SOLUTIONS CHAPTER 2

SOLUTION 2.1. Using KCL at the center node of each circuit:

(a) $I_3 = I_2 - I_1 = -1 - 2 = -3A$

(b) $I_3 = I_1 + I_2 - I_4 = 2 - 1 - 0.5 = 0.5A$

SOLUTION 2.2. KCL at the bottom node gives $I_1 = -7 - 8 = -15A$, and at the right node $I_4 = -6 - 8 = -14$. From these, KCL at the top node gives $I_3 = I_4 - 5 = -19A$, and finally at the central node gives $I_2 = 6 + I_3 - 7 = -20A$,

SOLUTION 2.3. Use a gaussian surface on the top triangle. Performing KCL around this surface yields $1A - 2A + 3A + 4A - 5A = I = 1A$.

SOLUTION 2.4. Use a gaussian surface around the bottom rectangle. KCL yields $I_1 = 2A + 10A + 3A = 15A$.

SOLUTION 2.5. Using KVL, $V_1 = 55V - 15V + 105V - 100V - 30V = 15V$.

SOLUTION 2.6. Using KVL, $V_x = 5V - 1V - 1V - 1V + 1V - 1V = 2V$.

SOLUTION 2.7. Using KVL once again.

$v_1 = 7 + 6 + 5 = 18V$

$v_2 = 6 + 7 - 8 = 5V$

$v_3 = -5 - 6 = -11V$

$v_4 = 8 - 7 = 1V$

SOLUTION 2.8. KVL is used to find the voltage across each current source, and KCL to find the current through each voltage source.

$I_{3V} = 6A - 7A = -1A$

$I_{4V} = I_{3V} + 8A = 7A$

$I_{5V} = -8A - 6A = -14A$

$V_{7A} = 4V + 3V = 7V$

$V_{8A} = -4V + 5V = 1V$

$V_{6A} = V_{8A} - 3V = -2V$

SOLUTION 2.9. Using the same method as before, the current and voltages are found through and across each sources.

$I_{5V} = 9 + 8 - 7 = 10 \qquad P = 50W$

$I_{4V} = -6 - I_{5V} = -16 \qquad P = -64W$

$I_{2V} = 6 - 7 = -1A \qquad P = -2W$

$I_{3V} = -I_{2V} - 9 = -8A \qquad P = -24W$

$V_{8A} = 4 - 5 = -1V \qquad P = -8W$

$V_{9A} = 3 + V_{8A} = 2V \qquad P = 18W$

$V_{7A} = 2 - V_{9A} = 0 \qquad P = 0W$

$V_{6A} = 5 - V_{7A} = 5 \qquad P = 30W$

Summing all the power give 0W, hence conservation of power.

SOLUTION 2.10. Doing KVL around the right loop does not balance out. Changing 8V to 5V would fix this.

SOLUTION 2.11. Using KVL to determine the voltages, and KCL to determine the currents:

$V_y = 8V$

$V_x = V_y - 4 = 4V$

$I_a = 4A$

$I_y = 4 - 14 + 2I_a = -2A$

$I_x = I_a - I_y = 6A$

SOLUTION 2.12. First $V_{in} = I_2 \; 8\Omega = 24V$. Then $I_1 = V_{in} / 3\Omega = 8A$ and $I_3 = 12A - I_1 - I_2 = 1A$. Therefore $R_L = V_{in} / I_3 = 24\Omega \qquad P = I_3 \; V_{in} = 24W$

SOLUTION 2.13. (a) First, from current division, get

$$I_1 = \left(\frac{1/3}{1/3 + 1/6 + 1/R_L} \right) (12 - aI_1) \qquad I_1 = \left(\frac{12/3}{(1+a)/3 + 1/6 + 1/R_L} \right).$$

(b) Using the previous equation and solving for $1/R_L = (12/3I_1) - 1/6 - (1+a)/3 = 0.5S$ or $R_L = 2\Omega$.

The power $P = I_3^2 R_L = \left(\left(\frac{1/R_L}{1/3 + 1/6 + 1/R_L} \right) (12 - aI_1) \right) R_L = 18W$

SOLUTION 2.14. For the power delivered by the source to be 60W, the voltage across it should be $V = P / 2A = 30V$. Therefore the current through the 20Ω must be $I_{20\Omega} = 30 / 20 = 1.5A$, and by KCL the current through $I_{R_L} = 2 - I_{20\Omega} = 0.5A$. From this, $R_L = V / I_{R_L} = 60\Omega$.

SOLUTION 2.15. Writing KVL around the loop $25V - 4I - 15V - 5I - I = 0 \quad I = 1A$, and $P_{5\Omega} = I^2 R_{5\Omega} = 5W$

SOLUTION 2.16. The total power supplied by the source is $P = 50V \;\; 0.5A = 25W$. The power absorbed by the resistor is $P_{60\Omega} = (0.5A)^2 \;\; 60\Omega = 15W$. Therefore by conservation of power, the power absorbed by X is 10W.

