\text{ V}\ \angle 0°)$$

$\theta_{\mathbf{Z}_s} = \theta_{\mathbf{Z}_p} = \mathbf{-59.5°}$

Chapter 24 (Even)

2. a. **negative-going** b. **+7 mV** c. **3 μs**

d. **−8 mV** (from base line level)

e. $V = \dfrac{-8\text{ mV} - 7\text{ mV}}{2} = \dfrac{-15\text{ mV}}{2} = -7.5\text{ mV}$

$\%\text{ Tilt} = \dfrac{V_1 - V_2}{V} \times 100\% = \dfrac{-8\text{ mV} - (-7\text{ mV})}{-7.5\text{ mV}} \times 100\%$

$= \dfrac{-1\text{ mV}}{-7.5\text{ mV}} \times 100\% = \mathbf{13.3\%}$

f. $T = 15\ \mu s - 7\ \mu s = 8\ \mu s$

$\text{prf} = \dfrac{1}{T} = \dfrac{1}{8\ \mu s} = \mathbf{125\ kHz}$

g. $\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{3\ \mu s}{8\ \mu s} \times 100\% = \mathbf{37.5\%}$

4. $t_r \cong$ (0.2 div.)(2 ms/div.) = **0.4 ms**
$t_f \cong$ (0.4 div.)(2 ms/div.) = **0.8 ms**

6. a. t_r = 80% of straight line segment
= 0.8(2 μs) = **1.6 μs**

b. t_f = 80% of 4 μs interval
= 0.8(4 μs) = **3.2 μs**

c. At 50% level (10 mV)
$t_p = (8 - 1)\mu s = \mathbf{7\ \mu s}$

d. $\text{prf} = \dfrac{1}{T} = \dfrac{1}{20\ \mu s} = \mathbf{50\ kHz}$

8. $T = (3.6 - 2.0)\text{ms} = 1.6\text{ ms}$

$\text{prf} = \dfrac{1}{T} = \dfrac{1}{1.6\text{ ms}} = \mathbf{625\ Hz}$

$\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{0.2\text{ ms}}{1.6\text{ ms}} \times 100\% = \mathbf{12.5\%}$

10. $T = (3.6\text{ div.})(2\text{ ms/div.}) = 7.2\text{ ms}$

$\text{prf} = \dfrac{1}{T} = \dfrac{1}{7.2\text{ ms}} = \mathbf{138.89\ Hz}$

$\text{Duty cycle} = \dfrac{t_p}{T} \times 100\% = \dfrac{1.6\text{ div.}}{3.6\text{ div.}} \times 100\% = \mathbf{44.4\%}$

12. Eq. 24.5 cannot be applied due to tilt in the waveform.
(Method of Section 13.6)
Between 2 and 3.6 ms

$$V_{av} = \frac{(3.4\text{ ms} - 2\text{ ms})(2\text{ V}) + (3.6\text{ ms} - 3.4\text{ ms})(7.5\text{ V}) + \frac{1}{2}(3.6\text{ ms} - 3.4\text{ ms})(0.5\text{ V})}{3.6\text{ ms} - 2\text{ ms}}$$

$$= \frac{(1.4\text{ ms})(2\text{ V}) + (0.2\text{ ms})(7.5\text{ V}) + \frac{1}{2}(0.2\text{ ms})(0.5\text{ V})}{1.6\text{ ms}}$$

$$= \frac{2.8\text{ V} + 1.5\text{ V} + 0.05\text{ V}}{1.6} = \mathbf{2.719\text{ V}}$$

14. V_{av} = (Duty cycle)(Peak value) + (1 − Duty cycle)(V_b)

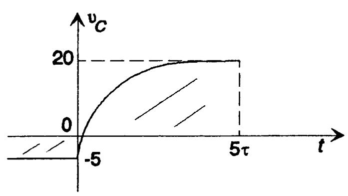
$$\text{Duty cycle} = \frac{t_p}{T}\text{ (decimal form)}$$

$$= \frac{(8 - 1)\mu\text{s}}{20\ \mu\text{s}} = 0.35$$

$$V_{av} = (0.35)(20\text{ mV}) + (1 - 0.35)(0)$$
$$= 7\text{ mV} + 0$$
$$= \mathbf{7\text{ mV}}$$

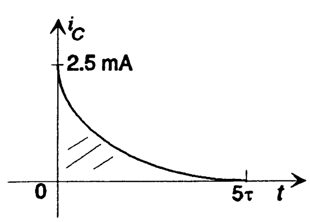
16. Using the defined polarity of Fig. 24.57 for v_C, $V_i = -5$ V, $V_f = +20$ V and $\tau = RC = (10\text{ k}\Omega)(0.02\ \mu\text{F}) = 0.2$ ms

a. $$v_C = V_i + (V_f - V_i)(1 - e^{-t/\tau})$$
$$= -5 + (20 - (-5))(1 - e^{-t/0.2\text{ ms}})$$
$$= -5 + 25(1 - e^{-t/0.2\text{ ms}})$$
$$= -5 + 25 - 25e^{-t/0.2\text{ ms}}$$
$$v_C = \mathbf{20 - 25e^{-t/0.2\text{ ms}}}$$

b. 

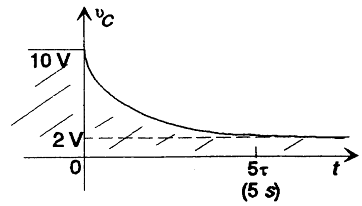
c. $I_i = 0$

$$i_C = \frac{E - v_C}{R} = \frac{20\text{ V} - [20\text{ V} - 25\text{ V}e^{-t/0.2\text{ ms}}]}{10\text{ k}\Omega} = \mathbf{2.5 \times 10^{-3}e^{-t/0.2\text{ ms}}}$$

d. 

18. $V_i = 10 \text{ V}, V_f = 2 \text{ V}, \tau = RC = (1 \text{ k}\Omega)(1000\ \mu\text{F}) = 1 \text{ s}$

$$\begin{aligned} v_C &= V_i + (V_f - V_i)(1 - e^{-t/\tau}) \\ &= 10 \text{ V} + (2 \text{ V} - 10 \text{ V})(1 - e^{-t}) \\ &= 10 - 8(1 - e^{-t}) \\ &= 10 - 8 + 8e^{-t} \\ v_C &= \mathbf{2 + 8e^{-t}} \end{aligned}$$



20. $\tau = RC = (5 \text{ k}\Omega)(0.04\ \mu\text{F}) = 0.2 \text{ ms}$ (throughout)

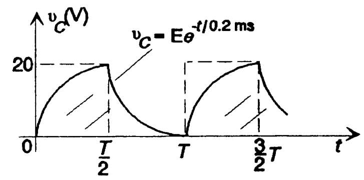
$v_C = E(1 - e^{-t/\tau}) = 20(1 - e^{-t/0.2 \text{ ms}})$

(Starting at $t = 0$ for each plot)

a. $T = \dfrac{1}{f} = \dfrac{1}{500 \text{ Hz}} = 2 \text{ ms}$

$\dfrac{T}{2} = 1 \text{ ms}$

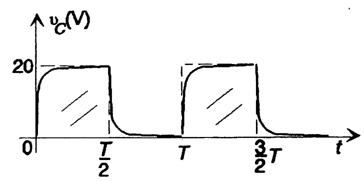
$5\tau = 1 \text{ ms} = \dfrac{T}{2}$



b. $T = \dfrac{1}{f} = \dfrac{1}{100 \text{ Hz}} = 10 \text{ ms}$

$\dfrac{T}{2} = 5 \text{ ms}$

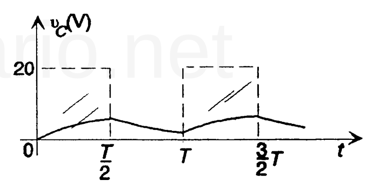
$5\tau = 1 \text{ ms} = \dfrac{1}{5}\left[\dfrac{T}{2}\right]$



c. $T = \dfrac{1}{f} = \dfrac{1}{5 \text{ Hz}} = 0.2 \text{ ms}$

$\dfrac{T}{2} = 0.1 \text{ ms}$

$5\tau = 1 \text{ ms} = 10\left[\dfrac{T}{2}\right]$



22. $\tau = 0.2 \text{ ms}$ as above

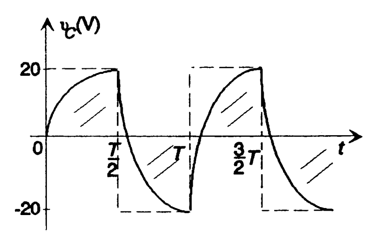
$T = \dfrac{1}{500 \text{ Hz}} = 2 \text{ ms}$

$5\tau = 1 \text{ ms} = \dfrac{T}{2}$

$0 \rightarrow \dfrac{T}{2}$: $v_C = 20(1 - e^{-t/0.2 \text{ ms}})$

$\dfrac{T}{2} \rightarrow T$: $V_i = 20 \text{ V}, V_f = -20 \text{ V}$

$$\begin{aligned} v_C &= V_i + (V_f - V_i)(1 - e^{-t/\tau}) \\ &= 20 + (-20 - 20)(1 - e^{-t/0.2 \text{ ms}}) \\ &= 20 - 40(1 - e^{-t/0.2 \text{ ms}}) \\ &= 20 - 40 + 40e^{-t/0.2 \text{ ms}} \\ v_C &= \mathbf{-20 + 40e^{-t/0.2 \text{ ms}}} \end{aligned}$$



$T \to \frac{3}{2}T$: $V_i = -20$ V, $V_f = +20$ V

$$\begin{aligned} v_C &= V_i + (V_f - V_i)(1 - e^{-t/\tau}) \\ &= -20 + (20 - (-20))(1 - e^{-t/\tau}) \\ &= -20 + 40(1 - e^{-t/\tau}) \\ &= -20 + 40 - 40e^{-t/\tau} \\ v_C &= \mathbf{20 - 40e^{-t/0.2\ ms}} \end{aligned}$$

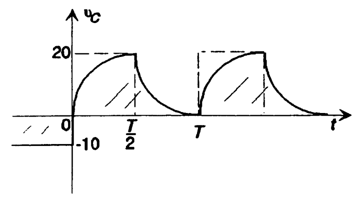
24. $\tau = RC = 0.2$ ms

$5\tau = 1 \text{ ms} = \frac{T}{2}$

$V_i = -10$ V, $V_f = +20$ V

$0 \to \frac{T}{2}$:

$$\begin{aligned} v_C &= V_i + (V_f - V_i)(1 - e^{-t/\tau}) \\ &= -10 + (20 - (-10))(1 - e^{-t/\tau}) \\ &= -10 + 30(1 - e^{-t/\tau}) \\ &= -10 + 30 - 30e^{-t/\tau} \\ v_C &= \mathbf{+20 - 30e^{-t/0.2\ ms}} \end{aligned}$$



