# EEGR2053-02 ELECTRIC CIRCUITS
## Homework Sets Assigned in the Spring Semester of 2019

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**EEGR2053 Electric Circuits**

## Homework Set 1

*But of him are ye in Christ Jesus, who of God is made unto us wisdom, and righteousness, and sanctification, and redemption. 1Co 1:30*

**Suggested Reading:** Overview of Chapter 1 (pages 2–4); Section 1-2 Units, Dimensions, and Notation; Section 1-4 Electric Charge and Current.

1. Consider a $0.22\,\text{mm} \times 400\,\mu\text{m} \times 5 \cdot 10^6\,\text{pm}$ rectangular parallelepiped. Write all results in scientific notation (such as $1.32 \cdot 10^{-13}$).
   (a) Find the total surface area in $\text{mm}^2$.
   (b) Find the volume in $\mu\text{m}^3$.
2. A communication channel transmits a sample of data every 0.125 ns. How many mega-samples of data are transmitted per second?
3. We will use the engineering notation in our class. In engineering notation, a quantity is represented by a number $N$ in the range $1 \leq N < 1000$, followed by an unit with the appropriate prefix. For example, 0.3 kJ is written as 300 J, 12000 nm as 12 $\mu$m, and 1234 kW as 1.234 MW. Write the following numbers in engineering notation. (a) 0.1 $\mu$m; (b) 0.003 GW; (c) 5675 mJ; (d) 12300 $\mu$g; (e) 0.133 ns.
4. The motor of an electric vehicle runs at an average of 50 hp for one hour and 25 minutes. Determine the total energy. Write the result in engineering notation and with SI units.
5. A current $i(t) = 3 - t\,\text{A}$ flows from point $E$ to point $F$.
   (a) Find the charge transferred to $F$ in the interval of time $t = 0 \ldots 4\,\text{s}$.
   (b) Find the average value of the current in the interval of time $t = 0 \ldots 4\,\text{s}$.

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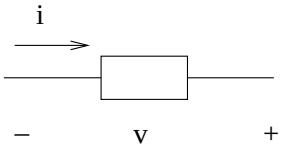
## Homework Set 2

*. . . as it is written, He that glorieth, let him glory in the Lord. 1Co 1:31*

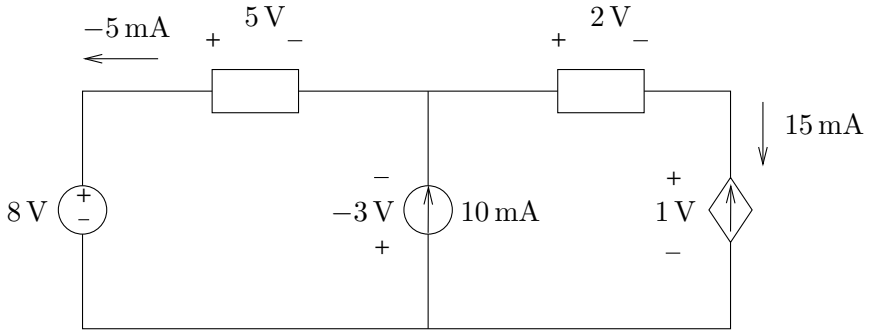
**Suggested Reading:** Section 1-4 Electric Charge and Current; Section 1-5 Voltage and Power; Section 1-6 Circuit Elements

1. Assume $v = 10\,\text{V}$ and $i = -t + 2\,\text{A}$.




   (a) Find the absorbed power at time $t = 0$.
   (b) Find the generated power at time $t = 1$.
   (c) Find the generated power at time $t = 5$.

2. Determine the power for each component.




   (a) The power generated by the voltage source.
   (b) The power generated by the current source.
   (c) The power generated by the dependent source.
   (d) The power absorbed by the 5 V element.
   (e) The power absorbed by the 2 V element.
   (f) Verify that the algebraic sum of the generated power values at parts (a), (b), and (c) equals the algebraic sum of the absorbed power values at parts (d) and (e).

3. A conductor connects the points A and B of a circuit. The total amount of charge transferred from A to B is $q(t) = 3t - t^2\,\text{C}$.

   (a) Determine the current $i_1(t)$ from $A$ to $B$ at time $t = 1$.
   (b) Determine the current $i_2(t)$ from $B$ to $A$ at time $t = 1$.
   (c) Determine the time at which $q(t)$ is maximum.
   (d) Sketch the graph of $q(t)$ for the interval $t = 0 \ldots 3$.

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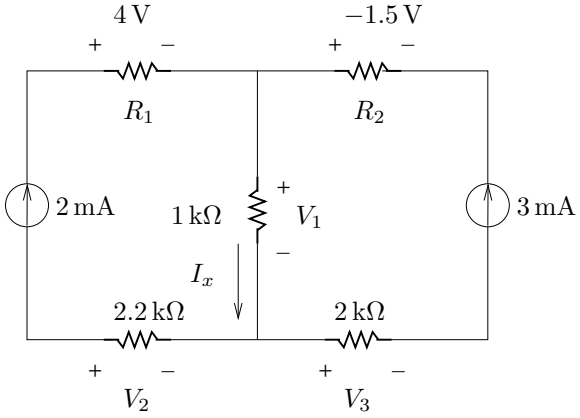
## Homework Set 3

*My son, forget not my law; but let thine heart keep my commandments: For length of days, and long life, and peace, shall they add to thee. Prov 3:1-2*

**Suggested Reading:** Section 2-1 Ohm's Law; Section 2-2 Kirchhoff's Laws

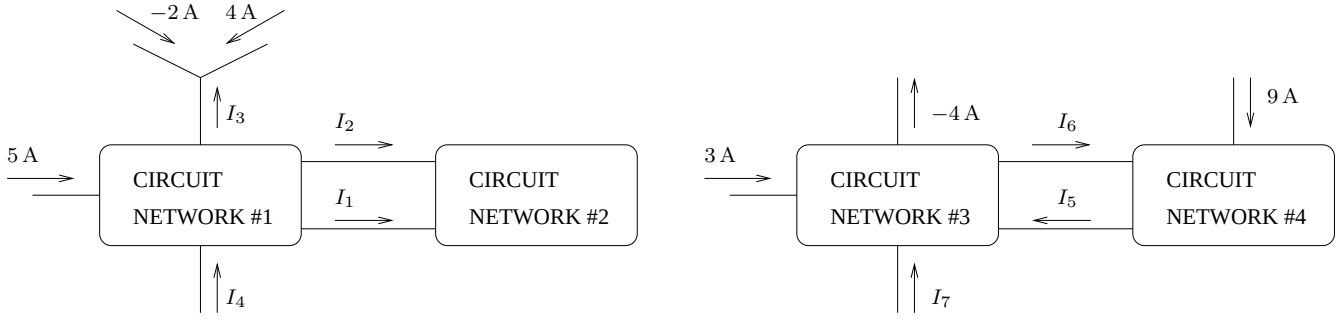
1. Answer the following questions. Make sure all signs are correct.




   (a) Find the value of $I_x$.
   (b) Find the value of $R_1$.
   (c) Find the value of $R_2$.
   (d) Find the value of $V_1$.
   (e) Find the value of $V_2$.
   (f) Find the value of $V_3$.
   (g) Find the number of branches and nodes of the circuit.

   Sample answers: $R_1 = 2\,\text{k}\Omega$; $V_2 = -4.4\,\text{V}$; 7 branches and 6 nodes.

2. Show all your work for each of the following questions.




   (a) Find $I_3$.
   (b) Assuming that $I_6 = -3\,\text{A}$, find $I_5$?
   (c) Find $I_4$.

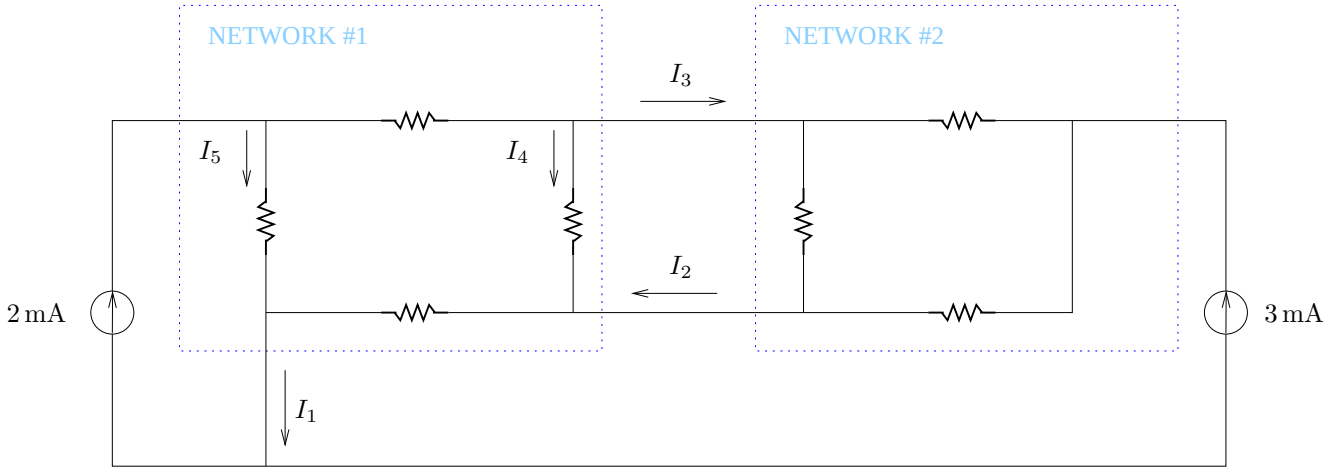
(d) Assuming that $I_1 = 8\,\text{A}$, find $I_2$?

(e) Find $I_7$.

(f) Assuming that $I_6 = -1\,\text{A}$, what will be $I_5$? Will the value of $I_7$ change? Why or why not?

Sample answers: (b) 6 A; (c) $-7$ A; (f) $I_7$ does not change.

3. Consider the following circuit.



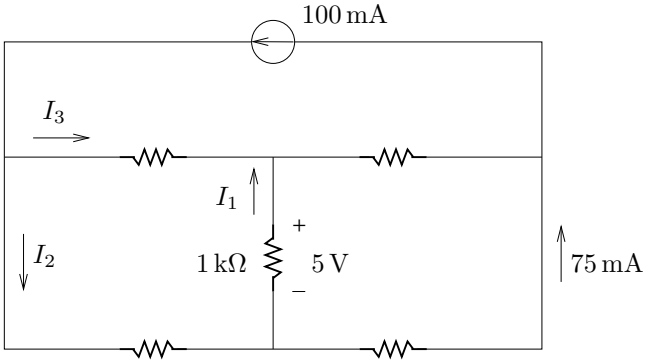

(a) Indicate the number of nodes and the number of branches of the circuit.

(b) Find $I_1$.

(c) Assuming $I_2 = 2\,\text{mA}$, find $I_3$.

(d) Assuming $I_2 = 2\,\text{mA}$ and $I_4 = 500\,\mu\text{A}$, find $I_5$.

4. Apply Ohm's law and KCL to find $I_1$, $I_2$, and $I_3$.



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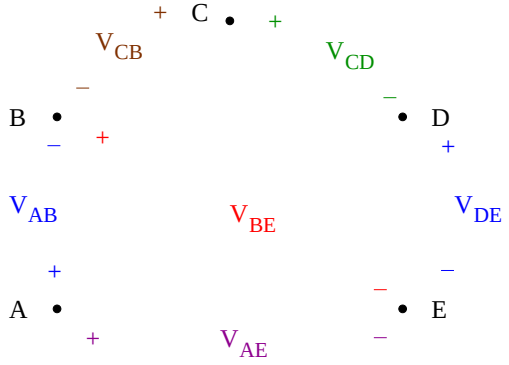
## Homework Set 4

*"If ye endure chastening, God dealeth with you as with sons; for what son is he whom the father chasteneth not?" Heb 12:7*

**Suggested Reading:** Section 2-2 Kirchhoff's Laws.

1. Let $V_{XY}$ denote the voltage between two nodes $X$ and $Y$, taken with the $+$ at $X$ and the $-$ at $Y$. Assume $V_{AB} = 1\,\text{V}$, $V_{BE} = -2\,\text{V}$, $V_{DE} = 4\,\text{V}$, and $V_{CD} = -3\,\text{V}$.




   (a) Find $V_{AE}$.

   (b) Find $V_{EA}$ (not shown in the figure).

   (c) Find $V_{CB}$.

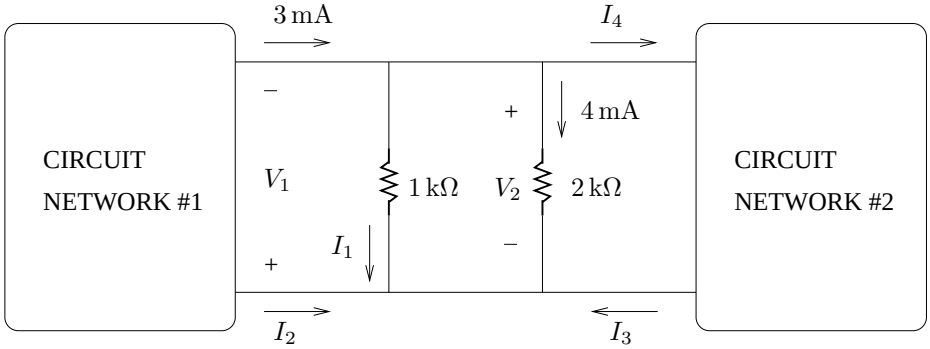
   (d) Find $V_{BD}$ (not shown in the figure).

   (e) Find $V_{AD}$ (not shown in the figure).

   (f) Write KVL for the closed path A, B, E, D, A, involving the voltages $V_{AB}$, $V_{BE}$, $V_{DE}$, and $V_{AD}$. Substitute numerical values and verify that KVL is satisfied.

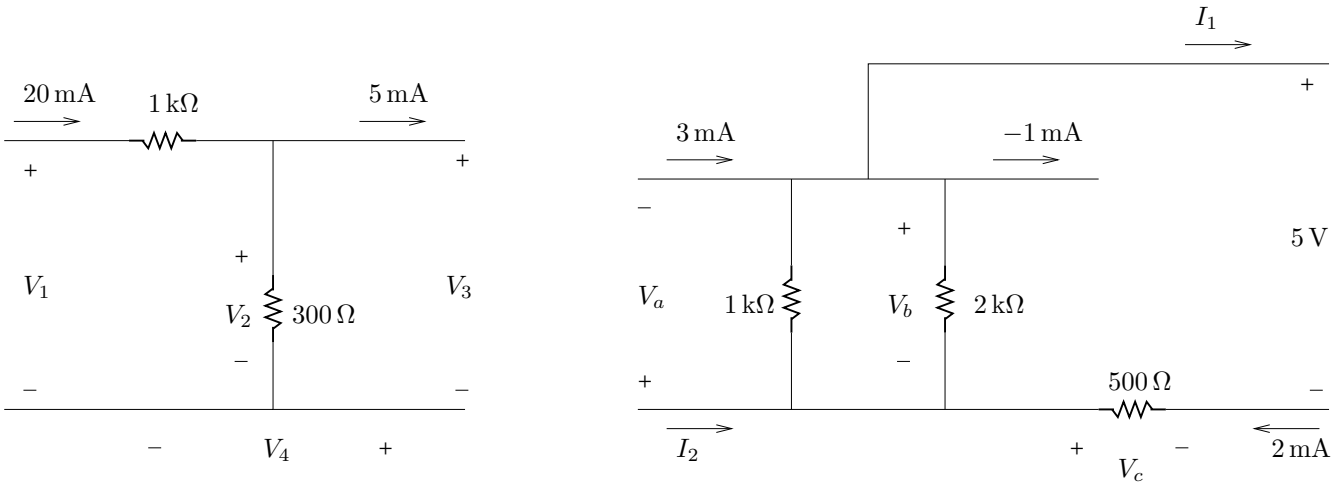
   Sample answers: $V_{EA} = 1\,\text{V}$; $V_{AD} = -5\,\text{V}$.

2. Determine $V_1$, $V_2$, $I_1$, $I_2$, $I_3$, and $I_4$. Show your work!



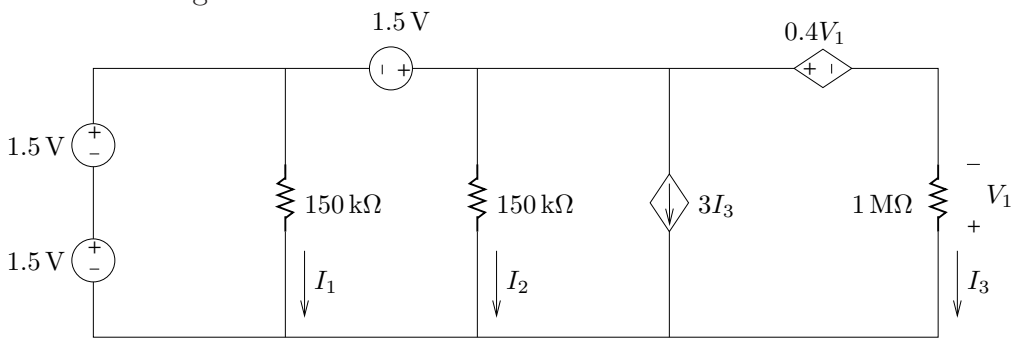

   Sample answers: $V_1 = -8\,\text{V}$; $I_1 = 8\,\text{mA}$; $I_2 = -3\,\text{mA}$.

3. Assume that each network is a part of a larger circuit. Determine $V_1$, $V_2$, $V_3$, $V_4$, $V_a$, $V_b$, $V_c$, $I_1$, and $I_2$. Explain all your answers.




Sample answers: $V_1 = 24.5\,\text{V}$; $V_4 = 0$; $V_a = -6\,\text{V}$; $I_2 = -11\,\text{mA}$.

4. Consider the following circuit.




(a) Determine $I_2$, $I_3$, and $V_1$.

(b) Determine the total power generated by the independent sources.

Sample answers: $P = 330\,\mu\text{W}$.

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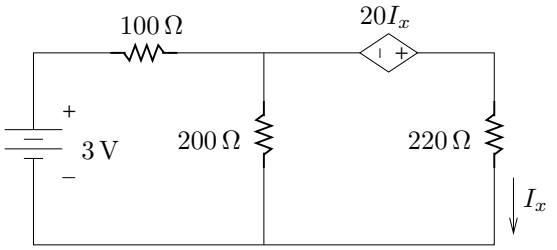
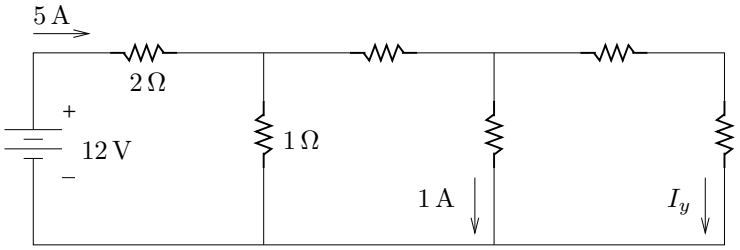
## Homework Set 5

*My son, give me thine heart, and let thine eyes observe my ways. Pr 23:26*

**Suggested Reading:** Section 2-2 Kirchhoff's Laws.

1. Determine $I_x$ and $I_y$.

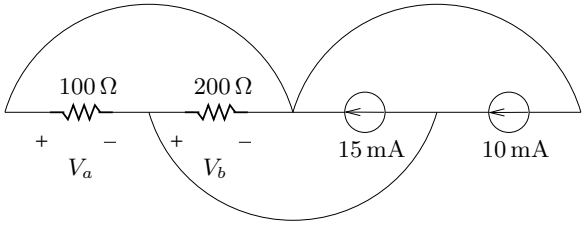


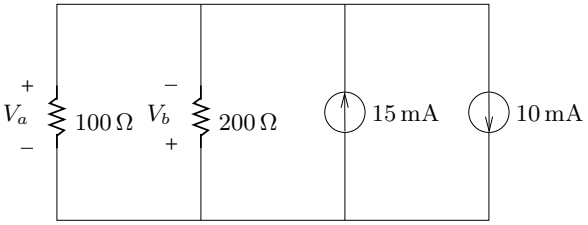




Scrambled answers: 2, −5, 20, 7.5, −10.