SOLUTION 2.17. (a) As this loop is open, no current flows through it, so I_R is 0A. The output voltage is $V_{OUT} = -2V + 3V - 2V = -1V$ by KVL.

(b) Writing out the KVL equation around the loop $3 - 2 - I_R R - 2 - I_R 2R - I_R R = 0 \quad -1 = I_R 4R$. Therefore $I_R = -1/4R$ and $V_{OUT} = I_R R = -1/\;4V$.

SOLUTION 2.18. Writing out KVL around the loop $60 - 30I - 30 - 20 + 60 - 40I = 0 \quad I = 1A$. From ohm's law $R = V / I = 30\Omega$.

SOLUTION 2.19. (a) Using Ohms law $I_{in} = V_2 / (20 + 12) = 0.75A$, and $V_1 = 12 \;\; I_{in} = 9V$. To find R, write KCL and get $V_R = 30 - V_2 = 6V$. Therefore using Ohms law again, $R = V_R / I_{IN} = 8\Omega$.

(b) Writing KVL around the loop, $30 = aV_1 + I_{in}R + I_{in}20 + V_1$, and substituting $I_{in} = V_1 / 12$, $V_1 = 30 / [(R + 32)/12 + a]$ is obtained. Next substitute back $V_1 = 12I_{in}$ and solve for

$$R = \left(\frac{30}{12 I_{IN}} - a\right) 12 - 32 = 40\Omega$$

SOLUTION 2.20. (a) i. Using $R = V_{xy} / I_{bat}$ the value of each resistors starting with the top one are 2.7Ω, 0.6Ω, and 0.25Ω. Using the same relationship, the resistance for the motor is 1.25Ω.

ii. Using $P = V_{xy}^2 / R$ the power dissipated by each resistor is 16.875W, 3.75W, 1.5625W, and for the motor 7.8125W.

iii. The relative efficiency is = 7.8125/ (12 2.5) 100 = 26 %

(b) i. Performing voltage division across each resistor

$V_{AB} = 0$

$V_{BC} = 12 \;\; R_{BC} / (R_{BC} + R_{CD} + R_{motor}) = 3.43V$

$V_{CD} = 12 \;\; R_{CD} / (R_{BC} + R_{CD} + R_{motor}) = 1.43V$

$V_{motor} = 12 \;\; R_{motor} / (R_{BC} + R_{CD} + R_{motor}) = 7.14V$

ii. $I_{bat} = 12/(R_{BC} + R_{CD} + R_{motor}) = 5.71A$

iii. The relative efficiency is $= (V^2_{motor} / R_{motor}) / (12 \quad 5.71) \quad 100 = 59.5\,\%$

(c) i. Repeating the steps from (b), the voltages across the first two resistance are 0, then across the other and the motor 2V, and 10V

ii. $I_{bat} = 12/(R_{CD} + R_{motor}) = 8A$

iii. And the relative efficiency is $= (V^2_{motor} / R_{motor}) / (12 \quad 8) \quad 100 = 83.3\,\%$

(d) What is the largest equivalent resistance of the motor that will draw 30A? $R = 12/\ 30A = 0.4\Omega$.

SOLUTION 2.21. (a) Observe that $i = -I_O$, thus $v = ki^3 = -kI_0^3$.

(b) Using KVL and previous equation, $v_x = (R_1 + R_2)I_O + V_O + kI_O^3$.

(c) The power is $= I_O v_x = (R_1 + R_2)I_O^2 + V_O I_O + kI_O^4$

SOLUTION 2.22. $I_{100\Omega} = \sqrt{\dfrac{0.04}{100}} = 0.02$ A. Therefore $V_{300\Omega} = 0.02 \times (100 + 200) = 6$ V. By KCL, $I_{150\Omega} = 0.02 + \dfrac{6}{300} = 0.04$ A. R_{eq}, seen by the source, is 300 Ω. Therefore $V_S = 0.04 \times 300 = 12$ V.

SOLUTION 2.23. Using KCL $I_R = 5 - 3 = 2A$, and KVL $V_R = 10 + 6 = 16V$. Thus $R = V_R / I_R = 16/2 = 8\Omega$.

SOLUTION 2.24. Using KCL, KVL, along with Ohm's law,

$I_{5\Omega} = 6 - 7 = -1A$

$I_{4V} = 8 - I_{5\Omega} = 9A$

$I_{2\Omega} = 8 + 7 = 15A$

$V_{6A} = 4 + 5I_{5\Omega} = -1V$

$V_{8A} = -4 + 2I_{2\Omega} = 26V$

$V_{7A} = V_{8A} - 5I_{5\Omega} = 31V$

Now, the power delivered or absorbed by each element is calculated:

$P_{6A} = I_{6A} \quad V_{6A} = -6W$

$P_{7A} = I_{7A} \quad V_{7A} = 217W$

$P_{8A} = I_{8A} \quad V_{8A} = 208W$

$P_{4V} = I_{4V} \quad 4 = 36W$

$P_{5\Omega} = I^2_{5\Omega} \quad 5 = 5W$

$P_{2\Omega} = I^2_{2\Omega} \quad 2 = 450W$

Note that for passive elements, when the power is positive it is absorbed, while for independent sources it is generated when the power is positive.