$\frac{T}{2} \to T$: $V_i = 20$ V, $V_f = 0$ V

$v_C = \mathbf{20e^{-t/0.2\ ms}}$

26. $\mathbf{Z}_p$: $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(10^5 \text{ rad/s})(3 \text{ pF})} = 3.333 \text{ M}\Omega$

$$\mathbf{Z}_p = \frac{(9 \text{ M}\Omega \angle 0°)(3.333 \text{ M}\Omega)}{9 \text{ M}\Omega - j3.333 \text{ M}\Omega} = 3.126 \text{ M}\Omega \angle -69.68°$$

$\mathbf{Z}_s$: $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(10^5 \text{ rad/s})(27 \text{ pF})} = 0.370 \text{ M}\Omega$

$$\mathbf{Z}_s = \frac{(1 \text{ M}\Omega \angle 0°)(0.370 \text{ M}\Omega \angle -90°)}{1 \text{ M}\Omega - j0.370 \text{ M}\Omega} = 0.347 \text{ M}\Omega \angle -69.68°$$

✓ $\theta_{\mathbf{Z}_p} = \theta_{\mathbf{Z}_s}$

$$\mathbf{V}_{\text{scope}} = \frac{\mathbf{Z}_s \mathbf{V}_i}{\mathbf{Z}_s + \mathbf{Z}_p} = \frac{(0.347 \text{ M}\Omega \angle -69.68°)(100 \text{ V} \angle 0°)}{(0.121 \text{ M}\Omega - j0.325 \text{ M}\Omega) + (1.086 \text{ M}\Omega - j2.931 \text{ M}\Omega)}$$

$$= \frac{34.70 \times 10^6 \text{ V} \angle -69.68°}{3.470 \times 10^6 \angle -69.68°}$$

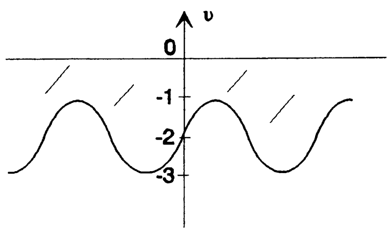
$$\cong \mathbf{10 \text{ V} \angle 0°} = \frac{1}{10}(100 \text{ V} \angle 0°)$$

CHAPTER 25 (Odd)

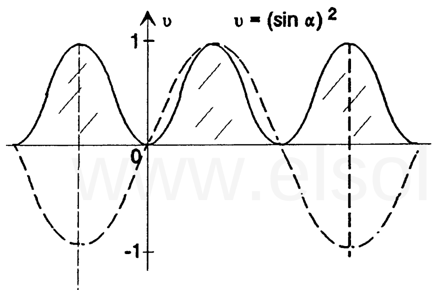
1.

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

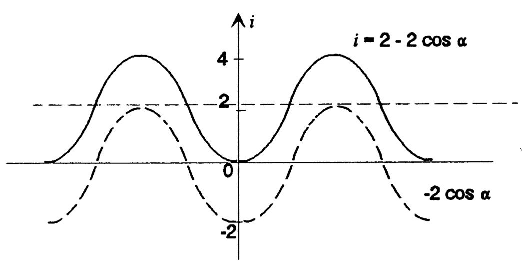
3. a. $v = -4 + 2 \sin \alpha$



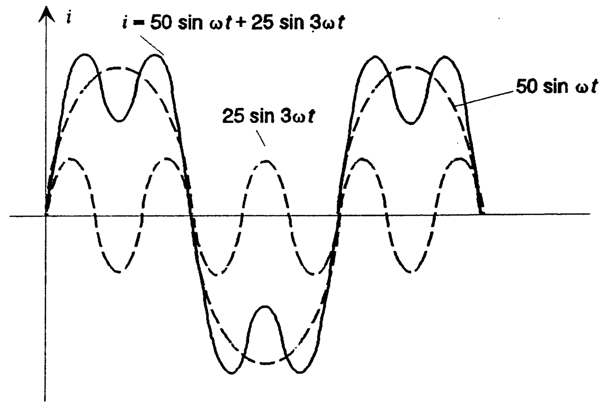
b. $v = (\sin \alpha)^2$



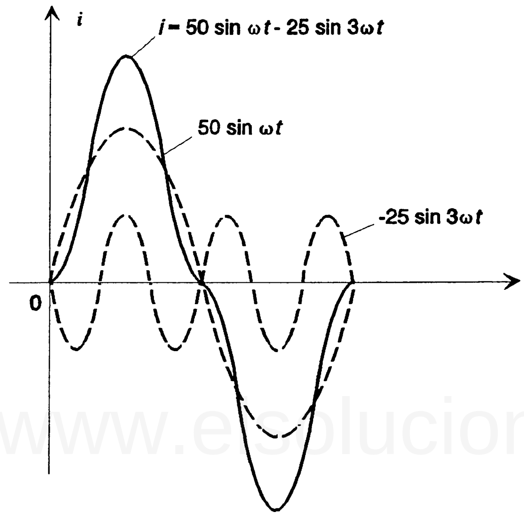
c. $i = 2 - 2 \cos \alpha$



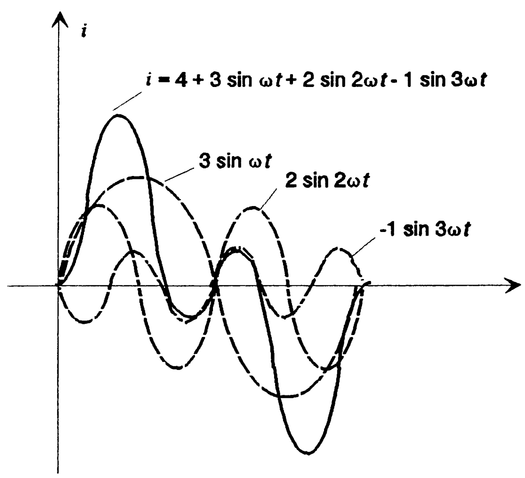
5. a.


i
i = 50 sin ωt + 25 sin 3ωt
50 sin ωt
25 sin 3ωt

b.


i
i = 50 sin ωt - 25 sin 3ωt
50 sin ωt
-25 sin 3ωt
0

c.


i
i = 4 + 3 sin ωt + 2 sin 2ωt - 1 sin 3ωt
3 sin ωt
2 sin 2ωt
-1 sin 3ωt

7. a. $V_{eff} = \sqrt{\dfrac{(20\text{ V})^2 + (15\text{ V})^2 + (10\text{ V})^2}{2}} = \mathbf{19.04\ V}$

b. $I_{eff} = \sqrt{\dfrac{(6\text{ A})^2 + (2\text{ A})^2 + (1\text{ A})^2}{2}} = \mathbf{4.53\ A}$

9. $P = \dfrac{(20\text{ V})(6\text{A})}{2}\cos 20° + \dfrac{(15\text{ V})(2\text{ A})}{2}\cos 30° + \dfrac{(10\text{ V})(1\text{ A})}{2}\cos 60°$

$= 60(0.9397) + 15(0.866) + 5(0.5)$

$= \mathbf{71.872\ W}$

11. a. DC: $I_{DC} = \dfrac{24\text{ V}}{12\ \Omega} = 2\text{ A}$

$\omega = 400$ rad/s:

$\mathbf{Z} = 12\ \Omega + j(400\text{ rad/s})(0.02\text{ H}) = 12\ \Omega + j8\ \Omega = 14.422\ \Omega \angle 33.69°$

$\mathbf{I} = \dfrac{30\text{ V} \angle 0°}{14.422\ \Omega \angle 33.69°} = 2.08\text{ A} \angle -33.69°$ (peak values)

$\omega = 800$ rad/s:

$\mathbf{Z} = 12\ \Omega + j(800\text{ rad/s})(0.02\text{ H}) = 12\ \Omega + j16\ \Omega = 20\ \Omega \angle 53.13°$

$\mathbf{I} = \dfrac{10\text{ V} \angle 0°}{20\ \Omega \angle 53.13°} = 0.5\text{ A} \angle -53.13°$ (peak values)

$\boldsymbol{i = 2 + 2.08 \sin(400t - 33.69°) + 0.5 \sin(800t - 53.13°)}$

b. $I_{eff} = \sqrt{I_{DC}^2 + \dfrac{(2.08\text{ A})^2 + (0.5\text{ A}^2)}{2}} = \mathbf{2.508\ A}$

c. $v_R = iR = i(12\ \Omega)$

$\boldsymbol{= 24 + 24.96 \sin(400t - 33.69°) + 6 \sin(800t - 53.13°)}$

d. $V_{eff} = \sqrt{(24\text{ V})^2 + \dfrac{(24.96\text{ V})^2 + (6\text{ V})^2}{2}} = \mathbf{30.092\ V}$

e. DC: $V_L = 0$ V

$\omega = 400$ rad/s: $\mathbf{V}_L = (2.08\text{ A} \angle -33.69°)(8\ \Omega \angle 90°)$

$= 16.64\text{ V} \angle 56.31°$

$\omega = 800$ rad/s: $\mathbf{V}_L = (0.5\text{ A} \angle -53.13°)(16\ \Omega \angle 90°)$

$= 8\text{ V} \angle 36.87°$

$\boldsymbol{v_L = 0 + 16.64 \sin(400t + 56.31°) + 8 \sin(800t + 36.87°)}$

f. $V_{eff} = \sqrt{(0)^2 + \dfrac{(16.64\text{ V})^2 + (8\text{ V})^2}{2}} = \mathbf{13.055\ V}$

g. $P_T = I_{eff}^2 R = (2.508\text{ A})^2\, 12\ \Omega = \mathbf{75.481\ W}$

13. a. DC: $I = \mathbf{0\ A}$

$\omega = 400$ rad/s: $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(400 \text{ rad/s})(125\ \mu\text{F})} = 20\ \Omega$

$\mathbf{Z} = 15\ \Omega - j20\ \Omega = 25\ \Omega\ \angle -53.13°$

$\mathbf{E} = (0.707)(30\text{ V})\ \angle 0° = 21.21\text{ V}\ \angle 0°$

$\mathbf{I} = \dfrac{\mathbf{E}}{\mathbf{Z}} = \dfrac{21.21\text{ V}\angle 0°}{25\ \Omega\ \angle -53.13°} = 0.848\text{ A}\ \angle 53.13°$

$i = 0 + (1.414)(0.848)\sin(400t + 53.13°)$

$i = \mathbf{1.2\ \sin(400}t\mathbf{ + 53.13°)}$

b. $I_{\text{eff}} = \sqrt{\dfrac{(1.2\text{ A})^2}{2}} = \mathbf{0.848\ A}$ as above

c. DC: $V_R = 0$ V

$\omega = 400$ rad/s: $\mathbf{V}_R = (0.848\text{ A}\ \angle 53.13°)(15\ \Omega\ \angle 0°) = 12.72\text{ V}\ \angle 53.13°$

$v_R = 0 + (1.414)(12.72)\sin(400t + 53.13°)$

$v_R = \mathbf{18\ \sin(400}t\mathbf{ + 53.13°)}$

d. $V_{R_{\text{eff}}} = \sqrt{\dfrac{(18\text{ V})^2}{2}} = \mathbf{12.73\ V}$

e. DC: $V_C = 18$ V

$\omega = 400$ rad/s: $\mathbf{V}_C = (0.848\text{ A}\ \angle 53.13°)(20\ \Omega\ \angle -90°)$

