ACTIVE EXERCISES

This document contains exercises to work in class to obtain understanding of the concepts of electricity and basic circuits. While it would be great if we could work every problem during our classroom time together, that is simply not possible. You are strongly encouraged to work the "unworked" problems on your own at home. Furthermore, as the semester progresses and you learn additional techniques for analyzing circuits, you are encouraged to return to earlier problems and work them with the later circuit analysis methods. In general, every problem in this workbook can be worked numerous ways. Obviously, the answer will be the same each time. Again, remember that the homework assigned in this course is minimal. It is very doubtful that working just the homework problems will be enough for you to gain a full understanding of the material. You will want to work as many problems as you can. And, work them repeatedly using different methods to reinforce your understanding.

An ability to work and fully understand the problems in this workbook should be highly beneficial to making a good grade in this course. The problems in this workbook are taken from my own personal course notes – the notes from which I teach the course, and the problems from exams given in this course during semesters past. Will you see the exact same problems from this workbook on an exam in your course? Highly unlikely. Will you see problems similar to the ones in this workbook on exams in your course? Very probable, since I created the problems in this workbook and I create the exam problems.

You are encouraged to study, discuss, and work with your colleagues. Pedagogical research has shown repeatedly that peer-instruction is highly effective for all parties involved. As you study in study groups, just be vigilant to contribute to the study effort and work on your own learning. While it may be easier to "mooch" answers to these problems and homework from your partners, it does you no good.[1]

[1] Besides, the point of this workbook and the homework is to help you teach yourself. Being a life-long learner is one of the most important skills you can perfect.

Work together so that everyone in the group has the fullest understanding. If you are confused, ask for assistance from a study partner that seems to already "get it". If you sense a study partner does not understand a topic or concept of which you have gained mastery, offer to help them. You are being a good citizen by helping them out, but it turns out that you are also helping yourself.[2]

[2] Research has proven that the person "tutoring" gains more benefit than the person being tutored. It is called *cognitive rehearsal* and is often expressed as the cliche: "You don't truly understand something until you have to teach it."

REVISION: FALL 2025

1
Fundamentals

Charge and Current

Problem#1·1 ■ The charge at a point in space is $q(t) = 5\,\text{C}$. What is the current?

Answer: 0 A

Problem#1·2 ■ The charge at a point in space is $q(t) = 7t^2\,\text{C}$. What is the current at $t = 3\,\text{s}$? At an arbitrary time t?

Answer: 42 A, $14t$ A

Problem# 1·3 ■ The charge at a point in space is $q(t) = 0.5\cos(6t)\,\text{C}$. What is the current at $t = -2\,\text{s}$? At an arbitrary time t?

Problem# 1·4 ■ The charge at a point in space is $q(t) = 5t \cdot e^{3t}\,\text{C}$. What is the current at $t = 0$? At an arbitrary time t?

Problem# 1·5 ■ The current that flows past a point in space is

$$i(t) = \begin{cases} 0 & t < 0 \\ 3\,\mathrm{A} & t \geq 0 \end{cases}$$

How much charge flows past the point between $t = 0\,\mathrm{s}$ and $t = 2\,\mathrm{s}$? What is the total amount of charge that has flowed past the point at an arbitrary time t?

Answer: 6 C

Problem# 1·6 ■ The current that flows past a point in space is

$$i(t) = \begin{cases} 0 & t < 0 \\ -2\,\mathrm{A} & 0 \leq t < 1 \\ 5\,\mathrm{A} & 1 \leq t < 4 \\ -1\,\mathrm{A} & 4 \leq t < 6 \\ 0\,\mathrm{A} & 6 \leq t \end{cases}$$

How much charge flows past the point between $t = 2\,\mathrm{s}$ and $t = 5\,\mathrm{s}$? What is the total amount of charge that has flowed past the point at an arbitrary time t?

Answer: 9 C

Problem#1·7 ■ The current that flows past a point in space is

$$i(t) = \begin{cases} 0 & t < 0 \\ 3e^{-2t}\,\mathrm{A} & t \geq 0 \end{cases}$$

How much charge flows past the point between $t = 1\,\mathrm{s}$ and $t = 4\,\mathrm{s}$? What is the total amount of charge that has flowed past the point at an arbitrary time t?

Problem#1·8 ■ The current that flows past a point in space is $i(t) = 10\cos(377t)\,\mathrm{A}$. How much charge flows past the point between $t = 1\,\mathrm{s}$ and $t = 1.02\,\mathrm{s}$? What is the total amount of charge that has flowed past the point between two arbitrary times t_0 and t_1?

Energy and Power

Problem# 1·9 ■ The energy at a point in time $w(t) = 5\,\text{J}$. What is the power?

Answer: 0 W

Problem# 1·10 ■ The energy in a system as a function of time is $w(t) = 7t^2\,\text{J}$. What is the instantaneous power at $t = 3\,\text{s}$? At an arbitrary time t?

Answer: $14t$ W

Problem#1·11 ■ The energy in a system as a function of time is $w(t) = 0.5\cos(6t)$ J. What is the instantaneous power at $t = -2$ s? At an arbitrary time t?

Problem#1·12 ■ The energy in a system as a function of time is $w(t) = 5t \cdot e^{3t}$ C. What is the instantaneous power at $t = 0$? At an arbitrary time t?

Problem# 1·13 ■ The instantaneous power expended by a system is

$$p(t) = \begin{cases} 0 & t < 0 \\ 3\,\mathrm{W} & t \geq 0 \end{cases}$$

How much energy is expended between $t = 0\,\mathrm{s}$ and $t = 2\,\mathrm{s}$? What is the total amount of energy expended at an arbitrary time t? What is the time-average power of this system?

Answer: 6 J, $3t$ J

Problem# 1·14 ■ The instantaneous power expended by a system is

$$p(t) = \begin{cases} 0 & t < 0 \\ -2\,\mathrm{W} & 0 \leq t < 1 \\ 5\,\mathrm{W} & 1 \leq t < 4 \\ -1\,\mathrm{W} & 4 \leq t < 6 \\ 0\,\mathrm{W} & 6 \leq t \end{cases}$$

How much emergy is expended between $t = 2\,\mathrm{s}$ and $t = 5\,\mathrm{s}$? What is the total amount of energy expended at an arbitrary time t? What is the time-average power of this system?

Answer: 9 J

Problem# 1·15 ■ The instantaneous power generated by a system is

$$p(t) = \begin{cases} 0 & t < 0 \\ 3e^{-2t}\,\mathrm{W} & t \geq 0 \end{cases}$$

How much energy is generated between $t = 1\,\mathrm{s}$ and $t = 4\,\mathrm{s}$? What is the total amount of energy generated at an arbitrary time t? What is the time-average power of this system?

Problem# 1·16 ■ The instantaneous power expended by a system is

$$p(t) = 500 + 1500\cos(377t)\,\mathrm{W}$$

How much energy is expended between $t = 1\,\mathrm{s}$ and $t = 1.02\,\mathrm{s}$? What is the total amount of energy expended between two arbitrary times t_0 and t_1? What is the time-average power of this system?

Problem# 1·17 ■ Before you started working these problems, you went to the Burger King and ate a Triple Whopper cheeseburger (1230 calories) with fries (600 calories) and a chocolate milkshake (950 calories) over a 10 minute period. While you were eating, your average power intake of food was most nearly (Note: 1 "food" calorie equals 4184 J.)

Answer: 19.4 kW

Problem# 1·18 ■ At rest, the average person "consumes" bodily energy stores at 105 W. Assume that you started working problems at 11AM sharp. At what time must you stop working if you want to "absorb" *all* energy provided by the Burger King Triple Whopper value meal *before* finish?

Answer: 5:45pm tomorrow

Kirchoff's Current Law (KCL)

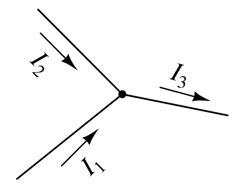

Figure 1.1: Kirchoff's Current Law #1

Problem#1·19 ■ If $I_1 = 10\,\text{A}$ and $I_2 = 3\,\text{A}$, what is I_3?

Answer: 13 A

Problem#1·20 ■ If $I_1 = -5\,\text{A}$ and $I_2 = 2\,\text{A}$, what is I_3?

Answer: -3 A

Problem#1·21 ■ If $I_3 = -12\,\text{A}$ and $I_2 = -7\,\text{A}$, what is I_1?

Answer: -19 A

Problem# 1·22 ■ What can you say about the relationship between I_{12} and I_{13}? (Write down an equation.)

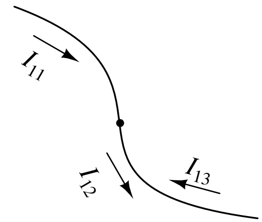

Figure 1.2: Kirchoff's Current Law #2

Problem# 1·23 ■ What can you say about the relationship between I_{11} and I_{12}? (Write down an equation.)

Problem# 1·24 ■ What can you say about the relationship between I_{11} and I_{13}? (Write down an equation.)

Problem# 1·25 ■ If $I_A = 5\,\text{A}$, $I_B = -12\,\text{A}$, and $I_C = 1\,\text{A}$, what is I_D?

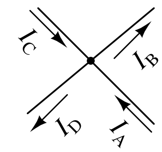

Figure 1.3: Kirchoff's Current Law #3

Answer: 18 A

Problem# 1·26 ■ If $I_A = 5\,\text{A}$, $I_B = -12\,\text{A}$, and $I_C = 1\,\text{A}$, what is I_D?

Problem# 1·27 ■ If $I_A = 5\,\text{A}$, $I_B = -12\,\text{A}$, and $I_C = 1\,\text{A}$, what is I_D?

Problem# 1·28 ■ If $I_u = 1\,\text{A}$, $I_v = -2\,\text{A}$, $I_w = 3\,\text{A}$, $I_x = -4\,\text{A}$, and $I_y = 5\,\text{A}$, what is I_z?

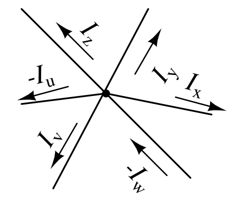

Figure 1.4: Kirchoff's Current Law #4

Problem# 1·29 ■ If $I_z = -1\,\text{A}$, $I_y = 2\,\text{A}$, $I_x = 3\,\text{A}$, $I_w = -4\,\text{A}$, and $I_v = 5\,\text{A}$, what is I_u?

Problem# 1·30 ■ Find I_1 in the circuit below.

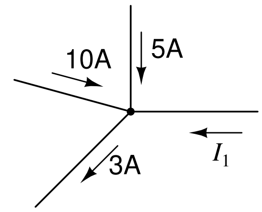

Figure 1.5: Kirchoff's Current Law #5

Kirchoff Voltage Law (KVL)

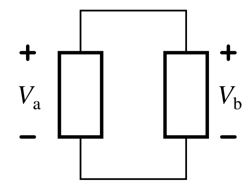

Figure 1.6: Kirchoff's Voltage Law #1

Problem# 1·31 ■ If $V_a = 10\,\text{V}$, what is V_b?

Problem# 1·32 ■ If $V_b = -25\,\text{V}$, what is V_a?

Problem# 1·33 ■ What can you say about the relationship between V_a and V_b?

Problem# 1·34 ■ If $V_x = 25\,\text{V}$ and $V_y = 5\,\text{V}$, what is V_z?

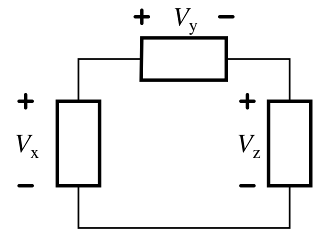

Figure 1.7: Kirchoff's Voltage Law #2

Problem# 1·35 ■ If $V_x = -10\,\text{V}$ and $V_y = 2\,\text{V}$, what is V_z?

Problem# 1·36 ■ If $V_x = -12\,\text{V}$ and $V_y = -3\,\text{V}$, what is V_z?

Problem# 1·37 ■ If $V_z = -16\,\text{V}$ and $V_x = \frac{-3 \cdot V_y}{2}$, what is V_y?

Problem# 1·38 ■ If $V_1 = 1\,\mathrm{V}$, $V_2 = 2\,\mathrm{V}$,and $V_3 = 5\,\mathrm{V}$, what is V_4?

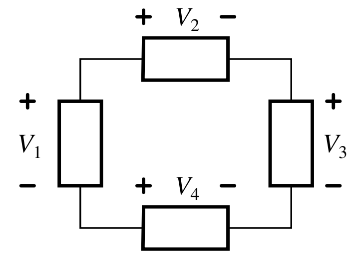

Figure 1.8: Kirchoff's Voltage Law #3

Problem# 1·39 ■ If $V_1 = 10\,\mathrm{V}$, $V_2 = -12\,\mathrm{V}$,and $V_3 = 4\,\mathrm{V}$, what is V_4?

Problem# 1·40 ■ If $V_1 = 17\,\mathrm{V}$, $V_4 = -2\,\mathrm{V}$,and $V_3 = -3\,\mathrm{V}$, what is V_2?

Problem# 1·41 ■ If $V_1 = -1\,\mathrm{V}$, $V_2 = -2\,\mathrm{V}$,and $V_4 = -5\,\mathrm{V}$, what is V_3?

Problem# 1·42 ■ If $V_1 = 10\,\mathrm{mV}$, $V_2 = -50\,\mathrm{mV}$,and $V_3 = 0.5 \cdot \mathrm{V}_2$, what is V_4?

Problem# 1·43 ■ Find V_{21} and V_{22}.

