CHAPTER 7 (Odd)

1. a. series: E, R_1 and R_4; parallel: R_2 and R_3

   b. series: E and R_1; parallel: R_2 and R_3

   c. series: E, R_1 and R_5; R_3 and R_4; parallel: none

   d. series: R_6 and R_7; parallel: E, R_1 and R_4; R_2 and R_5

3. a. yes (KCL)

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

   c. yes (KCL)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$V_{ab} = I_9R_9 - I_8R_8 = (4\ \text{A})(4\ \Omega) - (1\ \text{A})(2\ \Omega) = 16\ \text{V} - 2\ \text{V} = \mathbf{14\ V}$$

13. a. $I_G = 0 \therefore V_G = \dfrac{270\ \text{k}\Omega(16\ \text{V})}{270\ \text{k}\Omega + 2000\ \text{k}\Omega} = \mathbf{1.9\ V}$

$$V_G - V_{GS} - V_S = 0$$

$$V_S = V_G - V_{GS} = 1.9\ \text{V} - (-1.75\ \text{V}) = \mathbf{3.65\ V}$$

b. $I_1 = I_2 = \dfrac{16\ \text{V}}{270\ \text{k}\Omega + 2000\ \text{k}\Omega} = \mathbf{7.05\ \mu A}$

$$I_D = I_S = \frac{V_S}{R_S} = \frac{3.65\ \text{V}}{1.5\ \text{k}\Omega} = \mathbf{2.433\ mA}$$

c. $V_{DS} = V_{DD} - I_DR_D - I_SR_S = V_{DD} - I_D(R_D + R_S)$ since $I_D = I_S$

$$= 16\ \text{V} - (2.433\ \text{mA})(4\ \text{k}\Omega) = 16\ \text{V} - 9.732\ \text{V} = \mathbf{6.268\ V}$$

d. $V_{DD} - I_DR_D - V_{DG} - V_G = 0$

$$V_{DG} = V_{DD} - I_DR_D - V_G$$

$$= 16\ \text{V} - (2.433\ \text{mA})(2.5\ \text{k}\Omega) - 1.9\ \text{V} = 16\ \text{V} - 6.083\ \text{V} - 1.9\ \text{V} = \mathbf{8.02\ V}$$

15. a. $I = \dfrac{E}{R_2 + R_3} = \dfrac{9\text{ V}}{7\ \Omega + 8\ \Omega} = \mathbf{0.6\ A}$

b. $E_1 - V + E_2 = 0$

$V = E_1 + E_2 = 9\text{ V} + 19\text{ V} = \mathbf{28\ V}$

17. a. R_8 "shorted out"

$R' = R_3 + R_4 \parallel R_5 + R_6 \parallel R_7$
$= 10\ \Omega + 6\ \Omega \parallel 6\ \Omega + 6\ \Omega \parallel 3\ \Omega$
$= 10\ \Omega + 3\ \Omega + 2\ \Omega$
$= 15\ \Omega$

$R_T = R_1 + R_2 \parallel R'$
$= 10\ \Omega + 30\ \Omega \parallel 15\ \Omega = 10\ \Omega + 10\ \Omega$
$= 20\ \Omega$

$I = \dfrac{E}{R_T} = \dfrac{100\text{ V}}{20\ \Omega} = 5\text{ A}$

$I_2 = \dfrac{R'(I)}{R' + R_2} = \dfrac{(15\ \Omega)(5\text{ A})}{15\ \Omega + 30\ \Omega} = \mathbf{1.667\ A}$

$I_3 = I - I_2 = 5\text{ A} - 1\frac{2}{3}\text{ A} = 3\frac{1}{3}\text{ A}$

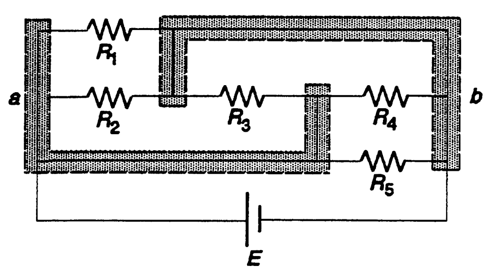
$I_6 = \dfrac{R_7 I_3}{R_7 + R_6} = \dfrac{3\ \Omega\left(\frac{10}{3}\text{ A}\right)}{3\ \Omega + 6\ \Omega} = \mathbf{1.111\ A}$

$I_8 = \mathbf{0\ A}$

b. $V_4 = I_3(R_4 \parallel R_5) = \left(\frac{10}{3}\text{ A}\right)(3\ \Omega) = \mathbf{10\ V}$

$V_8 = \mathbf{0\ V}$

19. a. All resistors in parallel (between terminals a & b)