$= 16.96\text{ V}\ \angle -36.87°$

$v_C = 18 + (1.414)(16.96)\sin(400t - 36.87°)$

$v_C = \mathbf{18 + 23.98\ \sin(400}t\mathbf{ - 36.87°)}$

f. $V_{C_{\text{eff}}} = \sqrt{(18\text{ V})^2 + \dfrac{(23.98\text{ V})^2}{2}} = \mathbf{24.73\ V}$

g. $P = I_{\text{eff}}^2 R = (0.848\text{ A})^2\ 15\ \Omega = \mathbf{10.79\ W}$

15. $i = 0.318I_m + 0.500\ I_m \sin \omega t - 0.212I_m \cos 2\omega t - 0.0424I_m \cos 4\omega t + \ldots\ (I_m = 10\text{ mA})$

$i = 3.18 \times 10^{-3} + 5 \times 10^{-3} \sin \omega t - 2.12 \times 10^{-3} \sin(2\omega t + 90°)$

$- 0.424 \times 10^{-3} \sin(4\omega t + 90°) + \ldots$

$i \cong 3.18 \times 10^{-3} + 5 \times 10^{-3} \sin \omega t - 2.12 \times 10^{-3} \sin(2\omega t + 90°)$

DC: $I_o = 0$ A, $V_o = 0$ V

$\omega = 377$ rad/s; $X_L = \omega L = (377\text{ rad/s})(1.2\text{ mH}) = 0.452\ \Omega$

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{(377\text{ rad/s})(200\ \mu\text{F})} = 13.26\ \Omega$

$\mathbf{Z}' = 200\ \Omega - j13.26\ \Omega = 200.44\ \Omega\ \angle -3.79°$

$\mathbf{I} = (0.707)(5 \times 10^{-3})\text{A}\ \angle 0° = 3.54\text{ mA}\ \angle 0°$

$\mathbf{I}_o = \dfrac{\mathbf{Z}_L\mathbf{I}}{\mathbf{Z}_L + \mathbf{Z}'} = \dfrac{(0.452\ \Omega\ \angle 90°)(3.54\text{ mA}\ \angle 0°)}{j0.452\ \Omega + 200\ \Omega - j13.26\ \Omega} = 7.98\ \mu\text{A}\ \angle 93.66°$

$\mathbf{V}_o = (7.98\ \mu\text{A}\ \angle 93.66°)(200\ \Omega\ \angle 0°) = 1.596\text{ mV}\ \angle 93.66°$

$\omega = 754$ rad/s: $\quad X_L = \omega L = (754 \text{ rad/s})(1.2 \text{ mH}) = 0.905\ \Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{(754 \text{ rad/s})(200\ \mu\text{F})} = 6.63\ \Omega$$

$$\mathbf{Z}' = 200\ \Omega - j6.63\ \Omega = 200.11\ \Omega\ \angle -1.9°$$

$$\mathbf{I} = (0.707)(2.12 \text{ mA})\ \angle 90° = 1.5 \text{ mA}\ \angle 90°$$

$$\mathbf{I}_o = \frac{\mathbf{Z}_L\mathbf{I}}{\mathbf{Z}_L + \mathbf{Z}'} = \frac{(0.905\ \Omega\ \angle 90°)(1.5 \text{ mA}\ \angle 90°)}{j0.905\ \Omega + 200\ \Omega - j6.63\ \Omega} = 6.8\ \mu\text{A}\ \angle 181.64°$$

$$\mathbf{V}_o = (6.8\ \mu\text{A}\ \angle 181.64°)(200\ \Omega\ \angle 0°) = 1.36 \text{ mA}\ \angle 181.64°$$

$$v_o = 0 + (1.414)(1.596 \times 10^{-3})\sin(377t + 93.66°) - (1.414)(1.360 \times 10^{-3})\sin(754t + 181.64°)$$

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

17. $i_T = i_1 + i_2$

$= 10 + 30 \sin 20t \quad - 0.5 \sin((40t + 90°)$

$+20 + 4 \sin(20t + 90°) + 0.5 \sin(40t + 30°)$

DC: $10 \text{ A} + 20 \text{ A} = 30 \text{ A}$

$\omega = 20$ rad/s: $\quad 30 \text{ A}\ \angle 0° + 4 \text{ A}\ \angle 90° = 30 \text{ A} + j4 \text{ A} = 30.27 \text{ A}\ \angle 7.59°$

$\omega = 40$ rad/s: $\quad -0.5 \text{ A}\ \angle 90° + 0.5 \text{ A}\ \angle 30°$

$= -j0.5 \text{ A} + 0.433 \text{ A} + j0.25 \text{ A}$

$= 0.433 \text{ A} - j0.25 \text{ A} = 0.5 \text{ A}\ \angle -30°$

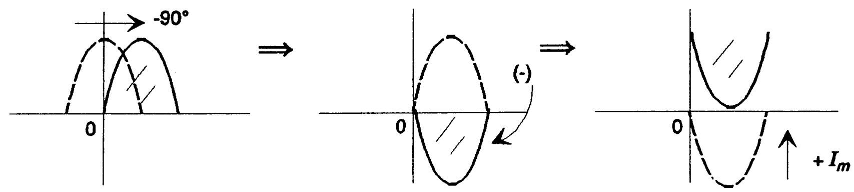
$$\boldsymbol{i_T = 30 + 30.27 \sin(20t + 7.59°) + 0.5 \sin(40t - 30°)}$$

CHAPTER 25 (Even)

2. b. $$i = \frac{2I_m}{\pi}\left[1 + \frac{2}{3}\cos(2\omega t - 90°) - \frac{2}{15}\cos(4\omega t - 90°) + \frac{2}{35}\cos(6\omega t - 90°) + \ldots\right]$$

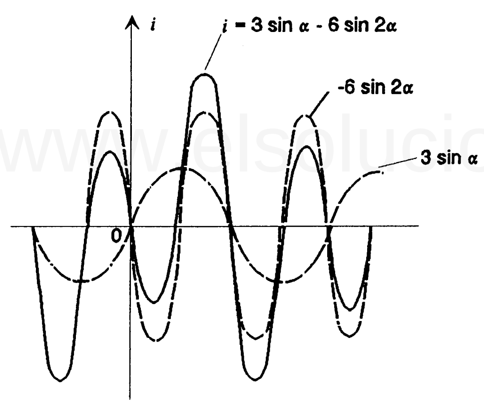
c. $$\frac{2I_m}{\pi} - \frac{I_m}{2} = \frac{2I_m}{\pi}\left[1 - \frac{\pi}{4}\right]$$
$$i = \frac{2I_m}{\pi}\left[1 - \frac{\pi}{4} + \frac{2}{3}\cos(2\omega t - 90°) - \frac{2}{15}\cos(4\omega t - 90°) + \frac{2}{35}\cos(6\omega t - 90°) + \ldots\right]$$

d.

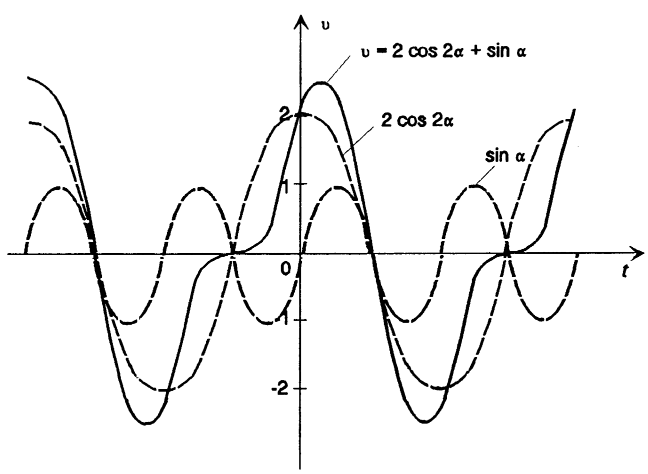


$$i = \frac{-2I_m}{\pi}\left[\mathbf{1 - \frac{\pi}{4} + \frac{2}{3}\cos(2\omega t - 90°) - \frac{2}{15}\cos(4\omega t - 90°) + \frac{2}{35}\cos(6\omega t - 90°) + \ldots}\right]$$

4. a.



b.



6. a. $V_{av} = \mathbf{100\ V}$

$$V_{eff} = \sqrt{(100\ V)^2 + \frac{(50\ V)^2 + (25\ V)^2}{2}} = \mathbf{107.53\ V}$$

b. $I_{av} = \mathbf{3\ A}$

$$I_{eff} = \sqrt{(3\ A)^2 + \frac{(2\ A)^2 + (0.8\ A)^2}{2}} = \mathbf{3.36\ A}$$

8.
$$\begin{aligned} P_T &= V_0I_0 + V_1I_1 \cos\theta_1 + \ldots + V_nI_n \cos\theta_n \\ &= (100\ V)(3\ A) + \frac{(50\ V)(2\ A)}{2}\cos 53^\circ + \frac{(25\ V)(0.8\ A)}{2}\cos 70^\circ \\ &= 300 + (50)(0.6018) + (10)(0.3420) \\ &= \mathbf{333.52\ W} \end{aligned}$$

10. a. DC: $E = 18\ V,\ I_o = \dfrac{E}{R} = \dfrac{18\ V}{12\ \Omega} = 1.5\ A$

$\omega = 400$ rad/s: $X_L = \omega L = (400\ \text{rad/s})(0.02\ H) = 8\ \Omega$

$$\mathbf{Z} = 12\ \Omega + j8\ \Omega = 14.42\ \Omega\ \angle 33.69^\circ$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{30\ V/\sqrt{2}\ \angle 0^\circ}{14.42\ \Omega\ \angle 33.69^\circ} = \frac{2.08\ A}{\sqrt{2}}\ \angle -33.69^\circ$$

$$i = 1.5 + \sqrt{2}\left[\frac{2.08}{\sqrt{2}}\right]\sin(400t - 33.69^\circ)$$

$$\boldsymbol{i = 1.5 + 2.08 \sin(400t - 33.69^\circ)}$$

b. $I_{eff} = \sqrt{(1.5\ A)^2 + \dfrac{(2.08\ A)^2}{2}} = \mathbf{2.101\ A}$

c. DC: $v_R = E = 18\ V,\ \mathbf{V}_R = \left[\dfrac{2.08\ A}{\sqrt{2}}\angle -33.69^\circ\right](12\ \Omega\ \angle 0^\circ)$

$$= \frac{24.96\ V}{\sqrt{2}}\angle -33.69^\circ$$

$$v_R = 18 + \sqrt{2}\left[\frac{24.96}{\sqrt{2}}\right]\sin(400t - 33.69^\circ)$$

$$\boldsymbol{v_R = 18 + 24.96 \sin(400t - 33.69^\circ)}$$

d. $V_{R_{eff}} = \sqrt{(18\ V)^2 + \dfrac{(24.96\ V)^2}{2}} = \mathbf{25.21\ V}$

e. DC: $V_L = 0 \text{ V}$

$$\omega = 400 \text{ rad/s: } \mathbf{V}_L = \left[\frac{2.08 \text{ A}}{\sqrt{2}} \angle -33.69°\right](8\ \Omega \angle 90°)$$

$$= \frac{16.64 \text{ A}}{\sqrt{2}} \angle 56.31°$$

$$\boldsymbol{v_L = 0 + 16.64 \sin(400t + 56.31°)}$$

f. $$V_{L_{\text{eff}}} = \sqrt{0^2 + \frac{(16.64 \text{ V})^2}{2}} = \mathbf{11.766\ V}$$

g. $$P = I_{\text{eff}}^2 R = (2.101 \text{ A})^2\, 12\ \Omega = \mathbf{52.97\ W}$$

