Intro

Monday, August 22, 2016 9:00 AM

Norm Galassi

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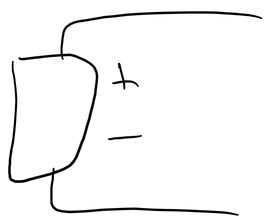
http://nrgalassi.org/$\underbrace{\text{EECE}}_{\text{must be caps}}$211

<u>use gmail</u>

charge $q_e = 1.602 \times 10^{-19}$ Coul

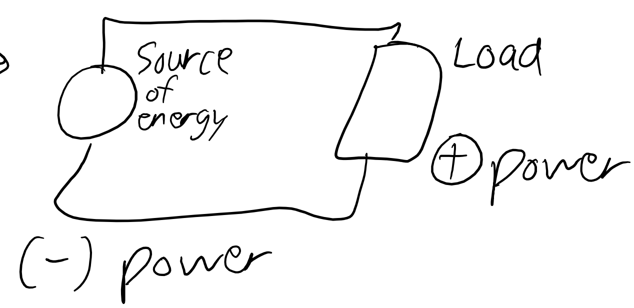
Current $= \dfrac{dq}{dt}$ $\dfrac{1\ \text{coul}}{1\ \text{sec}} = 1\text{amp}$ $\xrightarrow{+}$ $\xrightarrow{-}$

Voltage $= \dfrac{dw}{dq}$

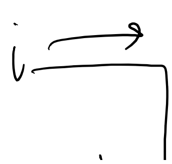


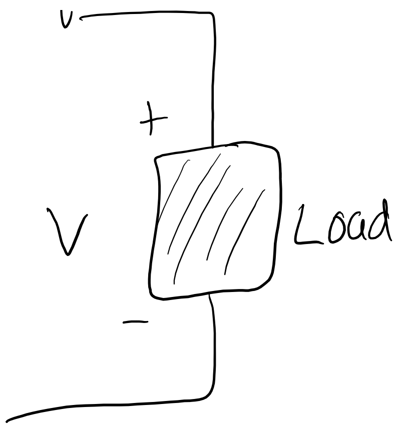
Power $= \dfrac{dw}{dt} = \underbrace{\dfrac{dw}{dq}}_{V} \cdot \underbrace{\dfrac{dq}{dt}}_{i} = V \cdot i$

Passive sign convention ⟶



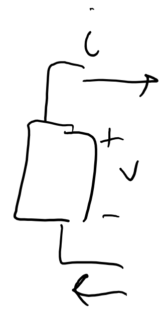
Load

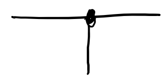




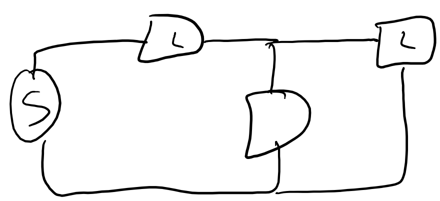
$P = (+)\, Vi$

Source

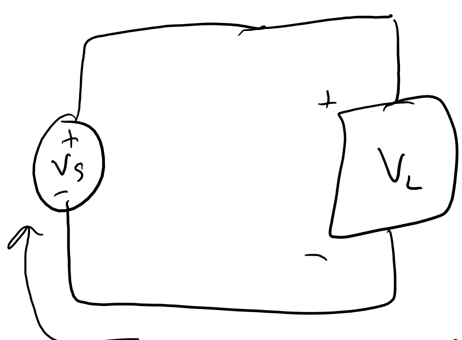




$\sum i = 0$ in = out



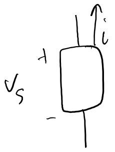
source = $\sum$ loads



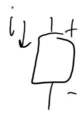
$-V_s + V_L = 0$ $\sum v = 0$

Passive Sign Convention

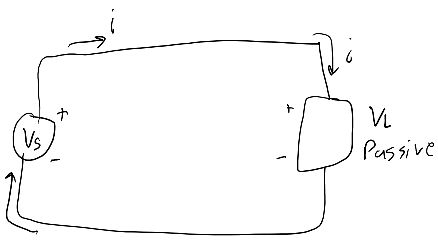
Wednesday, August 24, 2016 9:00 AM



current out of positive end – active device (source) (–)

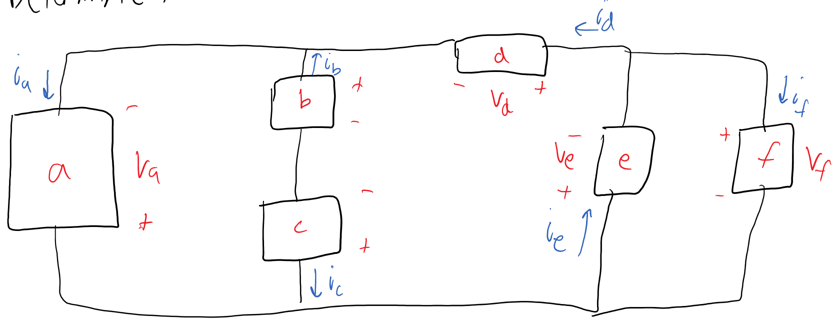


current into positive end – passive device (+)



$P_s = (-)\, V_s I_s \qquad P_L = +V_L I_L$

Ex: Determine if circuit is valid (Power in = Power out)



element	V	I
a	-3 kV	-250 μA
b	4 kV	-400 μA
c	1 kV	400 μA
d	1 kV	150 μA
e	-4 kV	200 μA
f	4 kV	50 μA

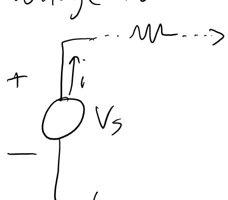
	Type of Filiment	Calculation	what it really is → element
a	active	$(-)(-3\times10^3)\cdot(250\times10^{-6}) = -0.75W$	active
b	active	$(-)(4\times10^3)\cdot(-400\times10^{-6}) = +1.6W$	passive
c	active	$(-)(1\times10^3)\cdot(400\times10^{-6}) = -0.4W$	active
d	passive	$(+)(1\times10^3)\cdot(150\times10^{-6}) = +0.15W$	passive
e	passive	$(+)(-4\times10^3)\cdot(200\times10^{-6}) = -0.8W$	active
f	passive	$(+)(4\times10^3)\cdot(50\times10^{-6}) = +0.2W$	passive

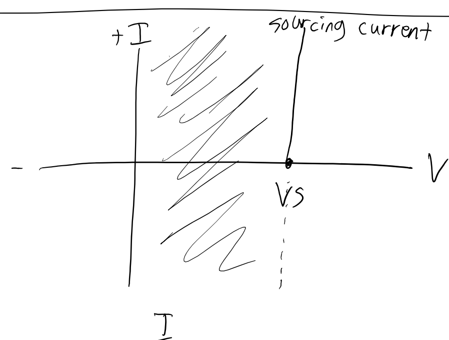
$\underbrace{-0.75 - 0.4 - 0.8}_{-1.95} + \underbrace{1.6 + 0.15 + 0.2}_{1.95} = 0$ Valid circuit ✓

(If not = 0, invalid circuit)

Indep Voltage Source

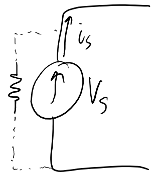
DC

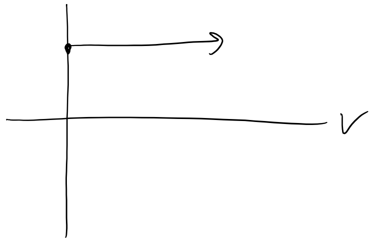




Indep Current Source

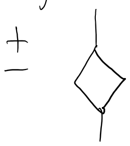
I





dependent Source Probably not on exam

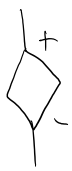
Voltage Controlled Voltage Source (VCVS)



$V_s = \mu V_x$

mew

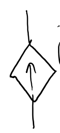
Current Controlled Voltage Source (CCVS)



$V_s = \rho i_x$

rho

Voltage Controlled Current Source (VCCS)



$i_s = \alpha V_x$

alpha

Current Controlled Current Source (CCCS)

$I_s = \beta I_x$

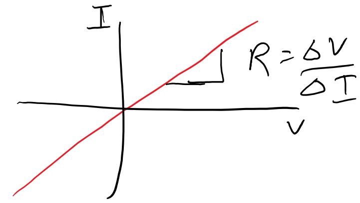
beta

All of these are usually in semiconductors/solid state

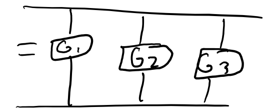
Kirchoff's Laws

Friday, August 26, 2016 9:00 AM

$G = \text{conductance} = \frac{1}{R}$

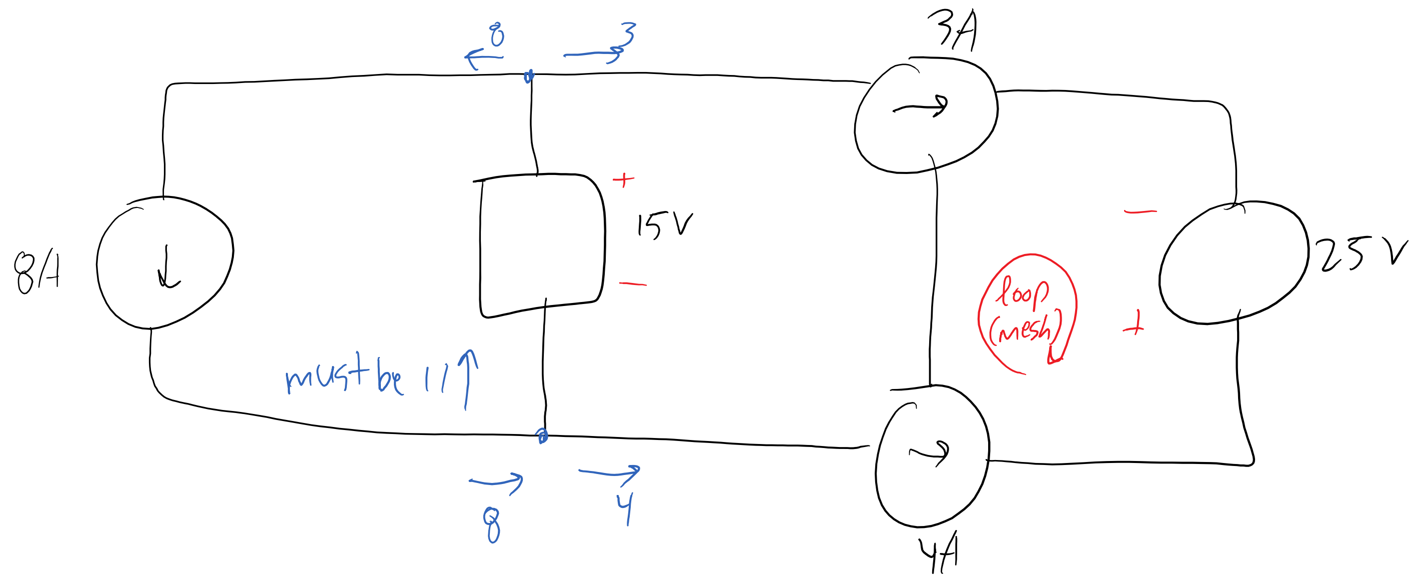


$G_T =$

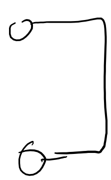


$R_T = \frac{1}{G_T}$

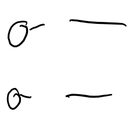
$P_R = (+)\ VI = I^2R = \frac{V^2}{R}$



15 ≠ 8 invalid circuit



short circuit
R = 0



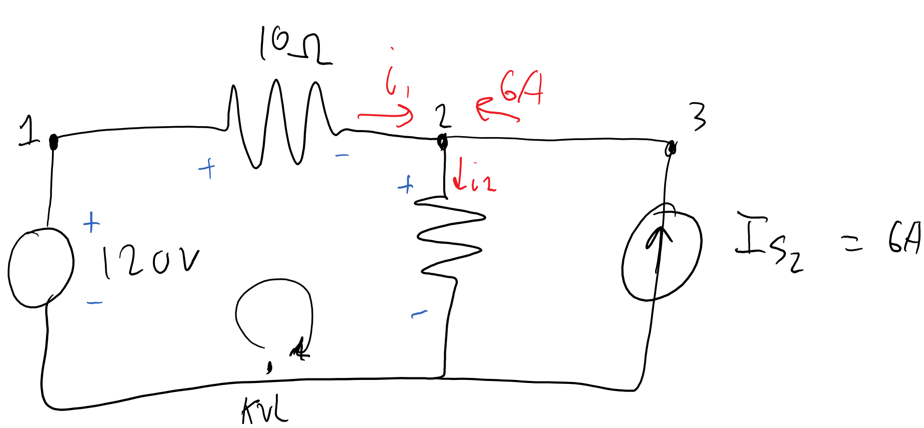
open circuit
R = ∞

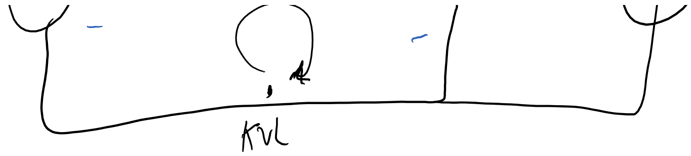
Kirchoff's Voltage Law (loops)

Σ Voltage around a loop = ∅

Kirchoff's Current Law (nodes)

Σ current entering node = ∅





Node 3 = 6A

KCL → Node 2

$I_1 - I_2 + I_3 = 0$

$I_1 - I_2 = -6$

$10I_1 + 50I_2 = 120$

KVL - loops

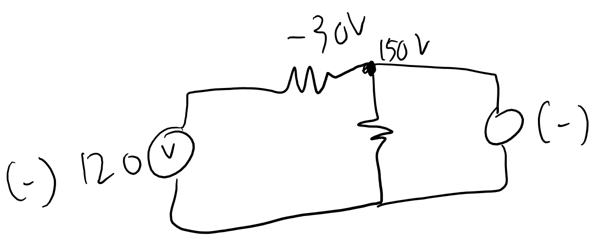
$-120V + i_1 10\Omega + i_2 50\Omega = 0$

$$\begin{vmatrix} 1 & -1 \\ 10 & 50 \end{vmatrix} \begin{matrix} I_1 \\ I_2 \end{matrix} \begin{vmatrix} -6 \\ 120 \end{vmatrix}$$

$I_1 = -3$

$I_2 = 3$

So $i_1 = -3$ $\leftarrow i_1$



30V drop

$-(120v)(-3A) + (-3A)(-30v) + (3A)(150v) - 150(6)$

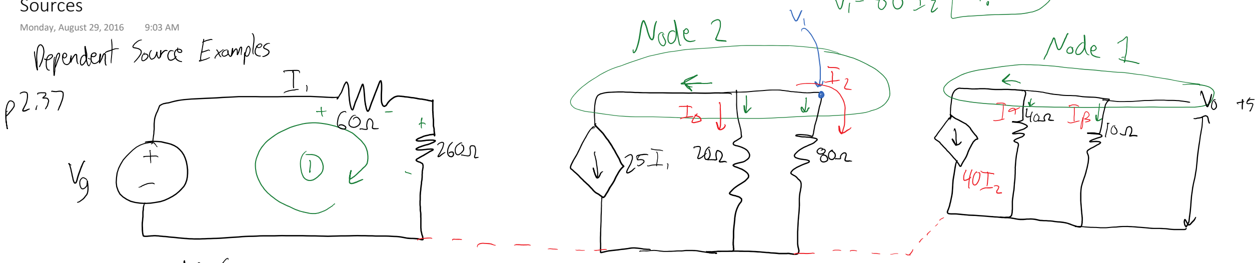
$+360W + 90W + 450W - 900W = 0$ ✓

Sources

Monday, August 29, 2016 9:03 AM

Dependent Source Examples

p2.37



$V_1 = 80 I_2 = \boxed{-1.25V}$

$I_\alpha = \frac{5}{40} = 0.125$

$I_\beta = \frac{5}{10} = 0.5$

Indep Source

Find V_1 and V_g when $V_0 = +5V$

Hint: Begin at right hand side (i.e. V_0)

$-V_g + 60 I_1 + 260 I_1 = 0$

$-V_g + 320 I_1 = 0$

$-V_g = -320 I_1$

$V_g = 320 I_1 = \boxed{1V}$

$-25 I_1 - I_\Delta - I_2 = 0$

$-25 I_1 - I_\Delta + 0.015625 = 0$

$I_\Delta = \frac{-1.25}{20} = -0.0625$

$-25 I_1 + 0.0625 + 0.015625 = 0$

$-25 I_1 + 0.07825 = 0$

$-25 I_1 = -0.02825$

$\boxed{I_1 = 0.003125}$

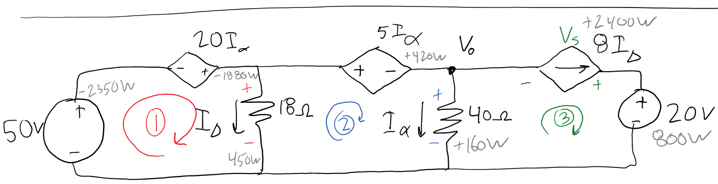
Node 1:

$-40 I_2 - I_\alpha - I_\beta = 0$

$-40 I_2 - 0.125 - 0.5 = 0$

$-40 I_2 = +0.625 A$

$\boxed{I_2 = -0.015625 A}$



$20V + V_s = V_0$ (-60)

$\boxed{V_0 = 80V}$

or

$V_0 = 40 I_\alpha = 80V$ (2)

Calculate I_Δ and V_0

Loop 1

$-50V - 20 I_\alpha + 18 I_\Delta = 0$

$-20 I_\alpha + 18 I_\Delta = 50$

Loop 2

$-18 I_\Delta + 5 I_\alpha + 40 I_\alpha = 0$

$45 I_\alpha - 18 I_\Delta = 0$

Loop 3

$-40 I_\alpha - V_s + 20 = 0$

$-40 I_\alpha - V_s = -20$

$$\begin{array}{ccc} I_\alpha & I_\Delta & V_s \\ \end{array}$$

$$\left|\begin{array}{ccc} -20 & 18 & 0 \\ 45 & -18 & 0 \\ -40 & 0 & -1 \end{array}\right| \begin{array}{c} I_\alpha \\ I_\Delta \\ V_s \end{array} \left| \begin{array}{c} 50 \\ 0 \\ -20 \end{array} \right|$$

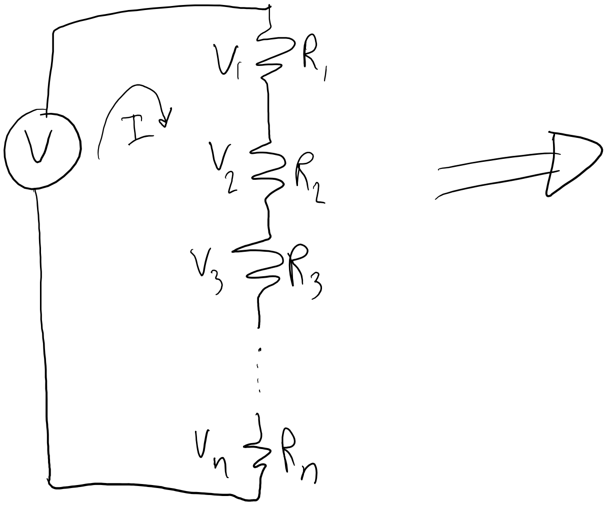
$I_\alpha = 2$

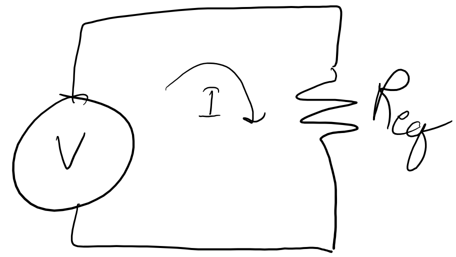
$\boxed{I_\Delta = 5}$

$V_s = -60$

Series and Parallel Circuit

Wednesday, August 31, 2016 9:00 AM





$$R_{eq} = \frac{V}{I}$$

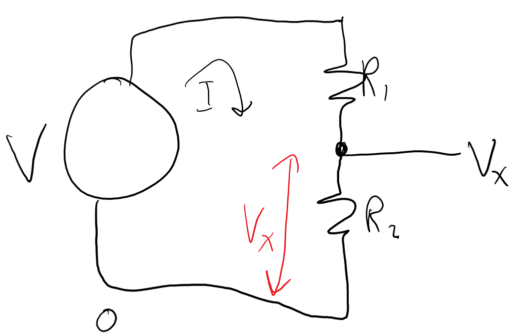
$$V = V_1 + V_2 + \dots V_n$$

$$IR_1 + IR_2 + \dots IR_n$$

$$V = I(R_1 + R_2 + \dots R_n)$$

$$R_{eq} = \frac{V}{I} \qquad \boxed{R_{eq} = R_1 + R_2 + \dots R_n}$$

Voltage Divider



$$I = \frac{V}{R_{eq}}$$

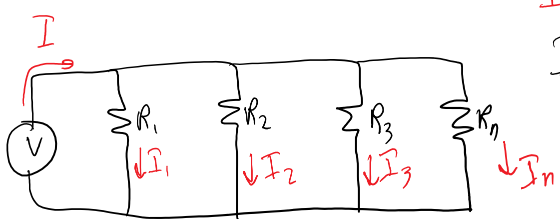
$$\frac{V_x}{V} = \frac{IR_2}{I(R_1 + R_2)} = \boxed{V_x = \frac{VR_2}{R_T}}$$

Parallel Resistors

$$I = I_1 + I_2 + I_3 + \dots I_n$$

I

Parallel Resistors



$$I = I_1 + I_2 + I_3 + \dots I_n$$

$$I = \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \dots \frac{V}{R_n}$$

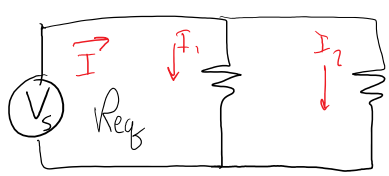
$$R_{eq} = \frac{V}{I} = \frac{V}{\frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \dots \frac{V}{R_n}} = \frac{1}{1/R_1 + 1/R_2 + 1/R_3 + \dots 1/R_n}$$

For 2 Resistors in Parallel $\overbrace{(\parallel)}^{\text{symbol}}$: $R_{eq} = \frac{1}{1/R_1 + 1/R_2} = \frac{1}{\frac{R_2 + R_1}{R_1 R_2}} = \frac{R_1 R_2}{R_1 + R_2}$

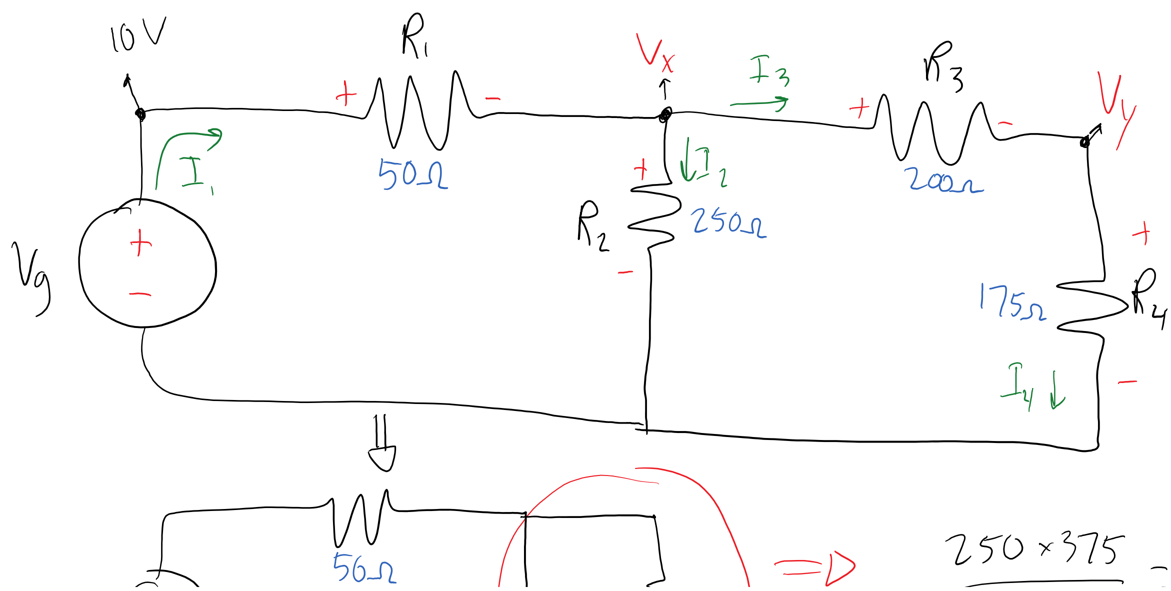
Resistance of each resistor

$$R_{eq} = \frac{R}{N} = \frac{1000}{20} = 50$$

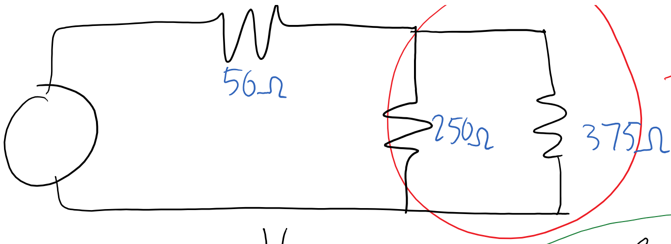
# of resistors



$$\frac{I_1}{I_2} = \frac{V_s/R_1}{\frac{V_s(R_1+R_2)}{R_1 R_2}} = \frac{1}{R_1} \times \frac{R_1 R_2}{R_1 + R_2} = \frac{I_1}{I} = \frac{R_2}{R_1 + R_2}$$



$\Rightarrow$ $\frac{250 \times 375}{\quad} = 150\Omega$

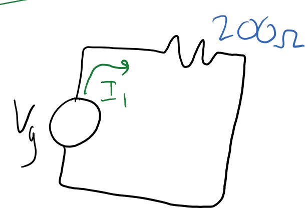


$$\Rightarrow \quad \frac{250 \times 375}{250+375} = 150\Omega$$

$$\Downarrow$$

$$V_x = \frac{150}{150+50} \cdot 10V = \frac{3}{4} \cdot 10 \qquad V_x = 7.5V$$

$\Rightarrow$



$$I_1 = \frac{10}{200} = 0.05A$$

$I_1 = 0.05A$

$I_2 = 0.03A$

$I_3 = 0.02A$

$I_4 = 0.02A$

voltage divider $\rightarrow V_x = 7.5V$

$V_y = 3.5V$

$$I_2 = \frac{7.5V}{250\Omega} = 0.03A$$

$\leftarrow V_x$

$I_2 \rightarrow$

$I_1 = I_2 + I_3$

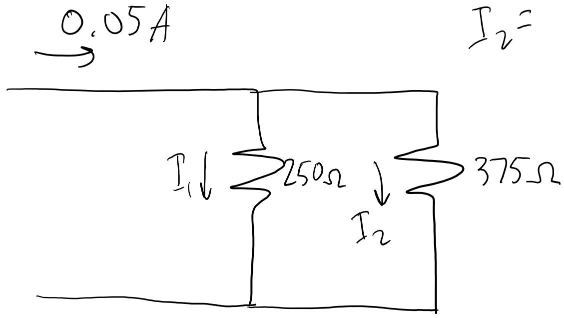
$0.05 = 0.03 + I_3 \qquad I_3 = 0.02A$

$I_3 = I_4 \rightarrow$ resistors R_3 and R_4 are in series

$$V_y = \frac{R_4}{R_3+R_4}(V_x)$$

$$V_y = \frac{175 \cdot (7.5v)}{200+175} = 3.5V$$

$\xrightarrow{0.05A}$ $\qquad$ $I_2 = 0.05 \times \frac{375}{625}$



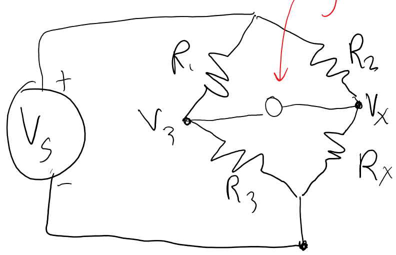
$$I_2 = 0.05 \times \frac{375}{625}$$

$$0.05 \times \frac{250}{625} = I_1$$

Delta and Wye Conversions

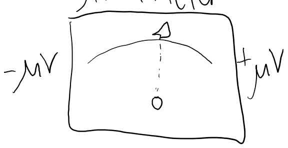
Friday, September 2, 2016 8:59 AM

Wheatstone Bridge — not on exam



- R_3 is a variable resistor
- no current thru galvonometer when no Voltage on galvonometer ⟹ balanced

galvonometer



$$V_3 = \frac{V_S(R_3)}{R_1 + R_3}$$

$$V_x = \frac{V_S(R_x)}{R_2 + R_x}$$

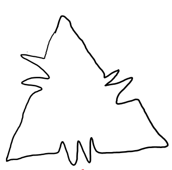
$$V_3 = V_x \quad \text{so} \quad \frac{\cancel{V_S}(R_3)}{R_1 + R_3} = \frac{\cancel{V_S}(R_x)}{R_2 + R_x}$$

$$R_3 R_2 + \cancel{R_3 R_x} = R_1 R_x + \cancel{R_3 R_x}$$

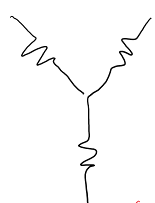
$$R_3 R_2 = R_1 R_x$$

$$\boxed{R_x = \frac{R_3 R_2}{R_1}}$$

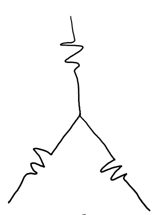
Delta to Wye & Wye to Delta Transformations — In HW, probably not on exam