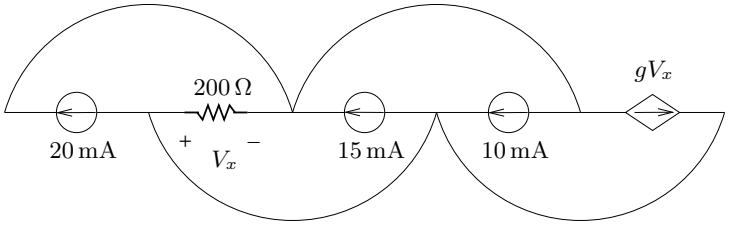
2. Sometimes circuits can be solved more easily by redrawing them into a more convenient form.

(a) Verify that the following two circuits are identical.



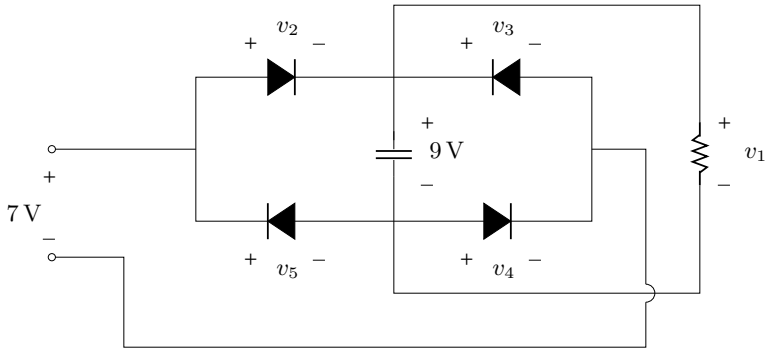




(b) Assume $g = 3$ in mA/V units. Find $V_x$ in the following circuit.




(c) Determine the power generated by the dependent source.

3. The following figure shows a *rectifier* circuit. Assume that at a certain time instant two of the voltages have the value indicated in the figure. Assume that $v_2 = v_4$. Apply KVL to find $v_1$, $v_2$, $v_3$, $v_4$, and $v_5$.



Sample answers: $v_5 = 8\,\mathrm{V}$.

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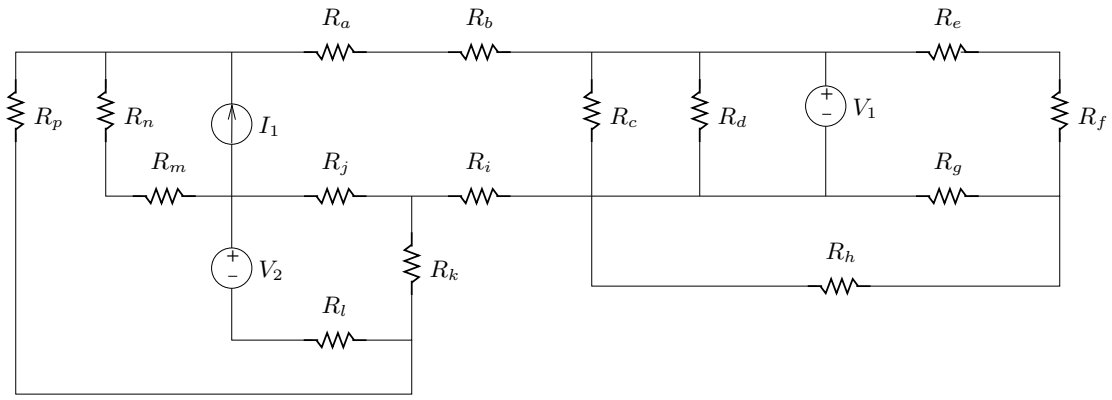
## Homework Set 6

*Be not overcome of evil, but overcome evil with good. Rom 12:21*

**Suggested Reading:** Section 2-3 Equivalent Circuits.

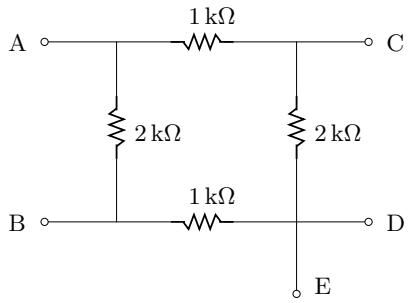
1. Consider the following circuit.

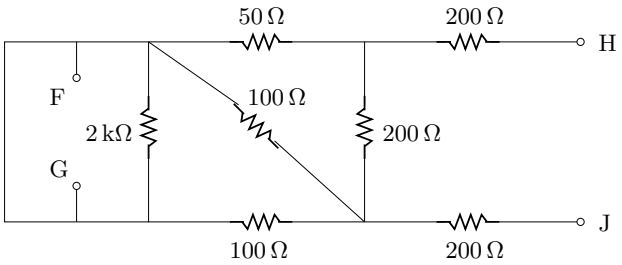



   (a) Find the number of nodes of the circuit.
   (b) Indicate all components in parallel with $R_c$.
   (c) Indicate all components in series with $R_a$.
   (d) Indicate all components in series with $R_k$.
   (e) Indicate all components in parallel with $R_p$.
   (f) Indicate all components in parallel with $R_h$.
   (g) Indicate all components in series with $R_e$.
   (h) Indicate all components in series with $R_n$.
   (i) Indicate all components in parallel with $R_j$.

   Sample answers: (b) $R_d$ and $V_1$; (c) $R_b$ (however, since the same current flows through $R_i$ and $R_a$, $R_i$ could also be included in the answer); (d) none; (e) none.

2. Determine the equivalent resistance in each of the following cases.




   (a) The resistance between $A$ and $B$.

(b) The resistance between $A$ and $D$.

(c) The resistance between $D$ and $E$.

(d) The resistance between $E$ and $F$.

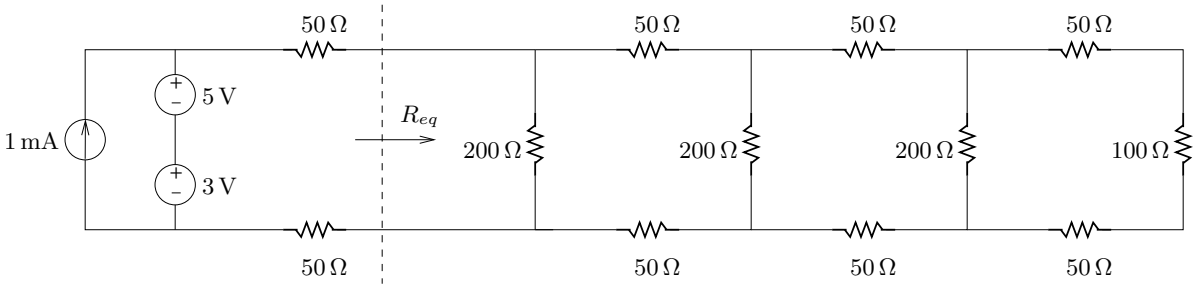
(e) The resistance between $H$ and $J$.

(f) The resistance between $F$ and $G$.

(g) The resistance between $J$ and $F$.

Sample answers: (b) $R_{AD} = 1.5\,\mathrm{k\Omega}$; (c) $R_{DE} = 0$; (d) $R_{EF} = \infty$; (f) $R_{FG} = 0$; (g) $R_{JF} = 241.67\,\Omega$.

3. Consider the following circuit.

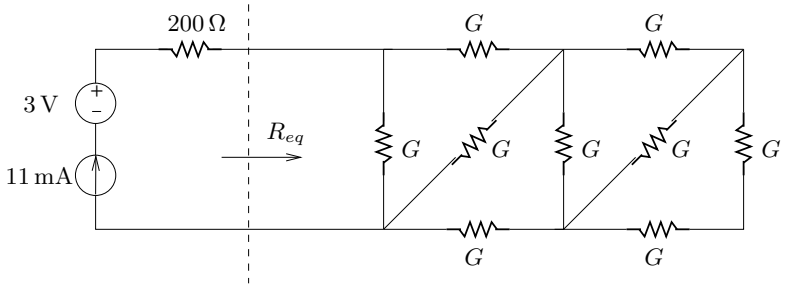



(a) Find the equivalent resistance $R_{eq}$.

(b) Find the power generated by the 5 V source. Hint: Replace first the resistors with a single equivalent resistor.

Sample answers: $R_{eq} = 100\,\Omega$.

4. Assume the conductance $G = 1\,\mathrm{mS}$.




(a) Find the equivalent resistance $R_{eq}$.

(b) Find the power generated by the current source. Hint: Replace first the resistors with a single equivalent resistor.

Sample answers: The power is 66 mW.

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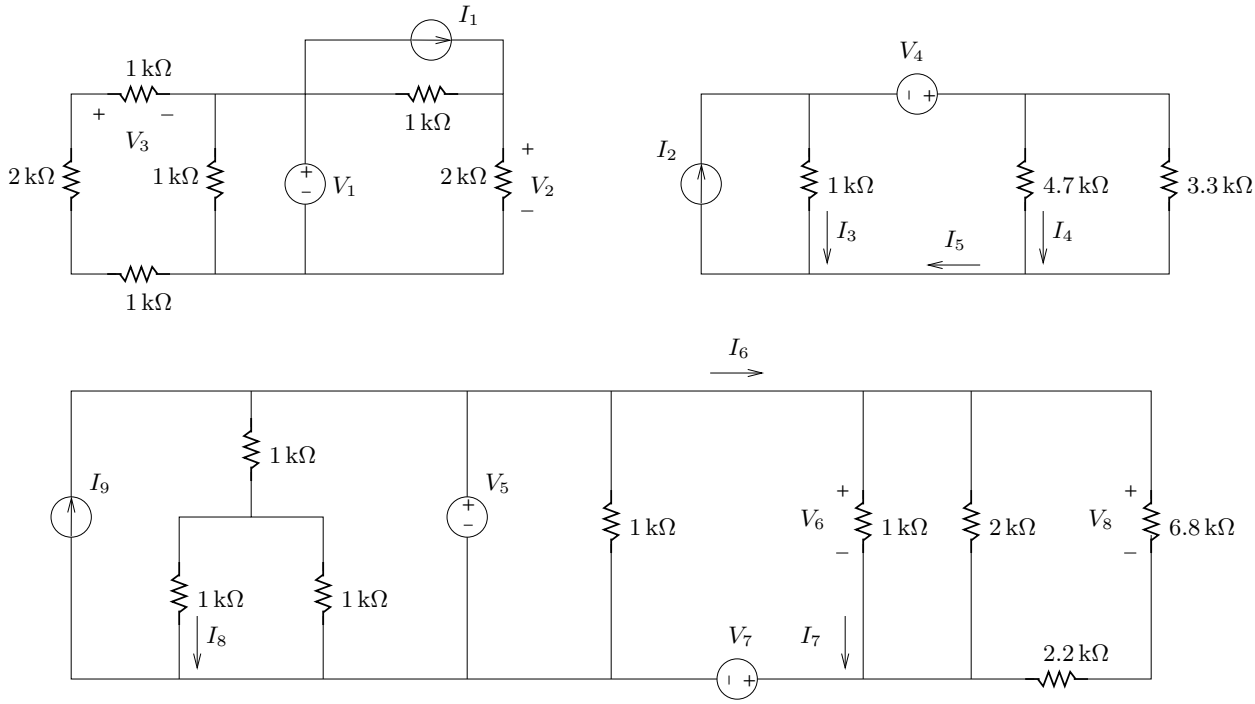
## Homework Set 7

*He that observeth the wind shall not sow; and he that regardeth the clouds shall not reap. Ecc 11:4*

**Suggested Reading:** Section 2-3 Equivalent Circuits.

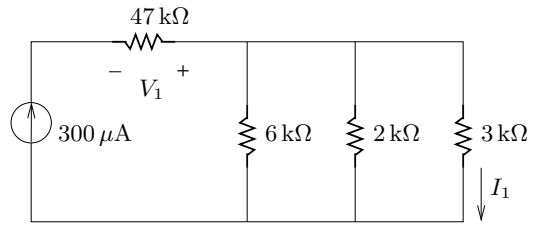
1. For each pair of currents or voltages, if current or voltage division applies, write the equation relating the two currents or the two voltages. If current or voltage division does not apply, explain why.

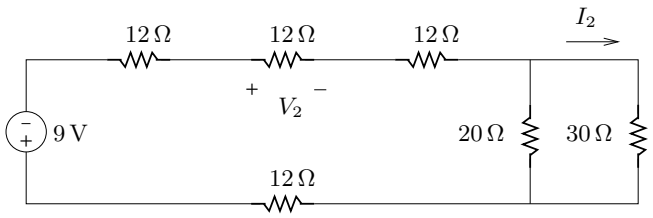


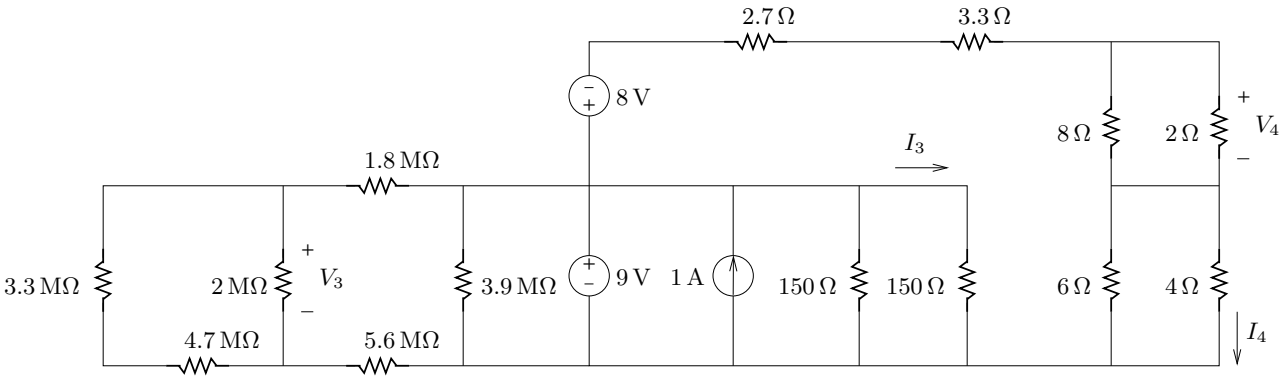

   (a) $V_1$ and $V_2$.
   (b) $V_1$ and $V_3$.
   (c) $I_2$ and $I_3$.
   (d) $I_4$ and $I_5$.
   (e) $I_6$ and $I_7$.
   (f) $I_9$ and $I_8$.
   (g) $V_6$ and $V_8$.
   (h) $V_5$ and $V_8$.

   Sample answers: (a) Voltage division does not apply; (b) $V_3 = -\frac{V_1}{4}$; (c) current division does not apply; (d) $I_4 = I_5\frac{3.3}{8}$.

2. Use resistance combination methods and current and/or voltage division to find $V_1$, $I_1$, $V_2$, $I_2$, $V_3$, $I_3$, $V_4$, and $I_4$.

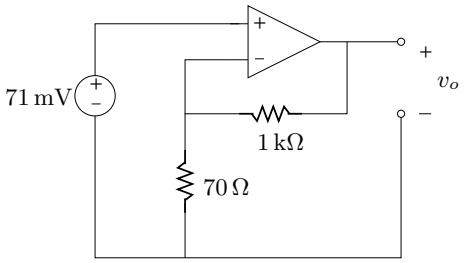


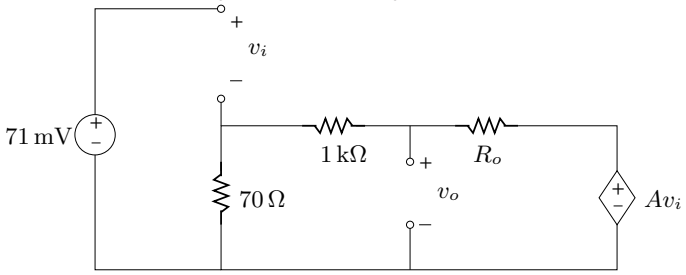




Sample answers: $V_1 = -14.1\,\text{V}$; $I_2 = -60\,\text{mA}$; $I_3 = 60\,\text{mA}$; $V_4 = 160\,\text{mV}$.

3. The figure below shows an *operational amplifier* circuit to the left and its equivalent circuit to the right. Use the equivalent circuit to determine $v_o$. Assume $R_o = 30\,\Omega$ and $A = 1100$.




Hint: *There is no current flowing through any of the four terminals, so voltage division applies and can be used to find the voltage on the* $70\,\Omega$ *resistor in terms of* $Av_i$*. Then KVL can be applied on a loop that includes the* $71\,mV$ *source.*

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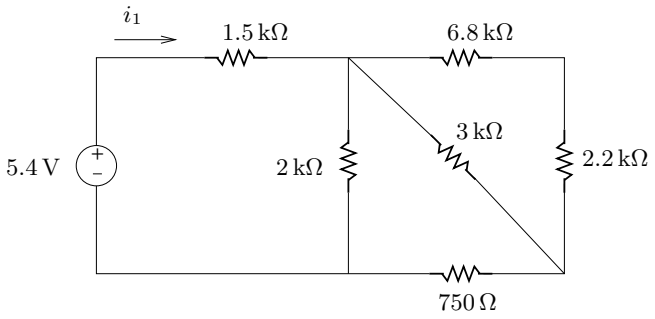
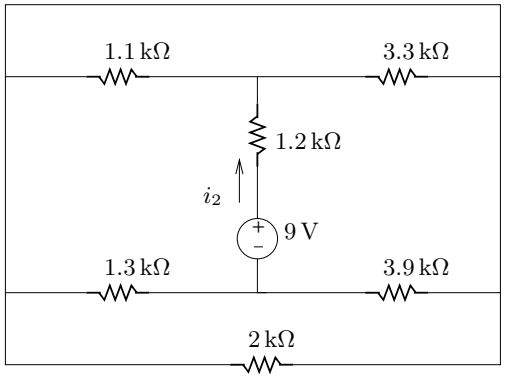
## Homework Set 8

*The eyes of the LORD preserve knowledge, and he overthroweth the words of the transgressor. Pro 22:12*

**Suggested Reading:** Section 2-3 Equivalent Circuits.

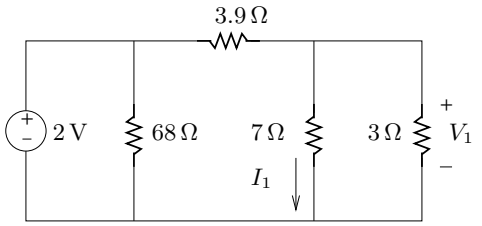
1. Find $i_1$ and $i_2$. Hint: *If helpful, redraw the circuit so that its nodes are represented by points.*

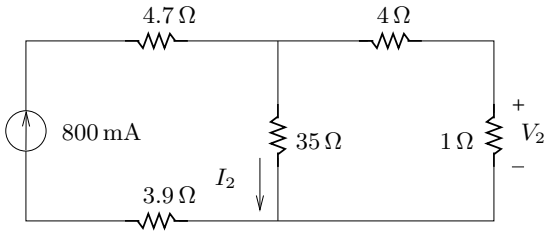


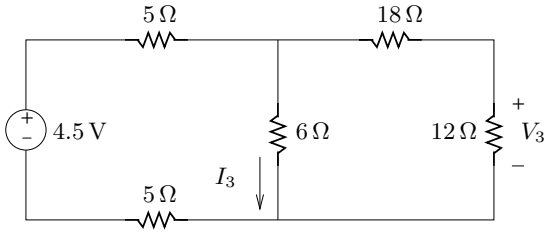



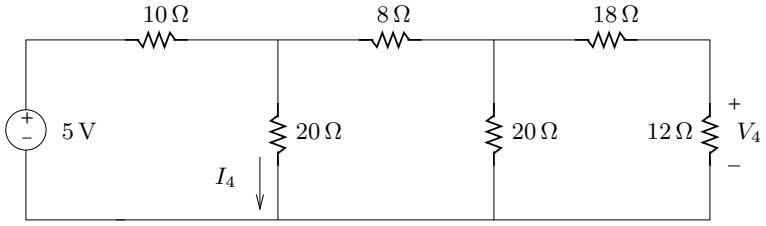

   Sample answers: $i_2 = 3\,\text{mA}$.

