Chapter 1

1. –

2. –

3. –

4. $$10\ \cancel{\text{min}}\left[\frac{1\text{ h}}{60\ \cancel{\text{min}}}\right] = 0.167\text{ h}$$

$$v = \frac{d}{t} = \frac{30.5\text{ mi}}{1.167\text{ h}} = 26.14\text{ mph}$$

5. a. mph = (0.6)(160 km/h) = **96 mph**
   b. km/h = (1.7)(70 mph) = **119 km/h**

6. $$100\ \cancel{\text{yds}}\left[\frac{3\ \cancel{\text{ft}}}{1\ \cancel{\text{yd}}}\right]\left[\frac{1\text{ mi}}{5{,}280\ \cancel{\text{ft}}}\right] = 0.0568\text{ mi}$$

$$\frac{60\text{ mi}}{\cancel{\text{h}}}\left[\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right]\left[\frac{1\ \cancel{\text{min}}}{60\text{ s}}\right] = 0.0167\text{ mi/s}$$

$$t = \frac{d}{v} = \frac{0.0568\text{ mi}}{0.0167\text{ mi/s}} = 3.40\text{ s}$$

7. a. $$\frac{95\ \cancel{\text{mi}}}{\cancel{\text{h}}}\left[\frac{5{,}280\text{ ft}}{\cancel{\text{mi}}}\right]\left[\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right]\left[\frac{1\ \cancel{\text{min}}}{60\text{ s}}\right] = 139.33\text{ ft/s}$$
   b. $$t = \frac{d}{v} = \frac{60\text{ ft}}{139.33\text{ ft/s}} = 0.43\text{ s}$$
   c. $$v = \frac{d}{t} = \frac{60\ \cancel{\text{ft}}}{1\ \cancel{\text{s}}}\left[\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right]\left[\frac{60\ \cancel{\text{min}}}{1\text{ h}}\right]\left[\frac{1\text{ mi}}{5{,}280\ \cancel{\text{ft}}}\right] = 40.91\text{ mph}$$

8. –

9. –

10. –

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

12. $$1000\ \cancel{\text{J}}\left[\frac{0.7378\text{ ft-lb}}{1\ \cancel{\text{J}}}\right] = 737.8\text{ ft-lbs}$$

13. a. $70.8\,\cancel{kg}\left[\frac{2.2\text{ lbs}}{\cancel{kg}}\right] = \mathbf{155.76\text{ lbs}}$

b. $145\,\cancel{lbs}\left[\frac{1\text{ kg}}{2.2\,\cancel{lbs}}\right] = \mathbf{65.91\text{ kg}}$

c. $6\,\cancel{ft}\left[\frac{12\,\cancel{in.}}{\cancel{ft}}\right]\left[\frac{2.54\text{ cm}}{1\,\cancel{in.}}\right] = \mathbf{182.88\text{ cm}}$

d. $179.9\,\cancel{cm}\left[\frac{1\,\cancel{in.}}{2.54\,\cancel{cm}}\right]\left[\frac{1\text{ ft}}{12\,\cancel{in.}}\right] = \mathbf{5.9\text{ ft} = 5\text{ ft }10.8\text{ in.}}$

14. a. $°F = 2(°C) + 30° = 40° + 30° = \mathbf{70°}$

b. $°F = \frac{9}{5}(°C) + 32° = \frac{9}{5}(20°) + 32° = \mathbf{68°}$

c. **very close**

d. **30°C → 90°F vs. 86°F**
5°C → 40°F vs 41°F

15. a. **14.6** b. **56.0**
c. **1,046.1** d. $\frac{1}{16} = 0.0625 = \mathbf{0.1}$
e. **3.14159 = 3.1**

16. a. **14.60** b. **56.04**
c. **1,046.06** d. $\frac{1}{16} = 0.0625 = \mathbf{0.06}$
e. **3.14159 = 3.14**

17. a. **14.603** b. **56.042**
c. **1,046.060** d. $\frac{1}{16} = 0.0625 = \mathbf{0.063}$
e. **3.14159 = 3.142**

18. a. 10^4 b. 10^6 c. 10^3 d. 10^{-3}
e. 10^0 f. 10^{-1}

19. a. 15×10^3 b. 5×10^{-3} c. 2.4×10^6 d. 60×10^3
e. 4.02×10^{-4} f. 2×10^{-10}

20. a. $4.2 \times 10^3 + 48.0 \times 10^3 = 52.2 \times 10^3 = \mathbf{5.22 \times 10^4}$
b. $90 \times 10^3 + 360 \times 10^3 = 450 \times 10^3 = \mathbf{4.50 \times 10^5}$
c. $50 \times 10^{-5} - 6 \times 10^{-5} = 44 \times 10^{-5} = \mathbf{4.40 \times 10^{-4}}$
d. $1.2 \times 10^3 + 0.05 \times 10^3 - 0.4 \times 10^3 = 0.85 \times 10^3 = \mathbf{850}$

21. a. $(10^2)(10^3) = 10^5 = \mathbf{100 \times 10^3}$
b. $(10^{-2})(10^3) = 10^1 = \mathbf{10}$
c. $(10^3)(10^6) = \mathbf{1 \times 10^9}$
d. $(10^2)(10^{-5}) = \mathbf{1 \times 10^{-3}}$
e. $(10^{-6})(10 \times 10^6) = \mathbf{10}$
f. $(10^4)(10^{-8})(10^{28}) = \mathbf{1 \times 10^{24}}$

22. a. $(50 \times 10^3)(2 \times 10^{-3}) = 100 \times 10^0 = \mathbf{100}$
b. $(2.2 \times 10^3)(2 \times 10^{-3}) = 4.4 \times 10^0 = \mathbf{4.40}$
c. $(82 \times 10^{-6})(1.2 \times 10^{-6}) = \mathbf{98.40}$
d. $(30 \times 10^{-4})(4 \times 10^{-3})(7 \times 10^8) = 840 \times 10^1 = \mathbf{8.40 \times 10^3}$

23. a. $10^2/10^4 = 10^{-2} = \mathbf{10 \times 10^{-3}}$
b. $10^{-2}/10^3 = 10^{-5} = \mathbf{10 \times 10^{-6}}$
c. $10^4/10^{-3} = 10^7 = \mathbf{10 \times 10^6}$
d. $10^{-7}/10^2 = \mathbf{1.0 \times 10^{-9}}$
e. $10^{38}/10^{-4} = \mathbf{1.0 \times 10^{42}}$
f. $\sqrt{100}/10^{-2} = 10^1/10^{-2} = \mathbf{1 \times 10^3}$

24. a. $(2 \times 10^3)/(8 \times 10^{-5}) = 0.25 \times 10^8 = \mathbf{2.50 \times 10^7}$
b. $(4 \times 10^{-3})/(4 \times 10^6) = 4/4 \times 10^{-9} = \mathbf{1 \times 10^{-9}}$
c. $(22 \times 10^{-5})/(5 \times 10^{-5}) = 22/5 \times 10^0 = \mathbf{4.40}$
d. $(78 \times 10^{18})/(4 \times 10^{-6}) = \mathbf{1.95 \times 10^{25}}$

25. a. $(10^2)^3 = \mathbf{1.0 \times 10^6}$ b. $(10^{-4})^{1/2} = \mathbf{10.0 \times 10^{-3}}$
c. $(10^4)^8 = \mathbf{100.0 \times 10^{30}}$ d. $(10^{-7})^9 = \mathbf{1.0 \times 10^{-63}}$

26. a. $(2 \times 10^2)^2 = \mathbf{4 \times 10^4}$
b. $(5 \times 10^{-3})^3 = \mathbf{125 \times 10^{-9}}$
c. $(4 \times 10^{-3})(3 \times 10^{-3})^2 = (4 \times 10^{-3})(9 \times 10^4) = 36 \times 10^1 = \mathbf{360}$
d. $((2 \times 10^{-3})(0.8 \times 10^4)(0.003 \times 10^5))^3 = (4.8 \times 10^3)^3 = (4.8)^3 \times (10^3)^3$
$= 110.6 \times 10^9 = \mathbf{1.11 \times 10^{11}}$

27. a. $\frac{(3\times10^2)^2(10^2)}{3\times10^4} = (9 \times 10^4)(10^2)/(3 \times 10^4) = (9 \times 10^6)/(3 \times 10^4) = 3 \times 10^2 = \mathbf{300}$

b. $\frac{(4\times10^4)^2}{(20)^3} = \frac{16\times10^8}{8\times10^3} = \mathbf{2 \times 10^5}$

c. $\frac{(6\times10^4)^2}{(2\times10^{-2})^2} = \frac{36\times10^8}{4\times10^{-4}} = \mathbf{9.0 \times 10^{12}}$

d. $\frac{(27\times10^{-6})^{1/3}}{2\times10^5} = \frac{3\times10^{-2}}{2\times10^5} = 1.5 \times 10^{-7} = \mathbf{150.0 \times 10^{-9}}$

e. $\frac{(4\times10^3)^2(3\times10^2)}{2\times10^{-4}} = \frac{(16\times10^6)(3\times10^2)}{2\times10^{-4}} = \frac{48\times10^8}{2\times10^{-4}} = \mathbf{24.0 \times 10^{12}}$

f. $(16 \times 10^{-6})^{1/2}(10^5)^5(2 \times 10^{-2}) = (4 \times 10^{-3})(10^{25})(2 \times 10^{-2}) = 8 \times 10^{20} = \mathbf{800.0 \times 10^{18}}$

g. $\dfrac{\left[(3\times10^{-3})^3\right]\left[.60\times10^{2}\right]^2\left[(2\times10^{2})(8\times10^{-4})\right]^{1/2}}{(7\times10^{-5})^2}$

$= \dfrac{(27\times10^{-9})(2.56\times10^{4})(16\times10^{-2})^{1/2}}{49\times10^{-10}}$

$= \dfrac{(69.12\times10^{-5})(4\times10^{-1})}{49\times10^{-10}} = \dfrac{276.48\times10^{-6}}{49\times10^{-10}}$

$= 5.64\times10^{4} = \mathbf{56.40\times10^{3}}$

28. Scientific:

a. $\mathbf{2.05\times10^{1}}$
b. $\mathbf{5.04\times10^{4}}$
c. $\mathbf{6.74\times10^{-4}}$
d. $\mathbf{4.60\times10^{-2}}$

Engineering:

a. $\mathbf{20.46\times10^{0}}$
b. $\mathbf{50.42\times10^{3}}$
c. $\mathbf{674.00\times10^{-6}}$
d. $\mathbf{46.00\times10^{-3}}$

29. Scientific

a. $\mathbf{5.0\times10^{-2}}$
b. $\mathbf{4.5\times10^{1}}$
c. $1/32 = 0.03125 = \mathbf{3.125\times10^{-2}}$
d. $3.14159 = \mathbf{3.142\times10^{0}}$

Engineering:

a. $\mathbf{50.0\times10^{-3}}$
b. $\mathbf{0.045\times10^{3}}$
c. $\mathbf{31.25\times10^{-3}}$
d. $\mathbf{3.142\times10^{0}}$

30.
a. $(6)(4)\times(10^{-3})(10^{4}) = 24\times10^{1} = \mathbf{240}$
b. $(70)(0.02)\times(10^{5})(10^{3}) = 4.4\times10^{8} = \mathbf{440\times10^{6}}$
c. $(0.001)(600)\times(10^{7})(10^{4}) = 0.6\times10^{11}$

$\dfrac{0.6\times10^{11}}{4\times10^{3}} = \left[\dfrac{0.6}{4}\right]\times\left[\dfrac{10^{11}}{10^{3}}\right] = 0.15\times10^{8} = \mathbf{150\times10^{6}}$

d. $(5.2)^2\times(10^{4})^2 = 27.04\times10^{8}$

$\dfrac{27.04\times10^{8}}{2.02\times10^{3}} = 13.39\times10^{5} = \mathbf{1.34\times10^{6}}$

31.
a. $6\times10^{4} \overset{+2}{\underset{-3}{=}} \underline{0.06}\times10^{+6} = \mathbf{0.06\times10^{+6}}$

b. $0.4\times10^{-3} \overset{-3}{\underset{+3}{=}} \underline{400}\times10^{-6} = \mathbf{400\times10^{-6}}$

c. $50\times10^{5} \overset{-2}{\underset{+2}{=}} \underline{5000}\times10^{3} \overset{+3}{\underset{-3}{=}} \underline{5}\times10^{6} \overset{+3}{\underset{-3}{=}} \underline{0.005}\times10^{9} = \mathbf{0.005\times10^{9}}$

d. $12\times10^{-7} \overset{+4}{\underset{-4}{=}} \underline{0.0012}\times10^{-3} \overset{-3}{\underset{+3}{=}} \underline{1.2}\times10^{-6} \overset{-3}{\underset{+3}{=}} \underline{1200}\times10^{-9} = \mathbf{1200\times10^{9}}$

32.
a. $0.05\times10^{0}\,s \overset{-3}{\underset{+3}{=}} \underline{50}\times10^{-3}\,s = \mathbf{50\ ms}$

b. $2000\times10^{-6}\,s \overset{+3}{\underset{-3}{=}} \underline{2}\times10^{-3}\,s = \mathbf{2\ ms}$

c. $0.04\times10^{-3}\,s \overset{-3}{\underset{+3}{=}} \underline{40}\times10^{-6}\,s = \mathbf{40\ \mu s}$

d. $8400\times10^{-12}\,s \overset{+6}{\underset{-6}{\Rightarrow}} \underline{0.0084}\times10^{-6}\,s = \mathbf{0.0084\ \mu s}$

e. $$\overset{+3 \text{ increase by } 3}{} \quad 100 \times \underbrace{10^{3} \times 10^{-3}}_{10^{0}} \text{ m} = \underline{0.1} \times 10^{3} \text{ m} = \mathbf{0.1\ km} \quad (-3)$$

33\. a. $1.5\ \cancel{\text{min}} \left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = \mathbf{90\ s}$

b. $2 \times 10^{-2}\ \cancel{\text{h}} \left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right] = \mathbf{72\ s}$

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

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

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

f. $4 \times 10^{8}\ \cancel{\text{s}} \left[\frac{1\ \cancel{\text{min}}}{60\ \cancel{\text{s}}}\right]\left[\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right]\left[\frac{1\text{ day}}{24\ \cancel{\text{h}}}\right] = \mathbf{4629.6\ days}$

34\. a. $80 \times 10^{-3}\ \cancel{\text{m}} \left[\frac{100\text{ cm}}{1\ \cancel{\text{m}}}\right] = 8000 \times 10^{-3}\text{ cm} = \mathbf{8\ cm}$

b. $60\ \cancel{\text{cm}} \left[\frac{1\ \cancel{\text{m}}}{100\ \cancel{\text{cm}}}\right]\left[\frac{1\text{ km}}{1000\ \cancel{\text{m}}}\right] = \mathbf{60 \times 10^{-5}\ km}$

c. $12 \times 10^{-3}\ \cancel{\text{m}} \left[\frac{1\ \mu\text{m}}{10^{-6}\ \cancel{\text{m}}}\right] = 12 \times 10^{-3} \times 10^{+6}\ \mu\text{m} = \mathbf{12 \times 10^{3}\ \mu m}$

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

35\. a. $100\ \cancel{\text{in.}} \left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{2.54\ m}$

b. $4\ \cancel{\text{ft}} \left[\frac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{1.22\ m}$

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

d. $60 \times 10^{3}\ \cancel{\text{dynes}} \left[\frac{1\ \cancel{\text{N}}}{10^{5}\ \cancel{\text{dynes}}}\right]\left[\frac{1\text{ lb}}{4.45\ \cancel{\text{N}}}\right] = \mathbf{0.13\ lb}$

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

f. $0.002\ \cancel{\text{mi}} \left[\frac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}}\right]\left[\frac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = \mathbf{3.22\ m}$

36\. **5280 ft,** $5280\ \cancel{\text{ft}} \left[\frac{1\text{ yd}}{3\ \cancel{\text{ft}}}\right] = \mathbf{1760\ yds}$

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

37\. $\frac{60\ \cancel{\text{mi}}}{\cancel{\text{h}}} \left[\frac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}}\right]\left[\frac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right]\left[\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right]\left[\frac{1\ \cancel{\text{min}}}{60\text{ s}}\right] = \mathbf{26.82\ m/s}$

38\. $10\ \cancel{\text{km}} \left[\frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}}\right]\left[\frac{39.37\ \cancel{\text{in.}}}{1\ \cancel{\text{m}}}\right]\left[\frac{1\ \cancel{\text{ft}}}{12\ \cancel{\text{in.}}}\right]\left[\frac{1\text{ mi}}{5280\ \cancel{\text{ft}}}\right] = 6.214\text{ mi}$

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

39\. $100\ \cancel{\text{yds}} \left[\frac{3\ \cancel{\text{ft}}}{1\ \cancel{\text{yd}}}\right]\left[\frac{12\text{ in.}}{1\ \cancel{\text{ft}}}\right] = 3600\text{ in} \Rightarrow \mathbf{3600\ quarters}$

40\. 60 mph: $t = \frac{d}{\upsilon} = \frac{500\text{ mi}}{60\text{ mph}} = 8.33\text{ h} = \mathbf{8\ h: 19.8\ min}$

70 mph: $t = \frac{d}{\upsilon} = \frac{500\text{ mi}}{70\text{ mph}} = 7.14\text{ h} = \mathbf{7\ h: 8.4\ min}$

difference = **1 h: 11.4 min**

41\. $d = \upsilon t = \left[500\frac{\cancel{\text{cm}}}{\cancel{\text{s}}}\right][0.016\ \cancel{\text{h}}]\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right]\left[\frac{1\text{ m}}{100\ \cancel{\text{cm}}}\right] = \mathbf{345.6\ m}$

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

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

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

$\frac{\text{min}}{\text{mile}} = \frac{10.22\ \text{min}}{0.228\ \text{miles}} = 44.82\ \text{min/mile}$

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

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

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

b. $24\ \cancel{\text{ounces}}\left[\frac{1\ \cancel{\text{gallon}}}{128\ \cancel{\text{ounces}}}\right]\left[\frac{1\ \text{m}^3}{264.172\ \cancel{\text{gallons}}}\right] = 7.1 \times 10^{-4}\ \text{m}^3$

c. $1.4\ \cancel{\text{days}}\left[\frac{86{,}400\ \text{s}}{1\ \cancel{\text{day}}}\right] = 1.21 \times 10^5\ \text{s}$

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

46. $6(4 \times 2 + 8) = 96$

47. $(42 + 6/5)/3 = 14.4$

48. $\sqrt{5^2 + \left(\frac{2}{3}\right)^2} = 5.044$

49. MODE = DEGREES: $\cos 21.87° = 0.928$

50. MODE = DEGREES: $\tan^{-1}(3/4) = 36.87°$

51. $\sqrt{\ }\left(400/(6^2 + 10/5)\right) = 7.071$

52. 205×10^{-6}

53. 1.20×10^{12}

54. $6.667 \times 10^6 + 0.5 \times 10^6 = 7.17 \times 10^6$

Chapter 2

1. –

2. a. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\,\text{C})(2\,\text{C})}{(1\,\text{m})^2} = \mathbf{18\times10^9\ N}$

   b. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\,\text{C})(2\,\text{C})}{(3\,\text{m})^2} = \mathbf{2\times10^9\ N}$

   c. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\,\text{C})(2\,\text{C})}{(10\,\text{m})^2} = \mathbf{0.18\times10^9\ N}$

   d. Exponentially, $\dfrac{r_3}{r_1} = \dfrac{10\,\text{m}}{1\,\text{m}} = 10$ while $\dfrac{F_1}{F_2} = \dfrac{18\times10^9\,\text{N}}{0.18\times10^9\,\text{N}} = 100$

3. a. $r = 1$ ft:

   $$1\,\cancel{\text{ft}}\left[\frac{12\,\cancel{\text{in}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\,\text{m}}{39.37\,\cancel{\text{in}}}\right] = 0.305\ \text{m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{(9\times10^9)(8\times10^{-6}\,\text{C})(40\times10^{-6}\,\text{C})}{(0.305\,\text{m})^2} = \frac{2880\times10^{-3}}{93\times10^{-3}}$$

   $= \mathbf{30.97\ N}$

   b. $r = 10$ ft:

   $$10\,\cancel{\text{ft}}\left[\frac{12\,\cancel{\text{in}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\,\text{m}}{39.37\,\cancel{\text{in}}}\right] = 3.05\ \text{m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{2880\times10^{-3}}{(3.05\,\text{m})^2} = \frac{2880\times10^{-3}}{9.30} = \mathbf{0.31\ N}$$

   c. $r = 100$ yds:

   $$100\,\cancel{\text{yds}}\left[\frac{3\,\cancel{\text{ft}}}{1\,\cancel{\text{yd}}}\right]\left[\frac{12\,\cancel{\text{in}}}{1\,\cancel{\text{ft}}}\right]\left[\frac{1\,\text{m}}{39.37\,\cancel{\text{in}}}\right] = 91.4\ \text{m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{2880\times10^{-3}}{(91.4\,\text{m})^2} = \frac{2880\times10^{-3}}{8.35\times10^3}$$

   $= \mathbf{345\ \mu N}$

4. –

5. $Q_1 = Q_2 = Q;\ F_1 = \dfrac{kQ^2}{r_1^2} \Rightarrow Q^2 = \dfrac{F_1r_1^2}{k};\ F_2 = \dfrac{kQ^2}{r_2^2} = \dfrac{\cancel{k}}{r_2^2}\left[\dfrac{F_1r_1^2}{\cancel{k}}\right]$ and $F_2 = \dfrac{r_1^2}{r_2^2}F_1$

6. $F = \dfrac{kQ_1Q_2}{r^2} \Rightarrow r = \sqrt{\dfrac{kQ_1Q_2}{F}} = \sqrt{\dfrac{(9\times10^9)(20\times10^{-6})^2}{3.6\times10^4}} = \mathbf{10\ mm}$

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

   $7.2 = kQ_1Q_2 = (9\times10^9)(Q_1)(2Q_1) = 9\times10^9(2Q_1^2)$

   $\dfrac{7.2}{18\times10^9} = Q_1^2 \Rightarrow Q_1 = \sqrt{\dfrac{7.2}{18\times10^9}} = \mathbf{20\ \mu C}$

   $Q_2 = 2Q_1 = 2(2\times10^{-5}\,\text{C}) = \mathbf{40\ \mu C}$

8. $V = \dfrac{W}{Q} = \dfrac{1.2\,\text{J}}{20\,\text{mC}} = \mathbf{120\ V}$

9. $W = VQ = (60\,\text{V})(8\,\text{mC}) = \mathbf{0.48\ J}$

10. $Q = \dfrac{W}{V} = \dfrac{200\,\mu\text{J}}{20\,\text{mV}} = 10\ \text{mC}$

11. $Q = \dfrac{W}{V} = \dfrac{620\,\text{mJ}}{9\,\text{V}} = \mathbf{68.9\ mC}$

12. a. $W = QV = (1\times10^{12}\ \text{electrons})(40\,\text{V}) = \mathbf{40\times10^{12}\ eV}$

    b. $40\times10^{12}\,\cancel{\text{eV}}\left[\dfrac{1\,\text{C}}{6.242\times10^{18}\ \cancel{\text{electrons}}}\right] = \mathbf{6.41\ \mu J}$

13. $I = \dfrac{Q}{t} = \dfrac{96\,\text{mC}}{8.4\,\text{s}} = \mathbf{11.43\ mA}$

14. $I = \dfrac{Q}{t} = \dfrac{312\,\text{C}}{(2)(60\,\text{s})} = \mathbf{2.60\ A}$

15. $Q = It = (40\,\text{mA})(1.2)(60\,\text{s}) = \mathbf{2.88\ C}$

16. $Q = It = (250\,\text{mA})(1.2)(60\,\text{s}) = \mathbf{18.0\ C}$

17. $t = \dfrac{Q}{I} = \dfrac{6\,\text{mC}}{2\,\text{mA}} = 3\ \text{s}$

18. $21.847 \times 10^{18}\ \cancel{\text{electrons}} \left[\dfrac{1\text{C}}{6.242\times10^{18}\ \cancel{\text{electrons}}}\right] = 3.5\text{ C}$

$I = \dfrac{Q}{t} = \dfrac{3.5\text{C}}{12\text{s}} = 0.29\text{ A}$

19. $5\text{ min} = (5)(60\text{ s}) = 300\text{ s}$

$Q = It = (4\text{ mA})(300\text{ s}) = 1.2\text{ C}$

$1.2\ \cancel{\text{C}} \left[\dfrac{6.242\times10^{18}\text{ electrons}}{1\cancel{\text{C}}}\right] = 7.49 \times 10^{18}\text{ electrons}$

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

21. $0.84 \times 10^{16}\ \cancel{\text{electrons}} \left[\dfrac{1\text{C}}{6.242\times10^{18}\ \cancel{\text{electrons}}}\right] = 1.346\text{ mC}$

$I = \dfrac{Q}{t} = \dfrac{1.346\text{ mC}}{60\text{ ms}} = 22.43\text{ mA}$

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

$2 \times 10^{-11}\ \cancel{\text{C}} \left[\dfrac{6.242\times10^{18}\ \cancel{\text{electrons}}}{1\cancel{\text{C}}}\right]\left[\dfrac{1\ ¢}{\cancel{\text{electron}}}\right]$

$= 1.25 \times 10^{8}\ ¢ = \$1.25 \times 10^{6} = 1.25\text{ million}$

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

$1.5 \times 10^{-13}\ \cancel{\text{C}} \left[\dfrac{6.242\times10^{18}\ \cancel{\text{electrons}}}{1\cancel{\text{C}}}\right]\left[\dfrac{\$1}{\cancel{\text{electron}}}\right] = 0.94\text{ million}$

(a) > (b)

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

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

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

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

25. $Q = \dfrac{W}{V} = \dfrac{0.4\text{ J}}{12\text{ V}} = 33.33\text{ mC}$

$I = \dfrac{Q}{t} = \dfrac{33.33\text{ mC}}{5 \times 10^{-3}\text{ s}} = 6.67\text{ A}$

26. $I = \dfrac{\text{Ah rating}}{t\text{(hours)}} = \dfrac{180\text{ Ah}}{40\text{ h}} = 4.5\text{ A}$

27. $\text{Ah} = (0.8\text{ A})(75\text{ h}) = 60.0\text{ Ah}$

28. $t\text{(hours)} = \dfrac{\text{Ah rating}}{I} = \dfrac{80\text{ Ah}}{1.28\text{ A}} = 62.5\text{ h}$

29. 40 Ah(for 1 h): $W_1 = VQ = V{\cdot}I{\cdot}t = (12\text{ V})(40\text{ A})(1\ \cancel{\text{h}})\left[\dfrac{60\ \cancel{\text{min}}}{1\cancel{\text{h}}}\right]\left[\dfrac{60\text{ s}}{1\cancel{\text{min}}}\right] = 1.728 \times 10^{6}\text{ J}$

60 Ah(for 1 h): $W_2 = (12\text{ V})(60\text{ A})(1\cancel{\text{h}})\left[\dfrac{60\ \cancel{\text{min}}}{1\cancel{\text{h}}}\right]\left[\dfrac{60\text{ s}}{1\cancel{\text{min}}}\right] = 2.592 \times 10^{6}\text{ J}$

Ratio $W_2/W_1 = 1.5$ or 50% more energy available with 60 Ah rating.

For 60 s discharge: $40\text{ Ah} = It = I[60\cancel{\text{s}}]\left[\dfrac{1\cancel{\text{min}}}{60\cancel{\text{s}}}\right]\left[\dfrac{1\text{h}}{60\ \cancel{\text{min}}}\right] = I(16.67 \times 10^{-3}\text{ h})$

and $I = \dfrac{40\text{ Ah}}{16.67\times10^{-3}\text{ h}} = 2400\text{ A}$

$60\text{ Ah} = It = I[60\cancel{\text{s}}]\left[\dfrac{1\cancel{\text{min}}}{60\cancel{\text{s}}}\right]\left[\dfrac{1\text{h}}{60\ \cancel{\text{min}}}\right] = I(16.67 \times 10^{-3}\text{ h})$

and $I = \dfrac{60\text{ Ah}}{16.67\times10^{-3}\text{ h}} = 3600\text{ A}$

$I_2/I_1 = 1.5$ or 50 % more starting current available at 60 Ah

30. $0.75(18\text{ Ah}) = 13.5\text{ Ah} \Rightarrow \cong 250\text{ mA}$

31. $(18\text{ Ah} - 15.5\text{ Ah})/18\text{ Ah} \times 100\% = 13.89\%$

32. At 100 mA, discharge time ≅ 120 H; At 25 mA, discharge time ≅ 425 h;
≅ **300 h more at 25 mA**

33. $I = \dfrac{3\text{ Ah}}{6.0\text{ h}} = 500\text{ mA}$

$Q = It = (500\text{ mA})(6\cancel{\text{h}})\left[\dfrac{60\ \cancel{\text{min}}}{1\cancel{\text{h}}}\right]\left[\dfrac{60\text{ s}}{1\cancel{\text{min}}}\right] = 10.80\text{ kC}$

$W = QV = (10.8\text{ kC})(12\text{ V}) \cong 129.6\text{ kJ}$

34. –

35. –

36. –

37. a. $0.5\ \cancel{\text{in}}\left[\dfrac{2.54\ \text{cm}}{1\ \cancel{\text{in}}}\right] = 1.27\ \text{cm}$

$1.27\ \cancel{\text{cm}}\left[\dfrac{30\ \text{kV}}{\cancel{\text{cm}}}\right] = \mathbf{38.1\ kV}$

b. $1.27\ \text{cm}\left[\dfrac{270\ \text{kV}}{\text{cm}}\right] = \mathbf{342.9\ kV}$

c. $342.9\ \text{kV}:38.1\ \text{kV} = \mathbf{9:1}$

38. –

39. –

40. –

41. –

BP-2

Chapter 3

1. a. $0.2\ \text{in.} = \mathbf{200\ mils}$

b. $\dfrac{1}{32}\ \text{in.} = 0.03152\ \text{in.} = \mathbf{31.52\ mils}$

c. $\dfrac{1}{4}\ \text{in.} = 0.25\ \cancel{\text{in.}}\left[\dfrac{1000\ \text{mils}}{1\ \cancel{\text{in.}}}\right] = \mathbf{250\ mils}$

d. $10\ \text{mm} = 10 \times 10^{-3}\ \cancel{\text{m}}\left[\dfrac{39.37\ \text{in}}{1\ \cancel{\text{m}}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \text{in}}\right] = \mathbf{393.7\ mils}$

e. $0.01\ \cancel{\text{ft}}\left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{10^3\ \text{mils}}{1\ \cancel{\text{in.}}}\right] = \mathbf{120\ mils}$

f. $1\ \cancel{\text{m}}\left[\dfrac{39.37\ \text{in.}}{1\ \cancel{\text{m}}}\right] = 39.37\ \text{in.} = \mathbf{39.37 \times 10^3\ mils}$

2. a. $A_{CM} = (30\ \text{mils})^2 = \mathbf{900\ CM}$

b. $0.08\ \text{in.} = 80\ \text{mils},\ A_{CM} = (80\ \text{mils})^2 = \mathbf{6.4 \times 10^3\ CM}$

c. $\left[\dfrac{1''}{16}\right] = 0.0625\ \text{in.} = 62.5\ \text{mils},\ A_{CM} = (62.5\ \text{mils})^2 = \mathbf{3.91 \times 10^3\ CM}$

d. $2\ \cancel{\text{cm}}\left[\dfrac{1\ \cancel{\text{in.}}}{2.54\ \cancel{\text{cm}}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \cancel{\text{in.}}}\right] = 787.4\ \text{mils},\ A_{CM} = (787.4\ \text{mils})^2 = \mathbf{620 \times 10^3\ CM}$

e. $0.02\ \cancel{\text{ft}}\left[\dfrac{12\ \cancel{\text{in.}}}{1\ \cancel{\text{ft}}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \cancel{\text{in.}}}\right] = 240\ \text{mils},\ A_{CM} = (240\ \text{mils})^2 = \mathbf{57.60 \times 10^3\ CM}$

f. $4 \times 10^{-3}\ \cancel{\text{m}}\left[\dfrac{39.37\ \cancel{\text{in.}}}{1\ \cancel{\text{m}}}\right]\left[\dfrac{1000\ \text{mils}}{1\ \cancel{\text{in}}}\right] = \mathbf{157.48\ mils},\ A_{CM} = (157.48\ \text{mils})^2 = \mathbf{24.8 \times 10^3\ CM}$

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. $d = \sqrt{640\ \text{CM}} = 25.3\ \text{mils} = \mathbf{25.3 \times 10^{-3}\ in.}$

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

d. $d = \sqrt{2400\text{ CM}} = 48.99\text{ mils} = \mathbf{48.99 \times 10^{-3}\text{ in.}}$

e. $d = \sqrt{6.25\text{ CM}} = 2.5\text{ mils} = \mathbf{0.0025\text{ in.}}$

f. $d = \sqrt{4 \times 10^3\text{ CM}} = 63.25\text{ mils} = \mathbf{63.25 \times 10^{-3}\text{ in.}}$

4. $0.016'' = 16\text{ mils}, A_{CM} = (16\text{ mils})^2 = 256\text{ CM}$

$R = \rho\frac{l}{A} = (10.37)\frac{(200')}{256\text{ CM}} = \mathbf{8.10\ \Omega}$

5. a. $A = \rho\frac{l}{R} = 17\left(\frac{80'}{2.5\ \Omega}\right) = \mathbf{544\text{ CM}}$

b. $d = \sqrt{A_{CM}} = \sqrt{544\text{ CM}} = 23.32\text{ mils} = \mathbf{23.3 \times 10^{-3}\text{ in.}}$

6. $\frac{1}{32}'' = 0.03125'' = 31.25\text{ mils}, A_{CM} = (31.25\text{ mils})^2 = 976.56\text{ CM}$

$R = \rho\frac{l}{A} \Rightarrow l = \frac{RA}{\Omega} = \frac{(2.2\ \Omega)(976.56\text{ CM})}{600} = \mathbf{3.58\text{ ft}}$

7. a. $A_{CM} = \rho\frac{l}{A} = \frac{(10.37)(300')}{3.3\ \Omega} = \mathbf{942.73\text{ CM}}$

$d = \sqrt{942.73\text{ CM}} = 30.70\text{ mils} = \mathbf{30.7 \times 10^{-3}\text{ in.}}$

b. larger

c. smaller

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

9. a. $1/32'' = 0.03125'' = 31.25\text{ mils}, A_{CM} = (31.25\text{ mils})^2 = 976.56\text{ CM}$

$R = \frac{\rho l}{A} \Rightarrow l = \frac{RA}{\rho} = \frac{(3.14\ \Omega)(976.56\text{ CM})}{10.37} = \mathbf{295.7\text{ ft}}$

b. $\frac{295.7'}{x} = \frac{1000'}{5\text{ lb}} \Rightarrow x = \frac{(5)(295.7)}{1000} = \mathbf{1.48\text{ lbs}}$

c. $-40°\text{ C}: F = \frac{9}{5}C + 32° = \frac{9}{5}(-40) + 32 = -40°$

$105°\text{ C}: F = \frac{9}{5}C = 32° = \frac{9}{5}(105) + 32 = 221°$

$\mathbf{F° = -40° \rightarrow 221°}$

10. a. $\frac{3}{8}'' = 0.375'' = 375\text{ mils}$

$4.8'' = 4800\text{ mils}$

$A = (375\text{ mils})(4800\text{ mils}) = 1.8 \times 10^6\text{ sq.}\cancel{\text{mils}}\left[\frac{4/\pi\text{ CM}}{1\text{ sq.}\cancel{\text{mil}}}\right] = \mathbf{2.29 \times 10^6\text{ CM}}$

b. $\frac{1}{12}'' = 0.083\text{ in.} = 83\text{ mils}$

$A_{CM} = = (83\text{ mils})^2 = 6.89 \times 10^3\text{ CM}$

$(\#12)\frac{2.29 \times 10^6\text{ CM}}{6.89 \times 10^3\text{ CM}} = \mathbf{332.37\text{ wires}}$

11. a. $3'' = 3000\text{ mils}, 1/2'' = 0.5\text{ in.} = 500\text{ mils}$

Area $= (3 \times 10^3\text{ mils})(5 \times 10^2\text{ mils}) = 15 \times 10^5\text{ sq. mils}$

$15 \times 10^5\text{ sq }\cancel{\text{mils}}\left[\frac{4/\pi\text{ CM}}{1\text{ sq }\cancel{\text{mil}}}\right] = 19.108 \times 10^5\text{ CM}$

$R = \rho\frac{l}{A} = \frac{(10.37)(4')}{19.108 \times 10^5\text{ CM}} = \mathbf{21.71\ \mu\Omega}$

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

Aluminum bus-bar has almost 64% higher resistance.

c. —

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

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

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

$\Delta R = 1.6\ - 0.2\ = 1.4$

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

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

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

$\frac{R_1}{R_2} = \frac{\rho_1\frac{l_1}{A_1}}{\rho_2\frac{l_2}{A_2}} = \frac{\rho_1 l_1 A_2}{\rho_2 l_2 A_1} = \frac{l_1 A_2}{l_2 A_1} \quad (\rho_1 = \rho_2)$

and $R_2 = \frac{R_1 l_2 A_1}{l_1 A_2} = \frac{(800\text{ m}\Omega)(300\text{ ft})(40{,}000\text{ CM})}{(200\text{ ft})(50{,}940.49\text{ CM})} = \mathbf{942.28\text{ m}\Omega}$

14. a. $\#12 = 6{,}529.9\ \text{CM},\ \#14 = 4{,}106.8\ \text{CM}$

$$\frac{6{,}529.9\ \text{CM} - 4{,}106.8\ \text{CM}}{4{,}106.8\ \text{CM}} \times 100\% = \mathbf{59\%\ larger}$$

b. $\frac{\#12}{\#14} = \frac{20\ \text{A}}{15\ \text{A}} = 1.33,\ \frac{\#12}{\#14} = \frac{6{,}529.9\ \text{CM}}{4{,}106.8\ \text{CM}} = 1.59$

I_{max} ratio = 1.33 vs Area ratio = 1.59

$$\frac{1.59 - 1.33}{1.33} \times 100\% = \mathbf{19.55\%\ higher\ ratio\ for\ area}$$

15. a. $\frac{\#9}{\#12} = \frac{13{,}094\ \text{CM}}{6{,}529.9\ \text{CM}} = 2$ yes

b. $\frac{\#0}{\#12} = \frac{105{,}530\ \text{CM}}{6{,}529.9\ \text{CM}} = 16.16$ yes

$\frac{\#0}{\#12} = \frac{150\ \text{A}}{20\ \text{A}} = 7.5$

16. a. $\frac{\#10}{\#20} = \frac{10{,}381\ \text{CM}}{1{,}021.5\ \text{CM}} = 10.16 \cong 10$ yes

b. $\frac{\#20}{\#40} = \frac{1{,}021.5\ \text{CM}}{9.89\ \text{CM}} = 103.28$

yes $\cong 100$

17. a. $A = \rho\frac{l}{R} = \frac{(10.37)(30')}{6\ \text{m}\Omega} = \frac{311.1\ \text{CM}}{6\times10^{-3}} = 51{,}850\ \text{CM} \Rightarrow \#3$

but 110 A $\Rightarrow$ #2

b. $A = \rho\frac{l}{R} = \frac{(10.37)(30')}{3\ \text{m}\Omega} = \frac{311.1\ \text{CM}}{3\times10^{-3}} = 103{,}700\ \text{CM} \Rightarrow \#0$

18. a. A/CM = 230 A/211,600 CM = **1.09 mA/CM**

b. $\frac{1.09\ \text{mA}}{\cancel{\text{CM}}}\left[\frac{1\ \cancel{\text{CM}}}{\frac{\pi}{4}\ \text{sq mils}}\right]\left[\frac{1000\ \cancel{\text{mils}}}{1\ \text{in.}}\right]\left[\frac{1000\ \cancel{\text{mils}}}{1\ \text{in.}}\right] = 1.39\ \text{kA/in.}^2$

c. $5\ \cancel{\text{kA}}\left[\frac{1\ \text{in.}^2}{1.39\ \cancel{\text{kA}}}\right] = 3.6\ \text{in.}^2$

19. $\frac{234.5 + 20}{2\ \Omega} = \frac{234.5 + 100}{R_2},\quad R_2 = \frac{(334.5)(2\ \Omega)}{254.5} = \mathbf{2.63\ \Omega}$

20. $\frac{236 + 0}{0.02\ \Omega} = \frac{236 + 100}{R_2}$

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

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

$C = \frac{5}{9}(68 - 32) = 20°\ (=68°F)$

$\frac{234.5° + 20°}{1.2\ \Omega} = \frac{234.5° + 0°}{R_2}$

$R_2 = \frac{(234.5)(1.2\ \Omega)}{254.5} = \mathbf{1.11\ \Omega}$

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

$°C = \frac{5}{9}(60° - 32°) = 15.56°$

$\frac{234.5 + 21.11}{0.025\ \Omega} = \frac{234.5 + 15.56}{R_2}$

$R_2 = \frac{(250.06)(0.025\ \Omega)}{255.61} = \mathbf{24.46\ m\Omega}$

b. $°C = \frac{5}{9}(50° - 32°) = 10°$

$\frac{234.5 + 21.11}{0.025\ \Omega} = \frac{234.5 + 10}{R_2}$

$R_2 = \frac{(244.5)(0.025\ \Omega)}{255.61} = \mathbf{23.91\ m\Omega}$

c. Part a: 25 mΩ − 24.46 mΩ = 0.54 mΩ
Part b: 24.45 mΩ − 23.91 mΩ = 0.55 mΩ
Linear 40°F ⇒ 23.91 mΩ − 0.55 mΩ = 23.36 mΩ

d. $°C = \frac{5}{9}(-30° - 32°) = -34.44°$

$\frac{234.5 + 21.11}{25\ \text{m}\Omega} = \frac{234.5 - 34.44}{R_2}$

$R_2 = \frac{(25\ \text{m}\Omega)(200.06)}{255.61} = \mathbf{19.57\ m\Omega}$

Yes, 25 mΩ − 19.57 mΩ = 5.43 mΩ

e. $°C = \frac{5}{9}(120° - 32°) = 48.89°$

$$\frac{234.5 + 21.11}{25\ m\Omega} = \frac{234.5 + 48.89}{R_2}$$

$$R_2 = \frac{(25\ m\Omega)(283.39)}{255.61} = \mathbf{27.72\ m\Omega}$$

Yes, 2.72 mΩ

23. a. $\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + t_2}{1.1\ \Omega}$, $t_2 = \mathbf{45.45°}$

b. $\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + t_2}{0.1\ \Omega}$, $t_2 = \mathbf{-209.05°}$

24. a. $68°F = 20°C$

$$\frac{234.5 + 20}{1\ \Omega} = \frac{234.5 + T_2}{2\ \Omega}$$

$$\frac{2(254.5)}{1} - 234.5 = T_2$$

$$T_2 = \mathbf{274.5°C}$$

b. #10 = **0.9989 Ω/1000′**

c. 