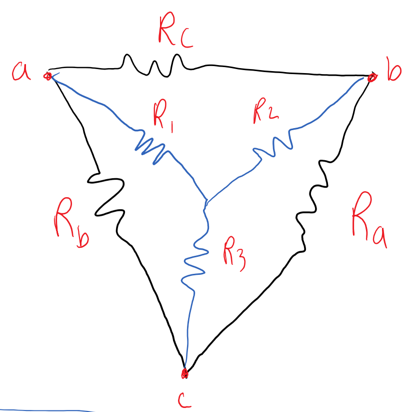
Delta Configuration



Wye Configuration



Wye (flipped)



Delta to Wye

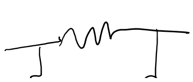
$$\boxed{R_1 = \frac{R_b R_c}{R_a + R_b + R_c}} \qquad \boxed{R_3 = \frac{R_a R_b}{R_a + R_b + R_c}}$$

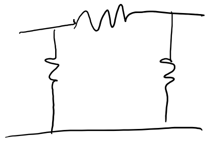
$$\boxed{R_2 = \frac{R_a R_c}{R_a + R_b + R_c}}$$

Wye to Delta

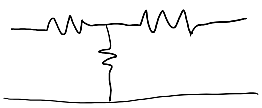
$$\boxed{R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}}$$

Delta seen as Pi Network (usually)





Wye seen as T Network (usually)

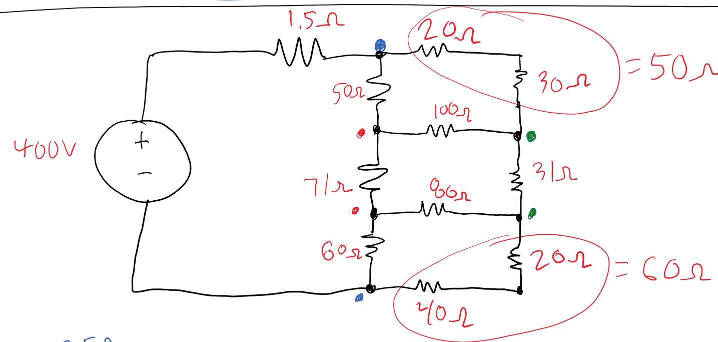


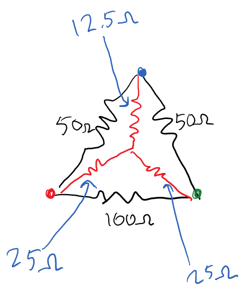
$$\boxed{R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}}$$

$$\boxed{R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}}$$

$$\boxed{R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}}$$

Ex:

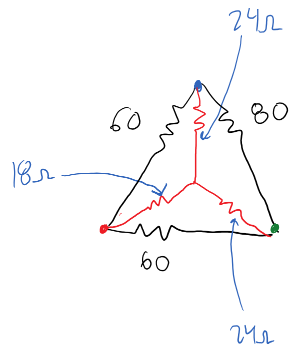




$$\frac{50 \cdot 50}{200} = 12.5\Omega$$

$$\frac{50 \cdot 100}{200} = 25\Omega$$

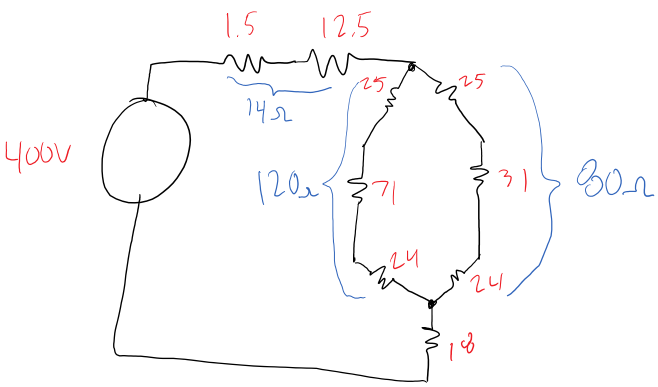
$$\frac{50 \cdot 100}{200} = 25\Omega$$



$$\frac{60 \cdot 80}{200} = 24$$

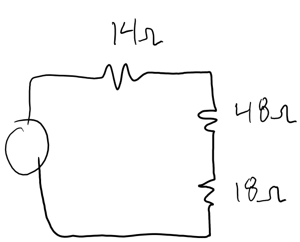
$$\frac{60 \cdot 80}{200} = 24$$

$$\frac{60 \cdot 60}{200} = 18$$



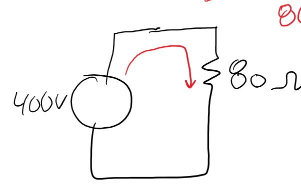
$$\frac{120 \cdot 80}{200} = 48\Omega$$

Find Power in 31Ω Resistor, Find Load



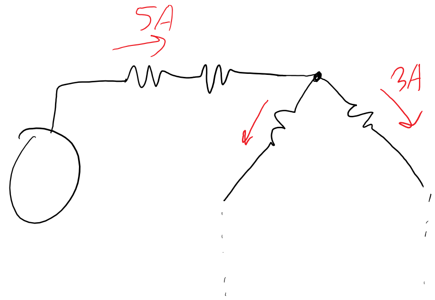
$\Rightarrow$

$$I = \frac{400V}{80\Omega} = 5A$$



$$\boxed{\text{Load} = 80\Omega}$$

$\boxed{\text{Load} = 80\Omega}$



$= \dfrac{5A(120)}{200}$

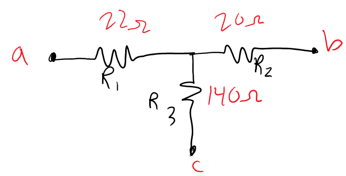
$I_R = \dfrac{R_{\text{Not Path}}}{R_{\text{Sum of Path}}} \cdot I_T$

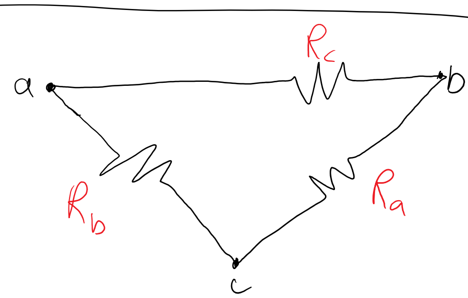
$P = I^2 R$

$P = 3^2(31)$

$\boxed{P = 9(31) = 279\Omega}$

Wye to Delta





$R_1 R_2 + R_2 R_3 + R_3 R_1$

$(22)(20) + 20(140) + 140(22) = 6320$

$R_a = \dfrac{6320}{R_1} = \dfrac{6320}{22} = 287\Omega$

$R_b = \dfrac{6320}{R_2} = \dfrac{6320}{20} = 316\Omega$

$R_c = \dfrac{6320}{R_3} = \dfrac{6320}{140} = 45\Omega$

Node Voltage Method

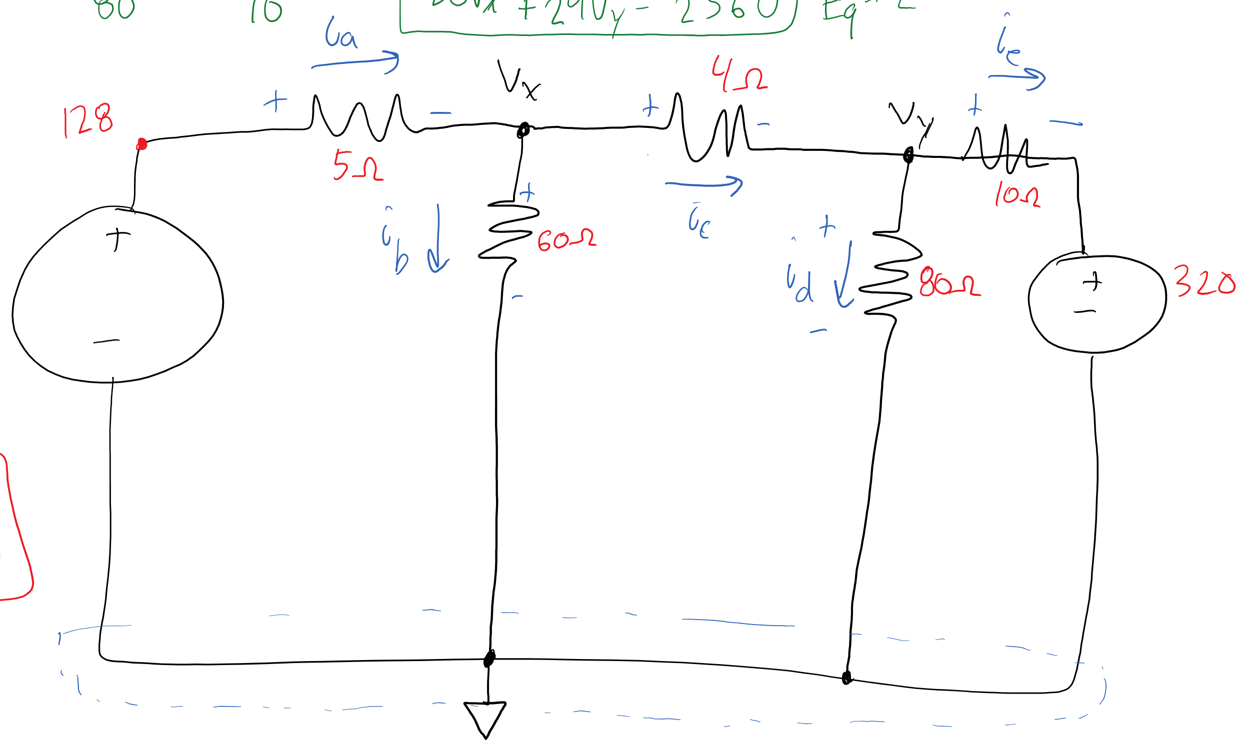
Wednesday, September 7, 2016 8:57 AM

$i_a = \frac{128 - V_x}{5\Omega}$ $\quad i_b = \frac{V_x - 0}{60\Omega}$ $\quad i_c = \frac{V_x - V_y}{4\Omega}$ $\quad i_d = \frac{V_y - 0}{80\Omega}$ $\quad i_e = \frac{V_y - 320}{10\Omega}$

$$\frac{V_x - V_y}{4} = \frac{V_y}{80} + \frac{V_y - 320}{10}$$

$$20V_x - 20V_y = V_y + 8V_y - 2560$$

$$\boxed{-20V_x + 29V_y = 2560} \quad \text{Eq\#2}$$



$\boxed{\begin{array}{l} V_x = 162 \\ V_y = 200 \end{array}}$

$i_a = i_b + i_c$ $\qquad \frac{128 - V_x}{5} = \frac{V_x}{60} + \frac{V_x - V_y}{4}$ $\qquad 1536 - 12V_x = V_x + 15V_x - 15V_y$

Eq#1: $\boxed{28V_x - 15V_y = 1536}$

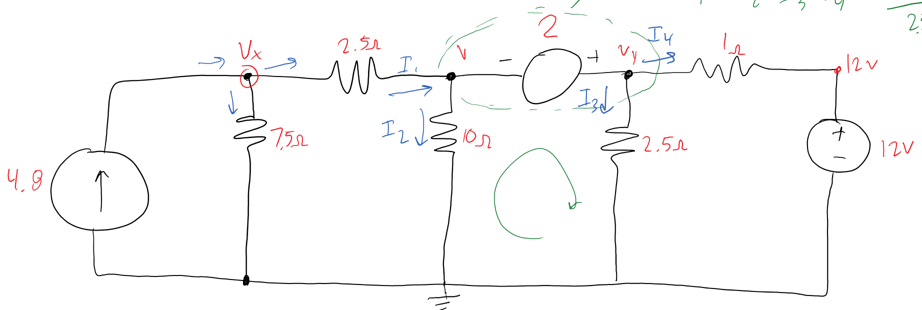
1. Identify a reference node in the circuit and assign a value of zero to that point in the circuit.
2. Identify independent nodes ← any node where the voltage is unknown
3. Assign current directions to all "branches" in the circuit. Write KCL for all independent nodes using Ohm's law to express the currents in terms of the voltages or voltage differences
4. Solve the system of equations
5. Use the node voltages to find the desired electrical quantities

Supernode

Friday, September 9, 2016 8:58 AM

$I_1 - I_2 - I_3 - I_4 = 0$

$I_1 = I_2 + I_3 + I_4 = \frac{V_x - V}{2.5} = \frac{V}{10} + \frac{V_y}{2.5} + \frac{V_y - 12}{1} \Rightarrow -5V + 4V_x - 14V_y = -120$



$4.8 = \frac{V_x}{7.5} + \frac{V_x - V}{2.5} \Rightarrow -3V + 4V_x = 36$

Loop containing super node

$-V - 2 + V_y = 0 \Rightarrow -V + V_y = 2$

$V = 8$

$V_x = 15$

$V_y = 10$

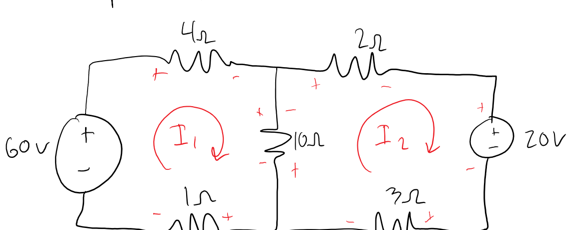
Whenever two non-reference nodes are directly connected by an independent or dependent voltage source, it is convenient to apply the supernode concept.

A supernode is a closed surface and Kirchoff's current law applies to closed surfaces as well.

1) Define supernode
2) Write KCL for Supernode
3) Write KCL for all other nodes
4) Write KVL for supernode

Mesh Current Method

A generalized technique only valid for Planar Circuits that can be drawn on a flat piece of paper.



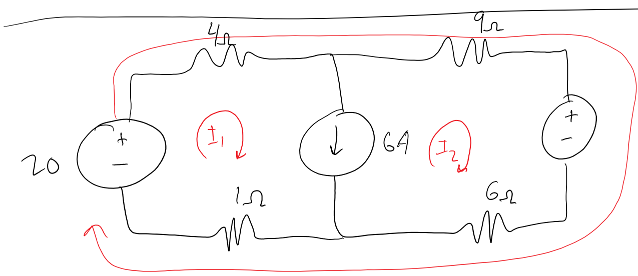
Mesh 1: $-60 + 4I_1 + 10(I_1 - I_2) + 1I_1 = 0 \Rightarrow 15I_1 - 10I_2 = 60$

Mesh 2: $10(I_2 - I_1) + 2I_2 + 20 + 3I_2 = 0 \Rightarrow -10I_1 + 15I_2 = 20$

$I_1 = 5.6\,A \quad I_2 = 2.4\,A$

1) Define currents flowing in meshes of a planar circuit
2) Write the KVL around the meshes using ohm's law to express the voltages across the resistors in terms of the mesh currents.
3) Solve the system of equations
4) Use the mesh currents to find desired electrical quantities.

Super Mesh

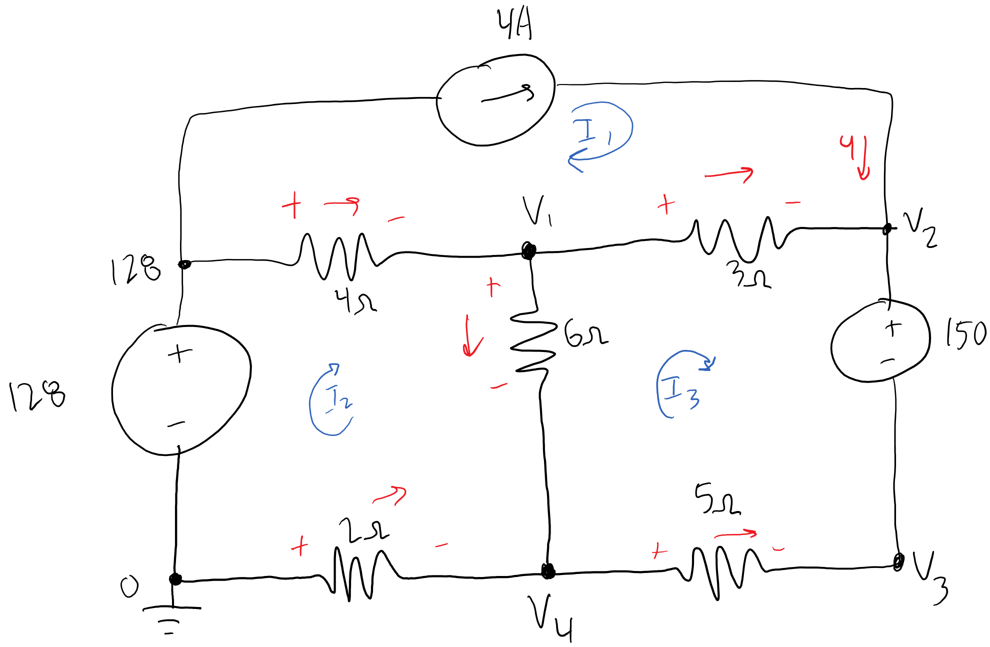


$6A = I_1 - I_2$

1) Pick a closed path that does not include the current Source
2) write mesh KVL for meshes not including current source
3) write equation for currents shared with current source
4) solve equations
5) use the currents to find all other electrical quantities

Node Voltage vs Mesh Current

Monday, September 12, 2016 9:00 AM



Node Voltage

$$\frac{128 - V_1}{4} = \frac{V_1 - V_4}{6} + \frac{V_1 - V_2}{3}$$

$$384 - 3V_1 = 2V_1 - 2V_4 + 4V_1 - 4V_2$$

(1) $\boxed{9V_1 - 4V_2 - 2V_4 = 384}$

Supernode

$$4 + \frac{V_1 - V_2}{3} + \frac{V_4 - V_3}{5} = 0$$

$$60 + 5V_1 - 5V_2 + 3V_4 - 3V_3 = 0$$

(2) $\boxed{5V_1 - 5V_2 + 3V_4 - 3V_3 = -60}$

(3) $\boxed{V_2 - V_3 = 150}$

Node V_4

$$\frac{0 - V_4}{2} + \frac{V_1 - V_4}{6} = \frac{V_4 - V_3}{5}$$

$$-15V_4 + 5V_1 - 5V_4 - 6V_4 + 6V_3 = 0$$

(4) $\boxed{5V_1 + 6V_3 - 26V_4 = 0}$

Mesh

4

(2) $-128 + 4(I_2 - I_1) + 6(I_2 - I_3) + 2I_2 = 0$

$$12I_2 - 6I_3 - 16 - 128 = 0$$

$$\boxed{12I_2 - 6I_3 = 144}$$

(3) $6(I_3 - I_2) + 3(I_1 - I_3) + 150 + 5I_3 = 0$

$$-6I_2 + 14I_3 - 12 + 150 = 0$$

$$\boxed{-6I_2 + 14I_3 = -138}$$

$I_1 = 4$ A

$I_2 = 9$A

$I_3 = -6$A

$-15V_4 + 5V_1 - 3V_4 - 6V_4 + 6V_3 = 0$

(4) $\boxed{5V_1 + 6V_3 - 26V_4 = 0}$

$V_1 = 108\ V$

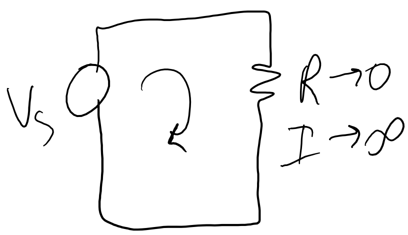
$V_2 = 138\ V$

$V_3 = -12\ V$

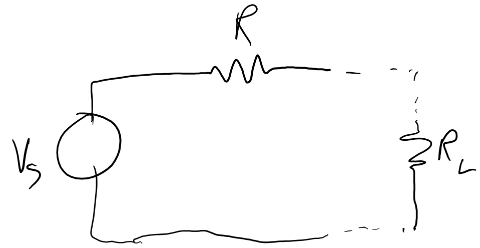
$V_4 = 18\ V$

Source Transformations

Wednesday, September 14, 2016 9:00 AM

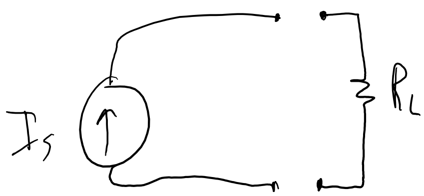


Ideal



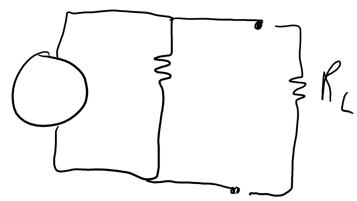
Practical

$$V_L = \frac{V_S R_L}{R_S + R_L}$$



$R \to \infty$

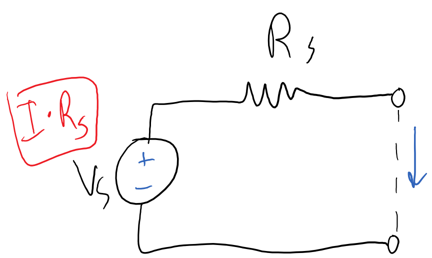
$V_S \to \infty$



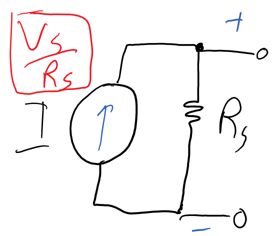
$$V_L = I_S \frac{R_S R_L}{R_S + R_L}$$

If $V_L = V_L$

$V_S = I_S R_S$



$\equiv$



$V_{open\ circuit} = V_S$

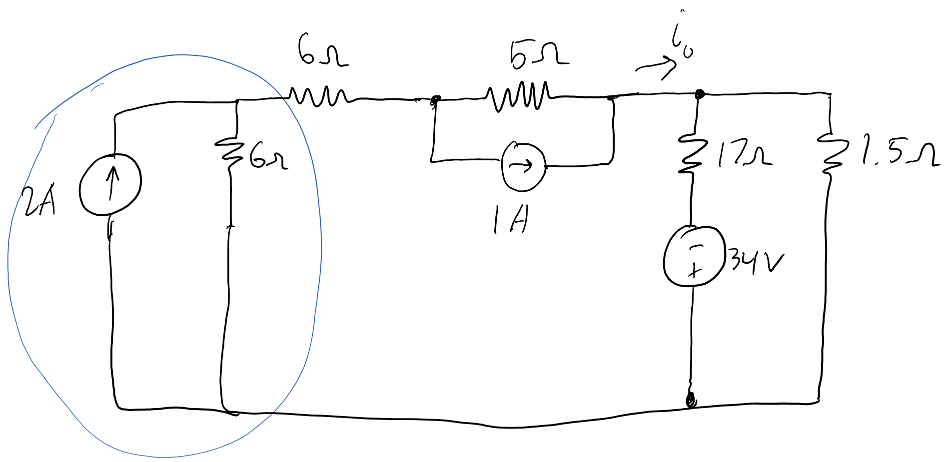
$I_{short\ circuit} = \frac{V_S}{R_S}$

$V_{oc} = I(R_S)$

$I_{sc} = I$

Method of Source Transformation

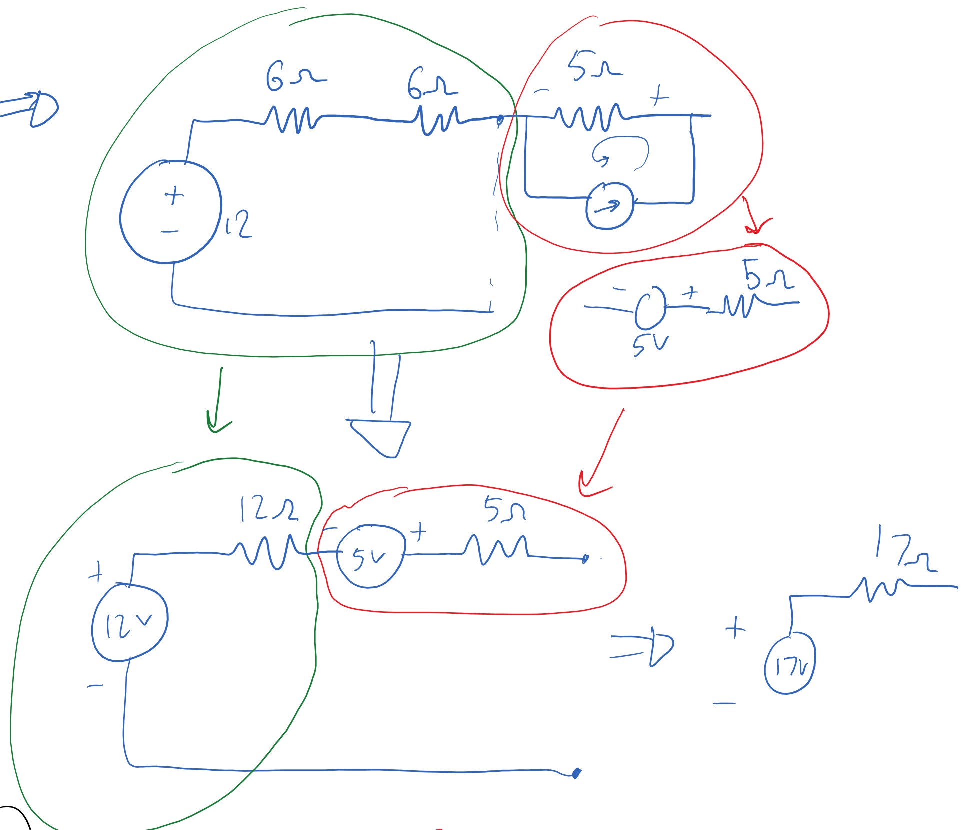
A practical voltage source can be replaced by a practical current source and a practical current source can be replaced by a practical voltage source as long as $V_S = I_S(R_S)$ and $I_S = \frac{V_S}{R_S}$