2. Use resistance combination methods and current and/or voltage division to find $V_1$, $I_1$, $V_2$, $I_2$, $V_3$, $I_3$, $V_4$, and $I_4$.



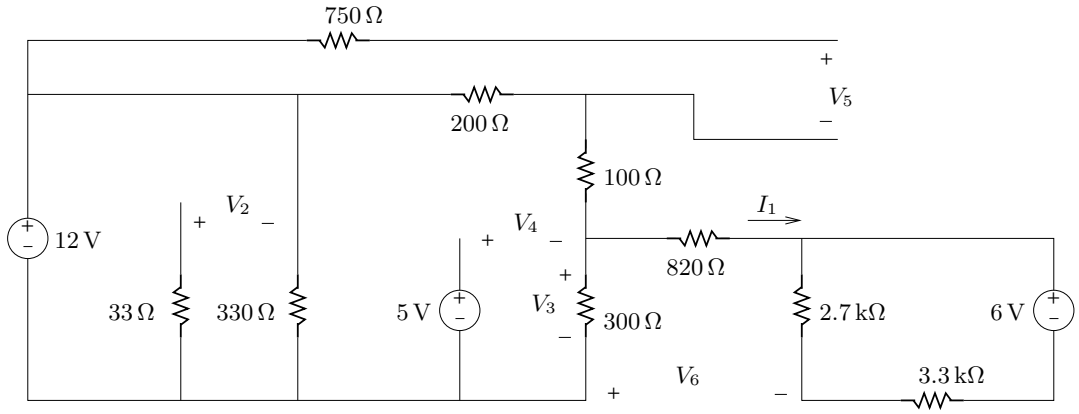




   Sample answers: $I_1 = 100\,\text{mA}$; $V_2 = 700\,\text{mV}$; $I_3 = 250\,\text{mA}$; $V_4 = 600\,\text{mV}$.

3. Find $I_1$, $V_2$, $V_3$, $V_4$, $V_5$, and $V_6$ using KVL, KCL, and whenever possible voltage division.




Sample answers: $V_2 = -12\,\mathrm{V}$ and $V_6 = -3.3\,\mathrm{V}$.

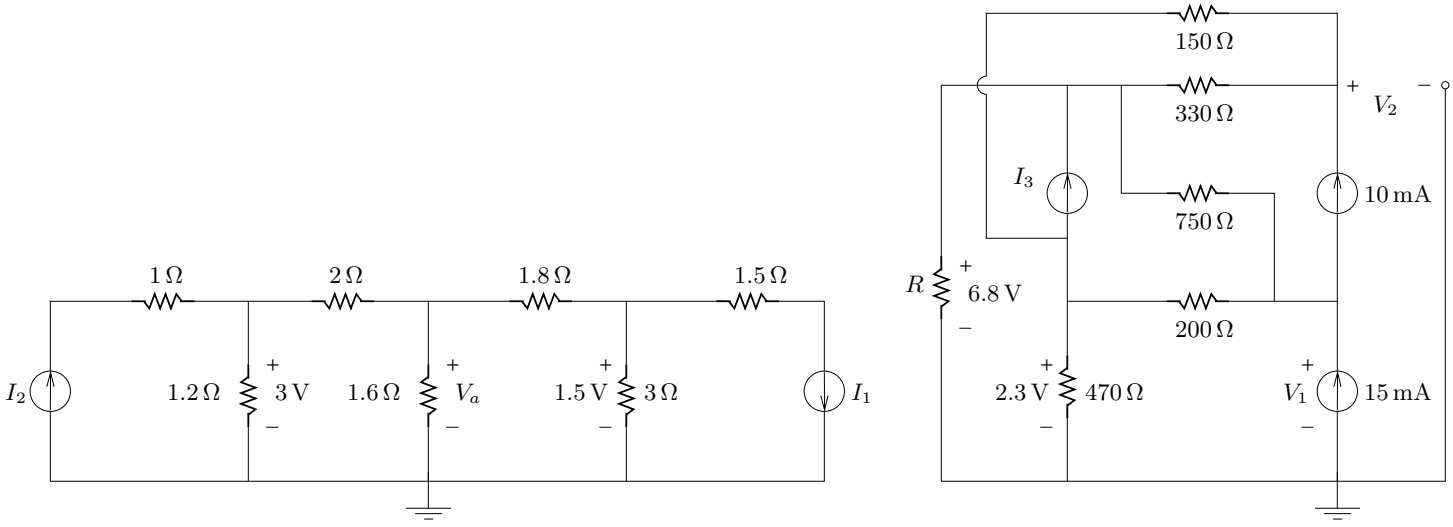
**EEGR2053 Electric Circuits**

## Homework Set 9

*He that followeth after righteousness and mercy findeth life, righteousness, and honour. Pro 21:21*

**Suggested Reading:** Section 3-2 Node-Voltage Method.

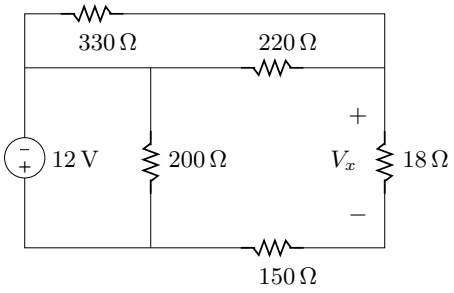
1. Apply nodal analysis to find (a) $V_a$; (b) $I_1$; (c) $I_2$; (d) $V_1$; (e) $V_2$; (f) $I_1$; (g) $R$.

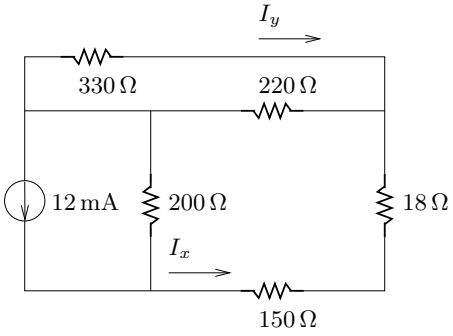



Sample answers: $I_1 = -562\,\text{mA}$, $V_2 = 4.7\,\text{V}$ and $R = 672.8\,\Omega$.

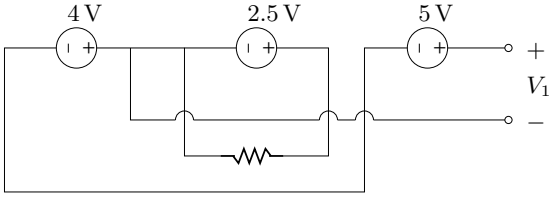
2. (a) Find $V_x$ using voltage division.
   (b) Find $I_x$ and $I_y$ using current division.

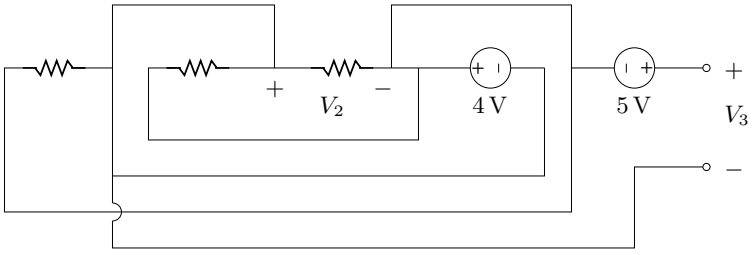
   Sample answers: $I_y = -1.92\,\text{mA}$.




3. Find (a) $V_1$; (b) $V_2$; (c) $V_3$.



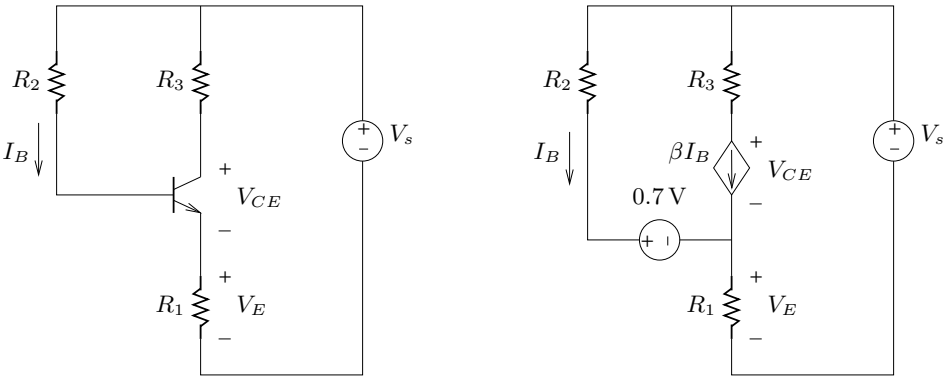
**EEGR2053 Electric Circuits**

## Homework Set 10

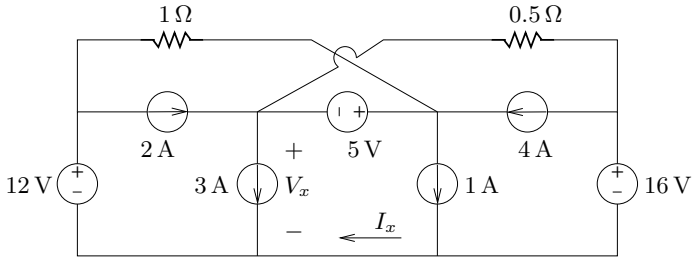
*Heaven and earth shall pass away: but my words shall not pass away. Mark 13:31*

**Suggested Reading:** Section 3-2 Node-Voltage Method.

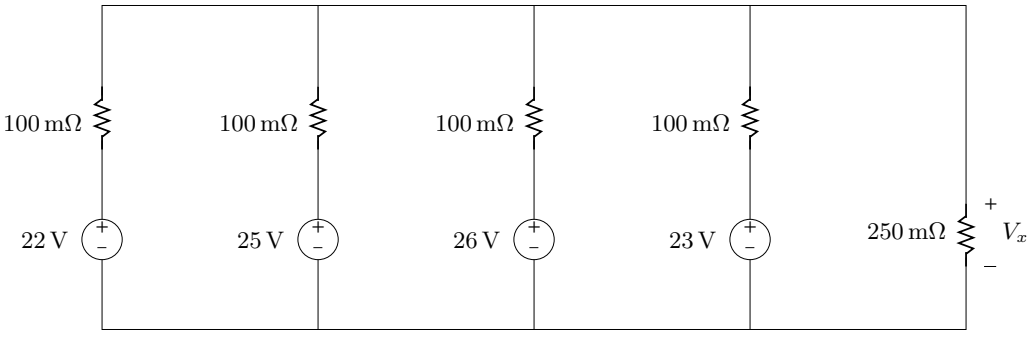
1. The *transistor* circuit shown to the left has the equivalent circuit shown to the right. Find $V_E$ and $V_{CE}$ using the equivalent circuit and nodal analysis. Assume the following numerical values: $V_s = 9\,\text{V}$, $R_1 = 470\,\Omega$, $R_2 = 100\,\text{k}\Omega$, $R_3 = 1\,\text{k}\Omega$, and $\beta = 100$.




2. (a) Find $V_x$ using nodal analysis.
   (b) Find $I_x$.



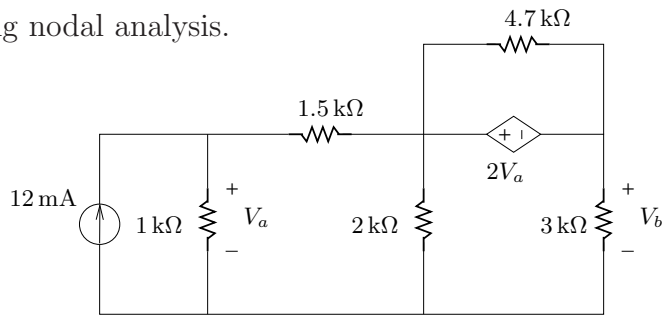

3. Consider the following circuit.




   (a) Find $V_x$ using nodal analysis.
   (b) Calculate the power delivered by the 22 V source.

   Sample answers: 40 W.

4. Find $V_a$ and $V_b$ using nodal analysis.




Sample answers: $V_b = -12.41\,\text{V}$.

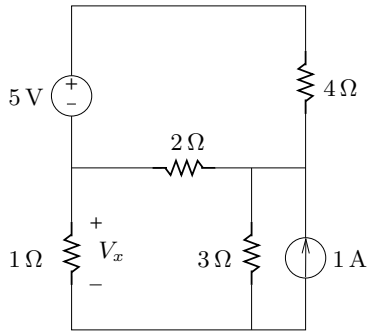
**EEGR2053 Electric Circuits**

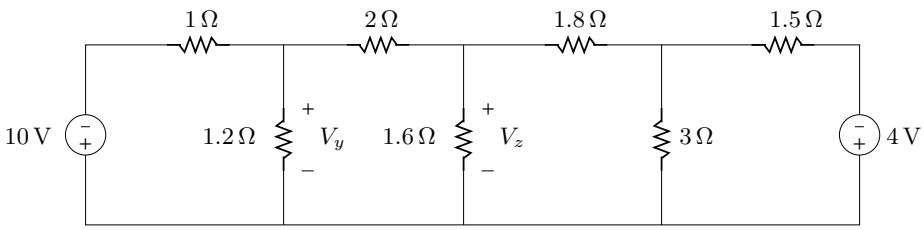
## Homework Set 11

*I wait for the LORD, my soul doth wait, and in his word do I hope. Psa 130:5*

**Suggested Reading:** Section 3-2 Node-Voltage Method.

1. Consider the following circuits.



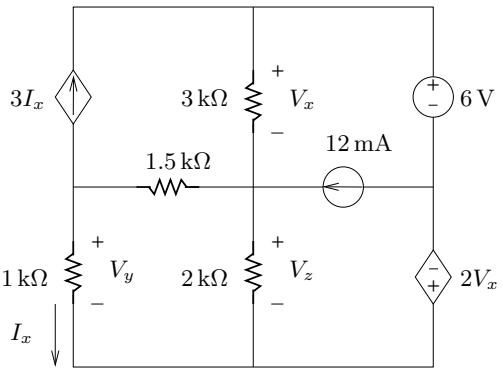




   (a) Write the nodal equations and find the unknown voltages using Cramer's rule. Calculate the determinants by hand. Do not use an advanced calculator!

   (b) Verify your results with math software or an advanced calculator.

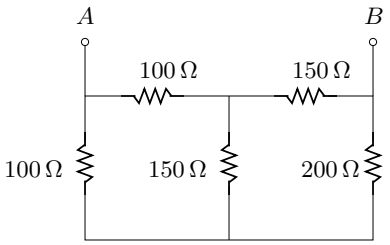
   Sample answers: $V_y = -4.77\,\text{V}$.

2. Apply nodal analysis and find $V_x$, $V_y$, and $V_z$. You are encouraged to solve the nodal equations with math software or an advanced calculator.




   Sample answers: $V_x = -1.57\,\text{V}$.

3. The general method of finding the equivalent resistance of a network consists in adding an external source to the network and then calculating the ratio voltage over current. Consider the following passive network.



(a) Add a current source between the terminals $A$ and $B$.

(b) Assign an arbitrary value to the source (such as $I_s = 1\,\mathrm{A}$).

(c) Select one of the terminals $A$ or $B$ as reference.

(d) Find the voltage $V_{AB}$ between $A$ and $B$ using nodal analysis.

(e) Calculate $R_{eq} = \dfrac{V_{AB}}{I_s}$.

**EEGR2053 Electric Circuits**

## Homework Set 12

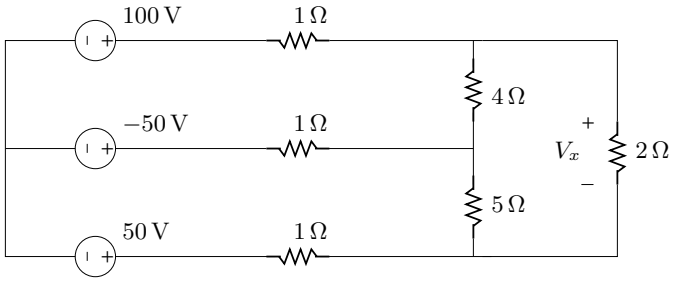
*The LORD is good unto them that wait for him, to the soul that seeketh him. Lam 3:25*

**Suggested Reading:** Section 3-3: Mesh-Current Method.

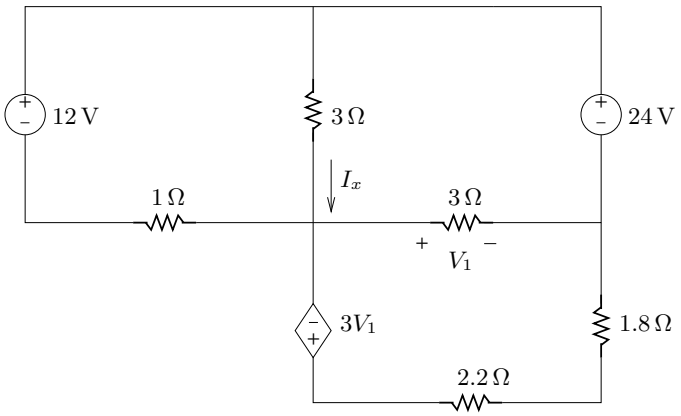
1. At a certain moment of time, the voltages applied by a three-phased source have the values indicated in the figure.

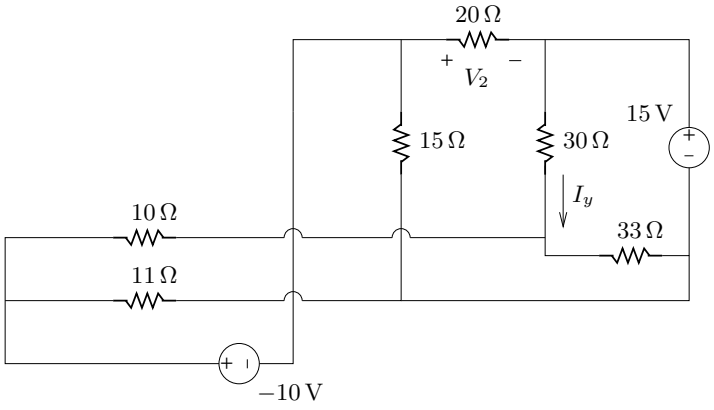
   (a) Determine $V_x$ using nodal analysis.

   (b) Determine $V_x$ using mesh analysis.




2. When necessary, redraw the circuits so that no branch passes over another branch. Then apply mesh analysis to find $I_x$, $V_1$, $I_y$, and $V_2$.




Sample answers: $V_1 = 7.5\,\text{V}$ and $I_y = 407.3\,\text{mA}$.