$d_{in} = 0.102\ \text{in} \cong \frac{1}{10}''$

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

b. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$
$1\ \Omega = 0.8\ \Omega\ [1 + 0.00393(t - 20°)]$
$1.25 = 1 + 0.00393t - 0.0786$
$1.25 - 0.9214 = 0.00393t$
$0.3286 = 0.00393t$
$t = \frac{0.3286}{0.00393} = \mathbf{83.61°C}$

26. $R = R_{20}[1 + \alpha_{20}(t - 20°C)]$
$= 0.4\ \Omega\ [1 + 0.00393(16 - 20)] = 0.4\ \Omega\ [1 - 0.01572] = \mathbf{0.39\ \Omega}$

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

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

$R = R_{20}[1 + \alpha_{20}(t - 20°C)]$
$= 1.588\ \Omega\ [1 + 0.00393(46.11 - 20)]$
$= \mathbf{1.75\ \Omega}$

28. $\Delta R = \frac{R_{nominal}}{10^6}(PPM)(\Delta T) = \frac{22\ \Omega}{10^6}(200)(65° - 20°) = 0.198\ \Omega$
$R = R_{nominal} + \Delta R = \mathbf{22.198\ \Omega}$

29. $\Delta R = \frac{R_{nominal}}{10^6}(PPM)(\Delta T) = \frac{100\ \Omega}{10^6}(100)(50° - 20°) = 0.30\ \Omega$
$R = R_{nominal} + \Delta R = 100\ \Omega + 0.30\ \Omega = \mathbf{100.30\ \Omega}$

30. a. 2 times larger b. 4 times larger

31. 10 k − 3.5 k = **6.5 kΩ**

32. **6.25 kΩ and 18.75 kΩ**

33. –

34. a. 820 Ω ± 5%, 820 Ω ± 41 Ω, 779 Ω ↔ **861 Ω**
b. 220 Ω ± 10%, 220 Ω ± 22 Ω, **198 Ω ↔ 242 Ω**
c. 91 kΩ ± 20%, 91 kΩ ± 18.2 kΩ, **77.8 kΩ ↔ 109.2 kΩ**
d. 9.1 kΩ ± 5%, 9100 Ω ± 455 Ω, **8,645 Ω ↔ 9,555 kΩ**
e. 3.9 MΩ ± 20%, 3.9 MΩ ± 0.78 MΩ, **3.12 MΩ ↔ 4.68 MΩ**

35. a. 68 Ω = **Blue, Gray, Black, Silver**
b. 0.33 Ω = **Orange, Orange, Silver, Silver**
c. 22 kΩ = **Red, Red, Orange, Silver**
d. 5.6 MΩ = **Green, Blue, Green, Silver**

36. a. $\left.\begin{array}{l} 10\ \Omega \pm 20\% \Rightarrow 8\ \Omega - 12\ \Omega \\ 15\ \Omega \pm 20\% \Rightarrow 12\ \Omega - 18\ \Omega \end{array}\right\}$ no overlap, continuance

b. $\left.\begin{array}{l} 10\ \Omega \pm 10\% \Rightarrow 9\ \Omega - 11\ \Omega \\ 15\ \Omega \pm 10\% \Rightarrow 13.5\ \Omega - 16.5\ \Omega \end{array}\right\}$ no overlap

37. 470 Ω ± 10% = 470 Ω ± 47 Ω
= **423 Ω ↔ 517 Ω**
Yes

38. **No change**

39. a. $621 = 62 \times 10^1\ \Omega = 620\ \Omega = \mathbf{0.62\ k\Omega}$
b. $333 = 33 \times 10^3\ \Omega = \mathbf{33\ k\Omega}$
c. $Q2 = 3.9 \times 10^2\ \Omega = \mathbf{390\ \Omega}$
d. $C6 = 1.2 \times 10^6\ \Omega = \mathbf{1.2\ M\Omega}$

40. a. $G = \dfrac{1}{R} = \dfrac{1}{120\ \Omega} = \mathbf{8.33\ mS}$

b. $G = \dfrac{1}{4\ k\Omega} = \mathbf{0.25\ mS}$

c. $G = \dfrac{1}{2.2\ M\Omega} = \mathbf{0.46\ \mu S}$
$G_a > G_b > G_c$ vs. $R_c > R_b > R_a$

41. a. Table 3.2, $\Omega/1000' = 1.588\ \Omega$
$G = \dfrac{1}{R} = \dfrac{1}{1.588\ \Omega} = \mathbf{629.72\ mS}$

or $G = \dfrac{A}{\rho l} = \dfrac{6529.9\ \text{CM (Table 3.2)}}{(10.37)(1000')} = \mathbf{629.69\ mS\ (Cu)}$

b. $G = \dfrac{6529.9\ \text{CM}}{(17)(1000')} = \mathbf{384.11\ mS\ (Al)}$

42. a. $G_1 = \dfrac{1}{10\ \Omega} = 100\ \text{mS}, G_2 = \dfrac{1}{20\ \Omega} = 50\ \text{mS}, G_3 = \dfrac{1}{100\ \Omega} = 10\ \text{mS}$

b. $G_2{:}G_1 = 50\ \text{mS}: 100\ \text{mS} = 1{:}2$ whereas $R_2{:}R_1 = 20\ \Omega{:}10\ \Omega = 2{:}1$. The rate of change is the same although one is increasing and the other decreasing.

c. inverse – linear

43. $A_2 = 1\frac{2}{3}\ A_1 = \frac{5}{3}\ A_1, l_2 = \left(1 - \frac{2}{3}\right)l_1 = \frac{l_1}{3}, \rho_2 = \rho_1$

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

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

44. –

45. –

46. –

47. –

48. $\dfrac{1}{12}\ \text{in.} = 0.083\ \cancel{\text{in.}}\left(\dfrac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right) = 0.21\ \text{cm}$

$A = \dfrac{\pi d^2}{4} = \dfrac{(3.14)(0.21\ \text{cm})^2}{4} = 0.035\ \text{cm}^2$

$l = \dfrac{RA}{\rho} = \dfrac{(2\ \Omega)(0.035\ \text{cm}^2)}{1.724 \times 10^{-6}} = 40{,}603\ \text{cm} = \mathbf{406.03\ m}$

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

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

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

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

c. increases

d. decreases

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

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

52. a. $d = 1\ \text{in.} = 1000\ \text{mils}$
$A_{CM} = (10^3\ \text{mils})^2 = 10^6\ \text{CM}$
$\rho_1 = \dfrac{RA}{l} = \dfrac{(1\ \text{m}\Omega)(10^6\ \text{CM})}{10^3\ \text{ft}} = \mathbf{1\ CM\text{-}\Omega/ft}$

b. $1\ \text{in.} = 2.54\ \text{cm}$
$A = \dfrac{\pi d^2}{4} = \dfrac{\pi(2.54\ \text{cm})^2}{4} = 5.067\ \text{cm}^2$
$l = 1000\ \text{ft}\left[\dfrac{12\ \text{in.}}{1\ \text{ft}}\right]\left[\dfrac{2.54\ \text{cm}}{1\ \text{in.}}\right] = 30{,}480\ \text{cm}$
$\rho_2 = \dfrac{RA}{l} = \dfrac{(1\ \text{m}\Omega)(5.067\ \text{cm}^2)}{30{,}480\ \text{cm}} = \mathbf{1.66 \times 10^{-7}\ \Omega\text{-cm}}$

c. $k = \frac{\rho_2}{\rho_1} = \frac{1.66\times10^{-7}\ \Omega\text{-cm}}{1\ \text{CM-}\Omega/\text{ft}} = \mathbf{1.66 \times 10^{-7}}$

53. –

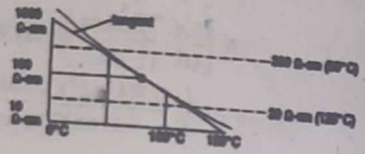
54. –

55. –

56. –

57. –

58. a. −50°C specific resistance ≅ 10^5 Ω-cm
50°C specific resistance ≅ 500 Ω-cm
200°C specific resistance ≅ 7 Ω-cm



b. negative

c. No

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

59. 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
$\left|\frac{\Delta R}{\Delta fc}\right| = \frac{10\ \text{k}\Omega - 1\text{k}}{30\ \text{fc} - 2\ \text{fc}} = 321.43\ \Omega/\text{fc}$
and $\frac{\Delta R}{\Delta \text{fc}}$ **321.43 Ω/fc**

60. a. @ 0.5 mA, V ≅ **195 V**
@ 1 mA, V ≅ **200 V**
@ 5 mA, V ≅ **215 V**

b. ΔV_{total} = 215 V − 195 V = **20 V**

c. 5 mA:0.5 mA = **10:1**
compared to
215 V: 200 V = **1.08:1**

Chapter 4

1. $V = IR = (5.6\ \text{mA})(220\ \Omega) = \mathbf{1.23\ V}$

2. $I = \frac{V}{R} = \frac{24\ \text{V}}{2.2\ \text{k}\Omega} = \mathbf{10.91\ mA}$

3. $R = \frac{V}{I} = \frac{24\ \text{V}}{1.5\ \text{mA}} = \mathbf{16\ k\Omega}$

4. $I = \frac{V}{R} = \frac{12\ \text{V}}{40\times10^{-3}\ \Omega} = \mathbf{300\ A}$

5. $V = IR = (3.6\ \mu\text{A})(100\ \text{k}\Omega) = 0.36\ \text{V} = \mathbf{360\ mV}$

6. $I = \frac{V}{R} = \frac{120\ \text{V}}{50\ \text{k}\Omega} = \mathbf{2.4\ mA}$

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

8. $I = \frac{V}{R} = \frac{120\ \text{V}}{8\ \text{k}\Omega} = \mathbf{15\ mA}$

9. $R = \frac{V}{I} = \frac{120\ \text{V}}{4.2\ \text{A}} = \mathbf{28.57\ \Omega}$

10. $R = \frac{V}{I} = \frac{4.5\ \text{V}}{80\ \text{mA}} = \mathbf{56.25\ \Omega}$

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

12. $V = IR = (12\ \text{A})(0.5\ \Omega) = \mathbf{6\ V}$

13. a. $R = \frac{V}{I} = \frac{120\ \text{V}}{9.5\ \text{A}} = \mathbf{12.63\ \Omega}$

b. $t = 2\cancel{\text{h}}\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\ \text{s}}{1\ \cancel{\text{min}}}\right] = 7200\ \text{s}$

$W = Pt = VIt$
$= (120\ \text{V})(9.5\ \text{A})(7200\ \text{s})$
$= \mathbf{8.21 \times 10^6\ J}$

14. $V = IR = (5.6\ \text{mA})(3.3\ \text{M}\Omega) = \mathbf{18.48\ V}$

15. –

16. –

17. –

18. –

19. –

20. $P = \frac{W}{t} = \frac{540\text{ J}}{3.6\ \cancel{\text{min}}\left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right]} = \frac{540\text{ J}}{216\text{ s}} = \mathbf{2.5\ W}$

21. $t = \frac{W}{P} = \frac{640\text{ J}}{40\text{ J/s}} = \mathbf{16\ s}$

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

$W = Pt = (8\text{ W})(28{,}000\text{ s}) = \mathbf{224\ kJ}$

b. $\text{kWh} = \frac{(8\text{ W})(8\text{ h})}{1000} = \mathbf{64 \times 10^{-3}\ kWh}$

23. $P = VI = (3\text{ V})(1.4\text{ A}) = 4.20\text{ W}$

$t = \frac{W}{P} = \frac{12\text{ J}}{4.2\text{ W}} = \mathbf{2.86\ s}$

24. $P = EI = (12\text{ V})(40\text{ A}) = \mathbf{480\ W}$

25. $P = I^2R = (7.2\text{ mA})^2\ 4\text{ k}\Omega = \mathbf{207.36\ mW}$

26. $P = I^2R \Rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{240\text{ mW}}{2.2\text{ k}\Omega}} = \mathbf{10.44\ mA}$

27. $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{2\text{ W}}{82\ \Omega}} = \mathbf{156.17\ mA}$

$V = IR = (156.17\text{ mA})(82\ \Omega) = \mathbf{12.81\ V}$

28. $I = \frac{E}{R} = \frac{22\text{ V}}{16.8\text{ k}\Omega} = \mathbf{1.31\ mA}$

$P = I^2R = (1.31\text{ mA})^2\ 16.8\text{ k}\Omega = \mathbf{28.83\ mW}$

$W = Pt = (28.83\text{ mW})\left(1\ \cancel{\text{h}}\left[\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right]\left[\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right]\right) = \mathbf{103.79\ J}$

29. $E = \frac{P}{I} = \frac{10\text{ kW}}{48\text{ A}} = \mathbf{208.33\ V}$

30. $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1\text{ W}}{4.7\text{ M}\Omega}} = \mathbf{461.27\ \mu A}$

no

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

32. $P = VI, I = \frac{P}{V} = \frac{100\text{ W}}{120\text{ V}} = 0.833\text{ A}$

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

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

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

34. a. $P = EI$ and $I = \frac{P}{E} = \frac{0.4\times10^{-3}\text{ W}}{3\text{ V}} = \mathbf{0.13\ mA}$

b. Ah rating $= (0.13\text{ mA})(500\text{ h}) = \mathbf{66.5\ mAh}$

35. $I = \sqrt{\frac{P}{R}} = \sqrt{\frac{100\text{ W}}{20\text{ k}\Omega}} = \sqrt{5\times10^{-3}} = \mathbf{70.71\ mA}$

$V = \sqrt{PR} = \sqrt{(100\text{ W})(20\text{ k}\Omega)} = \mathbf{1.42\ kV}$

36. $P = EI = (240\text{ V})(30\text{ A}) = 7.2\text{ kW}$

$P_{HP} = \frac{7.2\text{ kW}}{746\text{ W/HP}} = \mathbf{9.65\ hP}$

37. a. $W = Pt = \left(\frac{V^2}{R}\right)t = \left(\frac{12\text{ V}}{10\ \Omega}\right)^2 60\text{ s} = \mathbf{86.4\ J}$

b. Energy doubles, power the same

38. $W = Pt \Rightarrow t = \frac{W}{P} = \frac{12\times10^3\ \cancel{\text{W}}\text{h}}{1500\ \cancel{\text{W}}} = \mathbf{8\ h}$

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

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

40. a. $W = Pt = (60\text{ W})(10\cancel{\text{h}})\left(\dfrac{60\ \cancel{\text{min}}}{1\cancel{\text{h}}}\right)\left(\dfrac{60\text{ s}}{1\ \cancel{\text{min}}}\right) = \mathbf{2.16 \times 10^6\ Ws}$

b. $1\text{ Ws} = 1\text{ J} \therefore \mathbf{2.16 \times 10^6\ J}$

c. $W = Pt = (60\text{ W})(10\text{ h}) = \mathbf{600\ Wh}$

d. $\dfrac{600\text{ Wh}}{1000\text{ W/1 kWh}} = \mathbf{0.6\ kWh}$

e. $\text{Cost} = (0.6\text{ kWh})(12\text{ ¢/kWh}) = \mathbf{7.2\ ¢}$

41. a. $\text{kWh} = \dfrac{Pt}{1000} \Rightarrow P = \dfrac{(1000)(\text{kWh})}{P} = \dfrac{(1000)(1200\text{ kWh})}{10\text{ h}} = \mathbf{120\ kW}$

b. $I = \dfrac{P}{E} = \dfrac{120 \times 10^3\text{ Wh}}{240\text{ V}} = \mathbf{500\ A}$

c. $P_{lost} = P_i - P_o = P_i - \eta P_i = P_i(1-\eta) = 120\text{ kW}(1-0.76) = 28.8\text{ kW}$

$\text{kWh}_{lost} = \dfrac{Pt}{1000} = \dfrac{(28.8\text{ kW})(10\text{ h})}{1000} = \mathbf{288\ kWh}$

42. $\#\text{kWh} = \dfrac{\$1.00}{12¢} = 8.33$

$\text{kWh} = \dfrac{Pt}{1000} \Rightarrow t = \dfrac{(\text{kWh})(1000)}{P} = \dfrac{(8.33)(1000)}{250\text{ W}} = \mathbf{33.32\ h}$

43. a. $\dfrac{\$120}{30\text{ days}} = \mathbf{\$4/day}$

b. $\dfrac{\$4\ /\ \text{day}}{15\text{ h/day}} = \mathbf{26.7¢/h}$

c. $\dfrac{26.7¢/\text{h}}{12¢/\text{kWh}} = \mathbf{2.23\ kW}$

d. $\dfrac{2.23\text{ kW}}{60\text{ W}} = 37.17 \cong \mathbf{37\ bulbs}$

e. no

44. $\dfrac{\$1.00}{12¢/\text{kWh}} = 8.33\text{ kWh}$

$\dfrac{8.33\text{ kWh}}{187\text{ W}} = \mathbf{44.55\ h}$

45. $t = 5\text{ h/day}(365\text{ days}) = 1825\text{ h}$

$\text{kWh} = \dfrac{P \cdot t}{1000} = \dfrac{(339\text{ W})(1825\text{ h})}{1000} = 618.68\text{ kWh}$

$\text{Cost} = (618.68\text{ kWh})(12¢/\text{kWh}) = \$74.24$

$\text{kWh} = \dfrac{P \cdot t}{1000} = \dfrac{(213\text{ W})(1825\text{ h})}{1000} = 388.73\text{ kWh}$

$\text{Cost} = (388.73\text{ kWh})(12¢/\text{kWh}) = \$46.65$

$\text{Cost Savings} = \$74.24 - \$46.65 = \$27.59$

46. $\text{kWh} = \dfrac{P \cdot t}{1000} = \dfrac{(78\text{ W})(4\text{ h/day})(31\text{ days})}{1000} = 9.67\text{ kWh}$

$\text{Cost} = (12¢/\text{kWh})(9.67\text{ kWh}) = \$1.16$

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

b. $P_T = 2(250\text{ W}) + 3000\text{ W} + (10)(60\text{W}) + 2400\text{ W} + 2\text{ kW} + 1000\text{ W} = 9.5\text{ kW}$

Yes, 12 kW > 9.5 kW

c. $W = Pt = (9.5\text{ kW})(2\text{ h}) = 19\text{ kWh}$

48. $\text{kWh} = \dfrac{(1600\text{ W})(8\text{ h}) + (1200\text{ W})(1/3\text{ h}) + (4800\text{ W})(1\text{ h}) + (900\text{ W})(1/4\text{ h}) + (200\text{ W})(1.2\text{ h}) + (50\text{ W})(3.5\text{ h})}{1000}$

$= \dfrac{12{,}800\text{ Wh} + 400\text{ Wh} + 4800\text{ Wh} + 225\text{ Wh} + 240\text{ Wh} + 175\text{ Wh}}{1000} = 18.64\text{ kWh}$

$(18.64\text{ kWh})(12¢/\text{kWh}) = \$2.24$

49. $\text{kWh} = \dfrac{(200\text{W})(4\text{ h}) + (6)(60\text{ W})(6\text{ h}) + (1200\text{ W})(0.5\text{ h}) + (175\text{ W})(3.5\text{ h}) + (250\text{ W})\left(4\frac{1}{3}\text{ h}\right) + (30\text{ W})(8\text{ h})}{1000}$

$= \dfrac{800\text{ Wh} + 2160\text{ Wh} + 600\text{ Wh} + 612.5\text{ Wh} + 1083.32\text{ Wh} + 240\text{ Wh}}{1000} = 5.496\text{ kWh}$

$(5.496\text{ kWh})(12¢/\text{kWh}) = 65.95¢$

50. $\eta = \dfrac{P_o}{P_i} \times 100\% = \dfrac{(0.5\ \cancel{\text{hp}})\left[\dfrac{746\text{ W}}{\cancel{\text{hp}}}\right]}{410\text{ W}} \times 100\% = \dfrac{373}{410} \times 100\% = 90.98\%$

51. $\eta = \dfrac{P_o}{P_i},\ P_i = \dfrac{P_o}{\eta} = \dfrac{(1.8\ \cancel{\text{hp}})(746\text{ W}/\cancel{\text{hp}})}{0.72} = 1865\text{ W}$

$P_i = EI,\ I = \dfrac{P_i}{E} = \dfrac{1865\text{ W}}{120\text{ V}} = 15.54\text{ A}$

52. $\eta = \dfrac{P_o}{P_i} \times 100\% = \dfrac{(0.81\text{ hp})(746\text{ W/hp})}{(4\text{ A})(220\text{V})} \times 100\% = \dfrac{686.65}{880} \times 100\% = 78.03\%$

53. a. $P_i = EI = (120\ \text{V})(1.8\ \text{A}) = 216\ \text{W}$

$P_i = P_o + P_{lost}$, $P_{lost} = P_i - P_o = 216\ \text{W} - 50\ \text{W} = \mathbf{166\ W}$

b. $\eta\% = \frac{P_o}{P_i} \times 100\% = \frac{50\ \text{W}}{216\ \text{W}} \times 100\% = \mathbf{23.15\%}$

54. $P_i = EI = \frac{P_o}{\eta} \Rightarrow I = \frac{P_o}{\eta E} = \frac{(3.6\ \cancel{\text{hp}})(746\ \text{W}/\cancel{\text{hp}})}{(0.76)(240\ \text{V})} = \mathbf{14.72\ A}$

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

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

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

$I = \frac{1657.78\ \text{W}}{120\ \text{V}} = \mathbf{13.81\ A}$

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

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

$(120\ \text{V})I = 2131.43\ \text{W}$

$I = \frac{2131.43\ \text{W}}{120\ \text{V}} = \mathbf{17.76\ A}$

56. $P_i = \frac{P_o}{\eta} = \frac{(15\ \cancel{\text{hp}})(746\ \text{W}/\cancel{\text{hp}})}{(0.84)} = 13{,}321\ \text{W}$

$I = \frac{P_i}{E} = \frac{13{,}321\ \text{W}}{240\ \text{V}} = \mathbf{55.5\ A}$

57. $\eta_T = \eta_1 \cdot \eta_2$

$0.75 = 0.85 \times \eta_2$

$\eta_2 = 0.88$, $\eta_2 = \mathbf{88\%}$

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

59. $\eta_T = \eta_1 \cdot \eta_2 = 0.78 = 0.9\eta_2$

$\eta_2 = \frac{0.78}{0.9} = 0.867 \Rightarrow \mathbf{86.7\%}$

Chapter 5

1. a. E and R_1
   b. R_1 and R_2
   c. E_1, E_2, and R_1
   d. E and R_1; R_3, R_4, and R_5

2. a. E_1 and R_1; E_2, R_3, and R_4
   b. E_1 and R_1; R_5 and R_6
   c. R_2 and R_3
   d. E_1 and R_1

3. a. $R_T = 0.1\text{ k}\Omega + 0.39\text{ k}\Omega + 1.2\text{ k}\Omega + 6.8\text{ k}\Omega = \mathbf{8.49\text{ k}\Omega}$
   b. $R_T = 1.2\ \Omega + 2.7\ \Omega + 8.2\ \Omega = \mathbf{12.1\ \Omega}$
   c. $R_T = 1.2\ \Omega + 2.2\ \Omega + 3.3\ \Omega + 4.7\ \Omega = \mathbf{11.4\ \Omega}$

4. a. $R_T = 8.2\text{ k}\Omega + 10\text{ k}\Omega + 9.1\text{ k}\Omega + 1.8\text{ k}\Omega + 2.7\text{ k}\Omega = \mathbf{31.8\text{ k}\Omega}$
   b. $R_T = 47\ \Omega + 820\ \Omega + 91\ \Omega + 1.2\text{ k}\Omega = \mathbf{2158.0\ \Omega}$
   c. $R_T = 3.3\ \Omega + 10\text{ k}\Omega = \mathbf{13.3\text{ k}\Omega}$

5. a. $R_T = 1.2\text{ k}\Omega + 1\text{ k}\Omega + 2.2\text{ k}\Omega + 3.3\text{ k}\Omega = \mathbf{7.7\text{ k}\Omega}$
   b. $R_T = 1\text{ k}\Omega + 2\text{ k}\Omega + 3\text{ k}\Omega + 4.7\text{ k}\Omega + 6.8\text{ k}\Omega = \mathbf{17.5\text{ k}\Omega}$

6. a. **1 MΩ**
   b. **100 Ω, 1 kΩ**
   c. $R_T = 100\ \Omega + 1\text{ k}\Omega + 1\text{ M}\Omega + 200\text{ k}\Omega = \mathbf{1.2011\text{ M}\Omega}$ vs. **1.2 MΩ** for part b.

7. a. Reading $= 10\ \Omega + 33\ \Omega + 56\ \Omega + 68\ \Omega = \mathbf{167\ \Omega}$
   b. Reading $= 0.82\text{ k}\Omega + 1.2\text{ k}\Omega + 3.3\text{ k}\Omega = \mathbf{5.32\text{ k}\Omega}$

8. a. $R_T = 129\text{ k}\Omega = R + 56\text{ k}\Omega + 22\text{ k}\Omega + 33\text{ k}\Omega$, Reading $= \mathbf{18\text{ k}\Omega}$
   b. $R_T = 103\text{ k}\Omega = 24\text{ k}\Omega + R_1 + 43\text{ k}\Omega + 2R_1 = 67\text{ k}\Omega + 3R_1$, $R_1 = \mathbf{12\text{ k}\Omega}$
   $R_2 = \mathbf{24\text{ k}\Omega}$

9. a. $1.2\text{ k}\Omega + 2.2\text{ k}\Omega = \mathbf{3.4\text{ k}\Omega}$
   b. **0 Ω**
   c. **∞ Ω**

10. a. $R_T = 10\ \Omega + 12\ \Omega + 18\ \Omega = \mathbf{40\ \Omega}$
    b. $I_s = \dfrac{E}{R_T} = \dfrac{72\text{ V}}{40\ \Omega} = \mathbf{1.8\text{ A}}$
    c. $V_1 = I_1R_1 = (1.8\text{ A})(10\ \Omega) = \mathbf{18\text{ V}}$, $V_2 = I_2R_2 = (1.8\text{ A})(12\ \Omega) = \mathbf{21.6\text{ V}}$,
    $V_3 = I_3R_3 = (1.8\text{ A})(18\ \Omega) = \mathbf{32.4\text{ V}}$
    d. $P_s = EI_s = (72\text{ V})(1.8\text{ A}) = \mathbf{129.6\text{ W}}$
    e. $P_{18\Omega} = V_3I_3 = (32.4\text{ V})(1.8\text{ A}) = \mathbf{58.32\text{ W}}$

11. a. the most: R_3, the least: R_1
    b. R_3, $R_T = 1.2\text{ k}\Omega + 6.8\text{ k}\Omega + 82\text{ k}\Omega = \mathbf{90\text{ k}\Omega}$
    $I_s = \dfrac{E}{R_T} = \dfrac{45\text{ V}}{90\text{ k}\Omega} = \mathbf{0.5\text{ mA}}$
    c. $V_1 = I_1R_1 = (0.5\text{ mA})(1.2\text{ k}\Omega) = \mathbf{0.6\text{ V}}$, $V_2 = I_2R_2 = (0.5\text{ mA})(6.8\text{ k}\Omega) = \mathbf{3.4\text{ V}}$,
    $V_3 = I_3R_3 = (0.5\text{ mA})(82\text{ k}\Omega) = \mathbf{41\text{ V}}$, **results agree with part (a)**
    d. $P_s = EI_s = (72\text{ V})(1.8\text{ A}) = \mathbf{129.6\text{ W}}$
    e. $P_{18\Omega} = V_3I_3 = (32.4\text{ V})(1.8\text{ A}) = \mathbf{58.32\text{ W}}$

12. a. $R_T = 12\text{ k}\Omega + 4\text{ k}\Omega + 6\text{ k}\Omega = 22\text{ k}\Omega$
    $E = IR_T = (4\text{ mA})(22\text{ k}\Omega) = \mathbf{88\text{ V}}$
    b. $R_T = 12\ \Omega + 22\ \Omega + 82\ \Omega + 10\ \Omega = 126\ \Omega$
    $E = IR_T = (500\text{ mA})(126\ \Omega) = \mathbf{63\text{ V}}$

13. I. a. $I = \dfrac{V}{R} = \dfrac{5.2\text{ V}}{1.3\ \Omega} = \mathbf{4\text{ A}}$
    b. $E = IR_T = (4\text{ A})(9\ \Omega) = \mathbf{36\text{ V}}$
    c. $R_T = 9\ \Omega = 4.7\ \Omega + 1.3\ \Omega + R$, $R = \mathbf{3\ \Omega}$
    d. $V_{4.7\Omega} = (4\text{ A})(4.7\ \Omega) = \mathbf{18.8\text{ V}}$
    $V_{1.3\Omega} = (4\text{ A})(1.3\ \Omega) = \mathbf{5.2\text{ V}}$
    $V_{3\Omega} = (4\text{ A})(3\ \Omega) = \mathbf{12\text{ V}}$

    II. a. $I = \dfrac{V}{R} = \dfrac{6.6\text{ V}}{2.2\text{ k}\Omega} = \mathbf{3\text{ mA}}$
    b. $V_{3.3\text{k}\Omega} = (3\text{ mA})(3.3\text{ k}\Omega) = 9.9\text{ V}$
    $E = 6.6\text{ V} + 9\text{ V} + 9.9\text{ V} = \mathbf{25.5\text{ V}}$
    c. $R = \dfrac{V}{I} = \dfrac{9\text{ V}}{3\text{ mA}} = \mathbf{3\text{ k}\Omega}$
    d. $V_{2.2\text{k}\Omega} = \mathbf{6.6\text{ V}}$, $V_{3\text{k}\Omega} = \mathbf{9\text{ V}}$, $V_{3.3\text{k}\Omega} = \mathbf{9.9\text{ V}}$

14. a. $I_m = \dfrac{E}{R_T} = \dfrac{36\text{ V}}{4.4\text{ k}\Omega} = \mathbf{8.18\text{ mA}}$, $V_m = \dfrac{1}{2}E = \dfrac{1}{2}(36\text{ V}) = \mathbf{18\text{ V}}$
    b. $R_T = 1\text{ k}\Omega + 2.4\text{ k}\Omega + 5.6\text{ k}\Omega = 9\text{ k}\Omega$
    $I_m = \dfrac{E}{R_T} = \dfrac{22.5\text{ V}}{9\text{ k}\Omega} = \mathbf{2.5\text{ mA}}$, $V_m = 2.5\text{ mA}(2.4\text{ k}\Omega + 5.6\text{ k}\Omega) = \mathbf{20\text{ V}}$
    c. $V_{3.3\text{k}\Omega} = \dfrac{3.3\text{ k}\Omega(12\text{ V})}{4.5\text{ k}\Omega} = 8.8\text{ V}$
    $V_m = 12\text{ V} - 8.8\text{ V} = \mathbf{3.2\text{ V}}$
    $I_m = \dfrac{12\text{ V}}{4.5\text{ k}\Omega} = \mathbf{2.67\text{ mA}}$

15. a. $I = \dfrac{10\text{ V}}{30\ \Omega} = \mathbf{0.333\ A}$

$V = 0\text{ V}$

b. $I = 0\text{ A},\ V = IR = \dfrac{80\text{ V}}{60\ \Omega} = \mathbf{5.33\ V}$

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

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

$V_{R_1} = (20\text{ mA})(3\text{ k}\Omega) = \mathbf{60\ V}$

$V_{R_2} = (20\text{ mA})(1\text{ k}\Omega) = \mathbf{20\ V}$

$V_{R_3} = (20\text{ mA})(2\text{ k}\Omega) = \mathbf{40\ V}$

b. $P_{R_1} = I_1^2R_1 = (20\text{ mA})^2 \cdot 3\text{ k}\Omega = \mathbf{1.2\ W}$

$P_{R_2} = I_2^2R_2 = (20\text{ mA})^2 \cdot 1\text{ k}\Omega = \mathbf{0.4\ W}$

$P_{R_3} = I_3^2R_3 = (20\text{ mA})^2 \cdot 2\text{ k}\Omega = \mathbf{0.8\ W}$

c. $P_T = P_{R_1} + P_{R_2} + P_{R_3} = 1.2\text{ W} + 0.4\text{ W} + 0.8\text{ W} = \mathbf{2.4\ W}$

d. $P_T = EI_s = (120\text{ V})(20\text{ mA}) = \mathbf{2.4\ W}$

e. the same

f. R_1 – the largest

g. dissipated

h. R_1: 2 W, R_2 : 1/2 W, R_3: 1 W

17. $P = 21\text{ W} = (1\text{ A})^2 \cdot R,\quad R = \mathbf{21\ \Omega}$
$V_1 = I_1R_1 = (1\text{ A})(2\ \Omega) = \mathbf{2\ V},\ V_2 = I_2R_2 = (1\text{ A})(1\ \Omega) = \mathbf{1\ V}$
$V_3 = I_3R_3 = (1\text{ A})(21\ \Omega) = \mathbf{21\ V}$
$E = V_1 + V_2 + V_3 = 2\text{ V} + 1\text{ V} + 21\text{ V} = \mathbf{24\ V}$

18 $P = 8\text{ W} = I^2 \cdot 1\ \Omega,\ I = \sqrt{8} = \mathbf{2.828\ A}$
$P = 16\text{ W} = I^2R_1 = (2.828\text{ A})^2R_1,\quad R_1 = \mathbf{2\ \Omega}$
$R_T = 32\ \Omega = 2\ \Omega + R_2 + 1\ \Omega = 3\ \Omega + R_2,\quad R_2 = \mathbf{29\ \Omega}$
$E = IR_T = (2.828\text{ A})(32\ \Omega) = \mathbf{90.5\ V}$

19. a. $R_T = NR_1 = 8\left(28\tfrac{1}{8}\ \Omega\right) = 225\ \Omega$

$I = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{225\ \Omega} = \mathbf{0.53\ A}$

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

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!

20. $P_s = P_{R_1} + P_{R_2} + P_{R_3}$
$E \cdot I = I^2R_1 + I^2R_2 + 24$
$(R_1 + R_2)I^2 - E \cdot I + 24 = 0$
$6I^2 - 24I + 24 = 0$
$I^2 - 4I + 4 = 0$

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

$P = 24\text{ W} = (2\text{ A})^2R,\quad R = \dfrac{24\ \Omega}{4} = \mathbf{6\ \Omega}$

21. a. $V_{ab} + 4\text{ V} + 9\text{ V} - 12\text{ V} = 0,\ V_{ab} = -13\text{ V} + 12\text{ V} = \mathbf{-1\ V}$
b. $V_{ab} + 4\text{ V} + 8\text{ V} - 4\text{ V} = 0,\ V_{ab} = 4\text{ V} - 12\text{ V} = \mathbf{-8\ V}$
c. $V_{ab} + 12\text{ V} - 5\text{ V} + 6\text{ V} - 12\text{ V} = 0,\ V_{ab} = -18\text{ V} + 17\text{ V} = \mathbf{-1\ V}$

22. a. $E_T = 8\text{ V} - 32\text{ V} + 20\text{ V} = \mathbf{-4\ V},\ I = \dfrac{4\text{ V}}{10.3\ \Omega} = \mathbf{388.3\ mA}$

b. $E_T = -4\text{ V} + 10\text{ V} - 12\text{ V} = \mathbf{-6\ V},\ I = \dfrac{16\text{ V}}{11.5\ \Omega} = \mathbf{1.39\ A}$

23. a. $P = 8\text{ mW} = I^2R,\ R = \dfrac{8\text{ mW}}{I^2} = \dfrac{8\text{ mW}}{(2\text{ mA})^2} = \mathbf{2\ k\Omega}$

$I = \dfrac{E}{R_T} = \dfrac{20\text{ V} - E}{3\text{ k}\Omega + 2\text{ k}\Omega} = 2\text{ mA (CW)},\quad E = \mathbf{10\ V}$

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

$I = \dfrac{E}{R_T} = \dfrac{E - 4\text{ V} - 10\text{ V}}{2\text{ k}\Omega + 1.5\text{ k}\Omega} = \dfrac{E - 14\text{ V}}{3.5\text{ k}\Omega} = 8\text{ mA (CCW)}$

$E = \mathbf{42\ V}$

24. a. $-6\text{ V} + 4\text{ V} - 12\text{ V} - V = 0,\ V = -18\text{ V} + 4\text{ V} = \mathbf{-14\ V}$

b. $+30\text{ V} - 7\text{ V} - 8\text{ V} - V = 0,\ V = 30\text{ V} - 15\text{ V} = 15\text{ V}$

c. $-14\text{ V} - 22\text{ V} - V_1 + 12\text{ V} = 0,\ V_1 = -36\text{ V} + 12\text{ V} = -24\text{ V}$
$V_1 - V_2 - 12\text{ V} = 0,\ V_2 = V_1 - 12\text{ V} = -24\text{ V} - 12\text{ V} = -36\text{ V}$

25. a. $I = \dfrac{12\text{ V}}{8\,\Omega} = 1.5\text{ A}$

b. $V_2 = IR = (1.5\text{ A})(2\,\Omega) = 3\text{ V}$

c. $60\text{ V} - 12\text{ V} - V_1 - 3\text{ V} = 0$
$V_1 = 60\text{ V} - 15\text{ V} = 45\text{ V}$

26. a. $+10\text{ V} - V_2 = 0$
$V_2 = 10\text{ V}$
$+10\text{ V} - 6\text{ V} - V_1 = 0$
$V_1 = 4\text{ V}$

b. $+24\text{ V} - 10\text{ V} - V_1 = 0$
$V_1 = 14\text{ V}$
$+10\text{ V} - V_2 + 8\text{ V} = 0$
$V_2 = 18\text{ V}$

27. a. $V_{1.8\Omega} = IR = (3\text{ A})(1.8\,\Omega) = 5.4\text{ V}$
$24\text{ V} - V_1 - 10\text{ V} - 5.4\text{ V} = 0,\ V_1 = 24\text{ V} - 15.4\text{ V} = 8.6\text{ V}$
$V_{2.7\Omega} = IR = (3\text{ A})(2.7\,\Omega) = 8.1\text{ V}$
$10\text{ V} - 8.1\text{ V} - V_2 = 0$
$V_2 = 10\text{ V} - 8.1\text{ V} = 1.9\text{ V}$

b. $+10\text{ V} - V_1 + 6\text{ V} - 2\text{ V} - 3\text{ V} = 0,\ V_1 = 11\text{ V}$
$+10\text{ V} - V_2 - 3\text{ V} = 0,\ V_2 = 7\text{ V}$

28. $\dfrac{1\text{V}}{2\Omega} = \dfrac{50\text{ V}}{R_2},\ R_2 = \dfrac{(50\text{ V})(2\Omega)}{1\text{V}} = 100\,\Omega$

$\dfrac{1\text{V}}{2\Omega} = \dfrac{100\text{ V}}{R_3},\ R_3 = \dfrac{(100\text{ V})(2\Omega)}{1\text{V}} = 200\,\Omega$

29. a. $10\text{ k}\Omega$

b. $V_3 : V_2 = 10\text{ k}\Omega : 1\text{ k}\Omega = 10:1$
$V_3 : V_1 = 10\text{ k}\Omega : 100\,\Omega = 100:1$

c. $V_3 = \dfrac{R_3 E}{R_T} = \dfrac{(10\text{ k}\Omega)(60\text{ V})}{0.1\text{ k}\Omega + 1\text{ k}\Omega + 10\text{ k}\Omega} = 54.05\text{ V}$

d. $V' = \dfrac{(R_2 + R_3)E}{R_T} = \dfrac{(1\text{ k}\Omega + 10\text{ k}\Omega)(60\text{ V})}{11.1\text{ k}\Omega} = 59.46\text{ V}$

30. a. $V = \dfrac{40\,\Omega(30\text{ V})}{40\,\Omega + 20\,\Omega} = 20\text{ V}$

b. $V = \dfrac{(2\text{ k}\Omega + 3\text{ k}\Omega)(40\text{ V})}{4\text{ k}\Omega + 1\text{ k}\Omega + 2\text{ k}\Omega + 3\text{ k}\Omega} = \dfrac{(5\text{ k}\Omega)(40\text{ V})}{10\text{ k}\Omega} = 20\text{ V}$

c. $\dfrac{(1.5\,\Omega + 0.6\,\Omega + 0.9\,\Omega)(0.72\text{ V})}{(2.5\,\Omega + 1.5\,\Omega + 0.6\,\Omega + 0.9\,\Omega + 0.5\Omega)} = \dfrac{(3\,\Omega)(0.72\text{ V})}{6\text{ k}\Omega} = 0.36\text{ V}$

31. a. $\dfrac{V_1}{1.2\,\Omega} = \dfrac{20\text{ V}}{2\,\Omega},\ V_1 = \dfrac{(1.2\,\Omega)(20\text{ V})}{2\,\Omega} = 12\text{ V}$

$\dfrac{V_2}{6.8\,\Omega} = \dfrac{20\text{ V}}{2\,\Omega},\ V_2 = \dfrac{(6.8\,\Omega)(20\text{ V})}{2\,\Omega} = 68\text{ V}$

$E = V_1 + 20\text{ V} + V_2 = 12\text{ V} + 20\text{ V} + 68\text{ V} = 100\text{ V}$

b. $120\text{ V} - V_1 - 80\text{ V} = 0,\ V_1 = 40\text{ V}$
$80\text{ V} - 10\text{ V} - V_3 = 0;\ V_3 = 70\text{ V}$

32. a. $\dfrac{1000\text{ V}}{100\,\Omega} = \dfrac{V_2}{68\,\Omega},\ V_2 = \dfrac{68\,\Omega(1000\text{ V})}{100\,\Omega} = 680\text{ V}$

$\dfrac{1000\text{ V}}{100\,\Omega} = \dfrac{V_1}{2\,\Omega},\ V_1 = \dfrac{2\,\Omega(1000\text{ V})}{100\,\Omega} = 20\text{ V}$

$E = V_1 + V_2 + 1000\text{ V}$
$= 20\text{ V} + 680\text{ V} + 1000\text{ V}$
$= 1700\text{ V}$

b. $V_1 = 0\text{ V}$

$V_2 = \dfrac{10\text{ k}\Omega(50\text{ V} - 30\text{ V})}{10\text{ k}\Omega + 3.3\text{ k}\Omega + 4.7\text{ k}\Omega}$

$= \dfrac{10\text{ k}\Omega(20\text{ V})}{18\text{ k}\Omega} = 11.11\text{ V}$

$V_x = E_1 - V_{3.3\text{ k}\Omega}$

$V_{3.3\text{ k}\Omega} = \dfrac{3.3\text{ k}\Omega(20\text{ V})}{18\text{ k}\Omega}$
$= 3.67\text{ V}$

$V_x = 50\text{ V} - 3.67\text{ V} = 46.33\text{ V}$

33. $\dfrac{2\text{ V}}{1\text{k}\Omega} = \dfrac{V_2}{2\text{ k}\Omega},\ V_2 = \dfrac{2\text{ k}\Omega(2\text{ V})}{1\text{k}\Omega} = 4\text{ V}$

$\dfrac{2\text{ V}}{1\text{k}\Omega} = \dfrac{V_4}{3\text{ k}\Omega},\ V_4 = \dfrac{3\text{ k}\Omega(2\text{ V})}{1\text{k}\Omega} = 6\text{ V}$

$I = \dfrac{2\text{ V}}{1\text{k}\Omega} = 2\text{ mA}$
$E = 2\text{ V} + 4\text{ V} + 12\text{ V} + 6\text{ V} = 24\text{ V}$

34. a. $4\text{ V} = \dfrac{R(20\text{ V})}{2.2\text{ k}\Omega + 1.8\text{ k}\Omega + R}$

$4(4\text{ k}\Omega + R) = 20R$

$16\text{ k}\Omega + 4R = 20R$

$16R = 16\text{ k}\Omega$

$R = \dfrac{16}{16}\text{ k}\Omega = \mathbf{1\text{ k}\Omega}$

b. $110\text{ V} = \dfrac{(6\text{ M}\Omega + R)(140\text{ V})}{6\text{ M}\Omega + R + 3\text{ M}\Omega}$

$110(9\text{ M}\Omega + R) = 840\text{ M}\Omega + 140R$

$990\text{ M}\Omega + 110R = 840\text{ M}\Omega + 140R$

$30R = 150\text{ M}\Omega$

$R = \dfrac{150}{30}\text{ M}\Omega = \mathbf{5\text{ M}\Omega}$

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

$V_{\text{bulb}} = 8\text{ V} = \dfrac{R_{\text{bulb}}(12\text{ V})}{R_{\text{bulb}} + R_x} = \dfrac{160\ \Omega(12\text{ V})}{160\ \Omega + R_x}$, $R_x = \mathbf{80\ \Omega}$ **in series with the bulb**

b. $V_R = 12\text{ V} - 8\text{ V} = 4\text{ V}$, $P = \dfrac{V^2}{R} = \dfrac{(4\text{ V})^2}{80\ \Omega} = 0.2\text{ W}$, $\therefore$ **1/4 W okay**

36. $V_{R_1} + V_{R_2} = 72\text{ V}$

$\frac{1}{5}V_{R_2} + V_{R_2} = 72\text{ V}$

$V_{R_2}\left[1 + \frac{1}{5}\right] = 72\text{ V}$, $V_{R_2} = \dfrac{72\text{ V}}{1.2} = 60\text{ V}$

$R_2 = \dfrac{V_{R_2}}{I_{R_2}} = \dfrac{60\text{ V}}{4\text{ mA}} = \mathbf{15\text{ k}\Omega}$, $R_1 = \dfrac{V_{R_1}}{I_{R_1}} = \dfrac{72\text{ V} - 60\text{ V}}{4\text{ mA}} = \dfrac{12\text{ V}}{4\text{ mA}} = \mathbf{3\text{ k}\Omega}$

37. $R_T = R_1 + R_2 + R_3 = 2R_3 + 7R_3 + R_3 = 10R_3$

$V_{R_3} = \dfrac{R_3(60\text{ V})}{10R_3} = \mathbf{6\text{ V}}$, $V_{R_1} = 2V_{R_3} = 2(6\text{ V}) = \mathbf{12\text{ V}}$; $V_{R_2} = 7V_{R_3} = 7(6\text{ V}) = \mathbf{42\text{ V}}$

38. a. $V_{R_3} = 4V_{R_2}' = 4(3V_{R_1}) = 12V_{R_1}$

$E = V_{R_1} + 3V_{R_1} + 12V_{R_1}$ $\therefore R_T = R_1 + 3R_1 + 12R_1 = 16R_1 = \dfrac{64\text{ V}}{10\text{ mA}} = 6.4\text{ k}\Omega$

$R_1 = \dfrac{6.4\text{ k}\Omega}{16} = \mathbf{400\ \Omega}$, $R_2 = 3R_1 = \mathbf{1.2\text{ k}\Omega}$, $R_3 = 12R_1' = \mathbf{4.8\text{ k}\Omega}$

b. $R_T = \dfrac{64\text{ V}}{10\ \mu\text{A}} = 6.4\text{ M}\Omega$, $R_1 = \dfrac{6.4\text{ M}\Omega}{16} = \mathbf{400\text{ k}\Omega}$, $R_2 = \mathbf{1.2\text{ M}\Omega}$, $R_3 = \mathbf{4.8\text{ M}\Omega}$

$\dfrac{I_1}{I'} = \dfrac{10\text{ mA}}{10\ \mu\text{A}} = 10^3$ and $\dfrac{R_1'}{R_1} = \dfrac{400\text{ k}\Omega}{400\ \Omega} = 10^3$ also

39. a. $V_a = 12\text{ V} + 5\text{ V} = \mathbf{17\text{ V}}$

$V_b = 5\text{ V} + 16\text{ V} = \mathbf{21\text{ V}}$

$V_{ab} = 17\text{ V} - 21\text{ V} = \mathbf{-4\text{ V}}$

b. $V_a = \mathbf{-6\text{ V}}$

$-6\text{ V} + 6\text{ V} + 10\text{ V} - V_b = 0$, $V_b = \mathbf{10\text{ V}}$

$V_{ab} = V_a - V_b = -6\text{ V} - 10\text{ V} = \mathbf{-16\text{ V}}$

c. $-8\text{ V} + 3\text{ V} - V_a = 0$, $V_a = \mathbf{-5\text{ V}}$

$V_b = \mathbf{-8\text{ V}}$

$V_{ab} = V_a - V_b = -5\text{ V} - (-8\text{ V}) = -5\text{ V} + 8\text{ V} = \mathbf{+3\text{ V}}$

40. a. $I\downarrow = \dfrac{60\text{ V} + 20\text{ V}}{18\ \Omega + 82\ \Omega} = \dfrac{80\text{ V}}{100\ \Omega} = \mathbf{0.8\text{ A}}$

$V_a = 60\text{ V} - I(18\ \Omega) = 60\text{ V} - (0.8\text{ A})(18\ \Omega) = 60\text{ V} - 14.4\text{ V} = \mathbf{45.6\text{ V}}$

b. $\overrightarrow{I} = \dfrac{100\text{ V} - 60\text{ V}}{4(2\text{ k}\Omega)} = \dfrac{40\text{ V}}{8\text{ k}\Omega} = \mathbf{5\text{ mA}}$

$V_a - I(2\text{ k}\Omega) + 100\text{ V} = 0$

$V_a = (I)(2\text{ k}\Omega) - 100\text{ V} = (5\text{ mA})(2\text{ k}\Omega) - 100\text{ V} = 10\text{ V} - 100\text{ V} = \mathbf{-90\text{ V}}$

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

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

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

$V_d = -1[illegible]\text{ V}$, [illegible] $= \mathbf{0\text{ V}}$

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

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

42. $I_{R_1} = \dfrac{4\text{ V} + 4\text{ V}}{8\ \Omega} = \dfrac{8\text{ V}}{8\ \Omega} = 1\text{ A}$, $R_1 = \dfrac{V_{R_1}}{I} = \dfrac{12\text{ V} - 4\text{ V}}{1\text{ A}} = \dfrac{8\text{ V}}{1\text{ A}} = \mathbf{8\ \Omega}$,

$R_3 = \dfrac{V_{R_3}}{I} = \dfrac{8\text{ V} - 4\text{ V}}{1\text{ A}} = \dfrac{4\text{ V}}{1\text{ A}} = \mathbf{4\ \Omega}$

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

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

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

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

$V_{R_4} = 20\text{ V}$

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

$V_{R_1} = E - V_{R_2} - V_{R_3} - V_{R_4}$
$= 100\text{ V} - 36\text{ V} - 12\text{ V} - 20\text{ V} = 32\text{ V}$

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

44. a. $V_a = -8\text{ V} + 14\text{ V} = \mathbf{+6\ V}$, $V_b = \mathbf{14\ V}$
$V_c = +I(10\ \Omega) - 6\text{ V}$ with
$I = \frac{14\text{ V} + 6\text{ V}}{10\ \Omega + 10\ \Omega} = \frac{20\text{ V}}{20\ \Omega} = 1\text{ A}$
Therefore, $V_c = (1\text{ A})(10\ \Omega) - 6\text{ V} = 10\text{ V} - 6\text{ V} = \mathbf{4\ V}$
$V_d = \mathbf{0\ V}$

b. $V_{ab} = V_a - V_b = 6\text{ V} - 14\text{ V} = \mathbf{-8\ V}$
$V_{cb} = V_c - V_b = 4\text{ V} - 14\text{ V} = \mathbf{-10\ V}$
$V_{cd} = V_c - V_d = 4\text{ V} - 0\text{ V} = \mathbf{4\ V}$

c. $V_{ad} = V_a - V_d = 6\text{ V} - 0\text{ V} = \mathbf{6\ V}$
$V_{ca} = V_c - V_a = 4\text{ V} - 6\text{ V} = \mathbf{-2\ V}$

45. $V_0 = \mathbf{0\ V}$, $V_4 = (2\text{ k}\Omega)(6\text{ mA}) + 3\text{ V} = 12\text{ V} + 3\text{ V} = \mathbf{15\ V}$, $V_7 = \mathbf{4\ V}$
$V_{10} = V_1 - V_0 = 12\text{ V} - 0\text{ V} = \mathbf{12\ V}$, $V_{23} = V_2 - V_3 = 4\text{ V} - (-8\text{ V}) = 4\text{ V} + 8\text{ V} = \mathbf{12\ V}$
$V_{30} = V_3 - V_0 = -8\text{ V} - 0\text{ V} = \mathbf{-8\ V}$, $V_{67} = V_6 - V_7 = 4\text{ V} - 4\text{ V} = \mathbf{0\ V}$
$V_{56} = V_5 - V_6 = 3\text{ V} - 4\text{ V} = \mathbf{-1\ V}$, $I\!\uparrow = \frac{4\text{ V} + 8\text{ V}}{4\ \Omega} = \frac{12\text{ V}}{4\ \Omega} = \mathbf{3\ A}$

46. $V_0 = \mathbf{0\ V}$, $V_{03} = V_0 - V_3 = 0\text{ V} - 0\text{ V} = \mathbf{0\ V}$, $V_2 = (3\text{ mA})(3.3\text{ k}\Omega) = \mathbf{9.9\ V}$
$V_{23} = V_2 - V_3 = 9.9\text{ V} - 0\text{ V} = \mathbf{9.9\ V}$, $V_{12} = V_1 - V_2 = 20\text{ V} - 9.9\text{ V} = \mathbf{10.1\ V}$
$\Sigma I_i = \Sigma I_o$
$I_1 = 4\text{ mA} + 3\text{ mA} + 10\text{ mA} = \mathbf{17\ mA}$

47. a. $V_L = I_L R_L = (2\text{ A})(28\ \Omega) = 56\text{ V}$
$V_{int} = 60\text{ V} - 56\text{ V} = 4\text{ V}$
$R_{int} = \frac{V_{int}}{I} = \frac{4\text{ V}}{2\text{ A}} = \mathbf{2\ \Omega}$

b. $VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% = \frac{60\text{ V} - 56\text{ V}}{56\text{ V}} \times 100\% = \mathbf{7.14\%}$

48. a. $V_L = \frac{3.3\ \Omega(12\text{ V})}{3.3\ \Omega + 43\text{ m}\Omega} = \frac{39.6\text{ V}}{3.343\ \Omega} = \mathbf{11.85\ V}$

b. $VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% = \frac{12\text{ V} - 11.85\text{ V}}{11.85\text{ V}} \times 100\% = \mathbf{1.27\%}$

c. $I_s = I_L = \frac{11.85\text{ V}}{3.3\ \Omega} = 3.59\text{ A}$
$P_s = EI_s = (12\text{ V})(3.59\text{ A}) = \mathbf{43.08\ W}$
$P_{int} = I^2 R_{int} = (3.59\text{ A})^2\, 43\ \Omega = \mathbf{0.554\ W}$

49. a. $I = \frac{E}{R_T} = \frac{12\text{ V}}{2\text{ k}\Omega + 6.8\text{ k}\Omega} = \frac{12\text{ V}}{8.8\text{ k}\Omega} = \mathbf{1.36\ mA}$

b. $I = \frac{E}{R_T} = \frac{12\text{ V}}{8.8\text{ k}\Omega + 0.25\text{ k}\Omega} = \frac{12\text{ V}}{9.05\text{ k}\Omega} = \mathbf{1.33\ mA}$

c. not for most applications.