$R_T = \underbrace{16\ \Omega \parallel 16\ \Omega}\parallel 8\ \Omega \parallel 4\ \Omega \parallel 32\ \Omega$

$\underbrace{8\ \Omega \parallel 8\ \Omega} \parallel 4\ \Omega \parallel 32\ \Omega$

$\underbrace{4\ \Omega \parallel 4\ \Omega} \parallel 32\ \Omega$

$2\ \Omega \parallel 32\ \Omega = \mathbf{1.882\ \Omega}$

b. All in parallel. Therefore, $V_1 = V_4 = E = \mathbf{32\ V}$

c. $I_3 = V_3/R_3 = 32\text{ V}/4\ \Omega = \mathbf{8\ A} \leftarrow$

d. $I_s = I_1 + I_2 + I_3 + I_4 + I_5$

$$= \frac{32\text{ V}}{16\ \Omega} + \frac{32\text{ V}}{8\ \Omega} + \frac{32\text{ V}}{4\ \Omega} + \frac{32\text{ V}}{32\ \Omega} + \frac{32\text{ V}}{16\ \Omega}$$

$$= 2\text{ A} + 4\text{ A} + 8\text{ A} + 1\text{ A} + 2\text{ A}$$

$$= 17\text{ A}$$

$$R_T = \frac{E}{I_s} = \frac{32\text{ V}}{17\text{ A}} = \mathbf{1.882\ \Omega} \text{ as above}$$

21. a. Applying Kirchoff's voltage law in the CCW direction in the upper "window":

$$+18\text{ V} + 20\text{ V} - V_{8\Omega} = 0$$

$$V_{8\Omega} = 38\text{ V}$$

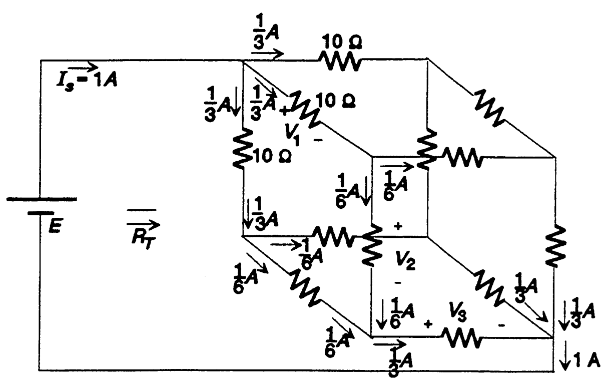
$$I_{8\Omega} = \frac{38\text{ V}}{8\ \Omega} = 4.75\text{ A}$$

$$I_{3\Omega} = \frac{18\text{ V}}{3\ \Omega + 6\ \Omega} = \frac{18\text{ V}}{9\ \Omega} = 2\text{ A}$$

$$\text{KCL: } I_{18\text{V}} = 4.75\text{ A} + 2\text{ A} = \mathbf{6.75\ A}$$

b. $V = (I_{3\Omega})(6\ \Omega) + 20\text{ V} = (2\text{ A})(6\ \Omega) + 20\text{ V} = 12\text{ V} + 20\text{ V} = \mathbf{32\ V}$

23. Assuming $I_s = 1$ A, the current I_s will divide as determined by the load appearing in each branch. Since balanced I_s will split equally between all three branches.



$$V_1 = \left[\frac{1}{3}\text{ A}\right](10\ \Omega) = \frac{10}{3}\text{ V}$$

$$V_2 = \left[\frac{1}{6}\text{ A}\right](10\ \Omega) = \frac{10}{6}\text{ V}$$

$$V_3 = \left[\frac{1}{3}\text{ A}\right](10\ \Omega) = \frac{10}{3}\text{ V}$$

$$E = V_1 + V_2 + V_3 = \frac{10}{3}\text{ V} + \frac{10}{6}\text{ V} + \frac{10}{3}\text{ V} = 8.333\text{ V}$$

$$R_T = \frac{E}{I} = \frac{8.333\text{ V}}{1\text{ A}} = \mathbf{8.333\ \Omega}$$

25. a. $R'_T = R_5 \parallel (R_6 + R_7) = 6\ \Omega \parallel 3\ \Omega = 2\ \Omega$
$R''_T = R_3 \parallel (R_4 + R'_T) = 4\ \Omega \parallel (2\ \Omega + 2\ \Omega) = 2\ \Omega$
$R_T = R_1 + R_2 + R''_T = 3\ \Omega + 5\ \Omega + 2\ \Omega = 10\ \Omega$
$I = \dfrac{240\text{ V}}{10\ \Omega} = \mathbf{24\ A}$