SOLUTION 2.25. Note that $I_1 = 6A$. Thus by KCL

$I_3 = 6 - 0.5I_1 = 3A$

$I_2 = 2 + 0.2I_1 = 3.2A$

$I_4 = 8 - 0.3I_1 = 6.2A$

And finally using KVL

$V_2 = 8A\ \ 1 + 4I_4 + 3I_3 = 41.8V$

$V_1 = 2I_2 - 3I_3 = -2.6V$

SOLUTION 2.26. (a) Using KCL,

$I_4 = 5 - 4 = 1A$

$I_3 = I_4 - 2 = -1A$

$I_2 = 3 - 2 = 1A$

$I_1 = -I_2 - 5 = -6A$

(b) Using KVL and Ohm's law,

$V_1 = 3I_1 = -18V$

$V_2 = 12I_2 = 12V$

$V_3 = 10I_3 = -10V$

$V_4 = 4I_4 = 4V$

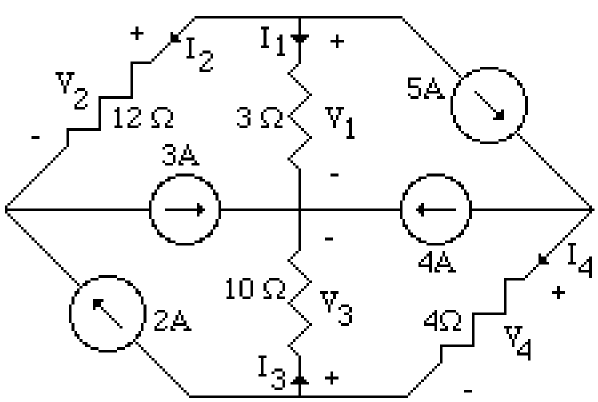
(c)

$P_{3A} = 3A(V_2 - V_1) = 90W$

$P_{2A} = 2(V_1 - V_2 - V_3) = -40W$

$P_{4A} = 4(-V_3 - V_4) = 24W$

$P_{5A} = 5(V_4 + V_3 - V_1) = 60W$



SOLUTION 2.27. Write KVL around the outside loop, $40 = 500I_x + (400+200)i$. And write KCL equation $i = I_x - 2I_x$. Solving yields $I_x = -0.4A$. The dependent source delivers $2I_x \ (-600i) = 192W$, and the independent $40I_x = -16W$. Finally the resistors absorb $500I_x^2 + 400i^2 + 200i^2 = 176W$ verifying the conservation of energy since the source generate 192W-16W=176W.

SOLUTION 2.28. By voltage division $V_2 = \dfrac{[((90\|180)+60)\|40]}{[((90\|180)+60)\|40]+160} \ \dfrac{60}{60+(90\|180)} \ V_s = 1/14 \ \ V_s$.

Therefore $V_S = 14V_2 = 280V$.

SOLUTION 2.29. By voltage division

$$v_x = 9V \ \frac{18+3}{(18+3)+6} = 7V$$

SOLUTION 2.30. By voltage division we get the following two equations in order to solve for the two unknowns.

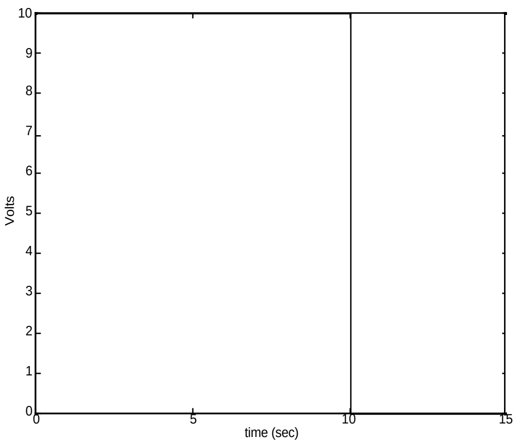
$$V_2 = V_1 \ \frac{R_1}{R_1 + R_2}$$

$$V_1 = 100V \ \frac{R_1 + R_2}{R_1 + R_2 + 60}$$

Solving yields $R_1 = 40\Omega$, and $R_2 = 100\Omega$.

SOLUTION 2.31. Dividing 1400 in four gives 350. If we only need 1/4 and 2/4, the resistor string can be made of three resistances: 350Ω, 350Ω, and 700Ω.

SOLUTION 2.32. Using voltage division, at t=0 $v_R = 15 \ \dfrac{2R}{3R} = 10V$, and t = 5 s $v_R = 10V$, and at t = 10 the voltage goes back to 0V.



SOLUTION 2.33. By voltage division

$$V_b = \frac{R_b}{R_a + R_b} V_{in} \quad \text{and} \quad V_d = \frac{R_d}{R_c + R_d} V_{in}$$

By KVL, if $V_{out} = 0$, then

$$0 = V_{out} = V_b - V_d = \left(\frac{R_b}{R_a + R_b} - \frac{R_d}{R_c + R_d} \right) V_{in}$$

For arbitrary V_{in}, this requires that $\frac{R_b}{R_a + R_b} = \frac{R_d}{R_c + R_d}$ or equivalently that $R_b R_c = R_a R_d$.