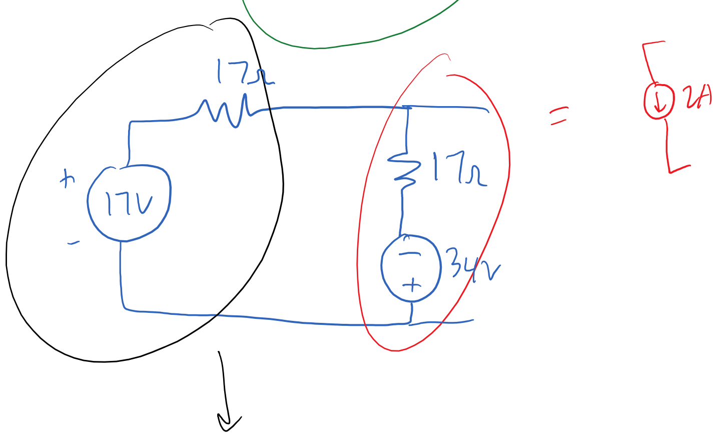


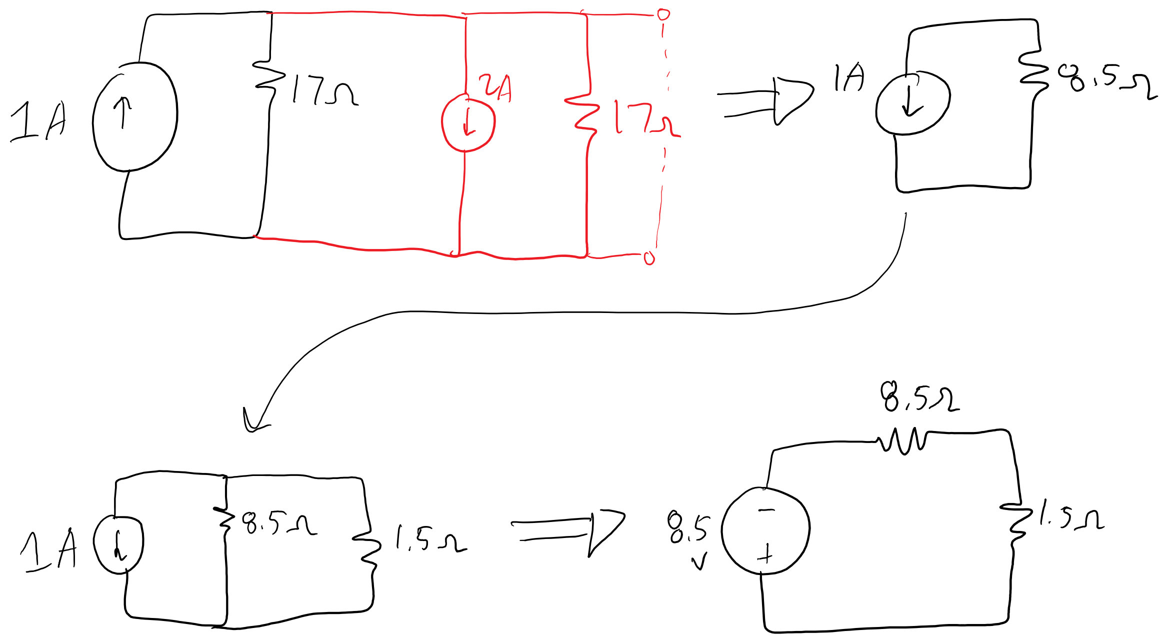
$I_{sc} = 2A$

$V_{oc} = 12V$ ⇒

$R_s = 6\Omega$



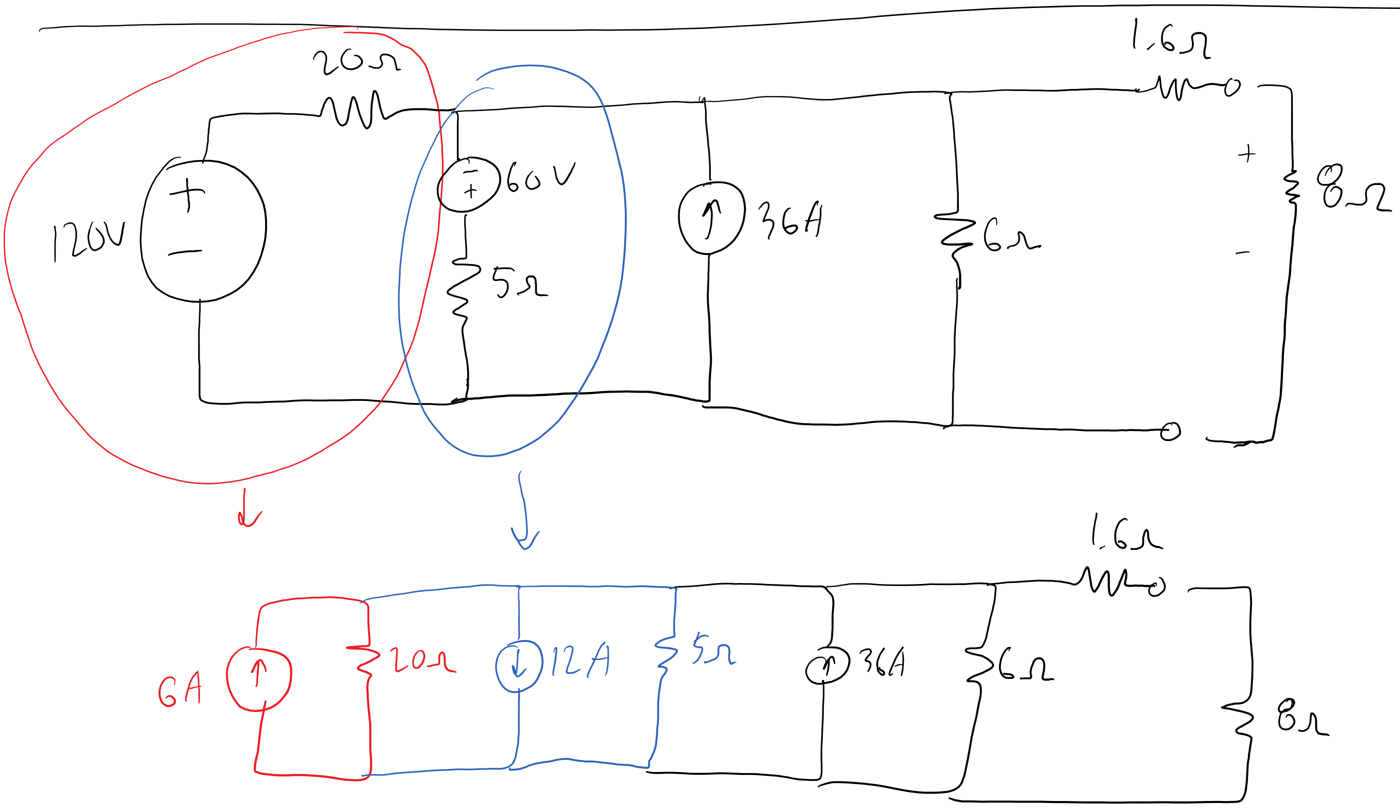


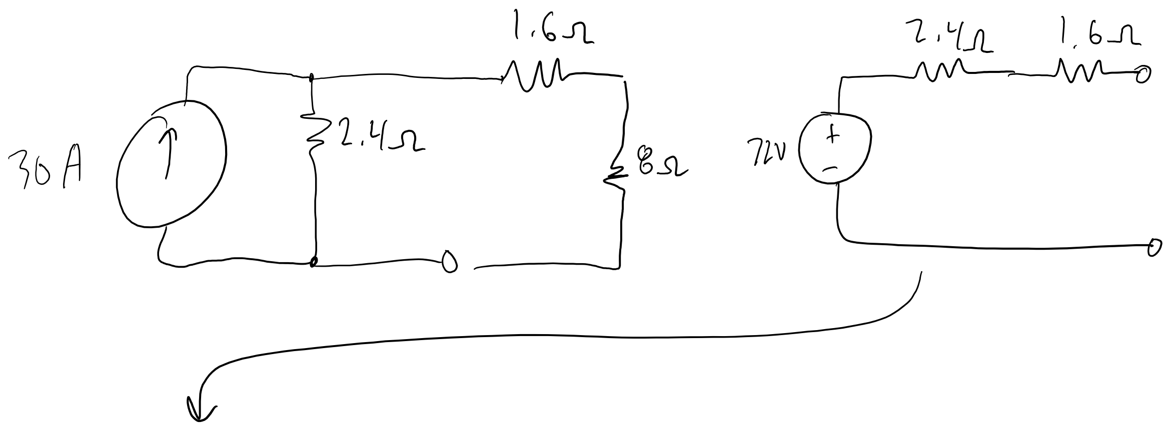


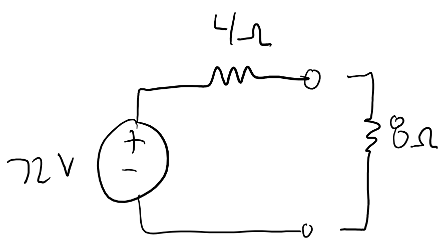
$$I_0 = \frac{8.5V}{10\Omega} = 0.85A$$

$$V_0 = \frac{8.5(1.5)}{10} = 1.275\ V$$

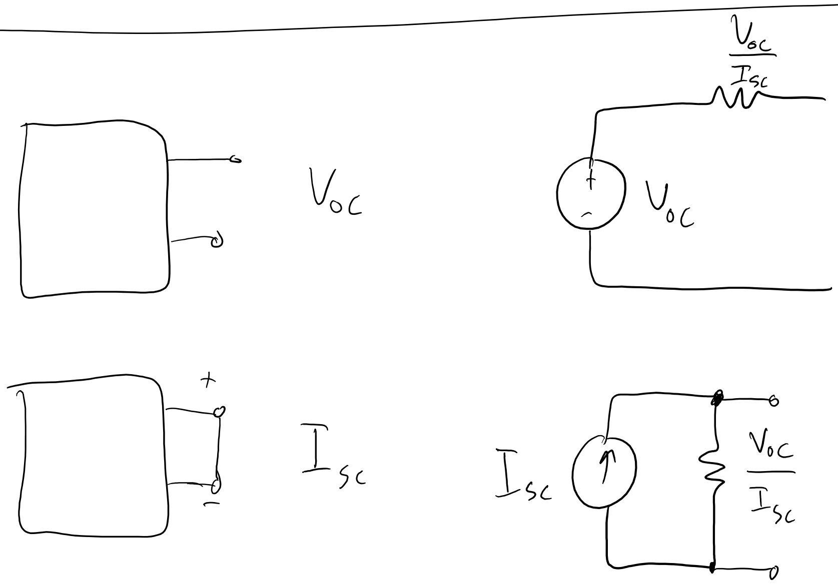
$$V_0 = \frac{R_1(R_2)}{R_1+R_2}$$

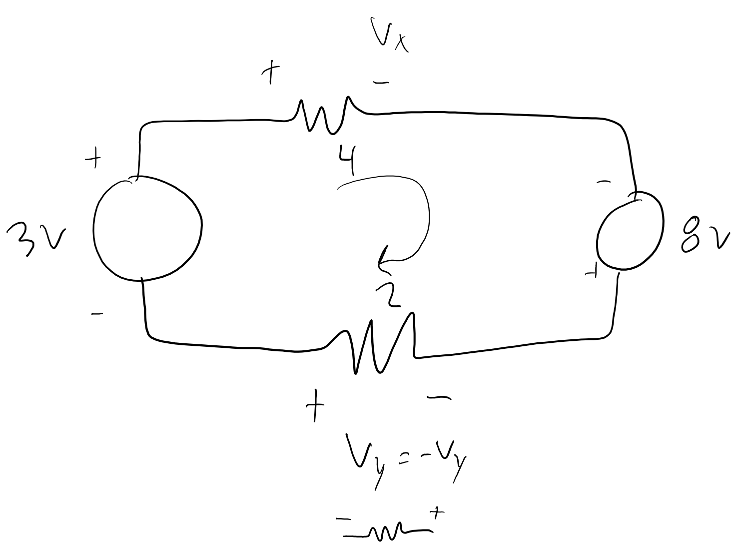




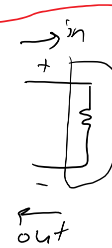


$$V_o = \frac{72(8)}{12} = 48$$





$-3 + 4I - 8 + 2I$

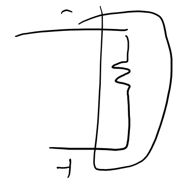
For passive 

in on +, out of −

For active 

$v_y = -v_y$

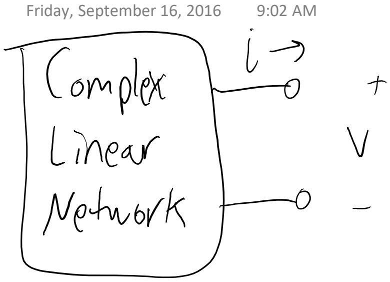
For active



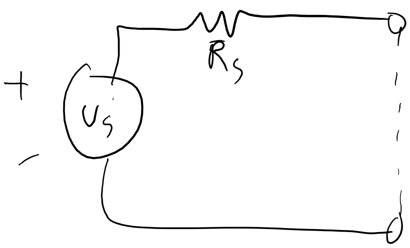
in on $-$, out of $+$

Thevenin and Norton

Friday, September 16, 2016 9:02 AM



Thevenin Form

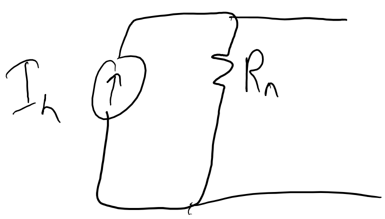


$V_{oc} = V_s$

$I_{sc} = \frac{V_s}{R_s}$

Equivalent if I_{sc} are equal and V_{oc} are equal $R_n = R_s$ and $V_{oc} = V_n$ or $I_{sc} = I_n$

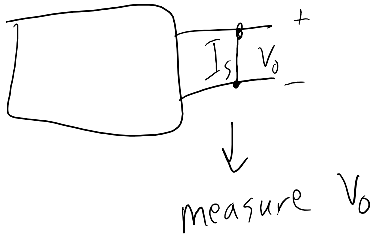
Norton Form



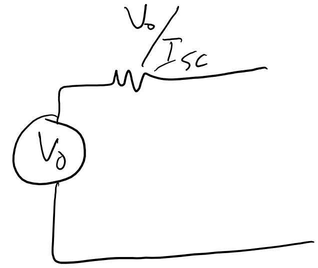
$V_{oc} = I_n R_n$

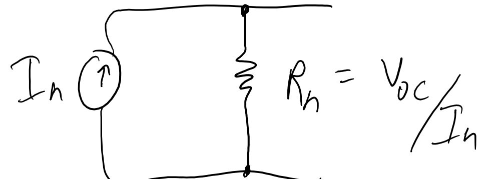
$I_{sc} = I_n$

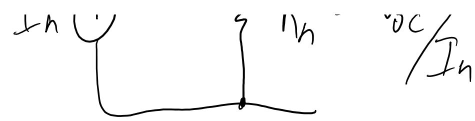
Any complex, linear, one port, network can be replaced with an equivalent circuit consisting of a source and a resistor such that the characteristics at the terminal are the same.

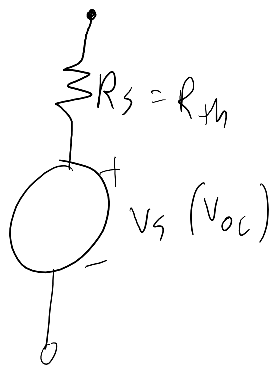


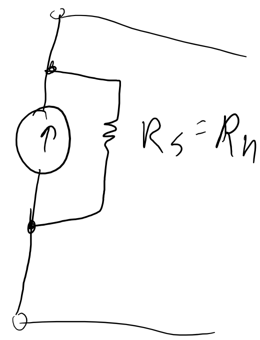
Thevenin Form =

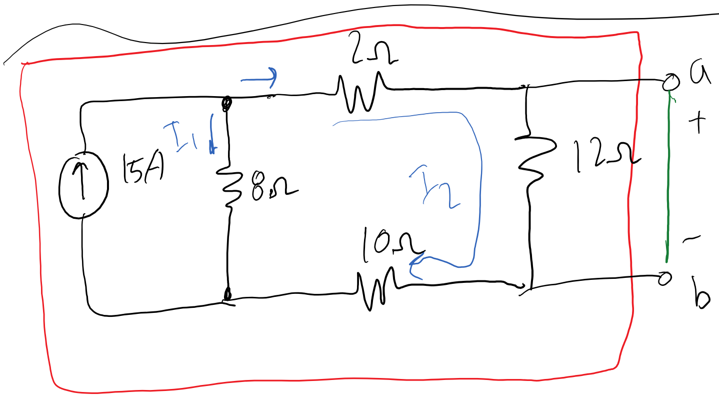




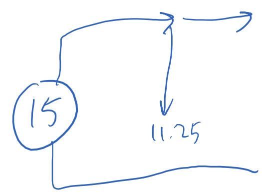








$V_{oc} = V_{th}$

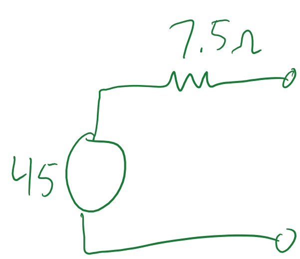


$V_o = 12 \times 3.75 = 45V$

$I_1 = \frac{15 \times 24}{32} = 11.25\ A$ $\quad I_2 = \frac{15 \times 8}{32} = 3.75A$

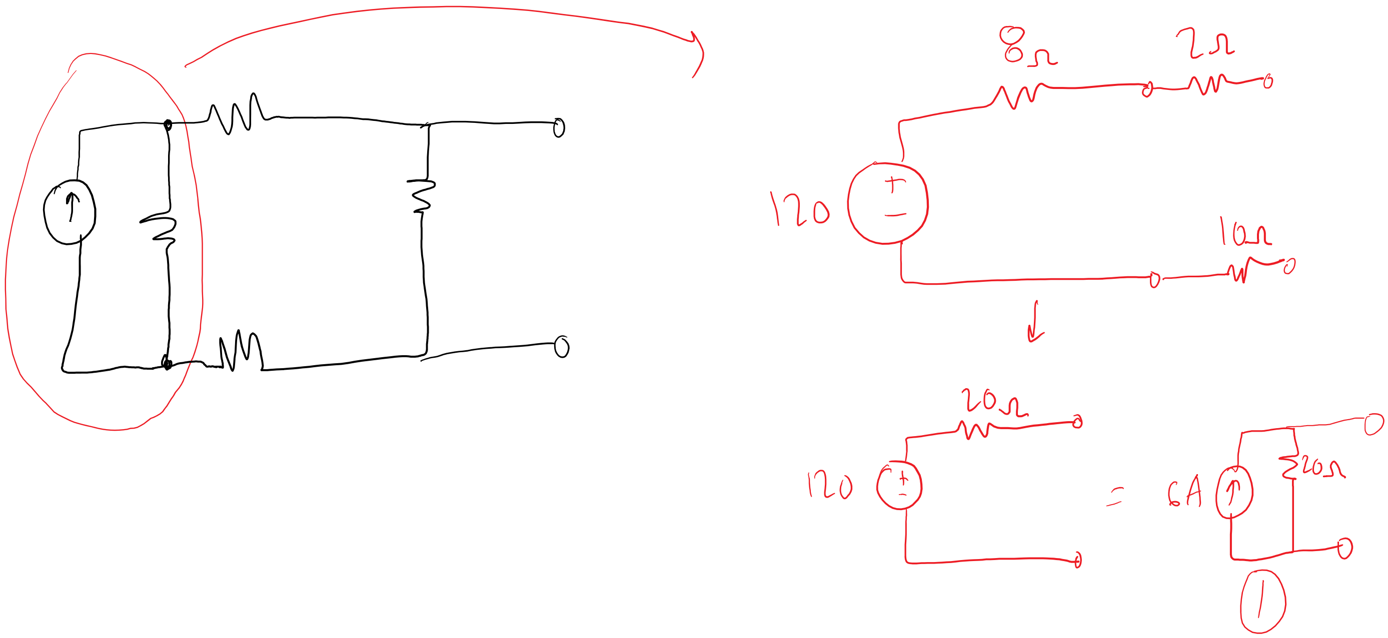
$I_{sc} = \frac{15 \times 8}{20} = 6A$ $\quad R_N = \frac{45V}{6A}$ $\quad R_N = 7.5\Omega$

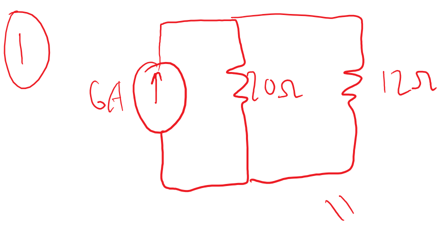
Norton



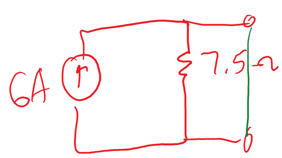
$V_{oc} = 45$
$I_s = 6A$

$V_{oc} = 45$
$I_{sc} = 6A$





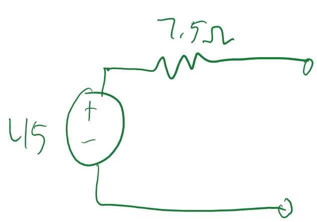
$$\frac{12 \times 20}{12+20} = \frac{240}{32} = 7.5\,\Omega$$



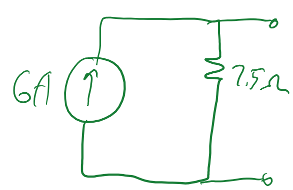
$V_{oc} = 6 \cdot 7.5 = 45\,V$

$I_N = I_{sc} = 6A$

$R_N = \frac{45}{6} = 7.5\,\Omega$



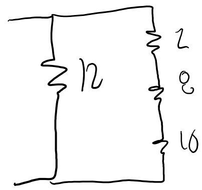
$V_{oc} = 45V$
$I_{sc} = 6A$



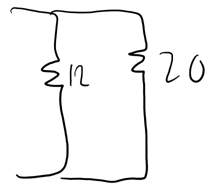
$V_{oc} = 45V$
$I_{sc} = 6A$

"Easy Way"

1) short all voltage sources or/and open all current sources
2) compare the equivalent resistance from the point of the output "Port"



=

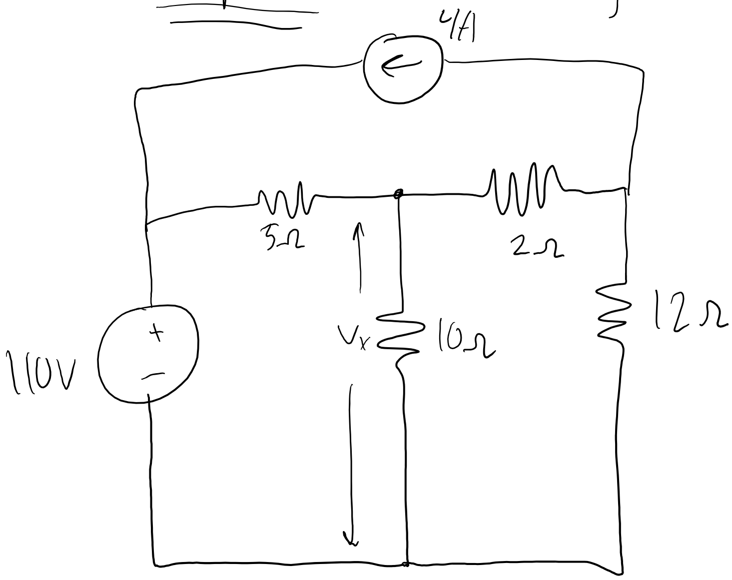


$$= \frac{20 \times 12}{12 + 20} = 7.5\Omega$$

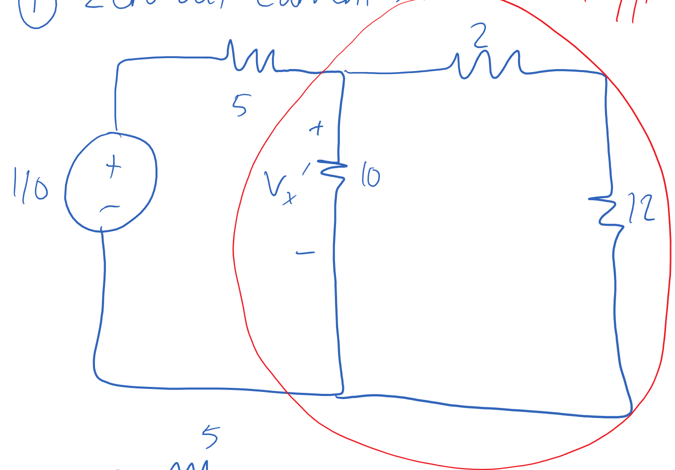
Superposition

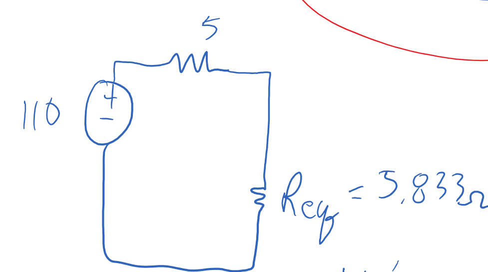
Monday, September 19, 2016 9:02 AM

Given a linear network, any circuit voltage or current may be calculated as the algebraic sum of the individual voltages or currents caused by two or more independent sources acting alone.



(1) Zero out current ~~source~~ 14||10

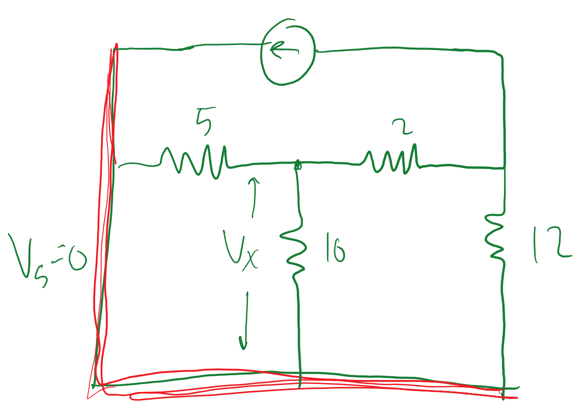


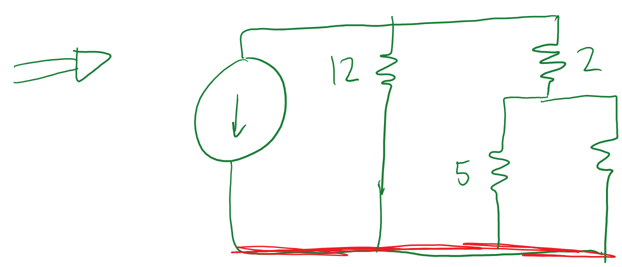


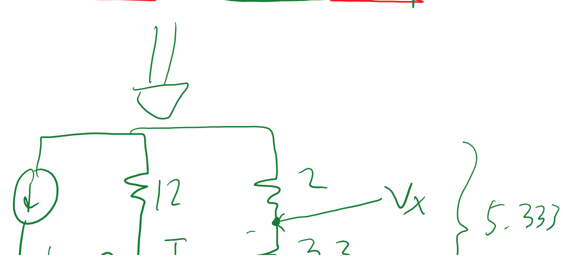
$$V_x' = \frac{5.833}{5+5.833} \cdot 110$$

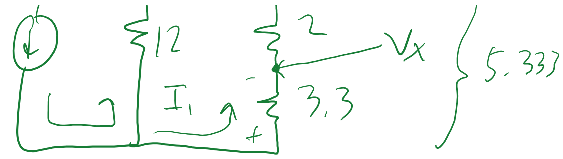
$$V_x' = 59.231\,v$$

(2) Zero out Voltage source. Activate current source









$$I_1 = \frac{4(12)}{12+5.33}$$

$$I_1 = 2.769\,A$$

$$V_x = I_1(3.33\,\Omega)$$

(Direction of resistor flipped) $V_x'' = -9.231\ V$

$$V_x = V_x' + V_x''$$

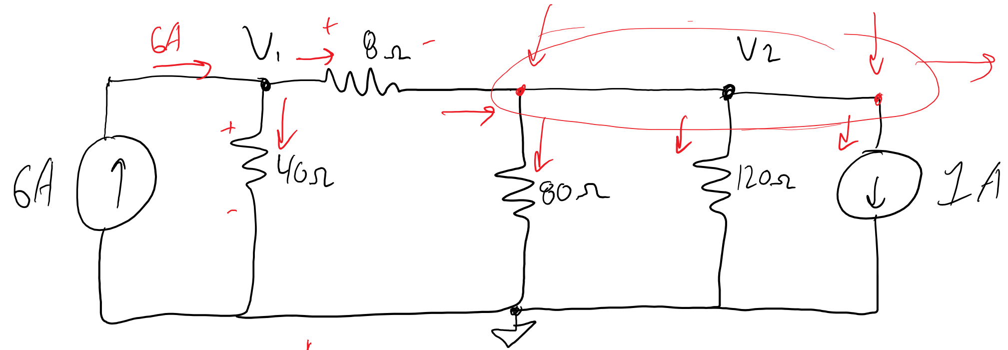
$$\boxed{V_x = 50\,V}$$

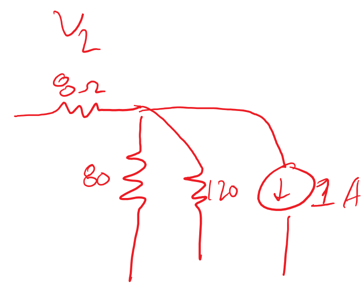
Max Power

If $R_{Th} = R_{Load}$, max power has been transferred

Test Prep

Wednesday, September 21, 2016 9:10 AM





Node Voltage Analysis

V_1: $6 = \dfrac{V_1 - 0}{40} + \dfrac{V_1 - V_2}{8}$ $\qquad 240 = V_1 + 5V_1 - 5V_2$

(1) $6V_1 - 5V_2 = 240$

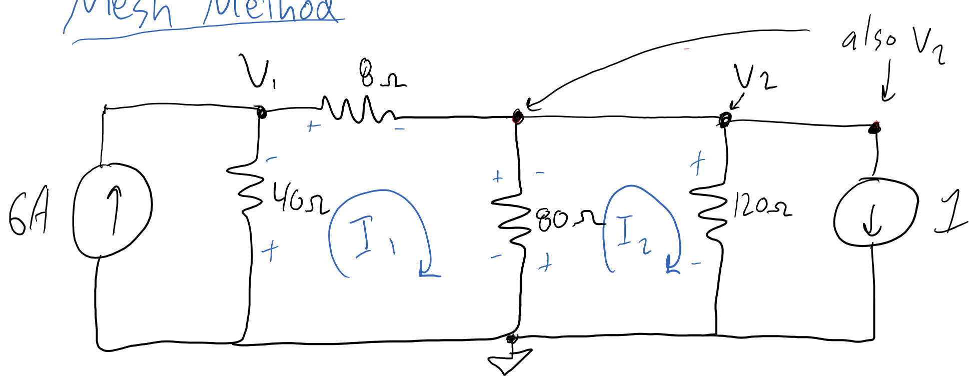
V_2: $\dfrac{V_1 - V_2}{8} = \dfrac{V_2 - 0}{80} + \dfrac{V_2 - 0}{120} + 1$

$15V_1 - 15V_2 = 1.5V_2 + V_2 + 120$

(2) $15V_1 - 17.5V_2 = 120$

$\boxed{V_1 = 120V \quad V_2 = 96V}$

Mesh Method



Mesh 1:

$40(I_1 - 6) + 8I_1 + 80(I_1 - I_2) = 0$

$40I_1 - 240 + 8I_1 + 80I_1 - 80I_2 = 0$

(1) $128I_1 - 80I_2 = 240$

Mesh 2:

$80(I_2 - I_1) + 120(I_2 - 1) = 0$

$80I_2 - 80I_1 + 120I_2 - 120 = 0$

(2) $-80I_1 + 200I_2 = 120$

$I_1 = 3A$

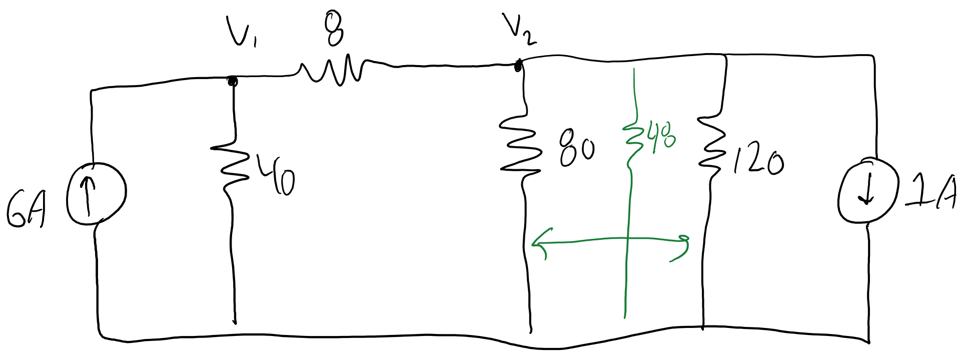
$I_2 = 1.8A$

$V_1 = 40(6 - I_1)$ $\quad V_1 = 40(3)$ $\quad \boxed{V_1 = 120\,V}$ ✓

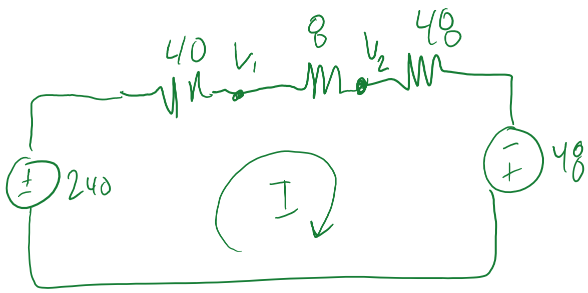
$V_2 = V_1 - 8(I_1)$ $\quad V_2 = 120 - 24$ $\quad \boxed{V_2 = 96}$ ✓

Test Prep (cont)