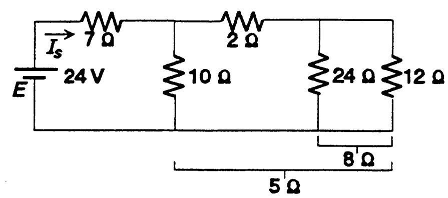
b. $I_4 = \dfrac{4\ \Omega(I)}{4\ \Omega + 4\ \Omega} = \dfrac{4\ \Omega(24\text{ A})}{8\ \Omega} = 12\text{ A}$
$I_7 = \dfrac{6\ \Omega(12\text{ A})}{6\ \Omega + 3\ \Omega} = \dfrac{72\text{ A}}{9} = \mathbf{8\ A}$

c. $V_3 = I_3R_3 = (I - I_4)R_3 = (24\text{ A} - 12\text{ A})4\ \Omega = \mathbf{48\ V}$
$V_5 = I_5R_5 = (I_4 - I_7)R_5 = (4\text{ A})6\ \Omega = \mathbf{24\ V}$
$V_7 = I_7R_7 = (8\text{ A})2\ \Omega = \mathbf{16\ V}$

d. $P = I_7^2R_7 = (8\text{ A})^2 2\ \Omega = \mathbf{128\ W}$
$P = EI = (240\text{ V})(24\text{ A}) = \mathbf{5760\ W}$

27. The 12 Ω resistors are in parallel.

Network redrawn:



$R_T = 12\ \Omega$
$I_s = \dfrac{E}{R_T} = \dfrac{24\text{ V}}{12\ \Omega} = 2\text{ A}$
$I_{2\Omega} = \dfrac{I_s}{2} = \dfrac{2\text{ A}}{2} = 1\text{ A}$
$I_{12\Omega} = \dfrac{24\ \Omega(I_{2\Omega})}{24\ \Omega + 12\ \Omega} = \dfrac{2}{3}\text{ A}$
$P_{10\Omega} = (I_{10\Omega})^2\, 10\ \Omega = \left(\dfrac{2}{3}\text{ A}\right)^2 \cdot 10\ \Omega = \mathbf{4.44\ W}$

29. a. $E = (40\text{ mA})(1.6\text{ k}\Omega) = \mathbf{64\ V}$

b. $R_{L_2} = \dfrac{48\text{ V}}{12\text{ mA}} = \mathbf{4\ k\Omega}$
$R_{L_3} = \dfrac{24\text{ V}}{8\text{ mA}} = \mathbf{3\ k\Omega}$

c. $I_{R_1} = 72\text{ mA} - 40\text{ mA} = 32\text{ mA}$
$I_{R_2} = 32\text{ mA} - 12\text{ mA} = 20\text{ mA}$
$I_{R_3} = 20\text{ mA} - 8\text{ mA} = 12\text{ mA}$
$R_1 = \dfrac{V_{R_1}}{I_{R_1}} = \dfrac{64\text{ V} - 48\text{ V}}{32\text{ mA}} = \dfrac{16\text{ V}}{32\text{ mA}} = \mathbf{0.5\ k\Omega}$
$R_2 = \dfrac{V_{R_2}}{I_{R_2}} = \dfrac{48\text{ V} - 24\text{ V}}{20\text{ mA}} = \dfrac{24\text{ V}}{20\text{ mA}} = \mathbf{1.2\ k\Omega}$
$R_3 = \dfrac{V_{R_3}}{I_{R_3}} = \dfrac{24\text{ V}}{12\text{ mA}} = \mathbf{2\ k\Omega}$

31. a. yes

b. VDR: $V_{R_2} = 3\text{ V} = \dfrac{R_2(12\text{ V})}{R_1 + R_2} = \dfrac{R_2(12\text{ V})}{1\text{ k}\Omega}$

$$R_2 = \frac{3\text{ V}(1\text{ k}\Omega)}{12\text{ V}} = 0.25\text{ k}\Omega = \mathbf{250\ \Omega}$$
$$R_1 = 1\text{ k}\Omega - 0.25\text{ k}\Omega = 0.75\text{ k}\Omega = \mathbf{750\ \Omega}$$

c. $V_{R_1} = E - V_L = 12\text{ V} - 3\text{ V} = 9\text{ V}$ (Chose V_{R_1} rather than $V_{R_2 \| R_L}$ since numerator of VDR equation "cleaner")

$$V_{R_1} = 9\text{ V} = \frac{R_1(12\text{ V})}{R_1 + (R_2 \| R_L)}$$
$$9R_1 + 9(R_2 \| R_L) = 12R_1$$
$$\left.\begin{aligned} R_1 &= 3(R_2 \| R_L) \\ R_1 + R_2 &= 1\text{ k}\Omega \end{aligned}\right\} \text{2 eq. 2 unk}(R_L = 10\text{ k}\Omega)$$