SOLUTION 2.34. First $G_{eq} = 1m + 1.5m + 2m + 3m = 7.5mS$. By current division

$I_2 = 100mA \frac{1.5m}{G_{eq}} = 20mA$, $P = 100mA \;\; I_2 / 1.5mS = 1.33W$.

SOLUTION 2.35. By current division, for I_1 to be 2A then $160 + R = 300 || 600$ for an even split. Thus $R = 40\Omega$.

SOLUTION 2.36. By current division, $i_1 = 0.4A \frac{1/10}{1/10 + 1/40} = 0.32A$. Therefore using KVL $v_d = 10i_1 - 0.25i_1 = 3.12V$.

SOLUTION 2.37. (a) $R_{eq} = (8k || 2k) + (9k || 1k) = 2.5k\Omega$

(b) $R_{eq} = 2k\,||[(2k\,||2k) + (2k\,||2k)] = 1k\Omega$

SOLUTION 2.38. (a) $R_{eq} = 2 + 15 + 10 + 10 + 40 + 30 + 20 + 8 = 135\Omega$.

(b) Four of the resistors are shorted, thus $R_{eq} = 2 + 15 + 10 + 8 = 35\Omega$.

(c) Lumping the series resistance together $R_{eq} = 8 + [50\,||(50||25)] + 2 = 22.5\Omega$

SOLUTION 2.39. (a) $R_{eq} = [2R + (4R\,||4R)]||[2R + (4R\,||4R)] = 2R$

(b) $R_{eq} = 2R\,||2R + (4R\,||4R\,||4R\,||4R) = 2R$

SOLUTION 2.40. (a) First $R_{eq} = 150 + [375||(250 + 500)] = 400\Omega$. Next $I_{in} = 14V / R_{eq} = 35mA$. The power delivered by the source is then $= 14I_{in} = 0.49W$.

(b) $R_{eq} = 150 + [375||(250 + 500)||1k] = 350\Omega$, and $I_{in} = 14 / R_{eq} = 40mA$. The power delivered by the source is $= 14I_{in} = 0.56W$.

As the equivalent resistance decreases, more of it gets dissipated by it.

SOLUTION 2.41. $R_{eq1} > R_{eq2}$. Without going into a detailed analysis using methods of Chapter 3, we present the following intuitive argument. First note that the points a and b represent points on an unbalanced bridge circuit meaning that the voltage between a and b would not be zero. Also note that when two resistors are placed in parallel, the equivalent resistance becomes smaller than either resistance. The addition of the resistor R in circuit 2 essentially creates an internal parallel resistance resulting in an R_{eq2} lower than R_{eq1}.

SOLUTION 2.42. $R_{eq1} = R_{eq2}$. As was the case in the previous problem, this is a balanced bridge circuit. Hence no voltage appears between a and b making the additional resistor irrelevent.

SOLUTION 2.43. (a) $R_{in} = [(20||20) + 10]||(1/0.12)||(1/0.08) = 4\Omega$.

(b) $R_{in} = 6R\,||[(R\,||R\,||0.5R) + 0.75R + (2R||2R)] = 1.5R$

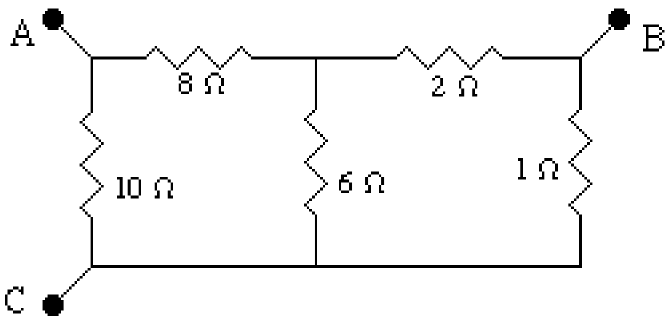
SOLUTION 2.44. (a) The infinite resistance are essentially open circuits, thus
$R_{eq} = 1 + 2 + 3 + 4 + 2 + 4 + 3 + 2 + 1 = 22\Omega$

(b) 0 resistances are short circuits. Labeling one branch x and the other y, it can be seen that the circuit is a set of 3 resistor strings in parallel to each other between x and y, then added in series to the two 1 Ohm resistor. Thus $R_{eq} = [(2 + 3)||(4 + 2 + 4)||(2 + 3)] + 1 + 1 = 4\Omega$.

(c) Writing out $R_{eq} = 1 + [R_x \| (2 + 3 + 4 + 2 + 4)] + 3 + 2 + 1 = 7 + [R_x \| 15]$, and solving for $R_x = 3.75\Omega$.

(d) No, it requires methods to be covered in the next chapter.