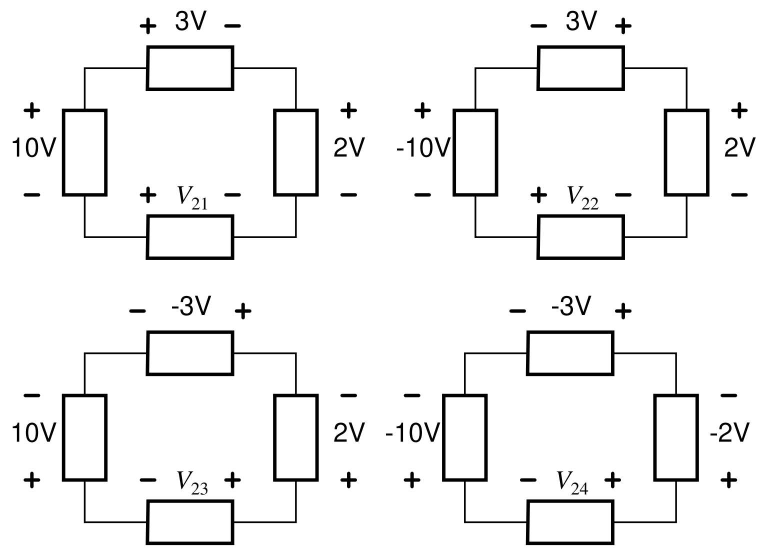

Figure 1.9: Kirchoff's Voltage Law #4

Problem# 1·44 ■ Find V_{23} and V_{24}.

Problem# 1·45 ■ Explain your answers for V_{21} and V_{24}.

Problem# 1·46 ■ In the circuit below, the voltage V_L is

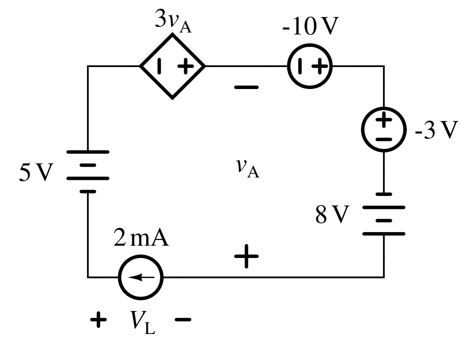

Figure 1.10: Easy

Answer: -9 V [1S11]

Ohm's Law

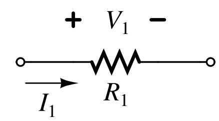

Figure 1.11: Ohm's Law #1

Problem# 1·47 ■ If $I_1 = 10\,\text{A}$ and $R_1 = 3\,\Omega$, what is V_1?

Problem# 1·48 ■ If $I_1 = -2\,\text{A}$ and $R_1 = 3\,\Omega$, what is V_1?

Problem# 1·49 ■ If $V_1 = 120\,\text{V}$ and $R_1 = 40\,\Omega$, what is I_1?

Problem# 1.50 ■ If $I_2 = 4\,\text{A}$ and $R_2 = 100\,\Omega$, what is V_2?

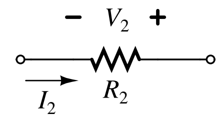

Figure 1.12: Ohm's Law #2

Problem# 1.51 ■ If $I_2 = -4\,\text{A}$ and $V_2 = 100\,\text{V}$, what is R_2?

Problem# 1·52 ■ If $I_3 = -5\,\mathrm{A}$ and $R_3 = 2\,\Omega$, what is V_3?

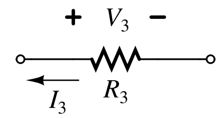

Figure 1.13: Ohm's Law #3

Problem# 1·53 ■ If $I_3 = 30\,\mathrm{A}$ and $R_3 = 300\,\Omega$, what is V_3?

Problem# 1·54 ■ If $I_3 = -2\,\mathrm{mA}$ and $R_3 = 3\,\mathrm{k}\Omega$, what is V_3?

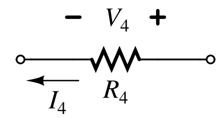

Figure 1.14: Ohm's Law #4

Problem# 1·55 ■ If $V_4 = -120\,\text{kV}$ and $R_4 = 40\,\text{M}\Omega$, what is I_4?

Problem# 1·56 ■ If $I_4 = -4\,\text{A}$ and $R_4 = 100\,\Omega$, what is V_4?

Problem# 1·57 ■ If $I_4 = -2\,\text{A}$ and $R_4 = 3\,\Omega$, what is V_4?

Passive Sign Convention

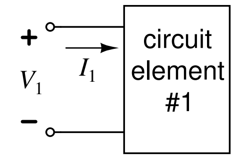

Figure 1.15: Passive Sign Convention #1

Problem#1·58 ■ If $I_1 = 2\,\text{A}$ and $V_1 = 3\,\text{V}$, what is the power absorbed by element #1?

Problem#1·59 ■ If $I_1 = -2\,\text{A}$ and $V_1 = 3\,\text{V}$, what is the power absorbed by element #1?

Problem#1·60 ■ If $I_1 = 2\,\text{A}$ and $V_1 = -3\,\text{V}$, what is the power absorbed by element #1?

Problem#1·61 ■ If $I_1 = -2\,\text{A}$ and $V_1 = -3\,\text{V}$, what is the power absorbed by element #1?

Problem# 1·62 ■ If $I_2 = -5\,\text{A}$ and $V_2 = 2\,\text{V}$, what is the power absorbed by element #2?

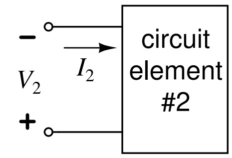

Figure 1.16: Passive Sign Convention #2

Problem# 1·63 ■ If $I_3 = 4\,\text{A}$ and $V_3 = 7\,\text{V}$, what is the power absorbed by element #3?

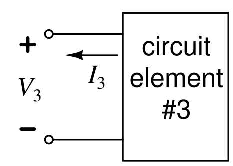

Figure 1.17: Passive Sign Convention #3

Problem# 1·64 ■ If $I_3 = -8\,\text{A}$ and $V_3 = 11\,\text{V}$, what is the power generated by element #3?

Problem# 1·65 ■ If $I_4 = -1\,\text{A}$ and $V_4 = 6\,\text{V}$, what is the power generated by element #4?

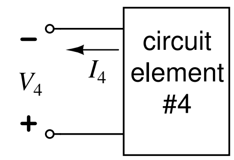

Figure 1.18: Passive Sign Convention #4

Problem# 1·66 ■ If $I_4 = -12\,\text{A}$ and $V_4 = -10\,\text{V}$, what is the power generated by element #4?

Problem# 1·67 ■ If $I_4 = 3\,\text{A}$ and $V_4 = -5\,\text{V}$, find V_1, I_1, V_2, I_2, V_3, and I_3, such that all four elements in Figs. 1.15-1.18 absorb the same power?

Problem# 1·68 ■ If the unknown (rectangular) circuit element is absorbing 21 W. What is the power absorbed by the 10 V voltage source?

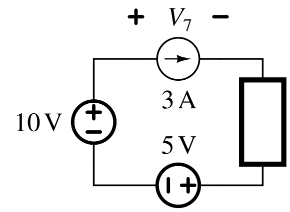

Figure 1.19: Passive Sign Convention #5

Answer: −30 W [1S13]

Problem# 1·69 ■ If the unknown (rectangular) circuit element is absorbing 21 W. What is the voltage V_7?

Answer: −2 V [1S13]

Series and Parallel

Problem# 1·70 ■ Find the powers associated with each circuit element.

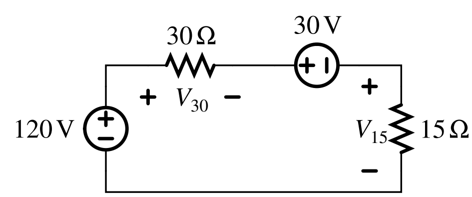

Figure 1.20: Series Circuit #1

Problem# 1·71 ■ Find the power associated with each circuit element.

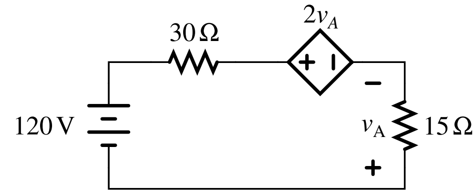

Figure 1.21: Series Circuit #2

Problem# 1·72 ■ Find the power associated with each circuit element.

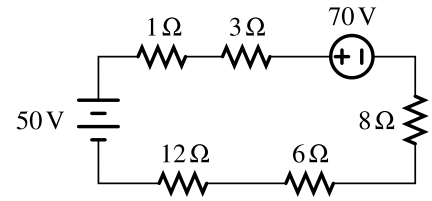

Figure 1.22: Series Circuit #3

Answer: $V_{12\,\Omega} = -8\,\mathrm{V}$ [1S11]

Problem# 1·73 ■ Find the powers associated with each circuit element.

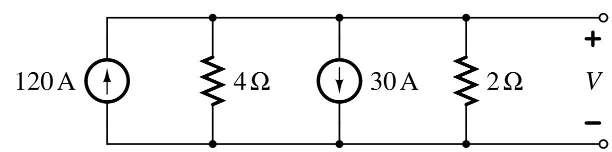

Figure 1.23: Parallel Circuit #1

Problem# 1·74 ■ Find the powers associated with each circuit element.

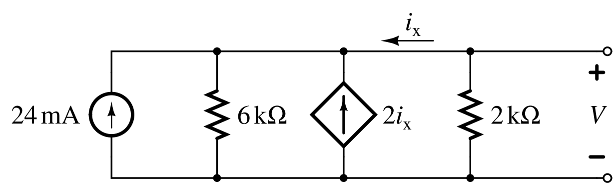

Figure 1.24: Parallel Circuit #2

Problem# 1·75 ■ Find the equivalent resistance R_1.

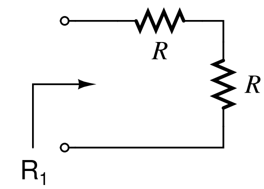

Figure 1.25: Series Resistance #1

Answer: $R + R$

Problem# 1·76 ■ Find the equivalent resistance R_2.

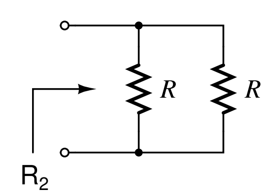

Figure 1.26: Parallel Resistance #1

Answer: $\frac{1}{\frac{1}{R}+\frac{1}{R}}$

Problem# 1·77 ■ Find the equivalent resistance R_3.

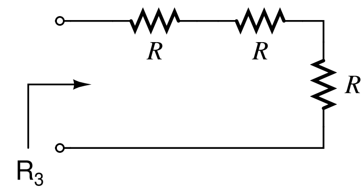

Figure 1.27: Series Resistance #2

Answer: $3R$

Problem# 1·78 ■ Find the equivalent resistance R_4.

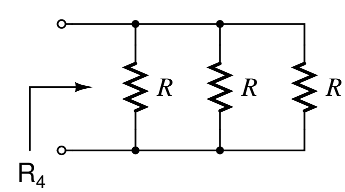

Figure 1.28: Parallel Resistance #2

Answer: $\frac{R}{3}$

Problem# 1.79 ■ Find the equivalent resistance R_{eq1}, where $R_1 = R_2 = ... = R_M$.

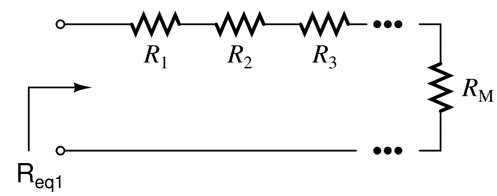

Figure 1.29: Series Resistance #2

Problem# 1.80 ■ Find the equivalent resistance R_{eq2}, where $R_1 = R_2 = ... = R_M$.

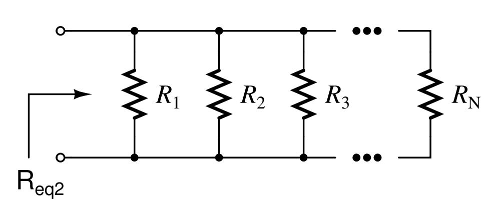

Figure 1.30: Parallel Resistance #2

Problem# 1·81 ■ Find the equivalent resistance R_{eq}.

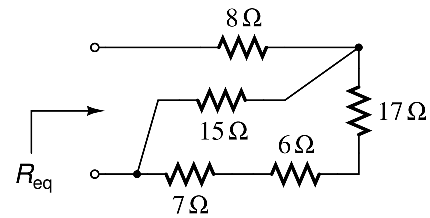

Figure 1.31: Equivalent Resistance #0

Problem# 1·82 ■ Find the equivalent resistance "seen" by the source.

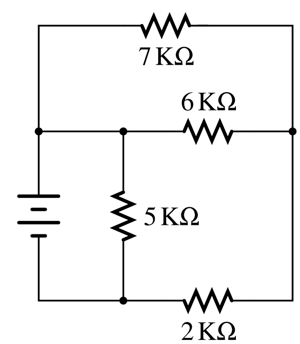

Figure 1.32: Equivalent Resistance

Problem# 1·83 ■ Find the equivalent resistance R_{eq}.

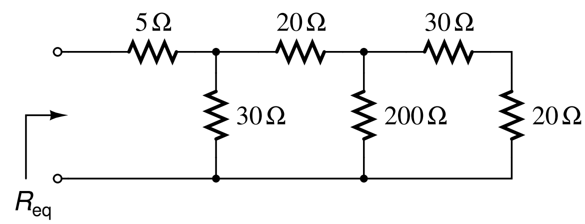

Figure 1.33: Equivalent resistance #1Not too bad either

Problem# 1·84 ■ Find the equivalent resistance R_{eq} when looking into the a-b terminals.

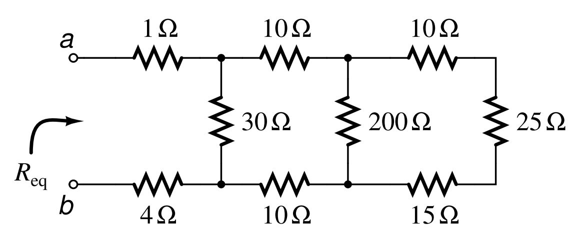

Figure 1.34: Equivalent resistor

Answer: 25 Ω [1S09]

Problem# 1·85 ■ Find the equivalent resistance R_{eq} when looking into the a-b terminals if the terminals c-d are shorted. What is R_{eq} if the terminals c-d are open?