$$R_1 = \frac{3R_2R_L}{R_2 + R_L} \Rightarrow \frac{3R_2\ 10\text{ k}\Omega}{R_2 + 10\text{ k}\Omega}$$
and $R_1(R_2 + 10\text{ k}\Omega) = 30\text{ k}\Omega\ R_2$
$$R_1R_2 + 10\text{ k}\Omega\ R_1 = 30\text{ k}\Omega\ R_2$$
$$R_1 + R_2 = 1\text{ k}\Omega: \ (1\text{ k}\Omega - R_2)R_2 + 10\text{ k}\Omega\ (1\text{ k}\Omega - R_2) = 30\text{ k}\Omega\ R_2$$
$$R_2^2 + 39\text{ k}\Omega\ R_2 - 10\text{ k}\Omega^2 = 0$$
$$R_2 = 0.255\text{ k}\Omega,\ \cancel{-39.255}\text{ k}\Omega$$
$$R_2 = \mathbf{255\ \Omega}$$
$$R_1 = 1\text{ k}\Omega - R_2 = \mathbf{745\ \Omega}$$

33. a. $I_{CS} = \mathbf{1\ mA}$

b. $R_{\text{shunt}} = \dfrac{R_m I_{CS}}{I_{\max} - I_{CS}} = \dfrac{(100\ \Omega)(1\text{ mA})}{20\text{ A} - 1\text{ mA}} \cong \dfrac{0.1}{20}\ \Omega = \mathbf{5\ m\Omega}$

35. a. $R_s = \dfrac{V_{\max} - V_{VS}}{I_{CS}} = \dfrac{15\text{ V} - (50\ \mu\text{A})(1\text{ k}\Omega)}{50\ \mu\text{A}} = \mathbf{300\ k\Omega}$

b. $\Omega/\text{V} = 1/I_{CS} = 1/50\ \mu\text{A} = \mathbf{20{,}000}$

37. $10\text{ M}\Omega = (0.5\text{ V})(\Omega/\text{V}) \Rightarrow \Omega/\text{V} = 20 \times 10^6$

$$I_{CS} = 1/(\Omega/\text{V}) = \frac{1}{20 \times 10^6} = \mathbf{0.05\ \mu A}$$

CHAPTER 7 (Even)

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

   b. $R_T = 4\ \Omega + 4\ \Omega \parallel 4\Omega = 4\ \Omega + 2\ \Omega = \mathbf{6\ \Omega}$

   c. $R_T = (4\ \Omega + 4\ \Omega) \parallel 4\Omega + 4\ \Omega = 8\ \Omega \parallel 4\ \Omega + 4\ \Omega$
   $= 2.667\ \Omega + 4\ \Omega = \mathbf{6.667\ \Omega}$

   d. $R_T = \mathbf{4\ \Omega}$

4. a. $R_T = R_1 \parallel R_2 + R_3 = 12\ \Omega \parallel 6\ \Omega + 12\ \Omega = 4\ \Omega + 12\ \Omega = \mathbf{16\ \Omega}$

   b. $I = \dfrac{E}{R_T} = \dfrac{64\text{ V}}{16\ \Omega} = \mathbf{4\text{ A}}$ CDR: $I_1 = \dfrac{6\ \Omega(4\text{ A})}{6\ \Omega + 12\ \Omega} = \mathbf{1\frac{1}{3}\text{ A}}$

   c. $V_3 = IR_3 = (4\text{ A})(12\ \Omega) = \mathbf{48\text{ V}}$

6. $I_1 = \dfrac{20\text{ V}}{5\ \Omega} = \mathbf{4\text{ A}}$
   $R_T = 16\ \Omega \parallel 25\ \Omega = 9.756\ \Omega$
   $I_2 = \dfrac{7\text{ V}}{9.756\ \Omega} = \mathbf{0.7175\text{ A}}$