SOLUTION 2.45. Using the formulas for parallel resistances, the circuit of figure 2.45 reduces to



(a) $R_{AC} = \left[\left((2+1)//6\right) + 8\right] //10 = 5\ \Omega$

(b) R_{AB} cannot be calculated by series parallel formulas, but R_{BC} can be done.

$$R_{BC} = \left[\left((8+10)//6\right) + 2\right] //1 = 0.86667\ \Omega$$

SOLUTION 2.46. (a) $R_{eq} = 300 + (R \| 5.6k)$, thus $R = 800\Omega$.

(b) $R_{eq} = R + (R \| 1.2K)$, the following quadratic equation must be solved $R^2 + 1.4k\ \ R - 1.2M = 0$. This yields $R = 600\Omega$.

(c) $R_{eq} = 500 + 300 + (800 \| 400 \| R)$. Solving for R yields 800Ω.

SOLUTION 2.47.

(a) Using the fact that the resistance seen into terminal a-b is the same as that seen in terminal c-d, we can obtain the following relationship. $R_{eq} = R + R \| R_{eq}$. This produces a quadratic equation whose solution is $R_{eq} = 1.618R$.

(b) Using the previous argument $R_{eq} = 5 + 10 \| (5 + R_{eq})$. Solving for $R_{eq} = 11.18\Omega$.

SOLUTION 2.48. By current division $I_x = \left(\dfrac{1/18k}{1/18k + 1/9k}\right)\left(\dfrac{\dfrac{1}{6k + (9k \| 18k)}}{\dfrac{1}{6k + (9k \| 18k)} + \dfrac{1}{4k}}\right) 36m = 3mA$

SOLUTION 2.49. The 500 Ω resistor has no effect on the current entering the circuit to its right.

$$0.15 = \frac{30}{R} + \frac{30}{600} = \frac{30}{R} + 0.05$$

Hence R = 30/0.1 = 300 Ω.

SOLUTION 2.50. (a) First, express the total current as $I = \frac{120}{0.5 + (20\,||30||40\,||\,R_{L2})}$. Next, find R_{L2} that will cause I to be 15A. Thus $R_{L2} = 40\Omega$ or less will cause the fuse to blow as this will cause the current to be 15A or more.

(b) Repeating the previous procedure, $R_{L2} = 20\Omega$.

(c) $R_{L2} = 120\Omega$.

SOLUTION 2.51. At time 0, all switches are open and $V_{out} = \frac{260}{260+40}\ 220 = 190.7V$.

Then at t = 5s, switch one closes and

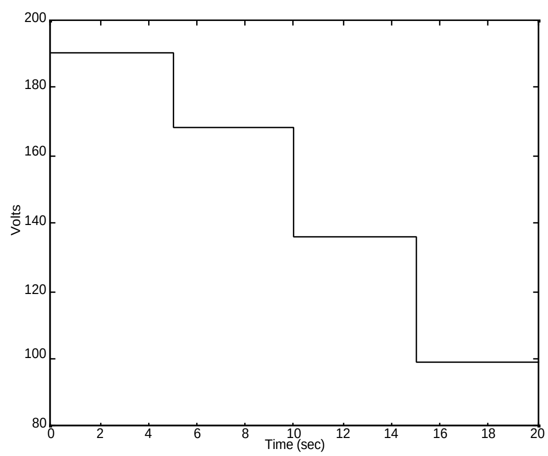
$$V_{out} = \frac{260||260}{(260\,||260) + 40}\ 220 = 168.2V.$$

At t = 10s,

$$V_{out} = \frac{130\,||260||260}{(130\,||260||260) + 40}\ 220 = 136.2V.$$

Finally at t =15 s,

$$V_{out} = \frac{65||130\,||260||260}{(65||130\,||260||260) + 40}\ 220 = 98.5V.$$



SOLUTION 2.52. (a) Lumping the two sources together and the resistors into an equivalent resistor gives

$$i_1(t) = \frac{9\cos(2t) - 3\cos(2t)}{7k + 9k + 8k + (2k\,||\,3k\,||\,6k)} = 0.24\cos(2t)mA.$$

(b) By current division $i_2(t) = \left(\frac{1/6k}{1/2k + 1/3k + 1/6k}\right) i_1(t) = 40\cos(2t)\mu A$.

SOLUTION 2.53. (a) Starting with,

$$R_{eq1} = 5||(10+10) = 4\Omega$$

$$R_{eq2} = 10||(6 + R_{eq1}) = 5\Omega$$

$$R_{eq3} = 5 + R_{eq2} = 10\Omega$$

(b) Using the values R just obtained,

$$V_a = 100 \; \frac{R_{eq2}}{R_{eq3}} = 50V$$

$$V_b = V_a \; \frac{R_{eq1}}{6 + R_{eq1}} = 20V$$

$$V_c = V_b \; \frac{10}{10+10} = 10V$$

(c) Finally,

$$I_{in} = \frac{100}{R_{eq3}} = 10A$$

$$I_d = \frac{V_a}{6 + R_{eq1}} = 5A.$$

$$I_e = \frac{V_b}{10+10} = 1A$$

SOLUTION 2.54. (a) Circuit a: Using voltage division,

$v_{out}(t) = v_{in}(t) \; \left(\frac{300||(20+30+50)}{[300\,||(20+30+50)]+5}\right) \left(\frac{30}{30+20+50}\right) = 33.75\sin(377t)V$, and Ohm's law