Chapter 6

1. a. R_2 and R_3
   b. E and R_3
   c. R_2 and R_3
   d. R_2 and R_3

2. a. E, R_1, R_2, R_3, and R_4
   b. E, R_1, R_2, and R_3
   c. E and R_1
   d. none

3. a. R_3 and R_4, R_5 and R_6
   b. E and R_1, R_6 and R_7

4. a. $R_T = \dfrac{(36\ \Omega)(18\Omega)}{36\ \Omega + 18\ \Omega} = 12\ \Omega$

   b. $R_T = \dfrac{1}{\dfrac{1}{1\ k\Omega} + \dfrac{1}{2\ k\Omega} + \dfrac{1}{30\ k\Omega}} + \dfrac{1}{1\times10^{-3}S + 0.5\times10^{-3}S + 33.33\times10^{-6}S}$

   $= \dfrac{1}{1.533\times10^{-3}S} = 0.652\ k\Omega$

   c. $R_T = \dfrac{1}{\dfrac{1}{1.2\ \Omega} + \dfrac{1}{120\ k\Omega} + \dfrac{1}{12\ k\Omega}} = \dfrac{1}{8.33.33\times10^{-6}S + 8.33\times10^{-3}S + 83.33\times10^{-3}S} = \dfrac{1}{92.49\times10^{-3}S}$

   $= 10.81\ \Omega$

5. a. $R_T' = \dfrac{18\ k\Omega}{3} = 6\ k\Omega$

   $R_T = \dfrac{(6\ k\Omega)(6\ k\Omega)}{6\ k\Omega + 6\ k\Omega} = 3\ k\Omega$

   b. $R_T' = \dfrac{22\ \Omega}{4} = 5.5\ \Omega,\ R_T'' = \dfrac{10\ \Omega}{2} = 5\ \Omega$

   $R_T = \dfrac{(5.5\ \Omega)(5\ \Omega)}{5.5\ \Omega + 5\ \Omega} = 2.62\ \Omega$

   c. $R_T = \dfrac{1}{\dfrac{1}{1\ \Omega} + \dfrac{1}{1\ k\Omega} + \dfrac{1}{1\ M\Omega}} = \dfrac{1}{1000\times10^{-3}S + 1\times10^{-3}S + 0.001\times10^{-3}S}$

   $= \dfrac{1}{1001.001\times10^{-3}S} = 0.99\ \Omega$

6. a. $R_T = \dfrac{1}{\dfrac{1}{1\ k\Omega} + \dfrac{1}{1.2\ k\Omega} + \dfrac{1}{0.3\ k\Omega}} = \dfrac{1}{1\times10^{-3}S + 0.833\times10^{-3}S + 3.333\times10^{-3}S}$

   $= \dfrac{1}{5.166\times10^{-3}S} = 193.57\ \Omega$

   b. $R_T = \dfrac{1}{\dfrac{1}{1\ k\Omega} + \dfrac{1}{1.2\ k\Omega} + \dfrac{1}{2.2\ k\Omega} + \dfrac{1}{1\ k\Omega}} = \dfrac{1}{1\times10^{-3}S + 0.833\times10^{-3}S + 0.455\times10^{-3}S + 1\times10^{-3}S}$

   $= \dfrac{1}{3.288\times10^{-3}S} = 304.14\ \Omega$

7. a. $R_T' = 3\ \Omega \parallel 6\ \Omega = 2\ \Omega$

   $R_T = 1.61\ \Omega = \dfrac{(2\ \Omega)(R)}{2\ \Omega + R},\ R = 8\ \Omega$

   b. $R_T' = \dfrac{6\ k\Omega}{3} = 2\ k\Omega$

   $R_T = 1.8\ k\Omega = \dfrac{(2\ k\Omega)(R)}{2\ k\Omega + R},\quad R = 18\ k\Omega$

   c. $R_T = 5.08\ k\Omega = \dfrac{(20\ k\Omega)(R)}{20\ k\Omega + R},\quad R = 6.8\ k\Omega$

8. a. $R_T = 1.02\ \Omega = \dfrac{1}{\dfrac{1}{2.4\ k\Omega} + \dfrac{1}{R} + \dfrac{1}{6.8\ k\Omega}} = \dfrac{1}{416.67\times10^{-6}S + \dfrac{1}{R} + 147.06\times10^{-6}\ S}$

   $1.02\ k\Omega = \dfrac{1}{563.73\times10^{-6} + \dfrac{1}{R}}$

   $575\times10^{-3} + \dfrac{1.020\ k\Omega}{R} = 1$

   $R = \dfrac{1.020\ k\Omega}{425\times10^{-3}} = 2.4\ k\Omega$

   b. $R_T = 6\ k\Omega = \dfrac{R_1}{4}$

   $R_1 = 24\ k\Omega$

   c. $\dfrac{1}{1.11\ k\Omega} = \dfrac{1}{R} + \dfrac{1}{8.2\ k\Omega} + \dfrac{1}{10\ k\Omega} + \dfrac{1}{2\ k\Omega}$

   $900.9\times10^{-6}S = \dfrac{1}{R} + 121.95\times10^{-6}S + 100\times10^{-6}S + 500\times10^{-6}S$

   $\dfrac{1}{R} = 178.95\times10^{-6}S$

   $R = \dfrac{1}{178.95\times10^{-6}S} = 5.588\ k\Omega \cong 5.6\ k\Omega$

9. a. 1.2 kΩ
   b. about 1 kΩ

c. $R_T = \dfrac{1}{\dfrac{1}{1.2\text{ k}\Omega}+\dfrac{1}{22\text{ k}\Omega}+\dfrac{1}{220\text{ k}\Omega}+\dfrac{1}{2.2\text{ M}\Omega}}$

$= \dfrac{1}{833.333\times10^{-6}\text{S}+45.455\times10^{-6}\text{S}+4.545\times10^{-6}\text{S}+0.455\times10^{-6}\text{S}}$

$= \dfrac{1}{883.788\times10^{-6}\text{S}} = 1.131\text{ k}\Omega$

d. 220 kΩ, 2.2 MΩ: $R_T = \dfrac{(1.2\text{ k}\Omega)(22\text{ k}\Omega)}{1.2\text{ k}\Omega+22\text{ k}\Omega} = 1.138\text{ k}\Omega$

e. R_T reduced.

10. a. $R_T = \dfrac{1}{\dfrac{1}{4\,\Omega}+\dfrac{1}{2\,\Omega}+\dfrac{1}{10\,\Omega}} = \dfrac{1}{0.25\text{ S}+0.50\text{ S}+0.10\text{ S}} = \dfrac{1}{0.85\text{ S}} = 1.18\,\Omega$

b. $\infty\,\Omega$

c. $R_T = 3\,\Omega \parallel 6\,\Omega = 2\,\Omega$

11. $24\,\Omega \parallel 24\,\Omega = 12\,\Omega$

$\dfrac{1}{R_T} = \dfrac{1}{R_1} + \dfrac{1}{12\,\Omega} + \dfrac{1}{120\,\Omega}$ (Two of the 24 Ω resistors "shorted" out.)

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

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

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

$R_1 = \dfrac{1}{0.00833\text{ S}} = 120\,\Omega$

12. a. $R_T = \dfrac{(8\,\Omega)(24\,\Omega)}{8\,\Omega+24\,\Omega} = 6\,\Omega$

b. $V_{R_1} = V_{R_2} = 36\text{ V}$

c. $I_s = \dfrac{E}{R_T} = \dfrac{36\text{ V}}{6\,\Omega} = 6\text{ A}$

$I_1 = \dfrac{V_{R_1}}{R_1} = \dfrac{36\text{ V}}{8\,\Omega} = 4.5\text{ A}$

$I_2 = \dfrac{V_{R_2}}{R_2} = \dfrac{36\text{ V}}{24\,\Omega} = 1.5\text{ A}$

d. $I_s = I_1 + I_2$

$6\text{ A} = 4.5\text{ A} + 1.5\text{ A} = 6\text{ A}$ (checks)

d. $I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{60\text{ V}}{20\text{ k}\Omega} = \mathbf{3.0\text{ mA}}$, $I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{60\text{ V}}{10\text{ k}\Omega} = \mathbf{6\text{ mA}}$

$I_{R_3} = \frac{V_{R_3}}{R_3} = \frac{60\text{ V}}{1\text{ k}\Omega} = \mathbf{60.0\text{ mA}}$, $I_{R_4} = \frac{V_{R_4}}{R_4} = \frac{60\text{ V}}{91\text{ k}\Omega} = \mathbf{0.659\text{ mA}}$

e. $I_s = \frac{E}{R_T} = \frac{60\text{ V}}{862.07\text{ k}\Omega} = \mathbf{69.6\text{ mA}}$

$I_s = 3\text{ mA} + 6\text{ mA} + 60\text{ mA} + 0.659\text{ mA} = \mathbf{69.66\text{ mA}}$ **(checks)**

f. always greater

16. a. $R_T = 6\,\Omega = \frac{(18\,\Omega)(R_2)}{18\,\Omega + R_2}$

$108\,\Omega + 6R_2 = 18R_2$

$12R_2 = 108\,\Omega$

$R_2 = \frac{108\,\Omega}{12} = \mathbf{9\,\Omega}$

b. $P = 81\text{ W} = \frac{V^2}{R} = \frac{E^2}{R} = \frac{E^2}{9\,\Omega}$

and $E^2 = (9)(81)$

or $E = \sqrt{729} = \mathbf{27\text{ V}}$

17. a. $P = \frac{V^2}{R} = \frac{E^2}{R}$ and $E = \sqrt{PR} = \sqrt{(100\text{ W})(4\,\Omega)} = \sqrt{400} = \mathbf{20\text{ V}}$

b. $R_2 = \frac{E}{I_2} = \frac{20\text{ V}}{2\text{ A}} = \mathbf{10\,\Omega}$

c. $I_1 = \frac{V_1}{R_1} = \frac{E}{R_1} = \frac{20\text{ V}}{10\,\Omega} = \mathbf{2\text{ A}}$

d. $I_s = I_1 + I_2 + I_3 = 2\text{ A} + 2\text{ A} + \frac{20\text{ V}}{4\,\Omega} = 4\text{ A} + 5\text{ A} = \mathbf{9\text{ A}}$

e. $P_s = EI_s = (20\text{ V})(9\text{ A}) = \mathbf{180\text{ W}}$

f. $P_{R_1} = \frac{E^2}{R_1} = \frac{(20\text{ V})^2}{10\,\Omega} = \mathbf{40\text{ W}}$, $P_{R_2} = \frac{E^2}{R_2} = \frac{(20\text{ V})^2}{\left(\frac{20\text{ V}}{2\text{ A}}\right)} = \frac{400\text{ W}}{10} = \mathbf{40\text{ W}}$,

g. $P_s = P_1 + P_2 + P_3$

$180\text{ W} = 40\text{ W} + 40\text{ W} + 100\text{ W} = 180\text{ W}$ (checks)

BP-4-/.

18. $I_3 = \frac{(20\,\Omega)(10.8\text{ A})}{20\,\Omega + 4\,\Omega} = 9\text{ A}$

$E = V_{R_3} = I_3R_3 = (9\text{ A})(4\,\Omega) = \mathbf{36\text{ V}}$

$I_{R_1} = 12.3\text{ A} - 10.8\text{ A} = 1.5\text{ A}$

$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{36\text{ V}}{1.5\text{ A}} = \mathbf{24\,\Omega}$

19. a. $V = \mathbf{48\text{ V}}$

b. $I_2 = \frac{48\text{ V}}{18\text{ k}\Omega} = \mathbf{2.67\text{ mA}}$

c. $I_s = \frac{48\text{ V}}{3\text{ k}\Omega} + \frac{48\text{ V}}{12\text{ k}\Omega} + I_2 = 16\text{ mA} + 4\text{ mA} + 2.67\text{ mA} = \mathbf{22.67\text{ mA}}$

d. $P = \frac{V^2}{R} = \frac{E^2}{R} = \frac{(48\text{ V})^2}{12\text{ k}\Omega} = \mathbf{192\text{ mW}}$

20. a. $I_{R_2}\uparrow = 4\text{ A} - 1\text{ A} = 3\text{ A}$, $R_2 = \frac{V_{R_2}}{I_2} = \frac{E}{I_2} = \frac{12\text{ V}}{3\text{ A}} = \mathbf{4\,\Omega}$

b. $R_3 = \frac{V_{R_3}}{I_3} = \frac{E}{I_3} = \frac{12\text{V}}{1\text{A}} = \mathbf{12\,\Omega}$

c. $I_1\uparrow = \frac{12\text{ V}}{2\,\Omega} = 6\text{ A}$, $I_s = I_1 + 4\text{ A} = 6\text{ A} + 4\text{ A} = \mathbf{10\text{ A}}$

21. –

22. a. $R_T = \frac{1}{\frac{1}{1\text{ k}\Omega} + \frac{1}{4.7\text{ k}\Omega} + \frac{1}{10\text{ k}\Omega}} = \frac{1}{1000 \times 10^{-6}\text{S} + 212.77 \times 10^{-6}\text{S} + 100 \times 10^{-6}\text{S}}$

$= \frac{1}{1.313 \times 10^{-3}\text{S}} = \mathbf{761.61\,\Omega}$

$I_{R_1} = \frac{V_{R_1}}{R_1} = \frac{60\text{ V}}{1\text{ k}\Omega} = \mathbf{60\text{ mA}}$, $I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{60\text{ V}}{4.7\text{ k}\Omega} = \mathbf{12.77\text{ mA}}$

$I_{R_3} = \frac{V_{R_3}}{R_3} = \frac{60\text{ V}}{10\text{ k}\Omega} = \mathbf{6\text{ mA}}$

b. $P_{R_1} = V_{R_1} \cdot I_{R_1} = (60\text{ V})(60\text{ mA}) = \mathbf{3.6\text{ W}}$

$P_{R_2} = V_{R_2} \cdot I_{R_2} = (60\text{ V})(12.77\text{ mA}) = \mathbf{766.2\text{ mW}}$

$P_{R_3} = V_{R_3} \cdot I_{R_3} = (60\text{ V})(6\text{ mA}) = \mathbf{360\text{ W}}$

c. $I_s = \dfrac{E}{R_T} = \dfrac{60\text{ V}}{761.61\ \Omega} = \mathbf{78.78\ mA}$

$P_s = E_sI_s = (60\text{ V})(78.78\text{ mA}) = \mathbf{4.73\ W}$

d. $P_s = \mathbf{4.73\ W} = 3.6\text{ W} + 766.2\text{ mW} + 360\text{ mW} = \mathbf{4.73\ W}$ **(checks)**

e. R_1 = **the smallest parallel resistor**

23. a. $I_{bulb} = \dfrac{E}{R_{bulb}} = \dfrac{120\text{ V}}{1.8\text{ k}\Omega} = \mathbf{66.667\ mA}$

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

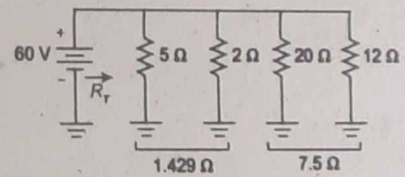
c. $I_s = \dfrac{E}{R_T} = \dfrac{120\text{ V}}{225\ \Omega} = \mathbf{0.533\ A}$

d. $P = \dfrac{V^2}{R} = \dfrac{(120\text{ V})^2}{1.8\text{ k}\Omega} = \mathbf{8\ W}$

e. $P_s = 8(8\text{ W}) = \mathbf{64\ W}$

f. **none, I_s drops by 66.667 mA**

24. Network redrawn:



$R_T = 1.429\ \Omega \parallel 7.5\ \Omega = 1.2\ \Omega$

$P_s = \dfrac{E^2}{R_T} = \dfrac{(60\text{ V})^2}{1.2\ \Omega} = \mathbf{3\ kW}$

25. a. $5 \times 60\text{ W} = 300\text{ W}$

$I_{bulbs} = \dfrac{300\text{ W}}{120\text{ V}} = \mathbf{2.5\ A}$

$I_{micro} = \dfrac{1200\text{ W}}{120\text{ V}} = \mathbf{10\ A}$

$I_{TV} = \dfrac{320\text{ W}}{120\text{ V}} = \mathbf{2.67\ A}$

$I_{DVD} = \dfrac{25\text{ W}}{120\text{ V}} = \mathbf{208.33\ mA}$

b. $I_s = \Sigma I = 2.5\text{ A} + 10\text{ A} + 2.67\text{ A} + 208.33\text{ mA} = \mathbf{15.38\ A}$

No

c. $R_T = \dfrac{E}{I_s} = \dfrac{120\text{ V}}{15.38\text{ A}} = \mathbf{7.8\ \Omega}$

d. $P_s = EI_s = (120\text{ V})(15.38\text{ A}) = \mathbf{1{,}845.60\ W}$

e. $P_s = 1845.60\text{ W} = 300\text{ W} + 1200\text{ W} + 320\text{ W} + 25\text{ W} = \mathbf{1845\ W}$ **(checks)**

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

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

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

c. $I_2 = I_1 = \mathbf{14.67\ A}$

27. $I_1 = 8\text{ mA} + 6\text{ mA} = \mathbf{14\ mA}$

$I_2 = 6\text{ mA} - 2\text{ mA} = \mathbf{4\ mA}$

28. a. $\Sigma I_i = \Sigma I_o$

$5\text{ A} + 7\text{ A} + 3\text{ A} = 9\text{ A} + I$

$15\text{ A} = 9\text{ A} + I$

$6\text{ A} = I$

b. $\Sigma I_i = \Sigma I_o$

$8\text{ mA} = 2\text{ mA} + I_1$

$I_1 = 8\text{ mA} - 2\text{ mA} = \mathbf{6\ mA}$

$\Sigma I_i = \Sigma I_o$

$I_1 + 9\text{ mA} = I_2$

$I_2 = 6\text{ mA} + 9\text{ mA} = \mathbf{15\ mA}$

$\Sigma I_i = \Sigma I_o$

$I_2 = 10\text{ mA} + I_3$

$I_3 = 15\text{ mA} - 10\text{ mA} = \mathbf{5\ mA}$

29. a. $\Sigma I_i = \Sigma I_o$

$8\text{ A} = 3\text{ A} + I_2$

$I_2 = 8\text{ A} - 3\text{ A} = \mathbf{5\ A}$, $I_3 = \mathbf{3\ A}$

$\Sigma I_i = \Sigma I_o$

$I_2 + I_3 = I_4$

$I_4 = 5\text{ A} + 3\text{ A} = \mathbf{8\ A}$

b. $\Sigma I_i = \Sigma I_o$

$I_1 = 36\text{ mA} + 4\text{ mA} = \mathbf{40\ mA}$

$\Sigma I_i = \Sigma I_o$

$36\text{ mA} = I_3 + 20\text{ mA}$

$I_3 = 36\text{ mA} - 20\text{ mA} = \mathbf{16\ mA}$

$\Sigma I_i = \Sigma I_o$

$4\text{ mA} + 20\text{ mA} = I_4$

$I_4 = \mathbf{24\ mA}$

$I_5 = I_s = \mathbf{40\ mA}$

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

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

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

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

$R_T = \dfrac{E}{I_T} = \dfrac{12\text{ V}}{9\text{ mA}} = 1.33\text{ k}\Omega$

31. a. $R_1 = \dfrac{E}{I_1} = \dfrac{10\text{ V}}{2\text{ A}} = 5\ \Omega$

$I_2 = I - I_1 = 3\text{ A} - 2\text{ A} = 1\text{ A}$

$R = \dfrac{E}{I_2} = \dfrac{10\text{ V}}{1\text{ A}} = 10\ \Omega$

b. $E = I_1R_1 = (2\text{ A})(6\ \Omega) = 12\text{ V}$

$I_2 = \dfrac{E}{R_2} = \dfrac{12\text{ V}}{9\ \Omega} = 1.33\text{ A}$

$I_3 = \dfrac{P}{V} = \dfrac{12\text{ W}}{12\text{ V}} = 1\text{ A}$

$R_3 = \dfrac{E}{I_3} = \dfrac{12\text{ V}}{1\text{ A}} = 12\ \Omega$

$I = I_1 + I_2 + I_3 = 2\text{ A} + 1.33\text{A} + 1\text{ A} = 4.33\text{ A}$

32. a. $I_1 = \dfrac{64\text{ V}}{1\text{ k}\Omega} = 64\text{ mA}$

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

$I_s = I_1 + I_2 + I_3$

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

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

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

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

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

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

Because $R_3 = R_2$, $I_3 = I_2$, and $I_s = I_1 + I_2 + I_3 = I_1 + 2I_2$

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

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

$I_3 = 0.5\text{ A}$

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

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

33. $I_2 = \dfrac{6\ \Omega}{12\ \Omega}I_1 = \dfrac{1}{2}I_1 = \dfrac{1}{2}(9\text{ A}) = 4.5\text{ A}$

$I_3 = \dfrac{6\ \Omega}{2\ \Omega}I_1 = 3I_1 = 3(9\text{ A}) = 27\text{ A}$

$I_4 = \dfrac{6\ \Omega}{18\ \Omega}I_1 = \dfrac{1}{3}I_1 = \dfrac{1}{3}(9\text{ A}) = 3\text{ A}$

$I_T = I_1 + I_2 + I_3 + I_4 = 9\text{ A} + 4.5\text{ A} + 27\text{ A} + 3\text{ A} = 43.5\text{ A}$

34. a. $I_1 = \dfrac{8\text{ k}\Omega(20\text{ mA})}{2\text{ k}\Omega + 8\text{ k}\Omega} = 16\text{ mA}$

$I_2 = 20\text{ mA} - 16\text{ mA} = 4\text{ mA}$

b. $I_{2.4k\Omega} = 2.5\text{ A} = \dfrac{1\text{ k}\Omega(I_T)}{1\text{ k}\Omega + 2.4\text{ k}\Omega} = \dfrac{1\text{ k}\Omega(I_T)}{3.4\text{ k}\Omega}$

and $I_T = \dfrac{3.4\text{ k}\Omega(2.5\text{ A})}{1\text{ k}\Omega} = 8.5\text{ A}$

$I_1 = I_T - 2.5\text{ A} = 8.5\text{ A} - 2.5\text{ A} = 6\text{ A}$

35. a. $R_T = \dfrac{1}{\dfrac{1}{4\ \Omega} + \dfrac{1}{8\ \Omega} + \dfrac{1}{12\ \Omega}} = \dfrac{1}{250\times10^{-3}\text{S} + 125\times10^{-3}\text{S} + 83.333\times10^{-3}\text{S}}$

$= \dfrac{1}{458.333\times10^{-3}} = 2.18\ \Omega$

$I_x = \dfrac{R_T}{R_x}I,\quad I_1 = \dfrac{2.18\ \Omega}{4\ \Omega}(6\text{ A}) = 3.27\text{ A}$

$I_2 = \dfrac{2.18\ \Omega}{8\ \Omega}(6\text{ A}) = 1.64\text{ A}$

$I_3 = \dfrac{2.18\ \Omega}{12\ \Omega}(6\text{ A}) = 1.09\text{ A}$

$I_4 = 6\text{ A}$

b. $4\,\Omega \parallel 4\,\Omega = 2\,\Omega$

$$I_2 = \frac{20\,\Omega(8\text{ A})}{20\,\Omega + 2\,\Omega + 8\,\Omega} = \frac{20\,\Omega(8\text{ A})}{30\,\Omega} = 5.33\text{ A}$$

$$I_1 = \frac{I_2}{2} = \frac{5.33\text{ A}}{2} = 2.67\text{ A}$$

$$I_3 = 8\text{ A} - I_2 = 8\text{ A} - 5.33\text{ A} = 2.67\text{ A}$$

$$I_4 = 8\text{ A}$$

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

b. $I_1/I_2 = 10\,\Omega/1\,\Omega = 10, \quad I_2 = \frac{I_1}{10} = \frac{9\text{ A}}{10} \cong 0.9\text{ A}$

c. $I_1/I_3 = 1\text{ k}\Omega/1\,\Omega = 1000,\ I_3 = I_1/1000 = 9\text{ A}/1000 \cong 9\text{ mA}$

d. $I_1/I_4 = 100\text{ k}\Omega/1\,\Omega = 100{,}000, \quad I_4 = I_1/100{,}000 = 9\text{ A}/100{,}000 \cong 90\,\mu\text{A}$

e. very little effect, 1/100,000

f. $$R_T = \frac{1}{\frac{1}{1\,\Omega} + \frac{1}{10\,\Omega} + \frac{1}{1\text{ k}\Omega} + \frac{1}{100\text{ k}\Omega}}$$

$$= \frac{1}{1\text{ S} + 0.1\text{ S} + 1\times10^{-3}\text{ S} + 10\times10^{-6}\text{ S}}$$

$$= \frac{1}{1.10\text{ S}} = 0.91\,\Omega$$

$$I_x = \frac{R_T}{R_x} I, \quad I_1 = \frac{0.91\,\Omega}{1\,\Omega}(10\text{ A}) = 9.1\text{ A} \text{ excellent (9 A)}$$

g. $I_2 = \frac{0.91\,\Omega}{10\,\Omega}(10\text{ A}) = 0.91\text{ A}$ excellent (0.9 A)

h. $I_3 = \frac{0.91\,\Omega}{1\text{ k}\Omega}(10\text{ A}) = 9.1\text{ mA}$ excellent (9 mA)

i. $I_4 = \frac{0.91\,\Omega}{100\text{ k}\Omega}(10\text{ A}) = 91\,\mu\text{A}$ excellent (90 μA)

37. a. CDR: $I_{36\Omega} = \frac{3\,\Omega I}{3\,\Omega + 36\,\Omega} = 1\text{ A}, \ I = \frac{39\,\Omega(1\text{ A})}{3\,\Omega} = 13\text{ A} = I_2$

$$I_1 = I - 1\text{ A} = 13\text{ A} - 1\text{ A} = 12\text{ A}$$

b. $I_3 = I = 24\text{ mA},\ V_{12\text{k}\Omega} = IR = (4\text{ mA})(12\text{ k}\Omega) = 48\text{ V}$

$$I_2 = \frac{V}{R} = \frac{48\text{ V}}{4\text{ k}\Omega} = 12\text{ mA}$$

$$I_1 = I - 4\text{ mA} - I_2$$
$$= 24\text{ mA} - 4\text{ mA} - 12\text{ mA}$$
$$= 8\text{ mA}$$

38. a. $R = 3(2\text{ k}\Omega) = 6\text{ k}\Omega$

$$V_2 = \frac{21.956\text{ k}\Omega(20\text{ V})}{21.956\text{ k}\Omega + 4.7\text{ k}\Omega} = \mathbf{16.47\text{ V}}$$ (very close to ideal)

c. $R_m = 20\text{ V}[20{,}000\ \Omega/\text{V}] = 400\text{ k}\Omega$
$R_T' = 400\text{ k}\Omega \parallel 22\text{ k}\Omega = 20.853\text{ k}\Omega$

$$V_2 = \frac{20.853\text{ k}\Omega(20\text{ V})}{20.853\text{ k}\Omega + 4.7\text{ k}\Omega} = \mathbf{16.32\text{ V}}$$ (still very close to ideal)

d. a. $$V_2 = \frac{200\text{ k}\Omega(20\text{ V})}{200\text{ k}\Omega + 100\text{ k}\Omega} = \mathbf{13.33\text{ V}}$$

b. $R_T' = 200\text{ k}\Omega \parallel 11\text{ M}\Omega = 196.429\text{ k}\Omega$

$$V_2 = \frac{(196.429\text{ k}\Omega)(20\text{ V})}{196.429\text{ k}\Omega + 100\text{ k}\Omega} = \mathbf{13.25\text{ V}}$$ (very close to ideal)

c. $R_m = 400\text{ k}\Omega$
$R_T' = 400\text{ k}\Omega \parallel 200\text{ k}\Omega = 133.333\text{ k}\Omega$

$$V_2 = \frac{(133.333\text{ k}\Omega)(20\text{ V})}{133.333\text{ k}\Omega + 100\text{ k}\Omega} = \mathbf{11.43\text{ V}}$$ (a 1.824 V drop from $R_{int} = 11\text{ M}\Omega$ level)

e. DMM level of 11 MΩ not a problem for most situations
VOM level of 400 kΩ can be a problem for some situations.

44. a. $V_{ab} = \mathbf{20\text{ V}}$

b. $$V_{ab} = \frac{11\text{ M}\Omega(20\text{ V})}{11\text{ M}\Omega + 1\text{ M}\Omega} = \mathbf{18.33\text{ V}}$$

c. $R_m = 200\text{ V}[20{,}000\ \Omega/\text{V}] = 4\text{ M}\Omega$

$$V_{ab} = \boxed{\frac{4\text{ M}\Omega(20\text{ V})}{4\text{ M}\Omega + 1\text{ M}\Omega}} = 16.0\text{ V}$$ (significant drop from ideal)

$R_m = 20\text{ V}[20{,}000\ \Omega/\text{V}] = 400\text{ k}\Omega$

$$V_{ab} = \frac{400\text{ k}\Omega(20\text{ V})}{400\text{ k}\Omega + 1\text{ M}\Omega} = \mathbf{5.71\text{ V}}$$ (significant error)

45. not operating properly, 6 kΩ not connected

$$R_T = \frac{6\text{ V}}{3.5\text{ mA}} = 1.71\text{ k}\Omega$$

$R_T = 3\text{ k}\Omega \parallel 4\text{ k}\Omega = 1.71\text{ k}\Omega$

46. $V_{ab} = E + I_{4\text{ k}\Omega} \cdot R_{4\text{ k}\Omega}$

$$I_{4\text{ k}\Omega} = \frac{12\text{ V} - 4\text{ V}}{1\text{ k}\Omega + 4\text{ k}\Omega} = \frac{8\text{ V}}{5\text{ k}\Omega} = 1.6\text{ mA}$$

$V_{ab} = 4\text{ V} + (1.6\text{ mA})(4\text{ k}\Omega) = 4\text{ V} + 6.4\text{ V} = 10.4\text{ V}$

4 V supply connected in reverse so that

$$I = \frac{12\text{ V} + 4\text{ V}}{1\text{ k}\Omega + 4\text{ k}\Omega} = \frac{16\text{ V}}{5\text{ k}\Omega} = 3.2\text{ mA}$$

and $V_{ab} = 12\text{ V} - (3.2\text{ mA})(1\text{ k}\Omega) = 12\text{ V} - 3.2\text{ V} = 8.8\text{ V}$ obtained

Chapter 7

1. a. R_1, R_2, and E are in series; R_3, R_4 and R_5 are in parallel
   b. E and R_1 are in series; R_2, R_3 and R_4 are in parallel.
   c. E and R_1 are in series; R_2, R_3 and R_4 are in parallel.

2. a. E_1 and R_1 in series; R_2 and R_3 in parallel.
   b. E and R_1 in series, R_2, R_3, and R_4 in parallel.
   c. E, R_1, R_4 and R_6 are in parallel; R_2 and R_5 are in parallel.

3. a. $R_T = 4\ \Omega + 10\ \Omega \parallel (4\ \Omega + 4\ \Omega) + 4\ \Omega = 4\ \Omega + 10\ \Omega \parallel 8\ \Omega + 4\ \Omega$
   $= 4\ \Omega + 4.44\ \Omega + 4\ \Omega = \mathbf{12.44\ \Omega}$

   b. $R_T = 10\ \Omega + \dfrac{10\ \Omega}{2} = 10\ \Omega + 5\ \Omega = \mathbf{15\ \Omega}$

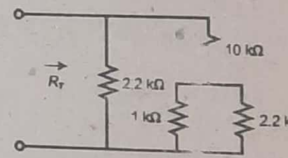
   c. $R_T = 6.8\ \Omega + 10\ \Omega \parallel (8.2\ \Omega + 1.2\ \Omega)$
   $= 6.8\ \Omega + 10\ \Omega \parallel 9.4\ \Omega$
   $= 6.8\ \Omega + 4.85\ \Omega = \mathbf{11.65\ \Omega}$

4. a. $R_T = \dfrac{4\ \Omega}{2} + 10\ \Omega = 2\ \Omega + 10\ \Omega = \mathbf{12\ \Omega}$

   b. $R_T = \mathbf{10\ \Omega}$

   c. $R_T = 2\ \Omega + 8\ \Omega \parallel (4\ \Omega + 6\ \Omega \parallel 12\ \Omega)$
   $= 2\ \Omega + 8\ \Omega \parallel (4\ \Omega + 4\ \Omega)$
   $= 2\ \Omega + 8\ \Omega \parallel 8\ \Omega = 2\ \Omega + 4\ \Omega$
   $= \mathbf{6\ \Omega}$

5.



$R_T = 2.2\text{ k}\Omega \parallel (10\text{ k}\Omega + 1\text{ k}\Omega \parallel 2.2\text{ k}\Omega)$
$= 2.2\text{ k}\Omega \parallel (10\text{ k}\Omega + 687.5\ \Omega)$
$= 2.2\text{ k}\Omega \parallel 10.687\text{ k}\Omega = \mathbf{1.82\text{ k}\Omega}$

6. $R_T = 7.2\text{ k}\Omega = R_1 \parallel \left(R_1 + \dfrac{R_1}{2}\right) = R_1 \parallel 1.5R_1$

so that $7.2\text{ k}\Omega = \dfrac{(R_1)(1.5R_1)}{R_1 + 1.5R_1} = \dfrac{1.5R_1^2}{2.5R_1} = \dfrac{1.5R_1}{2.5}$

and $R_1 = \dfrac{2.5(7.2\text{ k}\Omega)}{1.5}$ $\mathbf{1.2\text{ k}\Omega}$

7. a. **yes**
   b. $I_2 = I_s - I_1 = 10\text{ A} - 4\text{ A} = \mathbf{6\text{ A}}$
   c. **yes**
   d. $V_3 = E - V_2 = 14\text{ V} - 8\text{ V} = \mathbf{6\text{ V}}$
   e. $R_T' = 4\ \Omega \parallel 2\ \Omega = 1.33\ \Omega$, $R_T'' = 4\ \Omega \parallel 6\ \Omega = 2.4\ \Omega$
   $R_T = R_T' + R_T'' = 1.33\ \Omega + 2.4\ \Omega = \mathbf{3.73\ \Omega}$

f. $R'_T = R''_T = \frac{20\,\Omega}{2} = 10\,\Omega$, $R_T = R'_T + R''_T = 10\,\Omega + 10\,\Omega = 20\,\Omega$

$I_s = \frac{E}{R_T} = \frac{20\text{ V}}{20\,\Omega} = 1\text{ A}$

g. $P_s = EI_s = P_{absorbed} = (20\text{ V})(1\text{ A}) = \mathbf{20\text{ W}}$

8. a. $R'_T = R_1 \parallel R_2 = 10\,\Omega \parallel 15\,\Omega = 6\,\Omega$

$R_T = R'_T \parallel (R_3 + R_4) = 6\,\Omega \parallel (10\,\Omega + 2\,\Omega) = 6\,\Omega \parallel 12\,\Omega = \mathbf{4\,\Omega}$

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

$I_2 = \frac{E}{R_3 + R_4} = \frac{36\text{ V}}{10\,\Omega + 2\,\Omega} = \frac{36\text{ V}}{12\,\Omega} = \mathbf{3\text{ A}}$

$I_1 = I_s - I_2 = 6\text{ A} - 3\text{ A} = \mathbf{3\text{ A}}$

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

9. a. $R_T = 11\,\Omega + \frac{27\,\Omega}{3} = 11\,\Omega + 9\,\Omega = \mathbf{20\,\Omega}$

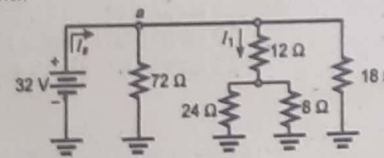
$I_s = \frac{E}{R_T} = \frac{60\text{ V}}{20\,\Omega} = \mathbf{3\text{ A}}$

b. $V_1 = I_sR_1 = (3\text{ A})(11\,\Omega) = \mathbf{33\text{ V}}$

$V_3 = I_s\left(\frac{27\,\Omega}{3}\right) = (3\text{ A})(9\,\Omega) = \mathbf{27\text{ V}}$

or $V_3 = E - V_1 = 60\text{ V} - 33\,\Omega = \mathbf{27\text{ V}}$

10. Redrawn:



a. $V_a = \mathbf{32\text{ V}}$

$8\,\Omega \parallel 24\,\Omega = 6\,\Omega$

$V_b = \frac{6\,\Omega(32\text{ V})}{6\,\Omega + 12\,\Omega} = \mathbf{10.67\text{ V}}$

b. $I_1 = \frac{32\text{ V}}{12\,\Omega + 6\,\Omega} = \frac{32\text{ V}}{18\,\Omega} = \mathbf{1.78\text{ A}}$

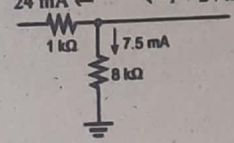
$R_T = 72\,\Omega \parallel \underbrace{18\,\Omega \parallel 18\,\Omega}_{9\,\Omega} = 8.12\,\Omega$

$I_s = \frac{E}{R_T} = \frac{32\text{ V}}{8.12\,\Omega} = \mathbf{3.94\text{ A}}$

11. a. $V_a = \mathbf{36\text{ V}}$, $V_b = \mathbf{60\text{ V}}$ $V_c = \frac{5\text{ k}\Omega(60\text{ V})}{5\text{ k}\Omega + 10\text{ k}\Omega} = \mathbf{20\text{ V}}$

b. $\overleftarrow{I_1} = \frac{60\text{ V} - 36\text{ V}}{1\text{ k}\Omega} = \mathbf{24\text{ mA}}$,

$I_{8k\Omega} = \frac{60\text{ V}}{8\text{ k}\Omega} = 7.5\text{ mA}$, $I_{10k\Omega} = \frac{60\text{ V}}{15\text{ k}\Omega} = 4\text{ mA}$



$\leftarrow I_2 = 31.5\text{ mA} + 4\text{ mA} = \mathbf{35.5\text{ mA}}$

12. a. $R'_T = 1.2\text{ k}\Omega + 6.8\text{ k}\Omega = 8\text{ k}\Omega$, $R''_T = 2\text{ k}\Omega \parallel R'_T = 2\text{ k}\Omega \parallel 8\text{ k}\Omega = 1.6\text{ k}\Omega$

$R'''_T = R''_T + 2.4\text{ k}\Omega = 1.6\text{ k}\Omega + 2.4\text{ k}\Omega = 4\text{ k}\Omega$

$R_T = 1\text{ k}\Omega \parallel R'''_T = 1\text{ k}\Omega \parallel 4\text{ k}\Omega = \mathbf{0.8\text{ k}\Omega}$

b. $I_s = \frac{E}{R_T} = \frac{48\text{ V}}{0.8\text{ k}\Omega} = \mathbf{60\text{ mA}}$

c. $V = \frac{R''_T E}{R''_T + 2.4\text{ k}\Omega} = \frac{(1.6\text{ k}\Omega)(48\text{ V})}{1.6\text{ k}\Omega + 2.4\text{ k}\Omega} = \mathbf{19.2\text{ V}}$

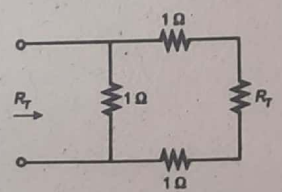
13. $R_T = 2R \parallel 2R \parallel (R + R) = 2R \parallel 2R \parallel 2R = \frac{2R}{3}$

$R_T = \frac{E}{I} = \frac{120\text{ V}}{8\text{ A}} = 15\,\Omega$

$15\,\Omega = \frac{2R}{3}$ and $R = \frac{3}{2}(15\,\Omega) = \mathbf{22.5\,\Omega}$

$2R = \mathbf{45\,\Omega}$

14.



$R_T = 1\,\Omega \parallel (1\,\Omega + 1\,\Omega + R_T) = 1\,\Omega \parallel (2\,\Omega + R_T)$

$= \frac{2\,\Omega + R_T}{1\,\Omega + 2\,\Omega + R_T} = \frac{2\,\Omega + R_T}{3\,\Omega + R_T}$

$R_T(3\,\Omega + R_T) = 2\,\Omega + R_T$

$3R_T + R_T^2 = 2\,\Omega + R_T$

$R_T^2 + 2R_T - 2\,\Omega = 0$

$R_T = \frac{-2 \pm \sqrt{(2)^2 - 4(1)(-2)}}{2}$

$= \frac{-2 \pm \sqrt{4+8}}{2} = \frac{2 \pm \sqrt{12}}{2} = \frac{-2 \pm 3.464}{2}$

$R_T = -1 \pm 1.732 = 0.732\,\Omega$ or $-2.732\,\Omega$

Since $R_T < 1\,\Omega$ and positive choose $R_T = \mathbf{0.732\,\Omega}$

15. a. $R_T = (R_1 \| R_2 \| R_3) \| (R_6 + R_4 \| R_5)$
$= (12\text{ k}\Omega \| 12\text{ k}\Omega \| 3\text{ k}\Omega) \| (10.4\text{ k}\Omega + 9\text{ k}\Omega \| 6\text{ k}\Omega)$
$= (6\text{ k}\Omega \| 3\text{ k}\Omega) \| (10.4\text{ k}\Omega + 3.6\text{ k}\Omega)$
$= 2\text{ k}\Omega \| 14\text{ k}\Omega = 1.75\text{ k}\Omega$

$I_s = \dfrac{E}{R_T} = \dfrac{28\text{ V}}{1.75\text{ k}\Omega} = 16\text{ mA}, \quad I_2 = \dfrac{E}{R_2} = \dfrac{28\text{ V}}{12\text{ k}\Omega} = 2.33\text{ mA}$

$R' = R_1 \| R_2 \| R_3 = 2\text{ k}\Omega$
$R'' = R_6 + R_4 \| R_5 = 14\text{ k}\Omega$
$I_6 = \dfrac{R'(I_s)}{R'+R''} = \dfrac{2\text{ k}\Omega(16\text{ mA})}{2\text{ k}\Omega+14\text{ k}\Omega} = 2\text{ mA}$

b. $V_1 = E = 28\text{ V}$
$R' = R_4 \| R_5 = 6\text{ k}\Omega \| 9\text{ k}\Omega = 3.6\text{ k}\Omega$
$V_5 = I_6 R' = (2\text{ mA})(3.6\text{ k}\Omega) = 7.2\text{ V}$

c. $P = \dfrac{V_{R_3}^2}{R_3} = \dfrac{(28\text{ V})^2}{3\text{ k}\Omega} = 261.33\text{ mW}$

16. a. $I_1 \downarrow = \dfrac{24\text{ V}}{4\,\Omega} = 6\text{ A};\ V_{R_2} = 24\text{ V} - 8\text{ V} = 16\text{ V},\ I_2 \downarrow = V_{R_2} / R_2 = 16\text{ V}/2\,\Omega = 8\text{ A}$

$I_1 \downarrow = \dfrac{8\text{ V}}{10\,\Omega} = 0.8\text{ A},\ I = I_1 + I_2 = 6\text{ A} + 8\text{ A} = 14\text{ A}$

17. $I_1 = \dfrac{20\text{ V}}{47\,\Omega} = 425.5\text{ mA}$

$I_2 = \dfrac{14\text{ V}}{160\,\Omega \| 270\,\Omega} = \dfrac{14\text{ V}}{100.47\,\Omega} = 139.35\text{ mA}$

18. a. $R' = R_4 + R_5 = 14\,\Omega + 6\,\Omega = 20\,\Omega$
$R'' = R_2 \| R' = 20\,\Omega \| 20\,\Omega = 10\,\Omega$
$R''' = R'' + R_1 = 10\,\Omega + 10\,\Omega = 20\,\Omega$
$R_T = R_3 \| R''' = 5\,\Omega \| 20\,\Omega = 4\,\Omega$

$I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{4\,\Omega} = 5\text{ A}$

$I_1 = \dfrac{20\text{ V}}{R_1 + R''} = \dfrac{20\text{ V}}{10\,\Omega+10\,\Omega} = \dfrac{20\text{ V}}{20\,\Omega} = 1\text{ A}$

$I_3 = \dfrac{20\text{ V}}{5\,\Omega} = 4\text{ A}$

$I_4 = \dfrac{I_1}{2} = (\text{since } R' = R_2) = \dfrac{1\text{A}}{2} = 0.5\text{ A}$

b. $V_a = I_3 R_3 - I_4 R_5 = (4\text{ A})(5\,\Omega) - (0.5\text{ A})(6\,\Omega) = 20\text{ V} - 3\text{ V} = 17\text{ V}$

$V_{bc} = \left(\dfrac{I_1}{2}\right) R_2 = (0.5\text{ A})(20\,\Omega) = 10\text{ V}$

19. a. $I_1 = \dfrac{E_1 - E_2}{R_1} = \dfrac{20\text{ V} - 15\text{ V}}{3\,\Omega} = 1.67\text{ A}$

b. $I_2 = \dfrac{E_2}{R_2 + R_3 \| R_5} = \dfrac{15\text{ V}}{3\,\Omega + 6\,\Omega \| 6\,\Omega} = \dfrac{15\text{ V}}{3\,\Omega + 3\,\Omega} = \dfrac{15\text{ V}}{6\,\Omega} = 2.5\text{ A}$

$I_3 = \dfrac{1}{2} I_2 = \dfrac{1}{2}(2.5\text{ A}) = 1.25\text{ A}$

c. $V_a = E_2 - I_2 R_2 = 15\text{ V} - (2.5\text{ A})(3\,\Omega) = 15\text{ V} - 7.5\text{ V} = 7.5\text{ V}$

20. a. $I_E = \dfrac{V_E}{R_E} = \dfrac{2\text{ V}}{1\text{ k}\Omega} = 2\text{ mA}$

$I_C = I_E = 2\text{ mA}$

b. $I_B = \dfrac{V_{R_B}}{R_B} = \dfrac{V_{CC} - (V_{BE} + V_E)}{R_B} = \dfrac{8\text{V} - (0.7\text{ V} + 2\text{V})}{220\text{ k}\Omega}$

$= \dfrac{8\text{ V} - 2.7\text{ V}}{220\text{ k}\Omega} = \dfrac{5.3\text{ V}}{220\text{ k}\Omega} = 24\ \mu\text{A}$

c. $V_B = V_{BE} + V_E = 2.7\text{ V}$
$V_C = V_{CC} - I_C R_C = 8\text{ V} - (2\text{ mA})(2.2\text{ k}\Omega) = 8\text{ V} - 4.4\text{ V} = 3.6\text{ V}$

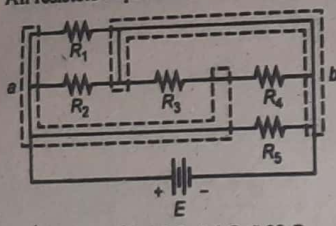
d. $V_{CE} = V_C - V_E = 3.6\text{ V} - 2\text{ V} = 1.6\text{ V}$
$V_{BC} = V_B - V_C = 2.7\text{ V} - 3.6\text{ V} = -0.9\text{ V}$