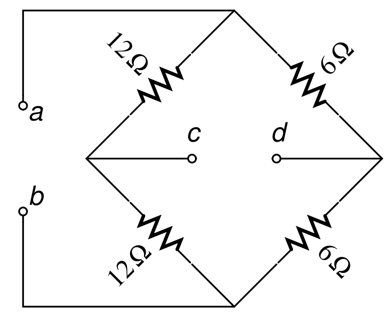

Figure 1.35: Equivalent resistance #3

Answer: 8 Ω [1S11]

Problem# 1·86 ■ Find the equivalent resistance R_{eq} when looking into the c-d terminals if the terminals a-b are shorted. What is R_{eq} if the terminals a-b are open?

Answer: 9 Ω [1S11]

Problem# 1·87 ■ Consider a cube, each edge of which is a resistor with resistance R. What is the resistance between two points on the same side of the cube but on opposite corners?

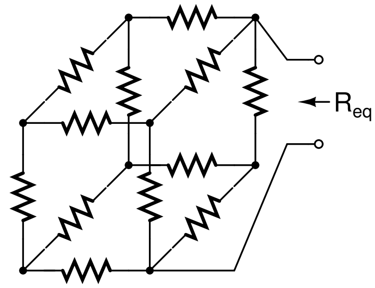

Figure 1.36: Equivalent resistance puzzler

Putting It All Together

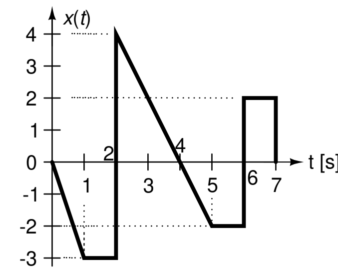

Figure 1.37: A curve $x(t)$ used in several problems

Problem# 1·88 ■ If the curve $x(t)$ is the charge function (in Coulombs) at a point in space, the current at that point at $t = 4\,\text{s}$ is

Answer: $-2\,\text{A}$ [1S13]

Problem# 1·89 ■ If the curve $x(t)$ above represents the current (in Amperes) flowing past a point in space, the total charge that passes the point is

Answer: $-\frac{3}{2}\,\text{A}$ [1S13]

Problem# 1·90 ■ If the curve $x(t)$ above represents the voltage (in Volts) across a 6 A current source where the current is directed into the "plus" polarity terminal, the power generated by the current source at time $t = 1.5\,\text{s}$ is

Answer: 15 W [1S13]

Problem# 1·91 ■ If the curve $x(t)$ above represents the voltage (in Volts) across a 6 A current source where the current is directed into the "plus" polarity terminal, the total energy dissipated by the current source during the time $0\,\text{s} \leq t \leq 7\,\text{s}$ is

Problem# 1·92 ■ A 120 V battery is connected to a 20Ω load. How many Coulombs of charge flow through the resistor each *minute*? How many Joules of electrical energy does the resistor convert into heat each *minute?*

Answer: 360 C; 43.2 kJ [1U09]

Problem# 1·93 ■ A 5Ω resistor is placed in series with a time-varying current source. The energy dissipated by the resistor over the 4 s interval shown is...

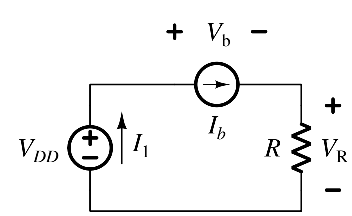

Figure 1.38: Energy in a resistor

Answer: 200 J [1U09]

Problem# 1·94 ■ If the current source is absorbing 12 W, find the resistance R.

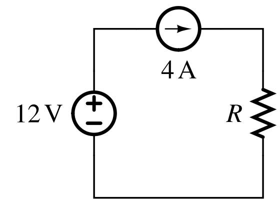

Figure 1.39: Use your brain

Answer: 2.25 Ω [1S11]

Problem# 1·95 ■ Find the power being absorbed by each element in the circuit below.

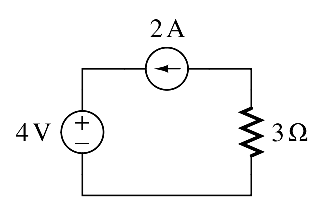

Figure 1.40: Use your brain

Answer: 8 W; -20 W; 12 W [1S11]

Problem# 1·96 ■ When $V_{DD} = 120$V, the voltage drop V_1 across the 7Ω resistor is...

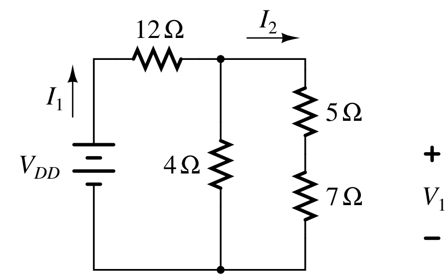

Figure 1.41: Try this one

Answer: 17.5 V [2S11]

Problem# 1·97 ■ In the circuit above, the voltage source V_{DD} is set to obtain $I_1 = 2$A. Find the value of V_{DD}.

Problem# 1·98 ■ In the circuit above, assume that $I_1 = 100$A, then the value of I_2 is...

Problem# 1·99 ■ The current I_B through the 40 V battery is

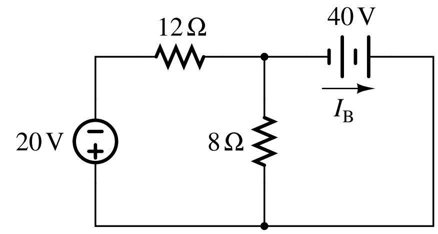

Figure 1.42: Another one

Answer: 6.7 A

Problem# 1·100 ■ Find I_x and V_x.

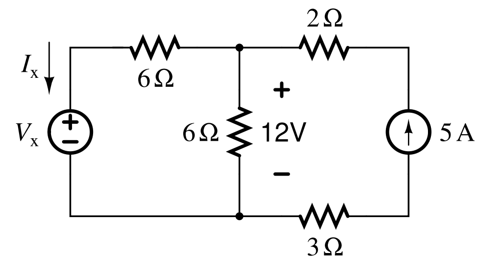

Figure 1.43: Not too bad circuit

Answer: 3 A; -6 V

Problem# 1·101 ■ Find I_x and V_x.

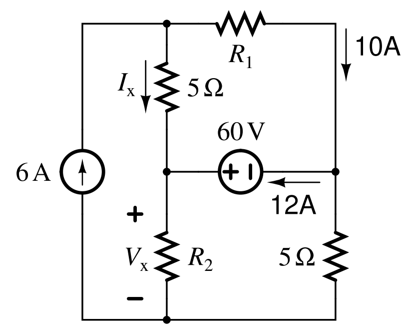

Figure 1.44: A little bit harder

Answer: -4 A; 50 V

Problem# 1·102 ■ Find I_1, V_2, and I_3

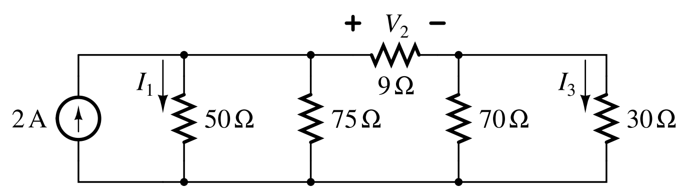

Figure 1.45: Not too bad either

Problem# 1·103 ■ When $V_{DD} = 150$V, the voltage drop across the 7Ω resistor

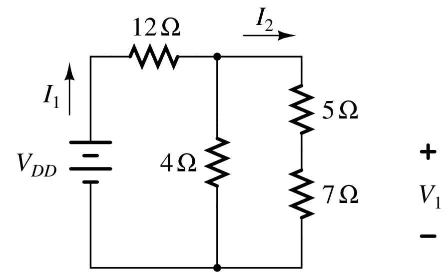

Figure 1.46: One more...

Problem# 1·104 ■ Find the power absorbed by the 10 V voltage source

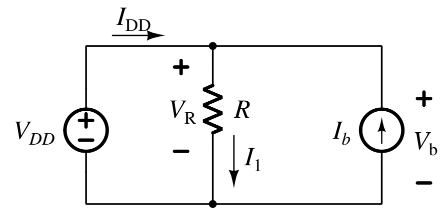

Figure 1.47: Power calculation

Answer: -30 V

Problem# 1·105 ■ Find the voltage (with the "+" polarity symbol on the left) across the 3 A current source in the circuit above

Answer: -1 V [1U12]

2

Circuit Analysis Techniques

Nodal Analysis

Problem#2·1 ■ How many nodes are there? How many nodal analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

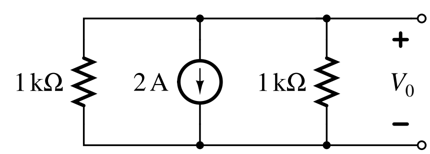

Figure 2.1: Nodal Analysis

Answer: 2; -1000 V

Problem#2·2 ■ Using nodal analysis, find the voltages V_1, V_2, and V_3. Find the power absorbed by the 8Ω resistor.

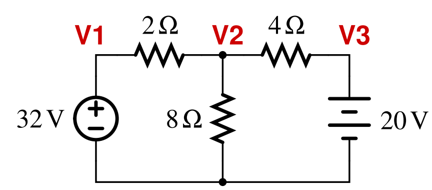

Figure 2.2: Nodal Analysis

Answer: 72 W [2S13]

Problem# 2·3 ■ How many nodes are there? How many nodal analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

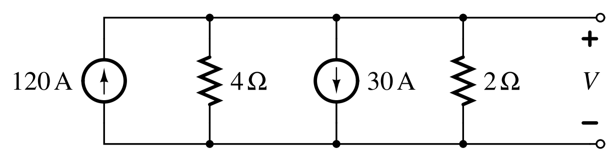

Figure 2.3: Nodal Analysis

Problem#2·4 ■ How many nodes are there? How many nodal analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

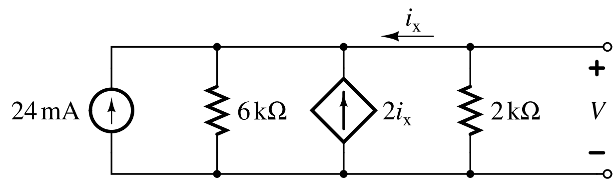

Figure 2.4: Nodal Analysis

Problem#2·5 ■ How many nodes are there? How many nodal analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

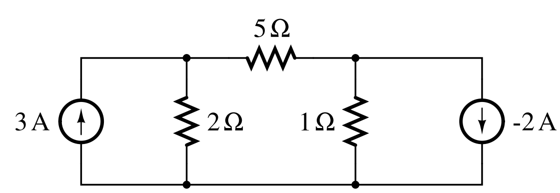

Figure 2.5: Nodal Analysis

Answer: 5 V; 2.5 V

Problem# 2·6 ■ How many nodes are there? How many nodal analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

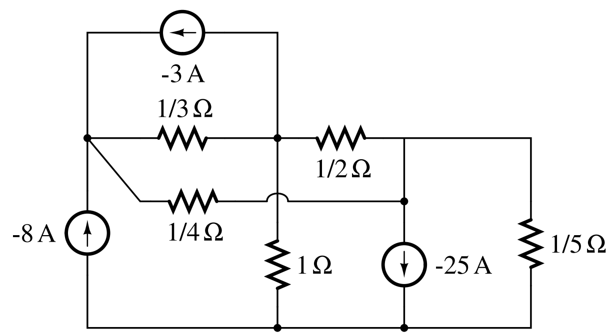

Figure 2.6: Nodal Analysis

Answer: 1 V; 2 V; 3 V

Problem# 2·7 ■ Determine the node voltages V_1, V_2, and V_3.

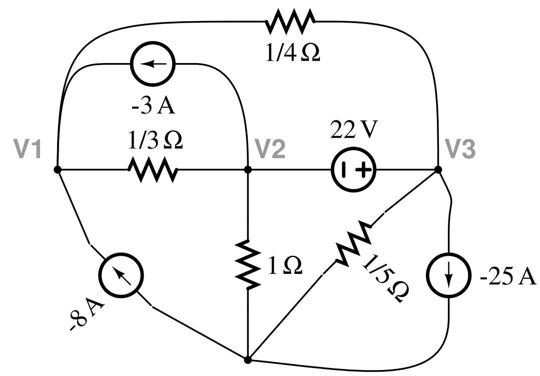

Figure 2.7: Nodal Analysis – super node

Answer: -4.5 V; -15.5 V; 6.5 V

Problem# 2·8 ■ Determine the node voltages V_1, V_2, V_3, and V_4. Determine the powers associated with each circuit element. (Note: If you can do/understand this problem, you know nodal analysis.)

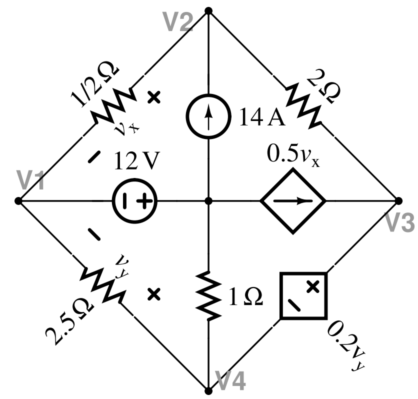

Figure 2.8: The whole enchilada!

Answer: -12 V; -4 V; 0; -2 V

Problem# 2·9 ■ Applying nodal analysis to the circuit below to determine the system of equations required to solve.

