Chapter 7

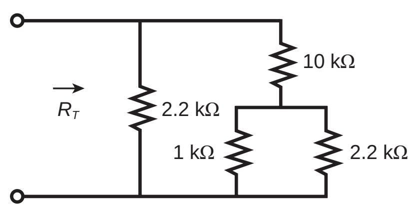
1. a. R_1, R_2,. and E are in series; R_3, R_4 and R_5 are in parallel
   b. E and R_1 are in series; R_2, R_3 and R_4 are in parallel.
   c. E and R_1 are in series; R_2, R_3 and R_4 are in parallel.

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.



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

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

7. a. **yes**
   b. $I_2 = I_s - I_1 = 10\ \text{A} - 4\ \text{A} = \mathbf{6\ A}$
   c. yes
   d. $V_3 = E - V_2 = 14\ \text{V} - 8\ \text{V} = \mathbf{6\ V}$
   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. $R'_T = R''_T = \dfrac{20\ \Omega}{2} = 10\ \Omega$, $R_T = R'_T + R''_T = 10\ \Omega + 10\ \Omega = 20\ \Omega$

$I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{20\ \Omega} = \mathbf{1\ A}$

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

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

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

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

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

9. a. $R_T = 11\ \Omega + \dfrac{27\ \Omega}{3} = 11\ \Omega + 9\ \Omega = 20\ \Omega$

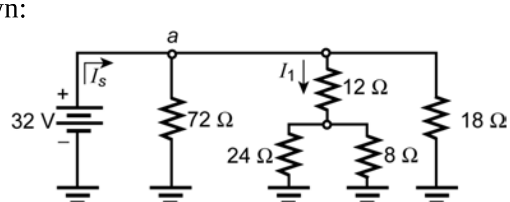
$I_s = \dfrac{E}{R_T} = \dfrac{60\text{ V}}{20\ \Omega} = \mathbf{3\ A}$

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

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

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

10. Redrawn:



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

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

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

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

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

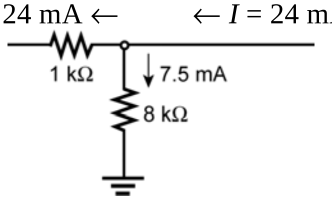
$I_s = \dfrac{E}{R_T} = \dfrac{32\text{ V}}{8.12\ \Omega} = \mathbf{3.94\ A}$

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

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

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

24 mA ← ← I = 24 mA + 7.5 mA = 31.5 mA



← I_2 = 31.5 mA + 4 mA = **35.5 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. $I_s = \dfrac{E}{R_T} = \dfrac{48\text{ V}}{0.8\text{ k}\Omega} = \mathbf{60\text{ mA}}$

c. $V = \dfrac{R''_T E}{R''_T + 2.4\text{ k}\Omega} = \dfrac{(1.6\text{ k}\Omega)(48\text{ V})}{1.6\text{ k}\Omega + 2.4\text{ k}\Omega} = \mathbf{19.2\text{ V}}$

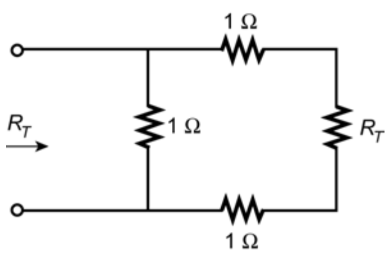
13. $R_T = 2R \parallel 2R \parallel (R + R) = 2R \parallel 2R \parallel 2R = \dfrac{2R}{3}$

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

$15\ \Omega = \dfrac{2R}{3}$ and $R = \dfrac{3}{2}(15\ \Omega) = \mathbf{22.5\ \Omega}$

$2R = \mathbf{45\ \Omega}$

14.



$R_T = 1\ \Omega \parallel (1\ \Omega + 1\ \Omega + R_T) = 1\ \Omega \parallel (2\ \Omega + R_T)$

$= \dfrac{2\ \Omega + R_T}{1\ \Omega + 2\ \Omega + R_T} = \dfrac{2\ \Omega + R_T}{3\ \Omega + R_T}$

$R_T(3\ \Omega + R_T) = 2\ \Omega + R_T$

$3R_T + R_T^2 = 2\ \Omega + R_T$

$R_T^2 + 2R_T - 2\ \Omega = 0$

$R_T = \dfrac{-2 \pm \sqrt{(2)^2 - 4(1)(-2)}}{2}$

$= \dfrac{-2 \pm \sqrt{4 + 8}}{2} = \dfrac{2 \pm \sqrt{12}}{2} = \dfrac{-2 \pm 3.464}{2}$