12. a. DC: $I = -\dfrac{60 \text{ V}}{12\ \Omega} = -5 \text{ A}$

$\omega = 300$ rad/s: $X_L = \omega L = (300 \text{ rad/s})(0.02 \text{ H}) = 6\ \Omega$

$$\mathbf{Z} = 12\ \Omega + j16\ \Omega = 13.42\ \Omega \angle 26.57°$$

$$\mathbf{E} = (0.707)(20 \text{ V}) \angle 0° = 14.14 \text{ V} \angle 0°$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = \frac{14.14 \text{ V} \angle 0°}{13.42\ \Omega \angle 26.57°} = 1.054 \text{ A} \angle -26.57°$$

$\omega = 600$ rad/s: $X_L = \omega L = (600 \text{ rad/s})(0.02 \text{ H}) = 12\ \Omega$

$$\mathbf{Z} = 12\ \Omega + j12\ \Omega = 16.97\ \Omega \angle 45°$$

$$\mathbf{E} = -(0.707)(10 \text{ V}) \angle 0° = -207 \text{ V} \angle 0°$$

$$\mathbf{I} = \frac{\mathbf{E}}{\mathbf{Z}} = -\frac{7.07 \text{ V} \angle 0°}{16.97\ \Omega \angle 45°} = -0.417 \text{ A} \angle -45°$$

$$i = -5 + (1.414)(1.054)\sin(300t - 26.57°) - (1.414)(0.417)\sin(600t - 45°)$$

$$\boldsymbol{i = -5 + 1.49 \sin(300t - 26.57°) - 0.59 \sin(600t - 45°)}$$

b. $$I_{\text{eff}} = \sqrt{(10 \text{ A})^2 + \frac{(1.49 \text{ A})^2 + (0.59 \text{ A})^2}{2}} = \mathbf{10.064\ A}$$

c. DC: $V = IR = (-5 \text{ A})(12\ \Omega) = -60 \text{ V}$

$\omega = 300$ rad/s: $\mathbf{V}_R = (1.054 \text{ A} \angle -26.57°)(12\ \Omega \angle 0°)$

$= 12.648 \text{ V} \angle -26.57°$

$\omega = 600$ rad/s: $\mathbf{V}_R = (-0.417 \text{ A} \angle -45°)(12\ \Omega \angle 0°)$

$= -5 \text{ V} \angle -45°$

$$v_R = -60 + (1.414)(12.648)\sin(300t - 26.57°) - (1.414)(5)\sin(600t - 45°)$$

$$\boldsymbol{v_R = -60 + 17.884 \sin(300t - 26.57°) - 7.07 \sin(600t - 45°)}$$

d. $$V_{R_{\text{eff}}} = \sqrt{(60 \text{ V})^2 + \frac{(17.884 \text{ V})^2 + (7.07 \text{ V})^2}{2}} = \mathbf{61.52\ V}$$

e. DC: $V_L = 0$ V

$\omega = 300$ rad/s: $\mathbf{V}_L = (1.054 \text{ A} \angle -26.57°)(6\ \Omega \angle 90°) = 6.324 \text{ V} \angle 63.43°$

$\omega = 600$ rad/s: $\mathbf{V}_L = (-0.417 \text{ A} \angle -45°)(6\ \Omega \angle 90°) = -2.502 \text{ V} \angle 45°$

$v_L = 0 + (1.414)(6.324)\sin(300t + 63.43°) - (1.414)(2.502)\sin(600t + 45°)$

$v_L = \mathbf{8.942 \sin(300t + 63.43°) - 3.538 \sin(600t + 45°)}$

f. $V_{L_{\text{eff}}} = \sqrt{\dfrac{(8.942 \text{ V})^2 + (3.538 \text{ V})^2}{2}} = \mathbf{6.8 \text{ V}}$

g. $P = I_{\text{eff}}^2 R = (10.064 \text{ A})^2\, 12\ \Omega = \mathbf{1215.41 \text{ W}}$

14. a. $e = \dfrac{200}{\pi} + \dfrac{400}{3\pi}\cos 2\omega t - \dfrac{400}{15\ \pi}\cos 4\omega t$

$= 63.69 + 42.46 \sin(2\omega t + 90°) - 8.49 \sin(4\omega t + 90°)$

$\omega = 377$ rad/s:

$e = 63.69 + 42.46 \sin(754t + 90°) - 8.49 \sin(1508t + 90°)$

DC: $X_L = 0 \therefore V_L = 0$ V

$\omega = 754$ rad/s: $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(754 \text{ rad/s})(1\ \mu\text{F})} = 1330\ \Omega$

$X_L = \omega L = (754 \text{ rad/s})(0.1 \text{ H}) = 75.4\ \Omega$

$\mathbf{Z}' = (1 \text{ k}\Omega \angle 0°) \| 75.4\ \Omega \angle 90° = 75.19\ \Omega \angle 85.69°$

$\mathbf{E} = (0.707)(42.46 \text{ V}) \angle 90° = 30.02 \text{ V} \angle 90°$

$\mathbf{V}_o = \dfrac{\mathbf{Z}'(\mathbf{E})}{\mathbf{Z}' + \mathbf{Z}_C} = \dfrac{(75.19\ \Omega \angle 85.69°)(30.02 \text{ V} \angle 90°)}{75.19\ \Omega \angle 85.69° + 1330\ \Omega \angle -90°} = 1.799 \text{ V} \angle -94.57°$

$\omega = 1508$ rad/s: $X_C = \dfrac{1}{\omega C} = \dfrac{1}{(1508 \text{ rad/s})(1\ \mu\text{F})} = 6631.13\ \Omega$

$X_L = \omega L = (1508 \text{ rad/s})(0.1 \text{ H}) = 150.8\ \Omega$

$\mathbf{Z}' = (1 \text{ k}\Omega \angle 0°) \| 150.8\ \Omega \angle 90° = 149.12\ \Omega \angle 81.42°$

$\mathbf{E} = (0.707)(8.49 \text{ V}) \angle 90° = 6 \text{ V} \angle 90°$

$\mathbf{V}_o = \dfrac{\mathbf{Z}'\mathbf{E}}{\mathbf{Z}' + \mathbf{Z}_C} = \dfrac{(149.12\ \Omega \angle 81.42°)(6 \text{ V} \angle 90°)}{149.12\ \Omega \angle 81.42° + 6631.13\ \Omega \angle -90°}$

$= 1.73 \text{ V} \angle -101.1°$

$v_o = 0 + 1.414(1.799)\sin(754t - 94.57°) - 1.414(1.73)\sin(1508t - 101.1°)$

$v_o = \mathbf{2.54 \sin(754t - 94.57°) - 2.45 \sin(1508t - 101.1°)}$

b. $V_{o_{\text{eff}}} = \sqrt{\dfrac{(2.54 \text{ V})^2 + (2.45 \text{ V})^2}{2}} = \mathbf{2.495 \text{ V}}$

c. $P = \dfrac{(V_{\text{eff}})^2}{R} = \dfrac{(2.495 \text{ V})^2}{1 \text{ k}\Omega} = \mathbf{6.225 \text{ mW}}$

16. a. $60 + 70 \sin \omega t + 20 \sin(2\omega t + 90°) + 10 \sin(3\omega t + 60°)$

$+20 + 30 \sin \omega t - 20 \sin(2\omega t + 90°) + 5 \sin(3\omega t + 90°)$

DC: $60 + 20 = 80$

ω: $70 + 30 = 100 \Rightarrow 100 \sin \omega t$

2ω: 0

3ω: $10 \angle 60° + 5 \angle 90° = 5 + j8.66 + j5 = 5 + j13.66 = 14.55 \angle 69.9°$

Sum = $\mathbf{80 + 100 \sin \omega t + 0 + 14.55 \sin(3\omega t + 69.9°)}$

b. $20 + 60 \sin \alpha + 10 \sin(2\alpha - 180°) + 5 \sin(3\alpha + 180°)$

$-5 + 10 \sin \alpha + \quad 0 \quad - 4 \sin(3\alpha - 30°)$

DC: $20 - 5 = 15$

α: $60 + 10 = 70 \Rightarrow 70 \sin \alpha$

2α: $10 \sin(2\alpha - 180°)$

3α: $5 \angle 180° - 4 \angle -30° = -5 - [3.46 - j2] = -8.46 + j2$

$= 8.69 \angle 166.7°$

Sum = $\mathbf{15 + 70 \sin \alpha + 10 \sin(2\alpha - 180°) + 8.69 \sin(3\alpha + 166.7°)}$

18. $e = v_1 + v_2$

$= \quad 20 - 200 \sin 600t + 100 \sin(1200t + 90°) + 75 \sin 1800t$

$\quad -10 + 150 \sin(600t + 30°) \quad + 0 \quad + 50 \sin(1800t + 60°)$

DC: $20\text{ V} - 10\text{ V} = 10\text{ V}$

ω: 600 rad/s: $-200\text{ V} \angle 0° + 150\text{ V} \angle 30° = 102.66\text{ V} \angle 133.07°$

$\omega = 1200$ rad/s: $100 \sin(1200t + 90°)$

$\omega = 1800$ rad/s: $75\text{ V} \angle 0° + 50\text{ V} \angle 60° = 108.97\text{ V} \angle 23.41°$

$e = \mathbf{10 + 102.66 \sin(600t + 133.07°) + 100 \sin(1200t + 90°) + 108.97 \sin(1800t + 23.41°)}$

CHAPTER 26 (Odd)

1. $Z_i = \dfrac{E_i}{I_i}$; $I_i = \dfrac{V_R}{R} = \dfrac{1.05\text{ V} - 1.00\text{ V}}{47\ \Omega} = \dfrac{50\text{ mV}}{47\ \Omega} = 1.064\text{ mA}$

$$Z_i = \frac{E_i}{I_i} = \frac{1.05\text{ V}}{1.064\text{ mA}} = \mathbf{986.84\ \Omega}$$

3. a. $I_{i_1} = \dfrac{E_{i_1}}{Z_{i_1}} = \dfrac{20\text{ mV}}{2\text{ k}\Omega} = \mathbf{10\ \mu A}$

b. $Z_{i_2} = \dfrac{E_{i_2}}{I_{i_2}} = \dfrac{1.8\text{ V}}{0.4\text{ mA}} = \mathbf{4.5\ k\Omega}$

c. $E_{i_3} = I_{i_3}Z_{i_3} = (1.5\text{ mA})(4.6\text{ k}\Omega) = \mathbf{6.9\ V}$