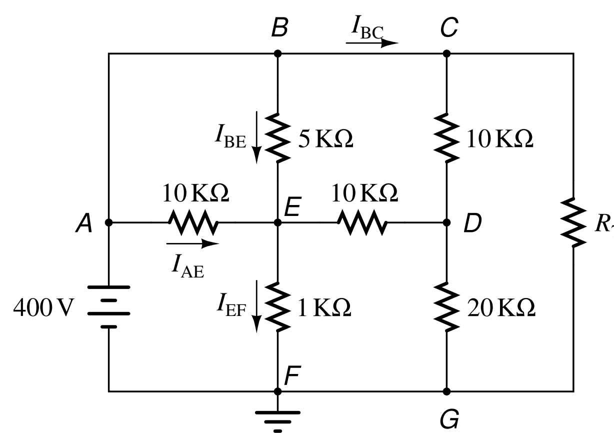

Figure 2.9: Nodal Analysis

Mesh Analysis

Problem#2·10 ■ How many mesh are there? How many mesh analysis equations do you expect? Find the voltages, currents, and power associated with each circuit element.

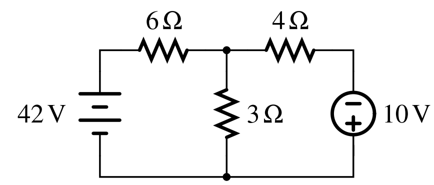

Figure 2.10: Mesh Analysis #1

Answer: 6 A; 4 A

Problem#2·11 ■ Find the mesh currents i_1 and i_2. Find the power absorbed by each circuit element.

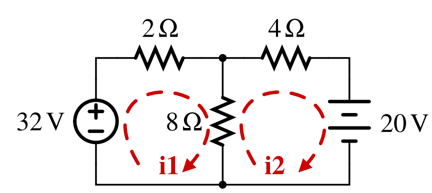

Figure 2.11: Superposition

Answer: 4 A; 1 A [2S13]

Problem# 2·12 ■ How many mesh are there? How many mesh analysis equations do you expect? Determine the mesh currents.

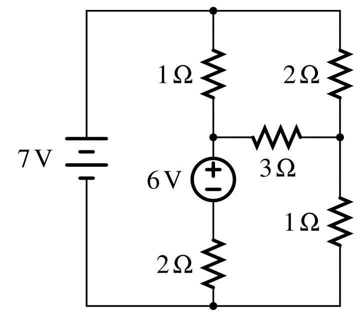

Figure 2.12: Mesh Analysis #2

Answer: 3 A; 2 A; 3 A

Problem#2·13 ■ How many mesh are there? How many mesh analysis equations do you expect? Determine the mesh currents.

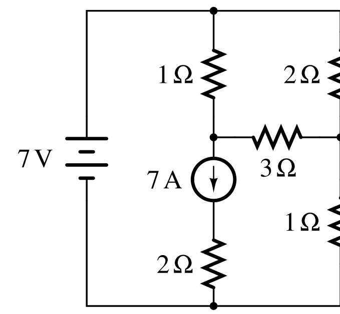

Figure 2.13: Mesh Analysis #3 – super mesh

Answer: 9 A; 2.5 A; 2 A

Problem # 2·14 ■ How many mesh are there? How many mesh analysis equations do you expect? Determine the mesh currents.

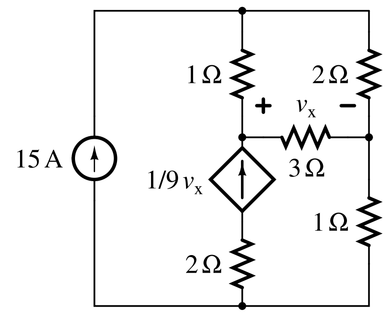

Figure 2.14: Mesh Analysis #4 – super mesh

Answer: 15 A; 11 A; 17 A

Problem#2·15 ■ Solve for the currents, voltages, and powers for each circuit element using mesh analysis. (Note: The values should match the numbers obtained with nodal analysis back in Fig. 2.8.)

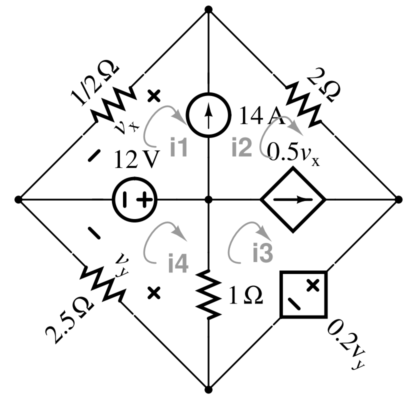

Figure 2.15: The whole enchilada – Take 2

Problem# 2·16 ■ Applying mesh analysis to the circuit below to determine the system of equations required to solve.

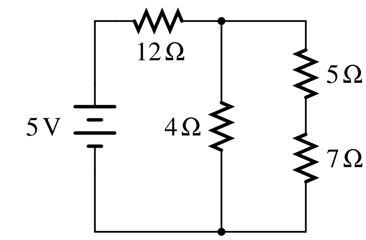

Figure 2.16: Mesh Analysis

Problem# 2·17 ■ The current I_B through the 40 V battery is most nearly

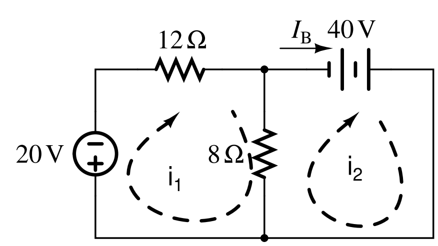

Figure 2.17: Mesh Analysis

Answer: 6.7 A [2U09]

Problem# 2·18 ■ Use mesh analysis to determine the required system of equations

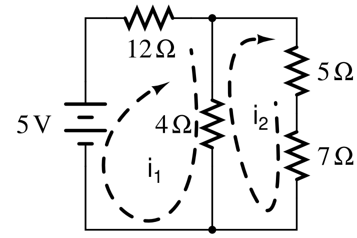

Figure 2.18: Mesh Analysis

Problem# 2·19 ■ In the mesh circuit in Fig. 2.18, the power absorbed by the 4Ω resistor is most nearly

Answer: $\frac{1}{4}$ W [2S11]

Superposition

Problem# 2·20 ■ Using superposition, find i_9, v_9, and the power absorbed by the $9\,\Omega$ resistor.

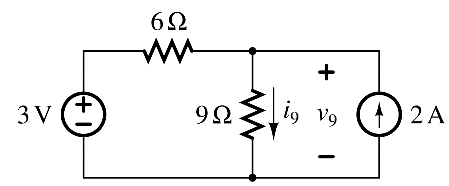

Figure 2.19: Superposition

Answer: 1 A; 9 V; 9 W

Problem# 2·21 ■ Using superposition, the 200 V battery's contribution to I_{20} is most nearly

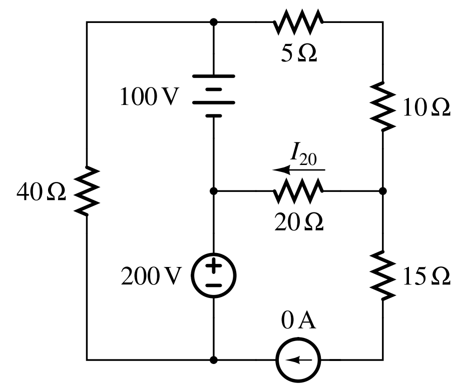

Figure 2.20: Superposition

Answer: 0 [2U09]

Problem# 2·22 ■ In the circuit in FIg. 2.20, the current I_{20} is most nearly

Answer: 2.9 A [2U09]

Problem# 2·23 ■ What is the current i_1 due to the 7 A current source acting alone?

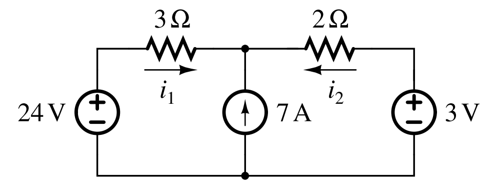

Figure 2.21: Superposition

Answer: -2.8 A [2S13]

Problem# 2·24 ■ What is the voltage V_2 due to the 3 A current source acting alone?

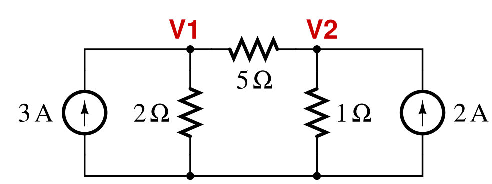

Figure 2.22: Superposition

Answer: 3/4 V [2S13]

Thevenin's and Norton's Theorem

Problem# 2·25 ■ Find the Thevenin and Norton equivalent circuits for the circuit contained in the box.

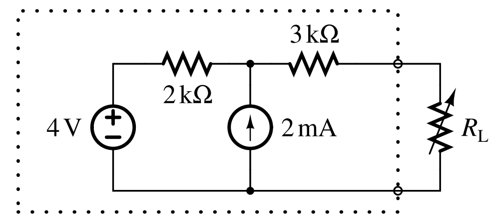

Figure 2.23: Thevenin and Norton #1

Answer: 8 V ⟷ 5 kΩ; 1.6 mA‖5 kΩ

Problem# 2·26 ■ Find the Thevenin and Norton equivalent circuits for the circuit contained in the box.

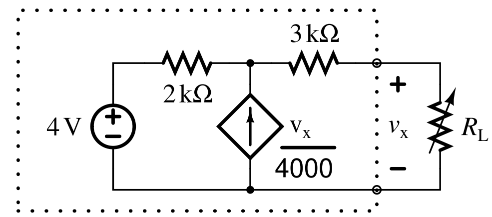

Figure 2.24: Thevenin and Norton #2

Answer: 8 V ⟷ 10 kΩ

Problem# 2·27 ■ The Norton equivalent circuit (as seen at terminals *a*-*b*) for the circuit below is

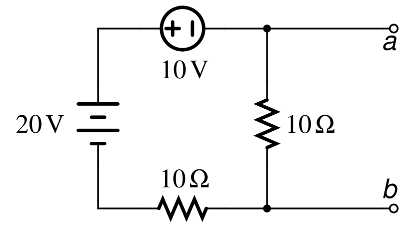

Figure 2.25: Thevenin and Norton

Answer: 1 A‖5 Ω [2U09]

Problem# 2·28 ■ What is the Thevenin equivalent circuit between terminals *a*-*b* looking to the left?

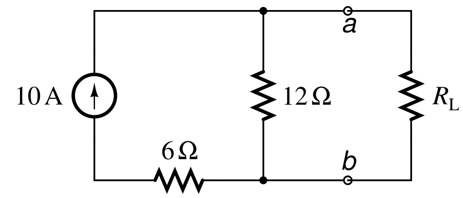

Figure 2.26: Thevenin and Norton

Answer: 120 V ↔ 12 Ω [2U09]

Problem# 2·29 ■ The Thevenin equivalent circuit for the network in the box is most nearly

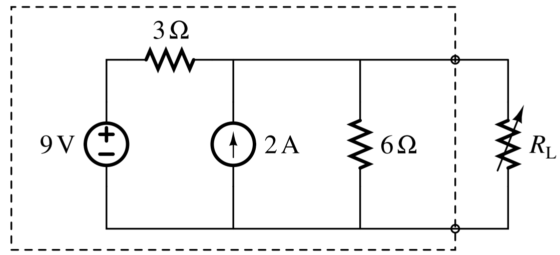

Figure 2.27: Thevenin and Norton circuits

Answer: 10 V ↔ 2 Ω [2U11]

Problem# 2·30 ■ If $R_L = 12\,\Omega$ in Fig. 2.27, the voltage across the $3\,\Omega$ resistor due to the 2 A source acting alone is most nearly

Answer: 3.43 V [2U11]

Problem# 2·31 ■ Find the Norton equivalent circuit for the network in the box in Fig. 2.27.

Answer: 5 A ‖ 2 Ω [3S13]

Problem# 2·32 ■ Find the Norton equivalent circuit as seen by the $a - b$ terminals

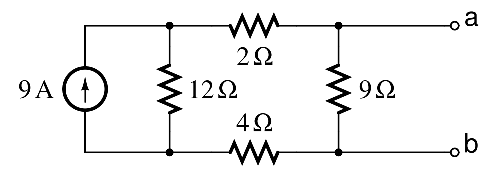

Figure 2.28: Norton equivalent circuit

Answer: 6 A‖6 Ω [???]

Maximum Power Transfer

Problem# 2·33 ■ Find the load resistance R_L that will absorb maximum possible power. What is the maximum power absorbed by the load?

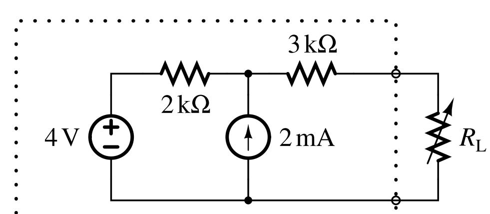

Figure 2.29: Maximum power transfer #1

Problem# 2·34 ■ Find the load resistance R_L that will absorb maximum possible power. What is the maximum power absorbed by the load?

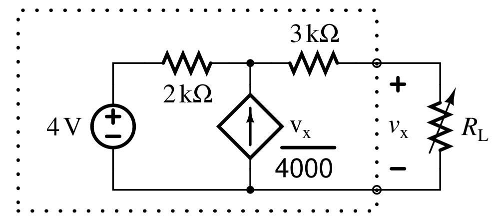

Figure 2.30: Maximum power transfer #2

Answer: 10 kΩ; 1.6 mW [2U11]

Problem# 2·35 ■ What is the maximum possible power that R_L can absorb?

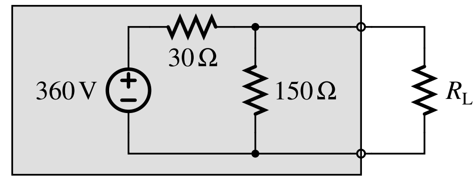

Figure 2.31: Maximum power transfer

Answer: 900 W [???]