**EEGR2053 Electric Circuits**

## Homework Set 13

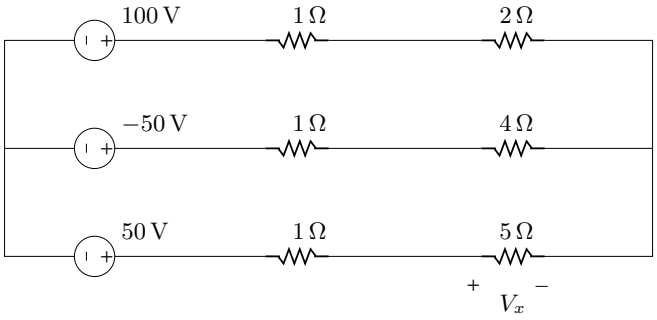
*The LORD of hosts is with us; the God of Jacob is our refuge. Ps 46:11*

**Suggested Reading:** Section 3-3: Mesh-Current Method.

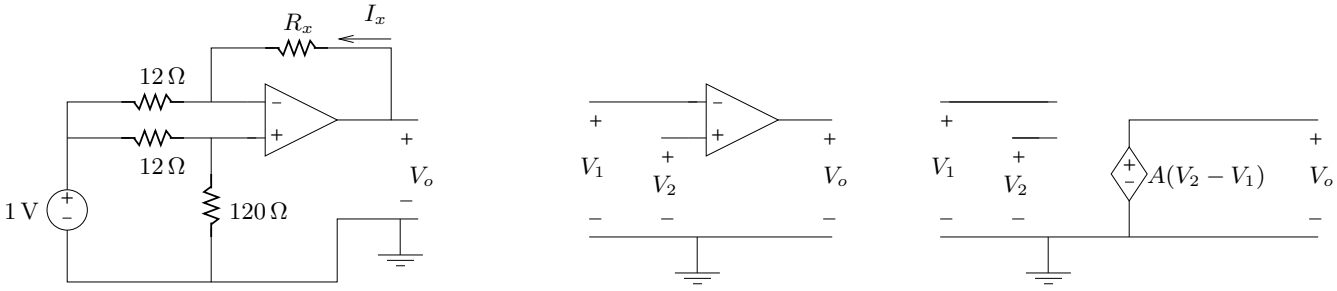
1. At a certain moment of time, the voltages applied by a three-phased source have the values indicated in the figure.

   (a) Determine $V_x$ using nodal analysis.

   (b) Determine $V_x$ using mesh analysis.




2. Recall the equivalent circuit of an operational amplifier, which is shown below to the right. The circuit shown to the left can be used to detect small changes in the resistance $R_x$ of a sensing element (such as a *strain gauge*). It assumes a value of $R_x$ that is close to $120\,\Omega$.



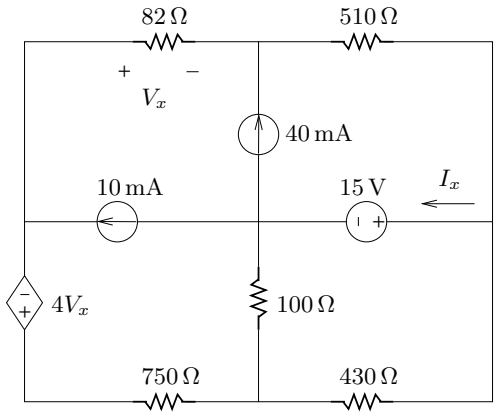

   (a) Redraw the left circuit by substituting the operational amplifier with its equivalent circuit.

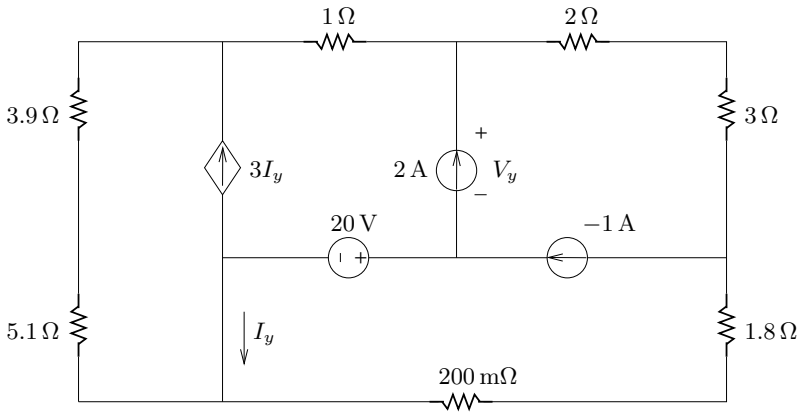
   (b) Assuming $R_x = 119.5\,\Omega$ and $A = 10^4$, find $I_x$ and $V_o$. You may use any method (voltage division and KVL, or nodal analysis, or mesh analysis).

   (c) What is $V_o$ when $R_x = 120\,\Omega$?

   Sample answers: At part (b), $V_o = 3.78\,\text{mV}$.

3. Find $V_x$, $V_y$, $I_x$, and $I_y$ using mesh analysis.




Sample answers: $V_x = -1.14\,\text{V}$ and $I_y = -750\,\text{mA}$.

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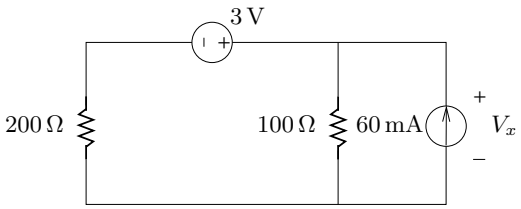
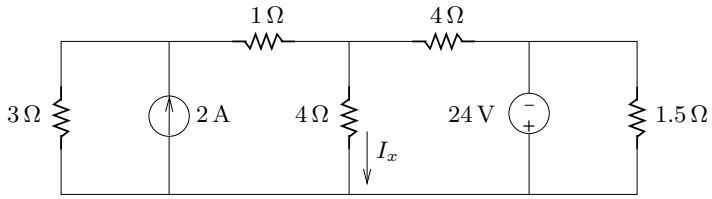
## Homework Set 14

*From the rising of the sun unto the going down of the same the LORD'S name is to be praised. Psa 113:3*

**Suggested Reading:** Section 3-5 Linear Circuits and Source Superposition.

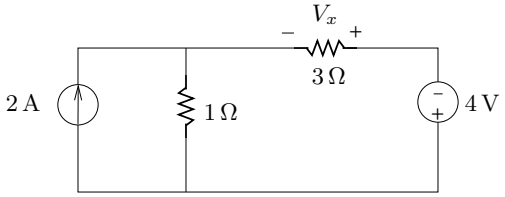
1. Apply superposition to find $V_x$ and $I_x$.

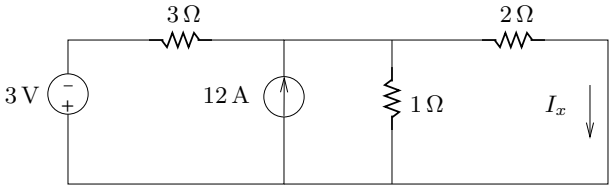


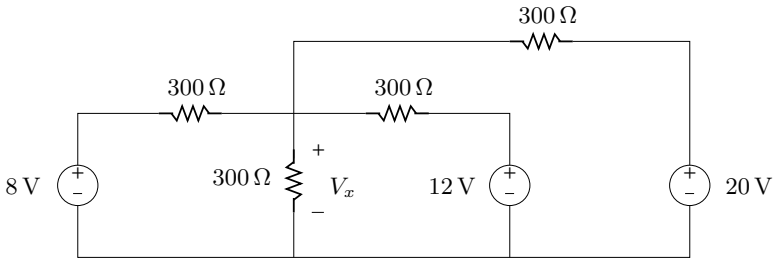

Sample answers: $I_x = -1.5\,\text{A}$.

2. (a) Find $V_x$ using a source transformation and voltage division.
   (b) Find $I_x$ using a source transformation and current division.
   (c) Find $V_x$ and $I_x$ using nodal analysis instead of source transformations.




3. (a) Find $V_x$ using superposition.
   (b) Find $V_x$ using nodal analysis.



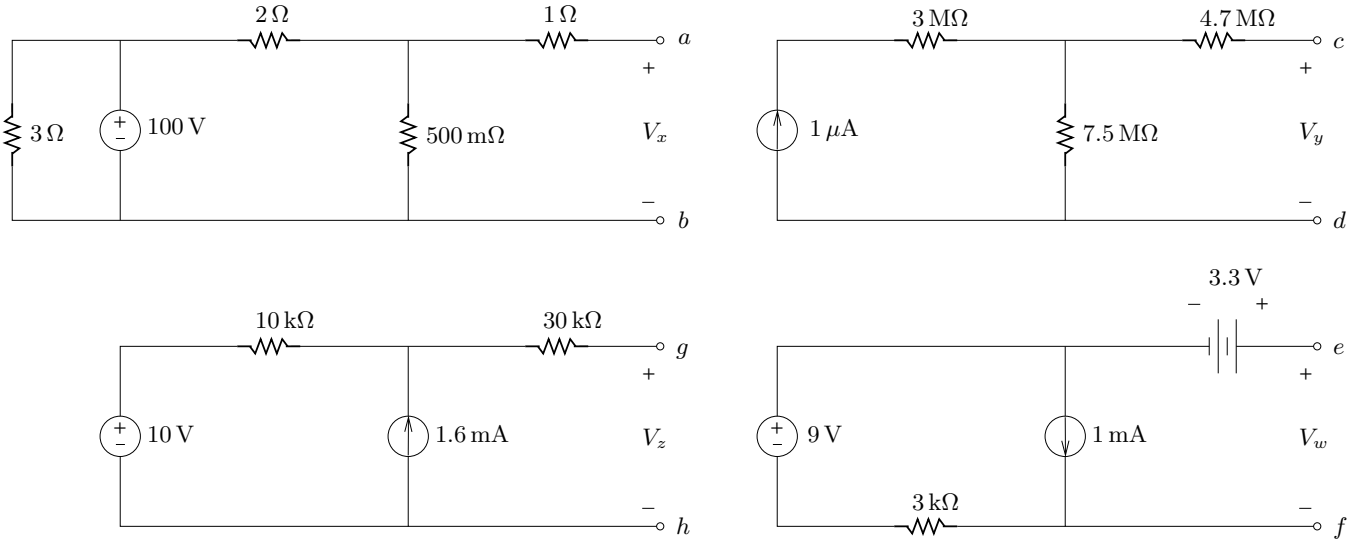
**EEGR2053 Electric Circuits**

## Homework Set 15

*Enter into his gates with thanksgiving, and into his courts with praise: be thankful unto him, and bless his name. Psa 100:4*

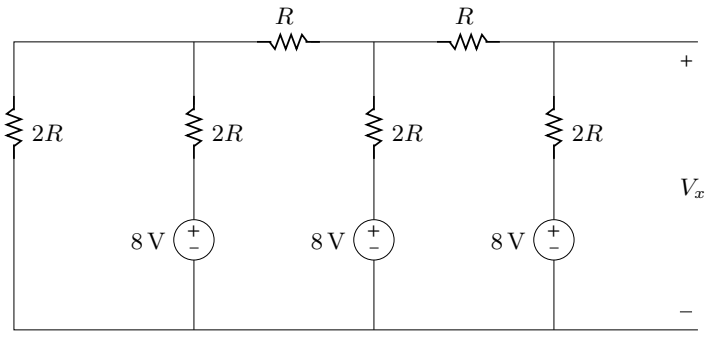
**Suggested Reading:** Section 3-6 Thevenin and Norton Equivalent Circuits.

1. (a) Find the Thevenin equivalent between the points $a$ and $b$.
   (b) Find the Norton equivalent between the points $c$ and $d$.
   (c) Find the Thevenin equivalent between the points $e$ and $f$.
   (d) Find the Norton equivalent between the points $g$ and $h$.




Sample answers: (a) $V_{th} = 20\,\text{V}$ and $R_{th} = 1.4\,\Omega$; (b) $I_n = 614.75\,\text{nA}$; (c) $V_{th} = 9.3\,\text{V}$; (d) $R_n = 40\,\text{k}\Omega$.

2. Find the voltage $V_x$ using nodal analysis or source transformations (by means of successive source transformations. resistor combinations, and source combinations. the circuit can be simplified to the point the value of $V_x$ can be easily calculated).

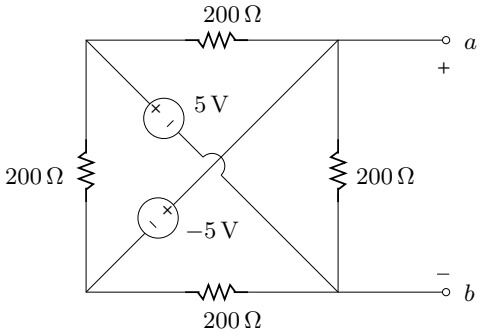


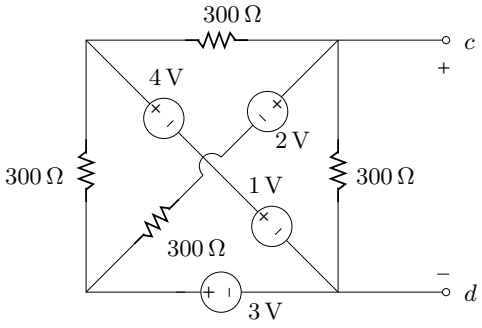

3. (a) Find $V_{th}$ and $R_{th}$ between the points $a$ and $b$.

(b) Find $V_{th}$ and $R_{th}$ between the points $c$ and $d$.

Hint: $V_{th}$ is rather easily found with nodal analysis.

Sample answers: $R_{th} = 100\,\Omega$ at part (b).



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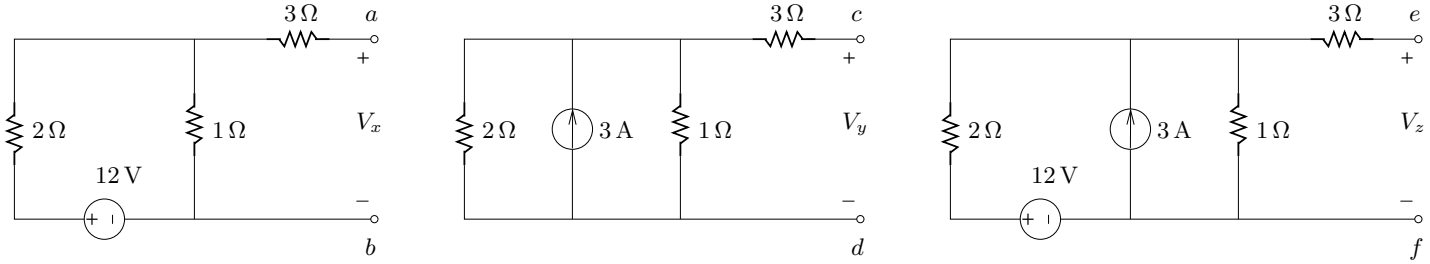
## Homework Set 16

*... he that doeth truth cometh to the light, that his deeds may be made manifest, that they are wrought in God. Jn 3:21*

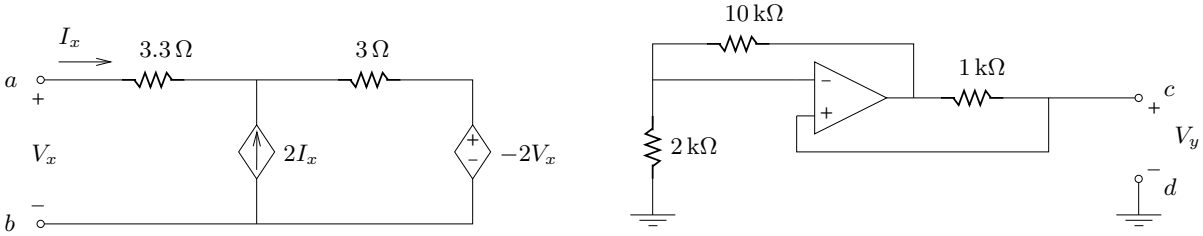
**Suggested Reading:** Section 3-6 Thevenin and Norton Equivalent Circuits.

1. (a) Determine $V_x$.
   (b) Determine $V_y$.
   (c) Determine the Norton equivalent between the points $c$ and $d$.
   (d) Determine $V_z$ using the principle of superposition.
   (e) Determine the Thevenin equivalent between the points $e$ and $f$.



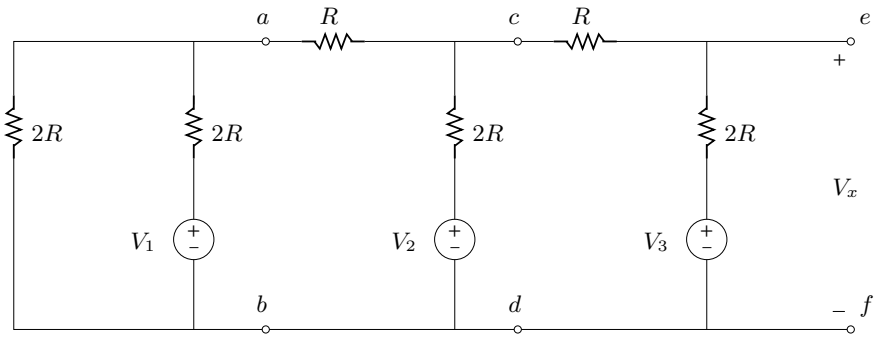

Sample answers: (c) $I_n = 545.5\,\text{mA}$; (d) $6\,\text{V}$; (e) $R_{th} = 3.67\,\Omega$.

2. (a) Find the Thevenin equivalent between the points $a$ and $b$.
   (b) Find the Thevenin equivalent between the points $c$ and $d$. Assume $A = 100$.




Sample answers: (a) $V_{th} = 0$; (b) $R_{th} = -214.6\,\Omega$.

3. (a) Find the Thevenin equivalent of the network located to the left of the points $a$ and $b$.
   (b) Substitute the network to the left of $a$ and $b$ with its Thevenin equivalent. Next, find the Thevenin equivalent of the network located to the left of the points $c$ and $d$.
   (c) Substitute the network to the left of $c$ and $d$ with its Thevenin equivalent. Next, find the Thevenin equivalent of the entire circuit between the points $e$ and $f$.




The circuit shown in the figure could be used as a three-bit digital to analog converter. It carries out the digital to analog conversion by means of a *resistor ladder network*.

Sample answers: (a) $V_{th} = \frac{V_1}{2}$; (b) $V_{th} = \frac{V_1}{4} + \frac{V_2}{2}$; (c) $R_{th} = R$.

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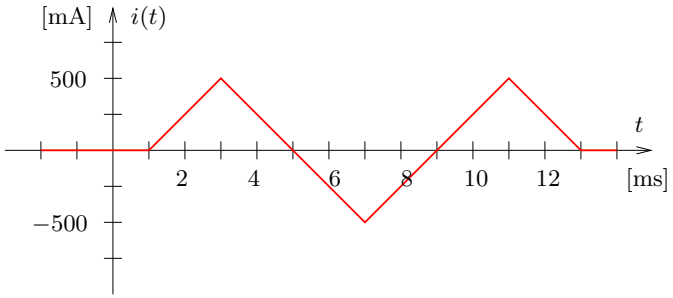
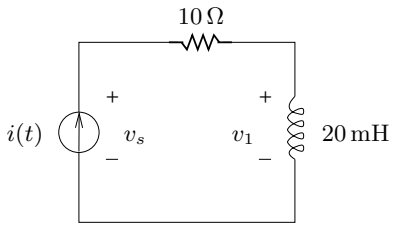
## Homework Set 17

*... the fruit of the Spirit is in all goodness and righteousness and truth. Eph 5:9*

**Suggested Reading:** Section 5-3 Inductors.

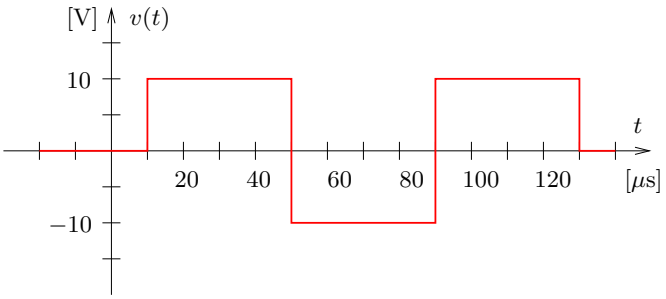
1. (a) Sketch the graph of $v_1(t)$.
   (b) Determine $v_s$ at time $t = 2\,\text{ms}$. Show your work!

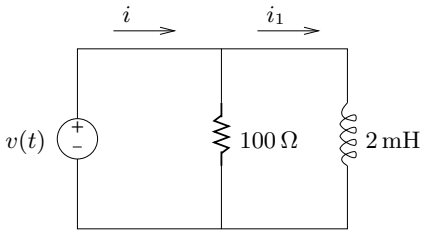



Sample answers: (b) 7.5 V.