5. $E_{o_{\text{peak}}} = E_{g_{\text{peak}}} - V_{R_{\text{peak}}} = 2\text{ V}\angle 0° - 40 \times 10^{-3}\text{ V}\angle 0° = 1.96\text{ V}\angle 0°$

$$I_{\text{peak}} = \frac{V_{R_{\text{peak}}}}{R_s} = \frac{40\text{ mV}}{0.91\text{ k}\Omega} = 43.96\ \mu\text{A}$$

$$Z_o = \frac{E_o}{I_R} = \frac{1.96\text{ V}\angle 0°}{43.96\ \mu\text{A}} = \mathbf{44.59\ k\Omega}$$

7. $Z_o = \dfrac{E_{o_{p\text{-}p}}}{I_{o_{p\text{-}p}}} = \dfrac{E_{g_{p\text{-}p}} - V_{R_{p\text{-}p}}}{I_{o_{p\text{-}p}}} = \dfrac{0.8\text{ V} - 0.4\text{ V}}{40\ \mu\text{A}} = \mathbf{10\ k\Omega}$

$$V_{R_{p\text{-}p}} = 2\ \cancel{\text{div}}[0.2\text{ V}/\cancel{\text{div}}.] = 0.4\text{ V}$$

$$E_{g_{p\text{-}p}} = 4\ \cancel{\text{div}}[0.2\text{ V}/\cancel{\text{div}}.] = 0.8\text{ V}$$

$$I_{o_{p\text{-}p}} = \frac{V_{R_{p\text{-}p}}}{10\text{ k}\Omega} = \frac{0.4\text{ V}}{10\text{ k}\Omega} = 40\ \mu\text{A}$$

9. a. $\mathbf{A}_v = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = \mathbf{A}_{v_{\text{NL}}}\dfrac{R_L}{R_L + R_o} = (-3200)\dfrac{(5.6\text{ k}\Omega)}{5.6\text{ k}\Omega + 40\text{ k}\Omega} = \mathbf{-392.98}$

b. $\mathbf{A}_{v_T} = \dfrac{\mathbf{E}_o}{\mathbf{E}_g} = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} \cdot \dfrac{\mathbf{E}_i}{\mathbf{E}_g}$

with $\mathbf{E}_i = \dfrac{\mathbf{Z}_i\mathbf{E}_g}{\mathbf{Z}_i + R_g}$ and $\dfrac{\mathbf{E}_i}{\mathbf{E}_g} = \dfrac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g}$

$$\mathbf{A}_{v_T} = \frac{\mathbf{E}_o}{\mathbf{E}_i} \cdot \frac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g} = (-392.98)\frac{(2.2\text{ k}\Omega)}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega} = \mathbf{-320.21}$$

11. a. $\mathbf{A}_v = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = \mathbf{A}_{v_{NL}} \dfrac{R_L}{R_L + R_o}$

$-160 = \mathbf{A}_{v_{NL}} \dfrac{2\text{ k}\Omega}{2\text{ k}\Omega + 28\text{ k}\Omega} = \mathbf{A}_{v_{NL}}(0.0667)$

$\mathbf{A}_{v_{NL}} = \mathbf{-2398.8}$

b. $\mathbf{E}_o = -\mathbf{I}_o R_L = -(4\text{ mA})(2\text{ k}\Omega) = -8\text{ V}$

$\mathbf{A}_v = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = -160$

$\mathbf{E}_i = \dfrac{\mathbf{E}_o}{-160} = \dfrac{-8\text{ V}}{-160\text{ V}} = \mathbf{50\text{ mV}}$

c. $I_i = \dfrac{E_g - E_i}{R_g} = \dfrac{70\text{ mV} - 50\text{ mV}}{0.4\text{ k}\Omega} = 50\ \mu\text{A}$

$Z_i = \dfrac{E_i}{I_i} = \dfrac{50\text{ mV}}{50\ \mu\text{A}} = \mathbf{1\text{ k}\Omega}$

13. a. $\mathbf{A}_G = \mathbf{A}_v^2 \dfrac{R_i}{R_L}$

$= (-392.98)^2 \dfrac{2.2\text{ k}\Omega}{5.6\text{ k}\Omega}$

$= \mathbf{6.067 \times 10^4}$

$\mathbf{A}_v = \mathbf{A}_{v_{NL}} \dfrac{R_L}{R_L + R_o}$

$= (-3200)\left[\dfrac{5.6\text{ k}\Omega}{5.6\text{ k}\Omega + 40\text{ k}\Omega}\right]$

$= -392.98$

$\mathbf{A_G} = -\mathbf{A}_v \mathbf{A}_i$

$= -(-392.98)(154.39)$

$= \mathbf{6.067 \times 10^4}$

$\mathbf{A}_i = -\mathbf{A}_{v_{NL}} \dfrac{R_i}{R_L + R_o}$

$= -(-3200)\left[\dfrac{2.2\text{ k}\Omega}{5.6\text{ k}\Omega + 40\text{ k}\Omega}\right]$

$= 154.39$

b. $\mathbf{A}_{v_T} = \mathbf{A}_v \dfrac{\mathbf{Z}_i}{\mathbf{Z}_i + R_g} = (-392.98)\left[\dfrac{2.2\text{ k}\Omega}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega}\right] = \mathbf{-320.21}$

$\mathbf{A}_{i_T} = -\mathbf{A}_{v_T} \dfrac{R_g + \mathbf{Z}_i}{R_L} = -(-320.21)\left[\dfrac{0.5\text{ k}\Omega + 2.2\text{ k}\Omega}{5.6\text{ k}\Omega}\right] = \mathbf{154.39}$

$\mathbf{A}_{G_T} = \mathbf{A}_{v_T}^2 \left[\dfrac{R_g + R_i}{R_L}\right] = (-320.21)^2 \left[\dfrac{0.5\text{ k}\Omega + 2.2\text{ k}\Omega}{5.6\text{ k}\Omega}\right] = \mathbf{4.94 \times 10^4}$

$\mathbf{A}_{G_T} = -\mathbf{A}_{v_T} \mathbf{A}_{i_T} = -(-320.21)(154.39) = \mathbf{4.94 \times 10^4}$

15. a. $\mathbf{A}_{v_T} = \mathbf{A}_{v_1} \cdot \mathbf{A}_{v_2} = (-30)(-50) = \mathbf{1500}$

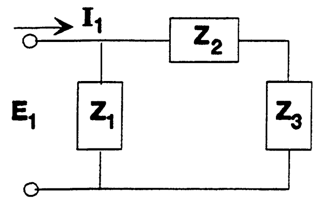
b. $\mathbf{A}_{i_T} = \mathbf{A}_{v_T} \dfrac{\mathbf{Z}_{i_1}}{R_L} = (1500)\left[\dfrac{1\text{ k}\Omega}{8\text{ k}\Omega}\right] = \mathbf{187.5}$

c. $\mathbf{A}_{i_1} = -\mathbf{A}_{v_1} \dfrac{\mathbf{Z}_{i_1}}{R_{L_1}} = -(-30)\left[\dfrac{1\text{ k}\Omega}{2\text{ k}\Omega}\right] = \mathbf{15}$

$$A_{i_2} = -A_{v_2}\frac{Z_{i_2}}{R_{L_2}} = -(-50)\left[\frac{2\text{ k}\Omega}{8\text{ k}\Omega}\right] = \mathbf{12.5}$$

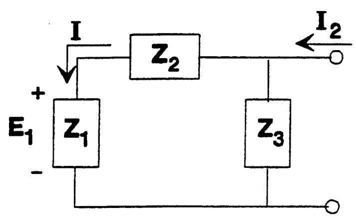
d. $A_{i_T} = A_{i_1} \cdot A_{i_2} = (15)(12.5) = \mathbf{187.5}$ as above

17. a.



$$z_{11} = \left.\frac{E_1}{I_1}\right|_{I_2=0} = Z_1 \| (Z_2 + Z_3)$$

$$z_{11} = \frac{Z_1Z_2 + Z_1Z_3}{Z_1 + Z_2 + Z_3}$$



$$I = \frac{Z_3I_2}{Z_1 + Z_2 + Z_3}$$

$$E_1 = I_1Z_1 = \frac{(Z_3I_2)(Z_1)}{Z_1 + Z_2 + Z_3}$$

$$z_{12} = \left.\frac{E_1}{I_2}\right|_{I_1=0} = \frac{Z_1Z_3}{Z_1 + Z_2 + Z_3}$$

$z_{21} = \left.\frac{E_2}{I_1}\right|_{I_2=0}$ Mirror image of z_{12}

$$\therefore z_{21} = \frac{Z_1Z_3}{Z_1 + Z_2 + Z_3}$$

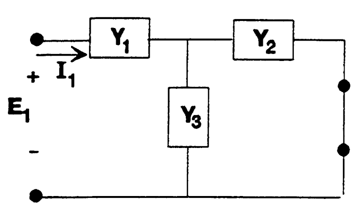
$z_{22} = \left.\frac{E_2}{I_2}\right|_{I_1=0}$ Mirror image of z_{11}

$$\therefore z_{22} = Z_3 \| (Z_1 + Z_2)$$

$$= \frac{Z_1Z_3 + Z_2Z_3}{Z_1 + Z_2 + Z_3}$$

b. —

19. a.



$$y_{11} = \left.\frac{I_1}{E_1}\right|_{E_2=0} \quad Y_T = Y_1 \| (Y_2 + Y_3)$$

$$= \frac{Y_1(Y_2 + Y_3)}{Y_1 + Y_2 + Y_3}$$

$$= \frac{Y_1Y_2 + Y_1Y_3}{Y_1 + Y_2 + Y_3}$$

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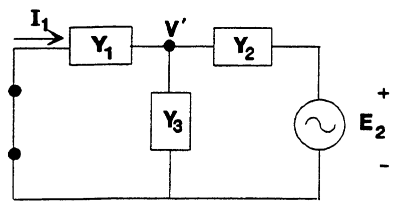


Nodal analysis:

$$V'[Y_1 + Y_2 + Y_3] = E_2Y_2$$
$$V' = I_1/Y_1$$

and

$$\frac{-I_1}{Y_1}[Y_1 + Y_2 + Y_3] = E_2Y_2$$

$$y_{12} = \left.\frac{I_1}{E_2}\right|_{E_1=0} = \frac{-Y_1Y_2}{Y_1 + Y_2 + Y_3}$$

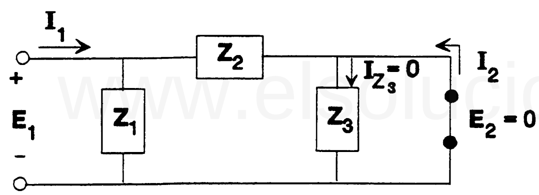
$$y_{21} = \left.\frac{I_2}{E_1}\right|_{E_2=0}$$ Mirror image of y_{12}

$$\therefore\ y_{21} = \frac{-Y_1Y_2}{Y_1 + Y_2 + Y_3}$$

$$y_{22} = \left.\frac{I_2}{E_2}\right|_{E_1=0}$$ Mirror image of y_{11}

$$y_{22} = Y_T = Y_2 \parallel (Y_1 + Y_3)$$
$$= \frac{Y_1Y_2 + Y_2Y_3}{Y_1 + Y_2 + Y_3}$$

21.