$R_T = -1 \pm 1.732 = 0.732\ \Omega$ or $-2.732\ \Omega$

Since $R_T < 1\ \Omega$ and positive choose $R_T = \mathbf{0.732\ \Omega}$

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

$I_s = \dfrac{E}{R_T} = \dfrac{28\text{ V}}{1.75\text{ k}\Omega} = \mathbf{16\ mA}$, $\quad I_2 = \dfrac{E}{R_2} = \dfrac{28\text{ V}}{12\text{ k}\Omega} = \mathbf{2.33\ mA}$

$R' = R_1 \parallel R_2 \parallel R_3 = 2\text{ k}\Omega$
$R'' = R_6 + R_4 \parallel R_5 = 14\text{ k}\Omega$

$I_6 = \dfrac{R'(I_s)}{R' + R''} = \dfrac{2\text{ k}\Omega(16\text{ mA})}{2\text{ k}\Omega + 14\text{ k}\Omega} = \mathbf{2\ mA}$

b. $V_1 = E = \mathbf{28\ V}$
$R' = R_4 \parallel R_5 = 6\text{ k}\Omega \parallel 9\text{ k}\Omega = 3.6\text{ k}\Omega$
$V_5 = I_6 R' = (2\text{ mA})(3.6\text{ k}\Omega) = \mathbf{7.2\ V}$

c. $P = \dfrac{V_{R_3}^2}{R_3} = \dfrac{(28\text{ V})^2}{3\text{ k}\Omega} = \mathbf{261.33\ mW}$

16. a. $I_1\downarrow = \dfrac{24\text{ V}}{4\ \Omega} = \mathbf{6\ A};\ V_{R_2} = 24\text{ V} - 8\text{ V} = 16\text{ V},\ I_2\downarrow = V_{R_2} / R_2 = 16\text{ V}/2\ \Omega = \mathbf{8\ A}$

$I_1\downarrow = \dfrac{8\text{ V}}{10\ \Omega} = \mathbf{0.8\ A},\ I = I_1 + I_2 = 6\text{ A} + 8\text{ A} = \mathbf{14\ A}$

17. $I_1 = \dfrac{20\text{ V}}{47\ \Omega} = \mathbf{425.5\ mA}$

$I_2 = \dfrac{14\text{ V}}{160\ \Omega \parallel 270\ \Omega} = \dfrac{14\text{ V}}{100.47\ \Omega} = \mathbf{139.35\ mA}$

18. a. $R' = R_4 + R_5 = 14\ \Omega + 6\ \Omega = 20\ \Omega$
$R'' = R_2 \parallel R' = 20\ \Omega \parallel 20\ \Omega = 10\ \Omega$
$R''' = R'' + R_1 = 10\ \Omega + 10\ \Omega = 20\ \Omega$
$R_T = R_3 \parallel R''' = 5\ \Omega \parallel 20\ \Omega = \mathbf{4\ \Omega}$

$I_s = \dfrac{E}{R_T} = \dfrac{20\text{ V}}{4\ \Omega} = \mathbf{5\ A}$

$I_1 = \dfrac{20\text{ V}}{R_1 + R''} = \dfrac{20\text{ V}}{10\ \Omega + 10\ \Omega} = \dfrac{20\text{ V}}{20\ \Omega} = \mathbf{1\ A}$

$I_3 = \dfrac{20\text{ V}}{5\ \Omega} = \mathbf{4\ A}$

$I_4 = \dfrac{I_1}{2} = (\text{since } R' = R_2) = \dfrac{1\text{ A}}{2} = \mathbf{0.5\ A}$

b. $V_a = I_3R_3 - I_4R_5 = (4\text{ A})(5\ \Omega) - (0.5\text{ A})(6\ \Omega) = 20\text{ V} - 3\text{ V} = \mathbf{17\ V}$

$V_{bc} = \left(\dfrac{I_1}{2}\right)R_2 = (0.5\text{ A})(20\ \Omega) = \mathbf{10\ V}$

19. a. $I_1 = \dfrac{E_1 - E_2}{R_1} = \dfrac{20\text{ V} - 15\text{ V}}{3\ \Omega} = \mathbf{1.67\ A}$

b. $I_2 = \dfrac{E_2}{R_2 + R_3 \parallel R_5} = \dfrac{15\text{ V}}{3\ \Omega + 6\ \Omega \parallel 6\ \Omega} = \dfrac{15\text{ V}}{3\ \Omega + 3\ \Omega} = \dfrac{15\text{ V}}{6\ \Omega} = \mathbf{2.5\ A}$