Friday, September 23, 2016 9:01 AM



$R_N = \frac{80 \cdot 120}{80 + 120} = 48$

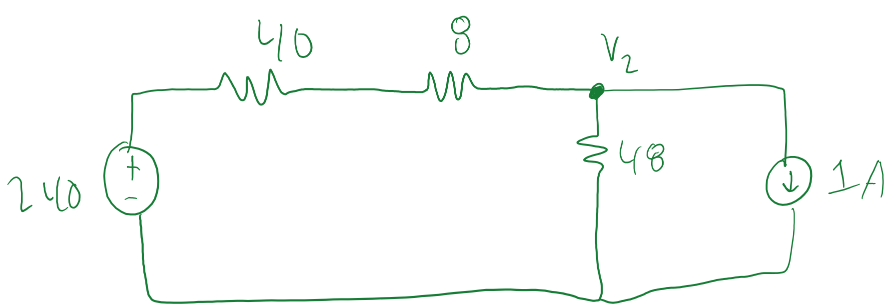


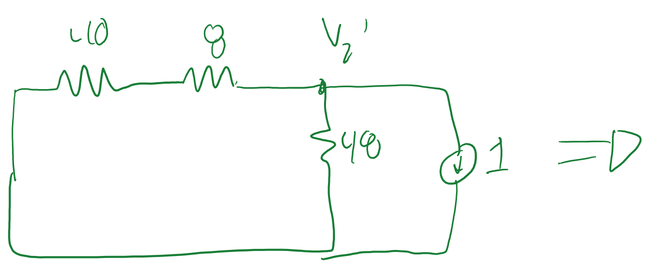
$-240 + 40I + 8I + 48I - 48 = 0$

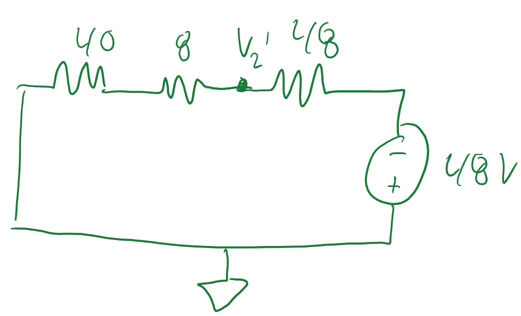
$96I = 288 \qquad I = 3A$

$240 - 3(40) = \boxed{120 = V_1}$

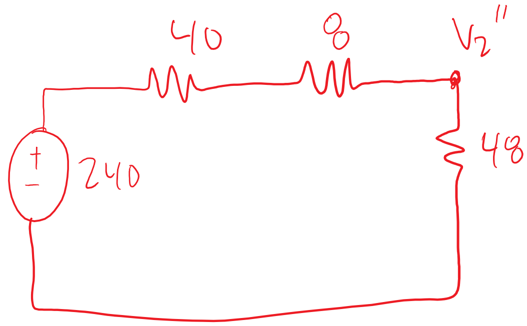
$120 - 8(3) = \boxed{96 = V_2}$





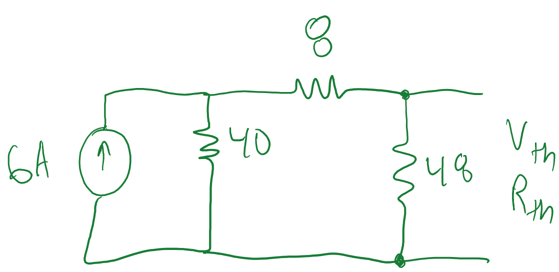


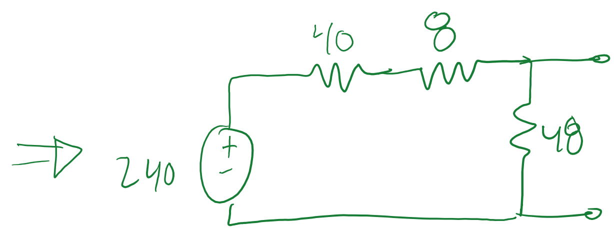
$$\underbrace{V_2' = -48\left(\frac{40+8}{96}\right)}_{\text{voltage divider}} = -24$$

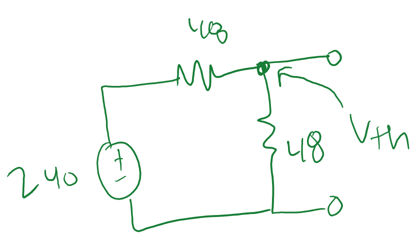


$$V_2'' = 240\left(\frac{48}{96}\right) = 120V$$

$$V_2 = V_2' + V_2'' = -24 + 120 = 96$$

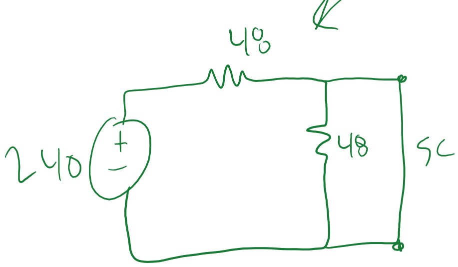






$$V_{th} = 240\left(\frac{48}{96}\right) = 120V$$

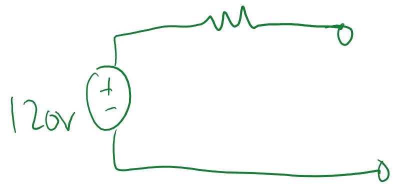
$$R_{th} = \frac{V_{th}}{I_{sc}}$$



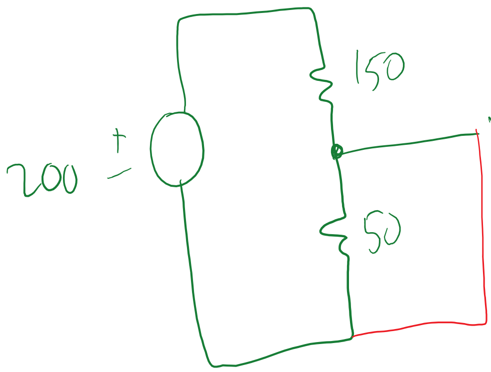
$$I_{sc} = \frac{V}{R} = \frac{240}{48} = 5A$$

$$R_{th} = \frac{120V}{5A} = 24\Omega$$

24

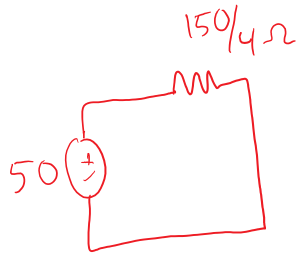


Voltage Divider



$V = 200\left(\frac{50}{200}\right)$ $V_{th} = 50V$

$I_{sc} = \frac{200}{150} = \frac{4}{3} A$



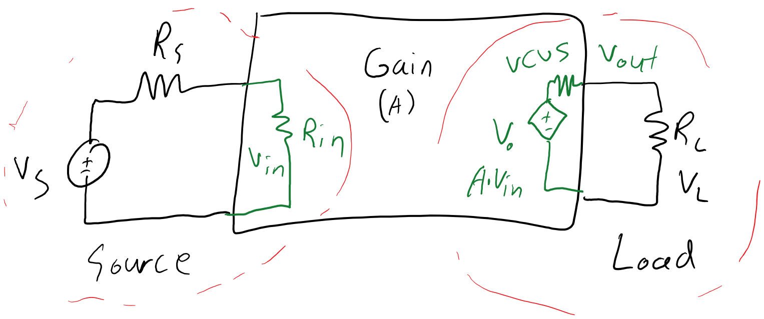
$R_{th} = \frac{V}{I}$ $R_{th} = \frac{50}{1} \cdot \frac{3}{4} = \frac{150}{4}$

Operational Amplifiers

Wednesday, September 28, 2016 8:59 AM

Role of an amplifier

- A circuit designed to boost the power of the source voltage V_s

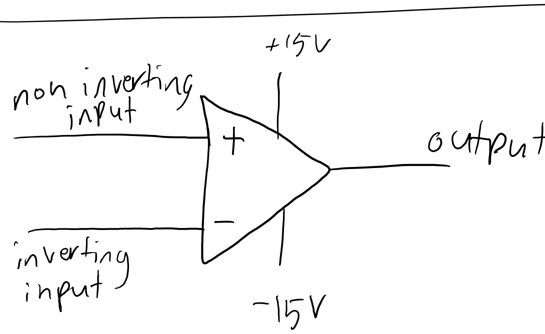


$$V_L = A \cdot V_s$$

$$V_{in} = \frac{R_{in}}{R_s + R_{in}}$$

$R_{in} \rightarrow$ large

- Input Resistance Large (10^6 to 10^9)
- High Gain (A) (10^5 to 10^6)
- $V_L = \dfrac{A \cdot V_{in} \cdot R_L}{R_L + R_o}$, so want very low output resistance ($< 1\,\Omega$)

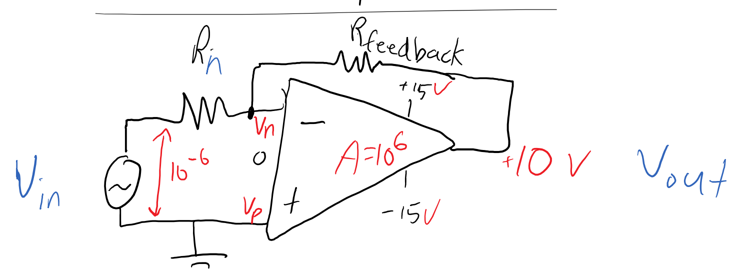


$R_{in} \rightarrow \infty$

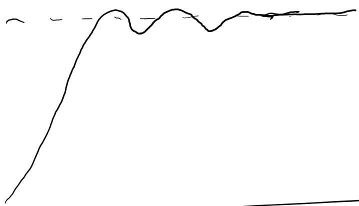
$R_{out} \sim 0$

$A \rightarrow \infty$

Classic opamp circuit



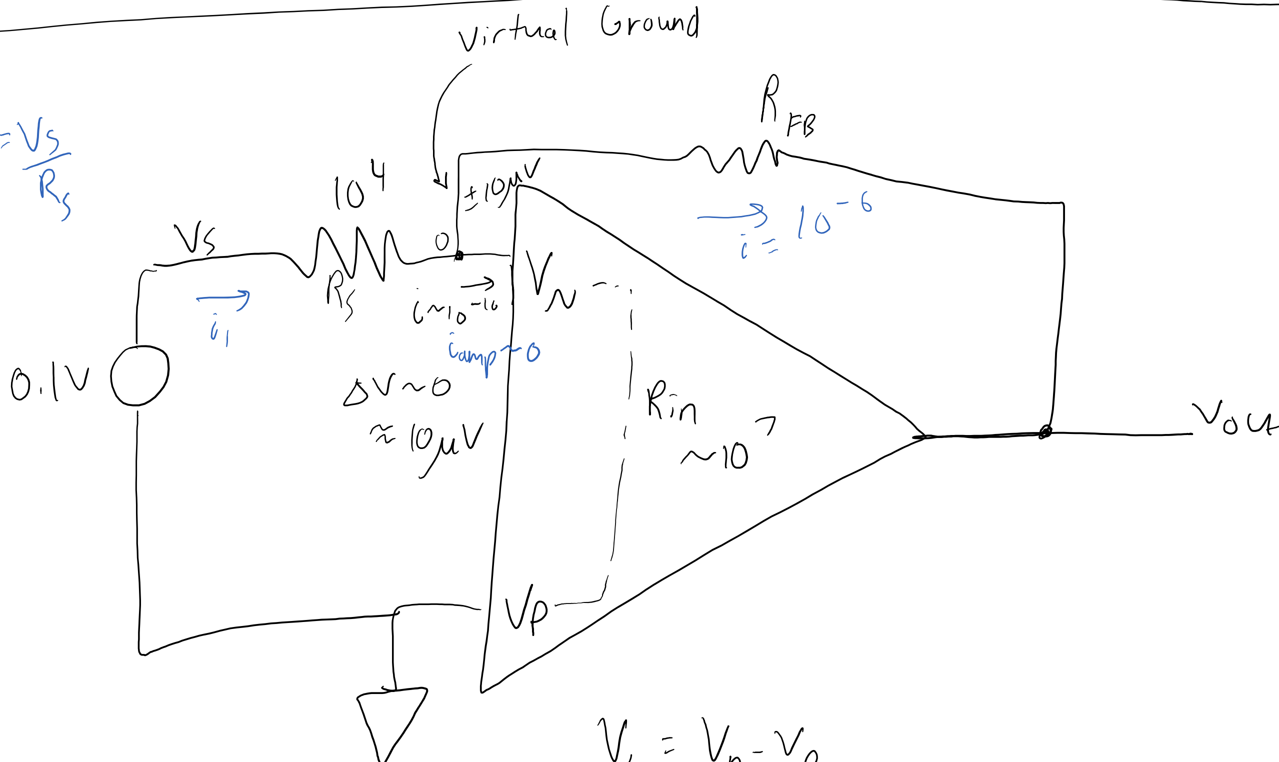
$$V_p - V_n = 0$$



$V_p - V_n = 0$

$$V_{in} = \frac{V_s \cdot R_n}{R}$$

$$i_1 = \frac{V_s}{R_s}$$

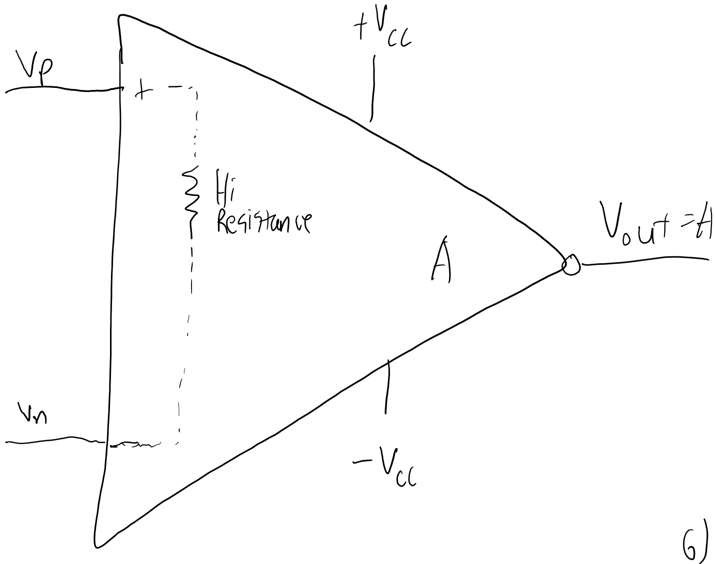


$$V_D = V_n - V_p$$

$$V_{out} = -10^6 \times 10^{-5} = -10\,V$$

Negative Feedback

Friday, September 30, 2016 9:03 AM



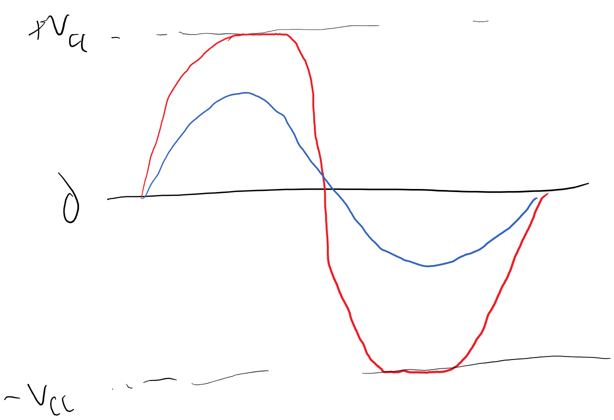
1) High Gain $(10^5, 10^6)$
2) Differential Input
3) High Input Resistance
4) Low output resistance

$V_{out} = A(V_p - V_n)$

5) Any differential signal in the input is multiplied by A

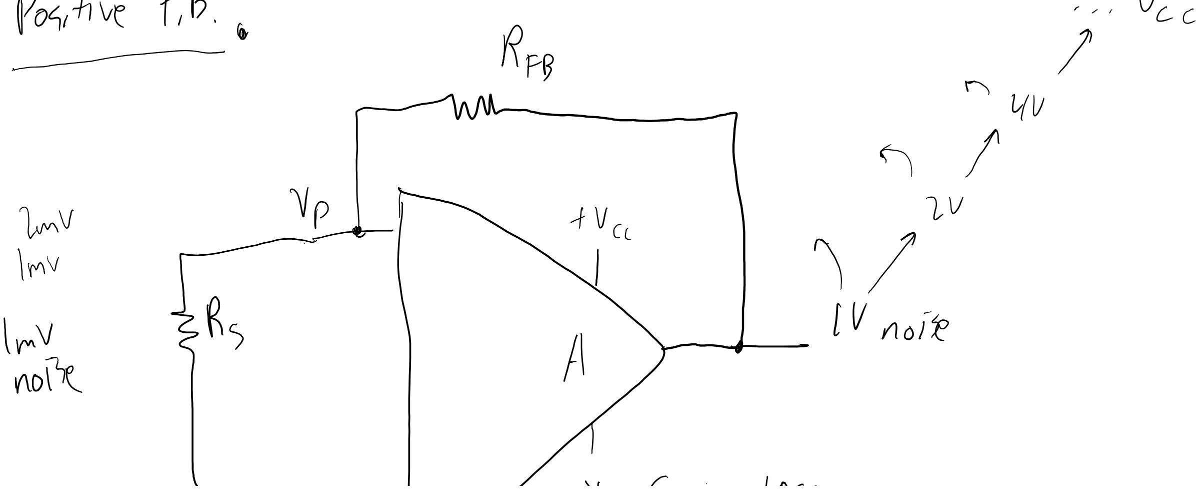
$V_{out} = A(V_p - V_n) = V(V_n - V_p)$

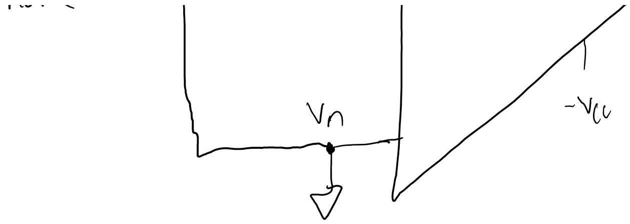
6) Has bipolar power supplies to support a bipolar output



Feedback

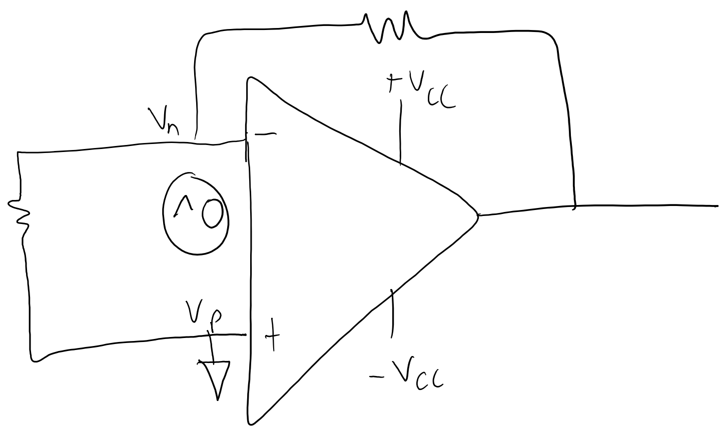
Positive F.B.:





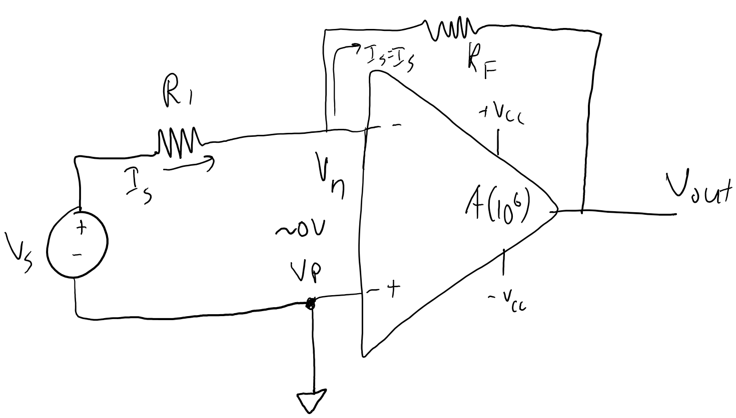
Gain 1000

Negative F.B.:



Gain ~1000

Inverting Op Amp Circuit

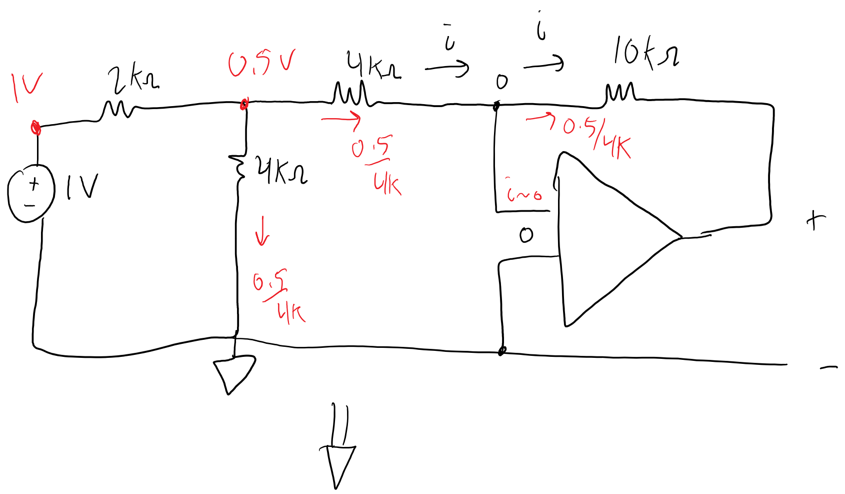


$$V_{out} = 0 - I_s R_F = -\frac{V_s}{R_s} R_F$$

$$I_s = \frac{V_s - 0}{R_s} = \frac{V_s}{R_s}$$

Gain of Circuit $= G = \frac{V_{out}}{V_s} = -\frac{\cancel{V_s} R_F}{R_s} \cdot \frac{1}{\cancel{V_s}}$

$$\text{Gain} = -\frac{R_f}{R_s}$$



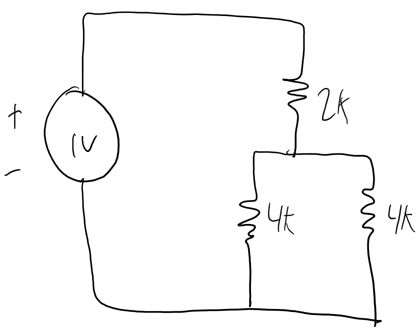
$$V_{out} = 0 - \underbrace{\left(\frac{0.5}{4k}\right)}_{I_F}\underbrace{(10k)}_{R_F}$$

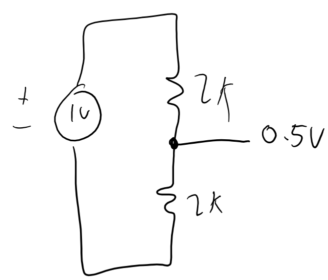
$$i_{FB} = \frac{0.5}{4k}$$

$$V_{out} = i_{FB} R_{FB}$$

$$V_{out} = -0.5 \cdot 2.5$$

$$V_{out} = -1.25V$$

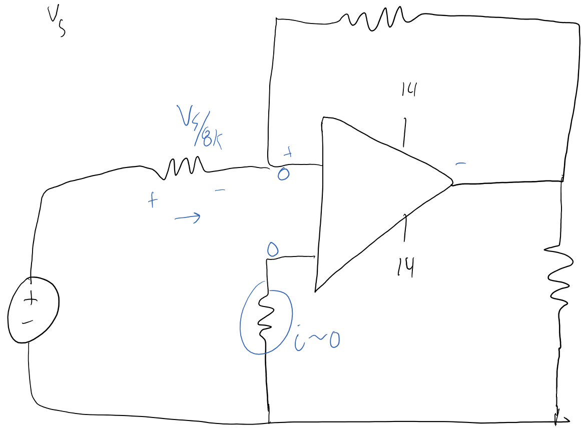




HW #5

Monday, October 3, 2016 9:09 AM

1)a) $A_v = \frac{V_o}{V_s}$



$V_{out} = 48k\left(\frac{V_s}{8k}\right) = -6V_s$

b) For -3V

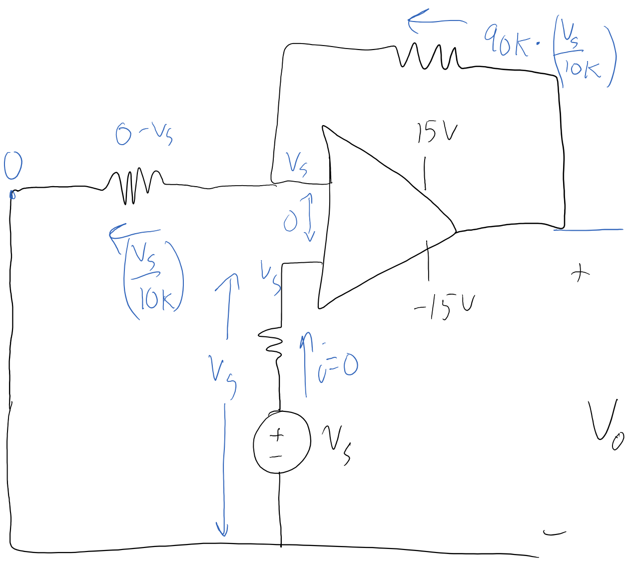
$V_{out} = -6(-3) = 18V$ - theor

14V - actual

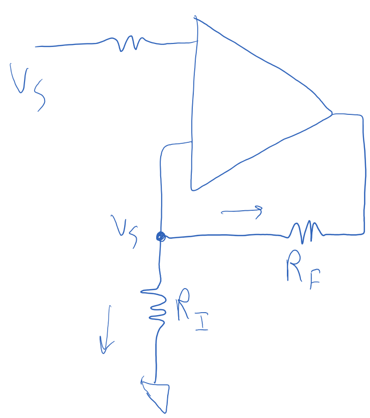
$V_{out} = -6(1.5) = -9V$ - theor

actual

2)



$V_s\left(\frac{R_F}{R_I} + 1\right) = V_s\left(\frac{90k}{10k} + 1\right) = 10V_s$



$\frac{V_s}{R_1}$

$V_{RF} = R_F \cdot \frac{V_s}{R_I}$

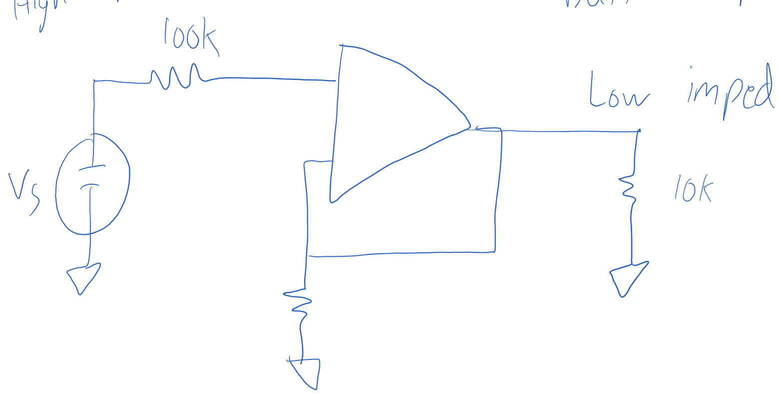
$V_{out} = V_{RF} + V_{RI}$

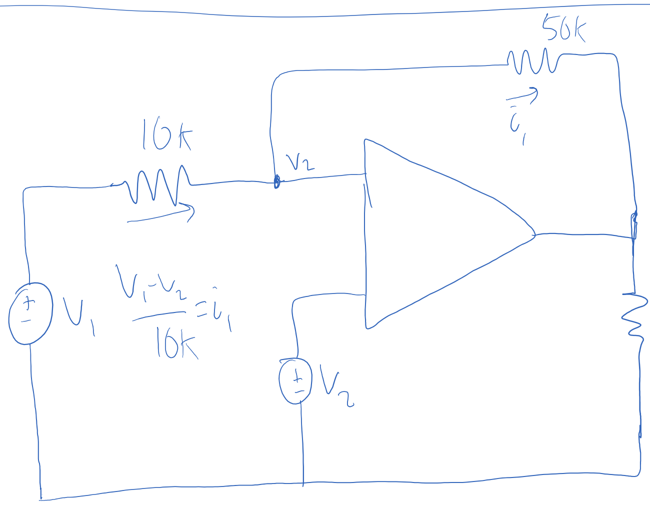
$$V_{out} = V_s\left(\frac{R_F}{R_I}\right) + V_s$$

$$= V_s\left(\frac{R_F}{R_I} + 1\right)$$

High imped

Buffer Amp

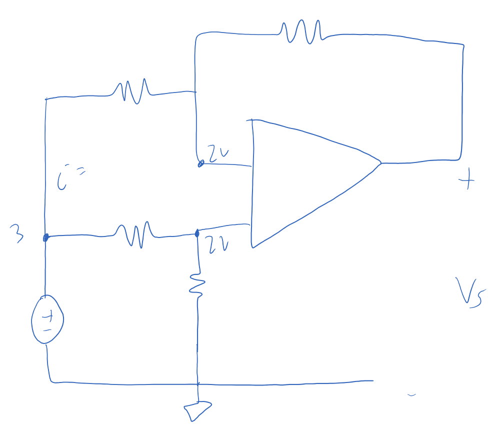




$V_{out} = V_2 - 50k\left(\frac{V_1 - V_2}{10k}\right)$

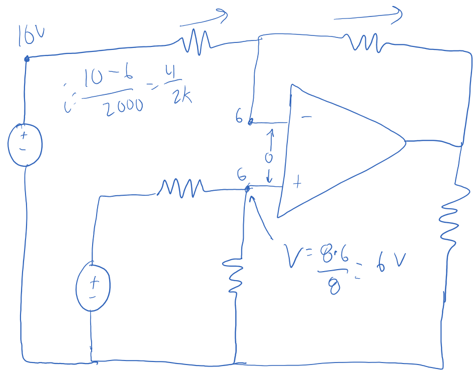
$V_{out} = V_2 - 5V_2 + 5V_1$

4) $V = \frac{3(10)}{15} = \frac{30}{15} = 2V$



$V_{out} = -8000\left(\frac{1}{2000}\right) + 2V$

$V_{out} = -4 + 2 = -2V$

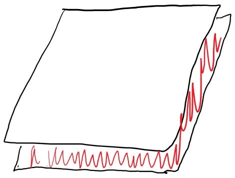


$$6 - 4k\left(\frac{4}{2k}\right)$$

$$6 - 8 = -2V$$

Inductors and Capacitors

Friday, October 7, 2016 9:02 AM



Constant ϵ_r

$\epsilon_0 = 8.85 \times 10^{-12} \frac{F}{m}$

$C = \frac{\epsilon_r \epsilon_0 A}{d}$

$V = L\frac{di}{dt}$ $\quad$ $V = \frac{1}{C}\int i\,dt$

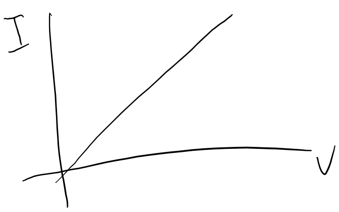
$i = \frac{1}{L}\int v\,dt$ $\quad$ $i = C\frac{dv}{dt}$