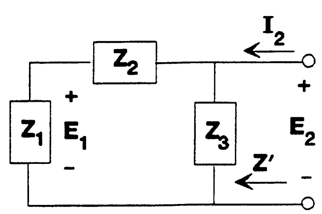


$$h_{11} = \left.\frac{E_1}{I_1}\right|_{E_2=0} = Z_T = Z_1 \parallel Z_2 = \frac{Z_1Z_2}{Z_1 + Z_2}$$

Using the above figure:

$$\text{CDR:}\quad I_2 = \frac{-Z_1(I_1)}{Z_1 + Z_2}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{E_2=0} = \frac{-Z_1}{Z_1 + Z_2}$$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

$$\text{VDR:}\qquad E_1 = \frac{Z_1E_2}{Z_1 + Z_2}$$

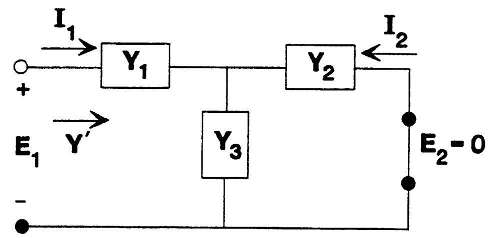
$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0} = \frac{Z_1}{Z_1 + Z_2}$$

Using above figure:

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} : Z' = Z_3 \parallel (Z_1 + Z_2) = \frac{Z_1Z_3 + Z_2Z_3}{Z_1 + Z_2 + Z_3}$$

$$h_{22} = \frac{1}{Z'} = \frac{Z_1 + Z_2 + Z_3}{Z_1Z_3 + Z_2Z_3}$$

23. $h_{11} = \left.\frac{E_1}{I_1}\right|_{E_2=0}$



$$Y' = Y_1 \parallel (Y_2 + Y_3)$$

$$Y' = \frac{Y_1Y_2 + Y_1Y_3}{Y_1 + Y_2 + Y_3}$$

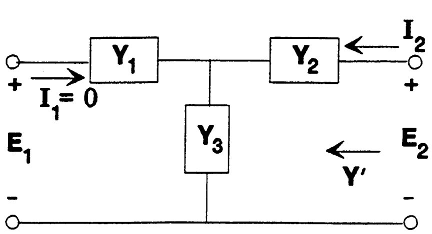
$$h_{11} = \frac{1}{Y'} = \frac{Y_1 + Y_2 + Y_3}{Y_1Y_2 + Y_1Y_3}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{E_2=0}$$

From above figure:

$$\text{CDR:} \quad I_2 = \frac{-Z_3I_1}{Z_3 + Z_2} = \frac{-I_1/Y_3}{1/Y_3 + 1/Y_2}$$

and $h_{21} = \left.\frac{I_2}{I_1}\right|_{E_2=0} = \frac{-1/Y_3}{1/Y_3 + 1/Y_2} = \frac{-Y_2}{Y_2 + Y_3}$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

$$\text{VDR:} \quad E_1 = \frac{Z_3E_2}{Z_3 + Z_2} = \frac{-1/Y_3E_2}{1/Y_3 + 1/Y_2}$$

and $E_1 = \frac{Y_2E_2}{Y_2 + Y_3}$

with $h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0} = \frac{Y_2}{Y_2 + Y_3}$

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} Y' = \frac{Y_2 \cdot Y_3}{Y_2 + Y_3} \text{ (from above figure)}$$

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} = Y' = \frac{Y_2Y_3}{Y_2 + Y_3}$$

25. a. Eq. 26.45:

$$A_i = \frac{h_f}{1 + h_o \mathbf{Z}_L} = \frac{50}{1 + \left[\frac{1}{40\text{ k}\Omega}\right](2\text{ k}\Omega)} = \mathbf{47.62}$$

b. Eq. 26.46:

$$\mathbf{A}_v = \frac{-h_f \mathbf{Z}_L}{h_i(1 + h_o \mathbf{Z}_L) - h_r h_f \mathbf{Z}_L}$$

$$= \frac{-50(2\text{ k}\Omega)}{1\text{ k}\Omega(1 + 0.05) - (4 \times 10^{-4})(50)(2\text{ k}\Omega)} = \mathbf{-99}$$

27. $\mathbf{z}_{11} = 1\text{ k}\Omega \angle 0°$, $\mathbf{z}_{12} = 5\text{ k}\Omega \angle 90°$, $\mathbf{z}_{21} = 10\text{ k}\Omega \angle 0°$, $\mathbf{z}_{22} = 2\text{ k}\Omega - j4\text{ k}\Omega$,
$\mathbf{Z}_L = 1\text{ k}\Omega \angle 0°$

$$\mathbf{Z}_i = \frac{\mathbf{E}}{\mathbf{I}} = \mathbf{z}_{11} - \frac{\mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22} + \mathbf{Z}_L} = 1\text{ k}\Omega - \frac{(5\text{ k}\Omega \angle 90°)(10\text{ k}\Omega)}{2\text{ k}\Omega - j4\text{ k}\Omega + 1\text{ k}\Omega} = \mathbf{9{,}219.5\ \Omega \angle -139.40°}$$

$$\mathbf{Z}_o = \frac{\mathbf{E}_2}{\mathbf{I}_2} = \mathbf{z}_{22} - \frac{\mathbf{z}_{12}\mathbf{z}_{21}}{R_s + \mathbf{z}_{11}} = 2\text{ k}\Omega - j4\text{ k}\Omega - \frac{(5\text{ k}\Omega \angle 90°)(10\text{ k}\Omega)}{1\text{ k}\Omega + 1\text{ k}\Omega} = \mathbf{29.07\text{ k}\Omega \angle -86.05°}$$

29. $$\mathbf{h}_{11} = \frac{\mathbf{z}_{11}\mathbf{z}_{22} - \mathbf{z}_{12}\mathbf{z}_{21}}{\mathbf{z}_{22}} = \frac{(4\text{ k}\Omega)(4\text{ k}\Omega) - (2\text{ k}\Omega)(3\text{ k}\Omega)}{4\text{ k}\Omega} = \mathbf{2.5\text{ k}\Omega}$$

$$\mathbf{h}_{12} = \frac{\mathbf{z}_{12}}{\mathbf{z}_{22}} = \frac{2\text{ k}\Omega}{4\text{ k}\Omega} = \mathbf{0.5}$$

$$\mathbf{h}_{21} = -\frac{\mathbf{z}_{21}}{\mathbf{z}_{22}} = -\frac{3\text{ k}\Omega}{4\text{ k}\Omega} = \mathbf{-0.75}$$

$$\mathbf{h}_{22} = \frac{1}{\mathbf{z}_{22}} = \frac{1}{4\text{ k}\Omega} = \mathbf{0.25\text{ mS}}$$

CHAPTER 26 (Even)

2. $\mathbf{Z}_i = \dfrac{\mathbf{E}_i}{\mathbf{I}_i} = \dfrac{120 \text{ V} \angle 0°}{6.2 \text{ A} \angle -10.8°} = 19.35\ \Omega \angle 10.8° = 19\ \Omega + j3.623\ \Omega$

$f = 60$ Hz: $R = \mathbf{19\ \Omega}$, $L = \dfrac{X_L}{2\pi f} = \dfrac{3.623\ \Omega}{2\pi(60 \text{ Hz})} = \mathbf{9.61\ mH}$

4. $I_o = \dfrac{E_g - E_o}{R_s} = \dfrac{4 \text{ V} - 3.8 \text{ V}}{2 \text{ k}\Omega} = \dfrac{0.2 \text{ V}}{2 \text{ k}\Omega} = 0.1 \text{ mA}(p - p)$

$Z_o = \dfrac{E_o}{I_o} = \dfrac{3.8 \text{ V}(p - p)}{0.1 \text{ mA}(p - p)} = \mathbf{38\ k\Omega}$

6. $E_{o_{(\text{peak})}} = \sqrt{2}\ 0.6 \text{ V}_{(\text{rms})} = 0.849 \text{ V}$

$E_{o_{(p-p)}} = 2\left(E_{o_{(\text{peak})}}\right) = 2(0.849 \text{ V}) = 1.697 \text{ V}$

$I_o = \dfrac{E_g - E_o}{R_s} = \dfrac{1.8 \text{ V} - 1.697 \text{ V}}{2 \text{ k}\Omega} = 51.5\ \mu\text{A}(p - p)$

$Z_o = \dfrac{E_o}{I_o} = \dfrac{1.697 \text{ V}(p - p)}{51.5\ \mu\text{A}(p - p)} = \mathbf{32.95\ k\Omega}$

8. $\mathbf{E}_i = \mathbf{I}_i\mathbf{Z}_i = (10\ \mu\text{A} \angle 0°)(1.8 \text{ k}\Omega \angle 0°) = 18 \text{ mV} \angle 0°$

$E_{i_{(\text{peak})}} = \sqrt{2}\ (18 \text{ mV}) = 25.46 \text{ mV}$

$E_{i_{(p-p)}} = 2(25.46 \text{ mV}) = 50.92 \text{ mV}$

$\mathbf{A}_{v_{\text{NL}}} = \dfrac{\mathbf{E}_o}{\mathbf{E}_i} = \dfrac{4.05 \text{ V} \angle 180°}{50.92 \text{ mV} \angle 0°} = 79.54 \angle 180° = -79.54$

10. $\mathbf{A}_{v_{\text{NL}}} = \dfrac{-1400 \text{ mV}}{1.2 \text{ mV} \angle 0°} = -1200$

$\mathbf{A}_v = \dfrac{-192 \text{ mV}}{1.2 \text{ mV}} = -160$

$$R_o = R_L\left[\frac{\mathbf{A}_{v_{\text{NL}}}}{\mathbf{A}_v} - 1\right] = 4.7 \text{ k}\Omega\left[\frac{-1200}{-160} - 1\right] = \mathbf{30.55\ k\Omega}$$