$I_3 = \dfrac{1}{2}I_2 = \dfrac{1}{2}(2.5\text{ A}) = \mathbf{1.25\ A}$

c. $V_a = E_2 - I_2R_2 = 15\text{ V} - (2.5\text{ A})(3\Omega) = 15\text{ V} - 7.5\text{ V} = \mathbf{7.5\ V}$

20. a. $I_E = \dfrac{V_E}{R_E} = \dfrac{2\text{ V}}{1\text{ k}\Omega} = \mathbf{2\ mA}$

$I_C = I_E = \mathbf{2\ mA}$

b. $I_B = \dfrac{V_{R_B}}{R_B} = \dfrac{V_{CC} - (V_{BE} + V_E)}{R_B} = \dfrac{8\text{ V} - (0.7\text{ V} + 2\text{ V})}{220\text{ k}\Omega}$

$= \dfrac{8\text{ V} - 2.7\text{ V}}{220\text{ k}\Omega} = \dfrac{5.3\text{ V}}{220\text{ k}\Omega} = \mathbf{24\ \mu A}$

c. $V_B = V_{BE} + V_E = \mathbf{2.7\ V}$

$V_C = V_{CC} - I_CR_C = 8\text{ V} - (2\text{ mA})(2.2\text{ k}\Omega) = 8\text{ V} - 4.4\text{ V} = \mathbf{3.6\ V}$

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

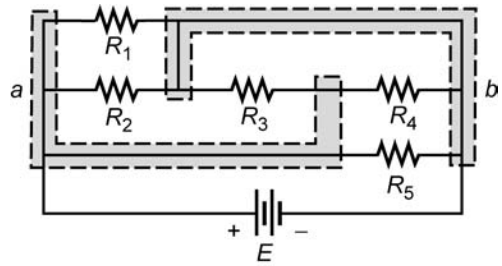
$V_{BC} = V_B - V_C = 2.7\text{ V} - 3.6\text{ V} = \mathbf{-0.9\ V}$

21. a. $I_2 = \dfrac{E_1}{R_2 + R_3} = \dfrac{2\text{ V}}{4\ \Omega + 18\ \Omega} = \dfrac{22\text{ V}}{22\ \Omega} = \mathbf{1\ A}$

b. $+22\text{ V} + V_1 - 22\text{ V} = 0,\ V_1 = 22\text{ V} - 22\text{ V} = \mathbf{0\ V}$

c. $I_1 = I_2 + \dfrac{V_1}{R_1} = 1\text{ A} + \dfrac{0\text{ V}}{R_1} = \mathbf{1\ A}$

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



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

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

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

$2\ \Omega \parallel 32\ \Omega =$ **1.88 Ω**

b. All in parallel. Therefore, $V_1 = V_4 = E =$ **32 V**

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

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

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

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

$= 17\text{ A}$

$R_T = \frac{E}{I_s} = \frac{32\text{ V}}{17\text{ A}} =$ **1.88 Ω** as above

23. a. $V_a = -6\text{ V}$, $V_b = -20\text{ V}$

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

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

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

$I_{3\Omega} = I_{2\Omega} + I_{6\text{V}}\uparrow$, $I_{6\text{V}} = I_{3\Omega} - I_{2\Omega} = 2\text{ A} - 7\text{ A} = -5\text{ A}$

$I + I_{6\text{V}} = I_{5\Omega}$, $I = I_{5\Omega} - I_{6\text{V}} = 4\text{ A} - (-5\text{A}) =$ **9 A**

c. $V_{ab} = V_a - V_b = (-6\text{ V}) - (-20\text{ V}) = -6\text{ V} + 20\text{ V} =$ **+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: $I_{18\text{V}} = 4.75\text{ A} + 2\text{ A} =$ **6.75 A**

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

25. $I_2R_2 = I_3R_3$ and $I_2 = \frac{I_3R_3}{R_2} = \frac{2R_3}{20} = \frac{R_3}{10}$ (since the voltage across parallel elements is the same)