21. a. $I_2 = \dfrac{E_1}{R_2 + R_3} = \dfrac{2\text{ V}}{4\,\Omega + 18\,\Omega} = \dfrac{22\text{ V}}{22\,\Omega} = 1\text{ A}$

b. $+22\text{ V} + V_1 - 22\text{ V} = 0,\ V_1 = 22\text{ V} - 22\text{ V} = 0\text{ V}$

c. $I_1 = I_2 + \dfrac{V_1}{R_1} = 1\text{ A} + \dfrac{0\text{ V}}{R_1} = 1\text{ A}$

22. a. All resistors in parallel (between terminals a & b)



$$R_T = \underbrace{16\,\Omega \parallel 16\,\Omega}\parallel 8\,\Omega \parallel 4\,\Omega \parallel 32\,\Omega$$
$$\underbrace{8\,\Omega \parallel 8\,\Omega} \parallel 4\,\Omega \parallel 32\,\Omega$$
$$\underbrace{4\,\Omega \parallel 4\,\Omega} \parallel 32\,\Omega$$
$$2\,\Omega \parallel 32\,\Omega = \mathbf{1.88\,\Omega}$$

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. $I_s = I_1 + I_2 + I_3 + I_4 + I_5$
$$= \frac{32\text{ V}}{16\Omega} + \frac{32\text{ V}}{8\Omega} + \frac{32\text{ V}}{4\Omega} + \frac{32\text{ V}}{32\Omega} + \frac{32\text{ V}}{16\Omega}$$
$$= 2\text{ A} + 4\text{ A} + 8\text{ A} + 1\text{ A} + 2\text{ A}$$
$$= 17\text{ A}$$
$$R_T = \frac{E}{I_s} = \frac{32\text{ V}}{17\text{ A}} = \mathbf{1.88\,\Omega}\text{ as above}$$

23. a. $V_a = -6\text{ V}, V_b = -20\text{ V}$

b. $I_{5\Omega}\downarrow = \dfrac{20\text{ V}}{5\Omega} = 4\text{ A}$

$I_{2\Omega}\rightarrow = \dfrac{V_{ab}}{2\Omega} = \dfrac{14\text{ V}}{2\Omega} = 7\text{ A}$

$I_{3\Omega}\uparrow \dfrac{6\text{ V}}{3\Omega} = 2\text{ A}$

$I_{3\Omega} = I_{2\Omega} + I_{6V}\uparrow,\ I_{6V} = I_{3\Omega} - I_{2\Omega} = 2\text{ A} - 7\text{ A} = -5\text{ A}$

$I + I_{6V} = I_{5\Omega},\ I = I_{5\Omega} - I_{6V} = 4\text{ A} - (-5\text{A}) = \mathbf{9\ A}$

c. $V_{ab} = V_a - V_b = (-6\text{ V}) - (-20\text{ V}) = -6\text{ V} + 20\text{ V} = \mathbf{+14\ V}$

24. a. Applying Kirchoff's voltage law in the CCW direction in the upper "window":

$$+18\text{ V} + 20\text{ V} - V_{8\Omega} = 0$$
$$V_{8\Omega} = 38\text{ V}$$
$$I_{8\Omega} = \frac{38\text{ V}}{8\Omega} = 4.75\text{ A}$$
$$I_{3\Omega} = \frac{18\text{ V}}{3\Omega + 6\Omega} = \frac{18\text{ V}}{9\Omega} = 2\text{ A}$$

KCL: $I_{18V} = 4.75\text{ A} + 2\text{ A} = \mathbf{6.75\ A}$

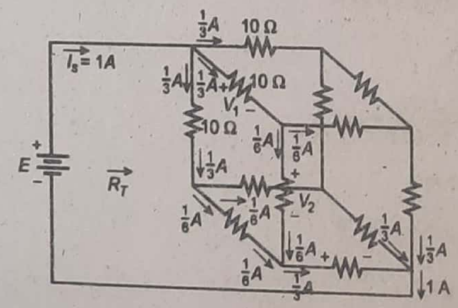
b. $V = (I_{3\Omega})(6\,\Omega) + 20\text{ V} = (2\text{ A})(6\,\Omega) + 20\text{ V} = 12\text{ V} + 20\text{ V} = \mathbf{32\ V}$

25. $I_2R_2 = I_3R_3$ and $I_2 = \dfrac{I_3R_3}{R_2} = \dfrac{2R_3}{20} = \dfrac{R_3}{10}$ (since the voltage across parallel elements is the same)

$I_1 = I_2 + I_3 = \dfrac{R_3}{10} + 2$

KVL: $120 = I_1 12 + I_3R_3 = \left(\dfrac{R_3}{10} + 2\right)12 + 2R_3$
$$\text{and } 120 = 1.2R_3 + 24 + 2R_3$$
$$3.2R_3 - 96\,\Omega$$
$$R_3 = \frac{96\,\Omega}{3.2} = \mathbf{30\,\Omega}$$

26. 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.



$$V_1 = \left(\frac{1}{3}\text{A}\right)(10\,\Omega) = \frac{10}{3}\text{ V}$$
$$V_2 = \left(\frac{1}{6}\text{A}\right)(10\,\Omega) = \frac{10}{6}\text{ V}$$
$$V_3 = \left(\frac{1}{3}\text{A}\right)(10\,\Omega) = \frac{10}{3}\text{ V}$$

$$E = V_1 + V_2 + V_3 = \frac{10}{3}\text{ V} + \frac{10}{6}\text{ V} + \frac{10}{3}\text{ V} = 8.33\text{ V}$$

$$R_T = \frac{E}{I} = \frac{8.33\text{ V}}{1\text{A}} = \mathbf{8.33\ \Omega}$$

27. a. $R'_T = R_5 \parallel (R_6 + R_7) = 6\ \Omega \parallel 3\ \Omega = 2\ \Omega$
$R''_T = R_3 \parallel (R_4 + R'_T) = 4\ \Omega \parallel (2\ \Omega + 2\ \Omega) = 2\ \Omega$
$R_T = R_1 + R_2 + R''_T = 3\ \Omega + 5\ \Omega + 2\ \Omega = 10\ \Omega$
$$I = \frac{240\text{ V}}{10\Omega} = \mathbf{24\ A}$$

b. $$I_4 = \frac{4\Omega(I)}{4\Omega+4} = \frac{4\Omega(24\text{ A})}{8} = 12\text{ A}$$
$$I_7 = \frac{6\Omega(12\text{ A})}{6\Omega+3} = \frac{72\text{ A}}{9} = \mathbf{8\ A}$$

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. $P = I_7^2R_7 = (8\text{ A})^2 2\ \Omega = \mathbf{128\ W}$
$P = EI = (240\text{ V})(24\text{ A}) = \mathbf{5760\ W}$

28. a. $R'_T = R_4 \parallel (R_6 + R_7 + R_8) = 2\ \Omega \parallel 7\ \Omega = 1.56\ \Omega$
$R''_T = R_2 \parallel (R_3 + R_5 + R'_T) = 2\ \Omega \parallel (4\ \Omega + 1\ \Omega + 1.56\ \Omega) = 1.53\ \Omega$
$R_T = R_1 + R''_T = 4\ \Omega + 1.53\ \Omega = \mathbf{5.53\ \Omega}$

b. $I = 40\text{ V}/5.53\ \Omega = \mathbf{7.23\ A}$

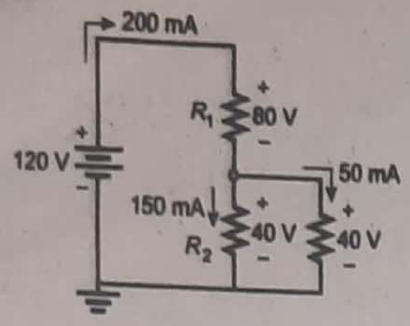
c. $$I_3 = \frac{2\ \Omega(I)}{2\ \Omega + 6.56} = \frac{2\ \Omega(7.23\text{ A})}{2\ \Omega + 6.56\ \Omega} = 1.69\text{ A}$$
$$I_7 = \frac{2\Omega(1.69\text{ A})}{2\Omega+7\Omega} = 0.375\text{ mA}$$
$$P_{R_7} = I^2R = (0.375\text{ A})^2\, 2\ \Omega = \mathbf{0.281\ W}$$

29. a. $E = (40\text{ mA})(1.6\text{ k}\Omega) = \mathbf{64\ V}$

b. $$R_{L_2} = \frac{48\text{ V}}{12\text{ mA}} = \mathbf{4\ k\Omega}$$
$$R_{L_3} = \frac{24\text{ V}}{8\text{ mA}} = \mathbf{3\ k\Omega}$$

c. $I_{R_1} = 72\text{ mA} - 40\text{ mA} = 32\text{ mA}$
$I_{R_2} = 32\text{ mA} - 12\text{ mA} = 20\text{ mA}$
$I_{R_3} = 20\text{ mA} - 8\text{ mA} = 12\text{ mA}$

31.



$$R_1 = \frac{80\text{ V}}{200\text{ mA}} = 400\ \Omega \Rightarrow \mathbf{390\ \Omega}$$

$$R_2 = \frac{40\text{ V}}{150\text{ mA}} = 266.67\ \Omega \Rightarrow \mathbf{270\ \Omega}$$

32. a. **yes, $R_L \gg R_{max}$ (potentiometer)**

b. VDR: $V_{R_2} = 3\text{ V} = \frac{R_2(12\text{ V})}{R_1+R_2} = \frac{R_2(12\text{ V})}{1\text{ k}\Omega}$

$$R_2 = \frac{3\text{ V}(1\text{ k}\Omega)}{12\text{ V}} = 0.25\text{ k}\Omega = \mathbf{250\ \Omega}$$

$$R_1 = 1\text{ k}\Omega - 0.25\text{ k}\Omega = 0.75\text{ k}\Omega = \mathbf{750\ \Omega}$$

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")

$$V_{R_1} = 9\text{ V} = \frac{R_1(12\text{ V})}{R_1 + (R_2 \| R_L)}$$

$$9R_1 + 9(R_2 \| R_L) = 12R_1$$

$$\left.\begin{aligned} R_1 &= 3(R_2 \| R_L) \\ R_1 + R_2 &= 1\text{ k}\Omega \end{aligned}\right\} 2\text{ eq. } 2\text{ unk}(R_L = 10\text{ k}\Omega)$$

$$R_1 = \frac{3R_2R_L}{R_2+R_L} \Rightarrow \frac{3R_2\ 10\text{ k}\Omega}{R_2+10\text{ k}\Omega}$$

and $R_1(R_2 + 10\text{ k}\Omega) = 30\text{ k}\Omega\ R_2$

$$R_1R_2 + 10\text{ k}\Omega\ R_1 = 30\text{ k}\Omega\ R_2$$

$$R_1 + R_2 = 1\text{ k}\Omega:\ (1\text{ k}\Omega - R_2)R_2 + 10\text{ k}\Omega\ (1\text{ k}\Omega - R_2) = 30\text{ k}\Omega\ R_2$$

$$R_2^2 + 39\text{ k}\Omega\ R_2 - 10\text{ k}\Omega^2 = 0$$

$$R_2 = 0.255\text{ k}\Omega, -39.255\text{ k}\Omega$$

$$R_2 = \mathbf{255\ \Omega}$$

$$R_1 = 1\text{ k}\Omega - R_2 = \mathbf{745\ \Omega}$$

33. a. $V_{ab} = \frac{80\ \Omega(40\text{ V})}{100\ \Omega} = \mathbf{32\text{ V}}$

$V_{bc} = 40\text{ V} - 32\text{ V} = \mathbf{8\text{ V}}$

b. $80\ \Omega \| 1\text{ k}\Omega = 74.07\ \Omega$

$20\ \Omega \| 10\text{ k}\Omega = 19.96\ \Omega$

$$V_{ab} = \frac{74.07\ \Omega(40\text{ V})}{74.07\ \Omega + 19.96\ \Omega} = \mathbf{31.51\text{ V}}$$

$V_{bc} = 40\text{ V} - 31.51\text{ V} = \mathbf{8.49\text{ V}}$

c. $$P = \frac{(31.51\text{ V})^2}{80\ \Omega} + \frac{(8.49\text{ V})^2}{20\ \Omega} = 12.411\text{ W} + 3.604\text{ W} = \mathbf{16.02\text{ W}}$$

38. a. $I_{CS} = 1\ \text{mA}$

b. $R_{shunt} = \dfrac{R_m I_{CS}}{I_{max} - I_{CS}} = \dfrac{(100\ \Omega)(1\ \text{mA})}{20\ \text{A} - 1\ \text{mA}} \cong \dfrac{0.1}{20}\ \Omega = 5\ \text{m}\Omega$

39. 25 mA: $R_{shunt} = \dfrac{(1\ \text{k}\Omega)(50\ \mu\text{A})}{25\ \text{mA} - 0.05\ \text{mA}} \cong 2\ \Omega$

50 mA: $R_{shunt} = \dfrac{(1\ \text{k}\Omega)(50\ \mu\text{A})}{50\ \text{mA} - 0.05\ \text{mA}} = 1\ \Omega$

100 mA: $R_{shunt} \cong 0.5\ \Omega$

40. a. $R_s = \dfrac{V_{max} - V_{VS}}{I_{CS}} = \dfrac{15\ \text{V} - (50\ \mu\text{A})(1\ \text{k}\Omega)}{50\ \mu\text{A}} = 300\ \text{k}\Omega$

b. $\Omega/\text{V} = 1/I_{CS} = 1/50\ \mu\text{A} = 20{,}000$

41. 5 V: $R_s = \dfrac{5\ \text{V} - (1\ \text{mA})(1000\ \Omega)}{1\ \text{mA}} = 4\ \text{k}\Omega$

50 V: $R_s = \dfrac{50\ \text{V} - 1\ \text{V}}{1\ \text{mA}} = 49\ \text{k}\Omega$

500 V: $R_s = \dfrac{500\ \text{V} - 1\ \text{V}}{1\ \text{mA}} = 499\ \text{k}\Omega$

42. $10\ \text{M}\Omega = (0.5\ \text{V})(\Omega/\text{V}) \Rightarrow \Omega/\text{V} = 20 \times 10^6$

$I_{CS} = 1/(\Omega/\text{V}) = \dfrac{1}{20 \times 10^6} = 0.05\ \mu\text{A}$

43. a. $R_s = \dfrac{E}{I_m} - R_m - \dfrac{\text{zero adjust}}{2} = \dfrac{3\ \text{V}}{100\ \mu\text{A}} - 1\ \text{k}\Omega - \dfrac{2\ \text{k}\Omega}{2} = 28\ \text{k}\Omega$

b. $xI_m = \dfrac{E}{R_{series}} + R_m + \dfrac{\text{zero adjust}}{2} + R_{unk}$

$R_{unk} = \dfrac{E}{xI_m} - \left(R_{series} + R_m + \dfrac{\text{zero adjust}}{2}\right)$

$= \dfrac{3\ \text{V}}{x 100\ \mu\text{A}} - 30\ \text{k}\Omega \Rightarrow \dfrac{30 \times 10^3}{x} - 30 \times 10^3$

$x = \dfrac{3}{4}, R_{unk} = 10\ \text{k}\Omega; x = \dfrac{1}{2}, R_{unk} = 30\ \text{k}\Omega; x = \dfrac{1}{4}, R_{unk} = 90\ \text{k}\Omega$

44. –

Chapter 8

1. a. $I_1 = \frac{8\ \Omega(6A)}{8\ \Omega + 2\ \Omega} = \mathbf{4.8\ A}$ $\quad I_2 = 6\ A - I_1 = 6\ A - 4.8\ A = \mathbf{1.2\ A}$

   b. $V_s = I_1R_1 = (4.8\ A)(2\ \Omega) = \mathbf{9.6\ V}$

2. a. $I_1 = I_2 = \mathbf{20\ mA}$

   b. $V_2 = I_2R_2 = (20\ mA)(3.3\ k\Omega) = \mathbf{66\ V}$
   $V_s = IR_T = (20\ mA)((1.2\ k\Omega + 3.3\ k\Omega) = 20\ mA(4.5\ k\Omega) = \mathbf{90\ V}$

3. $E + V_{R_1} - V_s = 0,\ V_{R_1} = (8\ mA)(2.7\ k\Omega) = 21.6\ V$
   $V_s = E + V_{R_1} = 10\ V + 21.6\ V = \mathbf{31.6\ V}^{+}_{-}$

4. a. $V_s = E = \mathbf{24\ V}$

   b. $I_2 = \frac{E}{R_1 + R_2} = \frac{24\ V}{1\Omega + 3\Omega} = \frac{24\ V}{4\Omega} = 6\ A$

   c. $I + I_s = I_2,\ I_s = I_2 - I = 6\ A - 2\ A = 4\ A$

5. $V_1 = V_2 = V_s = IR_T = 0.6\ A[6\ \Omega \parallel 24\ \Omega \parallel 24\ \Omega] = 0.6\ A[6\ \Omega \parallel 12\ \Omega] = 2.4\ V$
   $I_2 = \frac{V_2}{R_2} = \frac{2.4\ V}{24\Omega} = \mathbf{0.1\ A}$
   $V_3 = \frac{R_3V_s}{R_3 + R_4} = \frac{16\Omega(2.4\ V)}{24\ \Omega} = \mathbf{1.6\ V}$

6. a. $I_1 = \frac{E}{R_1} = \frac{24\ V}{2\Omega} = 12\ A,\ I_{R_2} = \frac{E}{R_2 + R_3} = \frac{24\ V}{6\Omega + 2\Omega} = \frac{24\Omega}{8\Omega} = 3\ A$
   KCL: $I + I_s - I_1 - I_{R_2} = 0$
   $I_s = I_1 + I_{R_2} - I = 12\ A + 3\ A - 4\ A = 11\ A$

   b. $V_s = E = 24\ V$
   VDR: $V_3 = \frac{R_3E}{R_2 + R_3} = \frac{2\Omega(24\ V)}{6\Omega + 2\Omega} = \frac{48\ V}{8\ \Omega} = 6\ V$

7. a. $I = \frac{E}{R_s} = \frac{22\ V}{4.7\Omega} = \mathbf{4.68\ A},\ R_p = R_s = \mathbf{4.7\ \Omega}$

   b. $I = \frac{E}{R_T} = \frac{E}{R_1 + R_2} = \frac{9\ V}{1.2\ k\Omega + 2.2\ k\Omega} = \frac{9\ V}{3.4\ k\Omega} = \mathbf{2.65\ A}$
   $R_p = \mathbf{3.4\ k\Omega}$

8. a. $E = IR_p = (6\ A)(12\ \Omega) = \mathbf{72\ V},\ R_s = \mathbf{12\ \Omega}$

   b. $R_p = R_1 \parallel R_2 = 2.7\ k\Omega \parallel 8.1\ k\Omega = 2.03\ k\Omega$
   $E = IR_p = (18\ mA)(2.03\ k\Omega) = \mathbf{36.54\ V},\ R_s = \mathbf{2.03\ k\Omega}$

9. a. CDR: $I_L = \frac{R_s(I)}{R_s + R_L} = \frac{(91\ \Omega)(12\ mA)}{91\ \Omega + 10\ \Omega} = \mathbf{10.81\ mA}$

   b. $E_s = IR = (12\ mA)(91\ \Omega) = \mathbf{1.092\ V}$
   $R_s = 91\ \Omega$
   $I = \frac{E_s}{R_s + R_L} = \frac{1.092\ V}{91\ \Omega + 10\ \Omega} = \mathbf{10.81\ mA}$

10. a. $E = IR_2 = (2\ A)(5.6\ \Omega) = \mathbf{11.2\ V},\ R = \mathbf{5.6\ \Omega}$

    b. $E_T = 12\ V + 11.2\ V = \mathbf{23.2\ V},\ R_T = 10\ \Omega + 5.6\ \Omega = \mathbf{15.6\ \Omega}$

    c. $I_3 = \frac{E_T}{R_T + 91\ \Omega} = \frac{23.2\ V}{15.6\ \Omega + 91\ \Omega} = \mathbf{217.64\ mA}$

11. a. $I_T = 6.2\ A - 1.2\ A + 0.8\ A = 7\ A - 1.2\ A = \mathbf{5.8\ A}$

    b. $V_s = I_T R = (5.8\ A)(4\ \Omega) = \mathbf{23.2\ V}$

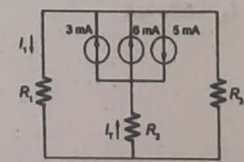
12. $I_T\uparrow = 7\ A - 3\ A = 4\ A$
    CDR: $I_1 = \frac{R_2(I_T)}{R_1 + R_2} = \frac{6\Omega(4\ A)}{4\Omega + 6\Omega} = \mathbf{2.4\ A}$
    $V_2 = I_1R_1 = (2.4\ A)(4\ \Omega) = \mathbf{9.6\ V}$

13. a. $I_T = \frac{E_2}{R_2} - \frac{E_1}{R_1} = \frac{20\ V}{2\Omega} - \frac{9\ V}{3\Omega}$
    $= 10\ A - 3\ A = 7\ A\downarrow$

    b. $V_{ab} = -I_T(R_1 \parallel R_2 \parallel R_3)$
    $= -7A\ (3\ \Omega \parallel 6\ \Omega \parallel 2\ \Omega)$
    $= -7\ A\ (1\ \Omega)$
    $= -7\ V$

    c. $I_3 = \frac{7\ V}{6\ \Omega} = \mathbf{1.17\ A}\uparrow$

14. a.



    $I_T = 3\ mA + 6\ mA - 5\ mA = 4\ mA\uparrow$
    $I_{R_1} = \frac{R_3I_T}{R_1 + R_3} = \frac{1\ k\Omega\ (4\ mA)}{2.2\ k\Omega + 1\ k\Omega} = 1.25\ mA$
    $V_1 = I_{R_1}(R_1) = (1.25\ mA)(2.2\ k\Omega) = \mathbf{2.75\ V}$

15. a.
$$\begin{aligned}4 - 4I_1 - 8I_3 &= 0\\ 6 - 2I_2 - 8I_3 &= 0\\ I_1 + I_2 &= I_3\end{aligned}$$

$$I_1 = -\frac{1}{7}\text{ A}, I_2 = \frac{5}{7}\text{ A}, I_3 = \frac{4}{7}\text{ A}$$

$$I_{R_1} = I_1 = -\frac{1}{7}\text{ A}, I_{R_2} = I_2 = \frac{5}{7}\text{ A}, I_{R_3} = I_3 = \frac{4}{7}\text{ A}$$

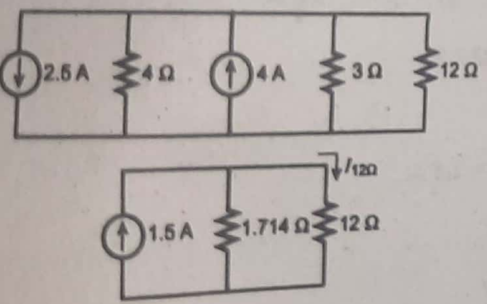
b. $V_a = I_3R_3 = \left(\frac{4}{7}\text{ A}\right)(8\ \Omega) = \mathbf{4.57\ V}$

16. a.
$$\begin{aligned}10 + 12 - 3I_3 - 4I_1 &= 0\\ 12 - 3I_3 - 12I_2 &= 0\\ I_1 + I_2 &= I_3\end{aligned}$$

$I_1 = \mathbf{3.06\ A}$
$I_2 = \mathbf{0.19\ A}$
$I_3 = \mathbf{3.25\ A}$

$I_{R_1} = I_1 = 3.06\text{ A},\ I_{R_2} = I_2 = 0.19\text{ A} = I_{12\Omega}$
$I_{R_3} = I_3 = 3.25\text{ A}$

b.



$$I_{12\Omega} = \frac{(1.714\ \Omega)(1.5\text{ A})}{1.714\ \Omega + 12\ \Omega} = \mathbf{0.19\ A}$$

c. **the same**

17.
$$\begin{aligned}10 - I_1\,5.6\text{ k}\Omega - I_3\,2.2\text{ k}\Omega + 20 &= 0\\ -20 + I_3\,2.2\text{ k}\Omega + I_2\,3.3\text{ k}\Omega - 30 &= 0\\ I_1 + I_2 &= I_3\end{aligned}$$

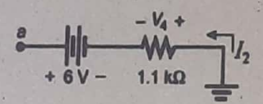
$I_1 = I_{R_1} = \mathbf{1.45\ mA}, I_2 = I_{R_2} = \mathbf{8.51\ mA}, I_3 = I_{R_3} = \mathbf{9.96\ mA}$

18. a.
$$\begin{aligned}-1.2\text{ k}\Omega\, I_1 + 9 - 8.2\text{ k}\Omega\, I_3 &= 0\\ -10.2\text{ k}\Omega\, I_2 + 8.2\text{ k}\Omega\, I_3 + 6 &= 0\\ I_2 + I_3 &= I_1\end{aligned}$$

$I_1 = \mathbf{2.03\ mA}, I_2 = \mathbf{1.23\ mA}, I_3 = \mathbf{0.8\ mA}$

$I_{R_1} = I_1 = 2.03\text{ mA}$
$I_{R_2} = I_3 = 0.8\text{ mA}$
$I_{R_3} = I_{R_4} = I_2 = \mathbf{1.23\ mA} = I_{9.1\text{k}\Omega}$

b.



$V_4 = I_2R_4 = (1.23\text{ mA})(1.1\text{ k}\Omega) = 1.35\text{ V}$
$V_a = 6\text{ V} - V_4 = 6\text{ V} - 1.35\text{ V} = \mathbf{4.65\ V}$

19.

$I_1 = I_{R_1}$ **(CW)**, $I_2 = I_{R_2}$ **(down)**, $I_3 = I_{R_3}$ **(CW)**, $I_4 = I_{R_4}$ **(down)**
$I_5 = I_{R_5}$ **(CW)**

a.
$$\begin{aligned}E_1 - I_1R_1 - I_2R_2 &= 0\\ I_2R_2 - I_3R_3 - I_4R_4 &= 0\\ I_4R_4 - I_5R_5 - E_2 &= 0\\ I_1 &= I_2 + I_3\\ I_3 &= I_4 + I_5\end{aligned}$$

b.
$$\begin{aligned}E_1 - I_1(R_1 + R_2) - I_3R_1 &= 0\\ I_2R_2 - I_3(R_3 + R_4) + I_5R_4 &= 0\\ I_3R_4 - I_5(R_4 + R_5) - E_2 &= 0\end{aligned}$$

c.
$$\begin{array}{llll} I_2(R_1 + R_2) + I_3R_1 & + 0 & & = E_1\\ I_2(R_2) & - I_3(R_3 + R_4) + I_5R_4 & & = 0\\ 0 & + I_3R_4 & - I_5(R_4 + R_5) & = E_2\end{array}$$

$$\begin{aligned}3I_2 + 2I_3 + 0 &= 10\\ 1I_2 - 9I_3 + 5I_5 &= 0\\ 0 + 5I_3 - 8I_5 &= 6\end{aligned}$$

d. $I_3 = I_{R_3} = \mathbf{-63.69\ mA\ (CW)}$

20. a. $I_1 \circlearrowright \; I_2 \circlearrowright$

$$4 - 4I_1 - 8(I_1 - I_2) = 0$$
$$-8(I_2 - I_1) - 2I_2 - 6 = 0$$

$$I_1 = -\frac{1}{7}\text{A}, I_2 = -\frac{5}{7}\text{A}$$

$$I_{R_1} = I_1 = -\frac{1}{7}\text{ A}$$

$$I_{R_2} = I_2 = -\frac{5}{7}\text{A}$$

$$I_{R_3} = I_1 - I_2 = \left(-\frac{1}{7}\text{A}\right) - \left(-\frac{5}{7}\text{A}\right) = \frac{4}{7}\text{ A (dir. of } I_1)$$

b. $V_a = I_{R_3} R_3 = \left(\frac{4}{7}\text{A}\right)(8\ \Omega) = \mathbf{4.57\ V}$

21 a. $I_1 \circlearrowright \; I_2 \circlearrowright$

$$-10 - 4I_1 - 3(I_1 - I_2) - 12 = 0$$
$$12 - 3(I_2 - I_1) - 12I_2 = 0$$

$$I_1 = -3.06\text{ A}, I_2 = 0.19\text{ A}$$

I_{E_1} = **3.06 A** (CCW)

I_{E_2} = 3.06 A + 0.19 A = **3.25 A (up)**

$I_{R_2} = I_1 - I_2$ = (–3.06 A) – (0.19 A) = **–3.25 A**

b. $P_{E_2} = I_{E_2} E_2$ = (3.25 A)(12 V) = **39 W**

$P_{R_3} = I_{R_3}^2 R_3 = (0.19\text{ A})^2\ 12\ \Omega$ = **433.2 mW**

22. a. $I_1 \circlearrowright \; I_2 \circlearrowright$

$$10 - I_1(5.6\text{ k}\Omega) - 2.2\text{ k}\Omega(I_1 - I_2) + 20 = 0$$
$$-20 - 2.2\text{ k}\Omega(I_2 - I_1) - I_2\,3.3\text{ k}\Omega - 30 = 0$$

I_1 = 1.45 mA, I_2 = 8.51 mA

$I_{R_1} = I_1$ = **1.45 mA**, $I_{R_2} = I_2$ = **8.51 mA**

$I_{R_3} = I_2 - I_1$ = **7.06 mA** (direction of I_2)

b. $V_{3.3\text{k}\Omega} = I_2 R_2$ = (8.51 mA)(3.3 kΩ) = **28.1 V**

23. a. $I_1 \circlearrowright$ $I_2 \circlearrowright$

$$-I_1(1.2\text{ k}\Omega) + 9 - 8.2\text{ k}\Omega(I_1 - I_2) = 0$$
$$-I_2(1.1\text{ k}\Omega) + 6 - I_2(9.1\text{ k}\Omega) - 8.2\text{ k}\Omega(I_2 - I_1) = 0$$

I_1 = 2.03 mA, I_2 = 1.23 mA

$I_{R_1} = I_1$ = **2.03 mA**, $I_{R_3} = I_{R_4} = I_2$ = **1.23 mA**

$I_{R_2} = I_1 - I_2$ = 2.03 mA – 1.23 mA = **0.80 mA** (direction of I_1)

b. V_a = 6 V – I_2(1.1 kΩ) = 6 V – (1.23 mA)(1.1 kΩ) = 6 V – 1.35 V = **4.65 V**

24. a. $I_1 \circlearrowright \; I_2 \circlearrowright \; I_3 \circlearrowright$

$$10 - I_1 2 - 1(I_1 - I_2) = 0$$
$$-1(I_2 - I_1) - I_2 4 - 5(I_2 - I_3) = 0$$
$$-5(I_3 - I_2) - I_3 3 - 6 = 0$$

$$3I_1 - 1I_2 + 0 = 10$$
$$-1I_1 + 10I_2 - 5I_3 = 0$$
$$0 - 5I_2 + 8I_3 = -6$$

I_1 = **3.31 A**, I_2 = **–63.69 mA**, I_3 = **–789.8 mA**

b, c. Ignore

d. $I_{10\text{V}}\uparrow = I_1$ = **3.31 A**

$I_{6\text{V}}\uparrow = -I_3$ = –(–789.8 mA) = **789.8 mA**

25. a. $I_1 \circlearrowright \; I_2 \circlearrowright \; I_3 \circlearrowright$

$$-I_1\,2.2\text{ k}\Omega - (I_1 - I_2)9.1\text{ k}\Omega + 18\text{ V} = 0$$
$$-18\text{ V} - (I_2 - I_1)9.1\text{ k}\Omega - 7.5\text{ k}\Omega\, I_2 - (I_2 - I_3)6.8\text{ k}\Omega = 0$$
$$-6.8\text{ k}\Omega(I_3 - I_2) - 3\text{ V} - 3.3\text{ k}\Omega\, I_3 = 0$$

with

$$11.3\text{ k}\Omega\, I_1 - 9.1\text{ k}\Omega I_2 = 18\text{ V}$$
$$23.4\text{ k}\Omega\, I_2 - 9.1\text{ k}\Omega I_1 - 6.8\text{ k}\Omega\, I_3 = -18\text{ V}$$
$$10.1\text{ k}\Omega\, I_3 - 6.8\text{ k}\Omega\, I_2 = -3\text{ V}$$

or

$$11.3\text{ k}\Omega\, I_1 - 9.1\text{ k}\Omega\, I_2 = 18\text{ V}$$
$$-9.1\text{ k}\Omega\, I_2 + 23.4\text{ k}\Omega\, I_2 - 6.8\text{ k}\Omega\, I_3 = -18\text{ V}$$
$$-6.8\text{ k}\Omega\, I_2 + 10.1\text{ k}\Omega\, I_3 = -3\text{ V}$$

b. I_1 = **1.21 mA**, I_2 = **–0.48 mA**, I_3 = **–0.62 mA**

c. $I_{E_1}\downarrow = I_1 - I_2$ = 1.21 mA – (–0.48 mA) = **1.69 mA**

$I_{E_2}\uparrow = -I_3$ = –(–0.62 mA) = **0.62 mA**

26. a. $I_1 \circlearrowright$ $I_3 \circlearrowright$ $I_2 \circlearrowright$

$$-4I_1 - 3(I_1 - I_2) - 4(I_1 - I_3) = 0$$
$$-3(I_2 - I_1) - 10I_2 - 15 - 4(I_2 - I_3) = 0$$
$$-7I_3 - 4(I_3 - I_1) - 4(I_3 - I_2) = 0$$

b. I_1 = **–430.4 mA**, I_2 = **–1.05 A**, I_3 = **–395.1 mA**

c. $I_{R_1} = I_1$ = **–430.4 mA**

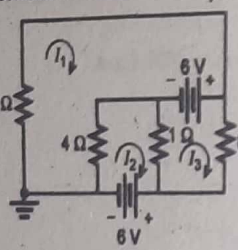
27. a. $I_1 \circlearrowright \; I_2 \circlearrowright$ $I_4 \circlearrowright \; I_3 \circlearrowright$

$$-6.8\text{ k}\Omega\, I_1 - 4.7\text{ k}\Omega(I_1 - I_2) + 6 - 2.2\text{ k}\Omega(I_1 - I_4) = 0$$
$$-6 - 4.7\text{ k}\Omega(I_2 - I_1) - 8.2\text{ k}\Omega\,(I_2 - I_3) = 0$$
$$-1.1\text{ k}\Omega\, I_3 - 22\text{ k}\Omega(I_3 - I_4) - 8.2\text{ k}\Omega(I_3 - I_2) - 9 = 0$$
$$-1.2\text{ k}\Omega\, I_4 - 2\text{ k}\Omega(I_4 - I_1) - 22\text{ k}\Omega(I_4 - I_3) = 0$$

b. $I_1 = -0.597$ **mA**, $I_2 = -2.13$ **mA**, $I_3 = -2.27$ **mA**, $I_4 = -2.03$ **mA**

c. $I_{6V} = I_1 - I_2 = -0.597\text{ mA} - (-2.13\text{ mA}) = 1.53\text{ mA}$
$P_{6V} = E\,I_{6V} = (6\text{ V})(1.53\text{ mA}) = \mathbf{9.18\text{ mW}}$

28. a. Network redrawn:



b. $-2I_1 - 6 - 4I_1 + 4I_2 = 0$
$-4I_2 + 4I_1 - 1I_2 + 1I_3 - 6 = 0$
$-1I_3 + 1I_2 + 6 - 8I_3 = 0$

c. $I_1 = \mathbf{-3.8\text{ A}}$, $I_2 = \mathbf{-4.20\text{ A}}$, $I_3 = \mathbf{0.20\text{ A}}$

d. $P_{E_1} = E_1 I_3 = (6\text{ V})(0.2\text{ A}) = 1.2\text{ W}$
$P_{E_2} = E_2 I_2 = (6\text{ V})(4.2\text{ A}) = 25.2\text{ W}$
$P_T = P_{E_1} + P_{E_2} = 1.2\text{ W} + 25.2\text{ W} = \mathbf{26.4\text{ W}}$

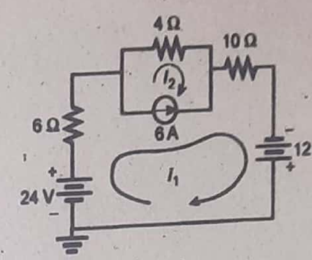
29. a. $20\text{ V} - I_B(270\text{ k}\Omega) - 0.7\text{ V} - I_E(0.51\text{ k}\Omega) = 0$
$I_E(0.51\text{ k}\Omega) + 8\text{ V} + I_C(2.2\text{ k}\Omega) - 20\text{ V} = 0$
$I_E = I_B + I_C$

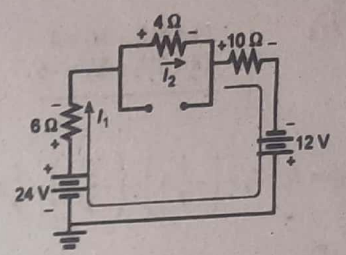
$I_B = \mathbf{63.02\ \mu A}$, $I_C = \mathbf{4.42\text{ mA}}$, $I_E = \mathbf{4.48\text{ mA}}$

b. $V_B = 20\text{ V} - I_B(270\text{ k}\Omega) = 20\text{ V} - (63.02\ \mu\text{A})(270\text{ k}\Omega) = 20\text{ V} - 17.02\text{ V} = \mathbf{2.98\text{ V}}$
$V_E = I_E R_E = (4.48\text{ mA})(510\ \Omega) = \mathbf{2.28\text{ V}}$
$V_C = 20\text{ V} - I_C(2.2\text{ k}\Omega) = 20\text{ V} - (4.42\text{ mA})(2.2\text{ k}\Omega) = 20\text{ V} - 9.72\text{ V} = \mathbf{10.28\text{ V}}$

c. $\beta \cong I_C/I_B = 4.42\text{ mA}/63.02\ \mu\text{A} = \mathbf{70.14}$

30.



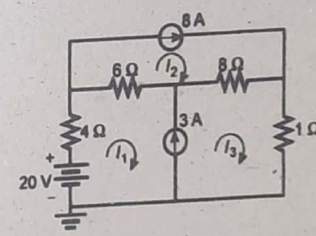


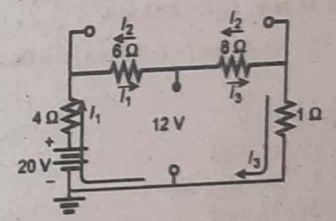
$24\text{ V} - 6I_1 - 4I_2 - 10I_1 + 12\text{ V} = 0$
and $16I_1 + 4I_2 = 36$
$I_1 - I_2 = 6\text{ A}$

$I_1 = I_2 + 6\text{ A}$
$16[I_2 + 6\text{ A}] + 4I_2 = 36$
$16I_2 + 96 + 4I_2 = 36$
$20I_2 = -60$
$I_2 = \mathbf{-3\text{ A}}$
$I_1 = I_2 + 6\text{ A} = -3\text{ A} + 6\text{ A} = \mathbf{3\text{ A}}$

$I_{24V} = I_{6\Omega} = I_{10\Omega} = I_{12V} = \mathbf{3\text{ A (CW)}}$
$I_{4\Omega} = \mathbf{3\text{ A (CCW)}}$

31.





$20\text{ V} - 4I_1 - 6(I_1 - I_2) - 8(I_3 - I_2) - 1I_3 = 0$
$10I_1 - 14I_2 + 9I_3 = 20$
$I_3 - I_1 = 3\text{ A}$
$I_2 = 8\text{ A}$

$10I_1 - 14(8\text{ A}) + 9[I_1 + 3\text{ A}] = 20$
$19I_1 = 105$
$I_1 = 5.526\text{ A}$
$I_3 = I_1 + 3\text{ A} = 5.526\text{ A} + 3\text{ A} = 8.526\text{ A}$
$I_2 = 8\text{ A}$
$I_{20V} = I_{4\Omega} = \mathbf{5.53\text{ A}}$ (dir. of I_1)
$I_{6\Omega} = I_2 - I_1 = \mathbf{2.47\text{ A}}$ (dir. of I_2)
$I_{8\Omega} = I_3 - I_2 = \mathbf{0.53\text{ A}}$ (dir. of I_3)
$I_{1\Omega} = \mathbf{8.53\text{ A}}$ (dir. of I_3)

32. a. $I_1 \curvearrowright\ I_2 \curvearrowright$

$$(4+8)I_1 - 8I_2 = 4$$
$$(8+2)I_2 - 8I_1 = -6$$

b. $I_{8\Omega}\downarrow = I_1 - I_2 = \left(-\frac{1}{7}\text{A}\right) - \left(-\frac{5}{7}\text{A}\right) = \frac{4}{7}\text{A}$

33. a. $I_1 \curvearrowright\ I_2 \curvearrowright$

$$(4+3)I_1 - 3I_2 = -10 - 12$$
$$(3+12)I_2 - 3I_1 = 12$$

b. $I_{3\Omega}\uparrow = I_2 - I_1 = 0.19\text{ A} - (-3.06\text{ A}) = \mathbf{3.25\text{ A}}$

34. a. $I_1 \curvearrowright\ I_2 \curvearrowright$

$$I_1(5.6\text{ k}\Omega + 2.2\text{ k}\Omega) - 2.2\text{ k}\Omega\,(I_2) = 10 + 20$$
$$I_2(2.2\text{ k}\Omega + 3.3\text{ k}\Omega) - 2.2\text{ k}\Omega\,(I_1) = -20 - 30$$

b. $I_{E_1} = I_1 = \mathbf{1.45\text{ mA}}$, $I_{E_2}\uparrow = \mathbf{8.51\text{ mA}}$,
$I_{E_3}\downarrow = I_1 - I_2 = (1.45\text{ mA}) - (-8.5\text{ mA}) = \mathbf{9.96\text{ mA}}$

35. a. $I_1 \curvearrowright\ I_2 \curvearrowright\ I_3 \curvearrowright$

$$I_1(2+1) - 1I_2 = 10$$
$$I_2(1+4+5) - 1I_1 - 5I_3 = 0$$
$$I_3(5+3) - 5I_2 = -6$$

b. $I_1 = \mathbf{3.31\text{ A}}$, $I_2 = \mathbf{-63.69\text{ mA}}$, $I_3 = \mathbf{-789.8\text{ mA}}$

c. $I_{R_1} = I_1 - I_2 = (3.31\text{ A}) - (-63.69\text{ mA}) = \mathbf{3.37\text{ A}}$

36. a. $I_1 \curvearrowright\ I_2 \curvearrowright\ I_3 \curvearrowright$

$$(2.2\text{ k}\Omega + 9.1\text{ k}\Omega)I_1 - 9.1\text{ k}\Omega I_2 = 18$$
$$(9.1\text{ k}\Omega + 7.5\text{ k}\Omega + 6.8\text{ k}\Omega)I_2 - 9.1\text{ k}\Omega\ I_1 - 6.8\text{ k}\Omega I_3 = -18$$
$$(6.8\text{ k}\Omega + 3.3\text{ k}\Omega)I_3 - 6.8\text{ k}\Omega I_2 = -3$$

b. $I_1 = \mathbf{1.21\text{ mA}}$, $I_2 = \mathbf{-0.48\text{ mA}}$, $I_3 = \mathbf{-0.62\text{ mA}}$

c. $I_{E_1}\downarrow = I_1 - I_2 = 1.21\text{ mA} - (-0.48\text{ mA}) = \mathbf{1.69\text{ mA}}$
$I_{E_2}\uparrow = -I_3 = -(-0.62\text{ mA}) = \mathbf{0.62\text{ mA}}$

40. a. $I_1(2\,\Omega + 4\,\Omega) - I_2 4\,\Omega = -6\text{ V}$

$I_2(4\,\Omega + 1\,\Omega) - I_1 4\,\Omega - I_3 1\,\Omega = -6\text{ V}$

$I_3(1\,\Omega + 8\,\Omega) - I_2 1\,\Omega = 6\text{ V}$

$$\begin{aligned} 6I_1 - 4I_2 \quad\quad &= -6\text{ V} \\ -4I_1 + 5I_2 - I_3 &= -6\text{ V} \\ -1I_2 + 9I_3 &= 6\text{ V} \end{aligned}$$

b. $I_1 = -3.8\text{ A}, I_2 = -4.20\text{ A}, I_3 = 0.2\text{ A}$

$$\begin{aligned} I_{R_1} &= I_1 - I_2 = -3.8\text{ A} - (-4.20\text{ A}) \\ &= -3.8\text{ A} + 4.20\text{ A} \\ &= 0.4\text{ A} \end{aligned}$$

c. $$\begin{aligned} I_{1\Omega} &= I_2 - I_3 = -4.20\text{ A} - 0.2\text{ A} \\ &= -4.4\text{ A} \end{aligned}$$

$$\begin{aligned} {}^{+}V_{1\Omega} &= (I_{1\Omega})(1\,\Omega) = (-4.4\text{ A})(1\,\Omega) \\ &= -4.4\text{ V} \end{aligned}$$

41. a. V_1 V_2

At V_1: $\Sigma I_i = \Sigma I_o$

$$0 = \frac{V_1}{2\,\Omega} + 5\text{ A} + \frac{V_1 - V_2}{8\,\Omega}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$\frac{V_1 - V_2}{8\,\Omega} = 3\text{ A} + \frac{V_2}{4\,\Omega}$$

and $$V_1\left[\frac{1}{2} + \frac{1}{8}\right] - V_2\left[\frac{1}{8}\right] = -5$$

$$-V_1\left[\frac{1}{8}\right] + V_2\left[\frac{1}{8} + \frac{1}{4}\right] = -3$$

b. $V_1 = -10.27\text{ V}, V_2 = -11.36\text{ V}$

c. $V_{8\Omega} = V_1 - V_2 = -10.27\text{ V} - (-11.36\text{ V}) = 1.09\text{ V}$

d. $$I_{2\Omega}\uparrow = \frac{V_1}{2\,\Omega} = \frac{10.27\text{ V}}{2\,\Omega} = 5.14\text{ A}$$

$$I_{4\Omega}\uparrow = \frac{V_2}{4\,\Omega} = \frac{11.36\text{ V}}{4\,\Omega} = 2.84\text{ A}$$

42. a. V_1 V_2

At V_1: $\Sigma I_i = \Sigma I_o$

$$0 = \frac{V_1}{8\,\Omega} + 12\text{ A} + I_{6\Omega} \text{ and } V_1 - I6\Omega - 54\text{ V} - V_2 = 0$$

$$\text{or } I = \frac{V_1 - V_2 - 54\text{ V}}{6\,\Omega} = \frac{V_1}{6\,\Omega} + \frac{V_2}{6\,\Omega} - 9\text{ A}$$

so that $$0 = \frac{V_1}{8\,\Omega} + 12\text{ A} + \frac{V_1}{6\,\Omega} - \frac{V_2}{6\,\Omega} - 9\text{ A}$$

or $$V_1\left[\frac{1}{8\,\Omega} + \frac{1}{6\,\Omega}\right] - V_2\left[\frac{1}{6\,\Omega}\right] = -12\text{ A} + 9\text{ A} = -3\text{ A}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$I = \frac{V_2}{20\,\Omega} + \frac{V_2}{5\,\Omega}$$

or $$\frac{V_1}{6\,\Omega} - \frac{V_2}{6\,\Omega} - 9\text{ A} = \frac{V_2}{20\,\Omega} + \frac{V_2}{5\,\Omega}$$

and $$V_2\left[\frac{1}{6\,\Omega} + \frac{1}{20\,\Omega} + \frac{1}{5\,\Omega}\right] - V_1\left[\frac{1}{6\,\Omega}\right] = -9\text{ A}$$

resulting in $$V_1\left[\frac{1}{8\,\Omega} + \frac{1}{6\,\Omega}\right] - V_2\left[\frac{1}{6\,\Omega}\right] = -3\text{ A}$$

$$-V_1\left[\frac{1}{6\,\Omega}\right] + V_2\left[\frac{1}{6\,\Omega} + \frac{1}{20\,\Omega} + \frac{1}{5\,\Omega}\right] = -9\text{ A}$$

b. $V_1 = -29.29\text{ V}, V_2 = -33.34\text{ V}$

c. $$I_{20\Omega}\uparrow = \frac{V_2}{20\,\Omega} - \frac{33.34\text{ V}}{20\,\Omega} = 1.67\text{ A}$$

43. a. V_1 V_2

At V_1: $\Sigma I_i = \Sigma I_o$

$$4\text{ A} = \frac{V_1}{2\,\Omega} + \frac{V_1 - V_2}{4\,\Omega} + 2\text{ A}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$2\text{ A} + \frac{V_1 - V_2}{4\,\Omega} = \frac{V_2}{20\,\Omega} + \frac{V_2}{5\,\Omega}$$

or $$V_1\left[\frac{1}{2} + \frac{1}{4}\right] - V_2\left[\frac{1}{4}\right] = 2$$

$$-V_1\left[\frac{1}{4}\right] + V_2\left[\frac{1}{4} + \frac{1}{20} + \frac{1}{5}\right] = 2$$

b. $V_1 = 4.8\text{ V}, V_2 = 6.4\text{ V}$

c. I_1: $P = V_1 I_1 = (4.8\text{ V})(4\text{ A}) = \mathbf{19.2\text{ W}}$

I_2: $P = |(V_1 - V_2)I_2| = |(4.8\text{ V} - 6.4\text{ V})(2\text{ A})| = \mathbf{3.2\text{ W}}$

44. a. V_1 V_2

At V_1: $\Sigma I_i = \Sigma I_o$

$$0 = 6\text{ A} + \frac{V_1}{5\,\Omega} + \frac{V_1 - V_2}{3\,\Omega} + \frac{V_1 - V_2}{2\,\Omega}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$7\text{ A} + \frac{V_1 - V_2}{3\,\Omega} + \frac{V_1 - V_2}{2\,\Omega} = \frac{V_2}{4\,\Omega} + \frac{V_2}{8\,\Omega}$$

so that $V_1\left[\frac{1}{5\,\Omega} + \frac{1}{3\,\Omega} + \frac{1}{2\,\Omega}\right] - V_2\left[\frac{1}{3\,\Omega} + \frac{1}{2\,\Omega}\right] = -6\text{ A}$

$$V_2\left[\frac{1}{4\,\Omega} + \frac{1}{8\,\Omega} + \frac{1}{3\,\Omega} + \frac{1}{2\,\Omega}\right] - V_1\left[\frac{1}{3\,\Omega} + \frac{1}{2\,\Omega}\right] = 7\text{ A}$$

or $\quad 1.03V_1 - 0.833V_2 = -6$

$\quad -0.833V_1 + 1.21V_2 = 7$

b. $V_1 = \mathbf{-2.59\text{ V}}$, $V_2 = \mathbf{4\text{ V}}$

c. $V_{2\Omega} = V_{3\Omega} = V_2 - V_1 = 4\text{ V} - (-2.59\text{ V}) = \mathbf{6.59\text{ V}}$

$V_{5\Omega} = V_1 = \mathbf{-2.59\text{ V}}$

$V_{4\Omega} = V_{8\Omega} = V_2 = \mathbf{4\text{ V}}$

45. a. V_1 V_2

Source conversion: $I_3 = \frac{12\text{ V}}{4\,\Omega} = 3\text{ A}, R_p = R_3 = 4\,\Omega$

At V_1: $\Sigma I_i = \Sigma I_o$

$$0 = \frac{V_1}{3\,\Omega} + \frac{V_1}{6\,\Omega} + 5\text{ A} + \frac{V_1 - V_2}{4\,\Omega} + 3\text{ A}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$3\text{ A} + \frac{V_1 - V_2}{4\,\Omega} = \frac{V_2}{8\,\Omega} + 4\text{ A}$$

Rewritten: $V_1\left[\frac{1}{3\,\Omega} + \frac{1}{6\,\Omega} + \frac{1}{4\,\Omega}\right] - \frac{V_2}{4\,\Omega} = -5\text{ A} - 3\text{ A}$

$$-V_1\left[\frac{1}{4\,\Omega}\right] + V_2\left[\frac{1}{4\,\Omega} + \frac{1}{8\,\Omega}\right] = -4\text{ A} + 3\text{ A}$$

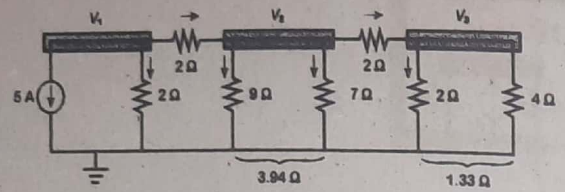
b. $V_1 = \mathbf{-14.86\text{ V}}$, $V_2 = \mathbf{-12.57\text{ V}}$

c. $I_{6\Omega}\uparrow = \frac{14.86\text{ V}}{6\,\Omega} = \mathbf{2.48\text{ A}}$

c. $V_{R_4} = V_1 - V_2$

$= (-5.43\text{ V}) - (8.53\text{ V})$
$= \mathbf{-13.96\text{ V}}$

48. a.