$i_{out}(t) = v_{out}(t)/30 = 1.125\sin(377t)A$. The instantaneous power is then

$$P(t) = i_{out}(t) \; v_{out}(t) = 37.969\sin^2(377t)W.$$

Circuit b: By current division

$i_{out}(t) = i_{in}(t) \; \left(\frac{1/(20+30+50)}{1/(20+30+50) + 1/300 + 1/(50+100)}\right) = 60\sin(377t)A$, and from Ohm's law

$v_{out}(t) = 50 \; i_{out}(t) = 3000\sin(377t)V$. The instantaneous power is $P(t) = 180\sin^2(377t)kW$.

(b) No, since the current source forces the amount of current in the circuit.

SOLUTION 2.55. (a) Noting that $i_2 = v_1 / 10 = 6A$, then we can write KCL at the top left node, $i_{source} = i_2 + v_1 / 6 + (v_1 - 5i_2) / 5 = 22A$. Thus $P = 60 \;\; 22 = 1.32kW$.

(b) First, determine the current through each resistor:

$i_2 = 60 / 10 = 6A$

$i_{2.5\Omega} = \left(\frac{60}{2.5 + (5||5)} \right) = 12A$

$i_{5\Omega} = 1/2 \;\; i_{2.5\Omega} = 6A$

Then calculate the power absorbed by each resistor:

$P_{10\Omega} = 10 i_2^2 = 360W$

$P_{2.5\Omega} = 2.5 i_{2.5\Omega}^2 = 360W$

$P_{5\Omega} = 5 i_{5\Omega}^2 = 180W$

SOLUTION 2.56. From Ohm's law $I_1 = 100m / 200 = 0.5mA$. By current division

$I_{RL} = \left(\frac{20k}{20k + 200} \right) 150 I_1 = 75.257mA$, and $P_{RL} = 200 I_{RL}^2 = 1.103W$.

SOLUTION 2.57. First, using voltage division, $V_x = V_s \left(\frac{2}{2+1} \right) = (2/3)V_s$. Then using KCL and the previous equation, $I_s = (V_s / 3) - V_x = -(1/3)V_s$. Finally using Ohm's law $R_{eq} = V_s / I_s = -3\Omega$.

SOLUTION 2.58. Observing the following relationship, $V_1 = V_{in}$, the following nodal equation can written: $I_{in} = V_{in} / 3 + V_{in} / 6 - 2V_{in} = -1.5V_{in}$.

SOLUTION 2.59. Step 1. From voltage division

$$V_1 = \frac{18}{18 + 4 + 2} V_s = 0.75 V_s \quad \text{and} \quad V_{in} = \frac{22}{24} V_s = \frac{11}{12} V_s$$

Hence

$$P_{in} = \frac{V_{in}^2}{22} = \frac{11 \times 11}{22 \times 144} V_s^2 = \frac{11}{288} V_s^2$$

Step 2. For the load, by current division

$$I_{2\Omega} = \frac{6}{6+2} AV_1 = \frac{3}{4} A\left(\frac{3}{4} V_s\right) = \frac{9A}{16} V_s$$

Therefore

$$P_{2\Omega} = 2 \times I_{2\Omega}^2 = 2\frac{81A^2}{256} V_s^2 = \frac{81A^2}{128} V_s^2$$

Step 3. $P_{2\Omega} = 10 \times P_{in}$ implies that

$$\frac{81A^2}{128} V_s^2 = 10\frac{11}{288} V_s^2$$

Hence

$$A = \sqrt{\frac{128 \times 110}{81 \times 288}} = 0.7769$$

SOLUTION 2.60. By voltage division $V_1 = \frac{6}{6+2} V_{in} = (3/\ 4)V_{in}$. By current division, and substituting the previous equation $I_2 = \frac{3}{3+6} 4V_1 = V_{in}$. Using voltage division and Ohm's law, and substituting the previous equation,

$$V_{out} = 4.5 I_2 \frac{10}{10+5} = 3V_{in} = 30V$$
$$I_{out} = 4.5 I_2 / (10+5) = 0.3V_{in} = 3A$$

Finally, from the previous equations $|V_{out} / V_{in}| = 3$.

SOLUTION 2.61. Writing out KCL when the switch is closed, $i_{bat} = 150A + \left(\frac{V_{bat} - 0.04 i_{bat}}{240}\right)$. Solving gives $i_{bat} = 150.02A$ and $V_{out} \approx 6V$. When the switch is open $V_{out} = V_{bat}\left(\frac{240}{240+0.04}\right) \approx 12V$. Therefore, the reason for the radio stopping is insufficient supply voltage.

SOLUTION 2.62. (a) Using the following relationship $P = V^2 / R$, the resistance of each headlight on low beam is $R = V^2 / P = 4.11\Omega$.

(b) Using the same relationship $R = 2.22\Omega$.

(c) By voltage division, $V_{out} = 14.7 \frac{240}{240 + 0.04} = 14.698V$.