12. a. $\mathbf{A}_i = -\mathbf{A}_{v_{\text{NL}}}\dfrac{R_i}{R_L + R_o} = \dfrac{-(-3200)(2.2 \text{ k}\Omega)}{5.6 \text{ k}\Omega + 40 \text{ k}\Omega} = \mathbf{154.39}$

b. $$\mathbf{A}_{i_T} = -\mathbf{A}_{v_T}\left(\frac{R_g + Z_i}{R_L}\right)$$

$$= -\left(\frac{\mathbf{A}_v Z_i}{Z_i + R_g}\right)\left(\frac{R_g + Z_i}{R_L}\right)$$

$$\mathbf{A}_{i_T} = -\mathbf{A}_v\frac{Z_i}{R_L} = -\left(\mathbf{A}_{v_{NL}}\frac{R_L}{R_L + R_o}\right)\frac{Z_i}{R_L}$$

$$= -\mathbf{A}_{v_{NL}}\frac{Z_i}{R_L + R_o}$$

$$= \frac{-(-3200)(2.2\ \text{k}\Omega)}{5.6\ \text{k}\Omega + 40\ \text{k}\Omega}$$

$$= \mathbf{154.39}$$

c. Same result since $\mathbf{I}_i = \mathbf{I}_g$

14. a. $$\mathbf{A}_i = \frac{\mathbf{I}_o}{\mathbf{I}_i} = -\mathbf{A}_v\frac{Z_i}{R_L}$$

$$= \frac{-(-160)(0.75\ \text{k}\Omega)}{2\ \text{k}\Omega}$$

$$= \mathbf{60}$$

b. $$A_{G_T} = \frac{P_L}{P_g} = A_{v_T}^2\left(\frac{R_g + R_i}{R_L}\right)$$

$$\mathbf{A}_{v_T} = \mathbf{A}_v\frac{Z_i}{Z_i + R_g}$$

$$= \frac{(-160)(0.75\ \text{k}\Omega)}{0.75\ \text{k}\Omega + 0.4\ \text{k}\Omega} = -104.35$$

$$A_{G_T} = (104.35)^2\left(\frac{0.4\ \text{k}\Omega + 0.75\ \text{k}\Omega}{2\ \text{k}\Omega}\right)$$

$$= \mathbf{6.261 \times 10^3}$$

16. a. $$\mathbf{A}_{v_T} = \mathbf{A}_{v_1}\cdot\mathbf{A}_{v_2}\cdot\mathbf{A}_{v_3}$$

$$-6912 = (-12)(A_{v_2})(-32)$$

$$\mathbf{A}_{v_2} = \mathbf{-18}$$

b. $$\mathbf{A}_{i_1} = \frac{-\mathbf{A}_{v_1}Z_{i_1}}{R_{L_1}} = \frac{-\mathbf{A}_{v_1}Z_{i_1}}{Z_{i_2}}$$

$$4 = \frac{-(-12)(1\ \text{k}\Omega)}{Z_{i_2}}$$

$$Z_{i_2} = \mathbf{3\ k\Omega}$$

c. $\mathbf{A}_{i_3} = \dfrac{-\mathbf{A}_{v_3} Z_{i_3}}{R_{L_3}} = \dfrac{-(-32)(2\ \mathrm{k}\Omega)}{2.2\ \mathrm{k}\Omega}$

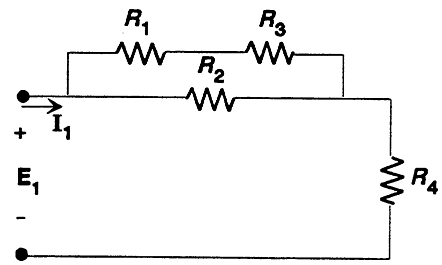
$= \mathbf{29.09}$

$\mathbf{A}_{i_T} = \mathbf{A}_{i_1} \cdot \mathbf{A}_{i_2} \cdot \mathbf{A}_{i_3}$

$= (4)(26)(29.09)$

$= \mathbf{3.025 \times 10^3}$

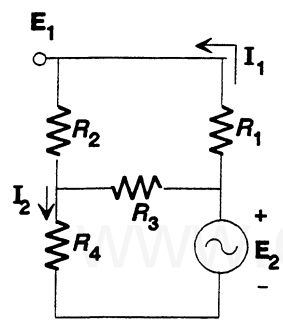
18. a. $\mathbf{z}_{11} = \left.\dfrac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{I}_2=0}$



$\mathbf{z}_{11} = R_4 + R_2 \| (R_1 + R_3)$

$= R_4 + \dfrac{R_2(R_1 + R_3)}{R_1 + R_2 + R_3}$

$\mathbf{z}_{12} = \left.\dfrac{\mathbf{E}_1}{\mathbf{I}_2}\right|_{\mathbf{I}_1=0}$

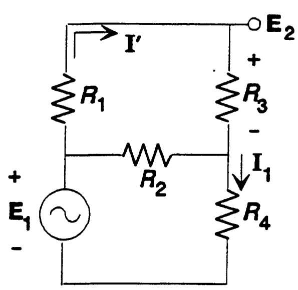


$\mathbf{I}' = \dfrac{R_2(\mathbf{I}_2)}{(R_1 + R_2) + R_3}$

$\mathbf{E}_1 = \mathbf{I}'R_2 + \mathbf{I}_2 R_4$

$= \dfrac{R_2 R_3 \mathbf{I}_2}{R_1 + R_2 + R_3} + R_4 \mathbf{I}_2$

and $\mathbf{z}_{12} = \dfrac{\mathbf{E}_1}{\mathbf{I}_2} = \dfrac{R_2 R_3}{R_1 + R_2 + R_3} + R_4 = \dfrac{R_2 R_3 + R_4(R_1 + R_2 + R_3)}{R_1 + R_2 + R_3}$



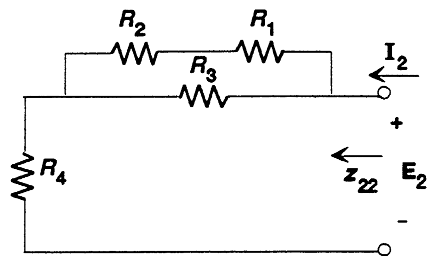
$\mathbf{E}_2 = \mathbf{I}'R_3 + \mathbf{I}_1 R_4$

CDR: $\mathbf{I}' = \dfrac{R_2(\mathbf{I}_1)}{(R_1 + R_3) + R_2}$

$\mathbf{E}_2 = \dfrac{R_2 R_3 \mathbf{I}_1}{R_1 + R_2 + R_3} + \mathbf{I}_1 R_4$

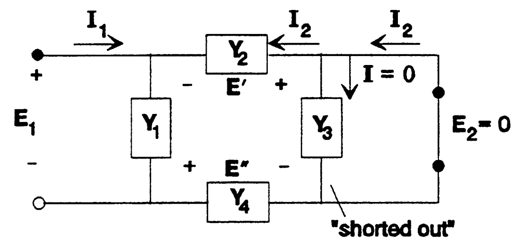
and $\mathbf{z}_{21} = \dfrac{\mathbf{E}_2}{\mathbf{I}_1} = \dfrac{R_2 R_3}{R_1 + R_2 + R_3} + R_4 = \dfrac{R_2 R_3 + R_4(R_1 + R_2 + R_3)}{R_1 + R_2 + R_3}$

$$z_{22} = \left.\frac{E_2}{I_2}\right|_{I_1=0}$$



$$z_{22} = R_4 + R_3 \| (R_1 + R_2)$$
$$= R_4 + \frac{R_3(R_1 + R_2)}{R_3 + (R_1 + R_2)}$$

20. a. $$y_{11} = \left.\frac{I_1}{E_1}\right|_{E_2=0}$$

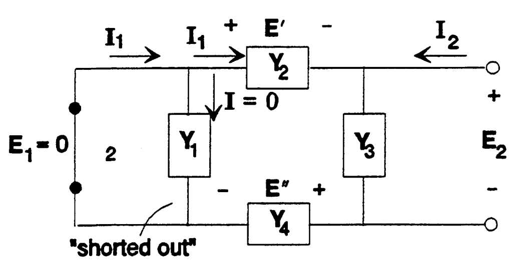


$$y_{11} = Y_1 + Y_2 \| Y_4$$
$$= Y_1 + \frac{Y_2Y_4}{Y_2 + Y_4}$$
$$= \frac{Y_1(Y_2 + Y_4) + Y_2Y_4}{Y_2 + Y_4}$$

$y_{21} = \left.\frac{I_2}{E_1}\right|_{E_2=0}$ (using the above diagram)

$$E_1 = \frac{I_2}{Y_1} = -(E' + E'') = -\left(\frac{I_2}{Y_2} + \frac{I_2}{Y_4}\right) = -I_2\left(\frac{1}{Y_2} + \frac{1}{Y_4}\right)$$

and $E_1 = -I_2\left(\frac{Y_4 + Y_2}{Y_4Y_2}\right)$ with $y_{21} = \frac{I_2}{E_1} = -\frac{Y_2Y_4}{Y_2 + Y_4}$



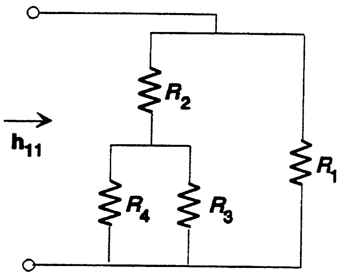
$$y_{12} = \left.\frac{I_1}{E_2}\right|_{E_1=0}$$

$$E_2 = \frac{I_1}{Y_3} = -(E' + E'') = -\left(\frac{I_1}{Y_2} + \frac{I_1}{Y_4}\right) = -I_1\left(\frac{1}{Y_2} + \frac{1}{Y_4}\right)$$

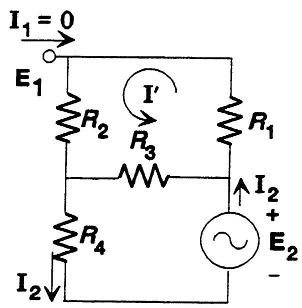
and $y_{12} = -\frac{Y_2Y_4}{Y_2 + Y_4} = y_{21}$

$$\mathbf{y}_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{E}_2}\right|_{\mathbf{E}_1=0} \qquad \mathbf{y}_{22} = \mathbf{Y}_3 + \mathbf{Y}_2 \| \mathbf{Y}_4 = \mathbf{Y}_3 + \frac{\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2 + \mathbf{Y}_4}$$
$$= \frac{\mathbf{Y}_3(\mathbf{Y}_2 + \mathbf{Y}_4)\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2 + \mathbf{Y}_4}$$

22. a.