8. a. $R' = R_4 + R_5 = 14\ \Omega + 6\ \Omega = 20\ \Omega$
   $R'' = R_2 \parallel R' = 20\ \Omega \parallel 20\ \Omega = 10\ \Omega$
   $R''' = R'' + R_1 = 10\ \Omega + 10\ \Omega = 20\ \Omega$
   $R_T = R_3 \parallel R''' = 5\ \Omega \parallel 20\ \Omega = \mathbf{4\ \Omega}$
   $I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{4\ \Omega} = \mathbf{5\text{ A}}$
   $I_1 = \dfrac{20\text{ V}}{R_1 + R''} = \dfrac{20\text{ V}}{10\ \Omega + 10\ \Omega} = \dfrac{20\text{ V}}{20\ \Omega} = \mathbf{1\text{ A}}$
   $I_3 = \dfrac{20\text{ V}}{5\ \Omega} = \mathbf{4\text{ A}}$
   $I_4 = \dfrac{I_1}{2} = (\text{since } R' = R_2) = \dfrac{1\text{ A}}{2} = \mathbf{0.5\text{ A}}$

   b. $V_a = I_3R_3 - I_4R_5 = (4\text{ A})(5\ \Omega) - (0.5\text{ A})(6\ \Omega) = 20\text{ V} - 3\text{ V} = \mathbf{17\text{ V}}$
   $V_{bc} = \left[\dfrac{I_1}{2}\right] R_2 = (0.5\text{ A})(20\ \Omega) = \mathbf{10\text{ V}}$

10. a. $R_T = R_1 \parallel R_2 \parallel R_3 \parallel (R_6 + R_4 \parallel R_5)$
   $= 12\text{ k}\Omega \parallel 12\text{ k}\Omega \parallel 3\text{ k}\Omega \parallel (10.4\text{ k}\Omega + 9\text{ k}\Omega \parallel 6\text{ k}\Omega)$
   $= 6\text{ k}\Omega \parallel 3\text{ k}\Omega \parallel (10.4\text{ k}\Omega + 3.6\text{ k}\Omega)$
   $= 2\text{ k}\Omega \parallel 14\text{ k}\Omega = \mathbf{1.75\text{ k}\Omega}$

$$I = \frac{E}{R_T} = \frac{28\text{ V}}{1.75\text{ k}\Omega} = \mathbf{16\text{ mA}}$$

$$R' = R_1 \parallel R_2 \parallel R_3 = 2\text{ k}\Omega$$
$$R'' = R_6 + R_4 \parallel R_5 = 14\text{ k}\Omega$$
$$I_6 = \frac{R'(I)}{R' + R''} = \frac{(2\text{ k}\Omega)(16\text{ mA})}{2\text{ k}\Omega + 14\text{ k}\Omega} = \mathbf{2\text{ mA}}$$

b. $V_1 = E = 28\text{ V}$
$V_5 = I_6(R_4 \parallel R_5) = (2\text{ mA})(3.6\text{ k}\Omega) = \mathbf{7.2\text{ V}}$

c. $P = \frac{V_5^2}{R_5} = \frac{(7.2\text{ V})^2}{6\text{ k}\Omega} = \mathbf{8.64\text{ mW}}$

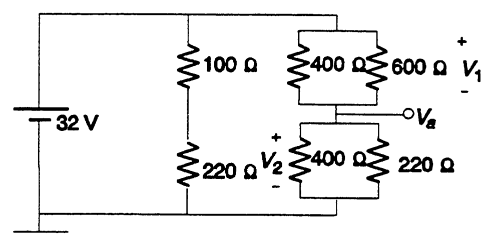
12. a. $I_E = \frac{V_E}{R_E} = \frac{2\text{ V}}{1\text{ k}\Omega} = \mathbf{2\text{ mA}}$
$I_C = I_E = \mathbf{2\text{ mA}}$

b. $I_B = \frac{V_{R_B}}{R_B} = \frac{V_{CC} - (V_{BE} + V_E)}{R_B} = \frac{8\text{V} - (0.7\text{ V} + 2\text{V})}{220\text{ k}\Omega}$
$= \frac{8\text{ V} - 2.7\text{ V}}{220\text{ k}\Omega} = \frac{5.3\text{ V}}{220\text{ k}\Omega} = \mathbf{24\ \mu A}$

c. $V_B = V_{BE} + V_E = \mathbf{2.7\text{ V}}$
$V_C = V_{CC} - I_C R_C = 8\text{ V} - (2\text{ mA})(2.2\text{ k}\Omega) = 8\text{ V} - 4.4\text{ V} = \mathbf{3.6\text{ V}}$

d. $V_{CE} = V_C - V_E = 3.6\text{ V} - 2\text{ V} = \mathbf{1.6\text{ V}}$
$V_{BC} = V_B - V_C = 2.7\text{ V} - 3.6\text{ V} = \mathbf{-0.9\text{ V}}$

14. a. Network redrawn:



$100\ \Omega + 220\ \Omega = 320\ \Omega$
$400\ \Omega \parallel 600\ \Omega = 240\ \Omega$
$400\ \Omega \parallel 220\ \Omega = 141.94\ \Omega$
$240\ \Omega + 141.94\ \Omega = 381.94\ \Omega$