V_1: $\Sigma I_i = \Sigma I_o$

$$0 = 5\text{ A} + \frac{V_1}{2\,\Omega} + \frac{V_1 - V_2}{2\,\Omega}$$

V_2: $\Sigma I_i = \Sigma I_o$

$$\frac{V_1 - V_2}{2\,\Omega} = \frac{V_2}{3.94\,\Omega} + \frac{V_2 - V_3}{2\,\Omega}$$

V_3: $\Sigma I_i = \Sigma I_o$

$$\frac{V_2 - V_3}{2\,\Omega} = \frac{V_3}{1.33\,\Omega}$$

b. $\mathbf{V_1 = -6.556\text{ V}, V_2 = -3.113\text{ V}}$
$\mathbf{V_3 = -1.245\text{ V}}$

c. $I_{9\Omega} = \dfrac{V_2}{9\,\Omega} = \dfrac{3.113\text{ V}}{9\,\Omega} = \mathbf{0.346\text{ A}\uparrow}$

49. a. $\circ V_1$ $\circ V_2$

$\circ V_3$

At V_1: $\Sigma I_i = \Sigma I_o$

$$0 = 5\text{ A} + \frac{V_1}{2\,\Omega} + \frac{V_1 - V_3}{6\,\Omega}$$

At V_2: $\Sigma I_i = \Sigma I_o$

$$5\text{ A} = 2\text{ A} + \frac{V_2}{4\,\Omega}$$

At V_3: $\Sigma I_i = \Sigma I_o$

$$\frac{V_1 - V_3}{6\,\Omega} + 2\text{ A} + \frac{V_3}{5\,\Omega}$$

Rewritten:

$$V_1\left[\frac{1}{2\,\Omega} + \frac{1}{6\,\Omega}\right] - \frac{1}{6\,\Omega}V_3 = -5\text{ A}$$

$$V_2\left[\frac{1}{4\,\Omega}\right] = 5\text{ A} - 2\text{ A}$$

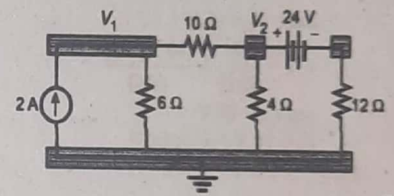
$$V_3\left[\frac{1}{6\,\Omega} + \frac{1}{5\,\Omega}\right] - \frac{1}{6\,\Omega}V_1 = 2\text{A}$$

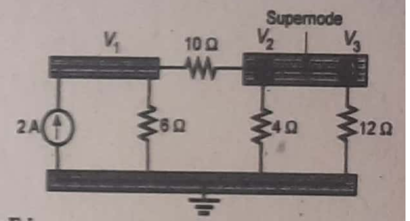
---

b. $\mathbf{V_1 = -6.92\text{ V}, V_2 = 12\text{ V}, V_3 = 2.3\text{ V}}$

c. $I_{4\Omega} = \dfrac{V_1}{4\,\Omega} = \dfrac{12\text{ V}}{4\,\Omega} = \mathbf{3\text{ A}}$

50. a.





$\Sigma I_i = \Sigma I_o$

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:

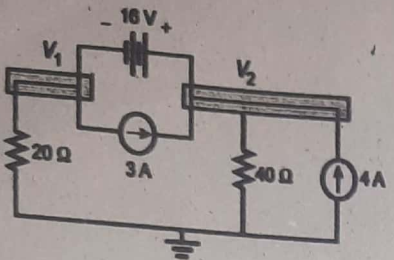
$$\frac{V_1}{6\,\Omega} + \frac{V_1 - V_2}{10\,\Omega} = 2\text{ A}$$

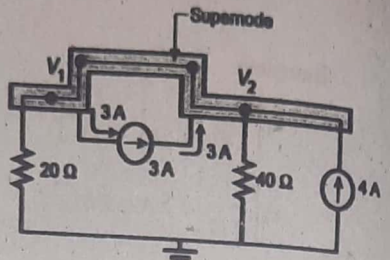
$$\frac{V_2 - V_1}{10\,\Omega} + \frac{V_2}{4\,\Omega} + \frac{V_2 - 24\text{ V}}{12\,\Omega} = 0$$

$0.267V_1 - 0.1V_2 = 2$
$+0.1V_1 - 0.433V_2 = -2$

$\mathbf{V_1 = 10.08\text{ V}, V_2 = 6.94\text{ V}}$
$\mathbf{V_3 = V_2 - 24\text{ V} = -17.06\text{ V}}$

51.





$\Sigma I_i = \Sigma I_o$

Supernode:

$$3\,A + 4\,A = 3\,A + \frac{V_1}{20\,\Omega} + \frac{V_2}{40\,\Omega}$$

2 eq. 2 unk. $\begin{cases} 4\,A = \dfrac{V_1}{20\,\Omega} + \dfrac{V_2}{40\,\Omega} \\ V_2 - V_1 = 16\,V \end{cases}$

Subt. $V_2 = 16\,V + V_1$

$$4\,A = \frac{V_1}{20\,\Omega} + \frac{(16\,V + V_1)}{40\,\Omega}$$

and $V_1 = 48\,V$

$V_2 = 16\,V + V_1 = 64\,V$

52. a. $V_1 \quad V_2$

$$V_1\left[\frac{1}{2}+\frac{1}{8}\right] - V_2\left[\frac{1}{8}\right] = -5$$

$$-V_1\left[\frac{1}{8}\right] + V_2\left[\frac{1}{8}+\frac{1}{4}\right] = -3$$

$V_1 = -10.27\,V,\ V_2 = -11.36\,V$

b. $V_{R_1} = V_1 = -10.27\,V,\ V_{R_2} = V_2 = -11.36\,V$

53. a. $V_1 \quad V_2$

$$V_1\left[\frac{1}{8}+\frac{1}{6}\right] - V_2\left[\frac{1}{6}\right] = -12\,A + 9\,A = -3\,A$$

$$V_2\left[\frac{1}{20}+\frac{1}{5}+\frac{1}{6}\right] - V_1\left[\frac{1}{6}\right] = -9\,A$$

$V_1 = -29.29\,V,\ V_2 = -33.34\,V$

b. $V_1 - V_{6\Omega} - 54\,V - V_2 = 0$

$V_{6\Omega} = V_1 - V_2 - 54\,V = -29.29\,V - (-33.34\,V) - 54\,V = -49.95\,V$

54. a.

$$V_1\left[\frac{1}{9\,\Omega}+\frac{1}{10\,\Omega}\right] - V_2\left[\frac{1}{10\,\Omega}\right] = -2\,A$$

$$V_2\left[\frac{1}{10\,\Omega}+\frac{1}{18\,\Omega}+\frac{1}{4\,\Omega}\right] - V_1\left[\frac{1}{10\,\Omega}\right] = 4\,A$$

b.

$$V_1\left[\frac{1}{9\,\Omega}+\frac{1}{10\,\Omega}\right] - V_2\left[\frac{1}{10\,\Omega}\right] = -2\,A$$

$$-V_1\left[\frac{1}{10\,\Omega}\right] + V_2\left[\frac{1}{10\,\Omega}+\frac{1}{18\,\Omega}+\frac{1}{4\,\Omega}\right] = 4\,A$$

$0.211\,V_1 - 0.1\,V_2 = -2$

$-0.1\,V_1 + .405\,V_2 = 4$

c. $V_1 = -5.43\,V,\ V_2 = 8.53\,V$

d. $I_{4\Omega} = \dfrac{V_2}{4\,\Omega} = \dfrac{8.53\,V}{4\,\Omega} = 2.13\,A\downarrow$

55. a.

$$V_1\left[\frac{1}{2\,\Omega}+\frac{1}{2\,\Omega}\right] - V_2\left[\frac{1}{2\,\Omega}\right] = -5\,A$$

$$V_2\left[\frac{1}{2\,\Omega}+\frac{1}{9\,\Omega}+\frac{1}{7\,\Omega}+\frac{1}{2\,\Omega}\right] - V_1\left[\frac{1}{2\,\Omega}\right] - V_3\left[\frac{1}{2\,\Omega}\right] = 0$$

$$V_3\left[\frac{1}{2\,\Omega}+\frac{1}{2\,\Omega}+\frac{1}{4\,\Omega}\right] - V_2\left[\frac{1}{2\,\Omega}\right] = 0$$

$V_1 = -6.556\,V,\ V_2 = -3.113\,V$

$V_3 = -1.245\,V$

b. $I_{9\Omega} = \dfrac{V_2}{9\,\Omega} = \dfrac{-3.113\,V}{9\,\Omega} = 0.346\,A\uparrow$

56. a.

$$V_1\left[\frac{1}{2\,\Omega}+\frac{1}{6\,\Omega}\right] - \frac{1}{6\,\Omega}V_3 = -5\,A$$

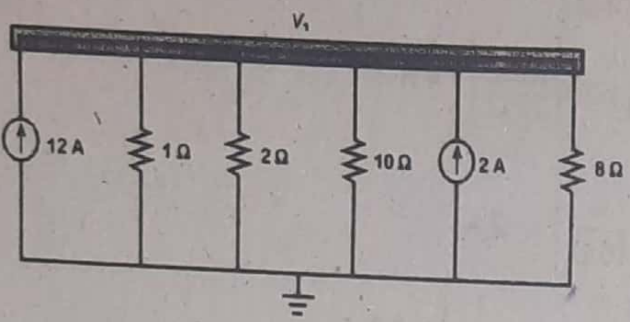
$$V_2\left[\frac{1}{4\,\Omega}\right] = 5\,A - 2\,A$$

$$V_3\left[\frac{1}{6\,\Omega}+\frac{1}{5\,\Omega}\right] - \frac{1}{6\,\Omega}V_1 = 2A$$

b. $V_1 = -6.92\ \text{V}, V_2 = 12\ \text{V}, V_3 = 2.3\ \text{V}$

c. $I_{2\Omega} = \dfrac{V_2}{2\ \Omega} = \dfrac{6.92\ \text{V}}{2\ \Omega} = 3.46\ \text{A}$

57. a.



$$V_1\left[\frac{1}{1\ \Omega} + \frac{1}{2\ \Omega} + \frac{1}{10\ \Omega} + \frac{1}{8\ \Omega}\right] = 14\ \text{A}$$

$$V_1[1.725\ \text{S}] = 14\ \text{A}$$

$$V_1 = \frac{14}{1.725}\text{V}$$

$$= 8.1\ \text{V}$$

b. $V_a = 0\ \text{V}, V_b = 8.12\ \text{V}$

$V_{ab} = V_a - V_b = 0\ \text{V} - 8.12\ \text{V} = -8.12\ \text{V}$

58. a. Same figure used for problem 46.

$V_1 = 0\ \text{V}$

$$V_2\left[\frac{1}{6\ \Omega} + \frac{1}{4\ \Omega} + \frac{1}{5\ \Omega}\right] - \frac{1}{6\ \Omega}V_1 = -3\ \text{A}$$

b. $V_1 = 0\ \text{V}$

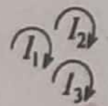
$\therefore\ V_2[0.617\ \text{S}] = -3\ \text{A}$

$$V_2 = \frac{-3}{0.617}\text{V}$$

$$= -4.86\ \text{V}$$

c. $I_{5\Omega} = \dfrac{V_2}{5\ \Omega} = \dfrac{4.86\ \text{V}}{5\ \Omega} = .972\ \text{A}$

59. a.



$$I_1(6\ \Omega + 2\ \Omega + 10\ \Omega) - 2\ \Omega I_2 - 10\ \Omega I_3 = 12\ \text{V}$$
$$I_2(2\ \Omega + 2\ \Omega + 5\ \Omega) - 5\ \Omega I_3 - 2\ \Omega I_1 = 0$$
$$I_3(5\ \Omega + 20\ \Omega + 10\ \Omega) - 5\ \Omega I_2 - 10\ \Omega I_1 = 0$$

$$18I_1 - 2I_2 - 10I_3 = 12$$
$$-2I_1 + 9I_2 - 5I_3 = 0$$
$$-10I_1 - 5I_2 + 35I_3 = 0$$

62. a. V_1 V_2 V_3

$$V_1\left[\frac{1}{2\text{ k}\Omega}+\frac{1}{33\text{ k}\Omega}+\frac{1}{56\text{ k}\Omega}\right]-\frac{1}{33\text{ k}\Omega}V_2-\frac{1}{56\text{ k}\Omega}V_3=12\text{ mA}$$
$$V_2\left[\frac{1}{33\text{ k}\Omega}+\frac{1}{3.3\text{ k}\Omega}+\frac{1}{36\text{ k}\Omega}\right]-\frac{1}{33\text{ k}\Omega}V_1-\frac{1}{36\text{ k}\Omega}V_3=0$$
$$V_3\left[\frac{1}{56\text{ k}\Omega}+\frac{1}{36\text{ k}\Omega}+\frac{1}{5.6\text{ k}\Omega}\right]-\frac{1}{36\text{ k}\Omega}V_2-\frac{1}{56\text{ k}\Omega}V_1=0$$

Rewritten: $548.16V_1-30.3V_2-17.86V_3=12\times 10^3$
$-30.3V_1+361.11V_1-27.78V_3=0$
$-17.86V_1-27.78V_2+224.21V_3=0$

$V_2=2.01\text{ V}, V_3=2.01\text{ V}$

b. $V_{R_5}=V_2-V_3=2.01\text{ V}-2.01\text{ V}=0\text{ V}$

c, d. yes

63. Mesh Analysis

I_1 I_2 I_3

$(1\text{ k}\Omega+2\text{ k}\Omega+2\text{ k}\Omega)I_1-2\text{ k}\Omega\, I_2-2\text{ k}\Omega\, I_3=10$
$(2\text{ k}\Omega+2\text{ k}\Omega+2\text{ k}\Omega)I_2-2\text{ k}\Omega\, I_1-2\text{ k}\Omega\, I_3=0$
$(2\text{ k}\Omega+2\text{ k}\Omega+2\text{ k}\Omega)I_3-2\text{ k}\Omega\, I_1-2\text{ k}\Omega\, I_2=0$

$I_1=I_{10V}=3.33\text{ mA}$

Nodal Analysis:

Source conversion: $I=10\text{ V}/1\text{ k}\Omega=10\text{ mA}$, 1 kΩ

V_1 V_2 V_3

$$V_1\left[\frac{1}{1\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}\right]-\frac{1}{2\text{ k}\Omega}V_2-\frac{1}{2\text{ k}\Omega}V_3=10\text{ mA}$$
$$V_2\left[\frac{1}{2\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}\right]-\frac{1}{2\text{ k}\Omega}V_1-\frac{1}{2\text{ k}\Omega}V_3=0$$
$$V_3\left[\frac{1}{2\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}+\frac{1}{2\text{ k}\Omega}\right]-\frac{1}{2\text{ k}\Omega}V_2-\frac{1}{2\text{ k}\Omega}V_1=0$$

$V_1=6.67\text{ V}=E-IR_s=10\text{ V}-I(1\text{ k}\Omega)$

$$I=\frac{10-6.67\text{ V}}{1\text{ k}\Omega}=3.33\text{ mA}$$

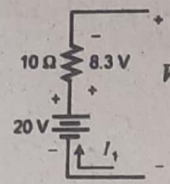
64. Mesh Analysis

Source conversion: $E=20\text{ V}, R=10\ \Omega$

I_1 I_2 I_3

$(10+10+20)I_1-10I_2-20I_3=20$
$(10+20+20)I_2-10I_1-20I_3=0$
$(20+20+10)I_3-20I_1-20I_2=0$

$I_1=I_{20V}=0.83\text{ A}$



$V=20\text{ V}-8.3\text{ V}$
$=11.7\text{ V}$

$$I_s=\frac{V}{R_s}=\frac{11.70\text{ V}}{10\Omega}=1.17\text{A}$$

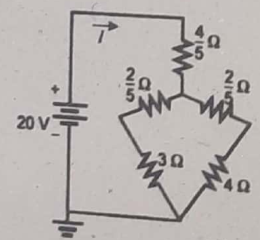
Nodal Analysis:

V_1 V_2 V_3

$$V_1\left[\frac{1}{10}+\frac{1}{10}+\frac{1}{20}\right]-\left[\frac{1}{20}\right]V_2-\left[\frac{1}{10}\right]V_3=2$$
$$V_2\left[\frac{1}{20}+\frac{1}{20}+\frac{1}{10}\right]-\left[\frac{1}{20}\right]V_1-\left[\frac{1}{20}\right]V_3=0$$
$$V_3\left[\frac{1}{10}+\frac{1}{20}+\frac{1}{20}\right]-\left[\frac{1}{10}\right]V_1-\left[\frac{1}{20}\right]V_2=0$$

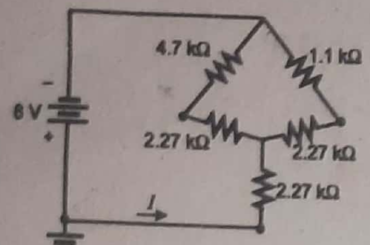
$$I_{R_s}=\frac{V_1}{R_s}=1.17\text{ A}$$

65.



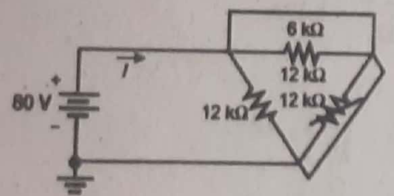
$$I=\frac{20\text{ V}}{\frac{4}{5}\Omega+\left[\frac{2}{5}\Omega+3\ \Omega\right]\|\left[\frac{2}{5}\Omega+4\ \Omega\right]}$$
$$=\frac{20\text{ V}}{\frac{4}{5}\Omega+(3.14\ \Omega)\|(4.4\ \Omega)}$$
$=7.36\text{ A}$

66.



$$R_T = 2.27\ k\Omega + [4.7\ k\Omega + 2.27\ k\Omega] \| [1.1\ k\Omega + 2.27\ k\Omega]$$
$$= 2.27\ k\Omega + [6.97\ k\Omega] \| [3.37\ k\Omega]$$
$$= 2.27\ k\Omega + 2.27\ k\Omega$$
$$= 4.54\ k\Omega$$
$$I = \frac{8\ V}{4.54\ k\Omega} = 1.76\ mA$$

67.



(Y-Δ conversion)

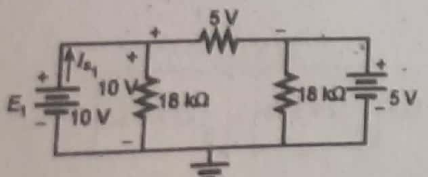
$$I = \frac{80\ V}{12\ k\Omega \| 12\ k\Omega \| 6\ k\Omega} = \frac{80\ V}{3\ k\Omega}$$
$$= 26.67\ mA$$

68. a. $$I = \frac{42\ V}{(18\ \Omega \| 18\ \Omega) \| [(18\ \Omega \| 18\ \Omega) + (18\ \Omega \| 18\ \Omega)]} = \frac{42\ V}{9\ \Omega \| [9\ \Omega + 9\ \Omega]}$$

$= 7\ A$ (Y–Δ conversion)

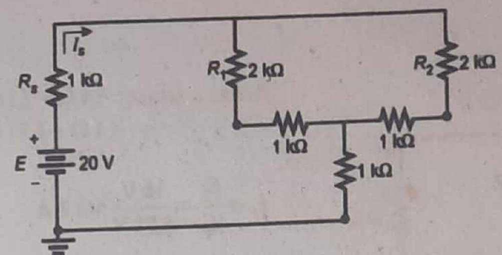
b. Δ – Y conversion

69.



$$I_s = \frac{10\ V}{18\ k\Omega} + \frac{5\ V}{18\ k\Omega} = \frac{15\ V}{18\ k\Omega} = 0.83\ mA$$

70. a.



b. $R' = R_1 + 1\ k\Omega = 3\ k\Omega$

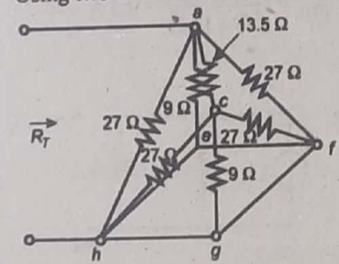
$R'' = R_2 + 1\ k\Omega = 3\ k\Omega$

$$R'_T = \frac{3\ k\Omega}{2} = 1.5\ k\Omega$$

$R_T = 1\ k\Omega + 1.5\ k\Omega + 1\ k\Omega = 3.5\ k\Omega$

$$I_s = \frac{E}{R_T} = \frac{20\ V}{3.5\ k\Omega} = 5.71\ mA$$

71. Using two Δ – Y conversions:



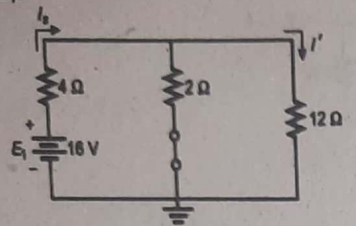
c – g: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

a – h: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

$R_T = 5.4\ \Omega \| (13.5\ \Omega + 5.4\ \Omega)$
$= 5.4\ \Omega \| 18.9\Omega$
$= 4.2\ \Omega$

Chapter 9

1\. a. E_1:

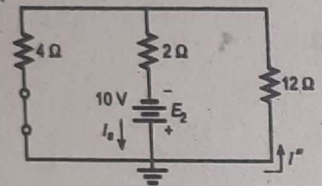


R_T (from source) $= 4\,\Omega + 2\,\Omega \parallel 12\,\Omega$
$= 4\,\Omega + 1.71\,\Omega$
$= 5.71\,\Omega$

$$I_s = \frac{E_1}{R_T} = \frac{16\text{ V}}{5.71\text{ V}} = 2.8\text{ A}$$

$$I'_{12\Omega} = \frac{2\,\Omega(2.8\text{ A})}{2\,\Omega + 12\,\Omega} = 0.4\text{ A}$$

E_2:



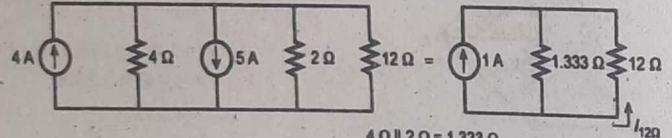
R_T (from source) $= 2\,\Omega + 4\,\Omega \parallel 12\,\Omega$
$= 2\,\Omega + 3\,\Omega$
$= 5\,\Omega$

$$I_S = \frac{E_2}{R_T} = \frac{10\text{ V}}{5\,\Omega} = 2\text{ A}$$

$$I''_{12\Omega} = \frac{4\,\Omega(2\text{ A})}{4\,\Omega + 12\,\Omega} = 0.5\text{ A}$$

$I_{12\Omega}\uparrow = 0.5\text{ A} - 0.4\text{ A} = \mathbf{0.1\text{ A}}$

b.

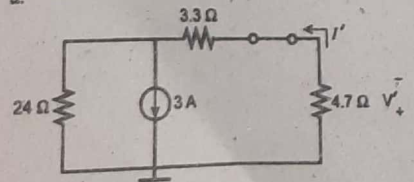


$4\,\Omega \parallel 2\,\Omega = 1.333\,\Omega$

$$I_{12\Omega} = \frac{1.333\,\Omega(1\text{ A})}{1.333\,\Omega + 12\,\Omega} = \mathbf{0.1\text{ A}}$$

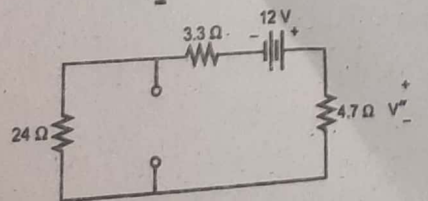
c. the same

2\. a.



$$I' = \frac{24\,\Omega(3\text{ A})}{24\,\Omega + 8\,\Omega} = 2.25\text{ A}$$

$V' = I'R = (2.25)(4.7\,\Omega) = 10.575\text{ V}$



$$V'' = \frac{4.7\,\Omega(12\text{ V})}{4.7\,\Omega + 3.3\,\Omega + 24\,\Omega} = 1.763\text{ V}$$

$V_{+}^{-} = 10.575\text{ V} - 1.763\text{ V} = \mathbf{8.81\text{ V}}$

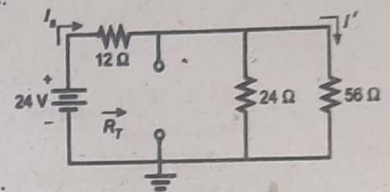
b. $$P = \frac{V'^2}{R} = \frac{(10.575\text{ V})^2}{4.7\,\Omega} = \mathbf{23.79\text{ W}}$$

c. $$P = \frac{V''^2}{R} = \frac{(1.763\text{ V})^2}{4.7\,\Omega} = \mathbf{0.661\text{ W}}$$

d. $$P = \frac{V^2}{R} = \frac{(8.81\text{ V})^2}{4.7\,\Omega} = \mathbf{16.51\text{ W}}$$

e. $23.79\text{ W} + 0.661\text{ W} \neq 16.51\text{ W}$
$24.45\text{ W} \neq 16.51\text{ W}$

3\. E:

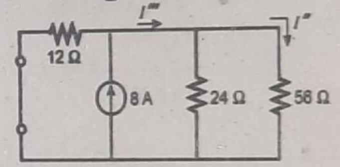


$R_T = 12\,\Omega + 24\,\Omega \parallel 56\,\Omega = 28.8\,\Omega$

$$I_s = \frac{E}{R_T} = \frac{24\text{ V}}{28.8\,\Omega} = 0.833\text{ A}$$

$$I'_{56\Omega} = \frac{24\,\Omega(0.833\text{ A})}{24\,\Omega + 56\,\Omega} = 0.25\text{ A}$$

I:



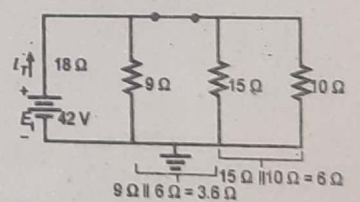
$24\,\Omega \parallel 56\,\Omega = 16.8\,\Omega$

$$I''' = \frac{12\,\Omega(8\text{ A})}{12\,\Omega + 16.8\,\Omega} = 3.33\text{ A}$$

$$I''_{56\Omega} = \frac{24\,\Omega(3.33\text{ A})}{24\,\Omega + 56\,\Omega} = 1\text{ A}$$

$I_{56\Omega} = I' + I'' = 0.25\text{ A} + 1\text{ A} = \mathbf{1.25\text{ A}}\downarrow$

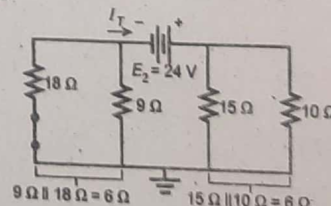
4\. E_1:



$$I_T = \frac{42\text{ V}}{18\,\Omega + 3.6\,\Omega} = 1.944\text{ A}$$

$$I_1 = \frac{9\,\Omega(I_T)}{9\,\Omega + 6\,\Omega} = \frac{9\,\Omega(1.944\text{ A})}{15\,\Omega}$$
$= 1.17\text{ A}$

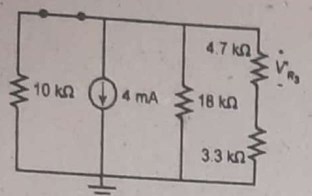
E_2:

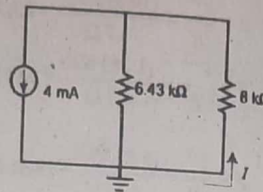


$$I_T = \frac{E_2}{R_T} = \frac{24\text{ V}}{12\,\Omega} = 2\text{ A}$$

$I_{24\text{V}} = I_T + I_1 = 2\text{ A} + 1.17\text{ A} = \mathbf{3.17\text{ A}}$ **(dir. of I_1)**

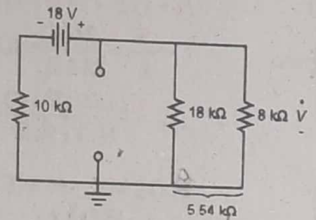
5. I:





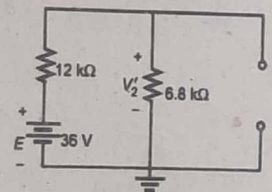
$$I = \frac{6.43\ k\Omega(4\ mA)}{6.43\ k\Omega + 8\ k\Omega} = 1.78\ mA$$
$$V'_{R_3} = -IR_3 = -(1.78\ mA)(4.7\ k\Omega)$$
$$V'_{R_3} = -8.37\ V$$

E:



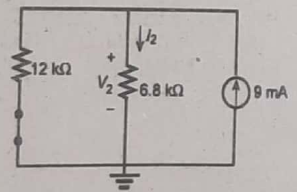
$$V = \frac{5.54\ k\Omega(18\ V)}{5.54\ k\Omega + 10\ k\Omega} = 6.42\ V$$
$$V''_{R_3} = \frac{4.7\ k\Omega(6.42\ V)}{4.7\ k\Omega + 3.3\ k\Omega} = 3.77\ V$$
$$V_{R_3} = V'_{R_3} + V''_{R_3} = -8.37\ V + 3.77\ V = -4.6\ V$$

6. E:



$$V'_2 = \frac{6.8\ k\Omega(36\ V)}{6.8\ k\Omega + 12\ k\Omega} = 13.02\ V$$

I:

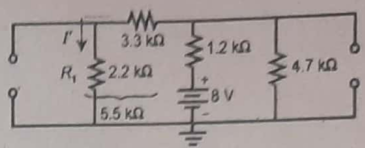


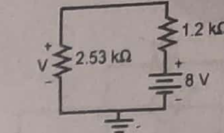
$$I_2 = \frac{12\ k\Omega(9\ mA)}{12\ k\Omega + 6.8\ k\Omega} = 5.75\ mA$$

$$V''_2 = I_2R_2 = (5.75\ mA)(6.8\ k\Omega) = 39.10\ V$$
$$V_2 = V'_2 + V''_2 = 13.02\ V + 39.10\ V = \mathbf{52.12\ V}$$

BP-7-

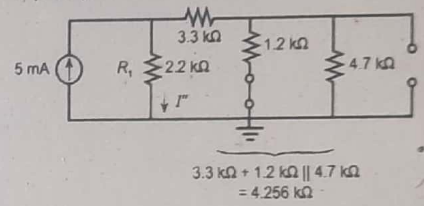
7. E:





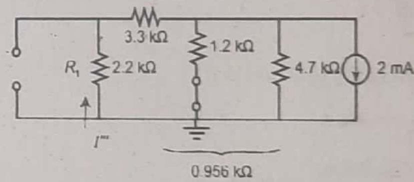
$$5.5\ k\Omega \parallel 4.7\ k\Omega = 2.53\ k\Omega$$
$$V = \frac{2.53\ k\Omega(8\ V)}{2.53\ k\Omega + 1.2\ k\Omega} = 5.43\ V$$
$$I' = \frac{V}{R_1 + R_2} = \frac{5.43\ V}{5.5\ k\Omega} = 0.987\ mA$$

I (5 mA):



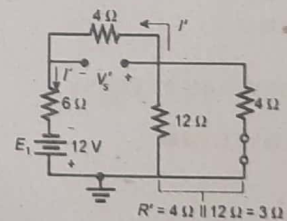
$$I'' = \frac{4.256\ k\Omega(5\ mA)}{4.256\ k\Omega + 2.2\ k\Omega} = 3.296\ mA$$

I (2 mA):



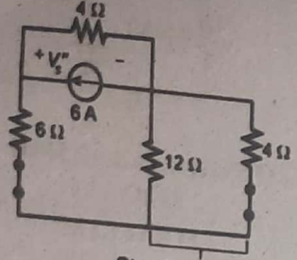
$$I''' = \frac{0.956\ k\Omega(2\ mA)}{0.956\ k\Omega + 5.5\ k\Omega} = 0.296\ mA$$
$$I_{R_1} = I' + I'' - I'''$$
$$= 0.987\ mA + 3.296\ mA - 0.296\ mA$$
$$= 3.99\ mA\downarrow$$

8. E_1:

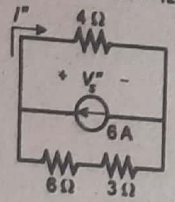


$$I' = \frac{12\ V}{12\ \Omega \parallel 4\ \Omega + 4\ \Omega + 6\ \Omega} = \frac{12\ V}{3\ \Omega + 10\ \Omega} = \frac{12\ V}{13\ \Omega} = 923.1\ mA$$
$$V'_s = IR = (923.1\ mA)(4\ \Omega) = 2.492\ V$$

I:



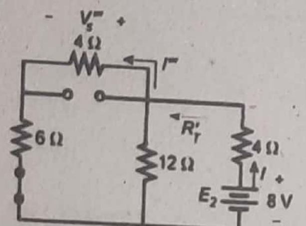
$R' = 12\,\Omega \parallel 4\,\Omega = 3\,\Omega$



$$I'' = \frac{9\,\Omega(6\text{ A})}{9\,\Omega + 4\,\Omega} = 4.154\text{ A}$$

$$V_s'' = I''4\Omega = (4.154\text{ A})(4\,\Omega) = 16.62\text{ V}$$

E_2:



$$R_T' = 12\,\Omega \parallel (4\,\Omega + 6\,\Omega) = 12\,\Omega \parallel 10\,\Omega = 5.455\,\Omega$$

$$I = \frac{E_2}{R_T} = \frac{8\text{ V}}{4\,\Omega + 5.455\,\Omega} = 0.846\text{ A}$$

$$I''' = \frac{12\,\Omega(I)}{12\,\Omega + 10\,\Omega} = \frac{12\,\Omega(0.846\text{ A})}{22\,\Omega} = 0.462\text{ A}$$

$$V_s''' = I'''(4\,\Omega) = 0.462\text{ A}(4\,\Omega) = 1.848\text{ V}$$

$$V_s\text{ (polarity of } V_s'') = V_s'' - V_s' - V_s'''$$

$$= 16.62\text{ V} - 2.492\text{ V} - 1.848\text{ V} = \mathbf{12.28\text{ V}}$$

9. a. $R_{Th} = R_3 + R_1 \parallel R_2 = 4\,\Omega + 6\,\Omega \parallel 3\,\Omega = 4\,\Omega + 2\,\Omega = 6\,\Omega$

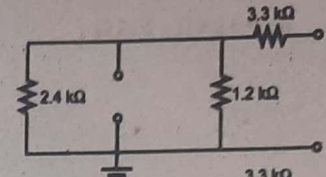
$$E_{Th} = \frac{R_2E}{R_1 + R_2} = \frac{3\,\Omega(18\text{ V})}{3\,\Omega + 6\,\Omega} = 6\text{ V}$$

b. $$I_1 = \frac{E_{Th}}{R_{Th} + R} = \frac{6\text{ V}}{6\,\Omega + 2\,\Omega} = 0.75\text{ A}$$

$$I_2 = \frac{6\text{ V}}{6\,\Omega + 30\,\Omega} = 166.67\text{ mA}$$

$$I_3 = \frac{6\text{ V}}{6\,\Omega + 100\,\Omega} = 56.60\text{ mA}$$

10. a. R_{Th}:

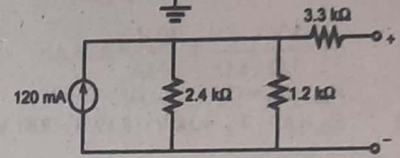


$\leftarrow R_{Th} = 3.3\text{ k}\Omega + 1.2\text{ k}\Omega \parallel 2.4\text{ k}\Omega$

$= 3.3\text{ k}\Omega + 0.8\text{ k}\Omega$

$= \mathbf{4.1\text{ k}\Omega}$

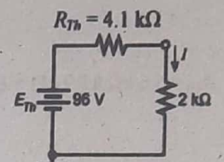
E_{Th}:



$E_{Th} = (120\text{ mA})(2.4\text{ k}\Omega \parallel 1.2\text{ k}\Omega)$

$= \mathbf{96\text{ V}}$

b.



$$I = \frac{96\text{ V}}{6.1\text{ k}\Omega} = 15.74\text{ mA}$$

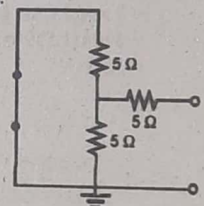
$$P = I^2R = (15.74\text{ mA})^2\,2\text{ k}\Omega = \mathbf{0.495\text{ W}}$$

$R = 100\text{ k}\Omega$:

$$I = \frac{96\text{ V}}{104.1\text{ k}\Omega} = 0.922\text{ mA}$$

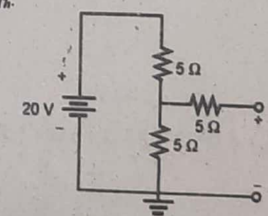
$$P = I^2R = (0.922\text{ mA})^2\,100\text{ k}\Omega = \mathbf{85\text{ mW}}$$

11. a. R_{Th}:



$\leftarrow R_{Th} = 5\,\Omega + 5\,\Omega \parallel 5\,\Omega = \mathbf{7.5\,\Omega}$

E_{Th}:

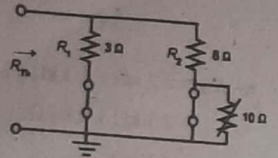


$$E_{Th} = \frac{20\text{ V}}{2} = 10\text{ V}$$

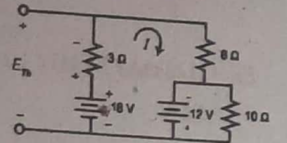
b. $$R = 2\,\Omega:\ P = \left(\frac{E_{Th}}{R_{Th} + R}\right)^2 R = \left(\frac{10\text{ V}}{7.5\,\Omega + 2\,\Omega}\right)^2 2\,\Omega = \mathbf{2.22\text{ W}}$$

$$R = 100\,\Omega:\ P = \left(\frac{10\text{ V}}{7.5\,\Omega + 100\,\Omega}\right)^2 100\,\Omega = \mathbf{0.87\text{ W}}$$

12.



$R_{Th} = 3 \parallel 8\,\Omega = \mathbf{2.18\,\Omega}$

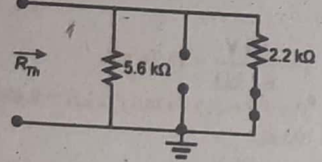


$I = \dfrac{18\text{ V} + 12\text{ V}}{3\,\Omega + 8\,\Omega} = \dfrac{30\text{ V}}{11\,\Omega} = 2.73\text{ A}$

$V_{3\Omega} = IR_1 = (2.73\text{ A})(3\,\Omega) = 8.19\text{ V}$

$E_{Th} = E_1 - V_{R_1} = 18\text{ V} - 8.19\text{ V} = \mathbf{9.81\text{ V}}$

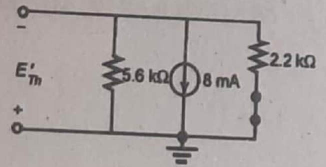
13. R_{Th}:



$R_{Th} = 5.6\text{ k}\Omega \parallel 2.2\text{ k}\Omega = \mathbf{1.58\text{ k}\Omega}$

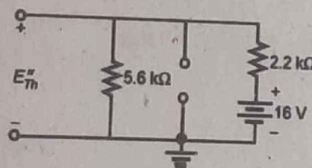
E_{Th}: Superposition:

I:



$E'_{Th} = IR_T$
$= 8\text{ mA}(5.6\text{ k}\Omega \parallel 2.2\text{ k}\Omega)$
$= 8\text{ mA}(1.579\text{ k}\Omega)$
$= 12.64\text{ V}$

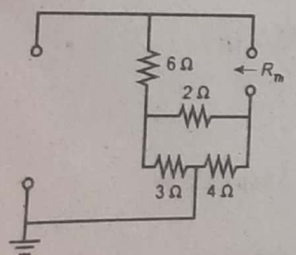
E:



$E''_{Th} = \dfrac{5.6\text{ k}\Omega(16\text{ V})}{5.6\text{ k}\Omega + 2.2\text{ k}\Omega}$
$= 11.49\text{ V}$

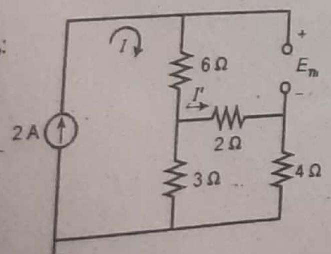
$E_{Th} = 11.49\text{ V} - 12.64\text{ V} = \mathbf{-1.15\text{ V}}$

14. R_{Th}:



$R_{Th} = 6\,\Omega + 2\,\Omega \parallel 7\,\Omega = 6\,\Omega + 1.56\,\Omega = \mathbf{7.56\,\Omega}$

E_{Th}:



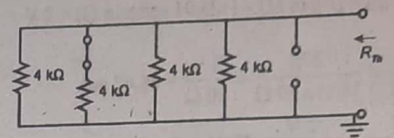
$I = 2\text{ A}$

$I' = \dfrac{3\,\Omega(2\text{ A})}{3\,\Omega + 6\,\Omega} = 0.667\text{ A}$

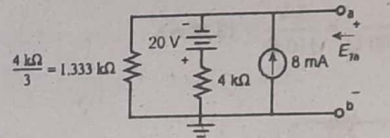
$V_{2\Omega} = I'R = (0.667\text{ A})(2\,\Omega) = 1.333\text{ V}$

$E_{Th} = I6\,\Omega + V_{2\Omega} = (2\text{ A})(6\,\Omega) + 1.333\text{ V}$
$= 12\text{ V} + 1.333\text{ V} = \mathbf{13.33\text{ V}}$

15. a. R_{Th}:

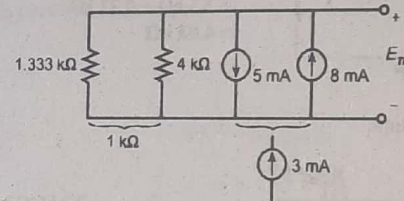


$R_{Th} = \dfrac{4\text{ k}\Omega}{4} = \mathbf{1\text{ k}\Omega}$



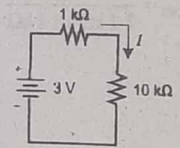
Source conversion:

$I = \dfrac{20\text{ V}}{4\text{ k}\Omega} = 5\text{ mA},\ R_p = 4\text{ k}\Omega$



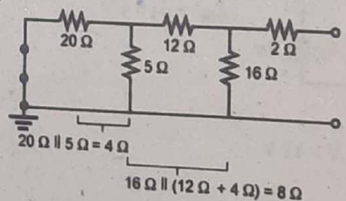
$E_{Th} = I_T R_T = (3\text{ mA})(1\text{ k}\Omega) = \mathbf{3\text{ V}}$

b.