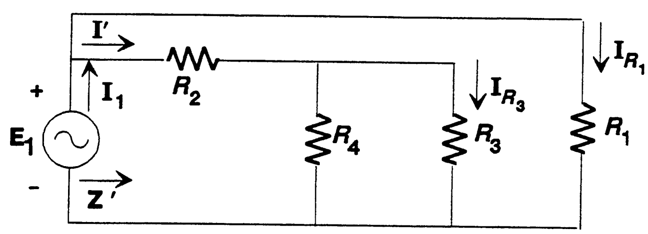


$$\mathbf{h}_{11} = \left.\frac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0}$$
$$= \mathbf{Z}_i = \mathbf{R}_1 \| (\mathbf{R}_2 + \mathbf{R}_3 \| \mathbf{R}_4)$$



$$\mathbf{h}_{12} = \left.\frac{\mathbf{E}_1}{\mathbf{E}_2}\right|_{\mathbf{I}_1=0}$$
$$\mathbf{E}_1 = \mathbf{I}'R_2 + \mathbf{I}_2R_4$$
$$\mathbf{I}' = \frac{R_3(\mathbf{I}_2)}{R_1 + R_2 + R_3}$$
$$\therefore\ \mathbf{E}_1 = \frac{R_2R_3\mathbf{I}_2}{R_1 + R_2 + R_3} + \mathbf{I}_2R_4$$
$$\text{and } \mathbf{I}_2 = \frac{\mathbf{E}_2}{\mathbf{Z}'} = \frac{\mathbf{E}_2}{R_4 + R_3 \| (R_1 + R_2)}$$

$$\mathbf{E}_1 = \left[\frac{R_2R_3}{R_1 + R_2 + R_3} + R_4\right]\left[\frac{\mathbf{E}_2}{R_4 + \dfrac{R_3R_1 + R_2R_3}{R_1 + R_2 + R_3}}\right]$$
$$\text{and } \mathbf{h}_{12} = \frac{\mathbf{E}_1}{\mathbf{E}_2} = \frac{R_2R_3 + R_4(R_1 + R_2 + R_3)}{R_1R_3 + R_2R_3 + R_4(R_1 + R_2 + R_3)}$$



$$\mathbf{Z}' = R_2 + R_3 \| R_4$$
$$\mathbf{I}_{R_1} = \frac{(\mathbf{Z}')(\mathbf{I}_1)}{\mathbf{Z}' + R_1}$$
$$\mathbf{I}' = \frac{R_1\mathbf{I}_1}{R_1 + \mathbf{Z}'}$$

$$\mathbf{I}_{R_3} = \frac{R_4\mathbf{I}'}{R_4 + R_3} = \frac{R_4}{R_4 + R_3}\left[\frac{R_1(\mathbf{I}_1)}{R_1 + \mathbf{Z}'}\right]$$
$$= \frac{R_1R_4\mathbf{I}_1}{(R_3 + R_4)(R_1 + \mathbf{Z}')}$$

$$\mathbf{I}_2 = -\mathbf{I}_{R_1} - \mathbf{I}_{R_3} = \frac{-\mathbf{Z}'\mathbf{I}_1}{\mathbf{Z}' + R_1} - \frac{R_1R_4\mathbf{I}_1}{(R_3 + R_4)(R_1 + \mathbf{Z}')}$$

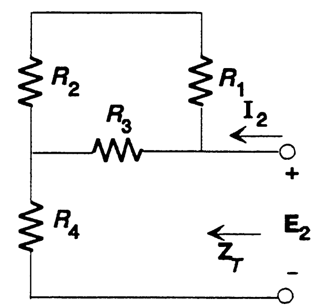
$$\mathbf{h}_{12} = \left.\frac{\mathbf{I}_2}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} = -\left[\frac{\mathbf{Z}'}{\mathbf{Z}' + R_1} + \frac{R_1R_4}{(R_3 + R_4)(R_1 + \mathbf{Z}')}\right]$$

$$= -\frac{1}{R_1 + \mathbf{Z}'}\left[\mathbf{Z}' + \frac{R_1R_4}{R_3 + R_4}\right]$$

$$\mathbf{h}_{22} = \left.\frac{\mathbf{I}_2}{\mathbf{E}_2}\right|_{\mathbf{I}_1=0} = \frac{1}{\mathbf{Z}_T}$$

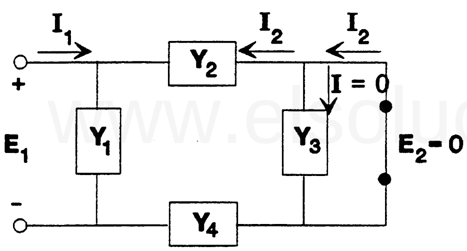
$$\mathbf{Z}_T = R_4 + R_3 \| (R_1 + R_2)$$

$$\mathbf{h}_{22} = \frac{1}{R_4 + R_3 \| (R_1 + R_2)}$$



A Y-Δ conversion would have simplified the problem to one similar to Fig. 26.70.

24.

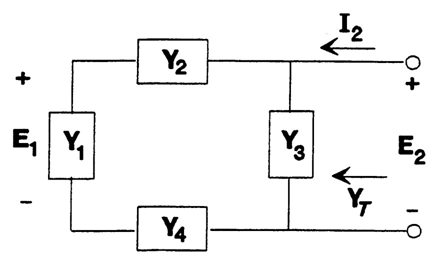


$$\mathbf{h}_{11} = \left.\frac{\mathbf{E}_1}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} = \frac{1}{\mathbf{Y}_T} = \frac{1}{\mathbf{Y}_1 + \mathbf{Y}_2 \| \mathbf{Y}_4}$$

$$\mathbf{h}_{21} = \left.\frac{\mathbf{I}_2}{\mathbf{I}_1}\right|_{\mathbf{E}_2=0} : \text{ CDR} \rightarrow \mathbf{I}_2 = \frac{-\mathbf{Z}_1(\mathbf{I}_1)}{\mathbf{Z}_1 + \mathbf{Z}_2 + \mathbf{Z}_4} = \frac{-1/\mathbf{Y}_1(\mathbf{I}_1)}{1/\mathbf{Y}_1 + 1/\mathbf{Y}_2 + 1/\mathbf{Y}_4}$$

$$= \frac{-1/\mathbf{Y}_1(\mathbf{I}_1)}{\dfrac{\mathbf{Y}_2\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_2}{\mathbf{Y}_1\mathbf{Y}_2\mathbf{Y}_4}}$$

$$\text{and } \mathbf{h}_{21} = -\frac{\mathbf{Y}_2\mathbf{Y}_4}{\mathbf{Y}_2\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_4 + \mathbf{Y}_1\mathbf{Y}_2}$$



$$h_{12} = \left.\frac{E_1}{E_2}\right|_{I_1=0}$$

$$\text{VDR: } E_1 = \frac{Z_1(E_2)}{Z_1 + Z_2 + Z_4} = \frac{1/Y_1\ (E_2)}{1/Y_1 + 1/Y_2 + 1/Y_4}$$

$$\text{and } h_{12} = \frac{Y_2Y_4}{Y_2Y_4 + Y_1Y_4 + Y_1Y_2}$$

$$h_{22} = \left.\frac{I_2}{E_2}\right|_{I_1=0} = Y_T \text{ (using the above figure)}$$

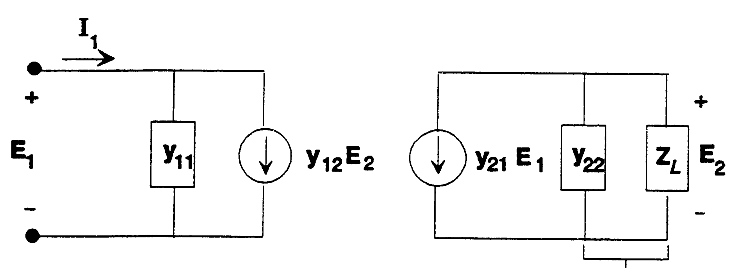
$$Y_T = Y_3 + Y_1 \| Y_2 \| Y_4$$
$$= Y_3 + \frac{Y_1Y_2Y_4}{Y_1Y_2 + Y_1Y_4 + Y_2Y_4}$$

26. a. $Z_i = \dfrac{E_1}{I_1} = h_i - \dfrac{h_rh_fZ_L}{1 + h_oZ_L}$

$$= 1\text{ k}\Omega - \frac{(4 \times 10^{-4})(50)(2\text{ k}\Omega)}{1 + \left[\dfrac{1}{40\text{ k}\Omega}\right](2\text{ k}\Omega)} = \mathbf{961.9\ \Omega}$$

b. $Z_o = \dfrac{1}{h_o - \dfrac{h_rh_f}{h_i + R_s}} = \dfrac{1}{\dfrac{1}{40\text{ k}\Omega} - \dfrac{(4 \times 10^{-4})(50)}{1\text{ k}\Omega + 0}} = \mathbf{200\text{ k}\Omega}$

28.



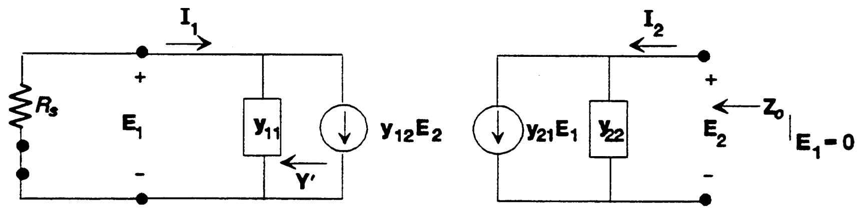
$$1/y_{22} \| Z_L = \frac{1/y_{22}Z_L}{1/y_{22} + Z_L} = \frac{Z_L}{1 + y_{22}Z_L}$$

$$E_2 = -y_{21}E_1\left[\frac{Z_L}{1 + y_{22}Z_L}\right]$$

$$I_1 = E_1y_{11} + y_{12}E_2 = E_1y_{11} + y_{12}\left[-y_{21}E_1\left(\frac{Z_L}{1 + y_{22}Z_L}\right)\right]$$

$$\frac{I_1}{E_1} = y_{11} - \frac{y_{12}y_{21}Z_L}{1 + y_{22}Z_L}$$

$$\text{and } Z_i = \frac{E_1}{I_1} = \cfrac{1}{y_{11} - \cfrac{y_{12}y_{21}Z_L}{1 + y_{22}Z_L}}$$



$$Y' = y_{11} + \frac{1}{R_s}$$

$$E_1 = \frac{-y_{12}E_2}{Y'} = \cfrac{-y_{12}E_2}{y_{11} + \cfrac{1}{R_s}} = \frac{-y_{12}R_sE_2}{y_{11}R_s + 1}$$

$$I_2 = y_{21}E_1 + y_{22}E_2 = y_{21}\left[\frac{-y_{12}R_sE_2}{y_{11}R_s + 1}\right] + y_{22}E_2$$

$$\frac{I_2}{E_2} = -\frac{y_{12}y_{21}R_s}{y_{11}R_s + 1} + y_{22}$$

$$\text{and } Z_o = \left.\frac{E_2}{I_2}\right|_{E_1=0} = \cfrac{1}{y_{22} - \cfrac{y_{12}y_{21}R_s}{1 + y_{11}R_s}}$$

30. a. $\Delta_h = h_{11}h_{22} - h_{12}h_{21} = (10^3)(20 \times 10^{-6}) - (2 \times 10^{-4})(100)$

$= 20 \times 10^{-3} - 20 \times 10^{-3} = 0$

$z_{11} = \frac{\Delta_h}{Z_{22}} = 0\ \Omega$, $z_{12} = \frac{h_{12}}{h_{22}} = \frac{2 \times 10^{-4}}{20 \times 10^{-6}\ S} = \mathbf{10\ \Omega}$

$z_{21} = \frac{-h_{21}}{h_{22}} = \frac{-100}{20 \times 10^{-6}\ S} = \mathbf{-5\ M\Omega}$, $z_{22} = \frac{1}{h_{22}} = \mathbf{50\ k\Omega}$

b. $y_{11} = \frac{1}{h_{11}} = \frac{1}{10^3\ \Omega} = \mathbf{10^{-3}\ S}$, $y_{12} = \frac{-h_{12}}{h_{11}} = \frac{-2 \times 10^{-4}}{10^3\ \Omega} = \mathbf{-2 \times 10^{-7}\ S}$

$y_{21} = \frac{h_{21}}{h_{11}} = \frac{100}{10^3\ \Omega} = \mathbf{100 \times 10^{-3}\ S}$, $y_{22} = \frac{\Delta_h}{h_{11}} = \mathbf{0\ S}$