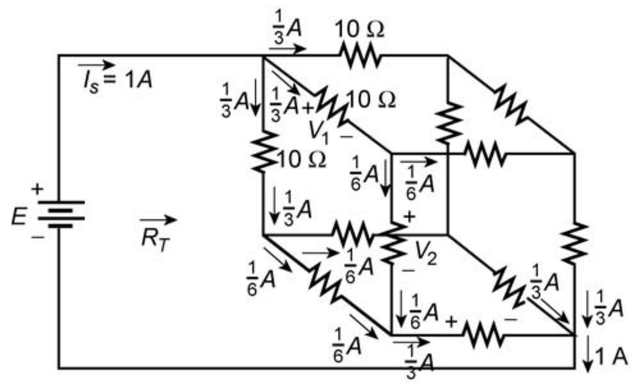
$$I_1 = I_2 + I_3 = \frac{R_3}{10} + 2$$

KVL: $120 = I_1 12 + I_3R_3 = \left(\frac{R_3}{10} + 2\right)12 + 2R_3$

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

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

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

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

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. $I = 40\text{ V}/5.53\ \Omega = \mathbf{7.23\text{ A}}$

c. $$I_3 = \frac{2\ \Omega(I)}{2\ \Omega + 6.56} = \frac{2\ \Omega(7.23\text{ A})}{2\ \Omega + 6.56\ \Omega} = 1.69\text{ A}$$
$$I_7 = \frac{2\ \Omega(1.69\text{ A})}{2\ \Omega + 7\ \Omega} = 0.375\text{ mA}$$
$$P_{R_7} = I^2 R = (0.375\text{ A})^2\ 2\ \Omega = \mathbf{0.281\text{ W}}$$

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

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

c. $I_{R_1} = 72\text{ mA} - 40\text{ mA} = 32\text{ mA}$
$I_{R_2} = 32\text{ mA} - 12\text{ mA} = 20\text{ mA}$
$I_{R_3} = 20\text{ mA} - 8\text{ mA} = 12\text{ mA}$

$$R_1 = \frac{V_{R_1}}{I_{R_1}} = \frac{64\text{ V} - 48\text{ V}}{32\text{ mA}} = \frac{16\text{ V}}{32\text{ mA}} = \mathbf{0.5\ k\Omega}$$

$$R_2 = \frac{V_{R_2}}{I_{R_2}} = \frac{48\text{ V} - 24\text{ V}}{20\text{ mA}} = \frac{24\text{ V}}{20\text{ mA}} = \mathbf{1.2\ k\Omega}$$

$$R_3 = \frac{V_{R_3}}{I_{R_3}} = \frac{24\text{ V}}{12\text{ mA}} = \mathbf{2\ k\Omega}$$

30. $I_{R_1} = 40$ mA

$I_{R_2} = 40$ mA – 10 mA = 30 mA

$I_{R_3} = 30$ mA – 20 mA = 10 mA

$I_{R_5} = 40$ mA

$I_{R_4} = 40$ mA – 4 mA = 36 mA

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

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

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

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

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

$P_1 = I_1^2 R_1$ = (40 mA)^{2}0.5 kΩ = **0.8 W** (1 watt resistor)

$P_2 = I_2^2 R_2$ = (30 mA)^{2}2 kΩ = **1.8 W** (2 watt resistor)

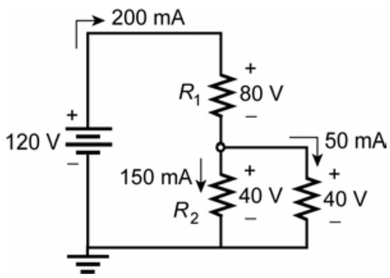
$P_3 = I_3^2 R_3$ = (10 mA)^{2}4 kΩ = **0.4 W** (1/2 watt or 1 watt resistor)

$P_4 = I_4^2 R_4$ = (36 mA)^{2}1 kΩ = **1.3 W** (2 watt resistor)

$P_5 = I_5^2 R_5$ = (40 mA)^{2}0.6 kΩ = **0.96 W** (1 watt resistor)

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

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

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

$R_1 = 1\text{ k}\Omega - 0.25\text{ k}\Omega = 0.75\text{ k}\Omega = \mathbf{750\ \Omega}$

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")

$$V_{R_1} = 9\text{ V} = \frac{R_1(12\text{ V})}{R_1 + (R_2 \| R_L)}$$

$9R_1 + 9(R_2 \| R_L) = 12R_1$

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

$$R_1 = \frac{3R_2R_L}{R_2 + R_L} \Rightarrow \frac{3R_2\ 10\text{ k}\Omega}{R_2 + 10\text{ k}\Omega}$$

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

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

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

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

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

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

c. $P = \dfrac{(31.51\text{ V})^2}{80\ \Omega} + \dfrac{(8.49\text{ V})^2}{20\ \Omega} = 12.411\text{ W} + 3.604\text{ W} = \mathbf{16.02\ W}$

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

The applied loads dissipate less than 20 mW of power.