$R_T = 320\ \Omega \parallel 381.94\ \Omega = \mathbf{174.12\ \Omega}$

b. $V_a = \frac{141.94\ \Omega(32\text{ V})}{141.94\ \Omega + 240\ \Omega} = \mathbf{11.892\text{ V}}$

c. $V_1 = 32\text{ V} - V_a = 32\text{ V} - 11.892\text{ V} = \mathbf{20.108\text{ V}}$

d. $V_2 = V_a = \mathbf{11.892\text{ V}}$

e. $I_{600\Omega} = \frac{20.108\text{ V}}{600\ \Omega} = 33.51\text{ mA}$
$I_{220\Omega} = \frac{11.892\text{ V}}{220\ \Omega} = 54.05\text{ mA}$
$I + I_{600\Omega} = I_{220\Omega}$
$I = I_{200\Omega} - I_{600\Omega}$
$= 54.05\text{ mA} - 33.5\text{ mA}$
$= \mathbf{20.54\text{ mA}} \rightarrow$

16. $R_T = 4\text{ k}\Omega + 2\text{ k}\Omega \parallel (1\text{ k}\Omega + 0.5\text{ k}\Omega + 1.5\text{ k}\Omega)$
$= 4\text{ k}\Omega + 2\text{ k}\Omega \parallel 3\text{ k}\Omega = 4\text{ k}\Omega + 1.2\text{ k}\Omega$
$= 5.2\text{ k}\Omega$

$$I_s = \frac{E}{R_T} = \frac{24\text{ V}}{5.2\text{ k}\Omega} = 4.615\text{ mA}$$

$$I = \frac{3\text{ k}\Omega(I_s)}{3\text{ k}\Omega + 2\text{ k}\Omega} = \frac{3\text{ k}\Omega(4.615\text{ mA})}{5\text{ k}\Omega} = \mathbf{2.769\text{ mA}}$$

$I_{R_3} = 4.615\text{ mA} - 2.769\text{ mA} = 1.846\text{ mA}$

$V_b = -I_{R_3}R_3 = -(1.846\text{ mA})(1\text{ k}\Omega) = \mathbf{-1.846\text{ V}}$

$V_a + 24\text{ V} - I_s 4\text{ k}\Omega = 0$

$V_a = I_s 4\text{ k}\Omega - 24\text{ V} = (4.615\text{ mA})(4\text{ k}\Omega) - 24\text{ V}$
$= 18.46\text{ V} - 24\text{ V} = \mathbf{-5.54\text{ V}}$

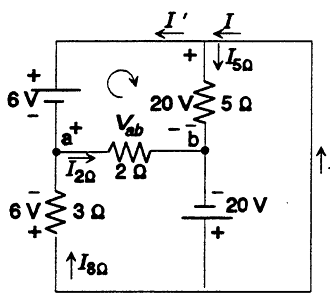
$V_{ab} = V_a - V_b = -5.54\text{ V} - (-1.846\text{ V}) = \mathbf{-3.694\text{ V}}$

18. $8\ \Omega \parallel 8\ \Omega = 4\ \Omega$

$$I = \frac{30\text{ V}}{4\ \Omega + 6\ \Omega} = \frac{30\text{ V}}{10\ \Omega} = 3\text{ A}$$

$V = I(8\ \Omega \parallel 8\ \Omega) = (3\text{ A})(4\ \Omega) = \mathbf{12\text{ V}}$

20. a.



KVL: $+ 6\text{ V} - 20\text{ V} + V_{ab} = 0$
$V_{ab} = +20\text{ V} - 6\text{ V} = \mathbf{14\text{ V}}$

b. $$I_{5\Omega} = \frac{20\text{ V}}{5\ \Omega} = 4\text{ A}$$

$$I_{2\Omega} = \frac{V_{ab}}{2\ \Omega} = \frac{14\text{ V}}{2\ \Omega} = 7\text{ A}$$

$$I_{3\Omega} = \frac{6\text{ V}}{3\ \Omega} = 2\text{ A}$$

$I' + I_{3\Omega} = I_{2\Omega}$
and $I' = I_{2\Omega} - I_{3\Omega} = 7\text{ A} - 2\text{ A} = 5\text{ A}$
$I = I' + I_{5\Omega} = 5\text{ A} + 4\text{ A} = \mathbf{9\text{ A}}$

22. $I_2R_2 = 2R_3 \Rightarrow I_2 = \dfrac{R_3}{10}$ (since the voltage across parallel elements is the same)

$$I_1 = I_2 + I_3 = \frac{R_3}{10} + 2$$

KVL: $120 = I_1 12 + I_3R_3 = \left[\dfrac{R_3}{10} + 2\right] 12 + 2R_3$
and $R_3 = \mathbf{30\ \Omega}$

24. $36\text{ k}\Omega \parallel 6\text{ k}\Omega \parallel 12\text{ k}\Omega = 3.6\text{ k}\Omega$

$V = \dfrac{3.6\text{ k}\Omega(45\text{ V})}{3.6\text{ k}\Omega + 6\text{ k}\Omega} = 16.875\text{ V} \neq 27\text{ V}$. Therefore, not operating properly!