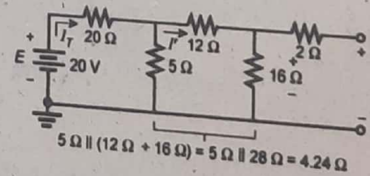
$I_{10k\Omega} = \dfrac{3\text{ V}}{1\text{ k}\Omega + 10\text{ k}\Omega} = \dfrac{3\text{ V}}{11\text{ k}\Omega} = \mathbf{0.273\text{ mA}}$

16. a. R_{Th}:



$\leftarrow R_{Th} = 2\,\Omega + 8\,\Omega = \mathbf{10\,\Omega}$

E_{Th}:



$E_{Th} = V_{16\Omega}$

$$I_T = \frac{20\text{ V}}{20\,\Omega + 4.24\,\Omega} = 825.08\text{ mA}$$

$$I' = \frac{5\,\Omega(I_T)}{5\,\Omega + 28\,\Omega} = \frac{5\,\Omega(825.08\text{ mA})}{33\,\Omega} = 125.01\text{ mA}$$

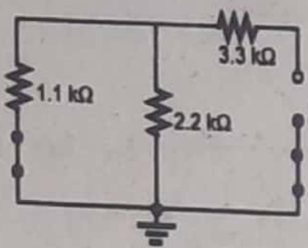
$$E_{Th} = V_{16\Omega} = (I')(16\,\Omega) = (125.01\text{ mA})(16\,\Omega) = \mathbf{2\text{ V}}$$

b. 20 Ω: $I = \dfrac{E_{Th}}{R_{Th} + R} = \dfrac{2\text{ V}}{10\,\Omega + 20\,\Omega} = \dfrac{2\text{ V}}{30\,\Omega} = \mathbf{66.67\text{ mA}}$

50 Ω: $I = \dfrac{2\text{ V}}{10\,\Omega + 50\,\Omega} = \dfrac{2\text{ V}}{60\,\Omega} = \mathbf{33.33\text{ mA}}$

100 Ω: $I = \dfrac{2\text{ V}}{10\,\Omega + 100\,\Omega} = \dfrac{2\text{ V}}{110\,\Omega} = \mathbf{18.18\text{ mA}}$

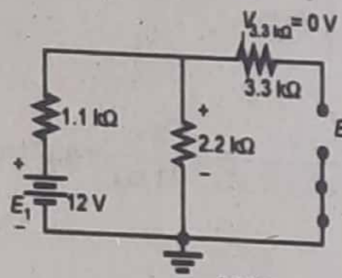
17. a. R_{Th}:



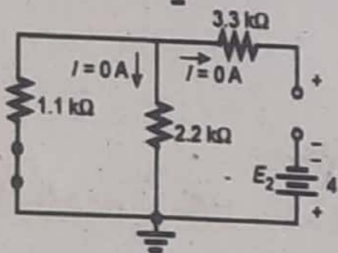
$\leftarrow R_{Th} = 3.3\text{ k}\Omega + 2.2\text{ k}\Omega \parallel 1.1\text{ k}\Omega$
$= 3.3\text{ k}\Omega + 0.73\text{ k}\Omega$
$= \mathbf{4.03\text{ k}\Omega}$

E_{Th}: Superposition:

E_1:



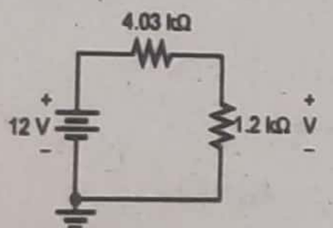
$$E'_{Th} = V_{2.2k\Omega} = \frac{2.2\text{ k}\Omega(12\text{ V})}{2.2\text{ k}\Omega + 1.1\text{ k}\Omega} = 8\text{ V}$$



$$E''_{Th} = E_2 = 4\text{ V}$$

$$E_{Th} = E'_{Th} + E''_{Th} = 8\text{ V} + 4\text{ V} = \mathbf{12\text{ V}}$$

b.



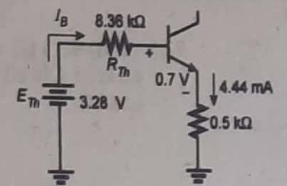
b. $I_E R_E + V_{CE} + I_C R_C = 20\text{ V}$

but $I_C = I_E$

and $I_E(R_C + R_E) + V_{CE} = 20\text{ V}$

$$\text{or } I_E = \frac{20\text{ V} - V_{CE}}{R_C + R_E} = \frac{20\text{ V} - 8\text{ V}}{2.2\text{ k}\Omega + 0.5\text{ k}\Omega} = \frac{12\text{ V}}{2.7\text{ k}\Omega} = \mathbf{4.44\text{ mA}}$$

c.



$E_{Th} - I_B R_{Th} - V_{BE} - V_E = 0$

$$\text{and } I_B = \frac{E_{Th} - V_{BE} - V_E}{R_{Th}} = \frac{3.28\text{ V} - 0.7\text{ V} - (4.44\text{ mA})(0.5\text{ k}\Omega)}{8.36\text{ k}\Omega}$$

$$= \frac{2.58\text{ V} - 2.22\text{ V}}{8.36\text{ k}\Omega} = \frac{0.36\text{ V}}{8.36\text{ k}\Omega} = \mathbf{43.06\ \mu A}$$

d. $V_C = 20\text{ V} - I_C R_C = 20\text{ V} - (4.44\text{ mA})(2.2\text{ k}\Omega)$

$= 20\text{ V} - 9.77\text{ V}$

$= \mathbf{10.23\text{ V}}$

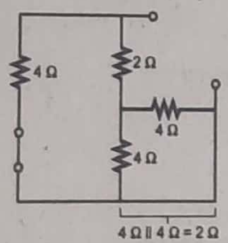
20. a. $E_{Th} = \mathbf{20\text{ V}}$

$$I = 1.6\text{ mA} = \frac{E_{Th}}{R_{Th}} = \frac{20\text{ V}}{R_{Th}}, R_{Th} = \frac{20\text{ V}}{1.6\text{ mA}} = \mathbf{12.5\text{ k}\Omega}$$

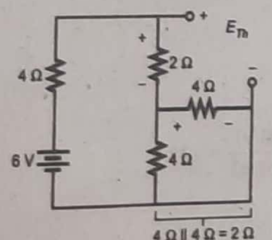
b. $E_{Th} = \mathbf{60\text{ mV}}, R_{Th} = \mathbf{2.72\text{ k}\Omega}$

c. $E_{Th} = \mathbf{16\text{ V}}, R_{Th} = \mathbf{2.2\text{ k}\Omega}$

21.



$$R_{Th} = 4\ \Omega \parallel (2\ \Omega + 2\ \Omega) = \frac{4\ \Omega}{2} = \mathbf{2\ \Omega}$$

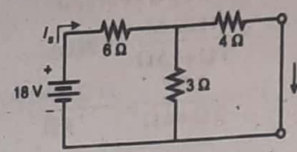


$$V_{4\Omega} = \frac{2\ \Omega(6\text{ V})}{2\ \Omega + 4\ \Omega + 2\ \Omega} = \frac{12\text{ V}}{8\ \Omega} = 1.5\text{ V}$$

$V_{2\Omega} = V_{4\Omega} = 1.5\text{ V}$

$E_{Th} = V_{4\Omega} + V_{2\Omega} = 1.5\text{ V} + 1.5\text{ V} = \mathbf{3\text{ V}}$

22. a. From Problem 9, $R_N = R_{Th} = \mathbf{6\ \Omega}$



$R_T = 6\ \Omega + 3\ \Omega \parallel 4\ \Omega$

$= 6\ \Omega + 1.714\ \Omega = 7.714\ \Omega$

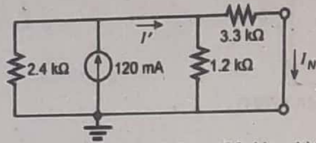
$$I_s = \frac{E}{R_T} = \frac{18\text{ V}}{7.714\ \Omega} = 2.333\text{ A}$$

$$I_N = \frac{3\ \Omega(2.333\text{ A})}{3\ \Omega + 4\ \Omega} = \mathbf{1\text{ A}}$$

b. $R_{Th} = \mathbf{6\ \Omega}, E_{Th} = I_N R_N = (1\text{ A})(6\ \Omega) = \mathbf{6\text{ V}}$

c. same results

23. a. From Problem 10, $R_N = R_{Th} = \mathbf{4.1\text{ k}\Omega}$



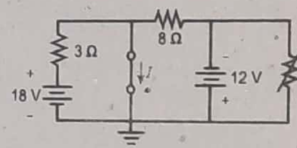
$$I' = \frac{2.4\text{ k}\Omega(120\text{ mA})}{2.4\text{ k}\Omega + (1.2\text{ k}\Omega \parallel 3.3\text{ k}\Omega)} = 87.80\text{ mA}$$

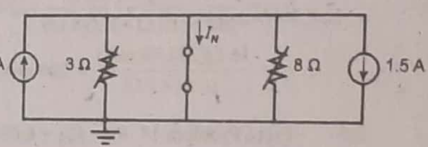
$$I_N = \frac{1.2\text{ k}\Omega(87.80\text{ mA})}{1.2\text{ k}\Omega + 3.3\text{ k}\Omega} = 23.41\text{ mA}$$

b. $R_{Th} = \mathbf{4.1\text{ k}\Omega}, E_{Th} = I_N R_N = (23.41\text{ mA})(4.1\text{ k}\Omega) = \mathbf{96\text{ V}}$

c. same results.

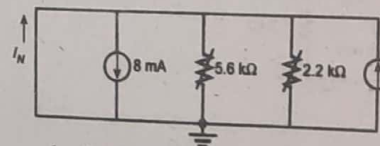
24. From Problem 12, $R_N = R_{Th} = \mathbf{2.18\ \Omega}$





$I_N = 6\text{ A} - 1.5\text{ A} = \mathbf{4.5\text{ A}}$

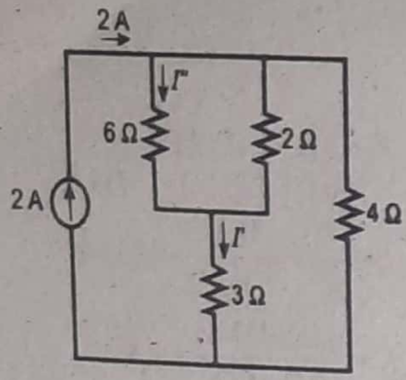
25. From Problem 13, $R_N = R_{Th} = \mathbf{1.58\text{ k}\Omega}$



$$\frac{16\text{ V}}{2.2\text{ k}\Omega} = 7.27\text{ mA}$$

$I_N = 8\text{ mA} - 7.27\text{ mA} = \mathbf{0.73\text{ mA}}$

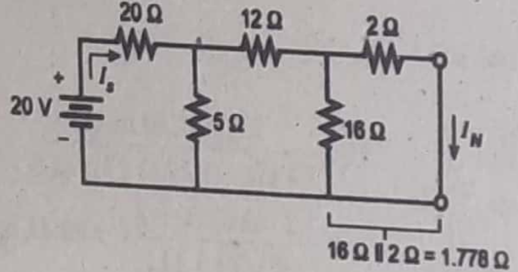
26. From Problem 14, $R_N = R_{Th} = \mathbf{7.56\ \Omega}$



$$I' = \frac{4\,\Omega(2\text{ A})}{4\,\Omega + 3\,\Omega + 6\,\Omega \parallel 2\Omega}$$
$$= \frac{4\,\Omega(2\text{ A})}{7\,\Omega + 1.5\,\Omega} = 0.941\text{ A}$$
$$I'' = \frac{2\,\Omega I'}{2\,\Omega + 6\,\Omega} = \frac{12\,\Omega(0.941\text{ A})}{8\,\Omega} = 0.235\text{ A}$$

$I_N = 2\text{ A} - I''$
$= 2\text{ A} - 0.235\text{ A}$
$= \mathbf{1.765\text{ A}}$

27. From Problem 16, $R_N = R_{Th} = \mathbf{10\ \Omega}$



$R_T = 20\,\Omega + 5\,\Omega \parallel (12\,\Omega + 1.778\,\Omega) = 23.67\,\Omega$

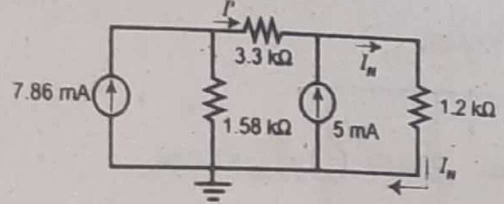
$$I_s = \frac{E_T}{R_T} = \frac{20\text{ V}}{23.67\,\Omega} = 844.95\text{ mA}$$

$$I_{12\Omega} = \frac{5\,\Omega(844.95\text{ mA})}{5\Omega + (12\,\Omega + 1.778\,\Omega)} = 224.98\text{ mA}$$

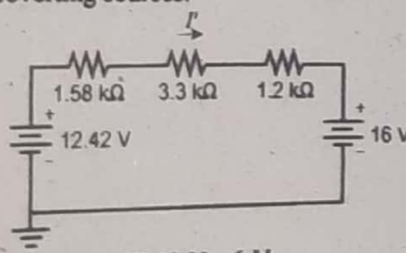
$$I_N = \frac{16\,\Omega(224.98\text{ mA})}{16\,\Omega + 2\,\Omega} = \mathbf{200\text{ mA}}$$

28. From Problem 18, $R_N = R_{Th} = \mathbf{6.08\text{ k}\Omega}$

I_N: Starting with figure from problem 18:



and coverting sources:



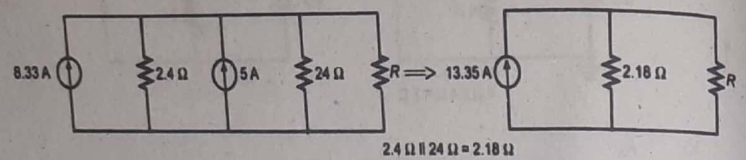
$$I' = \frac{12.42\text{ V} - 6\text{ V}}{1.58\text{ k}\Omega + 3.3\text{ k}\Omega + 1.2\text{ k}\Omega} = 1.06\text{ mA}$$

34. a. $R = R_{Th} = 6.08\ k\Omega$ from Problem 18

b. $E_{Th} = 36.8\ V$ from Problem 18

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(36.8\ V)^2}{4(6.08\ k\Omega)} = \mathbf{55.51\ mW}$$

35. a.



$R = R_N = R_{Th} = \mathbf{2.18\ \Omega}$

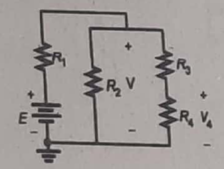
b. $$P_{max} = \frac{I_N^2 R_N}{4} = \frac{(13.33\ A)^2 2.18\ \Omega}{4} = \mathbf{96.84\ W}$$

36. $$P_{max} = \left[\frac{E_{Th}}{R_{Th} + R_4}\right]^2 R_4$$

with $R_1 = 0\ \Omega$, E_{Th} is a maximum and R_{Th} is a minimum.

$\therefore R_1 = \mathbf{0\ \Omega}$

37. 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 ($\infty\ \Omega$) and

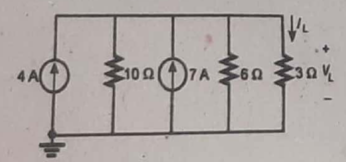
$$P_4 = \frac{V_4^2}{R_4} \text{ will be a maximum.}$$

b. No, examine each individually.

38. The voltage V_L across R_L will be a maximum when R of the potentiometer = **500 Ω** because the full voltage, E, will appear across R_L.

$$P_{max} = \frac{V_L^2}{R_L} = \frac{E^2}{R_L} = \frac{(12\ V)^2}{500\ \Omega} = \mathbf{1.44\ W}$$

39.



$I_T \uparrow = 4\ A + 7\ A = 11\ A$

$R_T = 10\ \Omega \parallel 6\ \Omega \parallel 3\ \Omega = 1.67\ \Omega$

$V_L = I_T R_T = (11\ A)(1.67\ \Omega) = \mathbf{18.37\ V}$

$$I_L = \frac{V_L}{R_L} = \frac{18.37\ V}{3\Omega} = \mathbf{6.12\ A}$$

40. $$E_{eq} = \frac{-5\ V/2.2\ k\Omega + 20\ V/8.2\ k\Omega}{1/2.2\ k\Omega + 1/8.2\ k\Omega} = 0.2879\ V$$

$$R_{eq} = \frac{1}{1/2.2\ k\Omega + 1/8.2\ k\Omega} = 1.7346\ k\Omega$$

$$I_L = \frac{E_{eq}}{R_{eq} + R_L} = \frac{0.2879\ V}{1.7346\ k\Omega + 5.6\ k\Omega} = \mathbf{39.3\ \mu A}$$

$V_L = I_L R_L = (39.3\ \mu A)(5.6\ k\Omega) = \mathbf{220\ mV}$

41. $I_T \downarrow = 5\ A - 0.4\ A - 0.2\ A = 4.40\ A$

$R_T = 200\ \Omega \parallel 80\ \Omega \parallel 50\ \Omega \parallel 50\ \Omega = 17.39\ \Omega$

$V_L = I_T R_T = (4.40\ A)(17.39\ \Omega) = \mathbf{75.52\ V}$

$$I_L = \frac{V_L}{R_L} = \frac{76.52\ V}{200\ \Omega} = \mathbf{0.38\ A}$$

42. $$I_{eq} = \frac{(4\ A)(4.7\ \Omega) + (1.6\ A)(3.3\ \Omega)}{4.7\ \Omega + 3.3\ \Omega} = \frac{18.8\ V + 5.28\ V}{8\ \Omega} = 3.01\ A$$

$R_{eq} = 4.7\ \Omega + 3.3\ \Omega = 8\ \Omega$

$$I_L = \frac{R_{eq}(I_{eq})}{R_{eq} + R_L} = \frac{8\Omega(3.01\ A)}{8\Omega + 2.7\Omega} = \mathbf{2.25\ A}$$

$V_L = I_L R_L = (2.25\ A)(2.7\ \Omega) = \mathbf{6.08\ V}$

43. $$\overleftarrow{I_{eq}} = \frac{(4\ mA)(8.2\ k\Omega) + (8\ mA)(4.7\ k\Omega) - (10\ mA)(2\ k\Omega)}{8.2\ k\Omega + 4.7\ k\Omega + 2\ k\Omega}$$

$$= \frac{32.8\ V + 37.6\ V - 20\ V}{14.9\ k\Omega} = 3.38\ mA$$

$R_{eq} = 8.2\ k\Omega + 4.7\ k\Omega + 2\ k\Omega = 14.9\ k\Omega$

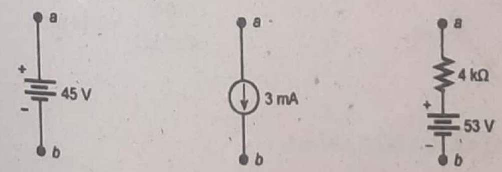
$$I_L = \frac{E_{eq} I_{eq}}{R_{eq} + R_L} = \frac{(14.9\ k\Omega)(3.38\ mA)}{14.9\ k\Omega + 6.8\ k\Omega} = \mathbf{2.32\ mA}$$

$V_L = I_L R_L = (2.32\ mA)(6.8\ k\Omega) = \mathbf{15.78\ V}$

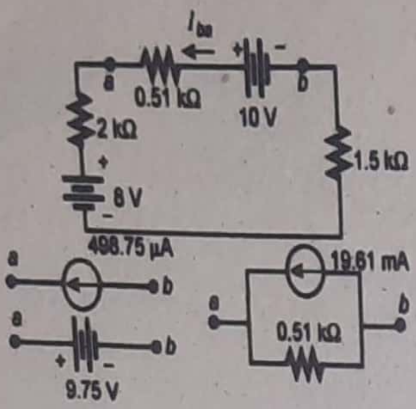
44. $15\ k\Omega \parallel (8\ k\Omega + 7\ k\Omega) = 15\ k\Omega \parallel 15\ k\Omega = 7.5\ k\Omega$

$$V_{ab} = \frac{7.5\ k\Omega(60\ V)}{7.5\ k\Omega + 2.5\ k\Omega} = 45\ V$$

$$I_{ab} = \frac{45\ V}{15\ k\Omega} = 3\ mA$$



45.

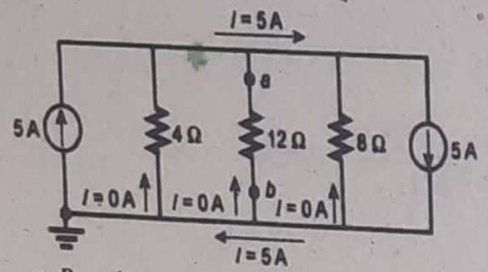


$$I_{ba} = \frac{10\text{ V} - 8\text{ V}}{2\text{ k}\Omega + 0.51\text{ k}\Omega + 1.5\text{ k}\Omega}$$
$= \mathbf{498.75\ \mu A}$

$V_{0.51\text{k}\Omega} = (498.75\ \mu\text{A})(0.51\text{ k}\Omega)$
$= 0.25\text{ V}$

$V_{ab} = 10\text{ V} - 0.25\text{ V} = 9.75\text{ V}$

46.



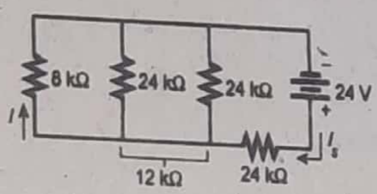
$\therefore R_2$ = short-circuit, open-circuit, any value

$V_{ab} = 0$ V (short)
$I_{ab} = 0$ A (open)

R_2 any resistive value

47. a. $I_s = \dfrac{24\text{ V}}{8\text{ k}\Omega + \dfrac{24\text{ k}\Omega}{3}} = 1.5\text{ mA}, I = \dfrac{I_s}{3} = \mathbf{0.5\ mA}$

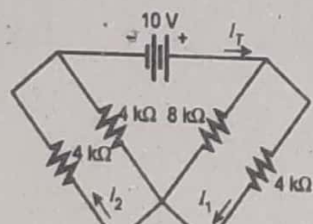
b.



$$I_s = \frac{24\text{ V}}{24\text{ k}\Omega + 8\text{ k}\Omega \parallel 12\text{ k}\Omega} = 0.83\text{ mA}$$
$$I = \frac{12\text{ k}\Omega(I_s)}{12\text{ k}\Omega + 8\text{ k}\Omega} = \mathbf{0.5\ mA}$$

c. yes

48. (a)



$$I_T = \frac{10\text{ V}}{4\text{ k}\Omega \parallel 8\text{ k}\Omega + 4\text{ k}\Omega \parallel 4\text{k}\Omega}$$
$$= \frac{10\text{ V}}{2.67\text{ k}\Omega + 2\text{ k}\Omega}$$
$$= \frac{10\text{ V}}{4.67\text{ k}\Omega} = 2.14\text{ mA}$$

$I_1 = \dfrac{8\ \Omega(I_T)}{8\ \Omega + 4\ \Omega} = 1.43\text{ mA}, I_2 = I_T/2 = 1.07\text{ mA}$

$I = I_1 - I_2 = 1.43\text{ mA} - 1.07\text{ mA} = \mathbf{0.36\ mA}$

Chapter 10

1. (a) $\mathscr{E} = k\dfrac{Q_1}{r^2} = \dfrac{(9\times10^9)(4\,\mu C)}{(1\,m)^2} = \mathbf{36 \times 10^3\ N/C}$

(b) $\mathscr{E} = k\dfrac{Q_1}{r^2} = \dfrac{(9\times10^9)(4\,\mu C)}{(1\,mm)^2} = \mathbf{36 \times 10^9\ N/C}$

$\mathscr{E}(1\,mm)$: $\mathscr{E}(2\,m) = 36 \times 10^9 : 36 \times 10^3 = \mathbf{1 \times 10^6}$

2. $\mathscr{E} = \dfrac{kQ}{r^2} \Rightarrow \sqrt{\dfrac{kQ}{\mathscr{E}}} = \sqrt{\dfrac{(9\times10^9)(2\mu C)}{72\,N/C}} = \mathbf{15.81\ m}$

3. $C = \dfrac{Q}{V} = \dfrac{1200\,\mu C}{24\,V} = \mathbf{50\,\mu F}$

4. $Q = CV = (0.15\,\mu F)(120\,V) = \mathbf{18\,\mu C}$

5. a. $1''\left[\dfrac{1\,m}{39.37''}\right] = 25.4\,mm$

$\mathscr{E} = \dfrac{V}{d} = \dfrac{500\,mV}{25.4\,mm} = \mathbf{19.69\ V/m}$

b. $\dfrac{25.4\,mm}{100} = 0.254\,mm$

$\mathscr{E} = \dfrac{V}{d} = \dfrac{500\,mV}{0.254\,mm} = \mathbf{1.97\ kV/m}$

6. $V = \dfrac{Q}{C} = \dfrac{160\,\mu C}{6.8\,\mu F} = 23.53\,V$

$\mathscr{E} = \dfrac{V}{d} = \dfrac{23.53\,V}{5\,mm} = \mathbf{4.71\ kV/m}$

7. $0.1''\left[\dfrac{1\,m}{39.37''}\right] = 2.54\,mm$

$C = 8.85 \times 10^{-12}\varepsilon_r\dfrac{A}{d} = 8.85 \times 10^{-12}(1)\dfrac{(0.1\,m^2)}{2.54\,mm} = \mathbf{348.43\ pF}$

8. $C = 8.85 \times 10^{-12}\,\varepsilon_r\dfrac{A}{d} = 8.85 \times 10^{-12}(2.5)\dfrac{(0.1\,m^2)}{2.54\,mm} = \mathbf{871.06\ pF}$

9. $C = 8.85 \times 10^{-12}\varepsilon_r\dfrac{A}{d} \Rightarrow d = \dfrac{8.85\times10^{-12}(4)(0.15\,m^2)}{2\,\mu F} = \mathbf{2.66\,\mu m}$

10. $C = \varepsilon_r C_o \Rightarrow \varepsilon_r = \dfrac{C}{C_o} = \dfrac{6.8\,nF}{1360\,pF} = \mathbf{5\ (mica)}$

11. a. $C = 8.85 \times 10^{-12}(7)\dfrac{(0.08\,m^2)}{0.2\,mm} = \mathbf{24.78\ nF}$

b. $\mathscr{E} = \dfrac{V}{d} = \dfrac{80\,V}{0.2\,mm} = \mathbf{400\ kV/m}$

c. $Q = CV = (24.78\,nF)(200\,V) = \mathbf{4.96\,\mu C}$

12. a. $C = \dfrac{1}{2}(4.7\,\mu F) = \mathbf{2.35\,\mu F}$

b. $C = 2(4.7\,\mu F) = \mathbf{9.4\,\mu F}$

c. $C = 20(4.7\,\mu F) = \mathbf{94\,\mu F}$

d. $C = \dfrac{(4)\left(\frac{1}{3}\right)}{\left(\frac{1}{4}\right)}(4.7\,\mu F) = \mathbf{25.1\,\mu F}$

13. $d = \dfrac{8.85\times10^{-12}\varepsilon_r A}{C} = \dfrac{(8.85\times10^{-12})(5)(0.02\,m^2)}{6800\,pF} = 130.15\,\mu m$

$d = 130.15\,\cancel{\mu m}\left[\dfrac{10^{-6}\,\cancel{m}}{1\,\cancel{\mu m}}\right]\left[\dfrac{39.37\,\cancel{in.}}{1\,\cancel{m}}\right]\left[\dfrac{1000\,mils}{1\,\cancel{in.}}\right] = 5.12\,mils$

$5.12\,\cancel{mils}\left[\dfrac{5000\,V}{\cancel{mil}}\right] = \mathbf{25.6\ kV}$

14. mica: $\dfrac{1200\,V}{\dfrac{5000\,V}{\cancel{mil}}} = 1200\,V\left[\dfrac{\cancel{mil}}{5000\,V}\right] = 0.24\,mils$

$0.24\,mils\left[\dfrac{\cancel{1''}}{1000\,mils}\right]\left[\dfrac{1\,m}{39.37\,\cancel{in.}}\right] = \mathbf{6.10\,\mu m}$

15. $\dfrac{200}{1\times10^6}(22\,\mu F)/°C = 4400\,pF/°C$

$\dfrac{4400\,pF}{°C}[\Delta T] = \dfrac{4400\,pF}{°C}[80°C] = \mathbf{0.35\,\mu F}$

16. J = ±5%, Size ⇒ 40 pF ± 2 pF, **38 pF → 42 pF**

17. F = ±1%, Size ⇒ 47 × 10^1 μF = 470 μF ± 4.7 μF, **465.3 μF → 474.7 μF**

18. K = ±10%, Size ⇒ 18 × 10^2 pF = **1800 pF ± 180 pF, 1620 pF → 1980 pF**

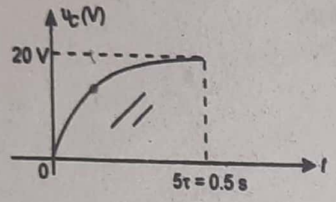
19. a. $\tau = RC = (10 \times 10^3\,\Omega)(10\,\mu F) = \mathbf{100\ ms}$

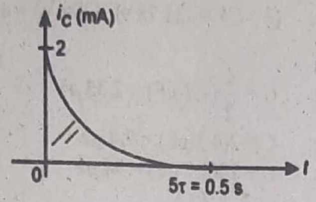
b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20\ V(1 - e^{-t/100\ ms})}$

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. $i_C = \dfrac{20\ V}{10\ k\Omega}e^{-t/\tau} = \mathbf{2\ mAe^{-t/100\ ms}}$
$v_R = Ee^{-t/\tau} = \mathbf{20\ Ve^{-t/100\ ms}}$

e.





20. a. $\tau = RC = (100\ k\Omega)(10\ \mu F) = \mathbf{1\ s}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20\ V(1 - e^{-t/1\ s})}$

c. $1\tau = \mathbf{12.64\ V}$, $3\tau = \mathbf{19\ V}$, $5\tau = \mathbf{19.87\ V}$

d. $i_C = \dfrac{20\ V}{100\ k\Omega}e^{-t/\tau} = \mathbf{200\ \mu A\ e^{-t/1\ s}}$
$v_R = Ee^{-t/\tau} = \mathbf{20V\ e^{-t/1\ s}}$

e. Same as problem 21 with $5\tau = 5$ s and $I_m = 200\ \mu A$

21. a. $\tau = RC = (2.2\ k\Omega + 3.3\ k\Omega)1\ \mu F = (5.5\ k\Omega)(1\ \mu F) = \mathbf{5.5\ ms}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{100\ V(1 - e^{-t/5.5\ ms})}$

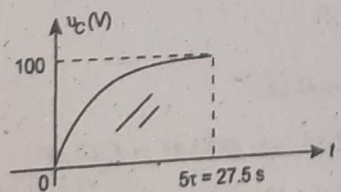
c. $1\tau = \mathbf{63.21\ V}$, $3\tau = \mathbf{95.02\ V}$, $5\tau = \mathbf{99.33\ V}$

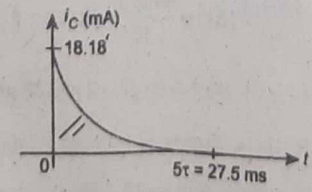
d. $i_C = \dfrac{E}{R_T}e^{-t/\tau} = \dfrac{100\ V}{5.5\ k\Omega}e^{-t/\tau} = \mathbf{18.18\ mAe^{-t/5.5\ ms}}$

$V_{R_2} = \dfrac{3.3\ k\Omega\,(100\ V)}{3.3\ k\Omega + 2.2\ k\Omega} = 60\ V$

$v_{R_2} = \mathbf{60\ Ve^{-t/5.5\ ms}}$

e.



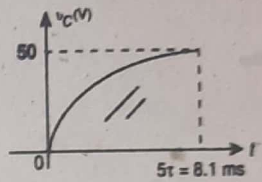


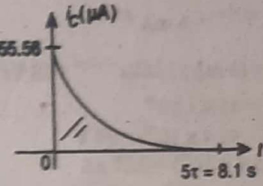
22. a. $R = 68\ k\Omega + 22\ k\Omega = \mathbf{90\ k\Omega}$
$\tau = RC = (90\ k\Omega)(18\ \mu F) = \mathbf{1.62\ s}$

b. $v_C = E(1 - e^{-t/\tau}) = (80\ V - 30\ V)(1 - e^{-t/\tau})$
$v_C = \mathbf{50\ V(1 - e^{-t/1.62s})}$

c. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{50\ V}{90\ k\Omega}e^{-t/\tau} = \mathbf{555.56\ \mu Ae^{-t/1.62s}}$

d.





23. a. **100 μs**

b. $v_C = 12\ V(1 - e^{-50\mu s/100\mu s}) = 12\ V(1 - e^{-0.5}) = 12\ V(1 - 0.607)$
$= 12\ V(.393) = \mathbf{4.72\ V}$

c. $v_C = 12\ V(1 - e^{-1ms/100\mu s}) = 12\ V(1 - e^{-10}) = 12\ V(1 - 45.4 \times 10^{-6})$
$\cong 12\ V(999.95 \times 10^{-3}) \cong \mathbf{12\ V}$

24. a. $\tau = 20$ ms, $5\tau = 5(20\ ms) = \mathbf{100\ ms}$

b. $\tau = RC$, $R = \dfrac{\tau}{C} = \dfrac{20\ ms}{10\ \mu F} = \mathbf{2\ k\Omega}$

c. $v_C\,(20\ ms) = 40\ mV(1 - e^{-20ms/20ms}) = 40\ mV(1 - e^{-1})$
$= 40\ mV(1 - .368) = 40\ mV(0.632) = \mathbf{25.28\ mV}$

d. $v_C = 40\ mV(1 - e^{-10}) = 40\ mV(1 - 45 \times 10^{-6}) \cong \mathbf{40\ mV}$

e. $Q = CV = (10\ \mu F)(40\ mV) = \mathbf{0.4\ \mu C}$

f. $\tau = RC = (1000 \times 10^6\ \Omega)(10\ \mu F) = 10 \times 10^3$ s

$5\tau = 50 \times 10^3\ \cancel{s}\left[\dfrac{1\ \cancel{min}}{60\ \cancel{s}}\right]\left[\dfrac{1\ h}{60\ \cancel{min}}\right] = \mathbf{13.89\ h}$

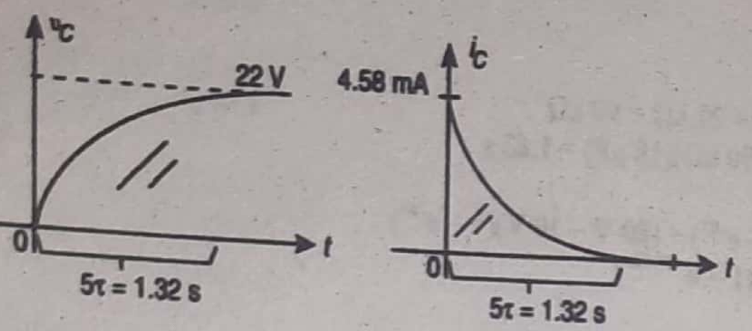
25. a. $\tau = RC = (4.7\ k\Omega)(56\ \mu F) = \mathbf{263.2\ ms}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{22\ V(1 - e^{-t/263.2ms})}$
$i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{22\ V}{4.7\ k\Omega}e^{-t/263.2ms} = \mathbf{4.68\ mAe^{-t/263.2ms}}$

c. $v_C(1\ s) = 22\ V(1 - e^{-1s/263.2ms}) = 22\ V(1 - e^{-3.8})$
$= 22\ V(1 - 22.37 \times 10^{-3}) = \mathbf{21.51\ V}$
$i_C\,(1\ s) = 4.68\ mAe^{-1s/263.2ms} = 4.68\ mA(22.37 \times 10^{-3}) = \mathbf{0.105\ mA}$

d. $v_C = \mathbf{21.51\ Ve^{-t/263.2ms}}$
$i_C = \dfrac{21.51\ V}{4.7\ k\Omega}e^{-t/263.2ms} = \mathbf{4.58\ mAe^{-t/263.2ms}}$

e.



26. a. $\tau = RC = (3\ \text{k}\Omega + 2\ \text{k}\Omega)(2\ \mu\text{F}) = 10$ ms

$v_C = 30\ \text{V}(1 - e^{-t/10\text{ms}})$

$i_C = \dfrac{30\ \text{V}}{5\ \text{k}\Omega} e^{-t/10\text{ms}} = 6\ \text{mA}^{-t/10\text{ms}}$

$v_{R_1} = i_C R_1 = (6\ \text{mA})(3\ \text{k}\Omega)e^{-t/10\text{ms}} = 18\ \text{V}e^{-t/10\text{ms}}$

b. 100ms: $e^{-10} = 45.4 \times 10^{-6}$

$v_C = 30\ \text{V}(1 - 45.4 \times 10^{-6}) = 30$ V

$i_C = 6\ \text{mA}(45.4 \times 10^{-6}) = 0.27\ \mu$A

$v_{R_1} = 18\ \text{V}(45.4 \times 10^{-6}) = 0.82$ mV

c. 200 ms: $\tau' = R_2C = (2\ \text{k}\Omega)(2\ \mu\text{F}) = 4$ ms

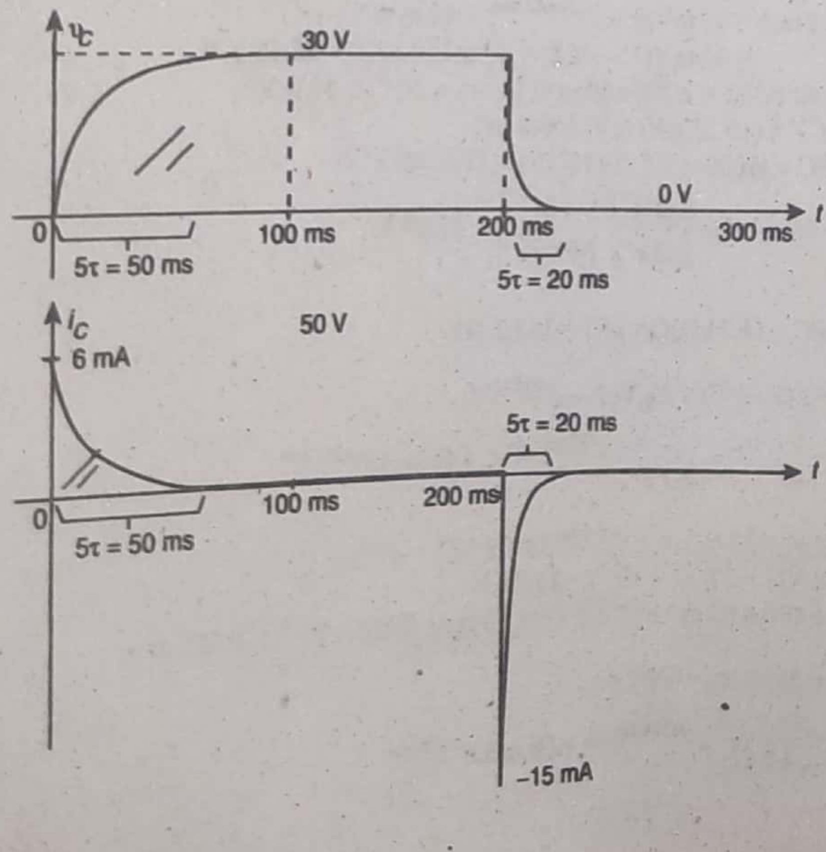
$v_C = 30\ \text{V}e^{-t/4\text{ms}}$

$i_C = -\dfrac{30\ \text{V}}{2\ \text{k}\Omega} e^{-t/4\text{ms}} = -15\ \text{mA}e^{-t/4\text{ms}}$

At $t = 0$: $v_{R_2} = i_C R_2 = (6\ \text{mA})(2\ \text{k}\Omega)e^{-t/10\text{ ms}}$
$= 12\ \text{V}e^{-t/10\text{ ms}}$

At $t = 200$ ms: $v_{R_2} = -(15\ \text{mA})(2\ \text{k}\Omega)e^{-t/4\text{ ms}}$
$= -30\ \text{V}e^{-t/4\text{ ms}}$

d.



28. a. $\tau = RC = (2\ \text{m}\Omega)(1000\ \mu\text{F}) = 2\ \mu\text{s}$
$5\tau = 10\ \mu\text{s}$

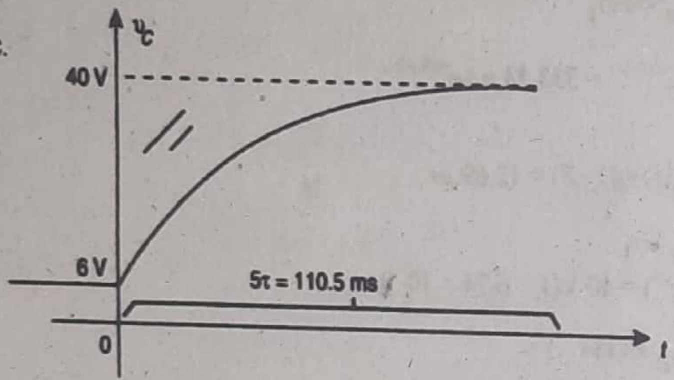
b. $I_m = \dfrac{V}{R} = \dfrac{12\ \text{V}}{2\ \text{m}\Omega} = 6\ \text{kA}$

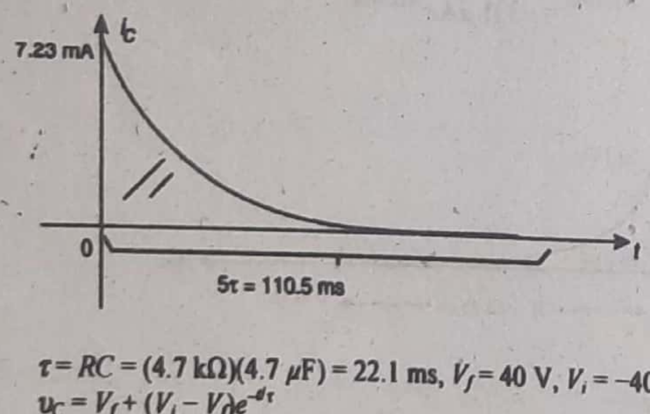
c. yes

29. a. $v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$\tau = RC = (4.7\ \text{k}\Omega)(4.7\ \mu\text{F}) = 22.1\ \text{ms},\ V_f = 40\ \text{V},\ V_i = 6\ \text{V}$
$v_C = 40\ \text{V} + (6\ \text{V} - 40\ \text{V})e^{-t/22.1\text{ms}}$
$v_C = 40\ \text{V} - 34\ \text{V}e^{-t/22.1\text{ms}}$

b. Initially $V_R = E + v_C = 40\ \text{V} - 6\ \text{V} = 34\ \text{V}$
$i_C = \dfrac{V_R}{R}e^{-t/\tau} = \dfrac{34\ \text{V}}{4.7\ \text{k}\Omega}e^{-t/22.1\text{ms}} = 7.23\ \text{mA}\,e^{-t/22.1\text{ms}}$

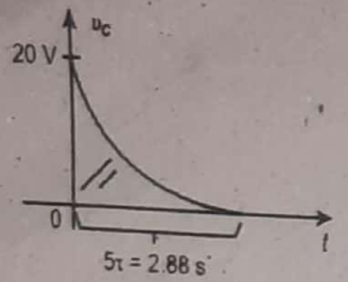
c.