(d) Using voltage division, $V_{out} = 14.7 \frac{240 \| 4.11 \| 4.11}{(240 \| 4.11 \| 4.11) + 0.04} = 14.417V$

(e) Using voltage division, $V_{out} = 14.7 \dfrac{240||2.22||2.22}{(240||2.22||2.22) + 0.04} = 14.186V$

SOLUTION 2.63. By voltage division

$$11.96 = \frac{15}{15 + R_0} 12 = \frac{180}{15 + R_0}$$

Therefore

$$R_0 = \frac{180 - 15 \times 11.96}{11.96} = 0.050167\ \Omega$$

SOLUTION 2.64. (a) Using KVL $V_t = 102 - 0.05\ \ 80 = 98\ \text{V}$.

(b) Using KVL $V_t = 102 + 0.05\ \ 50 = 104.5\ \text{V}$.

(c) $P = V_t\ \ 50 = 5.225.\ \text{kW}$

SOLUTION 2.65. Minimum load means the minimum load resistance that the system can handle.

»MaxPwr = 0.8*50e6

MaxPwr = 40000000

»Vs = 750e3;

»Iline = MaxPwr/Vs

Iline = 5.3333e+01

»Rmin = Vs/Iline

Rmin = 1.4062e+04, i.e., Rmin = 14.062 kΩ.

SOLUTION 2.66. (a) Using the following general form for a non-ideal voltage source: $v_{out} = -R_s i_{out} + V_s$, one sees that for zero current $v_{out} = V_s = 40V$. The slope of the line is $\dfrac{-40}{1000} = -R_s = -0.04\Omega$, thus $R_s = 0.04\Omega$.

(b) This curve represents a resistor's I-v characteristic, thus the slope $\dfrac{60}{1\frac{1}{3}} = R = 45\Omega$.

(c) The general form for a non-ideal current source is $i_{out} = -\dfrac{1}{R_s} V_{out} + I_s$. When the voltage is zero, $i_{out} = I_s = 5A$. From the slope of the line, $\dfrac{-4000}{5}$, $R_S = 4000 / 5 = 800\ \Omega$.

SOLUTION 2.67. Using the following formula: $\frac{T}{n}\left(\frac{nI}{C_n}\right)^{\alpha} = 1$, solve for T, and get 0.625 hrs, or 37.5 min.

SOLUTION 2.68. Using the same equation as before and solving for $C_n = nI\left(\frac{T}{n}\right)^{1/\alpha}$, with n=10, and T=55/60 hrs, the capacity obtained is 20 Ah.

SOLUTION 2.69. $C_{20} = 50\,Ah$

(a) In eq. 9, solving for I with n=20, and T=10, I=4.2A

(b) Calculate the capacity for n=10 and T=10, this yields 42 Ah.

SOLUTION 2.70. (a) Using a sequence of voltage division,

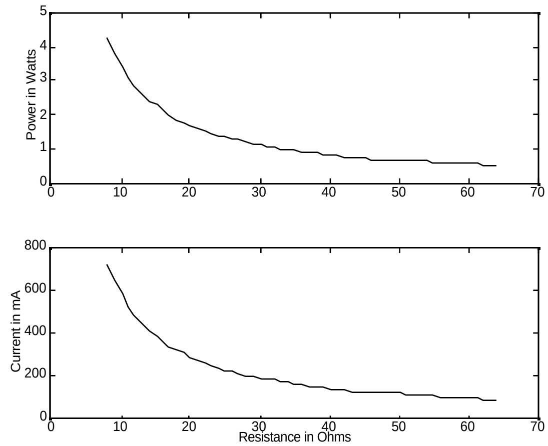
$$V_1 = 50mV\frac{48}{50} = 48mV$$

$$V_2 = 50V_1\frac{195}{200} = 2.34V$$

$$V_{load} = 2.5V_2 = 5.85V$$

And the power is $R_{R_L} = V_{load}^2 / R_L = 2.278W$.

(b) Following is the graph, and the script used to generate it.



%Script for Question 70 in chapter 2

RL=8:1:64;

V2=2.34;

*IL=2.5*V2 ./ RL;*
%Note the use of the "." which means that the division*
%is performed for each value of RL.

```
PL=RL .* (IL .^ 2);

%Plot the Power versus RL
subplot(2,1,1);
plot(RL,PL);
ylabel('Power in Watts');

%Plot the Current versus IL
subplot(2,1,2);
plot(RL,1000.*IL);
xlabel('Resistance in Ohms');
ylabel('Current in mA');

%The use of subplot lets you subdivide the graphing
%window in two halfs.
```

SOLUTION 2.71. (a) Using the following script:

```
%Script for problem 2.71

R1=15; R2=4; R3=9; R4=2; R5=8;
R6=18;

Ra= R4+R5;
Ga= 1/Ra;
Gb= Ga+1/R1;
Rb= 1/Gb;
Rc= 1/(1/R6+1/R3)+Rb;
Gc= 1/Rc;
Geq= Gc+1/4;
Req= 1/Geq;
Irc= 20*Gc/Geq;
Vrb= Irc*Rb;
Vout= Irc*(Ga/Gb)*8;

Req
Vout
```