$6\text{ k}\Omega$ resistor "open"

$$V = \frac{9\text{ k}\Omega(45\text{ V})}{9\text{ k}\Omega + 6\text{ k}\Omega} = \mathbf{27\text{ V}}$$

26. a. $R'_T = R_4 \parallel (R_6 + R_7 + R_8) = 2\ \Omega \parallel 7\ \Omega = 1.556\ \Omega$

$R''_T = R_2 \parallel (R_3 + R_5 + R'_T) = 2\ \Omega \parallel (4\ \Omega + 1\ \Omega + 1.556\ \Omega) = 1.532\ \Omega$

$R_T = R_1 + R''_T = 4\ \Omega + 1.532\ \Omega = \mathbf{5.532\ \Omega}$

b. $I = 2\text{ V}/5.532\ \Omega = 0.3615\text{ A} = \mathbf{361.5\text{ mA}}$

c. $I_3 = \dfrac{2\ \Omega(I)}{2\ \Omega + 6.56\ \Omega} = \dfrac{2\ \Omega(361.5\text{ mA})}{2\ \Omega + 6.56\ \Omega} = \mathbf{84.5\text{ mA}}$

$I_8 = \dfrac{2\ \Omega(84.5\text{ mA})}{2\ \Omega + 7\ \Omega} = \mathbf{18.78\text{ mA}}$

28. a. $R_{10} + R_{11} \parallel R_{12} = 1\ \Omega + 2\ \Omega \parallel 2\ \Omega = 2\ \Omega$

$R_4 \parallel (R_5 + R_6) = 10\ \Omega \parallel 10\ \Omega = 5\ \Omega$

$R_1 + R_2 \parallel (R_3 + 5\ \Omega) = 3\ \Omega + 6\ \Omega \parallel 6\ \Omega = 6\ \Omega$

$R_T = 2\ \Omega \parallel 3\ \Omega \parallel 6\ \Omega = 2\ \Omega \parallel 2\ \Omega = 1\ \Omega$

$I = 12\text{ V}/1\ \Omega = \mathbf{12\text{ A}}$

b. $I_1 = 12\text{ V}/6\ \Omega = 2\text{ A}$

$I_3 = \dfrac{6\ \Omega(2\text{ A})}{6\ \Omega + 6\ \Omega} = 1\text{ A}$

$I_4 = \dfrac{1\text{ A}}{2} = \mathbf{0.5\text{ A}}$

c. $I_6 = I_4 = \mathbf{0.5\text{ A}}$

d. $I_{10} = \dfrac{12\text{ A}}{2} = \mathbf{6\text{ A}}$

30. $I_{R_1} = 40\text{ mA}$

$I_{R_2} = 40\text{ mA} - 10\text{ mA} = 30\text{ mA}$

$I_{R_3} = 30\text{ mA} - 20\text{ mA} = 10\text{ mA}$

$I_{R_5} = 40\text{ mA}$

$I_{R_4} = 40\text{ mA} - 4\text{ mA} = 36\text{ mA}$

$$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{120\text{ V} - 100\text{ V}}{40\text{ mA}} = \frac{20\text{ V}}{40\text{ mA}} = \mathbf{0.5\text{ k}\Omega}$$

$$R_2 = \frac{V_{R_2}}{I_{R_2}} = \frac{100\text{ V} - 40\text{ V}}{30\text{ mA}} = \frac{60\text{ V}}{30\text{ mA}} = \mathbf{2\text{ k}\Omega}$$

$$R_3 = \frac{V_{R_3}}{I_{R_3}} = \frac{40\text{ V}}{10\text{ mA}} = \mathbf{4\text{ k}\Omega}$$

$$R_4 = \frac{V_{R_4}}{I_{R_4}} = \frac{36\text{ V}}{36\text{ mA}} = \mathbf{1\text{ k}\Omega}$$

$$R_5 = \frac{V_{R_5}}{I_{R_5}} = \frac{60\text{ V} - 36\text{ V}}{40\text{ mA}} = \frac{24\text{ V}}{40\text{ mA}} = \mathbf{0.6\ k\Omega}$$