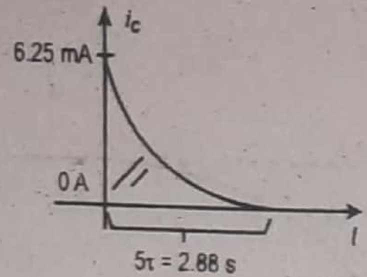


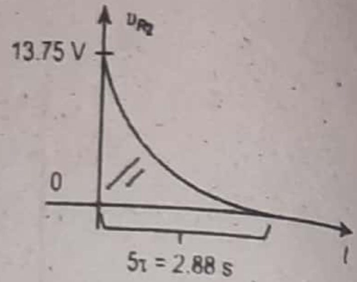


30. a. $\tau = RC = (4.7\ \text{k}\Omega)(4.7\ \mu\text{F}) = 22.1\ \text{ms},\ V_f = 40\ \text{V},\ V_i = -40\ \text{V}$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 40\ \text{V} + (-40\ \text{V} - 40\ \text{V})e^{-t/22.1\text{ms}}$
$v_C = 40\ \text{V} - 80\ \text{V}e^{-t/22.1\text{ms}}$

b. Initially $V_R = E + v_C = 40\ \text{V} - (-40\ \text{V}) = 80\ \text{V}$
and $i_C = \dfrac{V_R}{R} = \dfrac{80\ \text{V}}{4.7\ \text{k}\Omega}e^{-t/22.1\text{ms}} = 17.02\ \text{mA}e^{-t/22.1\text{ms}}$







33. $\upsilon_C = V_f + (V_i - V_f)e^{-t/\tau}$

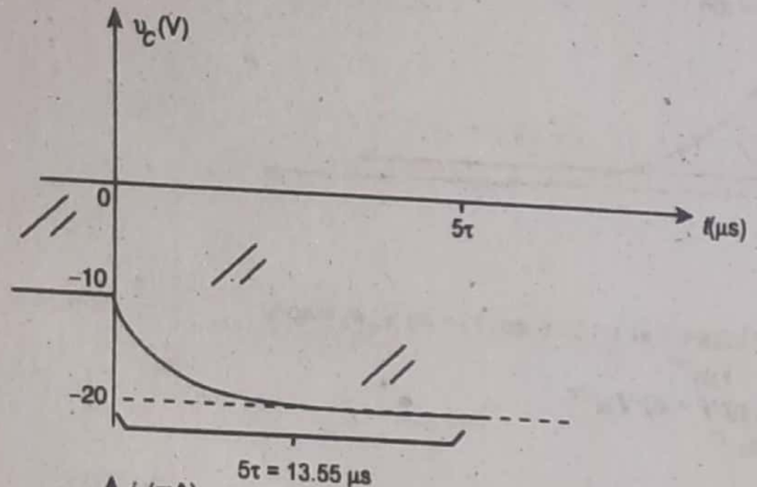
$\tau = RC = (820\ \Omega)(3300\ \text{pF}) = 2.71\ \mu\text{s},\ V_f = -20\ \text{V},\ V_i = -10\ \text{V}$

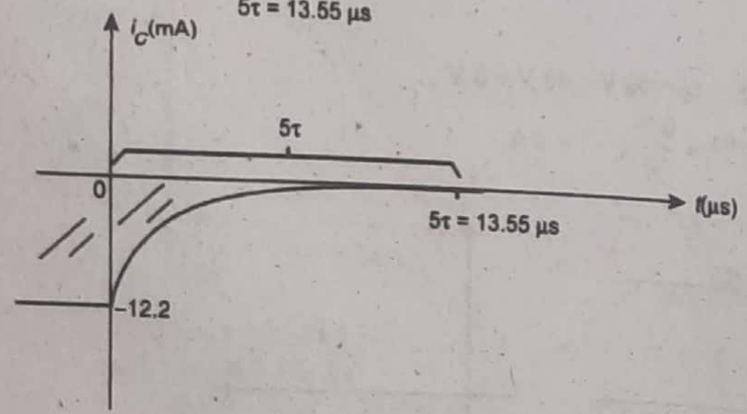
$\upsilon_C = -20\ \text{V} + (-10\ \text{V} - (-20\ \text{V}))e^{-t/2.71\mu\text{s}}$

$\boldsymbol{\upsilon_C = -20\ \text{V} + 10\ \text{V}e^{-t/2.71\mu\text{s}}}$

$$I_m = \frac{-(20\ \text{V} - 10\ \text{V})}{820\ \Omega} = \frac{-10\ \text{V}}{820\ \Omega} = -12.2\ \text{mA}$$

$\boldsymbol{i_C = i_R = -12.2\ \text{mA}e^{-t/2.71\mu\text{s}}}$





34. a. $R = 10\ \text{k}\Omega + 8.2\ \text{k}\Omega = 18.2\ \text{k}\Omega$

$\tau = RC = (18.2\ \text{k}\Omega)(6.8\ \mu\text{F}) = 123.76\ \text{ms}$

$\upsilon_C = V_f + (V_i - V_f)e^{-t/\tau}$

$V_f = 20\ \text{V} + 40\ \text{V} = 60\ \text{V}$

$V_i = -8\ \text{V}$

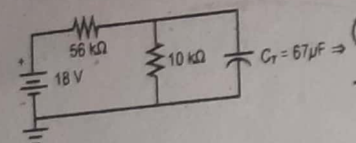
$\upsilon_C = 60\ \text{V} + (-8\ \text{V} - 60\ \text{V})e^{-t/123.76\ \text{ms}}$

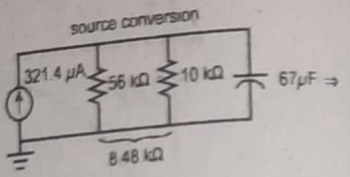
$\boldsymbol{\upsilon_C = 60\ \text{V} - 68\ \text{V}e^{-t/123.76\ \text{ms}}}$

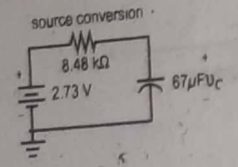
$$I_m = \frac{8\ \text{V} + 20\ \text{V} + 40\ \text{V}}{18.2\ \text{k}\Omega} = 3.74\ \text{mA}$$

$\boldsymbol{i_C = 3.74\ \text{mA}e^{-t/123.76\ \text{ms}}}$

36. a. Network redrawn:







$\tau = RC = (8.48\text{ k}\Omega)(67\ \mu\text{F}) = 568.2\text{ ms}$
$\upsilon_C = \mathbf{2.73\ V(1 - e^{-t/568.2\ ms})}$

b. $\upsilon_C = 2.73\text{ V}(1 - e^{-10s/568.2\text{ ms}})$
$= 2.73\text{ V}(1 - e^{-17.6})$
$= 2.73\text{ V}(1 - 22.72 \times 10^{-9})$
$\cong \mathbf{2.73\ V}$

c. $\upsilon_C = 2.73\text{ V}(1 - e^{-5}) = 2.73\text{ V}(0.993) = 2.72\text{ V}$
$Q_{20\mu F} = CV = (20\ \mu\text{F})(2.72\text{ V}) = \mathbf{54.4\ \mu C}$
$Q_{47\mu F} = CV = (47\ \mu\text{F})(2.72\text{ V}) = \mathbf{127.84\ \mu C}$

37. a. $\upsilon_C = 140\text{ mV}(1 - e^{-1ms/2\text{ ms}}) = 140\text{ mV}(1 - e^{-0.5}) = 140\text{ mV}(1 - 0.6065)$
$= 140\text{ mV}(0.3935) = \mathbf{55.59\ mV}$

b. $\upsilon_C = 140\text{ mV}(1 - e^{-10}) = 140\text{ mV}(1 - 45.4 \times 10^{-6})$
$\cong \mathbf{139.99\ mV}$

c. $100\text{ mV} = 140\text{ mV}(1 - e^{-t/2\text{ ms}})$
$0.714 = 1 - e^{-t/2\text{ ms}}$
$0.286 = e^{-t/2\text{ ms}}$
$\log_e 0.286 = \log_e e^{-t/2\text{ ms}}$
$1.252 = -t/2\text{ ms}$
$t = 1.252\ (2\text{ ms}) = \mathbf{2.5\ ms}$

d. $\upsilon_C = 138\text{ mV} = 140\text{ mV}(1 - e^{t/2\text{ ms}})$
$0.986 = 1 - e^{-t/2\text{ ms}}$
$-14 \times 10^{-3} = -e^{-t/2\text{ ms}}$
$\log_e 14 \times 10^{-3} = -t/2\text{ ms}$
$-4.268 = -t/2\text{ ms}$
$t = (4.268)(2\text{ ms}) = \mathbf{8.54\ \mu s}$

38. $\tau = RC = (33\text{ k}\Omega)(20\ \mu\text{F}) = 0.66\text{ s}$
$\upsilon_C = 12\text{ V}(1 - e^{-t/0.66\text{ s}})$
$8\text{ V} = 12\text{ V}(1 - e^{-t/0.66\text{ s}})$
$8\text{ V} = 12\text{ V} - 12\text{ V}(1 - e^{-t/0.66\text{ s}})$
$-4\text{ V} = -12\text{ V}e^{-t/0.66\text{ s}}$
$0.333 = e^{-t/0.66\text{ s}}$
$\log_e 0.333 = -t/0.66\text{ s}$
$-1.0996 = -t/0.66\text{ s}$
$t = 1.0996(0.66\text{ s}) = \mathbf{0.73\ s}$

39. $t = -\tau \log_e\left(1 - \dfrac{\upsilon_C}{E}\right)$

$10\text{ s} = -\tau \log_e\left(\underbrace{\underbrace{1 - \dfrac{12\text{ V}}{20\text{ V}}}_{.4}}_{-916.29 \times 10^{-3}}\right)$

$\tau = \dfrac{10\text{ s}}{0.916} = 10.92\text{ s}$

$\tau = RC \Rightarrow R = \dfrac{\tau}{C} = \dfrac{10.92\text{ s}}{200\ \mu\text{F}} = \mathbf{54.60\ k\Omega}$

40. a. $\tau = RC = (12\text{ k}\Omega + 8.2\text{ k}\Omega)(6.8\ \mu\text{F}) = 137.36\text{ ms}$
$\upsilon_C = 60\text{ V}(1 - e^{-t/\tau})$
$48\text{ V} = 60\text{ V}(1 - e^{-t/\tau})$
$0.8 = 1 - e^{-t/\tau}$
$0.2 = 1 - e^{-t/\tau}$
$\log_e 0.2 = \log_e e^{-t/\tau}$
$-1.61 = -t/\tau$
$t = (1.61)\tau = (1.61)(137.36\text{ ms}) = \mathbf{221.15\ ms}$

b. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{60\text{ V}}{20.2\text{ k}\Omega}e^{-t/\tau}$
$= 2.97\text{ mA}e^{-t/137.36\text{ ms}}$
$i_C(221.15\text{ ms}) = 2.97\text{ mA}e^{-221.15\text{ ms}/137.36\text{ ms}}$
$= 2.97\text{ mA}e^{-1.61}$
$= 2.97\text{ mA}\ (199.89 \times 10^{-3})$
$= \mathbf{0.594\ mA}$

c. $t = 2\tau$
$i_C = 2.97\text{ mA}e^{-2\tau/\tau} = 2.97\text{ mA}\underbrace{e^{-2}}_{0.135}$
$= 0.4\text{ mA}$

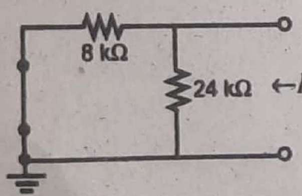
$P = EI = (60\text{ V})(0.4\text{ mA}) = \mathbf{24\ mW}$

41. a. $\upsilon_m = \upsilon_R = Ee^{-t/\tau} = 60\ \text{V}e^{-1\tau/\tau} = 60\ \text{V}e^{-1}$
$= 60\ \text{V}(0.3679)$
$= \mathbf{22.07\ V}$

b. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{60\ \text{V}}{10\ \text{M}\Omega}e^{-2\tau/\tau} = 6\ \mu\text{A}e^{-2}$
$= 6\ \mu\text{A}(0.1353)$
$= \mathbf{0.81\ \mu A}$

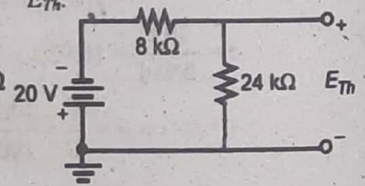
c. $\upsilon_C = E(1 - e^{-t/\tau})$ $\tau = RC = (10\ \text{M}\Omega)(0.2\ \mu\text{F}) = 2\ \text{s}$
$50\ \text{V} = 60\ \text{V}(1 - e^{-t/2\ \text{s}})$
$0.8333 = 1 - e^{-t/2\ \text{s}}$
$\log_e 0.1667 = -t/2\ \text{s}$
$t = -(2\ \text{s})(-1.792)$
$= \mathbf{3.58\ s}$

42. a. Thevenin's theorem:
R_{Th}:

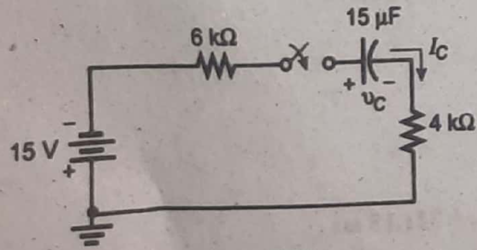


$\leftarrow R_{Th} = 8\ \text{k}\Omega \parallel 24\ \text{k}\Omega = 6\ \text{k}\Omega$

E_{Th}:



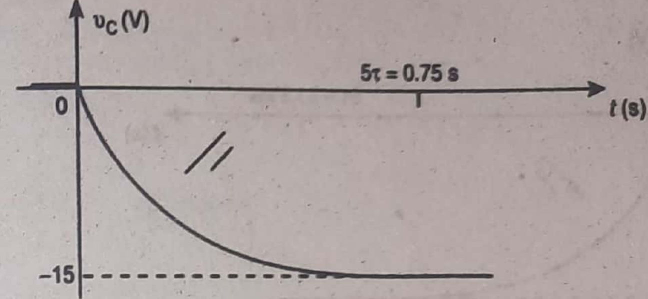
$E_{Th} = \dfrac{-24\ \text{k}\Omega\,(20\ \text{V})}{24\ \text{k}\Omega + 8\ \text{k}\Omega} = -15\ \text{V}$

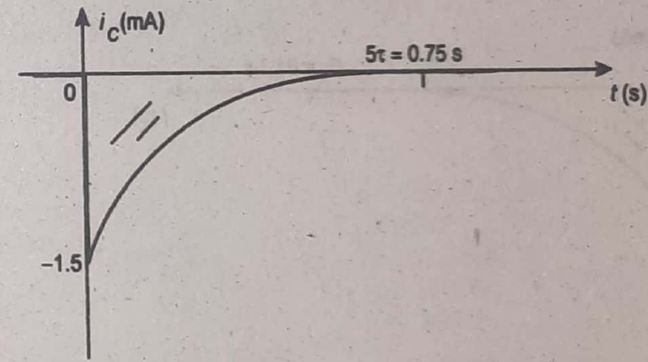


$\tau = RC = (10\ \text{k}\Omega)(15\ \mu\text{F}) = 0.15\ \text{s}$
$\upsilon_C = E(1 - e^{-t/\tau})$
$= \mathbf{-15\ V(1 - e^{-t/0.15\ s})}$

$i_C = \dfrac{E}{R}e^{-t/\tau} = -\dfrac{15\ \text{V}}{10\ \text{k}\Omega}e^{-t/0.15} = \mathbf{-1.5\ mAe^{-t/0.15\ s}}$

b.

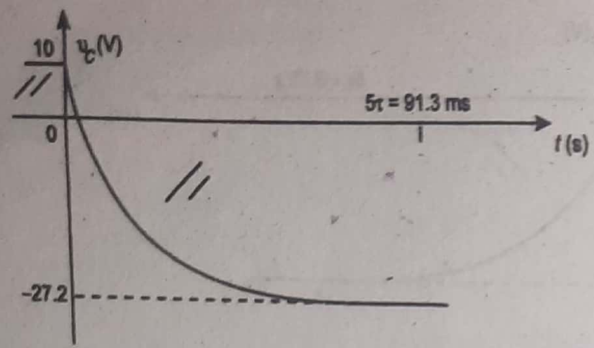


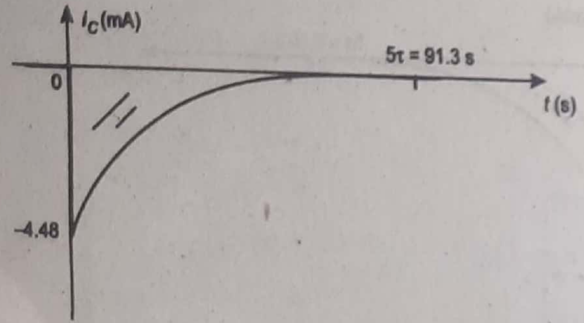


43. a. Source conversion and combining series resistors:

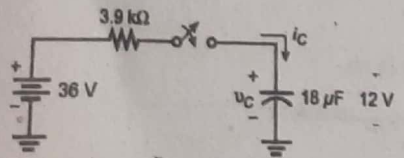
$E = -(4\ \text{mA})(6.8\ \text{k}\Omega) = -27.2\ \text{V}$
$R_T = 6.8\ \text{k}\Omega + 1.5\ \text{k}\Omega = 8.3\ \text{k}\Omega$
$V_f = -27.2\ \text{V},\ V_i = 10\ \text{V}$
$\tau = RC = (8.3\ \text{k}\Omega)(2.2\ \mu\text{F}) = 18.26\ \text{ms}$
$\upsilon_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= -27.2\ \text{V} + (10\ \text{V} - (-27.2\ \text{V}))e^{-t/18.26\ \text{ms}}$
$\upsilon_C = \mathbf{-27.2\ V + 37.2\ Ve^{-t/18.26\ ms}}$
$\upsilon_R(0+) = -27.2\ \text{V} - (-27.2\ \text{V}))e^{-t/18.26\ \text{ms}} = -37.2\ \text{V}$
$i_C = -\dfrac{32.7\ \text{V}}{8.3\ \text{k}\Omega}e^{-t/18.26\text{ms}}$
$i_C = \mathbf{-4.48\ mAe^{-t/18.26\ ms}}$

b.



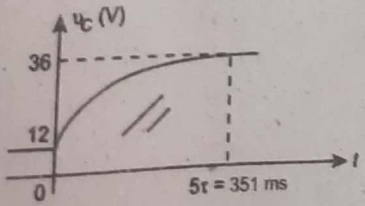


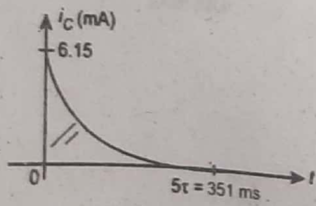
44. a. $R_{Th} = 3.9\ k\Omega + 0\ \Omega \parallel 1.8\ k\Omega = 3.9\ k\Omega$
$E_{Th} = 36\ V$



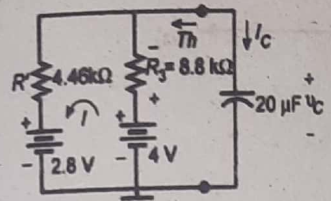
$\tau = RC = (3.9\ k\Omega)(18\ \mu F) = 70.2\ ms$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 36\ V + (+12\ V - 36\ V)e^{-t/70.2\ ms}$
$v_C = \mathbf{36\ V - 24\ V}e^{-t/70.2\ ms}$
$v_R(0+) = 24\ V - 12\ V = 24\ V$
$i_C = \dfrac{24\ V}{3.9\ k\Omega}e^{-t/70.2ms}$
$i_C = \mathbf{6.15\ mA}e^{-t/70.2\ ms}$

b.

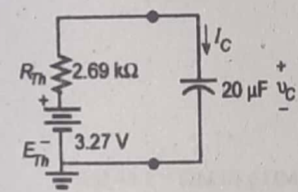




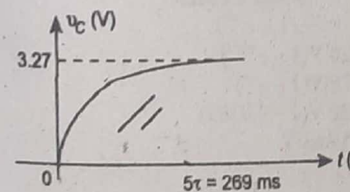
45. **Source conversion:**
$E = IR_1 = (5\ mA)(0.56\ k\Omega) = 2.8\ V$
$R' = R_1 + R_2 = 0.56\ k\Omega + 3.9\ k\Omega = 4.46\ k\Omega$

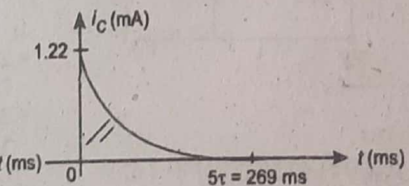


$R_{Th} = 4.46\ k\Omega \parallel 6.8\ k\Omega = 2.69\ k\Omega$
$I = \dfrac{4\ V - 2.8\ V}{6.8\ k\Omega + 4.46\ k\Omega} = \dfrac{1.2\ V}{11.26\ k\Omega} = 0.107\ mA$
$E_{Th} = 4\ V - (0.107\ mA)(6.8\ k\Omega)$
$= 4\ V - 0.727\ V$
$= 3.27\ V$

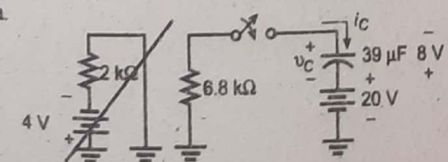


$v_C = 3.27\ V(1 - e^{-t/\tau})$
$\tau = RC = (2.69\ k\Omega)(20\ \mu F)$
$= 53.80\ ms$
$v_C = \mathbf{3.27\ V(1 - }e^{-t/53.80\ ms}\mathbf{)}$
$i_C = \dfrac{3.27\ V}{2.69\ k\Omega}e^{-t/\tau}$
$= \mathbf{1.22\ mA}\ e^{-t/53.80\ ms}$



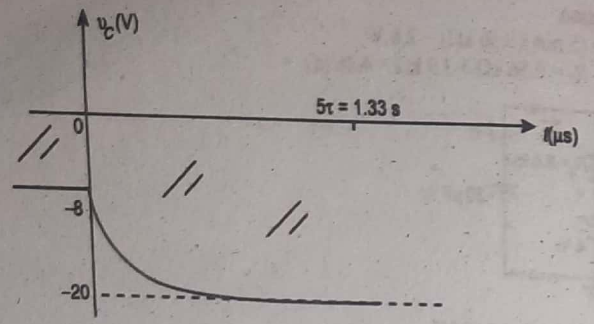


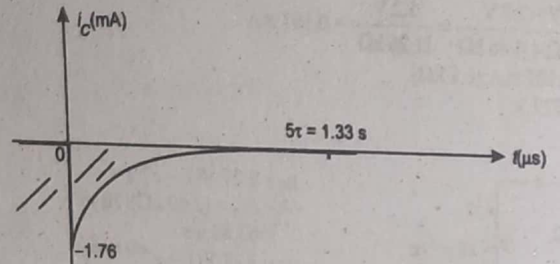
46. a.



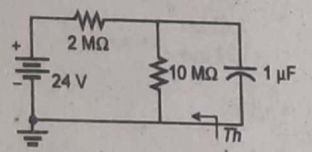
$\tau = RC = (6.8\ k\Omega)(39\ \mu F) = 265.2\ ms$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= -20\ V + (-8\ V - (-20\ V))e^{-t/265.2\ ms}$
$v_C = \mathbf{-20\ V + 12\ V}e^{-t/265.2\ ms}$
$v_R(0+) = +8\ V - 20\ V = -12\ V$
$i_C = -\dfrac{12\ V}{6.8\ k\Omega}e^{-t/265.2ms}$
$i_C = \mathbf{-1.76\ mA}e^{-t/265.2\ ms}$

b.





47. a.



$R_{Th} = 2\text{ M}\Omega \parallel 10\text{ M}\Omega = 1.67\text{ M}\Omega$

$$E_{Th} = \frac{10\text{ M}\Omega(24\text{ V})}{10\text{ M}\Omega + 2\text{ M}\Omega} = 20\text{ V}$$

$v_C = E_{Th}(1 - e^{-t/\tau})$
$= 20\text{ V}(1 - e^{-4\tau/\tau})$
$= 20\text{ V}(1 - e^{-4})$
$= 20\text{ V}(1 - 0.0183)$
$= \mathbf{19.63\text{ V}}$

$\tau = R_{Th}C = (1.67\text{ M}\Omega)(1\ \mu\text{F}) = 1.67\text{ s}$

$$i_C = \frac{E}{R}e^{-t/\tau}$$

$$3\ \mu\text{A} = \frac{20\text{ V}}{1.67\text{ M}\Omega}e^{-t/1.67\text{s}}$$

$0.25 = e^{-t/1.67\text{s}}$
$\log_e 0.25 = -t/1.67\text{ s}$
$t = -(1.67\text{ s})(-1.39)$
$= \mathbf{2.32\text{ s}}$

c. $v_{meter} = v_C$
$v_C = E_{Th}(1 - e^{-t/\tau})$
$10\text{ V} = 20\text{ V}(1 - e^{-t/1.67\text{s}})$
$0.5 = 1 - e^{-t/1.67\text{s}}$
$-0.5 = -e^{-t/1.67\text{s}}$
$\log_e 0.5 = -t/1.67\text{ s}$
$t = -(1.67\text{ s})(-0.69)$
$= \mathbf{1.15\text{ s}}$

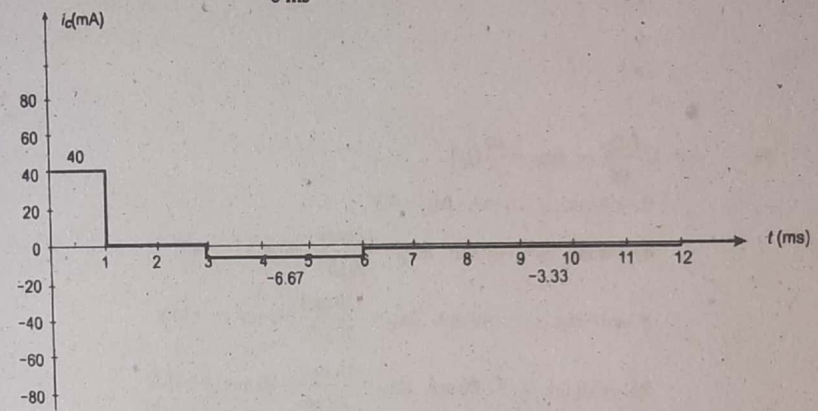
48. $i_{C_{av}} = C\dfrac{\Delta v_C}{\Delta t}$

$0 \to 1$ ms: $i_C = 2 \times 10^{-6}\dfrac{(20\text{ V})}{1\text{ ms}} = \mathbf{40\text{ mA}}$

$1 \to 3$ ms: $i_C = 2 \times 10^{-6}\dfrac{(0\text{ V})}{1\text{ ms}} = \mathbf{0\text{ mA}}$

$3 \to 6$ ms: $i_C = -2 \times 10^{-6}\dfrac{(10\text{ V})}{3\text{ ms}} = \mathbf{-6.67\text{ mA}}$

$6 \to 12$ ms: $i_C = -2 \times 10^{-6}\dfrac{(10\text{ V})}{6\text{ ms}} = \mathbf{-3.33\text{ mA}}$



49. $i_{C_{av}} = C\dfrac{\Delta v_C}{\Delta t}$

$0 \to 20\ \mu s$: $i_C = -4.7\ \mu\text{F}\dfrac{(5\text{ V})}{20\ \mu s} = \mathbf{-1.18\text{ A}}$

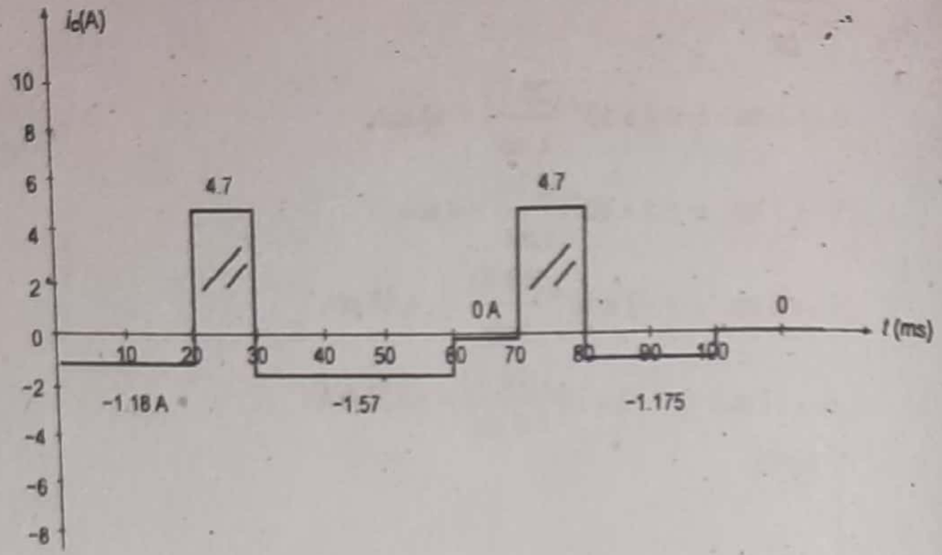
$20 \to 30\ \mu s$: $i_C = 4.7\ \mu\text{F}\dfrac{(10\text{ V})}{10\ \mu s} = \mathbf{4.7\text{ A}}$

$30 \to 60\ \mu s$: $i_C = -4.7\ \mu\text{F}\dfrac{(10\text{ V})}{30\ \mu s} = \mathbf{-1.57\text{ A}}$

$60 \to 70\ \mu s$: $i_C = 4.7\ \mu\text{F}\dfrac{(0\text{ V})}{10\ \mu s} = \mathbf{0\text{ A}}$

$70 \to 80\ \mu s$: $i_C = 4.7\ \mu\text{F}\dfrac{(10\text{ V})}{10\ \mu s} = \mathbf{4.7\text{ A}}$

$80\ \mu s \to 100\ \mu s$: $i_C = -4.7\ \mu\text{F}\dfrac{(5\text{ V})}{20\ \mu s} = \mathbf{-1.175\text{ A}}$



50. $i_C = C\dfrac{\Delta v_C}{\Delta t} \Rightarrow \Delta v_C = \dfrac{\Delta t}{C}(i_C)$

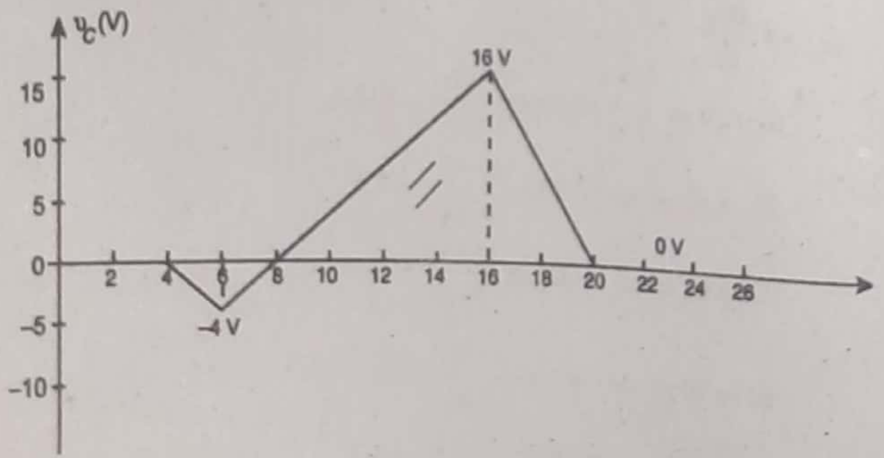
$0 \rightarrow 4$ ms: $i_C = 0$ mA $\Delta v_C = 0$ V

$4 \rightarrow 6$ ms: $i_C = -40$ mA $\Delta v_C = \dfrac{(2\text{ ms})}{20\,\mu\text{F}}(-40\text{ mA}) = -4$ **V**

$6 \rightarrow 16$ ms: $i_C = +40$ mA $\Delta v_C = \dfrac{(10\text{ ms})}{20\,\mu\text{F}}(40\text{ mA}) = +20$ **V**

$16 \rightarrow 20$ ms: $i_C = -80$ mA $\Delta v_C = \dfrac{(4\text{ ms})}{20\,\mu s}(-80\text{ mA}) = -16$ **V**

$20 \rightarrow 25$ ms: $i_C = 0$ mA $\Delta v_C = 0$ V



51. $6\,\mu\text{F} + 4\,\mu\text{F} = 10\,\mu\text{F}$, $8\,\mu\text{F} + 12\,\mu\text{F} = 20\,\mu\text{F}$
$10\,\mu\text{F} \parallel 20\,\mu\text{F} = $ **6.67 μF**

52. $C_T' = 6\,\mu\text{F} \parallel 12\,\mu\text{F} = 4\,\mu\text{F}$
$C_T'' = C_T' + 12\,\mu\text{F} = 4\,\mu\text{F} + 12\,\mu\text{F} = 16\,\mu\text{F}$
$6\,\mu\text{F} \parallel 6\,\mu\text{F} = 3\,\mu\text{F}$
$3\,\mu\text{F} \parallel 16\,\mu\text{F} = 2.53\,\mu\text{F}$
$C_T = $ **2.53 μF**

$$W_{200\mu F} = \frac{1}{2}(200\ \mu F)(9.85\ V)^2 = \mathbf{970\ mJ}$$

$$W_{100\mu F} = \frac{1}{2}(100\ \mu F)(5.91\ V)^2 = \mathbf{1.75\ mJ}$$

60\. a. $W_C = \frac{1}{2}CV^2 = \frac{1}{2}(1000\ \mu F)(100\ V)^2 = \mathbf{5\ pJ}$

b. $Q = CV = (1000\ \mu F)(100\ V) = \mathbf{0.1\ C}$

c. $I = Q/t = 0.1\ C/(1/2000) = \mathbf{200\ A}$

d. $P = V_{av}I_{av} = W/t = 5\ J(1/2000\ s) = \mathbf{10{,}000\ W}$

e. $t = Q/I = 0.1\ C/10\ mA = \mathbf{10\ s}$

Chapter 11

1\. a. $B = \frac{\Phi}{A} = \frac{4\times10^{-4}\ Wb}{0.01\ m^2} = 4\times10^{-2}\ Wb/m^2 = \mathbf{0.04\ Wb/m^2}$

b. **0.04 T**

c. $F = NI = (40\ t)(2.2\ A) = \mathbf{88\ At}$

d. $0.04\cancel{T}\left[\frac{10^4\ gauss}{1\cancel{T}}\right] = \mathbf{0.4\times10^3\ gauss}$

2\. $0.2\cancel{''}\left[\frac{2.54\ \cancel{cm}}{\cancel{1''}}\right]\left[\frac{1\ m}{100\ \cancel{cm}}\right] = 5.08\ mm$

$\cancel{1''}\left[\frac{2.54\ \cancel{cm}}{\cancel{1''}}\right]\left[\frac{1\ m}{100\ \cancel{cm}}\right] = 25.4\ mm$

$$A = \frac{\pi d^2}{4} = \frac{\pi(5.08\ mm)^2}{4} = 20.27\times10^{-6}\ m^2$$

$$L = \frac{N^2\mu A}{\ell} = \frac{(200\ t)^2(4\pi\times10^{-7})(20.27\times10^{-6}\ m^2)}{25.4\ mm} = \mathbf{40.1\ \mu H}$$

3\. a. $L = \frac{N^2\mu_r\mu_o A}{\ell} = \frac{(200\ t)^2(500)(4\pi\times10^{-7})(20.27\times10^{-6}\ m^2)}{25.4\ mm} = \mathbf{20.06\ mH}$

b. increase = change in μ_r

$L_{new} = \mu_r L_o$

4\. $L = N^2\frac{\mu_r\mu_o}{\ell} = \frac{(200\ t)^2(1000)(4\pi\times10^{-7})(1.5\times10^{-4}\ m^2)}{0.15\ m} = \mathbf{50.27\ mH}$

5\. $L = \frac{N^2\mu_r\mu_o A}{\ell}$

a. $L' = (3)^2L_o = 9L_o = 9(4.7\ mH) = \mathbf{42.3\ mH}$

b. $L' = \frac{1}{3}L_o = \frac{1}{3}(4.7\ mH) = \mathbf{1.57\ mH}$

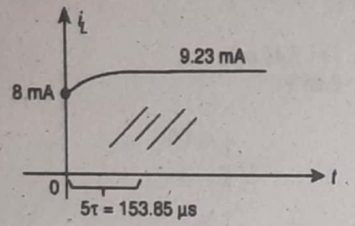
c. $L' = \frac{(2)(2)^2}{\frac{1}{2}}L_o = 16\ (4.7\ mH) = \mathbf{75.2\ mH}$

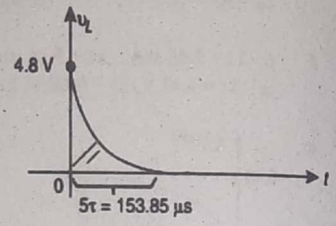
d. $L' = \frac{\left(\frac{1}{2}\right)^2\frac{1}{2}(1500)L_o}{\frac{1}{2}} = 375(4.7\ mH) = \mathbf{1.76\ mH}$

6\. a. $39\times10^2\ \mu H \pm 10\% \Rightarrow 3900\ \mu H \pm 10\% \Rightarrow \mathbf{3.9\ mH \pm 10\%}$

$i_L = 9.23\text{ mA} + (8\text{ mA} - 9.23\text{ mA})e^{-t/30.77\ \mu s}$
$i_L = \mathbf{9.23\ mA - 1.23\ mAe^{-t/30.77\ \mu s}}$
$+E - v_L - v_R = 0$ and $v_L = E - v_R$
$v_R = i_R R = i_L R = (8\text{ mA})(3.9\text{ k}\Omega) = 31.2\text{ V}$
$v_L = E - v_R = 36\text{ V} - 31.2\text{ V} = 4.8\text{ V}$
$v_L = \mathbf{4.8\ Ve^{-t/30.77\ \mu s}}$

b.



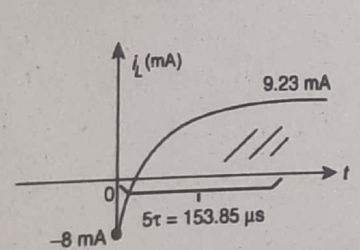


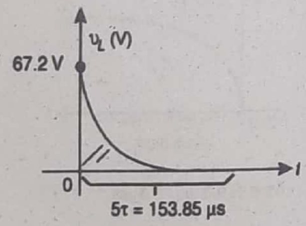
16. a. $I_i = -8\text{ mA}$, $I_f = 9.23\text{ mA}$, $\tau = \dfrac{L}{R} = \dfrac{120\text{ mH}}{3.9\text{ k}\Omega} = 30.77\ \mu s$

$i_L = I_f + (I_i - I_f)e^{-t/\tau}$
$= 9.23\text{ mA} + (-8\text{ mA} - 9.23\text{ mA})e^{-t/30.77\ \mu s}$
$i_L = \mathbf{9.23\ mA - 17.23\ mA\ e^{-t/30.77\ \mu s}}$

$+E - v_L - v_R = 0$ (at $t = 0^-$)
but, $v_R = i_R R = -i_L R = (-8\text{ mA})(3.9\text{ k}\Omega) = -31.2\text{ V}$
$v_L = E - v_R = 36\text{ V} - (-31.2\text{ V}) = 67.2\text{ V}$
$v_L = \mathbf{67.2\ V\ e^{-t/30.77\ \mu s}}$

b.





c. Final levels are the same. Transition period defined by 5τ is also the same.

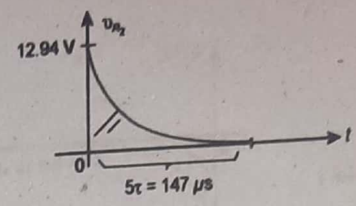
17. a. $\tau = \dfrac{L}{R} = \dfrac{100\text{ mH}}{R_1 + R_2} = \dfrac{100\text{ mH}}{3.4\text{ k}\Omega} = 29.41\ \mu s$

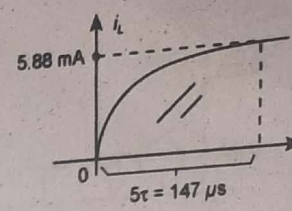
At 0^+ $v_{R_2} = \dfrac{2.2\text{ k}\Omega(20\text{ V})}{2.2\text{ k}\Omega + 1.2\text{ k}\Omega} = 12.94\text{ V}$

$v_{R_2} = \mathbf{12.94Ve^{-t/29.41\ \mu s}}$

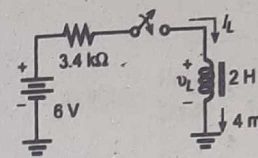
b. $i_L = \dfrac{E}{R_1 + R_2}(1 - e^{-t/\tau}) = \dfrac{20\text{ V}}{3.4\text{ k}\Omega}(1 - e^{-t/29.41\ \mu s})$
$i_L = \mathbf{5.88\ mA(1 - e^{-t/29.41\ \mu s})}$

c.

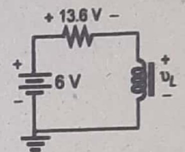




18. a. Source conversion:

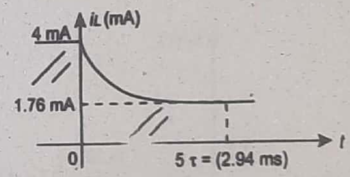


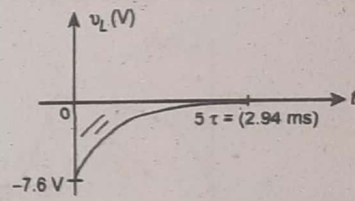
$\tau = \dfrac{L}{R} = \dfrac{2\text{ H}}{3.4\text{ k}\Omega} = 588.2\ \mu s$
$i_L = I_f + (I_i - I_f)e^{-t/\tau}$
$I_f = \dfrac{6\text{ V}}{3.4\text{ k}\Omega} = 1.76\text{ mA}$
$i_L = 1.76\text{ mA} + (4\text{ mA} - 1.76\text{ mA})e^{-t/588.2\ \mu s}$
$i_L = \mathbf{1.76\ mA + 2.24\ mA\ e^{-t/588.2\ \mu s}}$



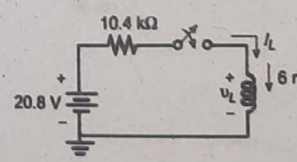
$v_R(0+) = 4\text{ mA}(3.4\text{ k}\Omega) = 13.6\text{ V}$
KVL: $+6\text{ V} - 13.6\text{ V} - v_L(0+) = 0$
$v_L(0+) = -7.6\text{ V}$
$v_L = \mathbf{-7.6\ Ve^{-t/588.2\ \mu s}}$

b.

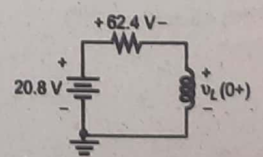




19. a.

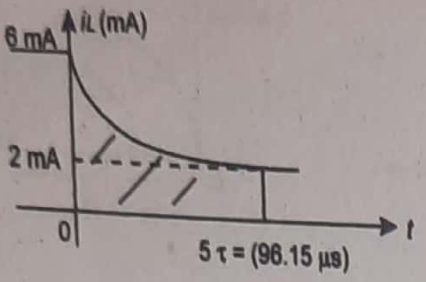


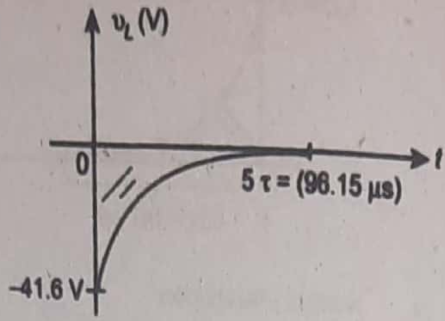
$I_f = \dfrac{20.8\text{ V}}{10.4\text{ k}\Omega} = 2\text{ mA}$
$\tau = \dfrac{L}{R} = \dfrac{200\text{ mH}}{10.4\text{ k}\Omega} = 19.23\ \mu s$
$i_L = I_f + (I_i - I_f)e^{-t/\tau}$
$= 2\text{ mA} + (6\text{ mA} - 2\text{ mA})e^{-t/19.23\ \mu s}$
$i_L = \mathbf{2\ mA + 4\ mAe^{-t/19.23\ \mu s}}$



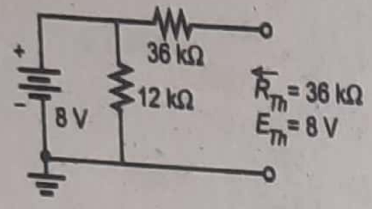
KVL: $20.8\text{ V} - 62.4\text{ V} - v_L(0+) = 0$
$v_L(0+) = -41.60\text{ V}$
$v_L = \mathbf{-41.6\ Ve^{-t/19.23\ \mu s}}$

b.





20. a.



$$\tau = \frac{L}{R} = \frac{10\text{ mH}}{36\text{ k}\Omega} = 0.278\ \mu s$$

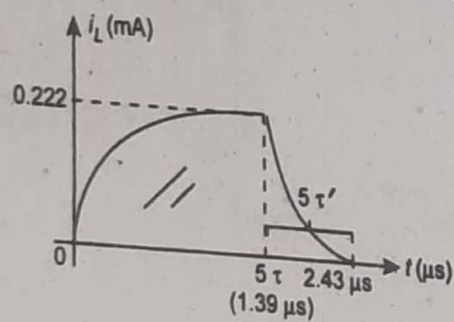
$$v_L = 8\text{ V}e^{-t/0.278\mu s},\ i_L = \frac{E}{R}(1-e^{-t/\tau}) = 0.222\text{ mA}(1-e^{-t/0.278\mu s})$$

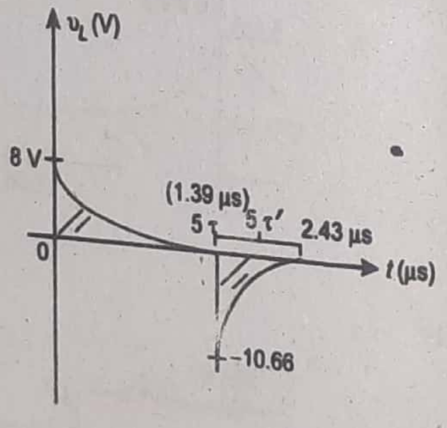
b. $5\tau \Rightarrow$ steady state

$$\tau' = \frac{L}{R} = \frac{10\text{ mH}}{12\text{ k}\Omega + 36\text{ k}\Omega} = 0.208\ \mu s$$

$$i_L = I_m e^{-t/\tau'} = 0.222\text{ mA}e^{-t/0.208\mu s}$$

$$v_L = -(0.222\text{ mA})(48\text{ k}\Omega)e^{-t/\tau} = -10.66\text{V}e^{-t/0.208\mu s}$$





21. a. $\tau = \dfrac{L}{R} = \dfrac{4.7\text{ mH}}{2\text{ k}\Omega} = 2.35\ \mu s$

$$i_L = \frac{E}{R}(1-e^{-t/\tau}) = \frac{12\text{ V}}{2\text{ k}\Omega}(1-e^{-t/\tau}) = 6\text{ mA}(1-e^{-t/2.35\mu s})$$

$$v_L = Ee^{-t/\tau} = 12\text{ V}e^{-t/2.35\mu s}$$

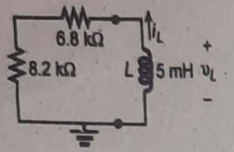
b. $i_L = 6\text{ mA}(1-e^{-t/2.35\mu s}) = 6\text{ mA}(1-e^{-1\mu s/2.35\mu s}) = 6\text{ mA}(1-e^{-0.426})$
$= 6\text{ mA}(1-.653) = 6\text{ mA}(.347) = 2.08\text{ mA}$

$$\tau' = \frac{L}{R_1+R_2} = \frac{4.7\text{ mH}}{12\text{ k}\Omega} = 392\text{ ns}$$

$$i_L = 2.08\text{ mA}e^{-t/392\text{ns}}$$

$$v_L = 12\text{ V}e^{-t/2.35\mu s} = 12\text{ V}e^{-1\mu s/2.35\mu s} = 12\text{ V}e^{-0.426}$$
$= 12\text{ V}(.653) = 7.84\text{ V}$

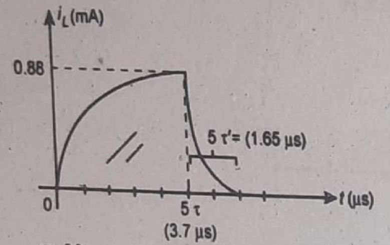
b. Assume steady state and $I_L = 0.88$ mA

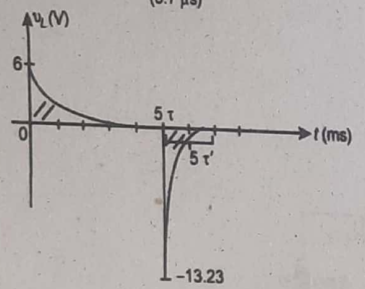


$\tau' = \frac{L}{R} = \frac{5\text{ mH}}{15\text{ k}\Omega} = 0.33\ \mu s$

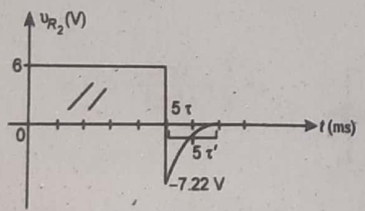
$i_L = I_m e^{-t/\tau'} = \mathbf{0.88\ mA}\ e^{-t/0.33\mu s}$
$v_L = -V_m e^{-t/\tau'}$
$V_m = I_m R = (0.88\text{ mA})(15\text{ k}\Omega) = 13.23\text{ V}$
$v_L = \mathbf{-13.23\ V}e^{-t/0.33\mu s}$

c.





d. $V_{R_{2max}} = I_m R_2 = (0.88\text{ mA})(8.2\text{ k}\Omega) = 7.22\text{ V}$



23. a. $R_{Th} = 2\text{ k}\Omega + 2.2\text{ k}\Omega + 6.2\text{ k}\Omega \parallel 3\text{ k}\Omega = 6.22\text{ k}\Omega$

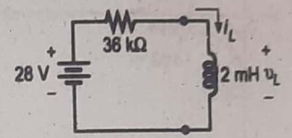
$E_{Th} = \frac{6.2\text{ k}\Omega(12\text{ V})}{6.2\text{ k}\Omega + 3\text{ k}\Omega} = 8.09\text{ V}$

$I_f = \frac{8.09\text{ V}}{6.22\text{ k}\Omega} = 1.3\text{ mA},\ \tau = \frac{L}{R} = \frac{47\text{ mH}}{6.22\text{ k}\Omega} = 7.56\ \mu s$

$i_L = \mathbf{1.3\ mA(1 - e^{-t/7.56\mu s})}$
$v_L = \mathbf{8.09\ V}e^{-t/7.56\mu s}$

b. $0.632(1.3\text{ mA}) = \mathbf{0.822\ mA}$
$0.368(8.09\text{ V}) = \mathbf{2.98\ V}$

24. a. Source conversion: $E = IR = (4\text{ mA})(12\text{ k}\Omega) = 48\text{ V}$, $E_{Net} = 48\text{ V} - 20\text{ V} = 28\text{ V}$



$\tau = \frac{L}{R} = \frac{2\text{ mH}}{36\text{ k}\Omega} = 55.56\text{ ns}$

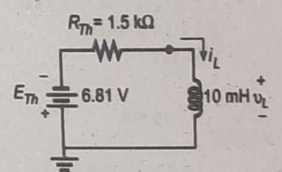
$i_L = \frac{E}{R}(1 - e^{-t/\tau}) = \frac{28\text{ V}}{36\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{0.778\ mA(1 - e^{-t/55.56ns})}$

$v_L = Ee^{-t/\tau} = \mathbf{28\ V}e^{-t/55.56ns}$

b. $t = 100$ ns:
$i_L = 0.778\text{ mA}(1 - e^{-100ns/55.56ns}) = 0.778\text{ mA}(\underbrace{1 - e^{-1.8}}_{0.165}) = \mathbf{0.65\ mA}$

$v_L = 28\text{ V}e^{-1.8} = \mathbf{4.62\ V}$

25. a.



$R_{Th} = 2.2\text{ k}\Omega \parallel 4.7\text{ k}\Omega = 1.50\text{ k}\Omega$

$E_{Th} = -\frac{4.7\text{ k}\Omega(10\text{ V})}{4.7\text{ k}\Omega + 2.2\text{ k}\Omega} = -6.81\text{ V}$

$\tau = \frac{L}{R} = \frac{10\text{ mH}}{1.50\text{ k}\Omega} = 6.67\ \mu s$

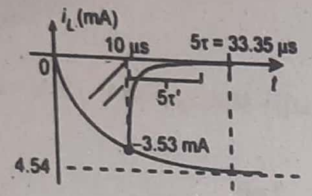
$i_L = -\frac{E}{R}(1 - e^{-t/\tau}) = -\frac{6.81\text{ V}}{1.5\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{-4.54\ mA(1 - e^{-t/6.67\mu s})}$
$v_L = Ee^{-t/\tau} = -E_{Th}e^{-t/\tau} = \mathbf{-6.81\ V}e^{-t/6.67\mu s}$

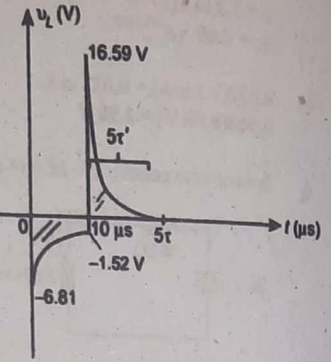
b. $t = 10\ \mu s$:
$i_L = -4.54\text{ mA}(1 - e^{-10\mu s/6.67\mu s}) = -4.54\text{ mA}(\underbrace{1 - e^{-1.5}}_{0.223})$

$= \mathbf{-3.53\ mA}$
$v_L = -6.81\text{ V}(0.223) = \mathbf{-1.52\ V}$

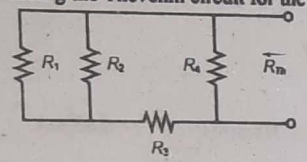
c. $\tau' = \frac{L}{R} = \frac{10\text{ mH}}{4.7\text{ k}\Omega} = 2.13\ \mu s$
$i_L = \mathbf{-3.53\ mA}e^{-t/2.13\mu s}$
At $t = 10\ \mu s$
$V_L = (3.53\text{ mA})(4.7\text{ k}\Omega) = 16.59\text{ V}$
$v_L = \mathbf{16.59\ V}e^{-t/2.13\mu s}$

d.