2. Assume that $i_1 = -100\,\text{mA}$ at time $t = 0$.

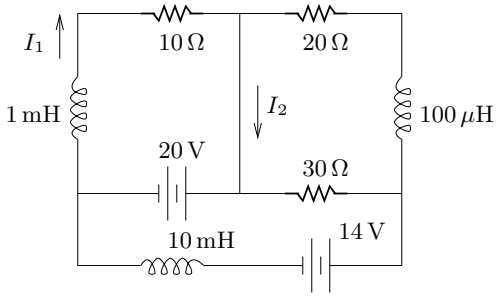



   (a) Sketch the graph of $i_1(t)$.
   (b) Determine $i$ at time $t = 20\,\mu\text{s}$. Show your work!
   (c) Determine the power absorbed by the inductor at time $t = 20\,\mu\text{s}$.

Sample answers: (b) 50 mA.

3. Assume the circuit operates at steady state.



(a) Find the current $I_1$.

(b) Find the current $I_2$.

(c) Find the energy of the 1 mH inductor.

(d) Find the energy of the 100 $\mu$H inductor.

(e) Find the energy of the 10 mH inductor.

Sample answers: (b) $-2.3$ A; (c) 2 mJ; (e) 1.25 mJ.

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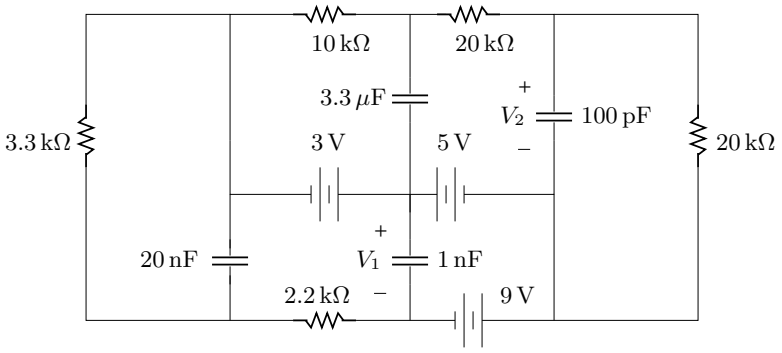
## Homework Set 18

*The LORD is my strength and my song, and he has become my salvation ... Ex 15:2*

**Suggested Reading:** Section 5-2 Capacitors.

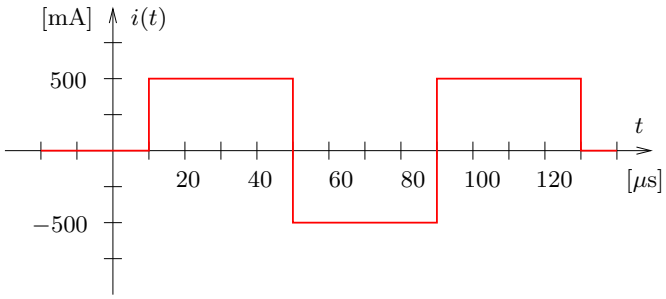
1. Assume the circuit operates at steady state.

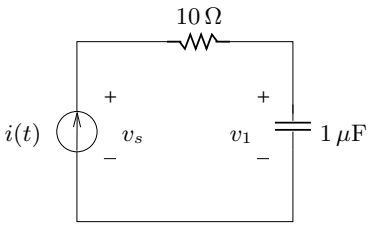



   (a) Find the voltage $V_1$.
   (b) Find the voltage $V_2$.
   (c) Find the energy of the 20 nF capacitor.
   (d) Find the energy of the 100 pF capacitor.
   (e) Find the energy of the 3.3 $\mu$F capacitor.

   Sample answers: (b) $V_2 = 0.8$ V; (c) 435.6 nJ; (e) 19.1 $\mu$J.

2. Assume that $v_1 = -5$ V at time $t = 0$.

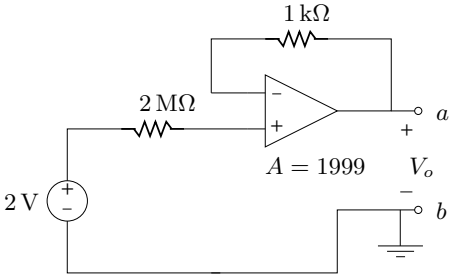


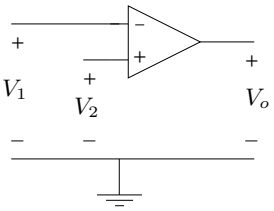



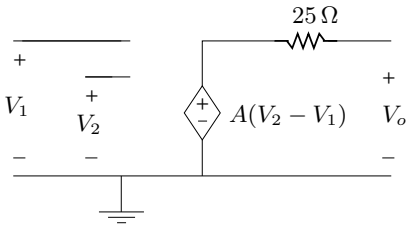

   (a) Sketch the graph of $v_1(t)$.
   (b) Find $v_s$ at time $t = 30\,\mu$s. Show your work!
   (c) Find the power absorbed by the capacitor at time $t = 30\,\mu$s.
   (d) What should be $i(t)$ so that $v_1(t) = 5\cos(100\,t)$ V? Show your work!
   (e) Assume $v_1(t) = 16e^{-t/\tau}$ V, where $\tau = 4\,\mu$s. Find $v_s$ at the time $t = 8\,\mu$s.

   Sample answers: (c) 2.5 W; (d) $-500\sin(100\,t)\,\mu$A.

3. Find the Thevenin equivalent between the points $a$ and $b$. For the operational amplifier assume the enhanced equivalent circuit shown to the right. Note that the equivalent circuit includes a $25\,\Omega$ output resistance.




Sample answers: $R_{th} = 12.5\,\mathrm{m}\Omega$.

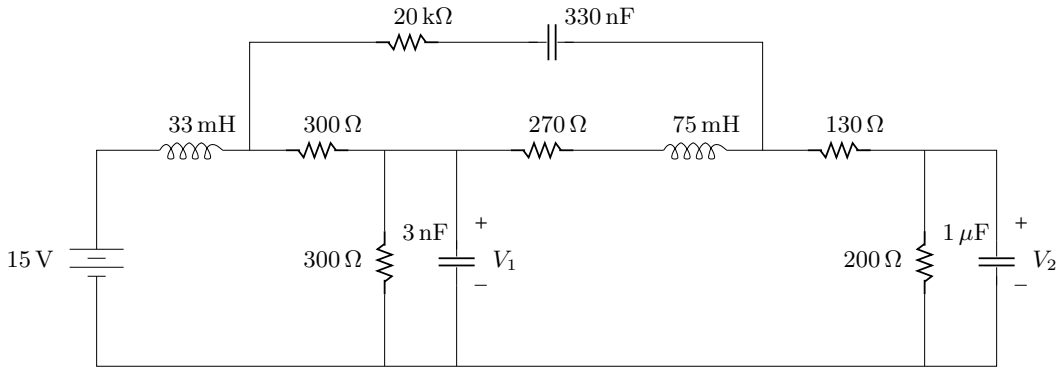
**EEGR2053 Electric Circuits**

## Homework Set 19

*The LORD is good to all: and his tender mercies are over all his works. All thy works shall praise thee, O LORD ... Ps 145:9-10*

**Suggested Reading:** Section 5-2.2 Series and Parallel Combinations of Capacitors; Section 5-3.2 Series and Parallel Combinations of Inductors.

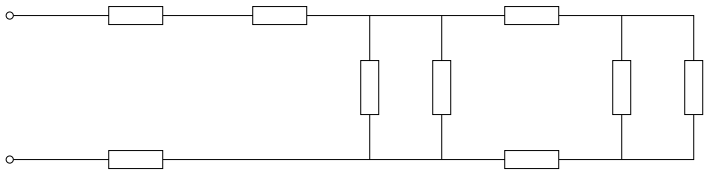
1. Assume the circuit has reached the steady state. Apply voltage division to answer the following questions.




   (a) Find the voltage $V_1$.
   (b) Find the voltage $V_2$.
   (c) Find the energy of the 330 nF capacitor.
   (d) Find the energy of the 75 mH inductor.

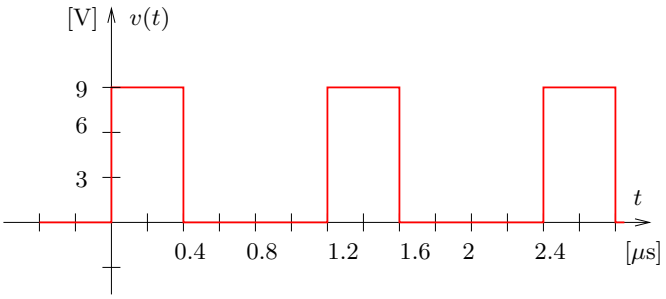
   Sample answers: (c) 22.6 $\mu$J; (d) 3.75 $\mu$J.

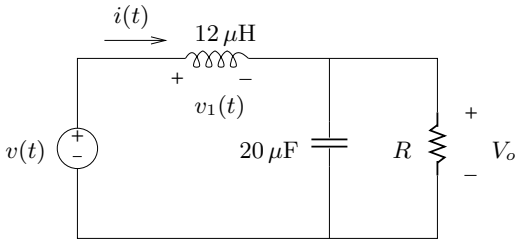
2. (a) If each element is a capacitor of value $C = 82\,\text{nF}$, find the equivalent capacity $C_{eq}$.
   (b) If each element is an inductor of value $L = 1.2\,\text{mH}$, find the equivalent inductance $L_{eq}$.
   (c) If each element is a resistor of value $R = 120\,\Omega$, find the equivalent resistance $R_{eq}$.



   Sample answers: (b) 4.1 mH.

3. The following circuit represents the output stage of a Buck converter (a DC to DC converter).




(a) Draw the graph of $v_1(t)$. Approximate the voltage $V_o$ as a constant of value $V_o = 3\,\text{V}$.

(b) Based on the graph at part (a), draw the graph of the current $i(t)$. Assume that the value of the current $i(t)$ at time 0 is 100 mA.

(c) Find the average value of the current $i(t)$. (You may estimate it from your graph.)

(d) Since $V_o$ is approximately constant, what is the average value of the capacitor current?

(e) Using the average value of the current $i(t)$ and Ohm's law, find the value of the load resistor $R$.

Sample answers: $R = 15\,\Omega$.

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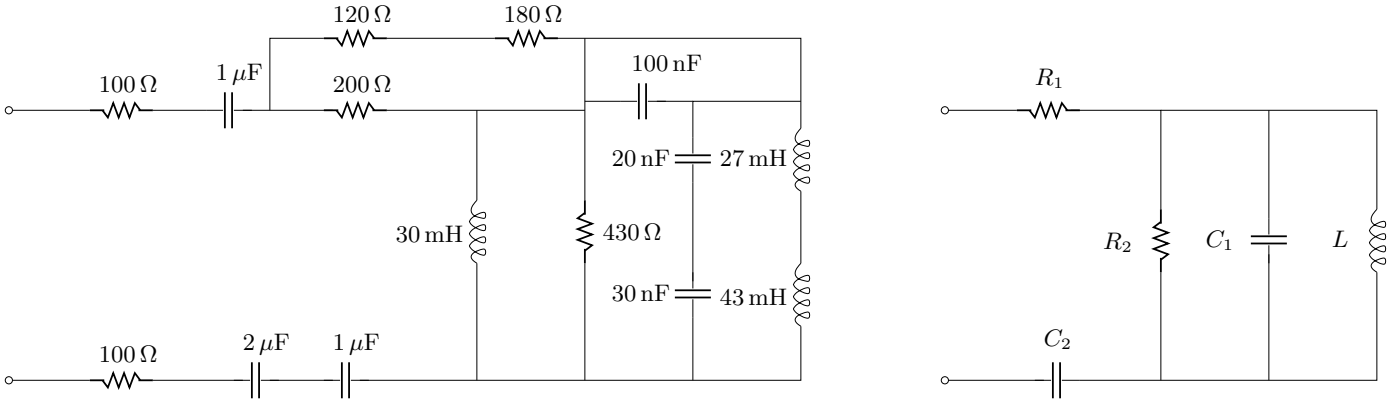
## Homework Set 20

*O LORD, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches. Ps 104:24*

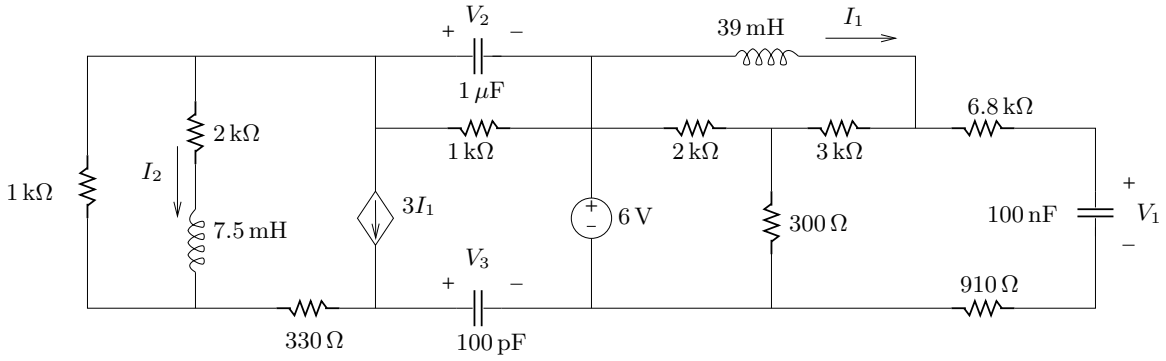
**Suggested Reading:** Section 5-4 Response of the RC Circuit; Section 5-5 Response of the RL Circuit.

1. By combining components of the same type, reduce the circuit shown to the left to the form shown to the right. Find $R_1$, $R_2$, $C_1$, $C_2$, and $L$.




Sample answers: $C_1 = 12\,\text{nF}$; $C_2 = 400\,\text{nF}$.

2. Assume that the following circuit is at the steady state.




(a) Find $V_1$.

(b) Apply current division and/or voltage division to find $I_1$.

(c) Find $V_2$.

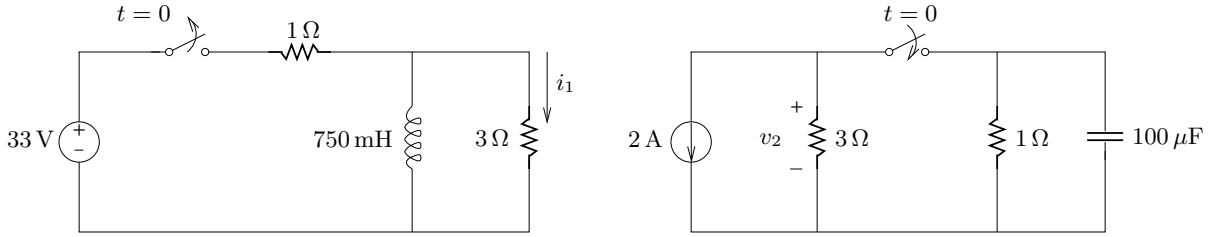
(d) Apply current division to find $I_2$.

(e) Find $V_3$.

(f) Assume that the terminals of the 100 pF capacitor are short-circuited (that is, the two terminals are connected together). Find $I_2$.

Sample answers: (b) $I_1 = 1.6\,\text{mA}$; (c) $V_2 = 0$; (f) $200.3\,\mu\text{A}$.

3. Assume steady-state operation before the time $t = 0$. Show your work.




(a) Find $i_1(0^-)$, $i_1(0^+)$, and $i_1(\infty)$.

(b) Find $v_2(0^-)$, $v_2(0^+)$, and $v_2(\infty)$.

Sample answers: $i_1(0^-) = 0$; $v_2(\infty) = -1.5\,\text{V}$.

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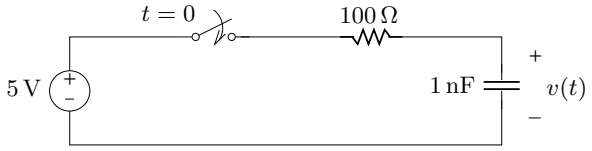
## Homework Set 21

*"... if ye will obey my voice indeed, and keep my covenant, then ye shall be a peculiar treasure unto me above all people: for all the earth is mine: And ye shall be unto me a kingdom of priests, and an holy nation ...". Ex 19:5-6*

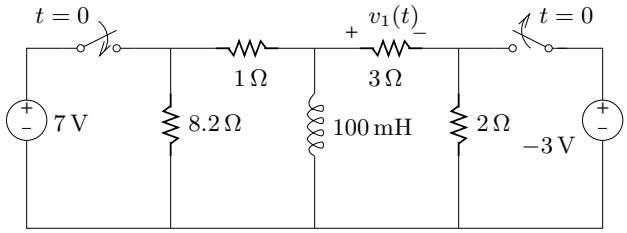
**Suggested Reading:** Section 5-4 Response of the RC Circuit; Section 5-5 Response of the RL Circuit.

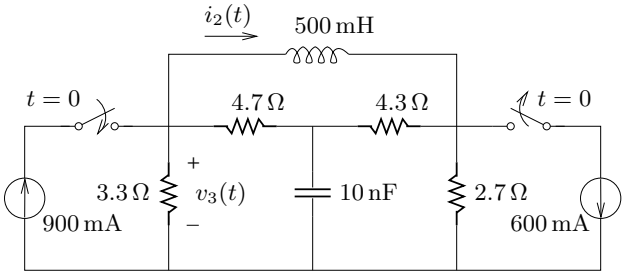
1. (a) Assume $v(0^-) = 1\,\text{V}$. Find the time at which $v(t) = 3\,\text{V}$.
   (b) Assuming the same initial value, find the time at which $v(t) = 4.999\,\text{V}$.
   (c) Assuming the same initial value, draw the graph of $v(t)$ versus $t$ for $t > 0$. Indicate clearly on the graph $v(0^-)$ and $v(\infty)$.
   (d) Assume $v(0^-) = 7\,\text{V}$. Draw the graph of $v(t)$ versus $t$ for $t > 0$. Indicate clearly on the graph $v(0^-)$ and $v(\infty)$.




Sample answers: (b) 829.4 ns.

2. Assume steady-state operation before the time $t = 0$.




   (a) Find $v_1(0^-)$, $v_1(0^+)$, and $v_1(\infty)$.
   (b) Find $i_2(0^-)$, $i_2(0^+)$, and $i_2(\infty)$.
   (c) Find $v_3(0^+)$.

Sample answers: $v_1(0^+) = 4\,\text{V}$; $v_1(\infty) = 0$; $i_2(\infty) = 495\,\text{mA}$.