Problem# 2·36 ■ Size the resistor R_L to absorb maximum power through terminals *a*-*b*.

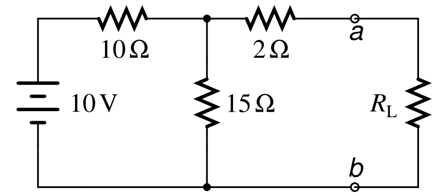

Figure 2.32: Maximum power transfer

Answer: 8 Ω [???]

Problem# 2·37 ■ What is the maximum possible power absorbed by any R_L in Fig. 2.27?

Answer: 12.5 W [3S13]

Problem# 2·38 ■ The maximum possible power absorbed by R_L is most nearly

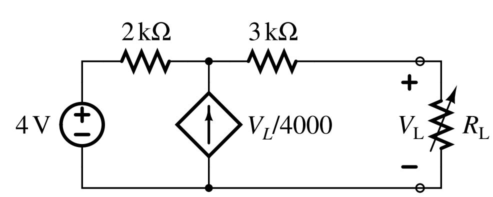

Figure 2.33: Maximum power transfer

Problem# 2·39 ■ Find the general formula for the current I_2 (in Amperes) as a function of R_2. (Hint: A Thevenin equivalent circuit makes this problem much easier.)

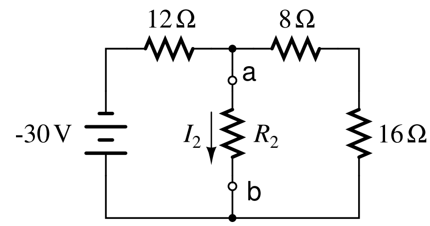

Figure 2.34: Thevenin equivalent circuit

Answer: $\frac{20}{8+R_2}$ [???]

Problem# 2·40 ■ Find the Norton equivalent circuit as seen by the $a-b$ terminals

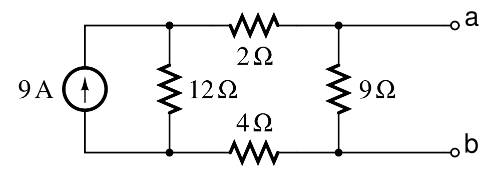

Figure 2.35: Norton equivalent circuit

Answer: $6\,\mathrm{A} \| 6\,\Omega$ [???]

Problem# 2·41 ■ Find the Norton equivalent circuit for the network in the box.

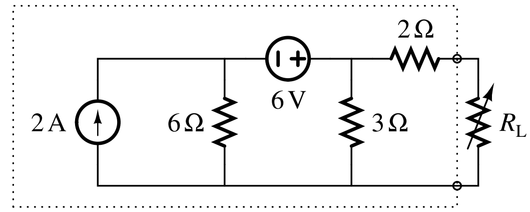

Figure 2.36: Norton equivalent circuit

Answer: 1.5 A and 4 Ω

Problem# 2·42 ■ The maximum possible power absorbed by the load R_L in the circuit above is

Answer: 2.25 W [2U12]

PROBLEM# 2·43 ■ What is the maximum amount of energy R_L can absorb in one minute?

Answer: 6 J [4S13]

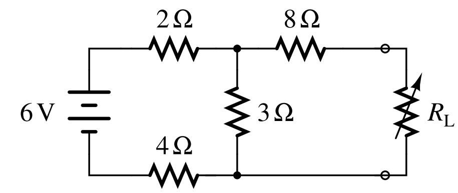

Figure 2.37: Norton equivalent circuit

3
Operational Amplifiers

Basic Op-amp Circuits

Problem# 3·1 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance (the resistance seen by the v_i voltage source)?

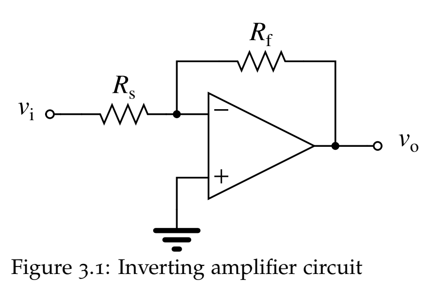

Figure 3.1: Inverting amplifier circuit

Problem# 3.2 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance?

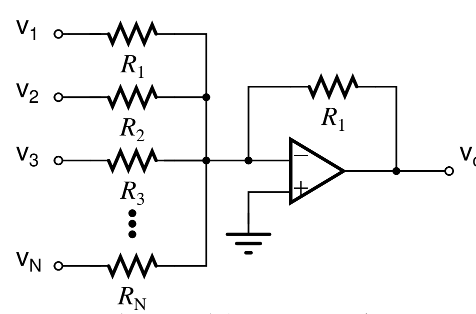

Figure 3.2: (Inverting) Summing amplifier circuit

Problem# 3·3 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance?

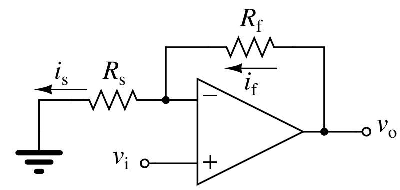

Figure 3.3: Non-inverting amplifier circuit

Problem# 3.4 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance?

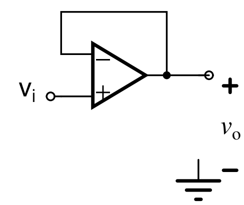

Figure 3.4: Voltage follower circuit

Problem# 3.5 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance? (My circuit is a more generalized version of the difference amplifier circuit that Rizzoni presents. Rizzoni's version has $R_1 = R_3$ and $R_2 = R_4$.)

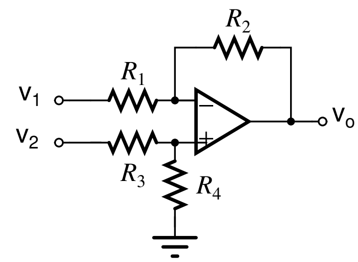

Figure 3.5: Difference Amplifier

Problem# 3·6 ■ Determine the gain $G = \frac{v_o}{v_i}$ of the circuit below? What can you say about your ability to control/change/determine the possible gains of the circuit? What can you say about the circuit's input resistance?

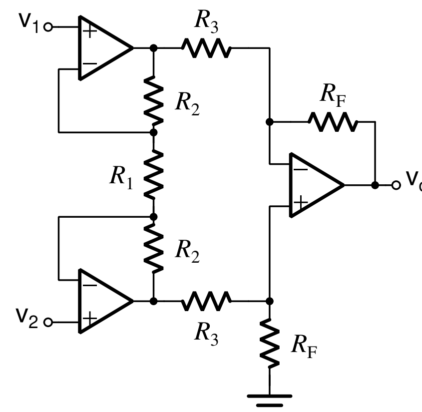

Figure 3.6: Instrumentation Amplifier

Op-Amp Circuit Analysis

Problem# 3.7 ■ Find V_o.

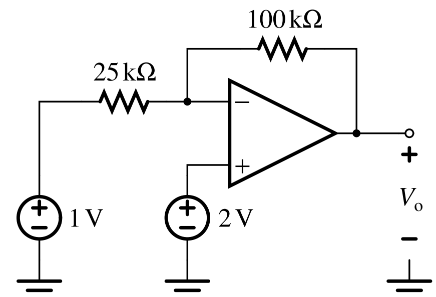

Figure 3.7: Op-Amp circuit

Answer: 6 V [???]

Problem# 3·8 ■ Determine the equation for the output voltage v_o in the circuit below where $R_F = 10\,\mathrm{K\Omega}$ and $R_S = 2\,\mathrm{K\Omega}$. Assume that the op-amp is ideal.

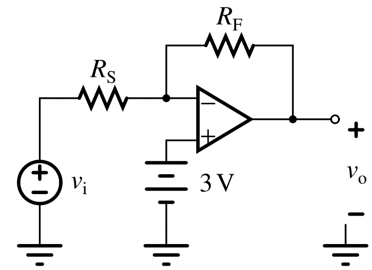

Figure 3.8: Op-Amp circuit

Answer: $18 - 5v_i$

Problem# 3.9 ■ Consider the circuit below with an ideal operational amplifier and $V_{bias} = 0$. The value of R_f that will give an output of -8 V is most nearly

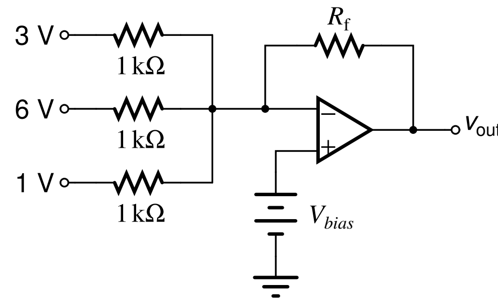

Figure 3.9: Op-Amp circuit

Answer: 800 Ω

Problem# 3·10 ■ The current I_5 in the circuit below is most nearly

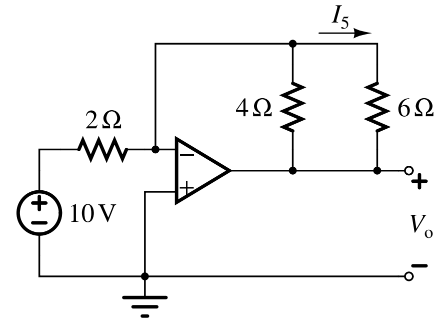

Figure 3.10: Op-Amp circuit

Answer: 2 A

Problem# 3·11 ■ You are given only four resistors – each with a different resistance value. The resistances are 1, 5, 10, and 50 Ohms. Using only those four resistors, the largest *magnitude* of gain $\frac{v_o}{v_i}$ you could construct in the circuit below is most nearly

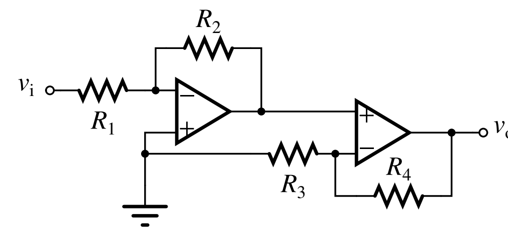

Figure 3.11: Op-Amp circuit

Answer: $\frac{v_o}{v_i} = -150$

Problem# 3·12 ■ The value of resistor R_f to obtain a voltage gain of 5 is most nearly

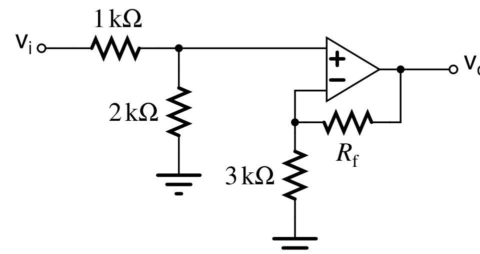

Figure 3.12: Op-Amp circuit

Answer: 19.5 kΩ

Problem# 3·13 ■ If $V_1 = V_4 = 10\,\text{V}$ and $V_2 = V_3 = 0$, the voltage v_o is most nearly

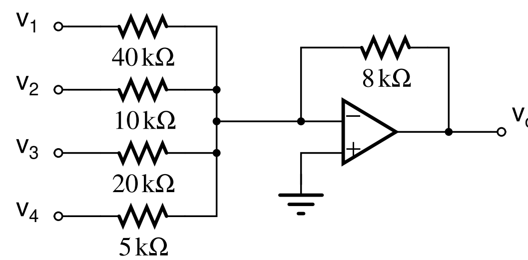

Figure 3.13: Op-Amp circuit

Answer: -18 V

Problem# 3·14 ■ Find the voltage v_o.

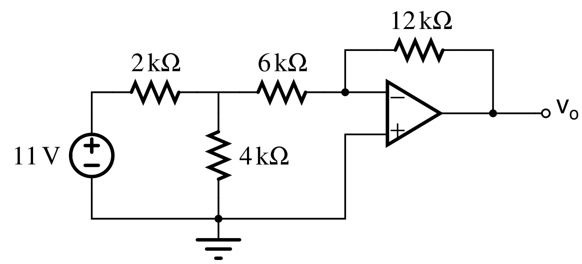

Figure 3.14: Op-Amp circuit

Answer: -12 V

Problem# 3·15 ■ Assuming the opamp below is ideal and can generate an output voltage of any value, find the voltage v_o.

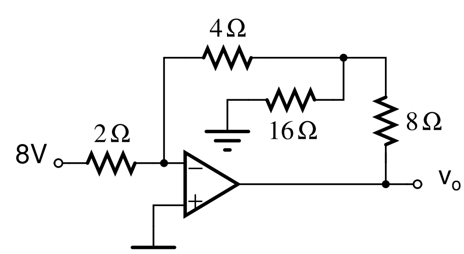

Figure 3.15: Op-Amp circuit

Answer: -56 V [3S13]

Problem# 3·16 ■ Determine the gain $G = v_o/v_i$ in the op-amp circuit below. You may assume that the op-amps are ideal.

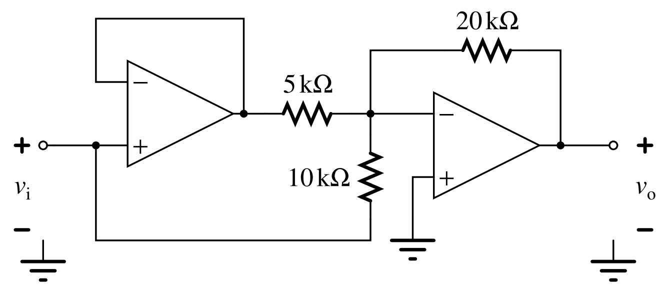

Figure 3.16: Op-Amp circuit

Answer: $\frac{v_o}{v_i} = -6$

Problem# 3·17 ■ Determine the voltage gain $G = \frac{v_o}{v_i}$. What is the input resistance seen by the "input" voltage v_i?