$U = \frac{1}{2}LI^2$ $\quad$ $U = \frac{1}{2}CV^2$

 cap (passive)

 inductor (passive)

conductor



$q = CV$

$\frac{Coul}{Volt} = \text{Farrad} = \frac{Amp - Sec}{Volt}$

$i = \frac{dq}{dt} = \frac{c\,dv}{dt}$ $\quad$ $i = C\frac{dv}{dt}$

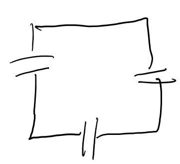
$\boxed{V = \frac{1}{C}\int i\,dt}$

$U = \int P\,dt = \int v \cdot I\,dt = V\frac{c\,dv}{dt} \quad C\int v\frac{dv}{dt} = \boxed{\frac{Cv^2}{2} = U}$

Caps in parallel

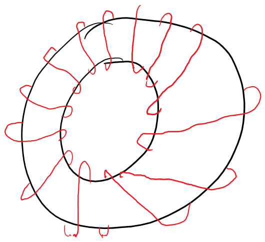
$C_T = C_1 + C_2 + C_3$

Caps in Series



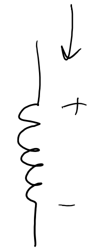
$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Inductance L = Henry = $\frac{Volt - Sec}{Amp}$



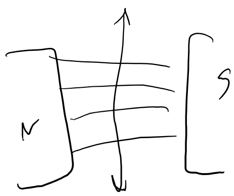
$$\lambda = LI = N\Phi$$

$$V = \frac{d\lambda}{dt} = \frac{d}{dt} LI \uparrow$$

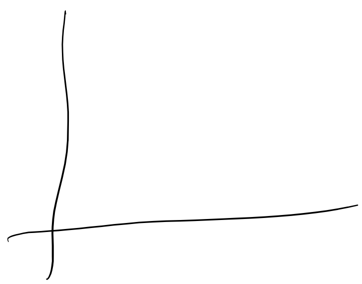


$$V = \frac{d}{dt} LI$$

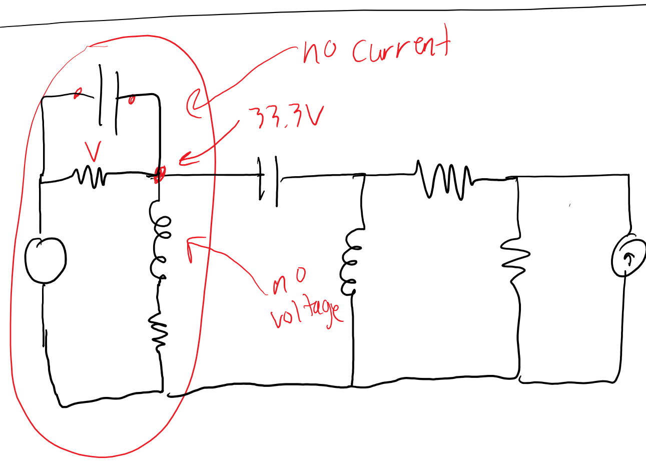
$$= L\frac{dI}{dt}$$

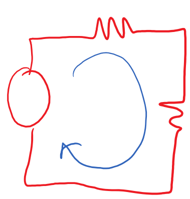


inductor



1)

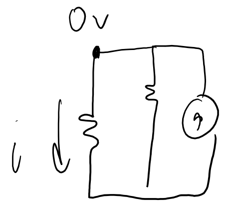




$$V = 100 \cdot \frac{100}{150}$$

$$U = \frac{1}{2}\, 10(66.6)$$

$$I = \frac{100V}{150\Omega} = \frac{2}{3}A \qquad U = \frac{1}{2} L I^2$$



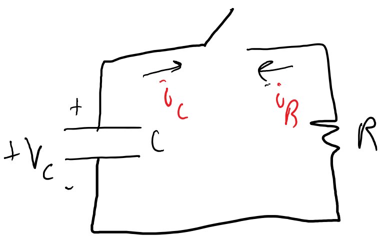
$$i = 5A\left(\frac{40}{40+20}\right) = 3.33A$$

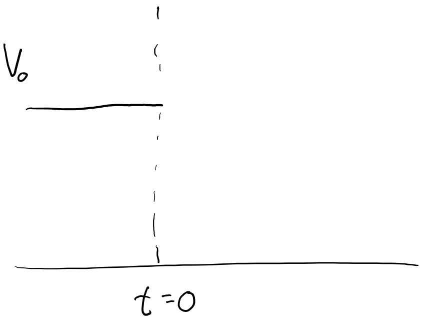
$$U = \tfrac{1}{2} L I^2$$

Transient Response of 1st Order Circuits

Monday, October 10, 2016 9:01 AM

Natural Response





$i_R = \frac{V_c}{R}$

$i_c = \frac{c\,dv_c}{dt}$

$\frac{V_c}{R} + \frac{c\,dV_c}{dt} = 0$

$V_c + Rc\frac{dv}{dt} = 0$

$V_c = ke^{st}$

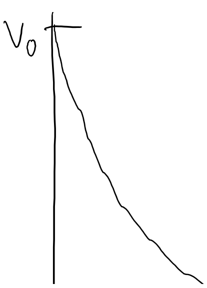
$V_c' = ske^{st}$

$Ke^{st} + sRcKe^{st} = 0$

$(1+sRc)Ke^{st} = 0$ $\quad 1+sRc=0 \quad s = \frac{-1}{RC}$

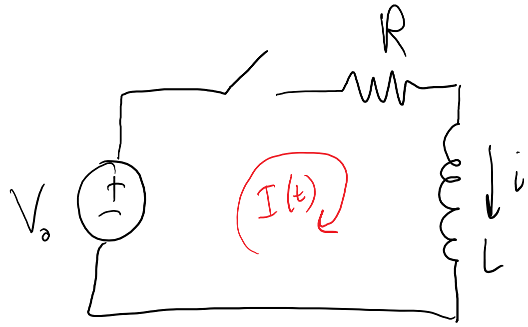
$V_{0_-} = V_{0_+} = V_c = ke^{-t/RC}$ $\quad V_c(0) = K$

$V_c = V_o e^{-t/\tau} \quad \tau = RC$



$V_c = V_0 e^{-t/\tau}$

RL - Natural Response



$$-V + i_t R + L\frac{di_t}{dt} = 0 \qquad i_t R + L\frac{di_t}{dt} = V$$

$$i_t = K_1 + K_2 e^{st}$$

$$R\left(K_1 + K_2 e^{st}\right) + K_2 L s e^{st} = V$$

$$R(K_1) + (R + sL)K_2 e^{st} = V$$

$$R + sL = 0$$

$$sL = -R \qquad s = \frac{-R}{L}$$

$$RK_1 = V$$

$$K_1 = \frac{V}{R}$$

$$i_t = \frac{V_s}{R} + K_2 e^{-\frac{R}{L}t} \qquad \frac{L}{R} = \tau$$

$$i_t = \frac{V_s}{R} + K_2 e^{-t/\tau}$$

$$i_{0+} = i_{0-} = 0 = \frac{V_s}{R} + K_2 e^{\frac{R}{L}(0)}$$

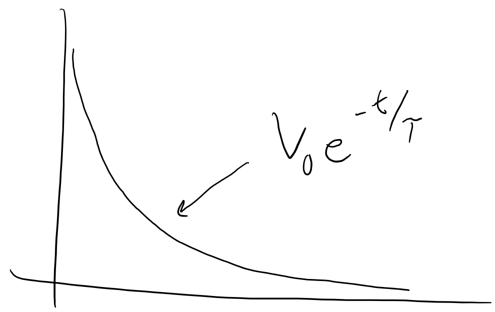
$$0 = \frac{V_o}{R} + K_2 \qquad K_2 = -\frac{V_o}{R} \qquad V_s = V_o$$

$$\boxed{i(t) = \frac{V_o}{R} - \frac{V_o}{R} e^{-t/\tau}}$$

$$i(t) = \frac{V_o}{R}\left(1 - e^{-t/\tau}\right)$$

$$i(t) = \frac{V_0}{R}\left(1 - e^{-t/\tau}\right)$$

$$V_L = V_0 - i_t R$$



Process for Switched LR & RC Circuits

Step 1) Find the time constant for RC: $\tau = R_{eq} \cdot C$

for LR: $\tau = L/R_{eq}$

Step 2) Evaluate the initial value

for L: i_0 is often $\emptyset$ at $t=0$

for C: V_0 is the voltage on the capacitor at $t=0$

Step 3) Evaluate the final value at t very large

Capacitors are open circuits at t large

Inductors are short circuits at t large

Step 4) $X(t) = X_F + (X_0 - X_F)e^{-t/\tau}$

for cap: $V(t) = 0 + (V - 0)e^{-t/RC} \longrightarrow V_0 e^{-t/RC}$

for ind: $I(t) = \frac{V}{R} + \left(0 - \frac{V}{R}\right)e^{-\frac{Rt}{L}} \longrightarrow \frac{V}{R} - \frac{V}{R}e^{-Rt/L}$

Transient Analysis: Step by Step Procedure

Step 1: Find the time constant

Cap: $\tau = R_{eq} \cdot C$

Ind: $\tau = L / R_{eq}$

Step 2: Find Initial Value X_0

Cap: $V_{s_0-} = V_{s_0+}$

Ind: $I_{s_0-} = I_{s_0+}$

Step 3: Find the Final Value $\boxed{X_F}$ (>5 time constants later)

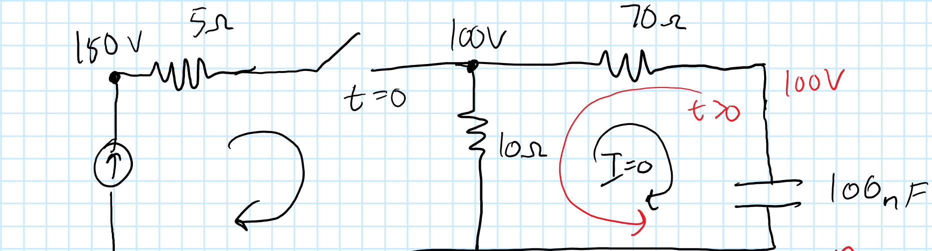
Step 4: $X_t = X_F + (X_0 - X_F)\, e^{-t/\tau}$

V_t

I_t

$X_t = X_F + (X_0 - X_F)\, e^{-t/\tau}$

HW #2



$100\text{ V} = V_{co-} = V_{co+}$

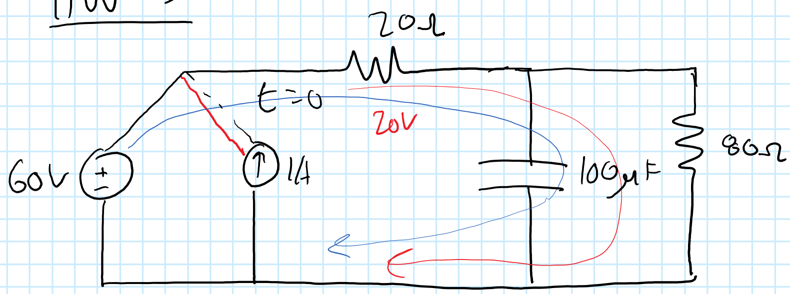
$R_{eq} = 70 + 10 \qquad \tau = 100nF \times 80\Omega$

$V_{cf} = 0\text{ V}$

$V_c(t) = 0 + (100 - 0)\, e^{-t/\tau}$

$V_c(t) = 100\, e^{-t/\tau}$

HW #3



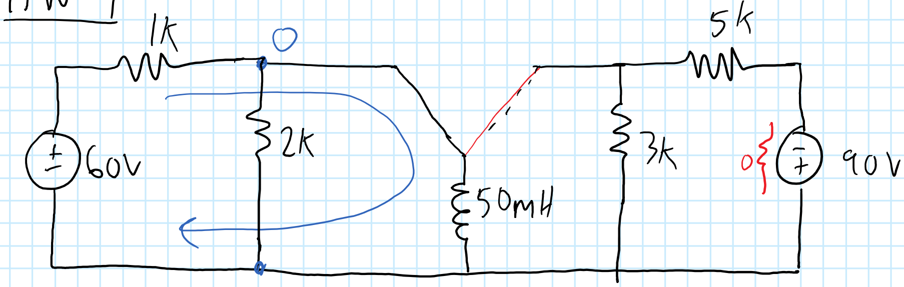
$V_{co} = \dfrac{60\,(80)}{80+20} = 48\text{V}$

$V_{co+} = 48\text{ V}$

$V_{cF} = 80\text{V}$

$x(t) = 80 + (-32)e^{-t/\tau}$ $\quad T = 100\mu F \cdot (80\Omega)$

HW#4



long time: inductor = wire

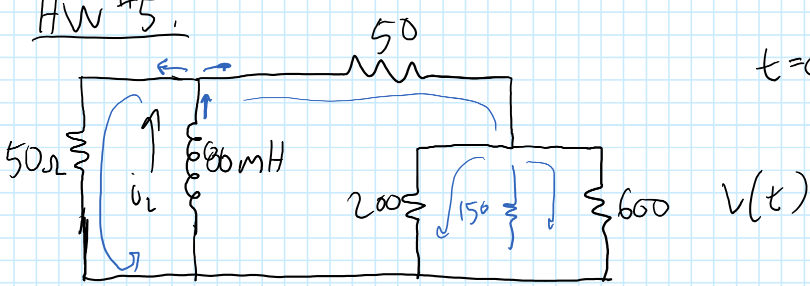
$I_L(t_0) = I_L(t_0^+) = \frac{60V}{1k} = 0.06A = X_0$

$R_{eq} = \frac{3 \times 5}{3+5} = 1.875k$

$\tau = \frac{0.05H}{1.875k}$

I_f: final: inductor = wire, so $i = \frac{-90V}{5K} = -0.018A$

HW#5:



$t = 0$ is 5A

$V(t)$

$I_{0+}(t) = 5A$ $\quad R_{eq} = 150 + 50 \,||\, 50$ $\quad R_{eq} = \frac{200(50)}{250}$ $\quad R_{eq} = 40\Omega$

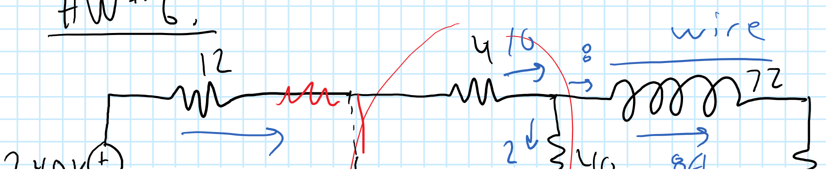
$\tau = \frac{L}{R_{eq}} = \frac{0.08H}{40\Omega}$

$I_F = 0A$ $\quad I(t) = 0 + (5-0)e^{-t/\tau}$

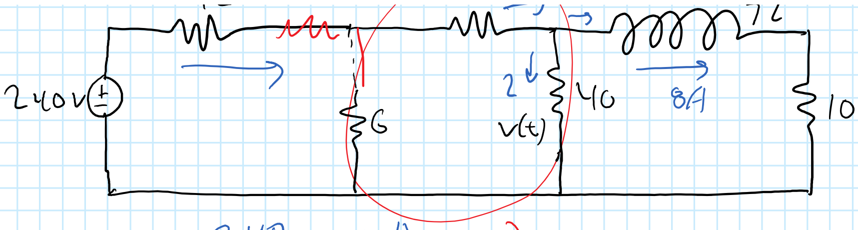
$V_{tF} = 0V$

$V_{ti} =$

HW#6:



$R_{eq} = \frac{10(40)}{} = 8\Omega$

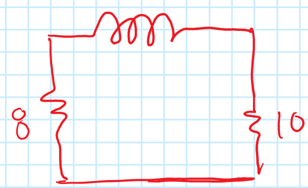


$$\frac{240}{24\,\Omega} = 10A \qquad 8\,\Omega$$

$$R_{eq} = \frac{10(40)}{50} = 8\,\Omega$$

$$I_o = \frac{10(40)}{50} = 8A$$

$$V_o(t) = 40(2) = 80V$$



$$X_F = 0$$

$$X(t) = 0 + (80 - 0)e^{-t/\tau}$$

Sequential Switching

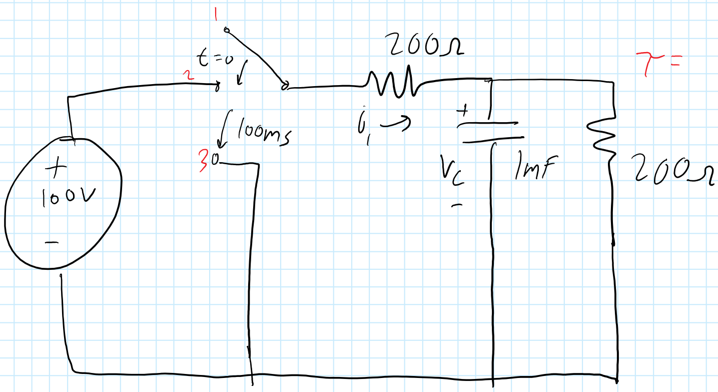
Friday, October 14, 2016 9:02 AM

General solution

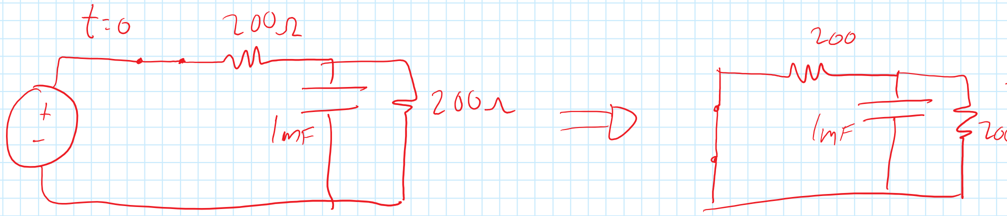
$x(t) = x_{Final} + [x_{initial} - x_{Final}]e^{-t/\tau}$

Find $i_1(t)$

Find $V_0(t)$



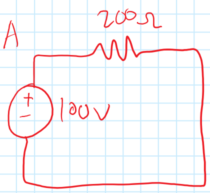
$\tau = 1mF \cdot 200Ω = 200ms$



$\tau = 0.001 \cdot 100Ω$

at t_0: $i_0 = 0.5A$

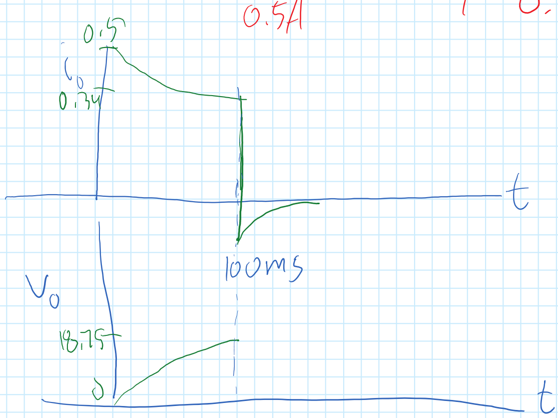
$V_0 = 0V$



cap is short circuit - No instantaneous change in voltage for cap

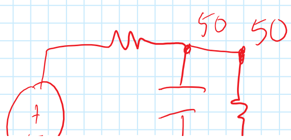
0.5A

$\tau = 0.1sec$ or $100ms$



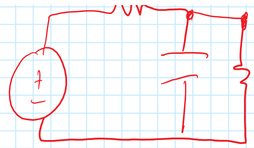
$V_{C\,Final} = 50V$

$i_{final} = 0.25A$



cap charged - no current

$i_{final} = 0.25A$



$i(t) = 0.25 + [0.5 - 0.25]e^{-t/\tau}$

$i(t) = 0.25 + 0.25e^{-t/\tau}$

$i(0.1) = 0.25 + 0.25e^{-0.1/0.1}$

$\boxed{i(0.1) = 0.3425 A}$

$V_c(t) = 50 + [0 - 50]e^{-t/\tau}$ $V_c(.1) = 50 - 50e^{-0.1/0.1}$

$V_c(0.1) = 18.5 V$

$i_{new_{0^+}} = -0.0925A$ $i_{f(new)} = 0$

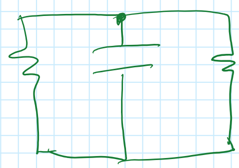
$V_{f(new)} = 0$

$V_{c\,new_{0^+}} = 18.5 V$

$\frac{18.5}{200}$

$= 0.0925A$

18.5



$\tau = 0.1 sec$

$i_{new}(t) = 0 + [-0.0925 - 0]e^{-t/0.1}$ $i_{new}(t) = -0.0925e^{-t/0.1}$

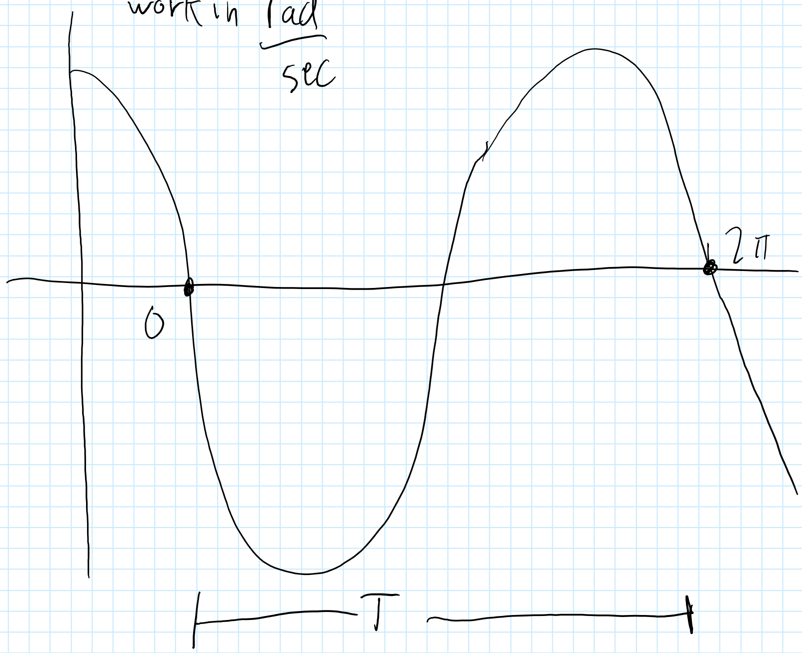
$V_{new}(t) = 0 + [18.5 - 0]e^{-t/0.1}$ $V_{new}(t) = 18.5e^{-t/0.1}$

Polar Math

Monday, October 17, 2016 9:05 AM

$f = \text{frequency} = \frac{1}{T} = \frac{\text{cycles}}{\text{sec}} = Hz$

work in $\frac{\text{rad}}{\text{sec}}$



$v(t) = \text{Amplitude} - VA$

$T = $ period of sine wave $=$ sec

$\omega = $ radian Frequency; /sec

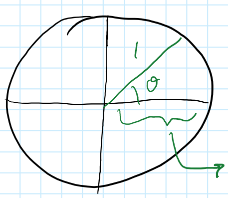
$\omega = 2\pi f$

$v(t) = \cos(\omega t + \phi)$

Note: $\sin\theta = \cos\theta + 90°$

Euler's Identity $e^{j\phi} = \cos\phi + j\sin\phi$ $j = \sqrt{-1}$ $j^2 = -1$

$v(t) = \text{Re}\{ V_m e^{j(\omega t + \theta)}$

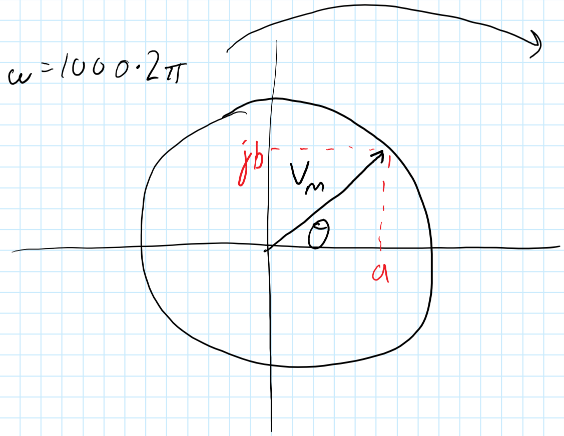


$V(t) = \text{Re}\{ V_m \cos(\omega t + \theta) + j \sin \omega t + \theta$

Phasor

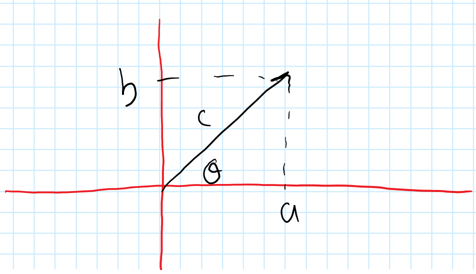
$\overline{V} = V_m \angle\theta = V\angle$

$f = 1000\ Hz$ $\omega = 1000 \cdot 2\pi$



$V_m \angle\theta$

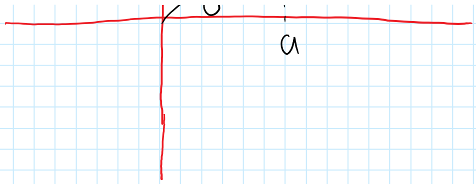
$V_m \cos(\omega t + \theta)$



Rectangular: $a + jb$

Polar: $C\angle\theta$

Rect → Polar



Polar: $C \angle \theta$

Rect $\rightarrow$ Polar

$$C = \sqrt{a^2 + b^2}$$

$$\theta = \tan^{-1}\left(\frac{b}{a}\right)$$

Polar $\rightarrow$ Rect

$$a = C\cos\theta$$

$$b = C\sin\theta$$

Basic Arithmetic:

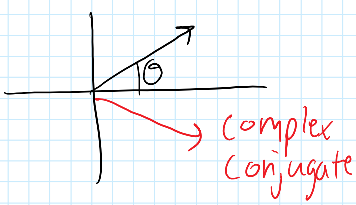
Add + Sub $\rightarrow$ use Rectangular

Mult + Div + Exponential $\rightarrow$ Use Polar

Complex Conjugate: $n = a + jb$

$n^* = a - jb$ $\rightarrow$ complex conjugate

$$n^k = (a+jb)^k = \left(Ce^{j\theta}\right)^k = C^k e^{j\theta k} = \left(\bar{V}\angle\right)^k = \bar{V}_m^k \angle k\theta$$



$n_1 = 4 + j3 = 5\angle 36^\circ$

$n_2 = 13\angle 67.4^\circ = 5 + j12$

$n_1 + n_2 = 4 + j3 + 5 + j12 = 9 + j15 = 17.5\angle 59^\circ$

$$\frac{n_1}{n_2} = \frac{4+j3}{5+j12} = \frac{5\angle 36^\circ}{13\angle 67.4^\circ} = \frac{5}{13}\angle -30.51^\circ$$

$(5\angle 36.9)^4 = 5^4 \angle 36.9^4 = 625\angle 147.48^\circ$

$(n_1^*)(n_2) = (5\angle -36^\circ)(13\angle 67.4^\circ) = 65\angle 31.4^\circ$

Circuit Elements in the Frequency Domain

Wednesday, October 19, 2016 9:02 AM

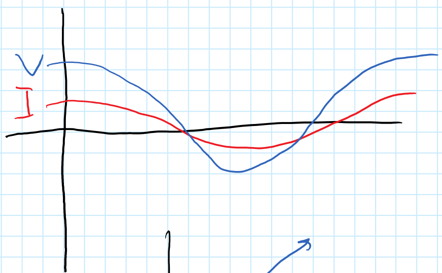
$v(t) = V_m \cos(\omega t + \theta)$ $\quad Re\{V_m e^{(j\omega t + \theta)}$

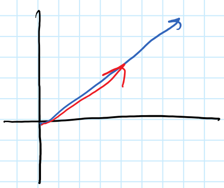
$i(t) = I_m \cos(\omega t + \theta)$ $\quad Re\{I_m e^{(j\omega t + \theta)}$

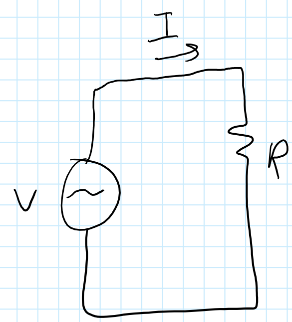
$$\frac{V_m e^{j\nu t + \theta_v}}{e^{j\nu t}} = \frac{R I e^{j\nu + \theta_i}}{e^{j\nu t}} \qquad V_m e^{j\theta_i} = R I e^{j\theta_i}$$