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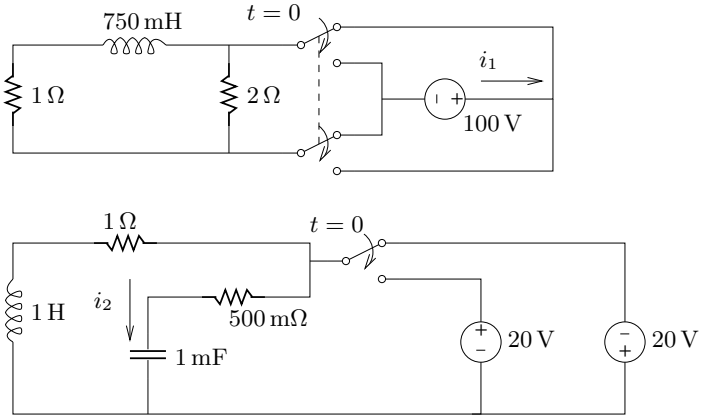
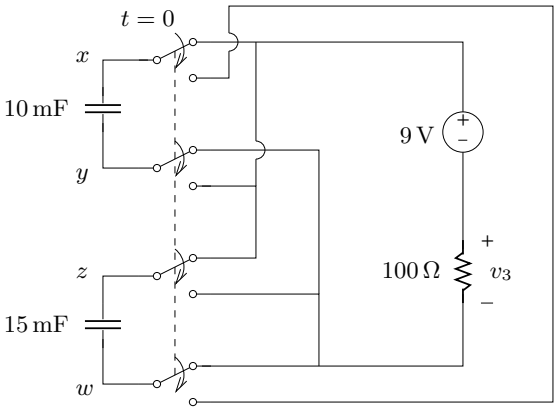
## Homework Set 22

*"... ye are a chosen generation, a royal priesthood, an holy nation, a peculiar people; that ye should shew forth the praises of him who hath called you out of darkness into his marvellous light". 1Pe 2:9*

**Suggested Reading:** Section 5-4 Response of the RC Circuit; Section 5-5 Response of the RL Circuit.

1. Assume steady-state operation before the time $t = 0$.

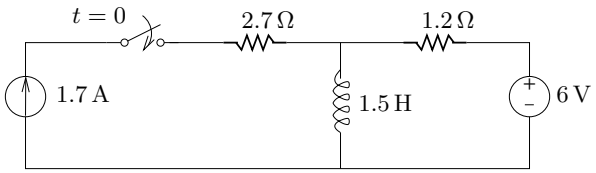


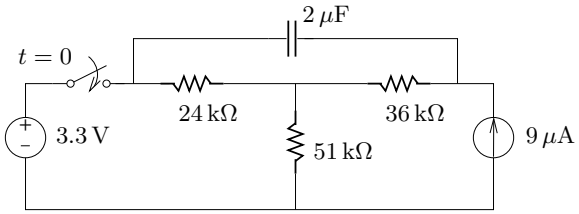

   (a) Find $i_1(0^-)$, $i_1(0^+)$, and $i_1(\infty)$.
   (b) Find $i_2(0^-)$, $i_2(0^+)$, and $i_2(\infty)$.
   (c) Find $v_3(0^-)$, $v_3(0^+)$, and $v_3(\infty)$.

   Sample answers: $i_1(0^+) = -50\,\text{A}$; $i_2(\infty) = 0$; $v_3(0^+) = -27\,\text{V}$.

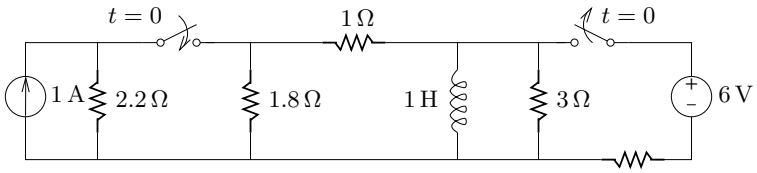
2. Find the time constant of each circuit after time $t = 0$.



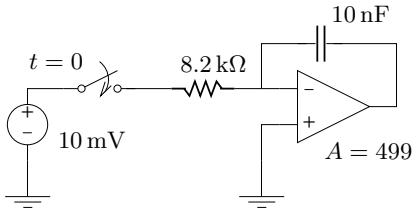

(a)




(c)




(b)




(d)

   Sample answers: (b) 835.85 ms; (c) 104.64 ms.

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## Homework Set 23

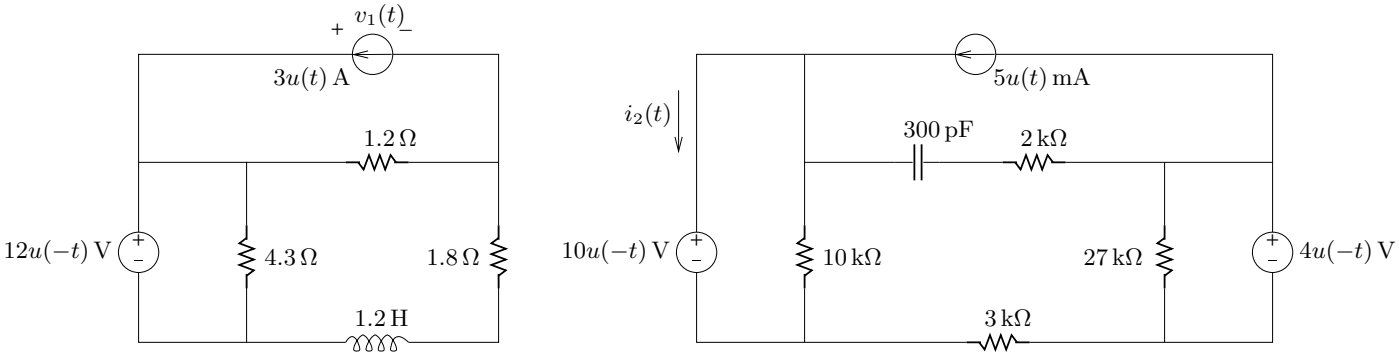
*Let your speech be alway with grace, seasoned with salt, that ye may know how ye ought to answer every man. Col 4:6*

**Suggested Reading:** Section 5-1.1 Step-Function Waveform; Section 7-1 Sinusoidal Signals.

1. (a) Find the frequency, period, and angular frequency of $v(t) = 5\cos(1300t + 30°)$ V.
   (b) Find the value of $v(t) = 5\cos(1300t + 30°)$ V at time $t = 0.5$ ms.
   (c) Find the angle by which $i(t) = 3\cos(1300t - 30°)$ A lags $v(t) = 5\cos(1300t + 30°)$ V.
   (d) Find the angle by which $i(t) = 3\cos(1300t - 30°)$ A lags $v_1(t) = 5\sin(1300t + 30°)$ V.
   (e) Find the angle by which $i(t) = 3\cos(1300t - 30°)$ A leads $v_2(t) = 5\cos(1300t - 50°)$ V.
   (f) Find the angle by which $i(t) = 3\cos(1300t - 30°)$ A leads $i_1(t) = -2.3\cos(1300t - 70°)$ A.

   Sample answers: (d) $-30°$; (e) $20°$.

2. (a) Find $v_1(0^-)$, $v_1(0^+)$, and $v_1(\infty)$.
   (b) Find the time constant of $v_1(t)$.
   (c) Find $v_1(t)$ for all $t > 0$.
   (d) Find $i_2(0^-)$, $i_2(0^+)$, and $i_2(\infty)$.
   (e) Find the time constant of $i_2(t)$.
   (f) Find $i_2(t)$ for all $t > 0$.




Selected answers: $v_1(0^-) = 4.8$ V, $i_2(0^+) = 3.2$ mA, at part (e) $\tau = 1.5\,\mu$s.

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## Homework Set 24

*... whosoever drinketh of the water that I shall give him shall never thirst; but the water that I shall give him shall be in him a well of water springing up into everlasting life. Jn 4:14*

**Suggested Reading:** Section 7-1 Sinusoidal Signals; Section 7-2 Review of Complex Algebra.

1. Answer the following questions without using an advanced calculator. You may verify your answers with an advanced calculator. *Angles should be in degrees and in the range* $-180°$ *to* $180°$.

   (a) Convert the following numbers to the polar form.
   (i) $-4-j5$; (ii) $2-j$; (iii) $1+j2$; (iv) $-3-j4$; (v) $-3+j4$; (vi) 30; (vii) $-j5$.

   (b) Convert the following numbers to the rectangular form.
   (i) $-5\angle 230°$; (ii) $6\angle 75°$; (iii) $9\angle -90°$; (iv) $5\angle 0°$; (v) $-8\angle -45°$; (vi) $6e^{j20°}$.

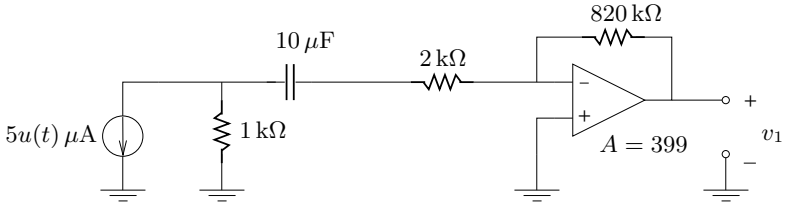
   (c) Obtain the result in polar form.
   (i) $3e^{j90°}-4e^{-j90°}$; (ii) $(5\angle 30°)+2e^{-j60°}$; (iii) $-j+2e^{j150°}$; (iv) $3\angle 60°-3\angle 120°-9\angle 180°$.

   Sample answers: (a) $-4-j5 = 6.40\angle -128.66°$; (b) $-5\angle 230° = 3.214+3.83j$; (c) $3\angle 60°-3\angle 120°-9\angle 180° = 12\angle 0°$.

2. (a) Find $v_1(0^-)$, $v_1(0^+)$, $v_1(\infty)$, and $\tau$.

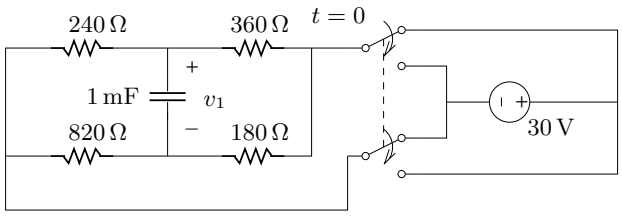
   (b) Find $v_1(t)$ for all $t > 0$.

   (c) Assuming $A \to \infty$, find $v_1(0^-)$, $v_1(0^+)$, $v_1(\infty)$, and $\tau$.
   Hint: Denoting by $v_+$ and $v_-$ the voltages on the + and − inputs of the amplifier, when $A \to \infty$ it is convenient to use the equation $v_+ - v_- = \frac{v_o}{A} = \frac{v_o}{\infty} = 0$ instead of $v_o = A(v_+ - v_-)$.




   Sample answers: (a) $v_1(0^+) = 809.95\,\text{mV}$; (c) $\tau = 30\,\text{ms}$.

3. Assume the circuit is at the steady state before time $t = 0$.




   (a) Find $v_1(0^-)$, $v_1(0^+)$, and $v_1(\infty)$.

(b) Find the time constant.

(c) Find $v_1(t)$ for all $t > 0$.

Sample answers: $v_1(0^+) = -12.6\,\mathrm{V}$; $\tau = 291.6\,\mathrm{ms}$.

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## Homework Set 25

*The mouth of a righteous* man is *a well of life: but violence covereth the mouth of the wicked. Pr 10:11*

**Suggested Reading:** Section 7-3 Phasor Domain.

1. Let $w(t) = -3\sin(100t + 30°)$, $x(t) = 5\sin(100t) + 10\cos(100t + 30°)$, $y(t) = 5\cos(100t + 20°) - 2\sin(100t + 65°)$, and $z(t) = -8\cos(300t + 60°)$.

   (a) Find the frequency of $w(t)$ and the period of $z(t)$.

   (b) Write $w$, $x$, $y$, and $z$ in phasor form.

   (c) Find $w(t)$ at $t = 15\,\text{ms}$.

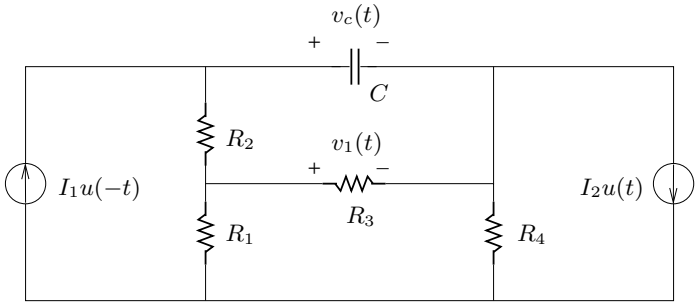
   (d) Given the phasors $\mathbf{A} = 5 - 5j$ and $\mathbf{B} = 10 + 2j$, find $a(t)$ and $b(t)$. Assume $\omega = 330\,\text{rad/s}$.

   (e) Obtain the result in rectangular form without an advanced calculator.

   (i) $\dfrac{1+j2}{2+j3}$; (ii) $\dfrac{5-j4}{-3-2e^{-j20°}}$; (iii) $6\angle 45° - 8\angle 40°$; (iv) $\dfrac{(1+j4)^2}{5-j4}\cdot e^{j30°}$; (v) $j\cdot\left(10 - \dfrac{3}{j^3}\right)$.

   Sample answers: (a) $T = 20.94\,\text{ms}$; (b) $\mathbf{W} = 3\angle 120°$, $\mathbf{Y} = 3.85\angle 41.52°$; (c) At $t = 15\,\text{ms}$, $w(t) = -2.7$; (d) $b(t) = 10.2\cos(330t + 11.31°)$; (e) $\dfrac{1+j2}{2+j3} = 0.615 + 0.0769j$.

2. Assume $R_1 = 1.7\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$, $R_3 = 3\,\text{k}\Omega$, $R_4 = 4.3\,\text{k}\Omega$, $C = 10\,\mu\text{F}$, $I_1 = 1.8\,\text{mA}$, and $I_2 = -2.88\,\text{mA}$.




   (a) Find $v_c(0^-)$ and $v_1(0^-)$.

   (b) Find $v_c(0^+)$ and $v_1(0^+)$.

   (c) Find $v_c(\infty)$ and $v_1(\infty)$.

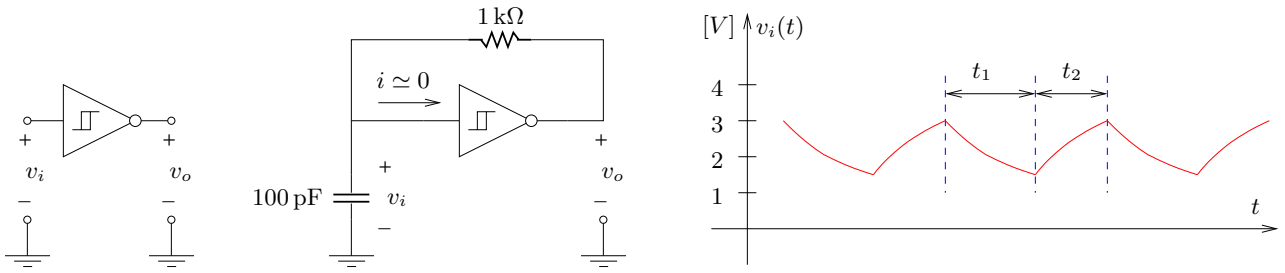
   (d) Find the time constant.

   Sample answers: $v_1(0^+) = 246\,\text{mV}$; $\tau = 40\,\text{ms}$.

3. The component shown in the left-hand side of the figure is equivalent to an electronic switch that switches the voltage $v_o$ between $v_o = 0$ and $v_o = 5\,\text{V}$ according to the following rules:

   - If $v_o = 5\,\text{V}$ and $v_i \geq 3\,\text{V}$, then $v_o$ is switched to $v_o = 0$.
   - If $v_o = 0$ and $v_i \leq 1.5\,\text{V}$, then $v_o$ is switched to $v_o = 5\,\text{V}$.

By adding a resistor and a capacitor as in the figure, an oscillator is obtained. It works as follows. When $v_o = 5\,\text{V}$, the capacitor charges until $v_i = 3\,\text{V}$. Then, $v_o$ is switched to $v_o = 0$ and the capacitor discharges until $v_i = 1.5\,\text{V}$. Then, $v_o$ is switched back to $v_o = 5\,\text{V}$ and the charge/discharge cycle repeats.




(a) Sketch $v_o(t)$ and $v_i(t)$ on the same graph.

(b) Find the interval of time $t_1$ shown in the figure. (Neglect the current $i$.)

(c) Find the interval of time $t_2$ shown in the figure. (Neglect the current $i$.)

(d) Find the frequency of $v_i(t)$ and $v_o(t)$.

Note that the component described in this problem is known as a *Schmitt trigger*.

Sample answers: (d) 7.982 MHz.

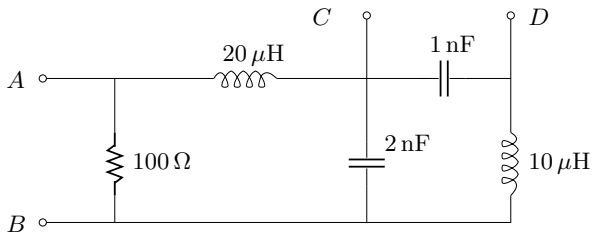
**EEGR2053 Electric Circuits**

## Homework Set 26

*But godliness with contentment is great gain. For we brought nothing into this world, and it is certain we can carry nothing out. 1Ti 6:6-7*

**Suggested Reading:** Section 7-3 Phasor Domain; Section 7-4 Phasor Domain Analysis; Section 7-5 Impedance Transformations.

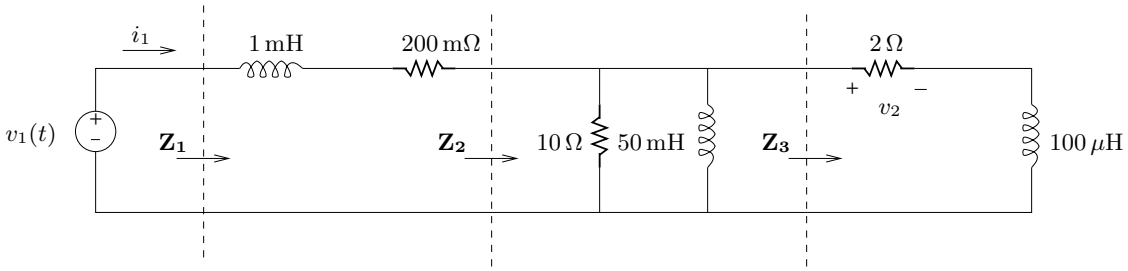
1. Assume $\omega = 10^7$ rad/s.




   (a) Find the impedance between the points $A$ and $B$ in rectangular form.
   (b) Find the admittance between the points $D$ and $C$ in rectangular form.
   (c) Find the resistance $R$ and the reactance $X$ between the points $B$ and $D$.

   Sample answers: (b) $\mathbf{Y_{CD}} = 5 - 15j$ mS; (c) $X = 260\,\Omega$.

2. Assume $v_1(t) = 100\cos(\omega t)$ V and a 60 Hz frequency.




   (a) Find $\mathbf{Z_1}$, $\mathbf{Z_2}$, and $\mathbf{Z_3}$ in polar form.
   (b) Find $i_1(t)$.
   (c) Find $v_2(t)$ using voltage division.
   (d) What should be $v_1(t)$ so that $v_2(t) = 50\cos(\omega t)$ V?

   Sample answers: $\mathbf{Z_3} = 2\angle 1.08°\,\Omega$, $i_1(t) = 51.84\cos(\omega t - 16.53°)$ A, and $v_1(t) = 58.17\cos(\omega t + 11.66°)$ V.

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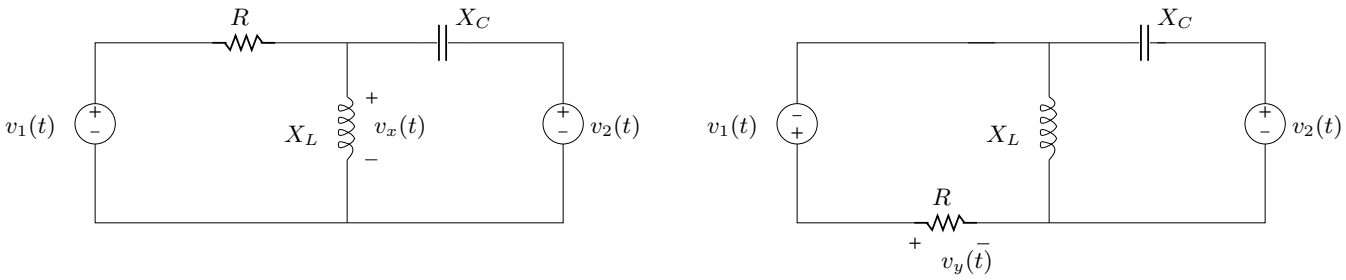
## Homework Set 27

*... I have learned, in whatsoever state I am,* therewith *to be content. Php 4:11*

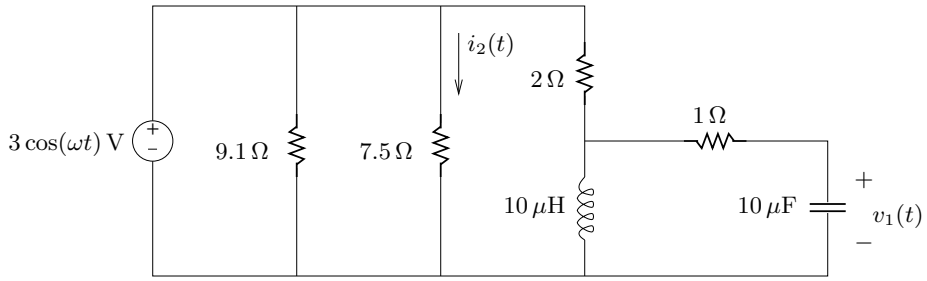
**Suggested Reading:** Section 7-4 Phasor Domain Analysis; Section 7-5 Impedance Transformations; Section 7-6 Equivalent Circuits; Section 7-9 Phasor-Domain Analysis Techniques.