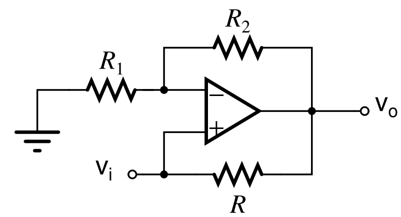

Figure 3.17: Bizarre Op-Amp circuit

Problem# 3·18 ■ Determine the output voltage v_o.

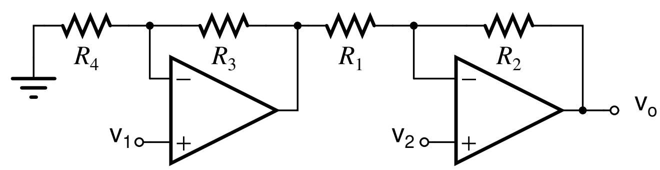

Figure 3.18: Another good Op-Amp circuit

Problem# 3·19 ■ Determine the current i_L.

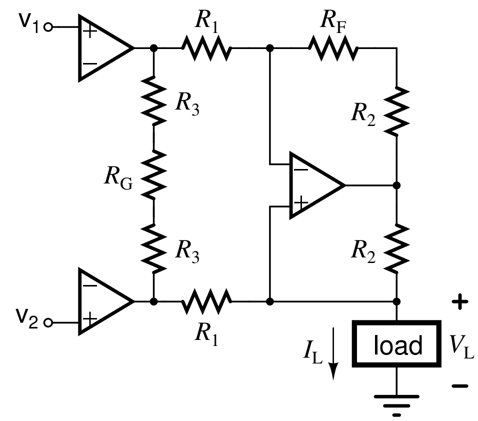

Figure 3.19: Another fun Op-Amp circuit

Problem# 3.20 ■ Find the voltage V_b in the circuit below.

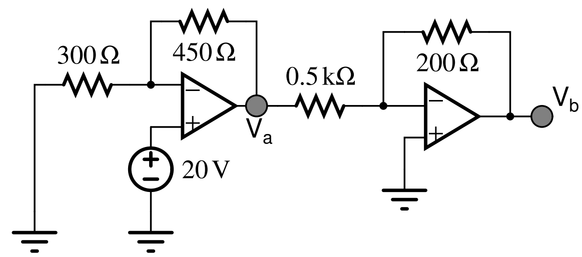

Figure 3.20: Another good Op-Amp circuit

Answer: -20 V [2U12]

Problem# 3.21 ■ If $V_1 = 15\,\mathrm{V}$ and $V_2 = 10\,\mathrm{V}$, find the power absorbed by the $1\,\mathrm{k\Omega}$ resistor.

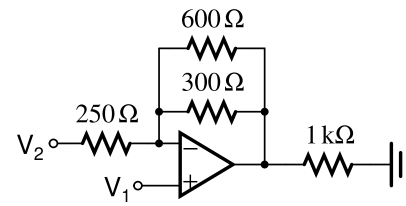

Figure 3.21: Another fun Op-Amp circuit

Answer: 360 mW [2U12]

Op-Amps (Take Two)

To be written at a later date.

4
AC Circuits

AC Circuits Fundamentals

Problem#4·1 ■ If $L = 2\,\text{H}$ and $i_L(t) = 5t^3\,\text{A}$, find the time-function for the voltage across the inductor. What is the inductor voltage at $t = 0.5\,\text{s}$?

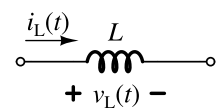

Figure 4.1: Inductor

Answer: 7.5 A

Problem#4·2 ■ If $L = 2\,\text{H}$ and $v_L(t) = 6\cos(5t)\,\text{V}$, find the time-function for the current through the inductor. What is the inductor current if you also know that $t = \frac{-\pi}{2}$ s the current is 1 A?

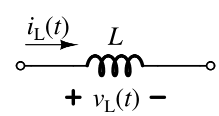

Figure 4.2: Inductor

Answer: $0.6\sin(5t)$ A

Problem#4·3 ■ If $i_L(t) = I_0 \cos(\omega t + \phi)$ A, find the time-function for the "instantaneous" power absorbed by the inductor? What is the time-average power absorbed by the inductor?

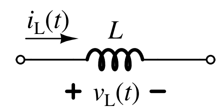

Figure 4.3: Power absorbed by an inductor

Problem#4·4 ■ What is the energy stored in the inductor below?

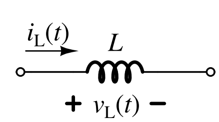

Figure 4.4: Energy stored in an inductor

Problem#4.5 ■ Find the expressions for the current, the resistor voltage, the inductor voltage, the power absorbed by the resistor, and the energy stored in the inductor.

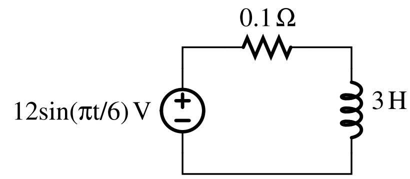

Figure 4.5: The first *LR* circuit

Problem#4·6 ■ If $C = 3\,\mathrm{F}$ and $v_C(t) = 3t^2\,\mathrm{A}$, find the time-function for the current through the capacitor. What is the capacitor current at $t = 0.5\,\mathrm{s}$?

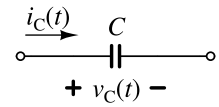

Figure 4.6: Capacitor

Answer: 9 A

Problem#4·7 ■ If $C = 3\,\mathrm{F}$ and $i_C(t) = 6\cos(5t)\,\mathrm{V}$, find the time-function for the voltage across the inductor. What is the capacitor voltage if you also know that $t = \frac{-\pi}{2}\,\mathrm{s}$ the voltage is 1 V?

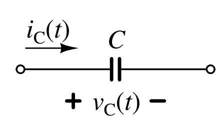

Figure 4.7: Capacitor

Problem#4·8 ■ If $v_C(t) = V_0 \cos(\omega t + \theta)$ V, find the time-function for the "instantaneous" power absorbed by the capacitor? What is the time-average power absorbed by the capacitor?

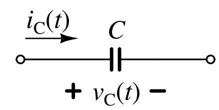

Figure 4.8: Power absorbed by a capacitor

Problem#4·9 ■ What is the energy stored in the capacitor below??

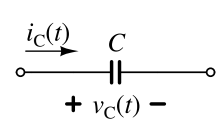

Figure 4.9: Energy stored in a capacitor

Problem#4·10 ■ Find the expressions for the voltage, the resistor current, the capacitor current, the power absorbed by the resistor, and the energy stored in the capacitor.

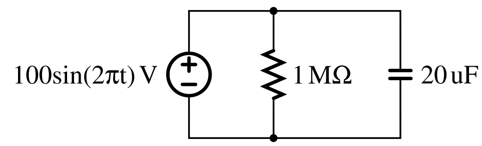

Figure 4.10: The first *RC* circuit

Answer: 2.5 mJ

Problem#4·11 ■ Find the equivalent inductance seen by the voltage source.

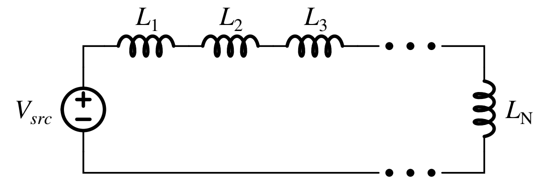

Figure 4.11: Series inductance

Problem#4·12 ■ Find the equivalent inductance seen by the current source.

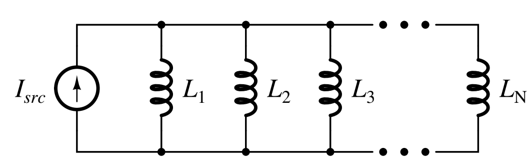

Figure 4.12: Parallel inductance

Problem#4·13 ■ Find the equivalent capacitance seen by the voltage source.

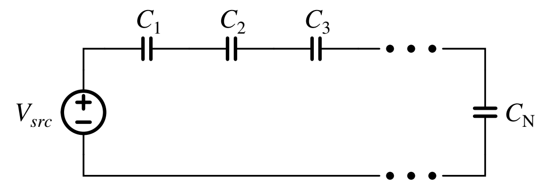

Figure 4.13: Series capacitance

Problem#4·14 ■ Find the equivalent capacitance seen by the current source.

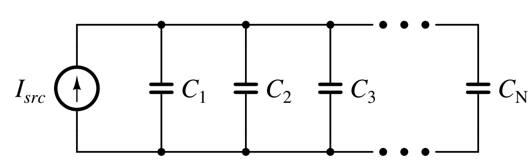

Figure 4.14: Parallel capacitance

Problem# 4·15 ■ What is the equivalent inductance L_{eq} (looking into terminals $a - b$) in the circuit below? Now, assume that your answer in the previous part is 10 H, what would be the equivalent impedance $\mathbf{Z}_{eq}$ of circuit at $f = 60\,\text{Hz}$?

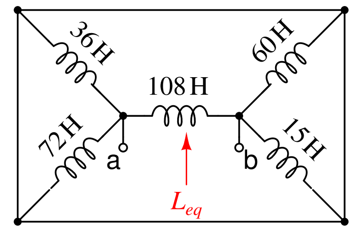

Figure 4.15: Equivalent inductance

Answer: $\jmath 3.77\,\text{k}\Omega$

Problem#4·16 ■ What is the equivalent capacitance C_{eq} (looking into terminals $a - b$) in the circuit below? Now, assume that your answer in previous part is 1768 nF, what would be the equivalent impedance $\mathbf{Z}_{eq}$ of circuit at $f = 60\,\text{Hz}$?

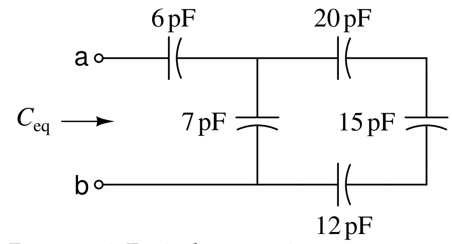

Figure 4.16: Equivalent capacitance

Answer: $-j1.5\,\text{k}\Omega$

Problem#4·17 ■ The capacitance seen by the source is most nearly

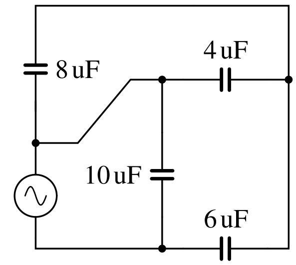

Figure 4.17: Equivalent capacitance

Answer: 14¯F

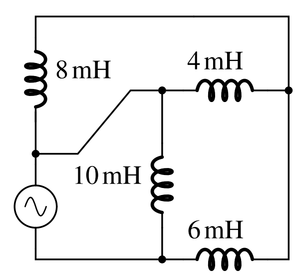

Figure 4.18: Equivalent inductance

Problem#4·18 ■ What is the inductance seen by the source?

Answer: 4.6 mH [4S13]

Problem#4·19 ■ Three capacitors in parallel have an equivalent capacitance of 37 F. The smallest and largest capacitor in series have an equivalent capacitance of 6 F. The largest capacitor is 150% of the smallest capacitor. What is the value (in Farads) of the middle-sized capacitor?

Answer: 12 F

Problem#4·20 ■ Three capacitors C_1, C_2, and C_3 are connected in *parallel* to create a total capacitance of 72 ¯F. Furthermore, you know that connecting capacitor C_1 in *series* with C_2 gives a total capacitance of $\frac{1}{2}C_1$. If you connect C_2 in *series* with C_3, the total capacitance is $\frac{1}{5}C_2$. What is the value of the *smallest* capacitor?

Answer: 8 ¯F [4S13]

Phasors

Problem#4·21 ■ If the circuit element *foo* is a *resistor*, determine the resistor's impedance $\mathbf{Z}_R = \frac{\mathbf{V}}{\mathbf{I}}$.

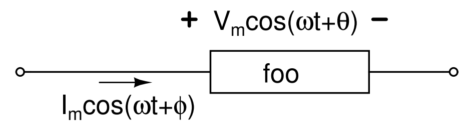

Figure 4.19: Impedance of an arbitrary circuit element

Problem#4·22 ■ If the circuit element *foo* is a *capacitor*, determine the capacitor's impedance $\mathbf{Z}_C = \frac{\mathbf{V}}{\mathbf{I}}$.

Problem#4·23 ■ If the circuit element *foo* is an *inductor*, determine the inductors impedance $\mathbf{Z}_L = \frac{\mathbf{V}}{\mathbf{I}}$.

Problem# 4·24 ■ Assuming that $R = 2\Omega$, $L = \frac{1}{2}$H, and $C = \frac{1}{8}$F, at what *natural* frequency does the equivalent impedance $\mathbf{Z}_{\text{eq}}$ in the circuit become "very reactive"?

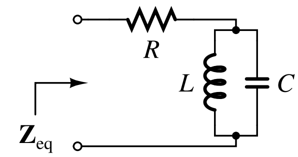

Figure 4.20: *RLC* circuit

Answer: $\frac{2}{\pi}$ Hz

Problem#4·25 ■ What is the equivalent impedance $\mathbf{Z}_{eq}$ (for the terminals $a - b$) in the circuit below, where $\mathbf{Z}_1 = 5 + \jmath 5\Omega$, $\mathbf{Z}_2 = \jmath 4\Omega$, and $\mathbf{Z}_3 = 1 - \jmath 2\Omega$?

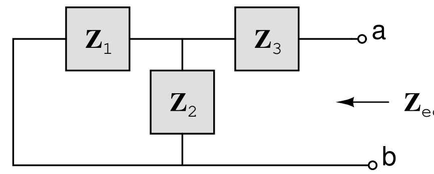

Figure 4.21: Impedance combinations

Answer: $\frac{1}{53}(93 + \jmath 34)\,\Omega$

Problem#4·26 ■ Determine the time-domain voltage $v(t)$ and both phasor representations of that voltage.