So (a) $R_{eq} = 3\Omega$, and (b) $V_{out} = 24V$

SOLUTION 2.72. Using the following script:

```
%Script for problem 2.72
R1=1e3; R2=2.2e3; R3=2e3; R4=5e3; R5=3e3; R6=R5;
R7=3.2e3; R8=1.2e3; R9=1.6e3;
```

```
Ga=1/R7+1/(R8+R9);
Ra=1/Ga;
Gb=Ga+1/R6;
Rb=1/Gb;
Gc=1/R4+1/(R5+Rb);
Rc=1/Gc;
Gd=1/R2+1/(R3+Rc);
Rd=1/Gd;
Geq=1/R1+Gd;
Req=1/Geq

%Going through the same step to find Vout
Id=200e-3*(Gd/(Geq));
Ic=Id*((1/(R3+Rc))/Gd);
Ib=Ic*((1/(R5+Rb))/Gc);
Ia=Ib*Ga/Gb;
Iout=Ia*((1/(R8+R9))/Ga)
Vout=Iout*R9
```

The following values are obtained:

Req =

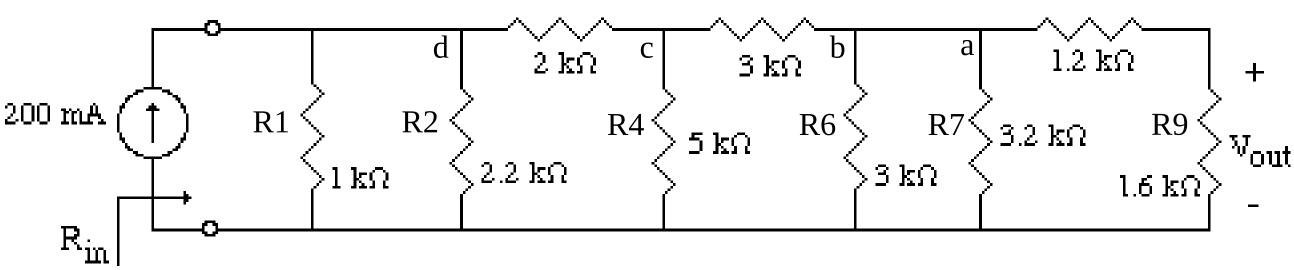
5.9121e+02

Iout =

5.5431e-03

Vout =

8.8689e+00



SOLUTION 2.73. Using the following script:

```
%Script for problem 2.73
R1=20; R2=40; R3=60; R4=30; R5=10; R6=135;
R7=150; R8=300; R9=130; R10=200; R11=50;

Ga=1/R10+1/R11;
Ra=1/Ga;
Rb=Ra+R9+(1/(1/R7+1/R8));
```

Gb=1/Rb;

Gc=Gb+1/R6;

Rc=1/Gc;

Rd=Rc+R5+(1/(1/R3+1/R4));

Gd=1/Rd;

Ge=Gd+1/R2;

Re=1/Ge;

Rin=R1+Re

Ie=10/Rin;

*Id=Ie*Gd/Ge;*

I1=Id(1/R6)/Gc*

*Ib=Id*Gb/Gc;*

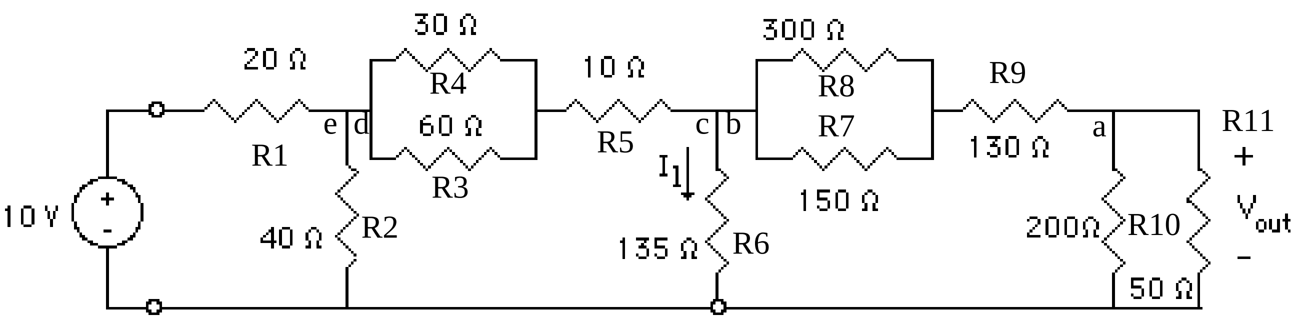
*Vout=Ib*Ra*

The following values are obtained:

$R_{in} = 50\Omega$

$V_{out} = 0.667V$

$I_1 = 33.3mA$



SOLUTION 2.74. An identical procedure to the one followed in the previous problem will yield the following values:

$R_{in} = 50.53\Omega$

$I_{out} = 133.8mA$