1. Let $X_L$ and $X_C$ denote the reactances of the inductor and capacitor, respectively. Assume $R = X_L = 100\,\Omega$, $X_C = -100\,\Omega$, $v_1(t) = 10\cos(\omega t)$ V, and $v_2(t) = 10\cos(\omega t - 90°)$ V. Find $v_x(t)$ and $v_y(t)$ using nodal analysis.



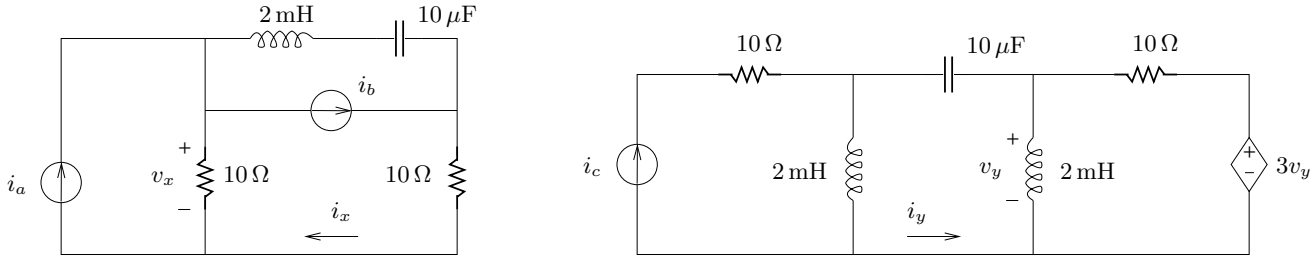

Sample answers: $v_y(t) = 10\cos(\omega t)$ V.

2. Apply voltage and/or current division to find $v_1(t)$ and $i_2(t)$. Assume $f = \dfrac{10^5}{2\pi}$ Hz.




Sample answers: $i_2(t) = 400\cos(\omega t)$ mA.

3. Find $i_x(t)$, $v_x(t)$, $i_y(t)$, and $v_y(t)$ using mesh analysis. Assume $i_a(t) = i_c(t) = 100\cos(\omega t - 30°)$ mA, $i_b(t) = 50\cos(\omega t)$ mA, and a frequency $f = \dfrac{10}{2\pi}$ kHz.




Sample answers: $i_x = 38.73\cos(\omega t - 26.57°)$ mA and $v_y = 800\cos(\omega t + 113.13°)$ mV.

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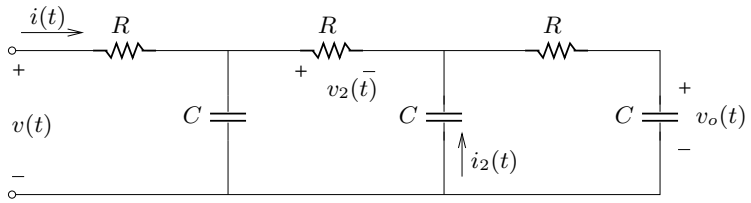
## Homework Set 28

*Not that we are sufficient of ourselves to think any thing as of ourselves; but our sufficiency* is *of God; 2Co 3:5*

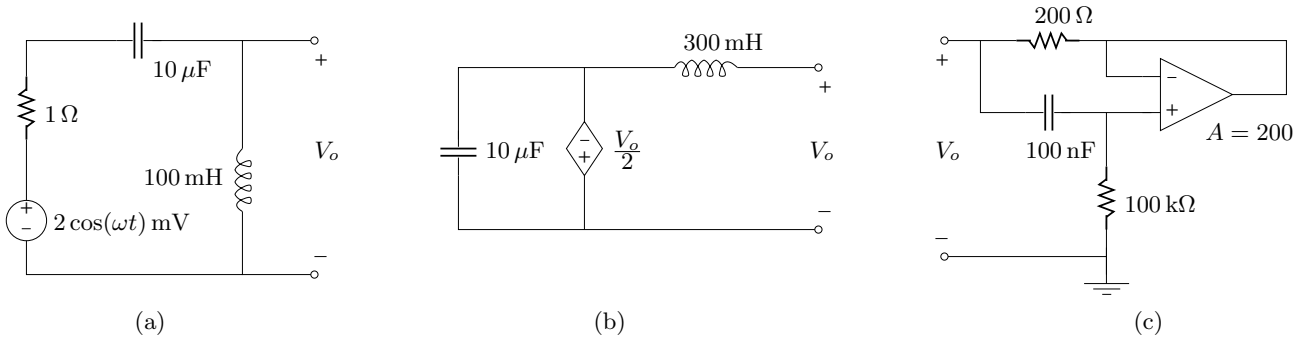
**Suggested Reading:** Section 7-4 Phasor Domain Analysis; Section 7-5 Impedance Transformations; Section 7-7 Phasor Diagrams; Section 7-9 Phasor-Domain Analysis Techniques.

1. Apply impedance combinations and voltage division and/or current division to find $i(t)$, $v_2(t)$, $i_2(t)$, and $v_o(t)$. Assume $v(t) = 6\cos(\omega t)\,\text{V}$, $f = 500\,\text{kHz}$, $R = 1\,\text{k}\Omega$, and $C = 1\,\text{nF}$.



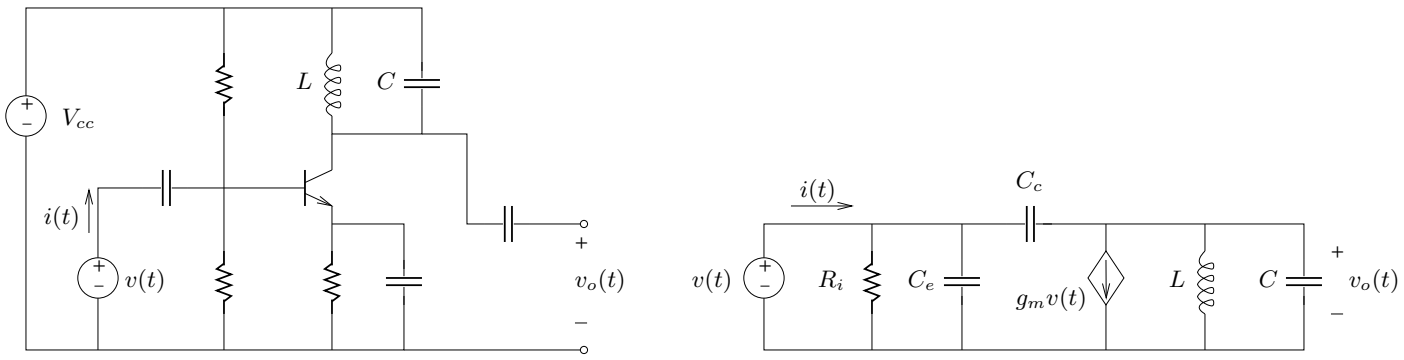

   Sample answers: $i(t) = 5.42\cos(\omega t + 14.55°)\,\text{mA}$; $v_2(t) = 1.41\cos(\omega t - 46.60°)\,\text{V}$.

2. Find the Thevenin equivalent in each case. Assume $\omega = 10^3\,\text{rad/s}$.




   Sample answers: (a) $v_{th} = 200\cos(\omega t + 90°)\,\text{mV}$; (c) $\mathbf{Z_{th}} = 2.01\angle 80.30°\,\text{k}\Omega$.

3. The *tuned amplifier* shown to the left has the equivalent circuit shown to the right. Assume $v(t) = 100\cos(\omega t)\,\mu\text{V}$, $f = 2\,\text{GHz}$, $R_i = 100\,\Omega$, $C_e = C_c = 0.5\,\text{pF}$, $g_m = 4\,\text{S}$, $L = 30\,\text{nH}$, and $C = 3\,\text{pF}$.




   (a) Find $v_o(t)$ using nodal analysis.

(b) Find $i(t)$.

Sample answers: $i(t) = 61.82\cos(\omega t + 1.08°)\,\mu\text{A}$.

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## Homework Set 29

*The LORD* is *good unto them that wait for him, to the soul* that *seeketh him. Lam 3:25*

**Suggested Reading:** Section 7-6 Equivalent Circuits; Section 7-7 Phasor Diagrams; Section 7-9 Phasor-Domain Analysis Techniques; Section 4-3 Ideal Op-Amp Model.

1. Assume $i_1(t) = 2\cos(\omega t)$ A, $i_2(t) = 6\cos(\omega t + 120°)$ A, and $i_3(t) = 6\cos(\omega t - 120°)$ A. Obtain the amplitude and phase angle of $i(t) = i_1(t) + i_2(t) + i_3(t)$ using the following procedure.

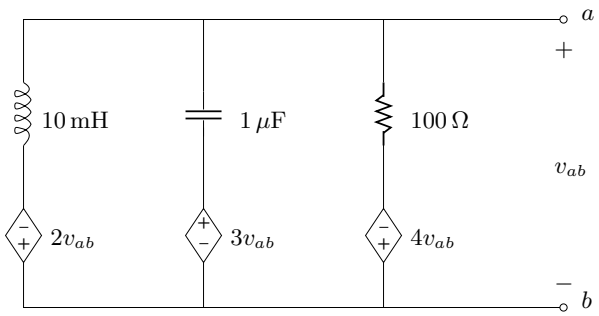
   (a) Using $\mathbf{I_1}$ as a reference, obtain a phasor diagram showing $\mathbf{I_1}$, $\mathbf{I_2}$, and $\mathbf{I_3}$.

   (b) Find $\mathbf{I} = \mathbf{I_1} + \mathbf{I_2} + \mathbf{I_3}$ based on the phasor diagram and geometrical considerations.

   (c) Determine $i(t)$ based on its phasor representation found at (b).

   Sample answer: $\mathbf{I} = 4\angle 180°$ A or $-4$ A. $i(t) = 4\cos(\omega t + 180°)$ A.

2. Find $\mathbf{V_{th}}$ and $\mathbf{Z_{th}}$ assuming a frequency $f = 2$ kHz.

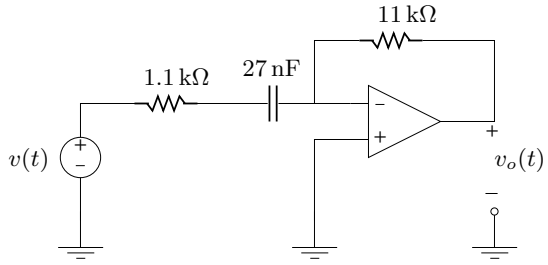



   Sample answers: $\mathbf{Z_{th}} = 14.3\angle 44.4° \, \Omega$.

3. Assume $v(t) = 10\cos(\omega t)$ mV and $f = 2.807$ kHz.

   (a) Find $v_o(t)$ when $A = 10$.

   (b) Find $v_o(t)$ when $A \to \infty$.




   Sample answer: (b) $v_o(t) = 46.4\cos(\omega t - 117.65°)$ mV.

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## Homework Set 30

Oh *how great* is *thy goodness, which thou hast laid up for them that fear thee;* which *thou hast wrought for them that trust in thee before the sons of men! Ps 31:19*

**Suggested Reading:** Section 7-6 Equivalent Circuits; Section 7-7 Phasor Diagrams; Section 8-2 Average power.

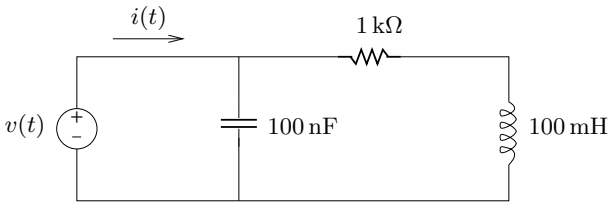
1. Assume $v(t) = 50\cos(\omega t)\,\text{V}$, where $f = \dfrac{10}{2\pi}\,\text{kHz}$.

   (a) Find $i(t)$.

   (b) Find the instantaneous power $p(t)$ that is generated by the source at time $t_1 = 14\,\text{s}$.

   (c) Find the instantaneous power $p(t)$ that is generated by the source at time $t_2 = 18\,\text{s}$.

   (d) Find the average power generated by the source.




   Sample answers: $i(t) = 35.36\cos(\omega t + 45°)\,\text{mA}$ and $p(t_1) = -257.45\,\text{mW}$.

2. Assume $v_1(t) = 20\sin(\omega t + 45°)\,\text{V}$, $v_2(t) = 20\sin(\omega t + 135°)\,\text{V}$, and $v_3(t) = 20\sin(\omega t - 90°)\,\text{V}$. Obtain the amplitude and phase angle of $v(t) = v_1(t) + v_2(t) + v_3(t)$ using the following procedure.

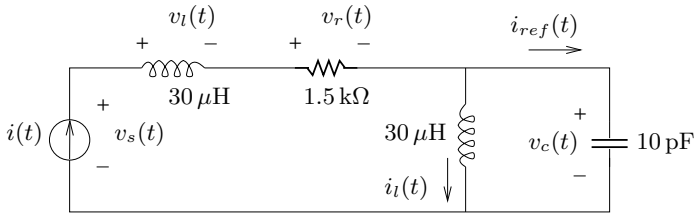
   (a) Using $\mathbf{V_1}$ as a reference, obtain a phasor diagram showing $\mathbf{V_1}$, $\mathbf{V_2}$, and $\mathbf{V_3}$.

   (b) Find $\mathbf{V} = \mathbf{V_1} + \mathbf{V_2} + \mathbf{V_3}$ based on the phasor diagram and geometrical considerations.

   (c) Determine $v(t)$ based on its phasor representation found at (b).

   Sample answer: $v(t) = 8.28\sin(\omega t + 90°)\,\text{V}$ or $8.28\cos(\omega t)\,\text{V}$.

3. Assume $i_{ref}(t) = 6\cos(\omega t)\,\text{mA}$, where the frequency is $f = \dfrac{100}{2\pi}\,\text{MHz}$. Using $\mathbf{I_{ref}}$ as a reference, obtain a phasor diagram showing $\mathbf{I_{ref}}$, $\mathbf{V_c}$, $\mathbf{I_l}$, $\mathbf{I}$, $\mathbf{V_r}$, $\mathbf{V_l}$, and $\mathbf{V_s}$. Find the magnitude and angle of $\mathbf{V_s}$ based on the phasor diagram and geometrical considerations. You could use 2 mA/in and 4 V/in on the phasor diagram.




   Sample answers: $\mathbf{V_s} = 8.49\angle 45°\,\text{V}$.

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## Homework Set 31

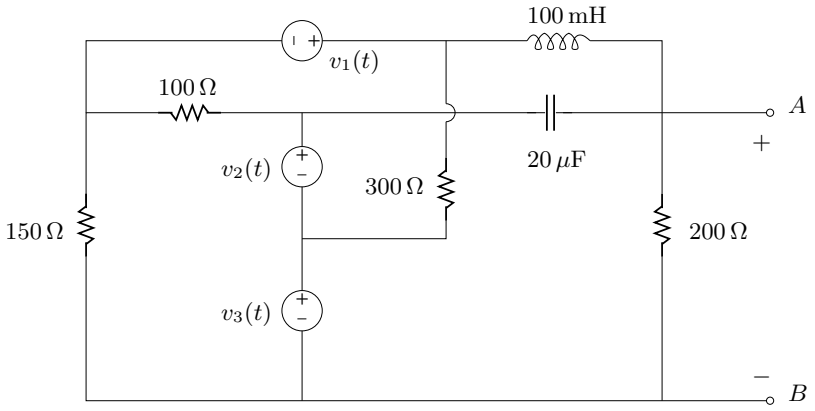
*My flesh and my heart faileth:* but *God* is *the strength of my heart, and my portion for ever. Psa 73:26*

**Suggested Reading:** Section 7-6 Equivalent Circuits; Section 8-2 Average power.

1. Assume $v_1(t) = 24\cos(500t)\,\text{V}$ and $v_2(t) = v_3(t) = 10\cos(500t)\,\text{V}$.

   (a) For each of the following methods indicate whether it can be applied to find the voltage between the terminals $A$ and $B$: nodal analysis, mesh analysis, current division, voltage division, source transformations.

   (b) Find $\mathbf{V_{th}}$ and $\mathbf{Z_{th}}$ in the frequency domain.



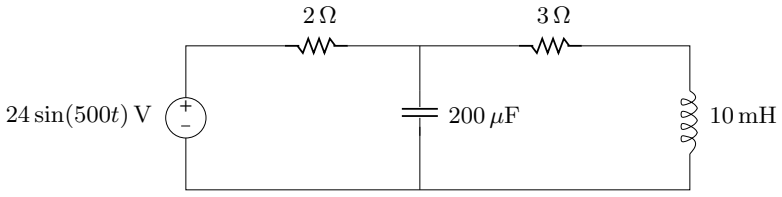

   Sample answers: $\mathbf{V_{th}} = 22.5\angle -20.2°\,\text{V}$.

2. (a) Find the average power absorbed by the 2 Ω resistor.

   (b) Find the average power absorbed by the 3 Ω resistor.

   (c) Find the average power delivered by the source.

   (d) Should the result at part (c) equal the sum of the results at parts (a) and (b)? Why or why not?




   Sample answers: (b) 18.24 W.

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## Homework Set 32

*He giveth power to the faint; and to them that have no might he increaseth strength. Isa 40:29*

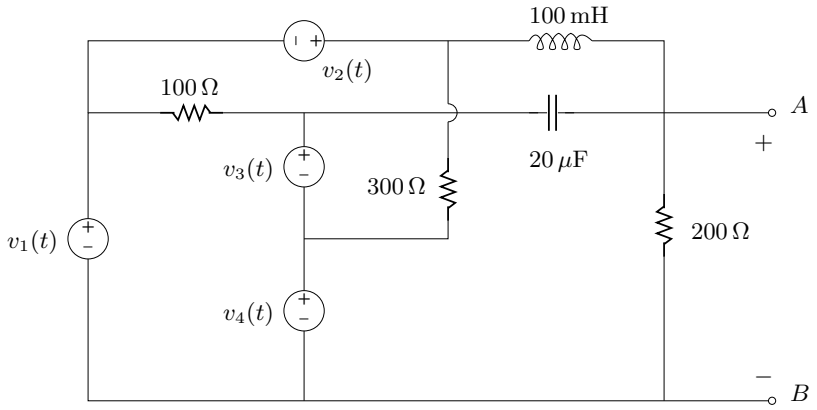
**Suggested Reading:** Section 7-6 Equivalent Circuits; Section 8-1.2 Root-Mean-Square (rms) Value; Section 8-2 Average power.

1. Assume $v_1(t) = v_2(t) = 24\cos(500t)\,\text{V}$ and $v_3(t) = v_4(t) = 10\cos(500t)\,\text{V}$.

   (a) For each of the following methods indicate whether it can be applied to find the voltage between the terminals $A$ and $B$: nodal analysis, mesh analysis, current division, voltage division, source transformations.

   (b) Find $\mathbf{V_{th}}$ and $\mathbf{Z_{th}}$ in the frequency domain.

   (c) Assume an impedance $\mathbf{Z} = 100\angle -45^\circ\,\Omega$ is connected between the terminals $A$ and $B$. Using the Thevenin equivalent found at part (b), find the average power dissipated on the impedance $\mathbf{Z}$.




   Sample answers: $\mathbf{V_{th}} = 68\angle -26.6^\circ\,\text{V}$.