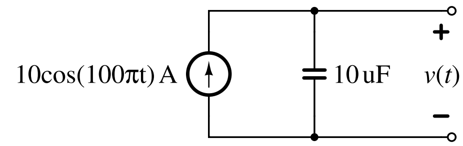

Figure 4.22: C phasor circuit

Answer: $3183\cos(100\pi t - 90^o)$ V

Problem#4·27 ■ Determine the time-domain voltage $v(t)$ and both phasor representations of that voltage.

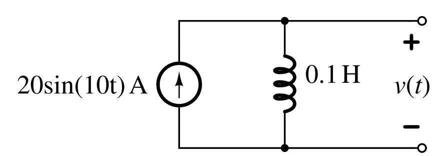

Figure 4.23: L phasor circuit

Answer: $20\angle 0$ V

Problem# 4·28 ■ The equivalent capacitance C_{eq} is most nearly

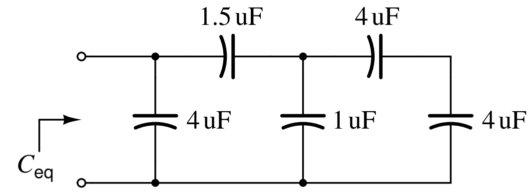

Figure 4.24: *L* phasor circuit

Answer: 5 ¯F

Problem#4·29 ■ A 1000 μF capacitor is given to you with 2 V across it. Then, you apply a 10 mA current to the cap starting at time $t = 0$. The voltage across the capacitor at time $t = 2$ s is most nearly

Answer: 22 mF

Problem#4·30 ■ A 1 H inductor is connected to a voltage source that is

$$\begin{cases} 0 & t < 0 \\ 2t^3\,\text{V} & t \geq 0 \end{cases}$$

Assuming the inductor has no current flowing through it for $t < 0$, the amount of charge that passes through the inductor between $t = 1$ s and $t = 2$ s is most nearly

Answer: 3.1 C

Putting it all together

Problem#4·31 ■ The graph $x(t)$ represents the current (in Amperes) through a 5 F capacitor. What is the energy stored in the capacitor at $t = 6\,\text{s}$?

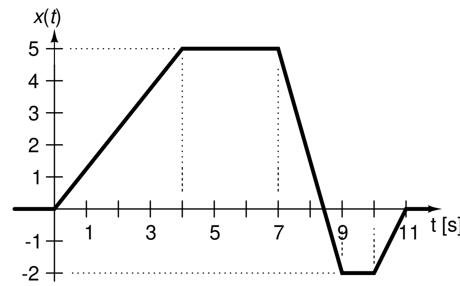

Figure 4.25: A time waveform

Answer: 40 J [4S13]

Problem#4·32 ■ Determine the time-domain voltage $v(t)$ and both phasor representations of that voltage.

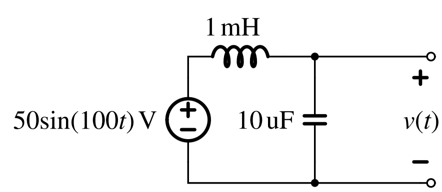

Figure 4.26: *LC* phasor circuit

Answer: $50\angle-90^{o}$ V

Problem#4·33 ■ Determine the time-domain voltage $v(t)$ and both phasor representations of that voltage.

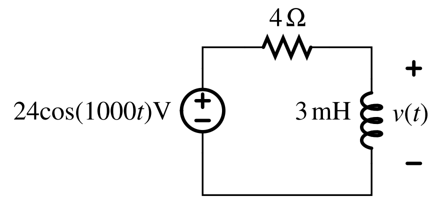

Figure 4.27: AC circuit

Answer: $14.4\angle 53.13^o$ V

Problem#4·34 ■ Find the equivalent impedance $\mathbf{Z}_L$ seen by the source if the operating frequency is 377 rad/s. If we want the source to see a purely resistive load, what value of capacitance should be placed between terminals a-b? What is the impedance seen by the source after the capacitor is added to the circuit?

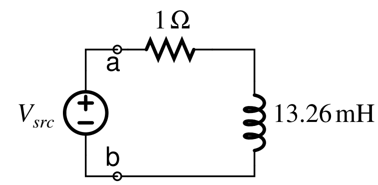

Figure 4.28: AC circuit

Answer: 26 Ω; 553μF

Problem#4·35 ■ Solve for $i(t)$ using phasor techniques.

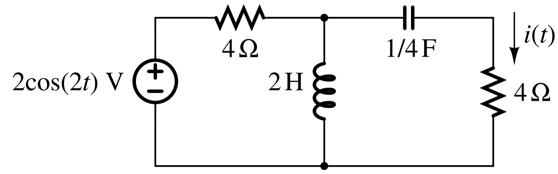

Figure 4.29: AC circuit

Answer: $\frac{\sqrt{2}}{6}\angle 45^o$ A

Problem#4·36 ■ Find the Thevenin equivalent circuit for the circuit that drives the "load".

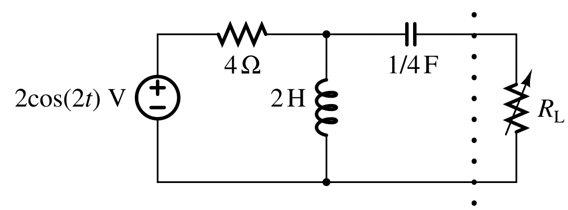

Figure 4.30: AC circuit

Answer: $\sqrt{2}\angle 45^o$ V $\leftrightarrow$ 2 Ω

Problem#4·37 ■ Determine the Thevenin equivalent circuit (as seen by the terminals $a - b$) in the circuit below when $\mathbf{Z}_1 = 1 + \jmath\Omega$, $\mathbf{Z}_2 = -\jmath 2\Omega$, and $\mathbf{I}_s = 2\angle 0^\circ$ A.

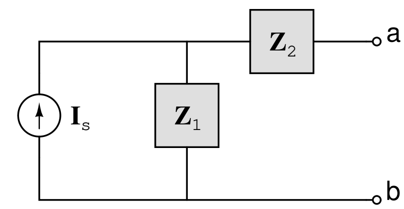

Figure 4.31: Thevenin circuit

Answer: $2\sqrt{2}\angle 45^o$ V $\leftrightarrow 1 - \jmath\Omega$

Problem#4·38 ■ Find the time-domain representation of the currents in both voltage sources.

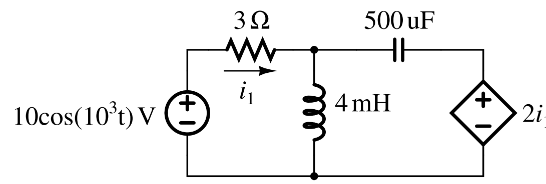

Figure 4.32: AC circuit

Answer: $1.24\angle 29.7^o$ A; $2.77\angle 56.3^o$ A

Problem# 4·39 ■ The current through the LC leg of the circuit is most nearly

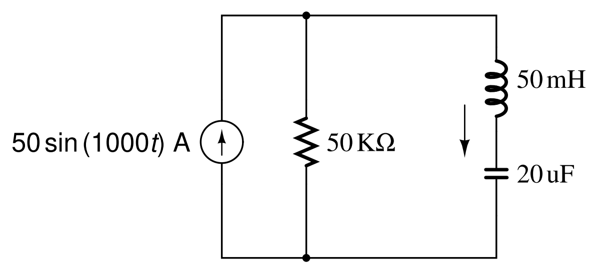

Figure 4.33: AC circuit

Problem#4·40 ■ The current through the 1 Ω *resistor* in the circuit in Fig. 4.34 is most nearly

Answer: $20.1\angle 8.2^o$ A

Problem#4·41 ■ In the circuit in Fig. 4.34, the Thevenin voltage seen by the 8 Ω capacitor load is most nearly

Answer: $69.9\angle 29.6^o$ V

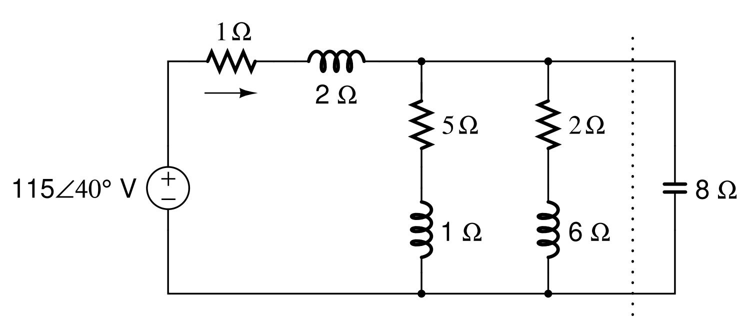

Figure 4.34: AC circuit

Problem# 4.42 ■ For the circuit shown below, the resonant frequency (the frequency at which the circuit becomes purely resistive) is most nearly

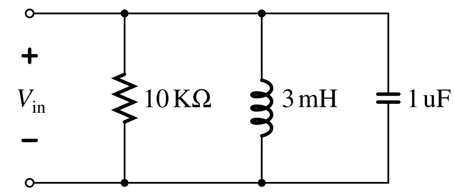

Figure 4.35: *RLC* circuit

Answer: 18257 rad/s

Problem#4·43 ■ For the circuit below, what value of C causes the circuit to resonate?

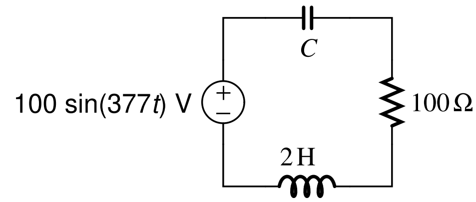

Figure 4.36: *RLC* circuit

Answer: $C = 3.52 \times 10^{-6}$ F

Problem#4·44 ■ The current through a 16 μH inductor at $t = 0$ is zero, and the voltage across the inductor is

$$v_L(t) = \begin{cases} 0 & t < 0 \\ 3t^2\,\mathrm{V} & 0 < t < 20\,\bar{\ }\mathrm{s} \\ 1.2\,\mathrm{nV} & t > 20\,\bar{\ }\mathrm{s} \end{cases}$$

The current in the inductor at $t = 30\mu\mathrm{s}$ is most nearly

Answer: 1.25 nA

Problem#4.45 ■ If the circuit in Fig. 4.37 is in a steady-state condition, the energy stored in the 2 F capacitor is most nearly

Answer: 0

Problem#4.46 ■ If the circuit in Fig. 4.37 is in a steady-state condition, the energy stored in the 2 H inductor is most nearly

Answer: 4 J

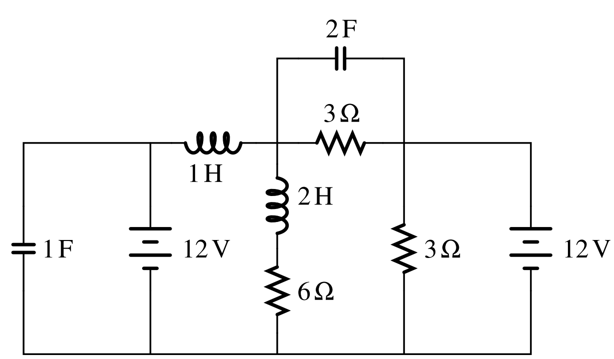

Figure 4.37: *RLC* circuit

Problem#4.47 ■ The magnitude of the voltage V in the circuit below is most nearly

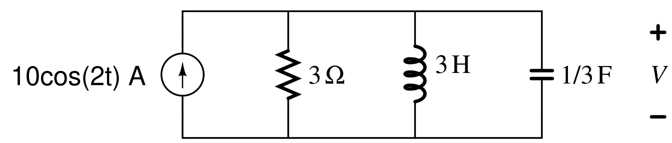

Figure 4.38: *RLC* circuit

Answer: $16.641\angle -56.31^o$ V

Problem#4·48 ■ The "loads" in the circuit in Fig. 4.39 represent capacitance in Farads. The equivalent capacitance looking into the network at the left is most nearly

Answer: 19.2 F

Problem#4·49 ■ Now assume that the "loads" in the circuit in Fig. 4.39 represent inductance in Henrys. The equivalent inductance looking into the network at the left is most nearly

Answer: 32.1 H

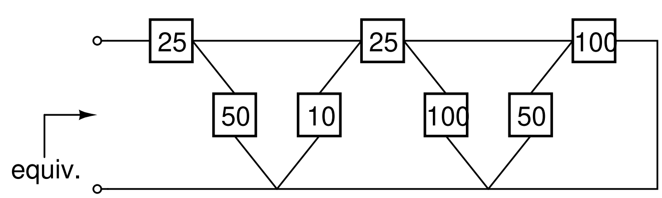

Figure 4.39: Equivalent impedance

Problem#4·50 ■ If the circuit below has $v_i(t) = 100\cos(1000t)$ mV, $L_y = 5\,\text{mH}$, $R_x = 130\,\text{m}\Omega$, and $R_z = 12\,\Omega$, the output voltage phasor $\mathbf{V}_o$ is most nearly

Answer: $3.55\angle -113^\circ$ V

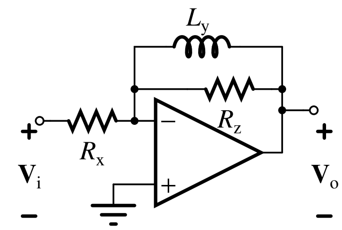

Figure 4.40: AC op-amp circuit

5
AC Power

AC Power Fundamentals

Problem#5·1 ■ The current waveform in Fig. 5.1 repeats every 10 ms. The *average* value of the waveform is most nearly

Answer: -3.2 A

Problem#5·2 ■ The RMS value of the periodic current (with period $T = 10\,\mathrm{ms}$) in Fig. 5.1 is most nearly

Answer: 9.8 A

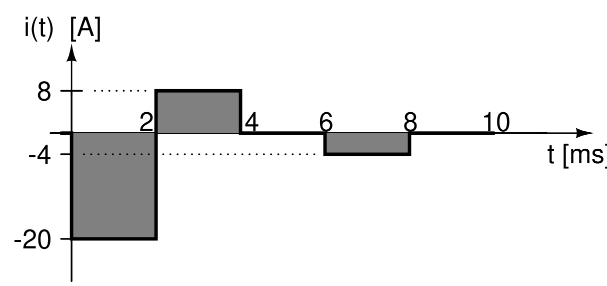

Figure 5.1: Current waveform

Problem#5·3 ■ What is the time-average value of the current waveform?