34. $I = \dfrac{12\text{ V}}{10\text{ k}\Omega}$ = **1.2 mA**

$V_{ab} = V_a - V_b$ = 12 V − (−18 V) = **30 V**

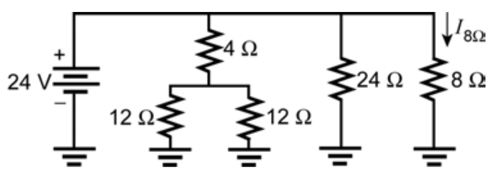
35. 36 kΩ ‖ 6 kΩ ‖ 12 kΩ = 3.6 kΩ

$V = \dfrac{3.6\text{ k}\Omega(45\text{ V})}{3.6\text{ k}\Omega + 6\text{ k}\Omega}$ = 16.88 V ≠ 27 V. Therefore, **not** operating properly!

6 kΩ resistor "open"

R' = 12 kΩ ‖ 36 kΩ = 9 kΩ, $V = \dfrac{R'(45\text{ V})}{R' + 6\text{ k}\Omega} = \dfrac{9\text{ k}\Omega(45\text{ V})}{9\text{ k}\Omega + 6\text{ k}}$ = **27 V**

36. Network redrawn:



$I_{8\Omega} = I_{6\Omega} = \dfrac{24\text{ V}}{8\,\Omega}$ = 3 A

$P_{6\Omega} = I^2R = (3\text{ A})^2 \cdot 6\,\Omega$ = **54 W**

37. a. $R_{10} + R_{11} \parallel R_{12}$ = 1 Ω + 2 Ω ‖ 2 Ω = 2 Ω

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

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

R_T = 2 Ω ‖ 3 Ω ‖ 6 Ω = 2 Ω ‖ 2 Ω = 1 Ω

I = 12 V/1 Ω = **12 A**

b. I_1 = 12 V/6 Ω = 2 A

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

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

c. $I_6 = I_4$ = **0.5 A**

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

38. a. I_{CS} = **1 mA**

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

39. 25 mA: $R_{\text{shunt}} = \dfrac{(1\text{ k}\Omega)(50\,\mu\text{A})}{25\text{ mA} - 0.05\text{ mA}} \cong$ **2 Ω**

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

100 mA: $R_{\text{shunt}} \cong$ **0.5 Ω**

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 kΩ**

b. Ω/V = 1/I_{CS} = 1/50 μA = **20,000**

41. 5 V: $R_s = \dfrac{5\text{ V} - (1\text{ mA})(1000\,\Omega)}{1\text{ mA}}$ = **4 kΩ**

50 V: $R_s = \dfrac{50\text{ V} - 1\text{ V}}{1\text{ mA}}$ = **49 kΩ**

500 V: $R_s = \dfrac{500\text{ V} - 1\text{ V}}{1\text{ mA}}$ = **499 kΩ**

42. 10 MΩ = (0.5 V)(Ω/V) ⇒ Ω/V = 20×10^6

I_{CS} = 1/(Ω/V) = $\dfrac{1}{20\times 10^6}$ = **0.05 μA**

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 kΩ**

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

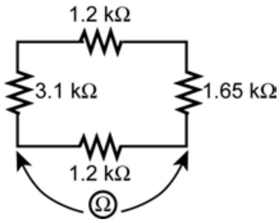
$R_{\text{unk}} = \dfrac{E}{xI_m} - \left(R_{\text{series}} + R_m + \dfrac{\text{zero adjust}}{2}\right)$

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

$x = \dfrac{3}{4}$, R_{unk} = **10 kΩ**; $x = \dfrac{1}{2}$, R_{unk} = **30 kΩ**; $x = \dfrac{1}{4}$, R_{unk} = **90 kΩ**

44. –

45. a. Network redrawn:



$R_{\text{ohmmeter}} = 1.2\text{ k}\Omega \parallel (3.1\text{ k}\Omega + 1.2\text{ k}\Omega + 1.65\text{ k}\Omega)$
$= 1.2\text{ k}\Omega \parallel 5.95\text{ k}\Omega$
$= \mathbf{1\ k\Omega}$

b. All three resistors are in parallel

$$R_{\text{ohmmeter}} = \frac{R}{N} = \frac{18\ \Omega}{3} = \mathbf{6\ \Omega}$$