2. Two electric loads are connected in parallel to a source of value $v(t) = 300\cos(380t)\,\text{V}$. The first load absorbs 3 kW at a power factor of 0.5 lagging. The second load absorbs 4 kW at a power factor of 0.8 leading.

   (a) Find the current $\mathbf{I_1}$ through the first load.

   (b) Find the total current $\mathbf{I}$.

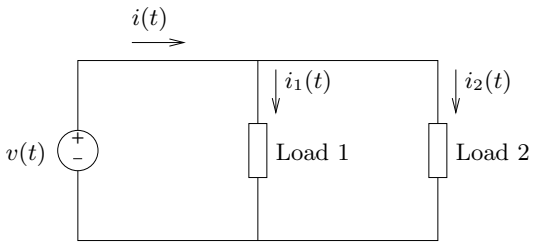
   (c) Find the total apparent power.

   (d) Find the total average power.

   (e) Find the overall power factor of the two loads.

   (f) Find the total instantaneous power delivered by the source at time $t = 1\,\text{s}$.

   (g) Find the total impedance of the two loads. Write the result in polar form.




Sample answers: (a) $\mathbf{I_1} = 40\angle -60^\circ$ A; (c) $S = 7.336\,\text{kVA}$; (e) 0.954 lagging; (f) $p = 13.18\,\text{kW}$.

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## Homework Set 33

*. . . I take pleasure in infirmities, in reproaches, in necessities, in persecutions, in distresses for Christ's sake: for when I am weak, then am I strong. 2Co 12:10*

**Suggested Reading:** Section 8-3 Complex Power; Section 8-4 The Power Factor.

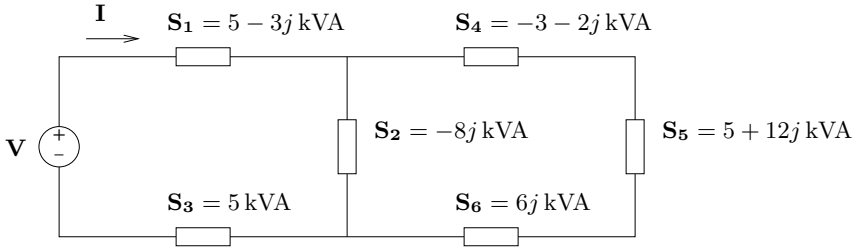
1. The figure shows the power delivered to each load. Assume $v(t) = 300\cos(380t)$ V.

   (a) Find the apparent power delivered by the source.

   (b) Find the average power delivered by the source.

   (c) Find the power factor of the source.

   (d) Find the current $\mathbf{I}$.




   Sample answers: $\mathbf{I} = 86.67\angle -22.62°$ A.

2. A 5 kW load is connected to a source $v(t) = 300\cos(380t)$ V. The load operates at a power factor of 0.6 lagging.

   (a) Find the effective current of the load.

   (b) A capacitor is connected in parallel to the load in order to correct the power factor. Find the value of the capacitor so that the total power factor is 1.

   (c) Find the effective current of the capacitor.

   (d) Find the total impedance.

   (e) Find the total effective current of the source.

   (f) Based on the effective values of the currents, find the apparent power $S$ delivered by the source, the apparent power $S_c$ absorbed by the capacitor, and the apparent power $S_l$ absorbed by the load.

   (g) Should $S$ equal $S_c + S_l$? Why or why not?

   Sample answers: (a) $I_l = 39.28$ A rms; (c) $I_c = 31.43$ A rms; (e) $I_t = 23.57$ A rms; (f) $S = 5$ kVA.

3. The figure shows the power delivered to each load. Assume $v(t) = 300\cos(380t)$ V.

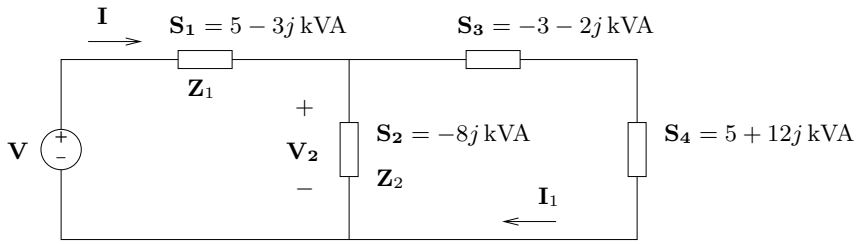
   (a) Find $\mathbf{I}$.

   (b) Find $\mathbf{Z_1}$.

(c) Find $\mathbf{V_2}$.

(d) Find $\mathbf{Z_2}$.

(e) Find $\mathbf{I}_1$.




Sample answers: $\mathbf{I} = 47.14\angle 8.13^\circ$ A and $\mathbf{Z_2} = 900\angle -90^\circ\,\mathrm{m}\Omega$.

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## Homework Set 34

*And let us not be weary in well doing: for in due season we shall reap, if we faint not. Gal 6:9*

**Suggested Reading:** Section 10-3 Y-Y Configuration; Section 10-4 Balanced Networks.

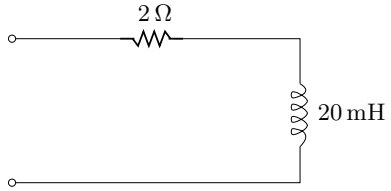
1. A load connected to a source of 120 V rms and 60 Hz. The load dissipates an average power of 2 kW at a power factor of 0.7 lagging.

   (a) Assume a capacitor is connected in parallel to the load. For what value of the capacitor is the power factor 0.9 lagging?

   (b) For what value of the capacitor is the power factor 0.9 leading?

   Selected answers: (b) 554.3 $\mu$F.

2. Balanced three-phase circuits can be studied as single-phase circuits by considering their equivalent circuit per phase. The following figure shows the equivalent circuit per phase of a $Y$-connected three-phased load. The phase voltage is 400 V rms and the frequency is 60 Hz.




   (a) Find the rms value of the line current.

   (b) Assume that a capacitor of value $C$ is added in parallel. Find $C$ so that the power factor is 1.

   (c) Find the rms value of the line current in case (b). (Note that the line current is the total current, including both the capacitor current and the load current.)

   (d) Should the answer at part (c) be smaller than at part (a)?

   Sample answers: (c) 13.15 A rms.

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## Homework Set 35

*Let your speech* be *alway with grace, seasoned with salt, that ye may know how ye ought to answer every man. Col 4:6*

**Suggested Reading:** Section 10-4 Balanced Networks; Section 10-5 Power in Balanced Three-Phase Networks.

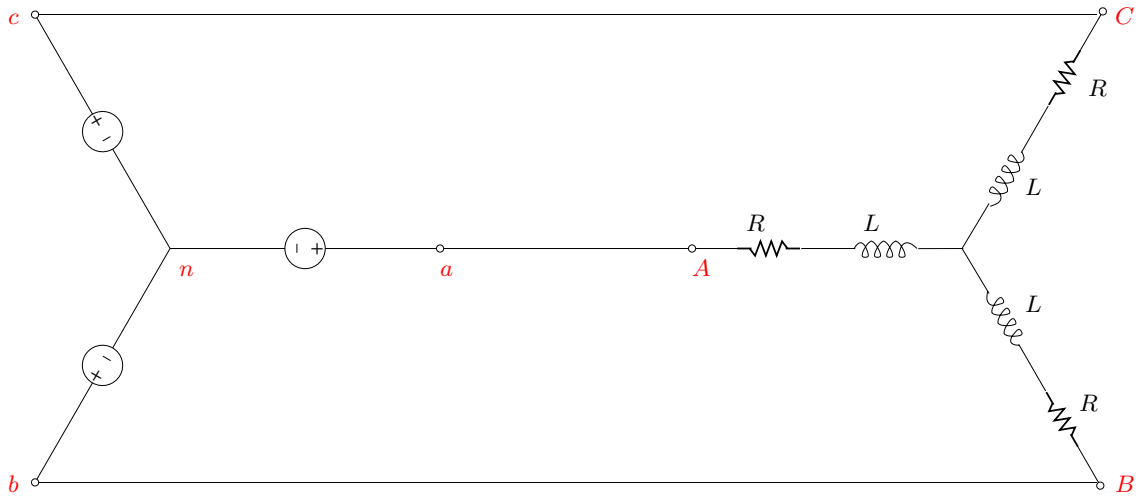
1. The amplitude of the sources is 300 V and the frequency 60 Hz. Each phase of the load absorbs 10 kW at a power factor of 0.7 lagging.

   (a) Find the line voltage (rms value).

   (b) Find the phase voltage (rms value).

   (c) Find the phase current (rms value).

   (d) Find $R$ and $L$.

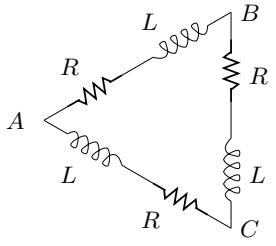



   Sample answers: (b) $V_p = 212.13\,\text{V}$ rms; (d) $L = 5.97\,\text{mH}$.

2. A balanced Y-connected load has an impedance $\mathbf{Z} = 2.5\angle 45^\circ\,\Omega$ per phase. Assume a positive phase sequence. Given $\mathbf{V_{ab}} = 400\angle 0^\circ\,\text{V}$, find (a) $\mathbf{V_{an}}$; (b) $\mathbf{I_{cC}}$; (c) $\mathbf{V_{CA}}$; (d) the power factor of the load; (e) the average power dissipated by the load.

   Sample answers: $\mathbf{I_{cC}} = 92.4\angle 45^\circ\,\text{A}$ and $P = 22.63\,\text{kW}$.

3. The $\Delta$-connected load shown in the figure has $R = 2\,\Omega$. The frequency is $f = 60\,\text{Hz}$, the line voltage is 300 V rms, and the line current is 20 A rms.



(a) Find the effective value of the phase current.

(b) Find $L$.

(c) Find the power factor.

(d) Find the average power.

Sample answers: $L = 68.7\,\text{mH}$.

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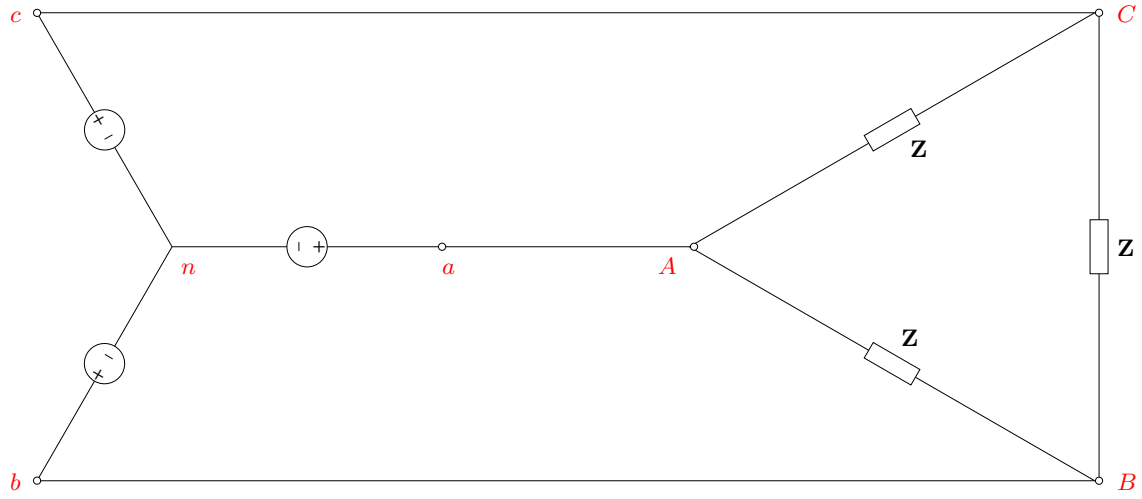
## Homework Set 36

*But I say unto you, That every idle word that men shall speak, they shall give account thereof in the day of judgment. Mt 12:36*

**Suggested Reading:** Section 10-4 Balanced Networks; Section 10-5 Power in Balanced Three-Phase Networks; Section 11-4 Ideal Transformers.

1. A $\Delta$-connected load has an impedance $\mathbf{Z} = 2.5\angle 45^\circ\,\Omega$ per phase. Assume a positive phase sequence. Given $\mathbf{V_{an}} = 400\angle 0^\circ\,\mathrm{V}$, find (a) $\mathbf{V_{AB}}$; (b) $\mathbf{I_{CA}}$; (c) $\mathbf{I_{cC}}$; (d) the power factor of the load; (e) the average power dissipated by the load; (f) the average power dissipated by the load when the load is reconnected in the Y configuration. (The following notation is used. Given two nodes $m$ and $n$, $\mathbf{V_{mn}}$ is the voltage between $m$ and $n$, where $+$ is at $m$ and $-$ at $n$. Moreover, $\mathbf{I_{mn}}$ is the current going from $m$ to $n$.)

   Sample answers: $\mathbf{I_{cC}} = 480\angle 75^\circ\,\mathrm{A}$; (e) $P = 203.6\,\mathrm{kW}$.




2. A $\Delta$-connected load has an impedance $\mathbf{Z} = 5\angle -75^\circ\,\Omega$ per phase. The load absorbs an average power of 30 kW. Each of the three lines connecting the load to the source has a resistance $r = 1\,\Omega$. The frequency is $f = 60\,\mathrm{Hz}$.

   (a) Find the effective value of the line current.

   (b) Find the power dissipated on the resistance of the lines.

   (c) To correct the power factor so that it equals 1, what component should be connected in parallel to each phase, and what should be its value?

   (d) Assuming the power factor of the load is corrected, what is the power dissipated on the resistance of the lines when the load absorbs 30 kW?

   Sample answers: (b) 69.5 kW; (d) 4.66 kW.

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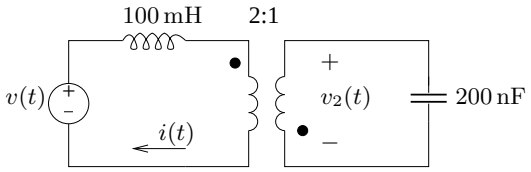
## Homework Set 37

*And let the peace of God rule in your hearts, to the which also ye are called in one body; and be ye thankful. Col 3:15*

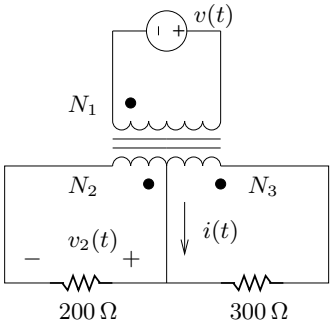
**Suggested Reading:** Section 10-4 Balanced Networks; Section 10-5 Power in Balanced Three-Phase Networks; Section 11-4 Ideal Transformers.

1. Assume $v(t) = 12\cos(\omega t)\,\text{V}$ and a frequency of 6366 Hz. Find $i(t)$ and $v_2(t)$.




   Sample answers: $i(t) = 3.43\cos(\omega t - 90°)\,\text{mA}$.

2. The number of turns of the coils are $N_1 = 500$, $N_2 = 300$, and $N_3 = 100$. Given $v(t) = 180\cos(4000 \cdot t)\,\text{V}$, find (a) $v_2(t)$; (b) $i(t)$.




3. A Y-connected load has an equivalent impedance $Z = 2\angle 30°\,\Omega$ per phase. The load is connected to a source that outputs a line voltage of 400 V rms. Each of the three lines connecting the load to the source has a resistance of $1\,\Omega$.

   (a) Determine the power factor of the load.

   (b) Determine the total power lost on the three lines.

   (c) What would be the answer at part (b) if capacitors are added in parallel to the load, so as to make the power factor 1?

   Sample answers: (b) 18.9 kW.

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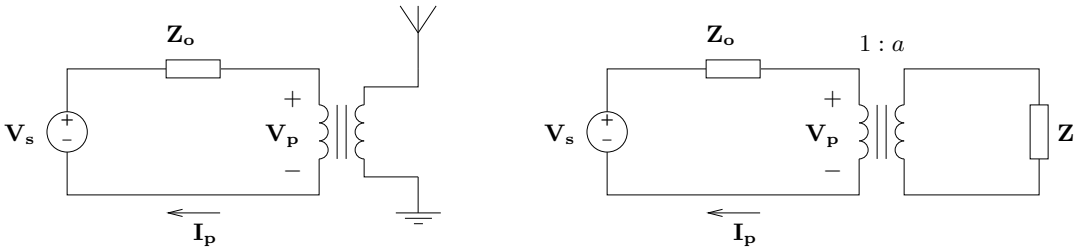
## Homework Set 38

*And ye shall be holy unto me: for I the LORD* am *holy, and have severed you from* other *people, that ye should be mine. Lev 20:26*

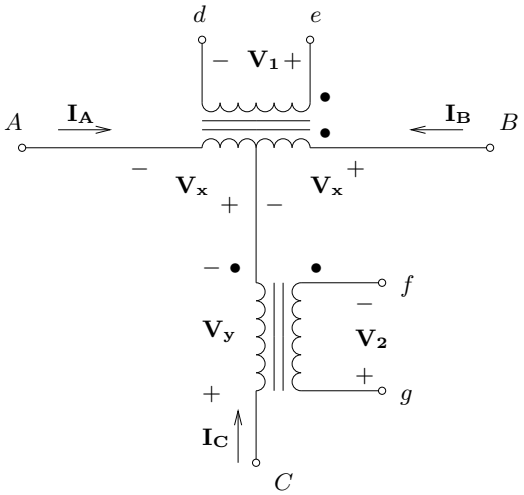
**Suggested Reading:** Section 10-4 Balanced Networks; Section 10-5 Power in Balanced Three-Phase Networks; Section 11-4 Ideal Transformers; Section 11-5 Three-Phase Transformers.

1. An amplifier of output impedance $\mathbf{Z_o} = 12.5\angle 0^\circ\,\Omega$ drives an antenna by means of a transformer. The equivalent circuit is shown to the right. It can be shown that the power transferred to the antenna is maximum when $\dfrac{\mathbf{V_p}}{I_p} = \mathbf{Z_o^*}$, where $\mathbf{Z_o^*}$ is the complex conjugate of $\mathbf{Z_o}$. Assuming the impedance of the antenna is $\mathbf{Z} = 50\angle 0^\circ\,\Omega$, find the turns ratio $a$ for which maximum power is applied to the antenna.




2. The Scott-T transformer can be used to connect a three-phase system to a two-phase system. It consists of two separate transformers of turn ratio $\dfrac{\mathbf{V_x}}{\mathbf{V_1}} = 0.5$ and $\dfrac{\mathbf{V_y}}{\mathbf{V_2}} = \dfrac{\sqrt{3}}{2}$. The three phased source is connected to the terminals $A$, $B$, and $C$. Assume the source has $V_{an} = 300\angle 0^\circ\,\text{V}$, $V_{bn} = 300\angle -120^\circ\,\text{V}$, and $V_{cn} = 300\angle 120^\circ\,\text{V}$. Assume that a load $\mathbf{Z} = 5\angle 30^\circ\,\Omega$ is connected between the points $d$ and $e$, and no load is connected between $f$ and $g$. Find (a) $\mathbf{V_x}$; (b) $\mathbf{V_1}$; (c) $\mathbf{V_2}$; (d) $\mathbf{I_A}$.

   Sample answers: (c) $\mathbf{V_2} = 519.6\angle 120^\circ\,\text{V}$.



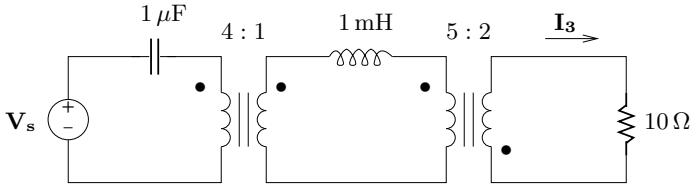

3. Assume $v_s(t) = 24\cos(\omega t + 20^\circ)\,\text{V}$ and $f = 100\,\text{Hz}$.

   (a) Find $\mathbf{I_3}$ in polar form.

(b) Find the average power absorbed by the resistor.

(c) Find the average power generated by the source.

(d) Find the apparent power of the source.




Sample answers: (c) $P = 82.3\,\text{mW}$.