Problem#5·4 ■ What is the RMS value of the current waveform?

Answer: 2.19 A [5S13]

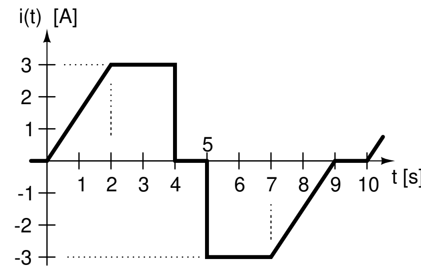

Figure 5.2: AC Power

Problem#5.5 ■ Determine the instantaneous power provided by the voltage source. What is the the time-average power?

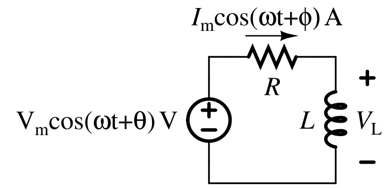

Figure 5.3: AC Power

Problem#5·6 ■ Find the time-average power of a resistor R that has a periodic current forced through it. The current waveform is a sawtooth waveform with amplitude I_m and period T.

Problem#5·7 ■ You have an impedance $\mathbf{Z} = 2\angle 60^\circ\ \Omega$ with a voltage $v(t) = 4\cos(\frac{\pi t}{6})$ V across it. What is the time-domain form of the current. What is the instantaneous power absorbed? Find the time-average power absorbed.

Answer: 2 W

Problem#5.8 ■ Find I_1 and I_2. What is the average power absorbed by all elements in the circuit?

Answer: 25 W; -50 W; 25 W; 0 W; 0 W

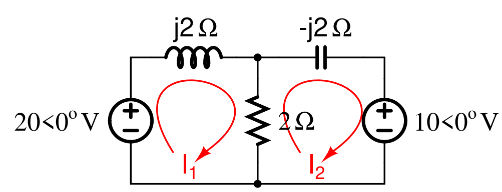

Figure 5.4: AC Power

PROBLEM#5·9 ■ Determine the effective value of a sinusoid with amplitude X_m, frequency ω, and phase-shift θ.

PROBLEM#5·10 ■ What is the average power absorbed by all elements in the circuit? What are the apparent powers? What is the PF of each element?

Answer: 288 W; -432 W; 144 W

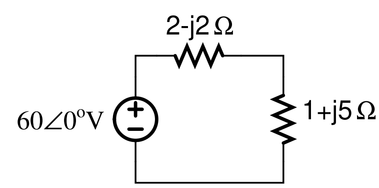

Figure 5.5: AC Power

Problem#5·11 ■ What is the power factor of a 86% efficient 6 HP/460 V/14 A single-phase motor at full load?

Answer: 0.81 lagging [5S13]

Problem#5·12 ■ What is the full load current drawn by a 2 HP, 230 V single phase motor, operating with an efficiency of 80% and 67% lagging?

Answer: 12.1 A [5S13]

Problem#5·13 ■ What is the reactive power when a 480 V feeder is supplying a load of 38.4 kW at PF=80%?

Answer: 28.8 kVAR [5S13]

Problem#5·14 ■ If the apparent power is 1.5 kVA with a power factor of 0.866 lagging, find the reactive power and complex power.

Answer: 0.748 kVAR

Problem#5·15 ■ Suppose you have a 230 V0-60 Hz-50 kW motor with a lagging PF of 0.80. You want to raise your PF to 0.95 to improve your utility rate. What load must you connect in parallel to the motor?

Answer: 1056 ¯F

AC Power Problems

Problem#5·16 ■ A single-ϕ induction motor nameplate reads: 2HP output / 110V-60Hz / 24A. Find the PF of the motor if the efficiency is 80%.

Problem#5·17 ■ An AC induction motor is connected to a power supply in the lab. The motor is rated for 120 V operation and draws 5 A continuously. You measure a shaft output of 1/2 HP and the motor is known to be 74.6% efficient. What is the PF, the real power, the apparent power and reactive power of the motor?

Problem#5·18 ■ An 240 V electric motor absorbs 8 kW at a power factor of 0.80 lagging. Find the complex power, the apparent power, and the motor impedance.

Problem#5·19 ■ You have a 230 V – 5 HP pump on your hot tub. The motor is 85% efficient when running at 72% lagging. The pump runs 14 hours per day, 365 days per year. What size circuit breaker does the pump need? What is the pump's complex power? SED charges 6 ¢ per kW-hour with the penalty schedule above. What is your annual cost to run your hot tub?

PF	penalty
$PF \geq 0.85$	0
$0.85 > PF \geq 0.80$	1%
$0.80 > PF \geq 0.75$	2%
$0.75 > PF \geq 0.70$	3%
$PF < 0.70$	25%

Figure 5.6: Power factor penalty table

Problem#5·20 ■ A voltage source $100\cos(377t)$ V powers a load impedance of $Z_L = 5 + \jmath 5\,\Omega$. What capacitor do you place in parallel to bring the power factor to unity?

Problem#5·21 ■ You are a design engineer for the Acme Electric Motor Company. What value of C_6 (in μF) should you design *into* your 12 KW electric motor such that the motor operates at unity PF?

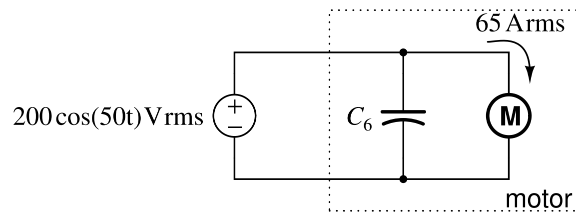

Figure 5.7: AC motor problem

Answer: 2500 F

Problem#5·22 ■ An electric motor is rated at 2.2 KW and operates from a 110 V rms line with $PF = 0.75$ lagging. What is the *smallest* circuit breaker you could use in the motor's circuit that will not "trip"? Note: Circuit breakers are rated in multiples of 5 A (rms).

Answer: 30 A

Problem#5·23 ■ In the circuit below, assume the voltage source is 10 Vrms at $f = 398\,\text{Hz}$. What value of Z_L would absorb maximum average power? What is this maximum power in the load?

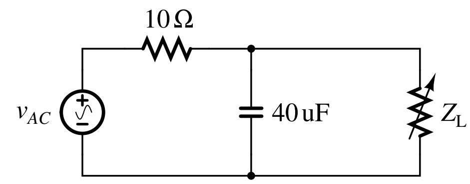

Figure 5.8: AC motor problem

Problem#5·24 ■ In the circuit below, assume the voltage source is 120 Vrms at $f = 60\,\mathrm{Hz}$. (a) Find the average power, apparent power, and complex power. (b) Find the power factor of the entire load (the part of the circuit to the right of the dashed line). (c) To what value should the inductor be changed to cause the PF of the load to be 0.90 lagging?

Answer: 2.74 kW; 2.89 kVA

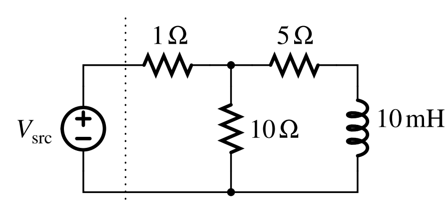

Figure 5.9: AC motor problem

Problem#5.25 ■ You are stationed at the European branch office of your employer. You have a 100 kW motor with a lagging PF of 0.75. What is the motor's complex power? What impedance is needed in parallel to bring the motor's PF to 0.90? What physical circuit element does this represent. (Hint: Europe uses 230 Vrms at 50 Hz.)

Problem#5·26 ■ The circuit below shows a circuit model of a power supply connected to a load via a wire. Wires have an inductance based on their construction material and conductor topology. Wire resistance is based largely on conductor diameter and length. How long should your wire be (find R_5) and design your load (find C_5) so that the maximum real power is transferred into the load? (Give your answers in Ω, μF, and/or mH.)

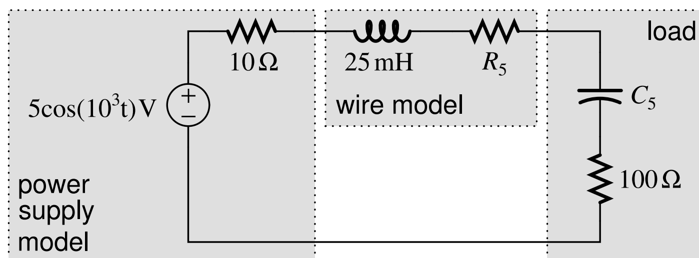

Figure 5.10: Maximum power transfer

Answer: 40 ⁻F

Problem#5·27 ■ You have a 480 Vrms system operating at 60 Hz with two attached loads. The first load consumes 100 kW at PF=0.7 lagging and the second load consumes 50 kW at PF=0.95 lagging. (Your loads are connected in parallel so as to receive the same voltage from the source.) The required parallel capacitor to bring the loads' PF to unity is most nearly

Answer: 1.36 mF

Problem#5·28 ■ You are a design engineer for the Acme Electric Motor Company. Your 60 Hz, 100 V, 15.8 HP induction motor is 85% efficient and operates at $PF = 0.70$. The smallest value of C that you should connect across your motor's terminals to improve the PF to 0.95 is most nearly

Answer: 2.54 mF

Problem#5·29 ■ What capacitance is required if you have a 85% efficient 50 V/200 Hz/100 HP motor at 0.66 lagging, and you wish to bring the load's PF up to 0.92?

Answer: 19.9 mF [5S13]

Ideal Transformers

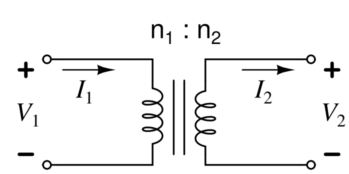

Figure 5.11: Ideal transformer operation

Problem#5·30 ■ An ideal transformer

Problem#5·31 ■ Determine the impedance seen looking into the "primary" when an impedance Z_L is located in the "secondary".

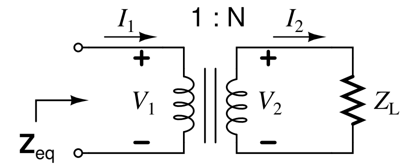

Figure 5.12: Reflecting impedances through a transformer

Problem#5·32 ■ Find the Thevenin equivalent circuit seen at the terminals a-b.

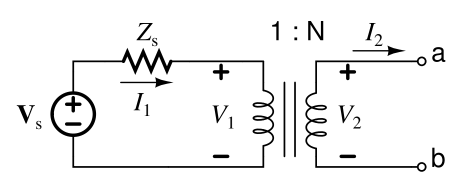

Figure 5.13: Thevenin equivalent circuit for an ideal transformer

Problem#5·33 ■ Find the impedance seen by the voltage source. Determine the voltage gain $\frac{V_2}{V_g}$. What load can replace the $16\,\Omega$ resistor will absorb maximum average power?

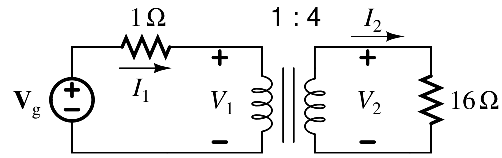

Figure 5.14: Transformer circuit

Problem#5.34 ■ Determine the equivalent impedance Z_{eq}

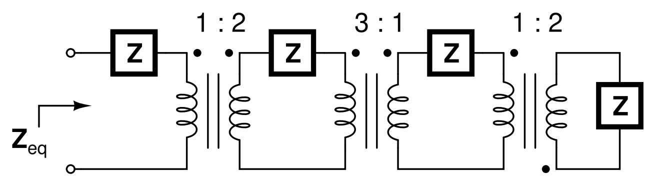

Figure 5.15: Impedance reflection

Problem#5.35 ■ A 60 Hz ideal transformer rated for 220/110 operation has an inductive load $Z_L = 10 + \jmath 10\,\Omega$ connected on the low voltage side.

- What are the primary and secondary currents?

- What is the load impedance referred to the primary side?

- What power is supplied by the source?

Problem#5·36 ■ An ideal transformer has a load Z_L connected to its secondary. The transformer is rated for 400 kVA @ 460 V.

- What current is supplied to the load?

- What is the maximum power delivered at PF=1.0?

- What is the maximum power delivered if the PF=0.8 lagging?

- What is the maximim power at PF=0.7 lagging?

- If Z_L requires 300 kW, what is the minimum PF?

Problem#5.37 ■ Determine the voltage across the primary windings, the secondary current, and the load voltage.

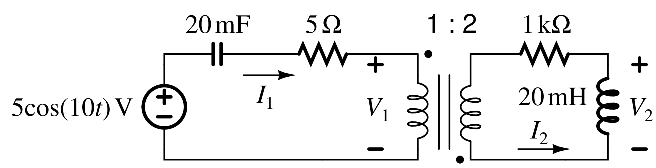

Figure 5.16: Transformer circuit

Problem#5·38 ■ The turns ratio ($N_1 : N_2$) for maximum power transfer in the following circuit is most nearly

Answer: 20:1

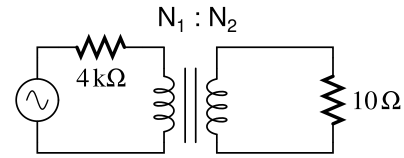

Figure 5.17: Transformer circuit