$P_1 = I_1^2R_1 = (40\text{ mA})^2 0.5\text{ k}\Omega = \mathbf{0.8\ W}$ (1 watt resistor)

$P_2 = I_2^2R_2 = (30\text{ mA})^2 2\text{ k}\Omega = \mathbf{1.8\ W}$ (2 watt resistor)

$P_3 = I_3^2R_3 = (10\text{ mA})^2 4\text{ k}\Omega = \mathbf{0.4\ W}$ (1/2 watt or 1 watt resistor)

$P_4 = I_4^2R_4 = (36\text{ mA})^2 1\text{ k}\Omega = \mathbf{1.296\ W}$ (2 watt resistor)

$P_5 = I_5^2R_5 = (40\text{ mA})^2 0.6\text{ k}\Omega = \mathbf{0.96\ W}$ (1 watt resistor)

All power levels less than **2 W**. Four less than **1 W**.

32. a. $V_{ab} = \dfrac{80\ \Omega(40\text{ V})}{100\ \Omega} = \mathbf{32\ V}$

$V_{bc} = 40\text{ V} - 32\text{ V} = \mathbf{8\ V}$

b. $80\ \Omega \parallel 1\text{ k}\Omega = 74.07\ \Omega$

$20\ \Omega \parallel 10\text{ k}\Omega = 19.96\ \Omega$

$V_{ab} = \dfrac{74.07\ \Omega(40\text{ V})}{74.07\ \Omega + 19.96\ \Omega} = \mathbf{31.51\ V}$

$V_{bc} = 40\text{ V} - 31.51\text{ V} = \mathbf{8.49\ V}$

c. $P = \dfrac{(31.51\text{ V})^2}{80\ \Omega} + \dfrac{(8.49\text{ V})^2}{20\ \Omega} = 12.411\text{ W} + 3.604\text{ W} = \mathbf{16.015\ W}$

d. $P = \dfrac{(32\text{ V})^2}{80\ \Omega} + \dfrac{(8\text{ V})^2}{20\ \Omega} = 12.8\text{ W} + 3.2\text{ W} = \mathbf{16\ W}$

34. 25 mA: $R_{\text{shunt}} = \dfrac{(1\text{ k}\Omega)(50\ \mu\text{A})}{25\text{ mA} - 0.05\text{ mA}} \cong \mathbf{2\ \Omega}$

50 mA: $R_{\text{shunt}} = \dfrac{(1\text{ k}\Omega)(50\ \mu\text{A})}{50\text{ mA} - 0.05\text{ mA}} = \mathbf{1\ \Omega}$

100 mA: $R_{\text{shunt}} \cong \mathbf{0.5\ \Omega}$

36. 5 V: $R_s = \dfrac{5\text{ V} - (1\text{ mA})(100\ \Omega)}{1\text{ mA}} = \mathbf{4.9\ k\Omega}$

50 V: $R_s = \dfrac{50\text{ V} - 0.1\text{ V}}{1\text{ mA}} = \mathbf{49.9\ k\Omega}$

500 V: $R_s = \dfrac{500\text{ V} - 0.1\text{ V}}{1\text{ mA}} = \mathbf{499.9\ k\Omega}$

38. a. $R_s = \dfrac{E}{I_m} - R_m - \dfrac{\text{zero adjust}}{2} = \dfrac{3\text{ V}}{100\ \mu\text{A}} - 1\text{ k}\Omega - \dfrac{2\text{ k}\Omega}{2} = \mathbf{28\ k\Omega}$

b. $$xI_m = \frac{E}{R_{\text{series}}} + R_m + \frac{\text{zero adjust}}{2} + R_{\text{unk}}$$

$$R_{\text{unk}} = \frac{E}{xI_m} - \left[R_{\text{series}} + R_m + \frac{\text{zero adjust}}{2}\right]$$

$$= \frac{3\ \text{V}}{x100\ \mu\text{A}} - 30\ \text{k}\Omega \Rightarrow \frac{30 \times 10^3}{x} - 30 \times 10^3$$

$$x = \frac{3}{4},\ R_{\text{unk}} = \mathbf{10\ k\Omega};\ x = \frac{1}{2},\ R_{\text{unk}} = \mathbf{30\ k\Omega};\ x = \frac{1}{4},\ R_{\text{unk}} = \mathbf{90\ k\Omega}$$

40. a. Carefully redrawing the network will reveal that all three resistors are in parallel and $R_T = \frac{R}{N} = \frac{12\ \Omega}{3} = \mathbf{4\ \Omega}$

b. Again, all three resistors are in parallel and $R_T = \frac{R}{N} = \frac{18\ \Omega}{3} = \mathbf{6\ \Omega}$