$V\angle = R I\angle$

$\theta_v = \theta_i$







$I = \frac{V}{R}$

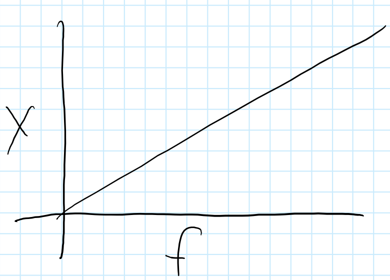
$I\angle = \frac{V\angle}{R}$

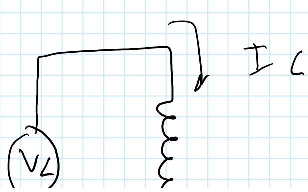
Inductor: $V_L = L\frac{di}{dt}$ $\qquad \frac{L d\, I_m e^{j(\omega t + \theta)}}{dt}$

$$\frac{V e^{j(\omega t + \theta_v)}}{e^{j\omega t}} = L j\omega \frac{I e^{j(\omega t + \theta_i)}}{e^{j\omega t}} \qquad V e^{j\theta_v} = j\omega L I e^{j\theta_i}$$

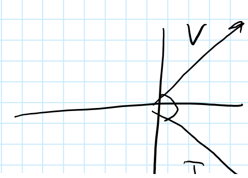
$$V\angle = \underbrace{j\omega L}_{X_L} I$$

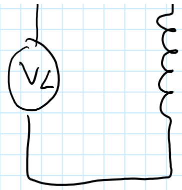
$X_L \rightarrow$ inductive reactance, frequency dependent, in ohms



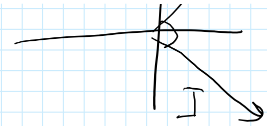


$I\angle = \frac{V\angle}{j\omega L} \cdot \frac{j}{j}$



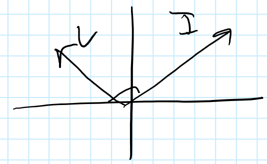


$$\frac{\;}{j\omega L} \quad \frac{}{j}$$



$$I = \frac{-jV}{\omega L}$$

$$V = j\omega L\, I$$



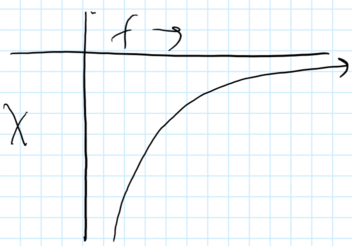
Capacitor: $i(t) = C\dfrac{dV(t)}{dt}$ $\qquad I_m e^{j(\omega t+\theta_v)} = C\dfrac{d}{dt} V_m e^{j(\omega t+\theta_i)}$

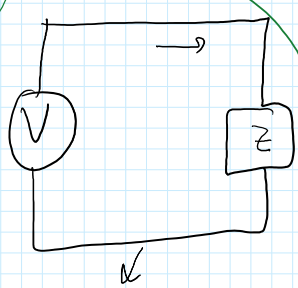
$$\frac{I_m e^{j(\omega t+\theta_i)}}{e^{j\omega t}} = \frac{j\omega C V e^{j(\omega t+\theta_i)}}{e^{j\omega t}}$$

$$I_m e^{j\theta_v} = C j\omega V e^{j\theta_i}$$

$$\frac{1}{j\omega t} = \frac{\bar{V}}{\bar{I}} = jX$$

$$X = \frac{1}{j\omega C} \qquad X_C = \frac{-j}{\omega C}$$





$I = \dfrac{V}{R}$

$\theta_i = \theta_v$

$I = \dfrac{V}{jX_L}$

$\theta_i = \theta_v - 90°$

Resistor

$V = IR$

$V_{\angle\theta} = I_{\angle\theta} R$

$\theta_v = \theta_i$ for resistors

Inductor

$V = I j X_L$

$V_{\theta_v} = I_{\theta_i}(X \angle 90°)$

$\theta_v = \theta_i + 90°$

Capacitor

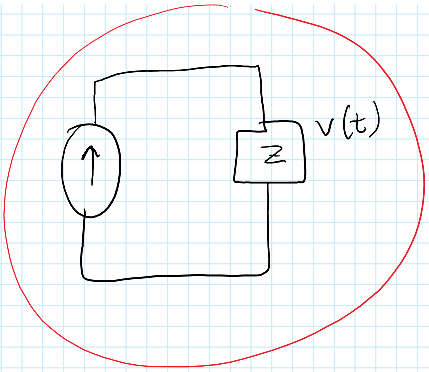
$V = I(-jX_C)$

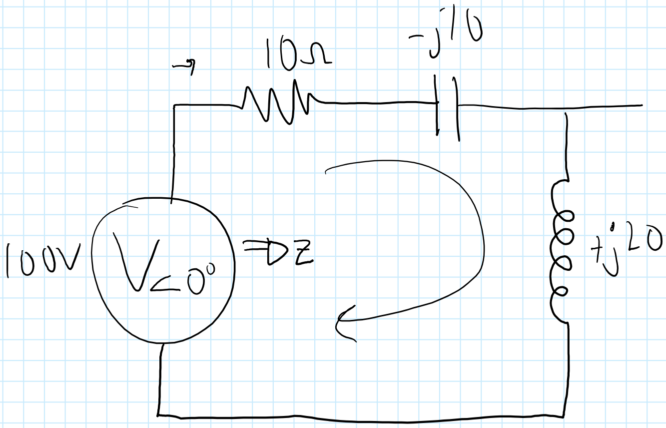
$V_{\theta_v} = I_{\theta_i}(X \angle -90°)$

$\theta_v = \theta_i - 90°$

$I = \dfrac{V}{-jX_C} \cdot \dfrac{j}{j} = \dfrac{jV}{X_C}$ $\qquad \theta_i = \theta_v + 90$

$$I = \frac{V}{-jX_L} \cdot \frac{j}{j} = \frac{jV}{X_c} \qquad \theta_i = \theta_v + 90$$





$Z = R \pm jX$

$$z = 10 - j10 - j20 \quad = 10 + j10$$

$$i = \frac{100V}{10+j10} \qquad V_{out} = \frac{j20(100V)}{10+j10}$$

- Reactance of Elements is frequency dependent
- Impedence:

	Resistor	Inductor	Capacitor
	R	$j\omega L$	$\frac{-j}{\omega C}$

Phasors, Impedance, and Admittance

Friday, October 21, 2016 9:04 AM

Element	Impedence	Reactance	Conductance Susceptance	Admittance
Resistor	$R + j0$	$j0$	$\frac{1}{R} = G$	$\frac{1}{R} + j0$
Inductor	$0 + j\omega L$	$j\omega L$	$\frac{1}{j\omega L} = \frac{-j}{\omega L}$	$0 - \frac{j}{\omega L}$
Capacitor	$0 - \frac{j}{\omega C}$	$\frac{-j}{\omega C}$	$\frac{1}{\frac{-j}{\omega C}} = j\omega C$	$0 + j\omega C$

Sinusoidal Steady State Analysis

1) Identify the frequency
2) Convert from the time domain to the frequency domain
3) Solve the linear system:

$\underline{V} = \underline{I}\, Z$

$\underline{I} = \frac{\underline{V}}{Z} = \underline{I} = \underline{V} \cdot Y \rightarrow$ (admittance)

4) When requested, convert back to the time domain

$V\angle \Rightarrow V_m \cos(\omega t + \theta)$

$v(t) = V_m \cos(\omega t + \theta)$

$I(t) = \underbrace{I_m}_{\text{magnitude}} \cos \underbrace{(\omega t + \theta)}_{\text{phase } \angle}$

frequency $= \omega = 2\pi f$

Angle $= \theta$

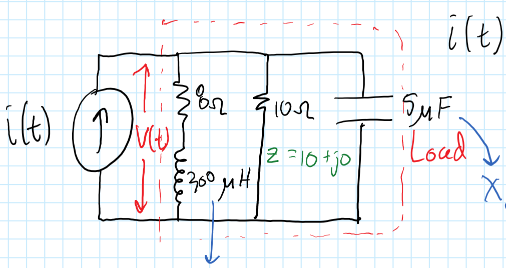
$f = 1000\,\text{Hz}$

$\omega = 2\pi f = 6280\ \frac{\text{rad}}{\text{sec}}$

Phasor $V = V_m \angle \theta$

$I = I_m \angle \theta$

$i(t) = 922 \cos(20000t + 30°)$ Amps

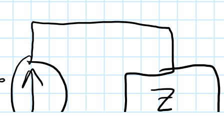


$X_C = \frac{-j}{\omega C} = \frac{1}{(2\times10^4)(5\times10^{-6})} = -j10$

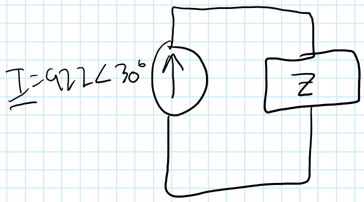
$X_L = j\omega L = j(300\times10^{-6} \cdot 20000) = j6\,\Omega$

$Z = 8 + j6$

$I = 922\angle 30°$



$Z = \frac{1}{\quad}$



$$Z = \frac{1}{\frac{1}{8+j6} + \frac{1}{j6} + \frac{-1}{j10}}$$

$$Y = (0.08 - j0.06) + 0.1 + 0.1j = 0.18 + 0.04j$$

$$Z = \frac{1}{Y} = \frac{1}{0.18 + 0.04j} = 5.294 - j1.176$$

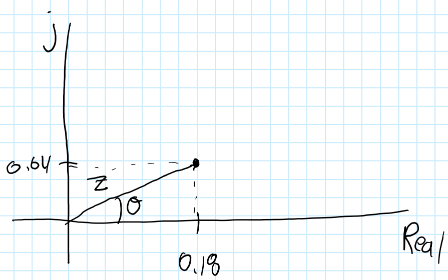
$$Z = \frac{1}{0.184\angle 12.52} \qquad \boxed{Z = 5.423\angle -12.52°}$$

$$\underline{V} = (922\angle 30°)\cdot(5.423\angle -12.52°)$$

$$\boxed{\underline{V} = 5000.24\angle 17.47°}$$

time domain equivalent → $\boxed{v(t) = 5000.24\cos(2000t + 17.47°)}$

$$\frac{1}{0.18 + j.04}$$

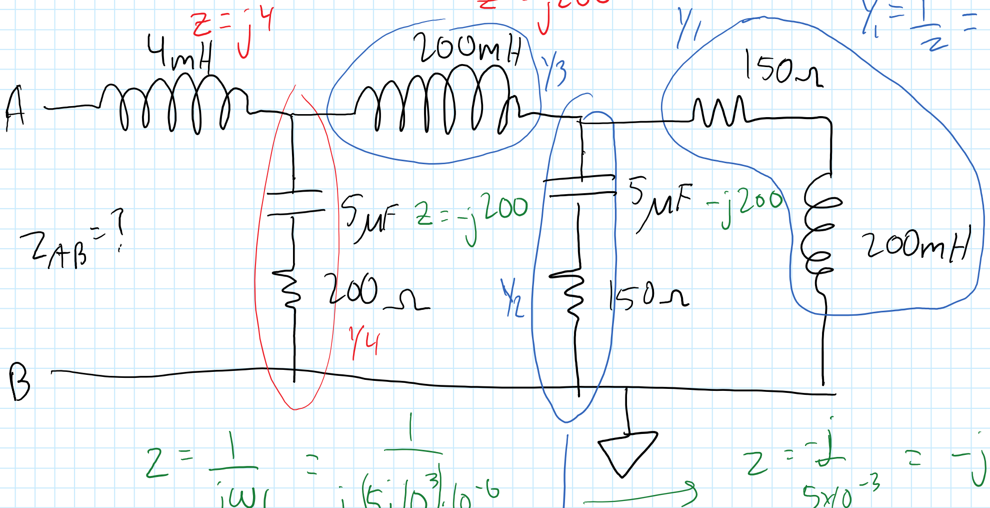


$$|Z| = \sqrt{0.18^2 + 0.04^2} = 0.184$$

$$\theta = \tan^{-1}\left(\frac{0.04}{0.18}\right) = 12.528°$$

Examples for Impedance

Monday, October 24, 2016 9:01 AM



$Z = 150 + j200$

$Y_1 = \frac{1}{Z} = 0.0024 - 0.0032j$

$\omega = 1000$

$Z_{AB} = ?$

$z = j\omega L$

$z = j200$

$Z = \frac{1}{j\omega L} = \frac{1}{j(5 \cdot 10^3) \cdot 10^{-6}}$

$z = \frac{-j}{5 \times 10^{-3}} = -j200$

$z = 150 - j200$

$Y_2 = \frac{1}{Z} = 0.0024 + 0.0032j$

$Y_T = Y_1 + Y_2 = 0.0048$

$Z_T = \frac{1}{Y_T} = 208.3\ \Omega$

$Y_3 = Y_3 + Y_T = (208.3 + j200)^{-1} = 0.002498 - 0.002398j$

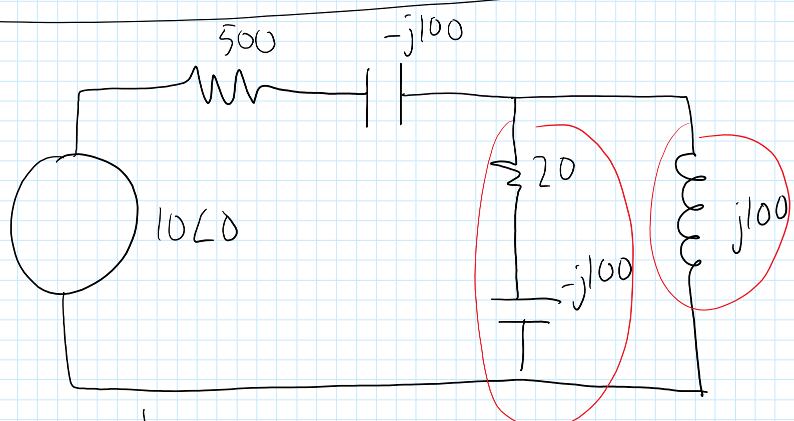
$Y_4 = (200 - j200)^{-1} = 0.0025 + 0.0025j$

$Y_T = Y_3 + Y_4 = 0.004998 + 0.000102j$ $\quad Z_T = 200 - 4.08163j$

$Z_{AB} = 200 - 4.08163j + j4$

$\boxed{Z_{AB} = 200 - 0.081633j} = 200 \angle -0.02j$

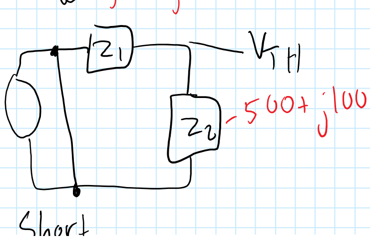
$Z_{AB} = 200 \angle -1.169$



$Y = \frac{1}{j100} = -j0.01$

$z = 20 - j100$

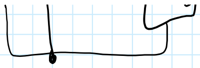
$500 - j100$



$Y_2 = 0.001923 + 0.009615j$

$Y_1 + Y_2 = 0.001923 - 0.000385j$

$Z_2 = 500 + 100j$



Short out source for Z_{th}

$Z_2 = 500 + 100j$

$$V_{TH} = \frac{10(Z_2)}{Z_1 + Z_2} = \frac{10(500+j100)}{500-j100+500+j100} = \frac{10(500+j100)}{1000}$$

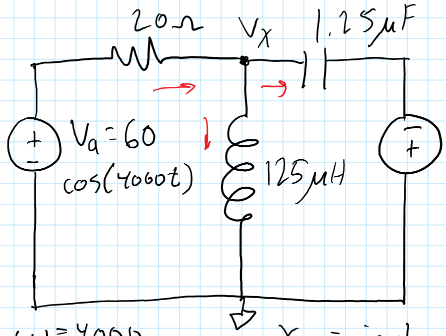
$$\boxed{V_{TH} = 5 + j1} = 5.099 \angle 11.31^\circ = \bar{V}_{TH}$$

$Z_{th} = Z_1 \| Z_2$ $\quad$ $Z_{th} = 500 - j100 \| -500 + j100$

$$\boxed{Z_{th} = 260\,\Omega}$$

More Transient Circuits

Wednesday, October 26, 2016 9:04 AM



$V_b = 90\cos(40{,}000t + 90°)$

$\omega = 4000$

$X_L = j\omega L = (4\times10^4)(125\times10^{-6}) = 5j\,\Omega$

$X_c = \dfrac{-j}{\omega C} = \dfrac{-j}{(4\times10^4)(1.25\times10^{-6})} = -j20$

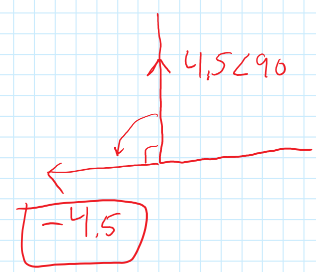
$V_a = 60\angle 0°$

$V_b = 90\angle 90°$

$$\frac{V_a - V_x}{20\Omega} = \frac{V_x - V_b}{j20\Omega} + \frac{V_x}{j5\Omega}$$

$$\frac{(60\angle 0) - V_x}{20} = \frac{V_x - (90\angle 90°)}{-j20} + \frac{V_x}{j5}$$

$3 - 0.05V_x = 0.05jV_x + j4.5\angle 90° - j0.2V_x$

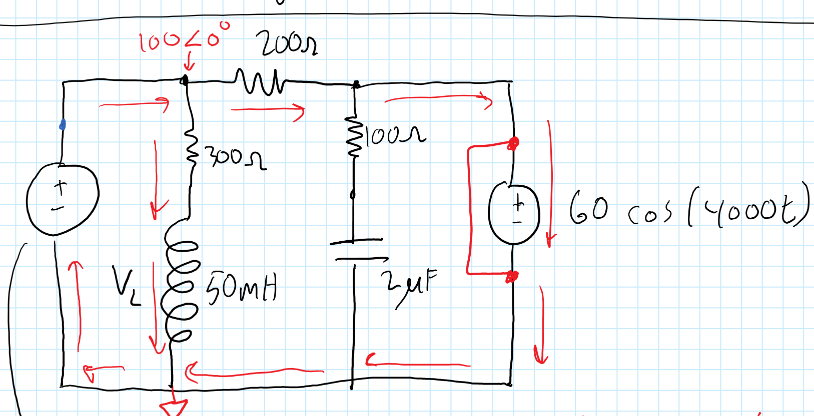


$7.5 - 0.05V_x = 0.05jV_x - j0.2V_x$

$7.5 = 0.05V_x - 0.15jV_x$

$V_x = \dfrac{7.5}{0.05 - j0.15}$

$\boxed{V_x = 47\angle 71.56°}$



Superposition

$\omega = 3000$

100 cos 3000t $= 100\angle 0°$

Cap: $j\omega L = j(50\times10^{-3})(3000) = j150$

$$V_L = \frac{(100\angle 0°)(j150)}{300 + j150}$$ voltage divider

$V_L' = 44\angle 63.4°$

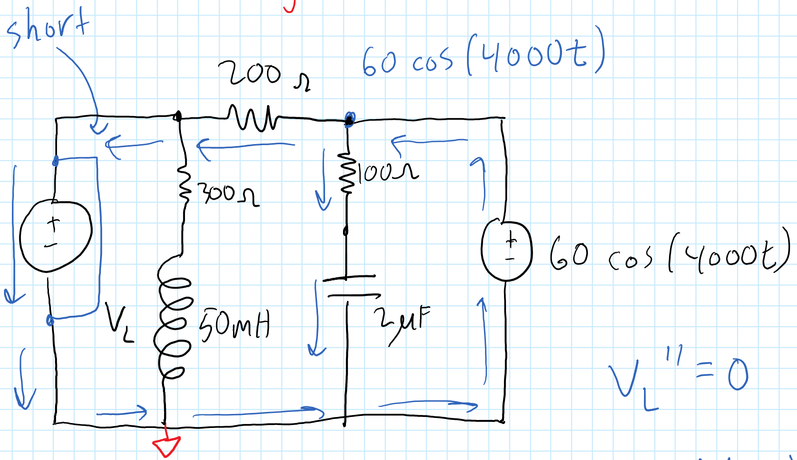
$V_L'(t) = 44\cos(3000t + 63.4°)$

short

60 cos(4000t)

$900 + j150 \qquad)$

$V_L'(t) = 44\cos(3000t + 63.4°)$



$V_L'' = 0$

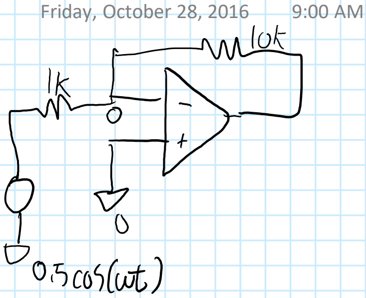
$V_L = V_L'' + V_L'$

$$\boxed{V_L(t) = 44\cos(3000t + 63.4°)}$$

Exam 2 Review

Friday, October 28, 2016 9:00 AM

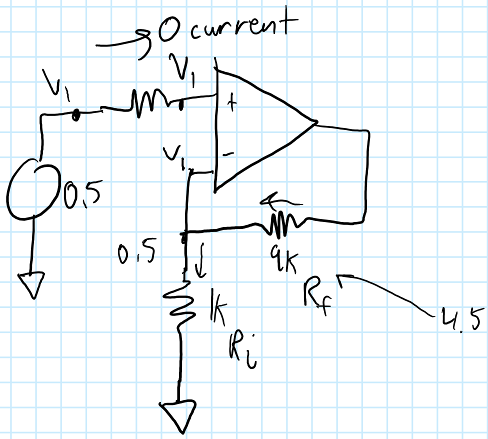
1) OP AMPs



inverting (negative feedback)

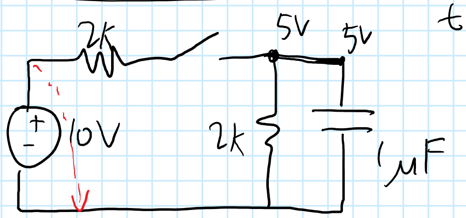
$$Gain = \left(-\frac{R_f}{R_i}\right) \qquad Gain = -10$$

$$Output = 5\cos(\omega t + 180^\circ) \quad \text{or} \quad -5\cos(\omega t)$$



$$Gain = +\left(\frac{R_f}{R_i} + 1\right)$$

2) Transient Response



$t=0$ switch closes

$V_{initial} = 0\ v \qquad \tau = R_{eq}\, C$

$V_{final} = 5\ v \qquad \tau = (1k)(10^{-6}) = 10^{-3}$

$$V(t) = V_f + (V_i - V_f)\, e^{-t/\tau}$$

$$V(t) = 5 + (0-5)e^{-t/10^{-3}} \qquad \boxed{V(t) = 5 - 5e^{-t/0.001}}$$

$\bar{V} = V_m \angle \theta$ → frequency domain

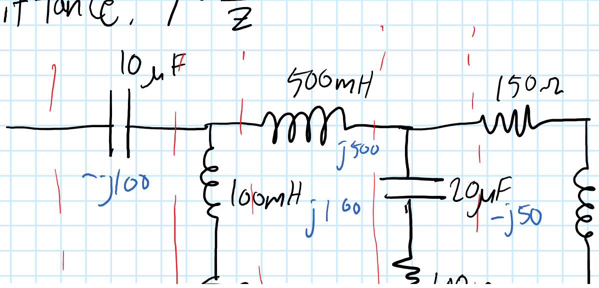
$V(t) = V_m(\cos\omega t + \theta)$ → time domain

$\omega = 2\pi f = \frac{rad}{sec}$

Impedance: $Z = R + x \qquad X_c = \frac{-j}{\omega C} \qquad X_L = j\omega L$

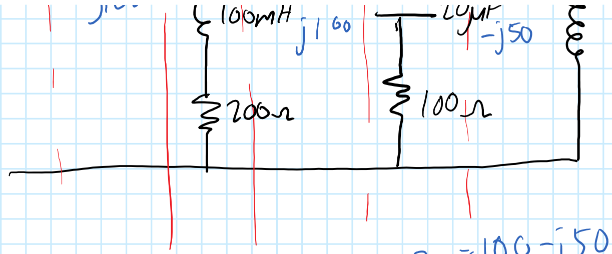
Admittance: $Y = \frac{1}{Z}$

Ex:



$X_L = 1000\,(200 \times 10^{-3})$

$x = j200$



$X_L = 1000\,(200 \times 10^{-3})$

$X = j200$

$Z_1 = 150 + j200$

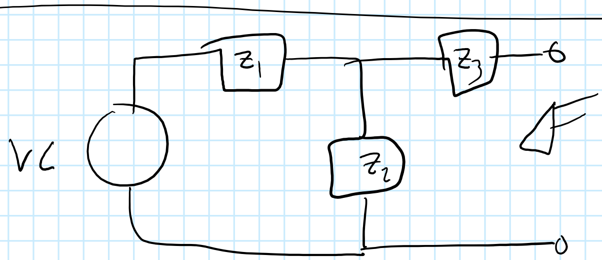
$Z_2 = 100 - j50$

$$Z_3 = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}}$$

$Z_4 = Z_3 + j500$

$Z_5 = \left((Z_4)^{-1} + (200 + j100)^{-1}\right)^{-1}$

$Z_{AB} = Z_5 - j100$



$$V_{TH} = \frac{V_C\,(Z_2)}{Z_1 + Z_2}$$

$$Z_{TH} = Z_3 + (Z_2 \,||\, Z_1)$$

Variable Frequency

Wednesday, November 2, 2016 9:01 AM

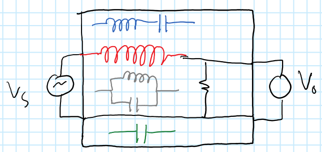
Power : 50/60 Hz + harmonics

Communications/Control

Frequency Spectrum

Steady State Analysis

Transfer Functions



$V_o = \frac{V_s(R)}{(R + jX_L)}$

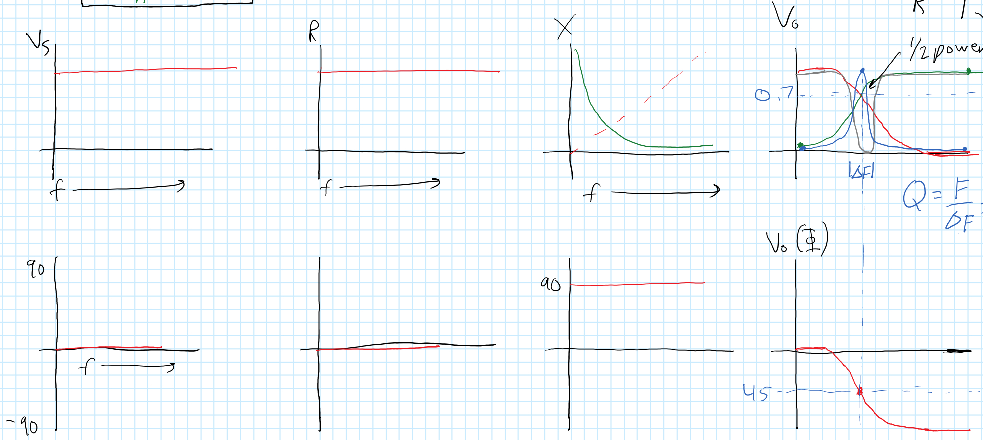
$V_o = \frac{V_s(R)}{(R - jX_c)}$

$V_o = \frac{V_s(R)}{R + jX_L - jX_c}$

$V_o = \frac{V_s(R)}{R + \left(\frac{1}{Y_L + Y_c}\right) \to X_0}$

at res, $\frac{1}{Y_{res}} \to 0$, so $X_{res} = \infty$

$P = \frac{V^2}{R} = \left|\frac{V_S}{\sqrt{2}}\right|^2 \cdot \frac{1}{R}$



1/2 power point -(3dB voltage point) → 0.707 $|V_{max}|$

-(6dB power point) → 1/2 power

Lowpass filter

High pass filter

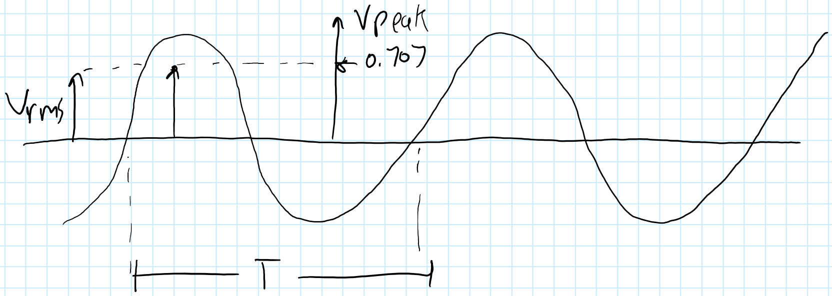
Band pass filter

Band reject filter

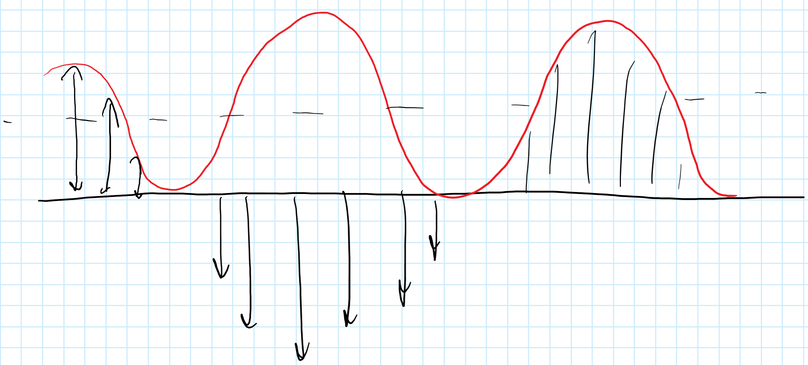
$Q = \frac{F}{\Delta F} = \frac{X}{R}$

Reactive Power

Friday, November 4, 2016 9:04 AM



$$P = \frac{v^2}{R}$$

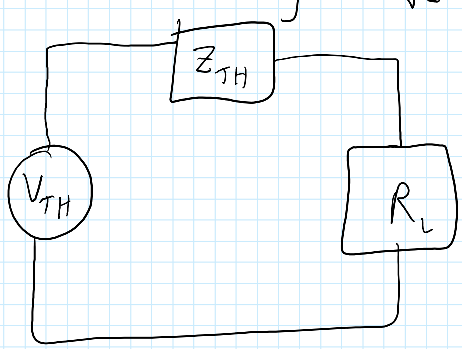


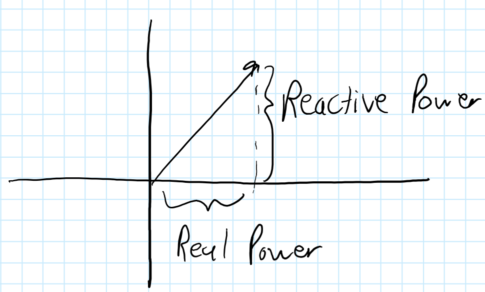
Appendix G:

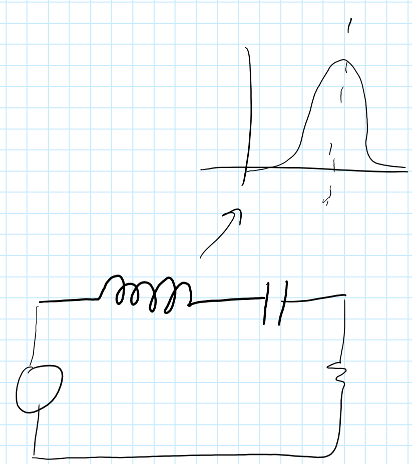
$$\int \cos^2 ax\,dx = \frac{x}{2} + \frac{\sin^2 \alpha x}{4a}$$

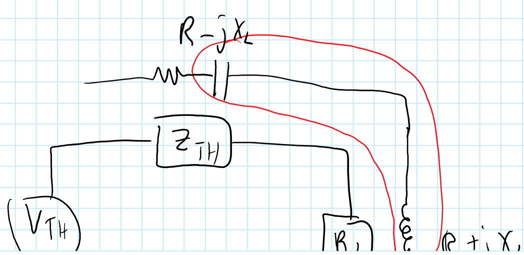
$$V_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v^2 \cos(\omega t + \theta)\,dt}$$

$$V_{rms} = \left[\frac{V_m^2}{T}\left(\frac{T}{2}\right)\right]^{1/2} = \frac{V_m}{\sqrt{2}} = \frac{V_m}{1.414} \approx 0.707 V_m$$

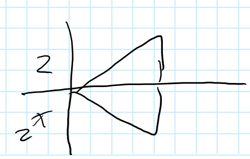


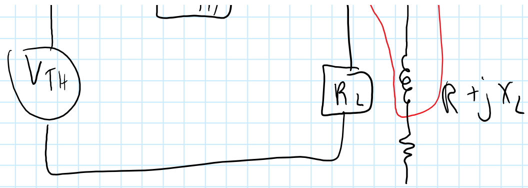


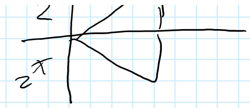




$$(R - jX_L)^* = (R + jX_L)$$




V_TH
R_L
R + jX_L



Sinusoidal Steady State Power

Monday, November 7, 2016 9:02 AM

$P(t) = vi$

$v(t) = V_{max}\cos(\omega t + \theta_v)$

$i(t) = I_{max}\cos(\omega t + \theta_i)$

$\vec{V}\angle(\theta_v - \theta_i) = V_m\cos(\omega t + \theta_v - \theta_i)$

$\vec{I}\angle 0 = I_m\cos(\omega t)$

$P(t) = V_m I_m[\cos(\omega t + \theta_v - \theta_i)\cdot(\cos(\omega t))]$

$\cos\alpha\cos\beta = \frac{1}{2}\cos(\alpha-\beta) + \frac{1}{2}\cos(\alpha+\beta)$

$P(t) = V_m I_m\left[\frac{1}{2}\cos(\omega t + \theta_v - \theta_i - \omega t) + \frac{1}{2}\cos(\omega t + \theta_v - \theta_i + \omega t)\right]$

$= V_m I_m\left[\frac{1}{2}\cos(\theta_v - \theta_i) + \frac{1}{2}\cos\underbrace{(2\omega t + \theta_v - \theta_i)}\right]$

$\cos(\alpha + \beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$

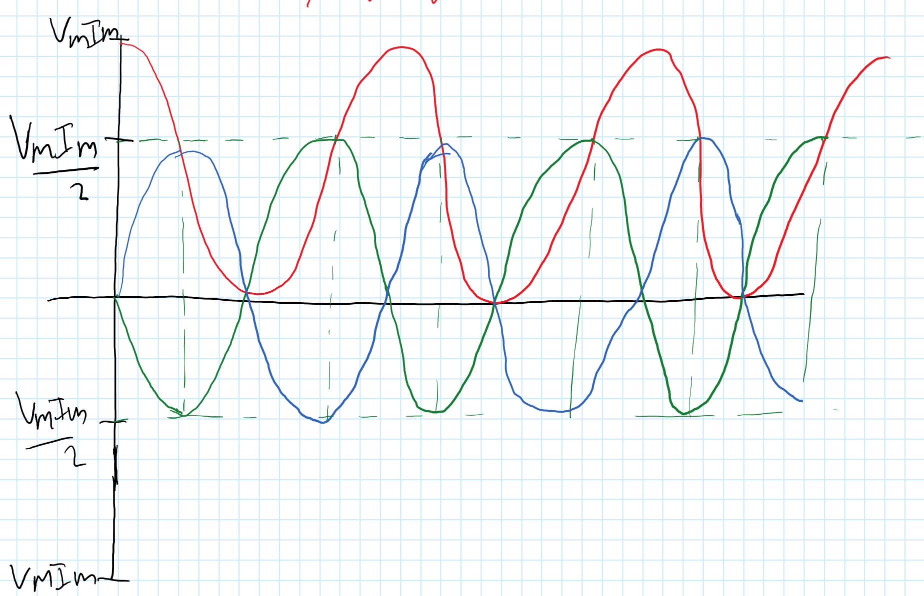
$\alpha = 2\omega t \qquad \beta = \theta_v - \theta_i$

$= \cos(\theta_v - \theta_i)\cos(2\omega t) - \sin(\theta_v - \theta_i)\sin(2\omega t)$

$P(t) = \frac{V_m I_m}{2}[\cos(\theta_v - \theta_i)] + \frac{V_m I_m}{2}[\cos(\theta_v - \theta_i)\cos(2\omega t) - \sin(\theta_v - \theta_i)\sin(2\omega t)]$

For a resistor (R), $\theta_v - \theta_i = 0$

$2\omega = 2\cdot$ line frequency [rad/sec]



For an inductor, $\theta_v - \theta_i = 90°$

For a capacitor, $\theta_v - \theta_i = -90°$

$S = P + jQ$

$S = \frac{V_m I_m}{2}\left[\cos(\theta_v - \theta_i) + j\sin(\theta_v - \theta_i)\right] = V_m I_m e^{j(\theta_v - \theta_i)} = \frac{1}{2} V_m I_m \angle(\theta_v - \theta_i)$

$S = \frac{V_m I_m}{2} \angle \theta_v - \theta_i = V_{rms} I_{rms} \angle \theta_v - \theta_i$

$I_{RMS}\, e^{-j\theta_i} = I_{RMS}\left(\cos\theta_i + j\sin(-\theta_i)\right) = I_{RMS}(\cos\theta_i - j\sin\theta_i)$

$S = V_{rms} I_{rms}^*$

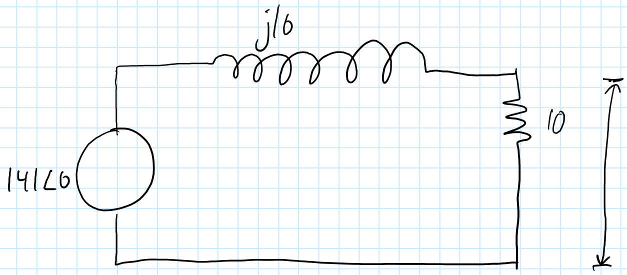
Note Also: $V_{rms} = I_{rms}(Z)$ $\qquad A \cdot A^* = |A|^2$

$S = (I_{rms})(I_{rms})^* Z = |I_{rms}|^2 Z = \frac{V_{rms}^2}{Z}$

$$\boxed{S = P + jQ;\quad S = |I_{rms}|^2 Z = \frac{|V_{rms}|^2}{Z}}$$

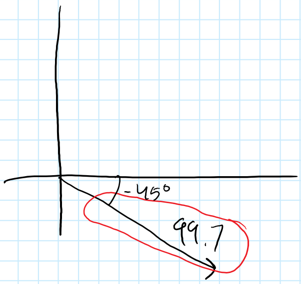
Power Factor

Wednesday, November 9, 2016 9:05 AM



$$V_R = \frac{141(10)}{10+j10}$$

$$V_{RMS} = 0.707\, V_m$$



$$S = P + jQ$$

$$S = V_{rms} + I_{rms}^*$$

$$V_{rms} = I_{rms} Z$$

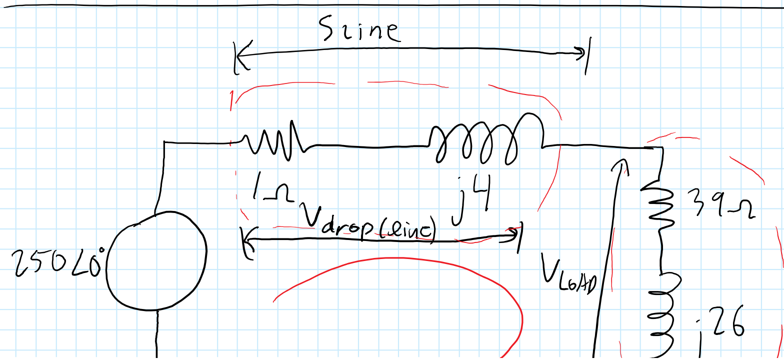
$$I_{rms} Z\, I_{rms}^*$$

$$|I_{rms}^2|$$

$$S = P + jQ$$

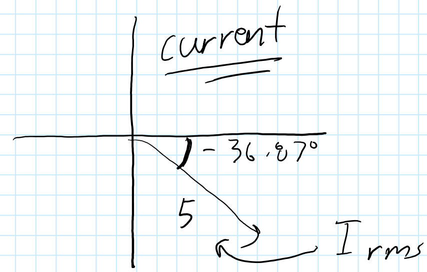
$$S = |I_{rms}|^2 R + |I_{rms}|^2 X$$

$$S = \frac{|V_{rms}|^2}{R} + \frac{|V_{rms}|^2}{X}$$



$$I = \frac{250\angle 0^\circ}{40 + j30} = 4 - j3 \quad \underline{\underline{OR}}$$

| current



$V_{Load} = (39 + j26)(4 - j3) = 234 - j13$

watts VAR = Volt Amperes Reactive

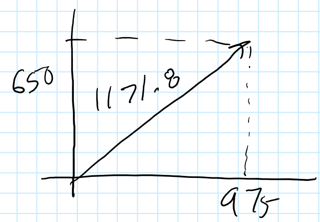
$S_{Load} = V_L \, I^* = (234 - j13)(4 + j3) = 975 + j650$

975 WATTS + 650 VAR

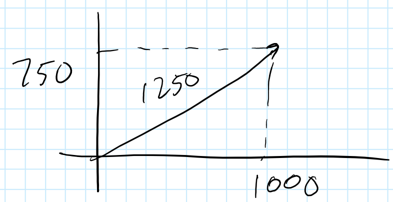
$\vdash V_{Line} \longrightarrow$

$S_{Line} = I_{Line} \, Z_{Line} \, I_{Line}^* = (4 - j3)(1 + j4)(4 + j3) = 25 \text{ watts} + j100 \text{ VAR}$

$S_{Total} \longrightarrow 1000 + j750$



$S = 1250 \angle 36.87 = 1000 + j750$



OR

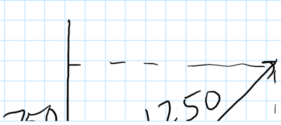
$S_{Line} = I_{rms}^2 R + I_{rms}^2 X = (5)^2 1 + (5)^2 (j4) = 25 + j100$ ✓

$S_{Load} = I_{rms}^2 R + I_{rms}^2 X = (5)^2 39 + (5)^2 j26 = 975 + j650$ ✓

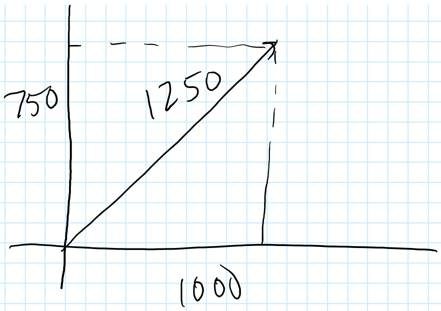
$1000 + j750$ ✓

Leading Implies Current Leads Voltage (Inductive)

Lagging Implies Current Lags Voltage (Capacitive)



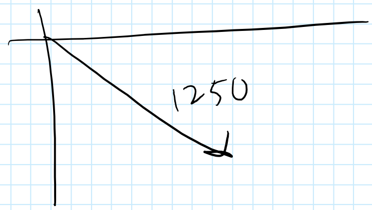
P.F. (Power Factor) $\dfrac{1000 \text{ watts}}{1250 \text{ watts}} = 0.8$



P.F. (Power Factor) $\frac{1000 \text{ watts}}{1250 \text{ watts}} = 0.8$

Leading

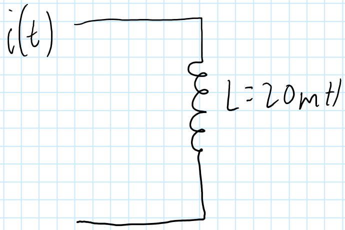
$36.87 = \cos^{-1}\left(\frac{1000}{1250}\right)$

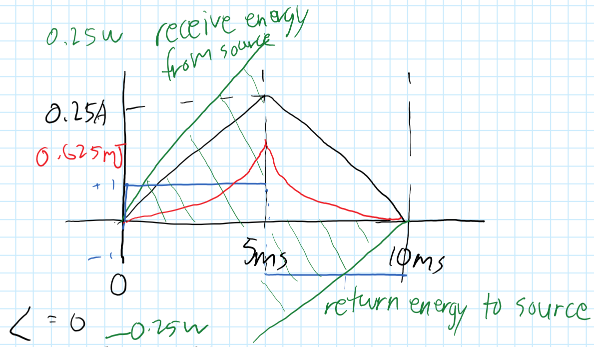


Lagging

Mutual Inductance

Monday, November 14, 2016 9:06 AM





Energy = Power · Time $= \frac{1}{2} L I^2$

$V(t) = L \frac{di(t)}{dt}$

$< 0 = 0$

$0 - 5$ $i(t) = 50t$

$\frac{250 \cancel{m}A}{5\cancel{m}s} = \frac{50A}{s}$

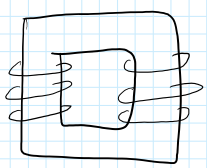
$L \frac{di(t)}{dt} = 20 \times 10^{-3} \times 50 = +1$ Volt

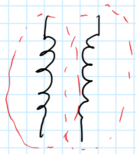
$> 10ms = 0$

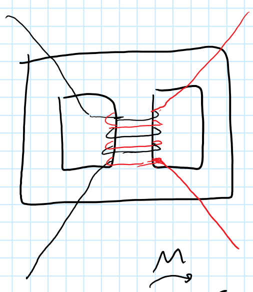
$5 - 10$ $i(t) = 0.25 - 50t$

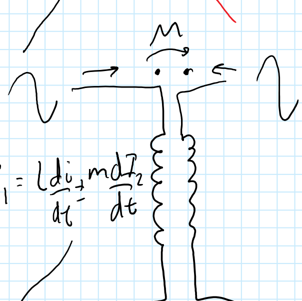
$L \frac{di(t)}{dt} = 20 \times 10^{-3} \times (-50) = -1$ Volt

Power = $V(t)\, I(t)$





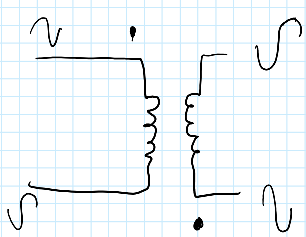




$m = \sqrt{L_1 L_2}$

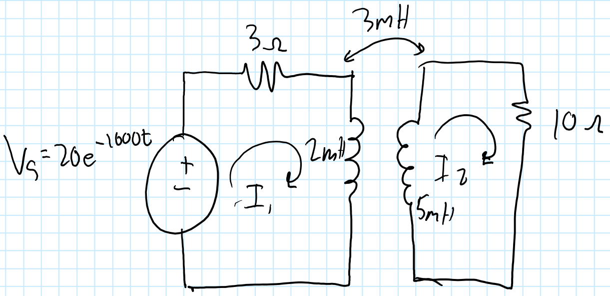
$V_1 = L \frac{di_1}{dt} + m \frac{dI_2}{dt}$

mutually induced voltage from L_2



$$V_1 = L\frac{dI_1(t)}{dt} + m\frac{dI_2(t)}{dt}$$

$$V_2 = L\frac{dI_2(t)}{dt} + m\frac{dI_1(t)}{dt}$$



Mesh 1 $\quad\quad L \quad\quad M$

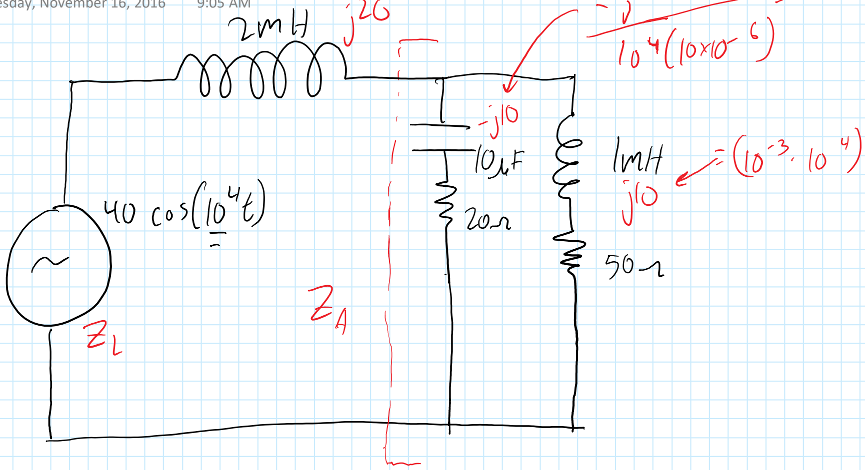
$$-V_s + 3i_1 + 2\times10^{-3}\frac{dI_1(t)}{dt} - 3\times10^{-3}\frac{dI_2}{dt} = 0$$

Mesh 2

$$10i_2 + 5\times10^{-3}\frac{dI_2}{dt} - 3\times10^{-3}\frac{dI_1}{dt} = 0$$

HW 8 Examples

Wednesday, November 16, 2016 9:05 AM



$Z_L = 2mH + Z_a$

$Z_a = \left((50+j10)^{-1} + (20-j10)^{-1} \right)^{-1}$

$= 15.7 - j4.28$

$Z_L = 15.7 + j15.7$

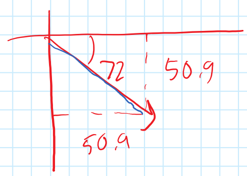
$S = \frac{V^2}{Z_L} = \frac{40^2}{15.7+j15.7}$

$S = 50.9 - j50.9$

$S = 72 \angle -45^\circ$

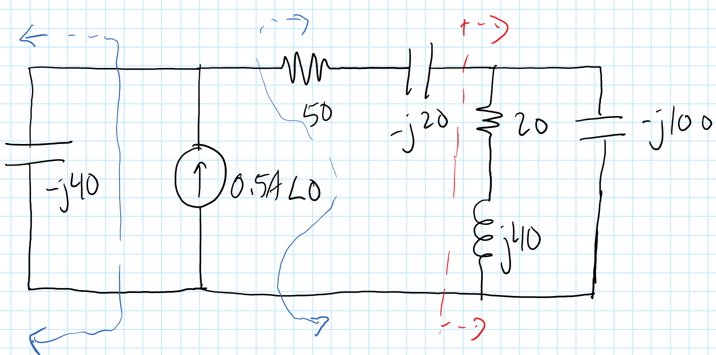
a) Real and Reactive Power — Real: 50.9, Reactive: 50.9 VAR

b) Apparent power → 72



c) Power Factor

$\cos(45) = 0.707 = 70.7\%$



$\left((20+j40)^{-1} + (-j100)^{-1} \right)^{-1} = 50+j50$

$50 - j20 + 50 + j50 = 100 + j30$

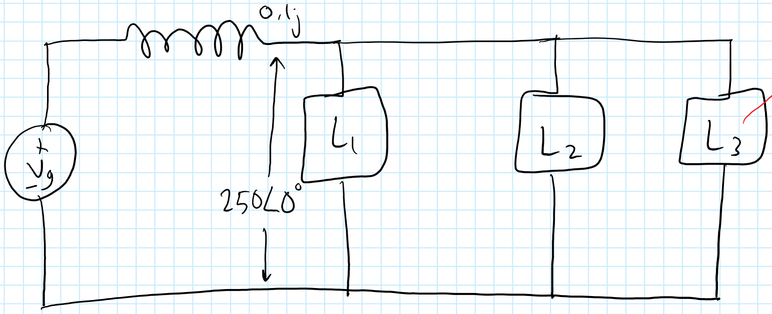
$\left((100+j30)^{-1} + (-j40)^{-1} \right)^{-1} = 15.84 - j38.4 = Z_T$

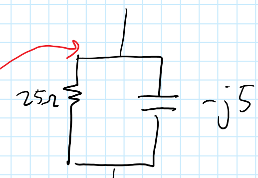
$S = (0.5)^2 (Z_T)$ $\quad S = (0.5)^2 (15.84 - j38.4) = 3.96 - j9.6$

$= 10.388 \angle 67.59^\circ$

$VA = 10.388 = \sqrt{3.96^2 + 9.6^2}$

WATTS = 3.96
VAR = 9.6
PF = cos(67.59) = 0.38 = 38%



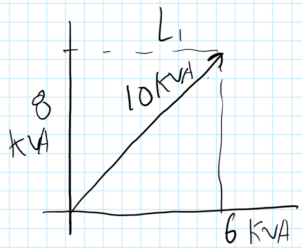


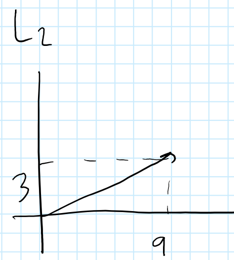
$$Z_3 = \left((25)^{-1} + (-j5)^{-1}\right)^{-1}$$

$$Z_3 = 0.96 - j4.8$$

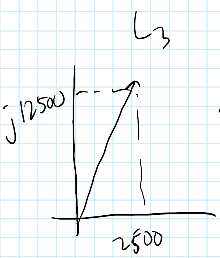
$$S_3 = \frac{250^2}{Z_3}$$

$$= 2500 + j12500$$





$= \sqrt{98}$
$= 9.49$



$= 12747$

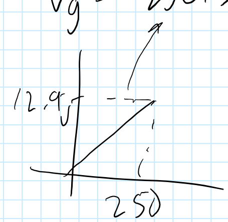
$$V_g = 250 + j0.1\,(I_T) \qquad I = \frac{S}{V}$$

$$I = \frac{9490}{250} + \frac{10{,}000}{250} + \frac{12747}{250}$$

$$I = 128.95$$

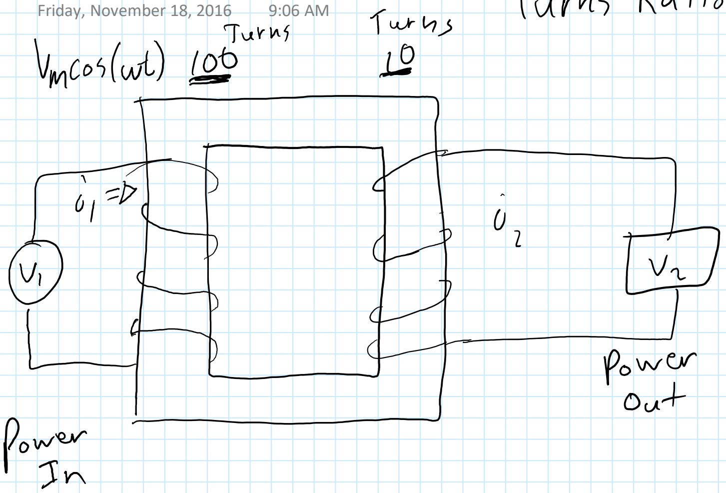
$$V_g = 250 + j0.1\,(129A) \qquad V_g = 250 + 12.9j$$

$$V_g = 250.3$$



Transformers

Friday, November 18, 2016 9:06 AM



Turns Ratio $= \frac{N_1}{N_2} = \frac{100}{10} = 10:1$

N_1 turns
Primary
(Source Side)

N_2 Turns
Secondary
(Load Side)

$V_1 = N_1 \frac{d\Phi}{dt}$

$V_2 = N_2 \frac{d\Phi}{dt}$

$\frac{V_1}{N_1} = \frac{d\Phi}{dt}$

$\frac{V_2}{N_2} = \frac{d\Phi}{dt}$

$V = N \frac{d\Phi}{dt}$

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2}}$$

$V_2 = V_1 \left(\frac{N_2}{N_1} \right)$ ← 10, ← 100

$V_2 = 0.1 V_1$

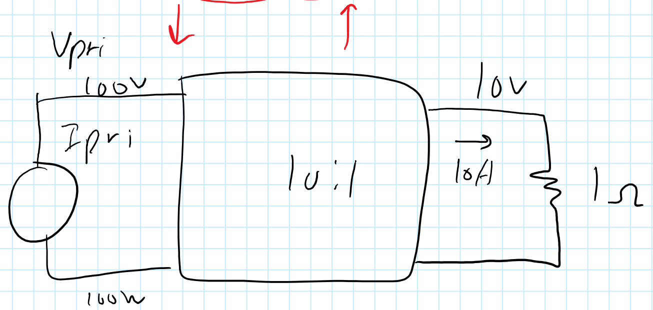
$$\boxed{V_2 = V_1 \left(\frac{N_2}{N_1} \right)}$$

Turns Ratio
100 : 10
$P_{in} = P_{out}$

$V_1 I_1 = V_2 I_2$
100 W

100V · 1A   10V · 10A

$V \downarrow, I \uparrow$



100W

V = 10 V
I = 10A
P = 100 W

V = 100V
I = 1A
P = 100W

Voltage Ratio = Turns Ratio

Current Ratio $= \frac{1}{\text{Turns Ratio}}$

S = S

$Z_{pri} = \frac{V_{pri}}{I_{pri}}$

$Z_2 = 1\Omega$

Z_{sec}

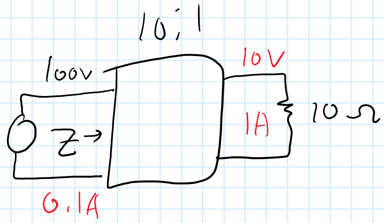
$$Z_{pri} = \frac{V_{pri}}{I_{pri}} \qquad Z_2 = 1\Omega$$

$$\frac{V_{pri}}{I_{pri}} = \frac{V_s \times 10}{I_s \times 0.1} = \frac{N\, V_{sec}}{\frac{1}{N} I_{sec}} = N^2 Z_{sec}$$