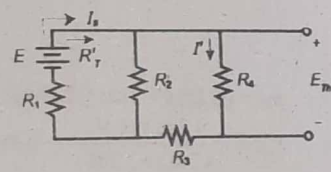




26. a. Finding the Thevenin circuit for the inductor:



$R_{Th} = R_4 \parallel (R_3 + R_1 \parallel R_2)$
$= 1\text{ k}\Omega \parallel (2.7\text{ k}\Omega + 8.2\text{ k}\Omega \parallel 2.2\text{ k}\Omega)$
$= 1\text{ k}\Omega \parallel 4.43\text{ k}\Omega$
$= 0.816\text{ k}\Omega$

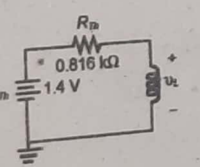


$R_T' = R_1 + R_2 \parallel (R_3 + R_4)$
$= 8.2\text{ k}\Omega + 2.2\text{ k}\Omega \parallel (2.7\text{ k}\Omega + 1\text{ k}\Omega)$
$= 8.2\text{ k}\Omega + 2.2\text{ k}\Omega \parallel 3.7\text{ k}\Omega$
$= 8.2\text{ k}\Omega + 1.38\text{ k}\Omega$
$= 9.58\text{ k}\Omega$

Then $I_s = \dfrac{E}{R_T'} = \dfrac{36\text{ V}}{9.58\text{ k}\Omega} = 3.76\text{ mA}$

and $I' = \dfrac{R_2(I_s)}{R_2 + R_3 + R_4} = \dfrac{2.2\text{ k}\Omega(3.76\text{ mA})}{2.2\text{ k}\Omega + 2.7\text{ k}\Omega + 1\text{ k}\Omega} = 1.4\text{ mA}$

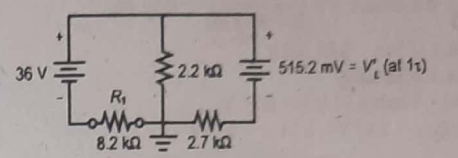
and finally $E_{Th} = I'R_4 = (1.4\text{ mA})(1\text{ k}\Omega) = 1.4\text{ V}$

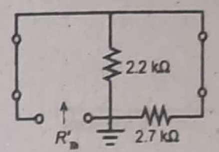


$\tau = \dfrac{L}{R} = \dfrac{10\text{ mH}}{0.816\text{ k}\Omega} = 12.25\ \mu s$
$v_L = 1.4\text{ V}e^{-t/12.25\mu s}$
$= 1.4\text{ V}e^{-25\mu s/12.25\mu s}$
$= 1.4\text{ V}e^{-2.05}$
$= 1.4\text{ V}(128.73 \times 10^{-3})$
$= 180\text{ mV}$

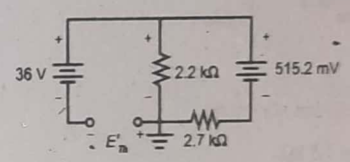
b. $v_L = 1.4\text{ V}e^{-t/12.25\mu s}$
$v_L = 1.4\text{ V}e^{-1\mu s/12.25\mu s}$
$= (1.4\text{ V})(e^{-0.082})$
$= (1.4\text{ V})(.0921)$
$= 1.29\text{ V}$

c. Finding the Thevenin equivalent for R_1 at 1τ
At 1τ: $v_L = 1.4\text{ V}e^{-t/\tau} = 1.4\text{ V}e^{-\tau/\tau} = 1.4\text{ V}e^{-1} = 1.4\text{ V}(0.368) = 515.2\text{ mV}$

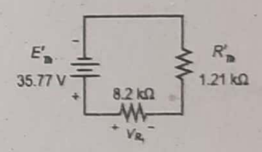




$R_{Th}' = 2.2\text{ k}\Omega \parallel 2.7\text{ k}\Omega = 1.21\text{ k}\Omega$



$-E_{Th}' + 36\text{ V} - v_{R_2} = 0$
$E_{Th}' = 36 - v_{R_2}$
$v_{R_2} = \dfrac{2.2\text{ k}\Omega(515.2\text{ mV})}{2.2\text{ k}\Omega + 2.7\text{ k}\Omega} = 0.231\text{ V}$
$\therefore E_{Th}' = 36\text{ V} - 0.231\text{ V} = 35.77\text{ V}$



$v_{R_1} = \dfrac{8.2\text{ k}\Omega(35.77\text{ V})}{8.2\text{ k}\Omega + 1.21\text{ k}\Omega} = 31.34\text{ V}$

d. $i_L = \dfrac{E_{Th}}{R_{Th}}(1 - e^{-t/\tau})$
$= \dfrac{1.4\text{ V}}{0.81\text{ k}\Omega}(1 - e^{-t/12.25\mu s})$
$= 1.72\text{ mA}(1 - e^{-t/12.25\mu s})$
$1\text{ mA} = 1.72\text{ mA}(1 - e^{-t/12.25\mu s})$
$0.581 = 1 - e^{-t/12.25\mu s}$
$0.419 = e^{-t/12.25\mu s}$
$t = 12.25\ \mu s \log_e 0.419$
$= 12.25\ \mu s(0.87)$
$= 10.66\ \mu s$

27. a. $I_i = \dfrac{16\text{ V}}{4.7\text{ k}\Omega + 3.3\text{ k}\Omega} = 2\text{ mA}$
$t = 0$ s: Thevenin:
$R_{Th} = 3.3\text{ k}\Omega + 1\text{ k}\Omega \parallel 4.7\text{ k}\Omega = 3.3\text{ k}\Omega + 0.82\text{ k}\Omega = 4.12\text{ k}\Omega$
$E_{Th} = \dfrac{1\text{ k}\Omega(16\text{ V})}{1\text{ k}\Omega + 4.7\text{ k}\Omega} = 2.81\text{ V}$
$i_L = I_f + (I_i - I_f)e^{-t/\tau}$

$$I_f = \frac{2.81\text{ V}}{4.12\text{ k}\Omega} = 0.68\text{ mA},\ \tau = \frac{L}{R} = \frac{2\text{ H}}{4.12\text{ k}\Omega} = 0.49\text{ ms}$$

$i_L = 0.68\text{ mA} + (2\text{ mA} - 0.68\text{ mA})e^{-t/0.49\text{ ms}}$

$\mathbf{i_L = 0.68\text{ mA} + 1.32\text{ mA}e^{-t/0.49\text{ ms}}}$

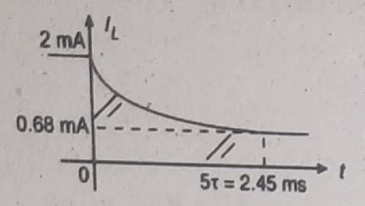
$v_R(0+) = 2\text{ mA}(4.12\text{ k}\Omega) = 8.24\text{ V}$

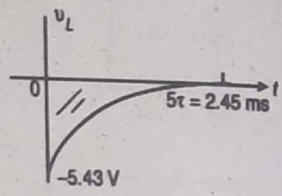
KVL(0+): $2.81\text{ V} - 8.24\text{ V} - v_L = 0$

$v_L = -5.43\text{ V}$

$\mathbf{v_L = -5.43\text{ V}e^{-t/0.49\text{ ms}}}$

b.

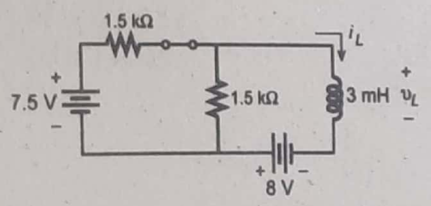




28. a. Steady-state: $I_L = \frac{8\text{ V}}{1.5\text{ k}\Omega} = 5.33\text{ mA},\ V_L = 0\text{ V}$

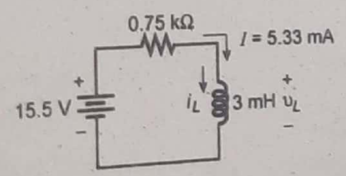
$R_{Th} = (3\text{ k}\Omega \parallel 12\text{ k}\Omega) \parallel 4\text{ k}\Omega = 1.5\text{ k}\Omega$

$$E_{Th} = \frac{2.4\text{ k}\Omega(20\text{ V})}{2.4\text{ k}\Omega + 4\text{ k}\Omega} = 7.5\text{ V}$$



$R'_{Th} = 1.5\text{ k}\Omega \parallel 1.5\text{ k}\Omega = 0.75\text{ k}\Omega$

$E'_{Th} = 8\text{ V} + 7.5\text{ V} = 15.5\text{ V}$



$$\tau = \frac{L}{R} = \frac{3\text{ mH}}{0.75\text{ k}\Omega} = 4\ \mu\text{s}$$

$$I_f = \frac{15.5\text{ V}}{0.75\text{ k}\Omega} = 20.67\text{ mA} \qquad I_i = 5.33\text{ mA}$$

$i_L = I_f + (I_i - I_f)e^{-t/\tau}$

$= 20.67\text{ mA} + (5.33\text{ mA} - 20.67\text{ mA})e^{-t/4\ \mu\text{s}}$

$\mathbf{i_L = 20.67\text{ mA} - 15.34\text{ mA}e^{-t/4\mu\text{s}}}$

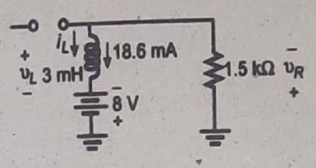
$\mathbf{v_L = 15.5\text{ V}e^{-t/4\mu\text{s}}}$

b. $i_L(2\tau) = 20.67\text{ mA} - 15.34\text{ mA}\underbrace{e^{-2}}_{0.135}$

$= \mathbf{18.6\text{ mA}}$

$v_L(2\tau) = 15.5\text{ V}e^{-2} = 15.5\text{ V}(0.135) = \mathbf{2.09\text{ V}}$

c. $I_i = 18.6\text{ mA}$



$v_L + v_R - 8\text{ V} = 0$

$v_L = 8\text{ V} - v_R = 8\text{ V} - (18.6\text{ mA})(1.5\text{ k}\Omega)$

$= -19.9\text{ V}$

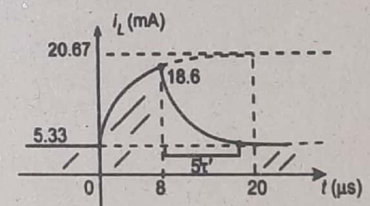
$$\tau' = \frac{L}{R} = \frac{3\text{ mH}}{1.5\text{ k}\Omega} = 2\ \mu\text{s}$$

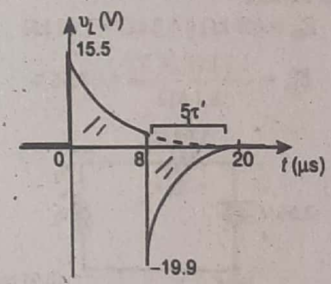
$$I_i = 18.6\text{ mA} \qquad I_f = \frac{8\text{ V}}{1.5\text{ k}\Omega} = 5.33\text{ mA}$$

$i_L = I_f + (I_i - I_f)e^{-t/\tau'} = 5.33\text{ mA} + (18.6\text{ mA} - 5.33\text{ mA})e^{-t/2\mu\text{s}}$

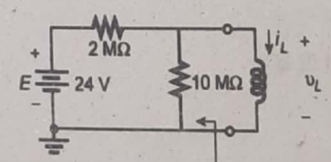
$= \mathbf{5.33\text{ mA} + 13.27\text{ mA}e^{-t/2\mu\text{s}}}$

$\mathbf{v_L = -19.9\text{ V}e^{-t/2\mu\text{s}}}$





29. a.



$R_{Th} = 2\text{ M}\Omega \parallel 10\text{ M}\Omega = 1.67\text{ M}\Omega$

$$E_{Th} = \frac{10\text{ M}\Omega(24\text{ V})}{10\text{ M}\Omega + 2\text{ M}\Omega} = 20\text{ V}$$

$$I_L(0^-) = \frac{E_{Th}}{R_{Th}} = \frac{20\text{ V}}{1.67\text{ M}\Omega} = 12\ \mu\text{A}$$

$$\tau' = \frac{L}{R_{meter}} = \frac{5\text{ H}}{10\text{ M}\Omega} = 5\mu\text{s}$$

$i_L = 12\ \mu\text{A}e^{-t/5\ \mu\text{s}}$

$10\ \mu\text{A} = 12\ \mu\text{A}e^{-t/5\ \mu\text{s}}$

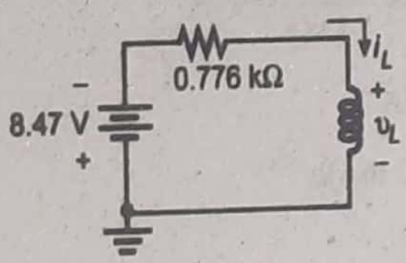
$$0.833 = e^{-t/5\,\mu s}$$
$$\log_e 0.833 = -t/5\ \mu s$$
$$0.183 = t/5\ \mu s$$
$$t = 0.183(5\ \mu s) = \mathbf{0.92\ \mu s}$$

b. $v_L(0^+) = i_L(0^+)R_m = (12\ \mu A)(10\ M\Omega) = 120\ V$
$v_L = 120\ Ve^{-t/5\mu s} = 120\ Ve^{-10\mu s/5\mu s} = 120\ Ve^{-2} = 120\ V(0.135) = \mathbf{16.2\ V}$

c. $v_L = 120\ Ve^{-5\tau/\tau} = 120\ Ve^{-5} = 120\ V(6.74 \times 10^{-3}) = \mathbf{0.81\ V}$

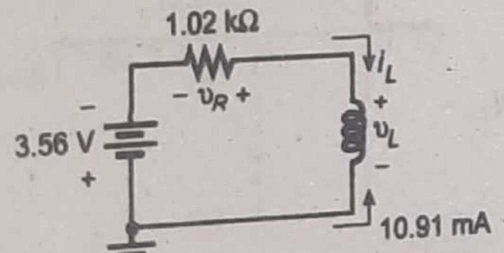
30. a. Closed Switch:

$$R_{Th} = 1.2\ k\Omega \parallel 2.2\ k\Omega = 0.776\ k\Omega$$
$$E_{Th} = \frac{1.2\ k\Omega(24\ V)}{1.2\ k\Omega + 2.2\ k\Omega} = 8.47\ V$$



Open Switch:

$$R'_{Th} = 6.9\ k\Omega \parallel 1.2\ k\Omega = 1.02\ k\Omega$$
$$E'_{Th} = \frac{1.2\ k\Omega(24\ V)}{8.1\ k\Omega} = -3.56\ V$$



$$-3.56\ V + v_R - v_L = 0$$
$$v_L = -3.56\ V + (10.91\ mA)(1.02\ k\Omega)$$
$$= 7.57\ V$$
$$v_L = 7.57Ve^{-t/1.18\ ms}$$

$$\tau = \frac{L}{R} = \frac{1.24\ H}{1.02\ k\Omega} = 1.18\ ms$$
$$I_{ss} = \frac{3.56\ V}{1.02\ k\Omega} = 3.49\ mA = I_f$$
$$i_L = I_f + (I_i - I_f)e^{-t/\tau}$$
$$= -3.49\ mA + ((-10.91\ mA - (-3.49\ mA))e^{-t/1.18\ ms}$$
$$i_L = \mathbf{-3.49\ mA - 7.42\ mAe^{-t/1.18\ ms}}$$

32. a. $I_L(1\tau) = 0.632 I_{max} = 126.4\ \mu A$

$$I_{max} = \frac{126.4}{0.632} = 200\ \mu A$$

$$i_L = I_m(1 - e^{-t/\tau})$$

$$160\ \mu A = 200\ \mu A\left(1 - e^{\frac{-64.4\mu s}{\tau}}\right)$$

b. $$0.8 = 1 - e^{\frac{-64.4\mu s}{\tau}}$$

$$0.2 = e^{\frac{-64.4\mu s}{\tau}}$$

$$\log_e 0.2 = -1.61 = \frac{-64.4\ \mu s}{\tau}$$

$$\tau = \frac{64.4\ \mu s}{1.61} = 40\ \mu s$$

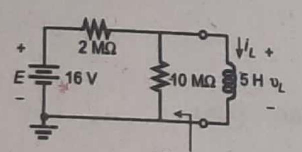
c. $\tau = \frac{L}{R} = 40\ \mu s = \frac{L}{500\ k\Omega}$, $L = (500\ k\Omega)(40\ \mu s) = 20\ mH$

d. $I_m = \frac{E}{R} \Rightarrow E = (200\ \mu A)(500\ \Omega) = 100\ mV$

33. a. $L \Rightarrow$ open circuit equivalent

$$V_L = \frac{10\ M\Omega(16\ V)}{10\ M\Omega + 2\ M\Omega} = 13.33\ V$$

b.



$$R_{Th} = 2\ M\Omega \parallel 10\ M\Omega = 1.67\ M\Omega$$

$$E_{Th} = \frac{10\ M\Omega(16\ V)}{10\ M\Omega + 2\ M\Omega} = 13.33\ V$$

$$I_{L_{final}} = \frac{E_{Th}}{R_{Th}} = \frac{13.33\ V}{1.67\ M\Omega} = 7.98\ \mu A$$

c. $i_L = 7.98\ \mu A(1 - e^{-t/3\ \mu s})$ $\qquad \tau = \frac{L}{R} = \frac{5\ H}{1.67\ M\Omega} = 3\ \mu s$

$10\ \mu A = 7.98\ \mu A(1 - e^{-t/3\ \mu s})$

$1.253 = 1 - e^{-t/3\ \mu s}$

$0.253 = e^{-t/3\ \mu s}$

$\log_e(0.253) = -t/3\ \mu s$

$1.374 = t/3\ \mu s$

$t = 1.374(3\ \mu s) = 4.12\ \mu s$

d. $v_L = 13.33\ V\ e^{-t/3\ \mu s} = 13.33\ V\ e^{-12\ \mu s/3\ \mu s} = 13.33\ V\ e^{-4}$
$= 13.33\ V(0.0183) = 0.244\ V$

34. $e_L = L\frac{\Delta i}{\Delta t}$: $\quad$ 0 – 4 ms, $e_L = (200\text{mH})\left[\frac{15\ mA}{4\ ms}\right] = 750\ mV$

4 – 10 ms, $e_L = (200\ mH)\left[\frac{0\ mA}{6\ ms}\right] = 0\ V$

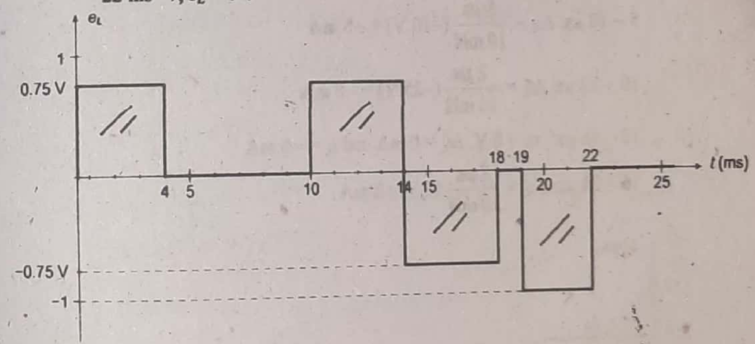
10 – 14 ms, $e_L = (200\ mH)\left[\frac{15\ mA}{4\ ms}\right] = 750\ mV$

14 – 18 ms, $e_L = -(200\ mH)\left[\frac{15\ mA}{4\ ms}\right] = -750\ mV$

18 – 19 ms, $e_L = 0\ V$

19 – 22 ms, $e_L = -(200\ mH)\left[\frac{15\ mA}{3\ ms}\right] = -1\ V$

22 ms →, $e_L = 0\ V$



35. $v_L = L\frac{\Delta i_L}{\Delta t}$

0 → 2 ms: $v_L = 0\ V$

2 → 6 ms: $v_L = -(5\ mH)\left(\frac{30\ mA}{4\ ms}\right) = -37.5\ mV$

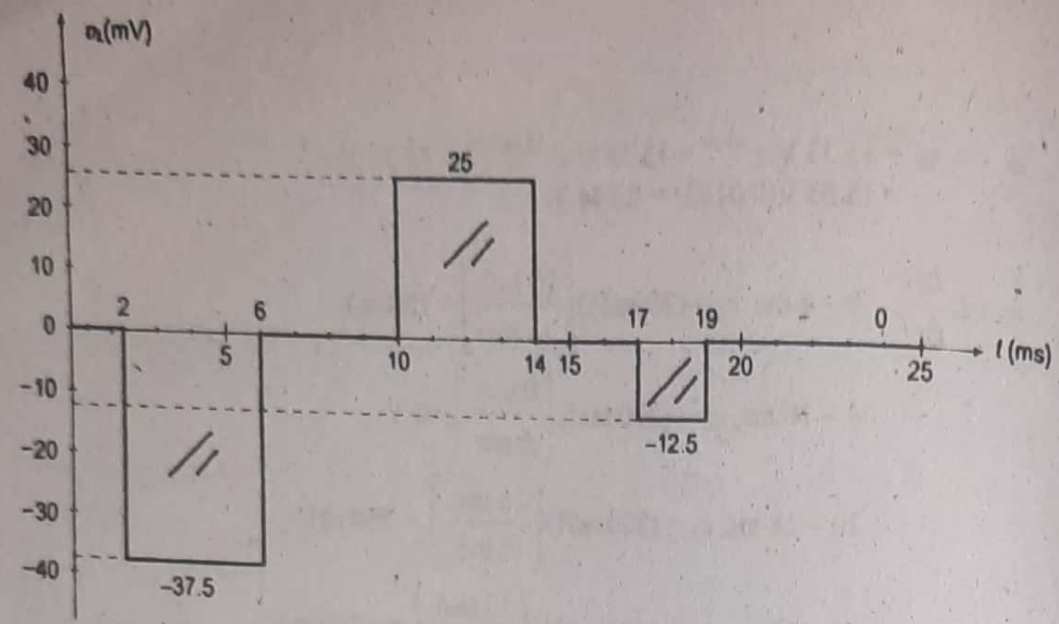
6 → 10 ms: $v_L = 0\ V$

10 → 14 ms: $v_L = (5\ mH)\left(\frac{20\ mA}{4\ ms}\right) = 25\ mV$

14 → 17 ms: $v_L = 0\ V$

17 → 19 ms: $v_L = -(5\ mH)\left(\frac{5\ mA}{2\ ms}\right) = -12.5\ mV$

19 →, $v_L = 0\ V$



36. $L = 10$ mH, 4 mA at $t = 0$ s

$$v_L = L\frac{\Delta i}{\Delta t} \Rightarrow \Delta i = \frac{\Delta t}{L}v_L$$

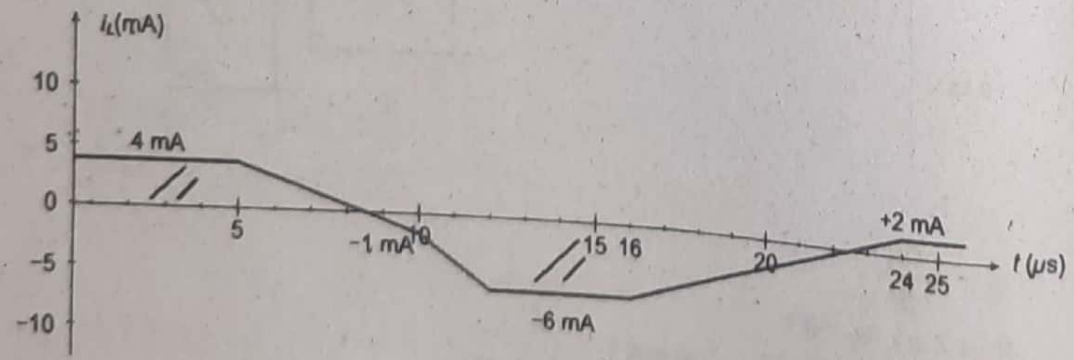
0 – 5 μs: $v_L = 0$ V, $\Delta i_L = 0$ mA and $i_L = 4$ **mA**

5 – 10 μs: $\Delta i_L = \dfrac{5\ \mu\text{s}}{10\ \text{mH}}(-10\ \text{V}) = \mathbf{-5\ mA}$

10 – 12 μs: $\Delta i_L = \dfrac{2\ \mu\text{s}}{10\ \text{mH}}(-25\ \text{V}) = \mathbf{-5\ mA}$

12 – 16 μs: $v_L = 0$ V, $\Delta i_L = 0$ mA and $i_L = \mathbf{-6\ mA}$

16 – 24 μs: $\Delta i_L = \dfrac{8\ \mu\text{s}}{10\ \text{mH}}10\ \text{V} = \mathbf{8\ mA}$



37. a. $L_4 + L_5 = 5.6$ mH + 2 mH = 7.6 mH
$L_3 \parallel 7.6$ mH = 3 mH $\parallel$ 7.6 mH = 2.15 mH
$L_2 + 2{,}18$ mH = 3.3 mH + 2.15 mH = 5.45 mH
$L_1 \parallel 5.45$ mH = 2.4 mH $\parallel$ 5.45 mH = 1.67 mH
$L_T = L_6 + 1.67$ mH = 9.1 mH + 1.67 mH = **10.77 mH**

38. $L_2 \parallel L_4 = 10$ mH $\parallel$ 30 mH = 7.5 mH
$L_3 + L_2 \parallel L_4 = 47$ mH + 7.5 mH = 54.5 mH
54.5 mH $\parallel$ 22 mH = 15.67 mH
$L_T = L_1 + 15.67$ mH = 18 mH + 15.67 mH = **33.67 mH**

43. a. Source conversion: $E = 16\text{ V}$, $R_s = 2\text{ k}\Omega$

$R_{Th} = 2\text{ k}\Omega + 2\text{ k}\Omega \parallel 8.2\text{ k}\Omega = 2\text{ k}\Omega + 1.61\text{ k}\Omega = 3.61\text{ k}\Omega$

$$E_{Th} = \frac{8.2\text{ k}\Omega(16\text{ V})}{8.2\text{ k}\Omega + 2\text{ k}\Omega} = 12.86\text{ V}$$

$$I_m = \frac{E_{Th}}{R_{Th}} = \frac{12.86\text{ V}}{3.61\text{ k}\Omega} = 3.56\text{ mA},\quad \tau = \frac{L}{R} = \frac{30\text{ mH}}{3.61\text{ k}\Omega} = 8.31\ \mu\text{s}$$

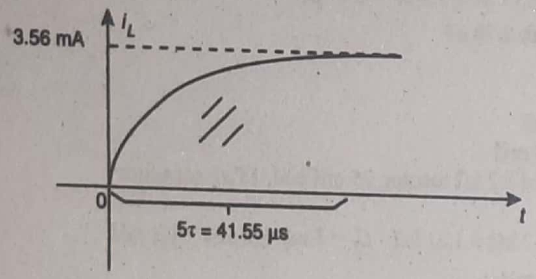
$i_L = \mathbf{3.56\ mA(1 - e^{-t/8.31\mu s})}$

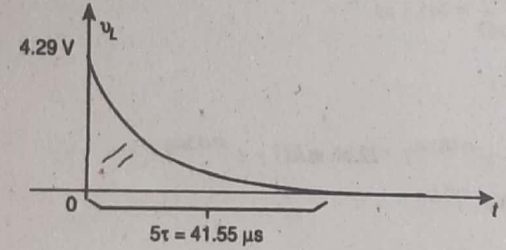
$\upsilon_{L_1} + \upsilon_{L_2} = 12.86\text{ V}$ initially $(t = 0+)$

$$\upsilon_L = \frac{10\text{ mH}}{10\text{ mH} + 20\text{ mH}}\text{ of total} = \frac{1}{3}(12.86\text{ V}) = 4.29\text{ V}$$

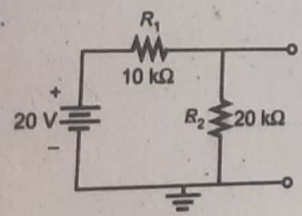
$\upsilon_L = \mathbf{4.29\ Ve^{-t/8.31\mu s}}$

b.





44. a.



$\leftarrow R_{Th} = 10\text{ k}\Omega \parallel 20\text{ k}\Omega = 6.67\text{ k}\Omega$

$$E_{Th} = \frac{20\text{ k}\Omega(20\text{ V})}{20\text{ k}\Omega + 10\text{ k}} = 13.33\text{ V}$$

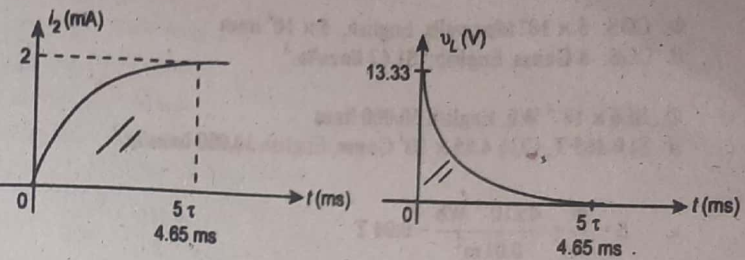
$L_T = 3\text{ H} + 4.7\text{ H} \parallel 10\text{ H} = 3\text{ H} + 3.197\text{ H} = \mathbf{6.197\ H}$

$$\tau = \frac{L_T}{R} = \frac{6.197\text{ H}}{6.67\text{ k}\Omega} = 0.93\text{ ms}$$

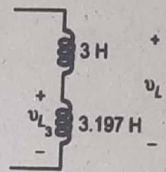
$\upsilon_L = \mathbf{13.33Ve^{-t/0.93\ ms}}$

$$i_L = \frac{13.33\text{ V}}{6.67\text{ k}\Omega}(1 - e^{-t/\tau}) = \mathbf{2\ mA(1 - e^{-t/0.93\ ms})}$$

b.



c.



$$\upsilon_{L_3} = \frac{3.197\text{ H}}{3\text{ H} + 3.197\text{ H}} = 0.52\,\upsilon_L$$

$\upsilon_{L_3} = (0.52)(13.33e^{-t/0.93\text{ ms}}) = 6.93\ Ve^{-t/0.93\text{ ms}}$

45. $$I_{R_1} = \frac{E}{R_1} = \frac{20\text{ V}}{4\Omega} = 5\text{ A}$$

$I_2 = \mathbf{0\ A}$

$I_1 = I_{R_1} + I_2 = 5\text{ A} + 0\text{ A} = \mathbf{5\ A}$

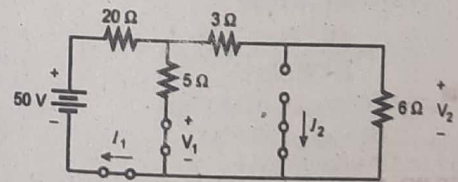
46. $I_1 = I_2 = \mathbf{0\ A}$

$V_1 = V_2 = E = \mathbf{60\ V}$

47. $$I_1 = \frac{12\text{ V}}{4\Omega} = \mathbf{3\ A},\ I_2 = \mathbf{0\ A}$$

$V_1 = \mathbf{12\ V},\ V_2 = \mathbf{0\ V}$

48.



$$V_2 = \frac{6\ \Omega(50\text{ V})}{6\ \Omega + 20\ \Omega + 3\ \Omega} = \mathbf{10.34\ V}$$

$$V_1 = \frac{(3\ \Omega + 6\ \Omega)(50\text{ V})}{29\ \Omega} = \mathbf{15.52\ V}$$

$$I_1 = \frac{50\text{ V}}{20\ \Omega + 3\ \Omega + 6\ \Omega} = \mathbf{1.72\ A}$$

$I_2 = \mathbf{0\ A}$

Chapter 12

1. Φ: CGS: **5×10^4 Maxwells**, English: **5×10^4 lines**
   B: CGS: **8 Gauss**, English: **51.62 lines/in.^{2}**

2. Φ: SI **6×10^{-4} Wb**, English **60,000 lines**
   B: SI **0.465 T**, CGS **4.65×10^3 Gauss**, English **30,000 lines/in.^{2}**

3. a. $B = \dfrac{\Phi}{A} = \dfrac{4\times10^{-4}\ \text{Wb}}{0.01\ \text{m}^2} = \mathbf{0.04\ T}$

4. a. $\mathscr{R} = \dfrac{l}{\mu A} = \dfrac{0.06\ \text{m}}{\mu 2\times10^{-4}\ \text{m}^2} = \dfrac{300}{\mu\ \text{m}}$

   b. $\mathscr{R} = \dfrac{l}{\mu A} = \dfrac{0.0762\ \text{m}}{\mu 5\times10^{-4}\ \text{m}^2} = \dfrac{152.4}{\mu\ \text{m}}$

   c. $\mathscr{R} = \dfrac{l}{\mu A} = \dfrac{0.1\ \text{m}}{\mu 1\times10^{-4}\ \text{m}^2} = \dfrac{1000}{\mu\ \text{m}}$

   from the above $\mathscr{R}_{(c)} > \mathscr{R}_{(a)} > \mathscr{R}_{(b)}$

5. $\mathscr{R} = \dfrac{\mathscr{F}}{\Phi} = \dfrac{400\ \text{At}}{4.2\times10^{-4}\ \text{Wb}} = \mathbf{952.4 \times 10^3\ At/Wb}$

6. $\mathscr{R} = \dfrac{\mathscr{F}}{\Phi} = \dfrac{120\ \text{gilberts}}{72{,}000\ \text{max wells}} = \mathbf{1.67 \times 10^{-3}\ rels\ (CGS)}$

7. $6\ \cancel{\text{in.}} \left[\dfrac{1\ \text{m}}{39.37\ \cancel{\text{in.}}}\right] = 0.1524\ \text{m}$

   $H = \dfrac{\mathscr{F}}{l} = \dfrac{400\ \text{At}}{0.1524\text{m}} = \mathbf{2624.67\ At/m}$

8. $\mu = \dfrac{2B}{H} = \dfrac{2(1200\times10^{-4}\ \text{T})}{600\ \text{At/m}} = \mathbf{4 \times 10^{-4}\ Wb/Am}$

9. $B = \dfrac{\Phi}{A} = \dfrac{10\times10^{-4}\ \text{Wb}}{3\times10^{-3}\ \text{m}^2} = 0.33\ \text{T}$

   Fig. 12.7: $H \equiv 800$ At/m
   $NI = Hl \Rightarrow I = Hl/N = (800\ \text{At/m})(0.2\ \text{m})/75\ \text{t} = \mathbf{2.13\ A}$

13. $N_1 I + N_2 = \underbrace{HI}_{\text{cast steel}} + \underbrace{HI}_{\text{cast iron}}$

$(20\text{ t})I + (30\text{ t})I =$ "

$(50\text{ t})I =$ "

$$B = \frac{\Phi}{A} \text{ with } 0.25\ \cancel{\text{in.}}^2 \left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right]\left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 1.6 \times 10^{-4}\text{ m}^2$$

$$B = \frac{0.8 \times 10^{-4}\text{ Wb}}{1.6 \times 10^{-4}\text{ m}^2} = 0.5\text{ T}$$

Fig. 12.8: $H_{\text{cast steel}} \cong 280$ At/m

Fig. 12.7: $H_{\text{cast iron}} \cong 1500$ At/m

$$l_{\text{cast steel}} = 5.5\ \cancel{\text{in.}} \left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 0.14\text{ m}$$

$$l_{\text{cast iron}} = 2.5\ \cancel{\text{in.}} \left[\frac{1\text{ m}}{39.37\ \cancel{\text{in.}}}\right] = 0.064\text{ m}$$

$(50\text{ t})I = (280\text{ At/m})(0.14\text{ m}) + (1500\text{ At/m})(0.064\text{ m})$

$50I = 39.20 + 96.00 = 135.20$

$\mathbf{I = 2.70\ A}$

14. a. $l_{ab} = l_{ef} = 0.05$ m, $l_{af} = 0.02$ m, $l_{bc} = l_{de} = 0.0085$ m

$NI = 2H_{ab}l_{ab} + 2H_{bc}l_{bc} + H_{fa}l_{fa} + H_g l_g$

$$B = \frac{\Phi}{A} = \frac{2.4 \times 10^{-4}\text{ Wb}}{2 \times 10^{-4}\text{ m}^2} = 1.2\text{ T} \Rightarrow H \cong 360\text{ At/m (Fig. 12.8)}$$

$100I = 2(360\text{ At/m})(0.05\text{ m}) + 2(360\text{ At/m})(0.0085\text{ m})$

$+ (360\text{ At/m})(0.02\text{ m}) + 7.97 \times 10^5(1.2\text{ T})(0.003\text{ m})$

$= 36\text{ At} + 6.12\text{ At} + 7.2\text{ At} + 2869\text{ At}$

$100I = 2918.32$ At

$\mathbf{I \cong 29.18\ A}$

b. air gap: metal = 2869 At:49.72 At = **58.17:1**

$$\mu_{\text{sheet steel}} = \frac{B}{H} = \frac{1.2\text{ T}}{360\text{ At/m}} = \mathbf{3.33 \times 10^{-3}\ Wb/Am}$$

$\mu_{\text{air}} = \mathbf{4\pi \times 10^{-7}\ Wb/Am}$

$\mu_{\text{sheet steel}} : \mu_{\text{air}} = 3.33 \times 10^{-3}$ Wb/Am:$4\pi \times 10^{-7}$ $\cong$ **2627:1**

15. $4\ \cancel{\text{cm}} \left[\frac{1\text{ m}}{100\ \cancel{\text{cm}}}\right] = 0.04\text{ m}$

$$f = \frac{1}{2}NI\frac{d\phi}{dx} = \frac{1}{2}(80\text{ t})(0.9\text{ A})\frac{(8 \times 10^{-4}\text{ Wb} - 0.5 \times 10^{-4}\text{ Wb})}{\frac{1}{2}(0.04\text{ m})} = \frac{36(7.5 \times 10^{-4})}{0.02}$$

$= \mathbf{1.35\ N}$

16. $C = 2\pi r = (6.28)(0.3\text{ m}) = 1.88\text{ m}$

$$B = \frac{\Phi}{A} = \frac{2 \times 10^{-4}\text{ Wb}}{1.3 \times 10^{-4}\text{ m}^2} = 1.54\text{ T}$$

Fig. 12.7: $H_{\text{sheet steel}} \cong 2100$ At/m

$H_g = 7.97 \times 10^5 B_g = (7.97 \times 10^5)(1.54\text{ T}) = 1.23 \times 10^6$ At/m

$N_1 I_1 + N_2 I_2 = H_g l_g + Hl_{(\text{sheet steel})}$

$(200\text{ t})I_1 + (40\text{ t})(0.3\text{ A}) = (1.23 \times 10^6\text{ At/m})(2\text{ mm}) + (2100\text{ At/m})(1.88\text{ m})$

$\mathbf{I_1 = 31.98\ A}$

17. a. $0.2\ \cancel{\text{cm}} \left[\frac{1\text{ m}}{100\ \cancel{\text{cm}}}\right] = 2 \times 10^{-3}\text{ m}$

$$A = \frac{\pi d^2}{4} = \frac{(3.14)(0.01\text{ m})^2}{4} = 0.79 \times 10^{-4}\text{ m}^2$$

$NI = H_g l_g,\ H_g = 7.96 \times 10^5 B_g$

$$(200\text{ t})I = \left[(7.96 \times 10^5)\left(\frac{0.2 \times 10^{-4}\text{ Wb}}{0.79 \times 10^{-4}\text{ m}^2}\right)\right]2 \times 10^{-3}\text{ m}$$

$\mathbf{I = 2.02\ A}$

b. $$B_g = \frac{\Phi}{A} = \frac{2 \times 10^{-4}\text{ Wb}}{0.79 \times 10^{-4}\text{ m}^2} = 0.25\text{ T}$$

$$F \cong \frac{1}{2}\frac{B_g^2 A}{\mu_o} = \frac{1}{2}\frac{(0.25\text{ T})^2(0.79 \times 10^{-4}\text{ m}^2)}{4\pi \times 10^{-7}}$$

$\mathbf{\cong 2\ N}$

18. **Table:**

Section	Φ(Wb)	A(m²)	B(T)	H	l(m)	HI
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	

$B_{bc} = B_{cd} = B_g = B_{ef} = B_{fg} = \dfrac{\Phi}{A} = \dfrac{2\times10^{-4}\ \text{Wb}}{5\times10^{-4}\ \text{m}^2} = 0.4\ \text{T}$

Air gap: $H_g = 7.97 \times 10^5(0.4\ \text{T}) = 3.19 \times 10^5\ \text{At/m}$

$H_g l_g = (3.19 \times 10^5\ \text{At/m})(2\ \text{mm}) = 638\ \text{At}$

Fig 12.8: $H_{bc} = H_{cd} = H_{ef} = H_{fg} = 55\ \text{At/m}$

$H_{bc}l_{bc} = H_{fg}l_{fg} = (55\ \text{At/m})(0.1\ \text{m}) = 5.5\ \text{At}$

$H_{cd}l_{cd} = H_{ef}l_{ef} = (55\ \text{At/m})(0.099\ \text{m}) = 5.45\ \text{At}$

For loop 2: $\Sigma\mathscr{F} = 0$

$H_{bc}l_{bc} + H_{cd}l_{cd} + H_g l_g + H_{ef}l_{ef} + H_{fg}l_{fg} - H_{gb}l_{gb} = 0$

$5.5\ \text{At} + 5.45\ \text{At} + 638\ \text{At} + 5.45\ \text{At} + 5.50\ \text{At} - H_{gb}l_{gb} = 0$

$H_{gb}l_{gb} = 659.90\ \text{At}$

and $H_{gb} = \dfrac{659.90\ \text{At}}{0.2\ \text{m}} = 3300\ \text{At/m}$

Fig 12.7: $B_{gb} \cong 1.55\ \text{T}$

with $\Phi_2 = B_{gb}A = (1.55\ \text{T})(2 \times 10^{-4}\ \text{m}^2) = 3.1 \times 10^{-4}\ \text{Wb}$

$\Phi_T = \Phi_1 + \Phi_2$

$= 2 \times 10^{-4}\ \text{Wb} + 3.1 \times 10^{-4}\ \text{Wb}$

$= 5.1 \times 10^{-4}\ \text{Wb} = \Phi_{ab} = \Phi_{ha} = \Phi_{gh}$

$B_{ab} = B_{ha} = B_{gh} = \dfrac{\Phi_T}{A} = \dfrac{5.1\times10^{-4}\ \text{Wb}}{5\times10^{-4}\ \text{m}^2} = 1.02\ \text{T}$

B–H curve: (Fig 12.8):

$H_{ab} = H_{ha} = H_{gh} \cong 180\ \text{At/m}$

$H_{ab}l_{ab} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

$H_{ha}l_{ha} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

$H_{gh}l_{gh} = (180\ \text{At/m})(0.2\ \text{m}) = 36\ \text{At}$

which completes the table!

Loop #1: $\Sigma\mathscr{F} = 0$

$NI = H_{ab}l_{ab} + H_{bg}l_{bg} + H_{gh}l_{gh} + H_{ah}l_{ah}$

$(200\ \text{t})I = 36\ \text{At} + 659.49\ \text{At} + 36\ \text{At} + 36\ \text{At}$

$(200\ \text{t})I = 767.49\ \text{At}$

$I \cong 3.84\ \text{A}$

19. $NI = Hl$

$l = 2\pi r = (6.28)(0.08\ \text{m}) = 0.50\ \text{m}$

$(100\ \text{t})(2\ \text{A}) = H(0.50\ \text{m})$

$H = 400\ \text{At/m}$

Fig. 12.8: $B \cong 0.68\ \text{T}$

$\Phi = BA = (0.68\ \text{T})(0.009\ \text{m}^2)$

$\Phi = 6.12\ \text{mWb}$

20. $NI = H_{ab}(l_{ab} + l_{bc} + l_{de} + l_{ef} + l_{fa}) + H_g l_g$

$300\ \text{At} = H_{ab}(0.8\ \text{m}) + 7.97 \times 10^5\ B_g(0.8\ \text{mm})$

$300\ \text{At} = H_{ab}(0.8\ \text{m}) + 637.6\ B_g$

Assuming $637.6\ B_g \gg H_{ab}(0.8\ \text{m})$

then $300\ \text{At} = 637.6\ B_g$

and $B_g = 0.47\ \text{T}$

$\Phi = BA = (0.47\ \text{T})(2 \times 10^{-4}\ \text{m}^2) = 0.94 \times 10^{-4}\ \text{Wb}$

$B_{ab} = B_g = 0.47\ \text{T} \Rightarrow H \cong 270\ \text{At/m}$ (Fig. 12.8)

$300\ \text{At} = (270\ \text{At/m})(0.8\ \text{m}) + 637.6(0.47\ \text{T})$

$300\ \text{At} \neq 515.67\ \text{At}$

$\therefore$ Poor approximation!

$\dfrac{300\ \text{At}}{515.67\ \text{At}} \times 100\% \cong 58\%$

Reduce Φ to 58%

$0.58(0.94 \times 10^{-4}\ \text{Wb}) = 0.55 \times 10^{-4}\ \text{Wb}$

$B = \dfrac{\Phi}{A} = \dfrac{0.55\times10^{-4}\ \text{Wb}}{2\times10^{-4}\ \text{m}^2} = 0.28\ \text{T} \Rightarrow H \cong 190\ \text{At/m}$ (Fig. 12.8)

$300\ \text{At} = (190\ \text{At/m})(0.8\ \text{m}) + 637.6(0.28\ \text{T})$

$300\ \text{At} \neq 330.53\ \text{At}$

Reduce Φ another $10\% = 0.55 \times 10^{-4}\ \text{Wb} - 0.1(0.55 \times 10^{-4}\ \text{Wb})$

$= 0.495 \times 10^{-4}\ \text{Wb}$

$B = \dfrac{\Phi}{A} = \dfrac{0.495\times10^{-4}\ \text{Wb}}{2\times10^{-4}\ \text{m}^2} = 0.25\ \text{T} \Rightarrow H \cong 175\ \text{At/m}$ (Fig. 12.7)

$300\ \text{At} = (175\ \text{At/m})(0.8) + 637.6(0.28\ \text{T})$

$300\ \text{At} \neq 318.53\ \text{At}$ but within 5% $\therefore$ OK

$\Phi \cong 0.55 \times 10^{-4}\ \text{Wb}$

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 $0.945\ \text{T}$, $H \cong 700\ \text{At/m}$ (Fig. 12.7)

$\therefore B = 1.5\ \text{T}(1 - e^{-H/700\ \text{At/m}})$

b. $H = 900\ \text{At/m}$:

$B = 1.5\ \text{T}\left(1 - e^{-\frac{900\ \text{At/m}}{700\ \text{At/m}}}\right) = 1.09\ \text{T}$

Graph: $\cong 1.1\ \text{T}$

$H = 1800\ \text{At/m}$:

$B = 1.5\ \text{T}\left(1 - e^{-\frac{1800\ \text{At/m}}{700\ \text{At/m}}}\right) = 1.39\ \text{T}$

Graph: $\cong 1.38\ \text{T}$

$H = 2700\ \text{At/m}$:

$B = 1.5\left(1 - e^{-\frac{2700\ \text{At/m}}{700\ \text{At/m}}}\right) = 1.47\ \text{T}$

Graph: $\cong 1.47\ \text{T}$

Excellent comparison!

c. $B = 1.5\text{ T}(1 - e^{-H/700\text{ At/m}}) = 1.5\text{ T} - 1.5\text{ T}e^{-H/700\text{ At/m}}$

$B - 1.5\text{ T} = -1.5\text{ T}e^{-H/700\text{ At/m}}$

$1.5 - B = 1.5\text{ T}e^{-H/700\text{ At/m}}$

$\dfrac{1.5\text{ T} - B}{1.5\text{ T}} = e^{-H/700\text{ At/m}}$

$\log_e\left(1 - \dfrac{B}{1.5\text{ T}}\right) = \dfrac{-H}{700\text{ At/m}}$

and $H = -700\log_e\left(1 - \dfrac{B}{1.5\text{ T}}\right)$

d. $B = 1\text{ T}$:

$$H = -700\log_e\left(1 - \frac{1\text{ T}}{1.5\text{ T}}\right) = 769.03\text{ At/m}$$

Graph: $\cong$ 750 At/m

$B = 1.4\text{ T}$:

$$H = -700\log_e\left(1 - \frac{1.4\text{ T}}{1.5\text{ T}}\right) = 1895.64\text{ At/m}$$

Graph: $\cong$ 1920 At/m

e. $H = -700\log_e\left(1 - \dfrac{B}{1.5\text{ T}}\right)$

$= -700\log_e\left(1 - \dfrac{0.2\text{ T}}{1.5\text{ T}}\right)$

$= 100.2\text{ At/m}$

$$I = \frac{Hl}{N} = \frac{(100.2\text{ At/m})(0.16\text{ m})}{400\text{ t}} = 40.1\text{ mA}$$

vs 44 mA for Ex. 12.1