Z_{sec}

$$\boxed{Z_{pri} = N^2 Z_{sec}}$$

$$Z_{pri} = 100\Omega$$



Given

Find

$V_{pri} = TR \times V_{sec}$

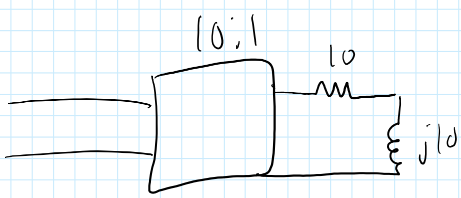
$I_{pri} = \dfrac{I_{sec}}{TR}$

$Z_{pri} = |TR|^2 \times Z_{sec}$

$Z = (10)^2 \cdot 10\Omega = 1000\Omega$

or

$Z = \dfrac{100V}{0.1A} = 1000\Omega$

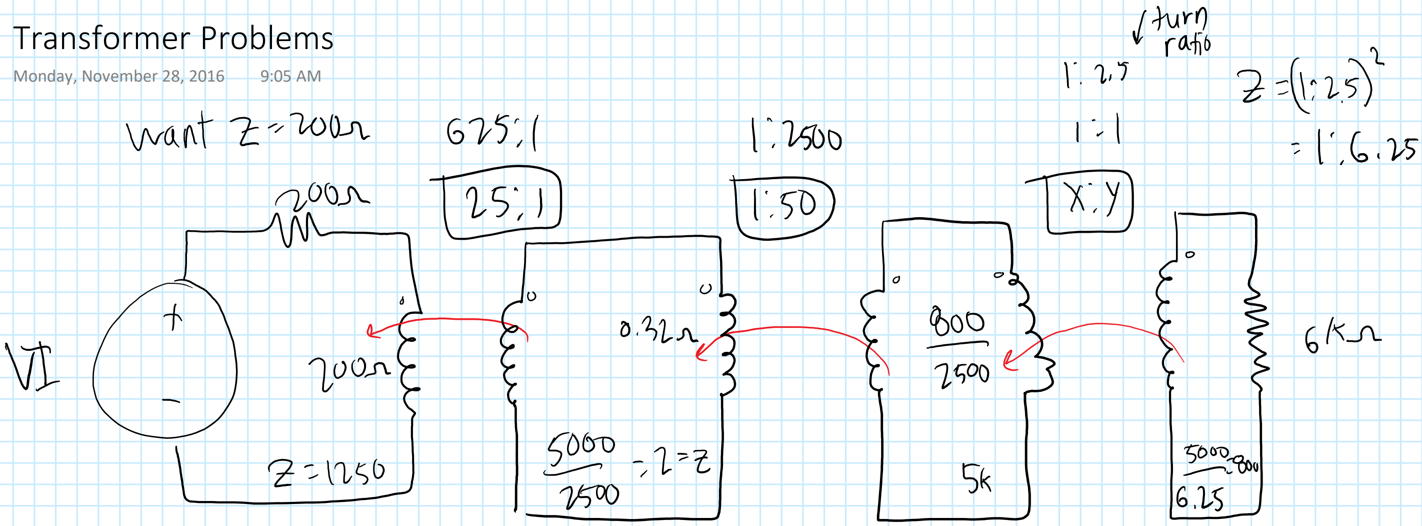


$Z = 10 + j10 = 14.14 \angle 45°$

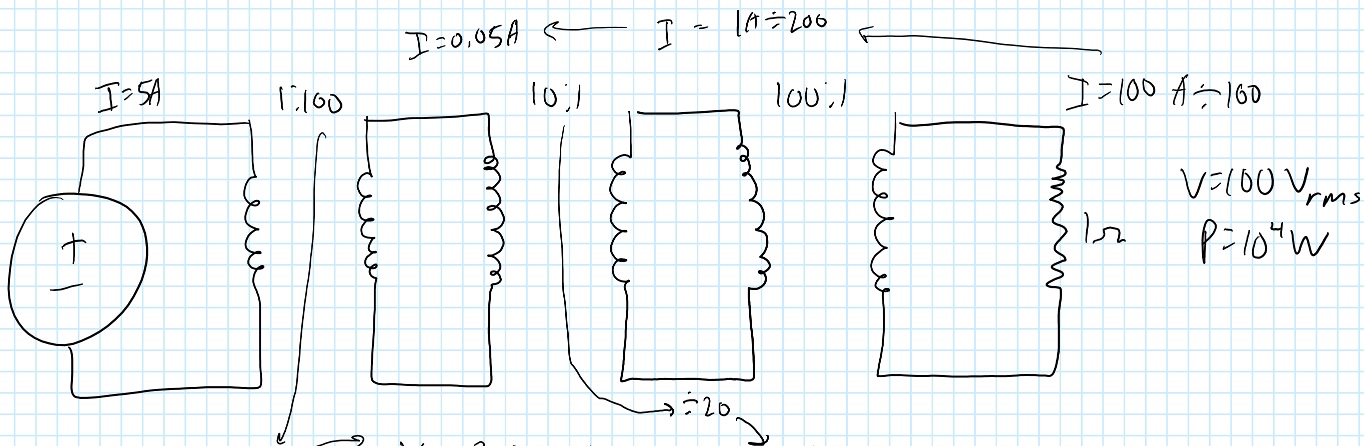
$100(10 + j10) = 100 \times 14.14 \angle 45° = 1000 + j1000$ or $1414 \angle 45°$

Transformer Problems

Monday, November 28, 2016 9:05 AM



$$\frac{\sqrt{1250}}{200} = \sqrt{6.25} = 2.5 \qquad Z_{pri} = Z_{sec} * (N_{ps})^2 \text{ or } Z_{sec} = \frac{Z_{pri}}{(N_{ps})^2}$$

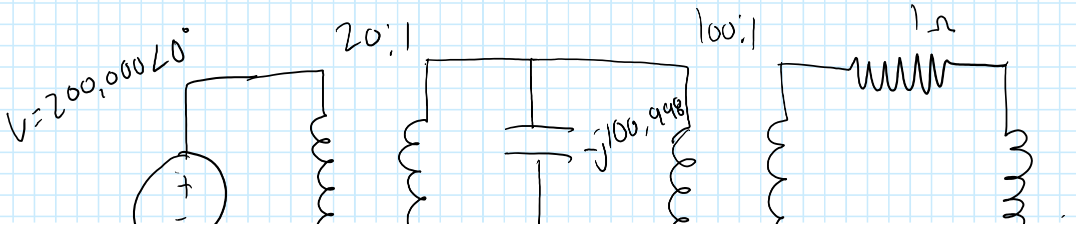


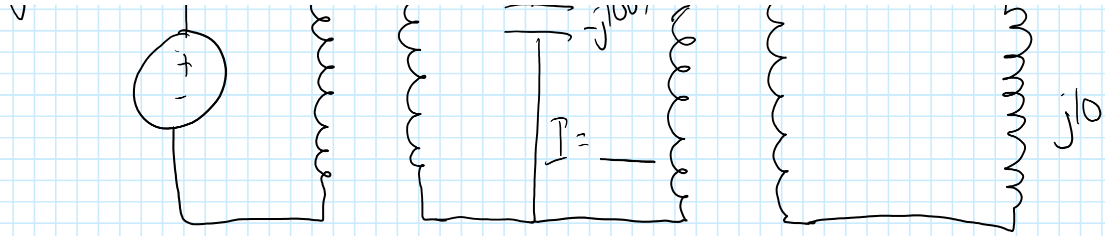
$V = 2000\ V_{RMS}$ $\quad V = 200{,}000\ V_{RMS}$ $\quad V = 10{,}000\ V_{RMS}$

$R = 400\,\Omega$ $\quad R = 4M\Omega$ $\quad R = 10^4\,\Omega$

$P = 10^4\,W$ $\quad P = 10^4\,W$ $\quad P = 10^4\,W$

$$(20)^2 \times 10^4 = 4 \times 10^6 = 4M\Omega$$





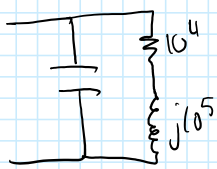
Z = ______ $\quad$ $Z = 1.01\times10^6$ $\quad$ $Z = 10^4 + j10^5$ $\quad$ $Z = 1 + j10$ $\quad$ $I = \frac{V}{Z}$

V = 200,000 $\quad$ V = 10,000 $\quad$ V = 10,000 $\quad$ V = 100

I = ______ $\quad$ $I = 0.0095$ $\quad$ $I = 0.0099 - j0.09$ $\quad$ $I = 0.99 - j9.9$

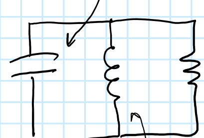
$S = P$ ______ $+ jQ$ ______

$S = P\ 9.84 + jQ\ 98.4$



$(10^4 + j10^5)^{-1}$

$+9.901\times10^{-6}$



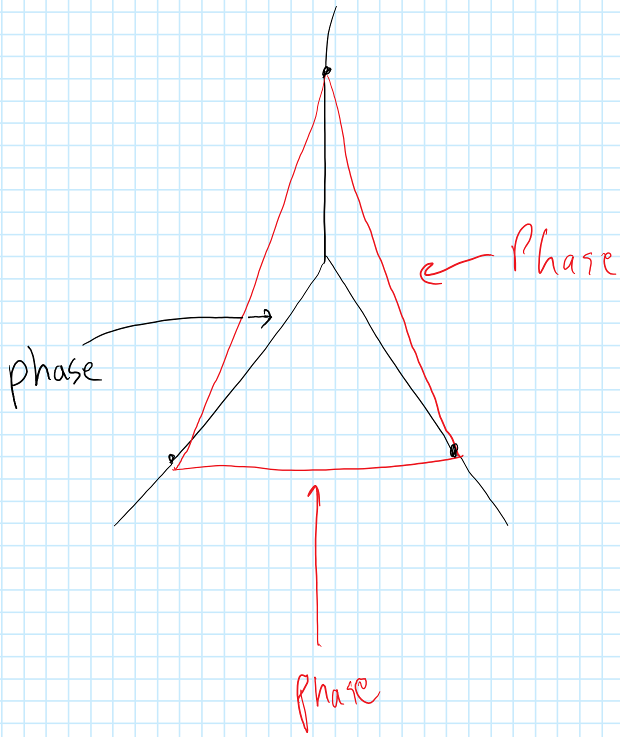
$G = 9.90\times10^{-9}$

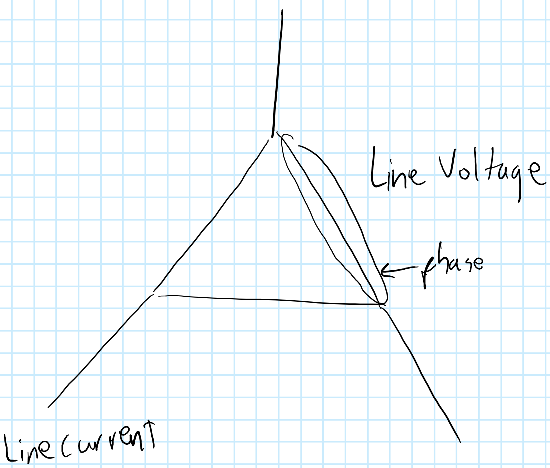
$B = -j9.901\times10^{-6}$

$$X_c = -j(9.901\times10^{-6})^{-1}$$
$$= -j\,100{,}998$$

3-Phase Delta and Wye

Wednesday, November 30, 2016 9:05 AM





For Delta Config

Delta phase voltage = Line-to-line phase voltage and the phase current = is the vector "sum" or "difference" of the line current

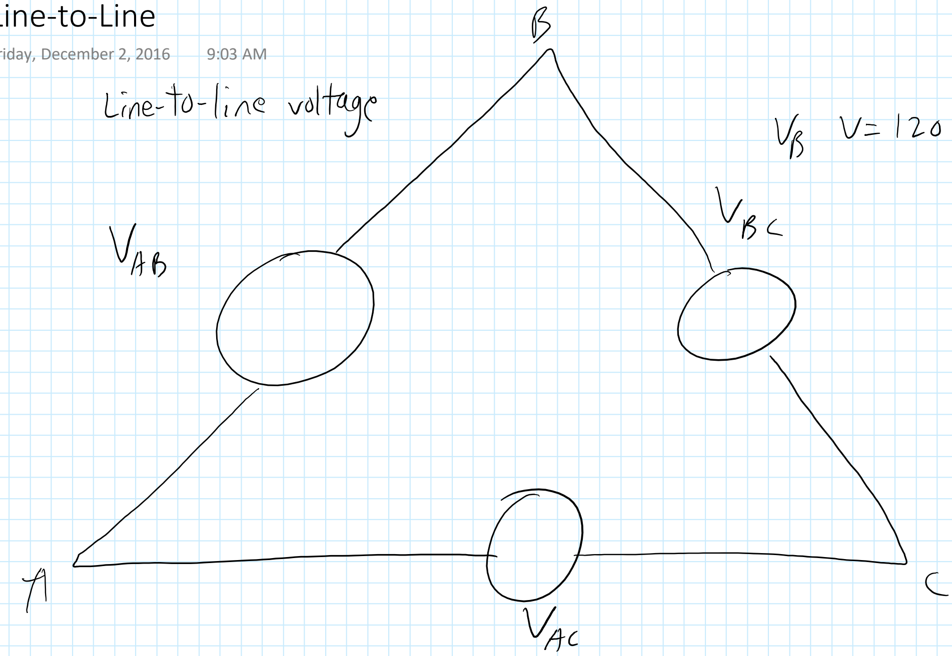
For Wye Config

the phase current = line current of the phase voltage is vectorally related to the line-to-line voltage

Line-to-Line

Friday, December 2, 2016 9:03 AM

Line-to-line voltage



V_B $V = 120$

Line voltage = phase voltage

Line current = $\sqrt{3} \times$ phase current

phase current = $\dfrac{\text{Line current}}{\sqrt{3}}$

$$I_{line\ A} = I_{AB} - I_{AC} = I_{rms} \angle -120^\circ = I_{rms}(e^{-j0} - e^{-j120})$$

$$= I_{rms}(1 - \cos(-120) - j\sin(-120))$$

$$= I_{rms}\left(1 - \left(-\tfrac{1}{2} - j\tfrac{\sqrt{3}}{2}\right)\right) = I_{rms}\left(\tfrac{3}{2} + j\tfrac{\sqrt{3}}{2}\right)$$

$$= (\sqrt{3})(I_{rms})\left(\frac{\sqrt{3} + j}{2}\right) = \frac{\sqrt{3}}{2} + j\frac{1}{2}$$

$I_{line\ A} = \sqrt{3} \times I_{rms} \angle 30^\circ$

$I_{line\ B} = \sqrt{3} \times I_{rms} \angle 150^\circ$

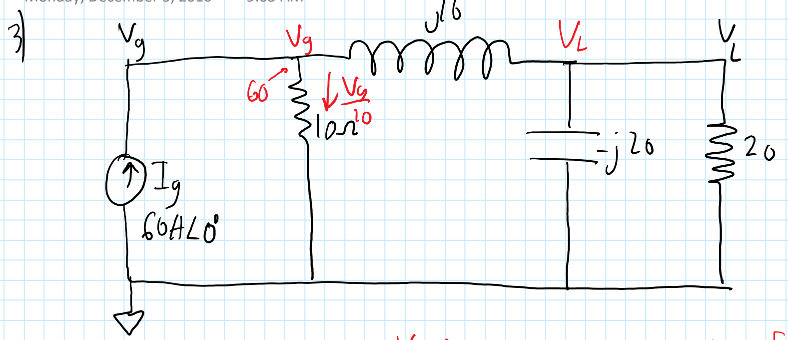
$I_{line\ C} = \sqrt{3} \times I_{rms} \angle -90^\circ$

Practice Final Exam Problems

Monday, December 5, 2016 9:03 AM

NODE VOLTAGE

3)



$V_g =$

$V_L =$

Node V_g: $\frac{60 - V_g}{10} - \frac{V_g - V_L}{j10} = 0$ $\quad j100[\quad] = 6000j - j10(V_g) - 10V_g + 10V_L = 0$

$6000j - V_g(10 + j10) + 10V_L = 0$

(1) $V_g(10 + j10) - 10V_L = 6000j$

Node V_L: $\frac{(V_g - V_L)}{j10} - \frac{V_L}{-j20} - \frac{V_L}{20}$ $\quad 200[\quad] \Rightarrow -20j(V_g - V_L) - 10jV_L - 10V_L = 0$

$-20j(V_g) + 20j(V_L) - 10j(V_L) - 10(V_L) = 0$

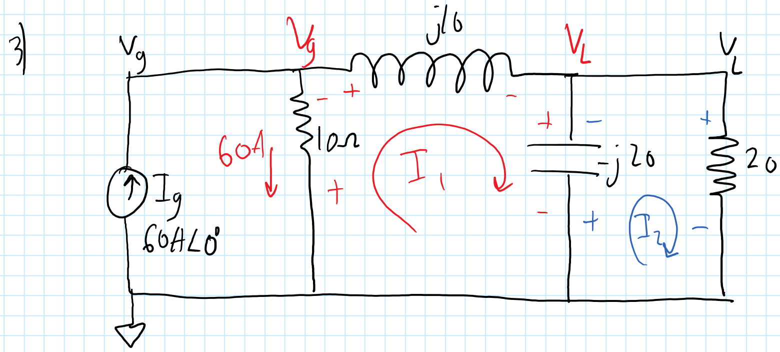
(2) $-20j(V_g) + V_L(10j - 10) = 0$

Solve (1) and (2) $\Rightarrow$ $V_g = 300 + j0 = 300\angle 0^\circ$

$V_L = 300 - j300 = 424.3\angle -45^\circ$

MESH CURRENT

3)



$V_g =$

$V_L =$

Loop 1: $10(I_1 - 60) + j10(I_1) - j20(I_1 - I_2) = 0$

$-600 + 10I_1 + j10(I_1) - j20(I_1) + j20(I_2) = 0$

$-600 + I_1(-j10 + 10) + I_2(j20) = 0$

(1) $I_1(10-j10) + I_2(j20) = 600$

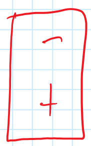
Loop 2: $-j20(I_2 - I_1) + 20(I_2) = 0$

(2) $I_1(j20) + I_2(20-j20) = 0$

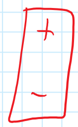
Solve (1) and (2) $\Longrightarrow$ $I_1 = 30 + j0$

$I_2 = 15 - j15$

$V_g = 10(I_1 - 60)$ $\quad V_g = 10(30-60) = -300$



$V_g = -300$ Reality $\Longrightarrow$



$300 = V_g$

$\boxed{V_g = 300V}$

$V_L = 20(15 - j15) = 300 - j300$

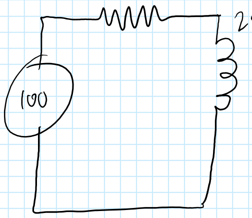
$\boxed{V_L = 300 - j300}$

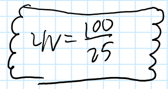
More Final Practice

Wednesday, December 7, 2016 9:08 AM

Z 625:1

$(25:1)^2$



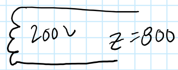


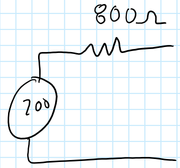
$Z = \frac{200}{625} = 0.32\Omega$

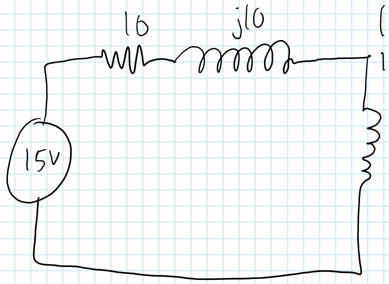
Z (1:2500)

$(1:50)^2$

1:50

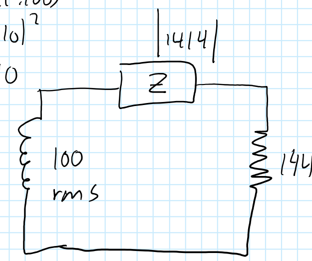




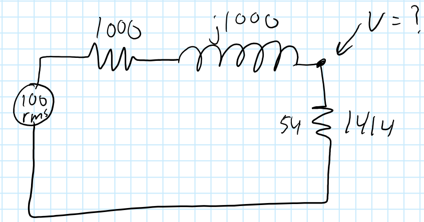


Z = (1:100)

$(1:10)^2$

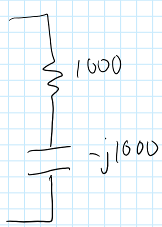


$Z = 1000 + j1000 \quad |Z| = 1414$



$V = \frac{100(1414)}{2414 + j1000} = 44.9956 - 20.7j = \boxed{54.1\angle -22^\circ}$

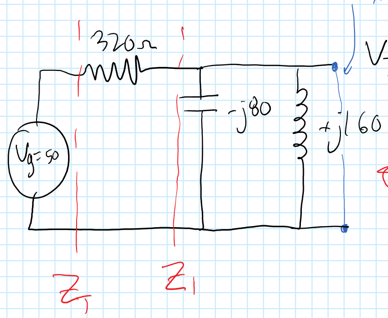
Complex Conjugate



$\frac{100}{1000 + j1000 + 1000 - j1000} = \frac{100}{2000\Omega} = 0.05A$

$= (0.05)^2 (1000\Omega) = 2.6W$

$I_N = \frac{50V}{320\Omega} = 0.15625A$ (cap and ind are shorted)



$V_{TH} \rightarrow \frac{50(Z_1)}{Z_1 + 320}$

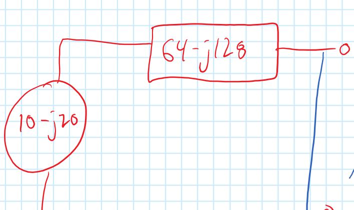
$Z_1 = ((-j80)^{-1} + (j160)^{-1})^{-1}$

$= -j160$

Z_{TH} (look in from the outside)

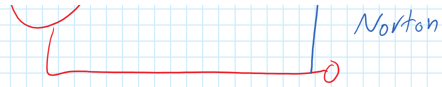
$\frac{50(-j160)}{-j160 + 320} = 10 - j20$

$Z_{TH} = ((320)^{-1} + (-j80)^{-1} + (j160)^{-1})^{-1} = 64 - j128$



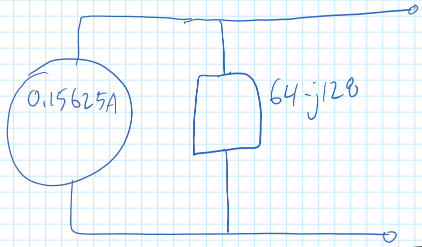
Thevenin

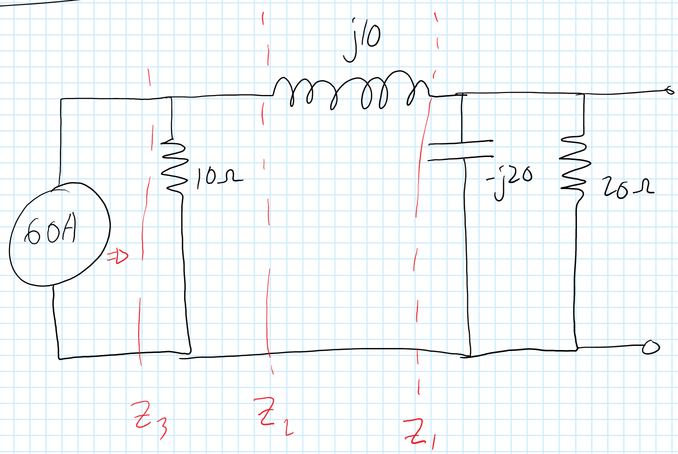
Norton



$$I_N = \frac{10-j20}{64-j128} \rightarrow I = \frac{V}{R}$$

$$I_N = 0.15625\ A$$

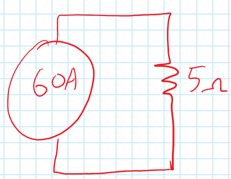




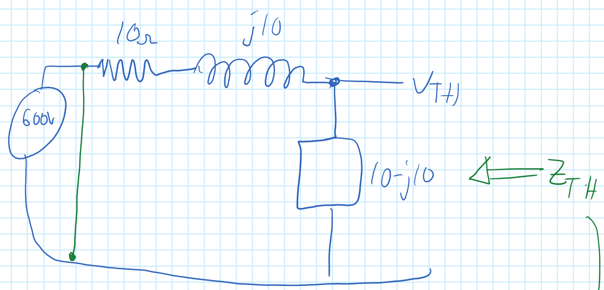
$$Z_1 = \left(\left(-j20\right)^{-1} + \left(20\right)^{-1}\right)^{-1} = 10 - j10$$

$$Z_2 = Z_1 + j10 = 10$$

$$Z_3 = 10 \parallel Z_2 = 5\Omega$$

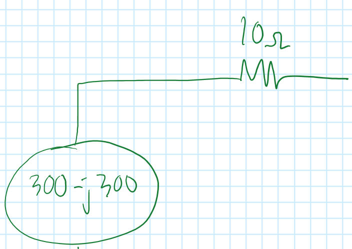


OR

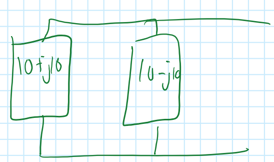


$$= \frac{600(10-j10)}{10-j10+10+j10} = \frac{600(10-j10)}{20\Omega}$$

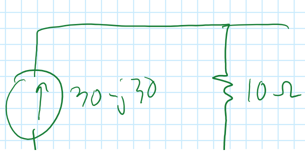
$$= 300 - j300$$



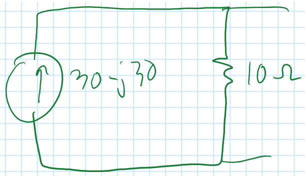
=Thevenin



$$Z_{TH} = 10\Omega$$



=Norton



=Norton

John Schad
E211
Dr. Galassi

Hw #9

Review Problems

1) 120°

2) Delta, wye

3) $480V = V_{Line}$ $V_{phase} = \frac{V_{Line}}{\sqrt{3}}$ $V_{phase} = \frac{480}{\sqrt{3}}$ $\boxed{V_{phase} = 277.13V}$

4) $I_{phase} = 25A$ $I_{line} = I_{phase}$ $\boxed{I_{line} = 25A}$

5) $V_{Line} = 560V$ $V_{phase} = V_{Line}$ $\boxed{V_{phase} = 560V}$

6) $I_{phase} = 30A$ $I_{line} = I_{phase}(\sqrt{3})$ $\boxed{I_{line} = 51.96A}$

7) $V_{phase} = 240V$ $I_{phase} = 18A$ $VA = 3 \times V_{phase} \times I_{phase}$ $VA = 3(240)(18)$ $\boxed{VA = 12960 \text{ Watts}}$

8) $VA = \sqrt{3} \times I_{Line} \times V_{Line}$ $V_{phase} = \frac{V_{line}}{\sqrt{3}}$ $V_{Line} = V_{phase}(\sqrt{3})$ $V_{Line} = 240(\sqrt{3})$ $\boxed{V_{Line} = 415.69V}$

$I_{Line} = \frac{VA}{\sqrt{3}(V_{Line})}$ $I_{Line} = \frac{12960}{(\sqrt{3})(415.69)}$ $\boxed{I_{Line} = 18A}$

9) $V_L = 2400V$ $I_L = 40A$ $I_L = \frac{V_L}{Z}$ $Z = \frac{V_L}{I_L}$ $Z = \frac{240\cancel{0}}{4\cancel{0}}$ $\boxed{Z = 60\Omega}$

10) $PF = 1$ $P = \sqrt{3}(PF)(V_L)(I_L)$ $P = \sqrt{3}(1)(2400)(40)$ $\boxed{P = 166,276.88W}$

Practice Problems

1)

$V_{p(A)} = 138.56V$	$V_{p(L)} = 240V$
$I_{p(A)} = 34.64A$	$I_{p(L)} = 20A$
$V_{L(A)} = 240V$	$V_{L(L)} = 240V$
$I_{L(A)} = 34.64A$	$I_{L(L)} = 34.64A$
$P = 14399.58W$	$Z_{(phase)} = 12\Omega$

$V_L(A) = V_L(L)$ alternator directly connected to load

$V_p(L) = V_L(L)$ $I_p(L) = \frac{V_p(L)}{Z}$ $I_p(L) = \frac{240}{12} = 20$

$I_L(L) = I_p(L) \times \sqrt{3}$ $I_L(L) = 34.64$

$I_L(L) = I_L(A)$ $I_p(A) = I_L(A)$ $V_p(A) = \frac{V_L(A)}{\sqrt{3}}$ $V_p(A) = \frac{240}{\sqrt{3}}$ $V_p(A) = 138.56$

$P = (\sqrt{3})(V_{L(A)})(I_{L(A)})\, PF$ $PF = 1$ $P = (\sqrt{3})(240)(34.64)(1) = 14399.58$

2)

$$\boxed{\begin{array}{ll} V_p(A) = 4160\,V & V_p(L) = 2401.78\,V \\ I_p(A) = 23.11\,A & I_p(L) = 40.03\,A \\ V_L(A) = 4160\,V & V_L(L) = 4160\,V \\ I_L(A) = 40.03\,A & I_L(L) = 40.03\,A \\ P = 288{,}429.41\,W & Z_{(phase)} = 60\,\Omega \end{array}}$$

$V_L(L) = V_L(A)$ $V_p(L) = \frac{V_L(L)}{\sqrt{3}} = \frac{4160}{\sqrt{3}} = 2401.78$

$I_p(L) = \frac{V_p(L)}{Z} = \frac{2401.78}{60} = 40.03$ $I_p(L) = I_L(L) = I_L(A)$

$I_p(A) = \frac{I_L(A)}{\sqrt{3}} = \frac{40.03}{\sqrt{3}} = 23.11$ $V_p(A) = V_L(A)$

$P = (\sqrt{3})(V_L)(I_L)(PF)$ $PF = 1$ $P = (\sqrt{3})(4160)(40.03)(1) = 288{,}429.41\,W$

3)

$$\boxed{\begin{array}{lll} V_p(A) = 323.32\,V & V_p(L_1) = 323.32\,V & V_p(L_2) = 560\,V \\ I_p(A) = 185.9\,A & I_p(L_1) = 64.66\,A & I_p(L_2) = 70\,A \\ V_L(A) = 560\,V & V_L(L_1) = 560\,V & V_L(L_2) = 560\,V \\ I_L(A) = 185.9\,A & I_L(L_1) = 64.66\,A & I_L(L_2) = 121.24\,A \\ P = 180{,}313.42\,W & Z_{(phase)} = 5\,\Omega & Z_{(phase)} = 8\,\Omega \end{array}}$$

$V_L(A) = V_L(L_1) = V_L(L_2) = V_p(L_2)$

$I_p(L_2) = \frac{V_p(L_2)}{Z} = \frac{560\,V}{8\,\Omega} = 70$ $I_L(L_2) = I_p(L_2)(\sqrt{3}) = 70(\sqrt{3}) = 121.24$

$I_{p(L2)} = \dfrac{V_{p(L_2)}}{Z} = \dfrac{560V}{8\Omega} = 70 \qquad I_{L(L_2)} = I_{p(L2)}(\sqrt{3}) = 70(\sqrt{3}) = 121.24$

$V_{p(L_1)} = \dfrac{V_{L(L_1)}}{\sqrt{3}} = \dfrac{560}{\sqrt{3}} = 323.32 \qquad I_{p(L_1)} = \dfrac{V_{p(L_1)}}{Z} = \dfrac{323.32}{5} = 64.66$

$I_{p(L_1)} = I_{L(L_1)} \qquad I_{L(A)} = I_{L(L_1)} + I_{L(L_2)} = 64.66 + 121.24 = 185.9$

$I_{p(A)} = I_{L(A)} \qquad V_{p(A)} = \dfrac{V_{L(A)}}{\sqrt{3}} = \dfrac{560}{\sqrt{3}} = 323.32$

$P = (\sqrt{3})(V_L)(I_L)(PF) \qquad P_F = 1 \qquad P = (\sqrt{3})(560)(185.9)(1) = 180{,}313.42\ W$

Three-Phase Power Practice

Friday, December 9, 2016 9:13 AM

8) **Alternator**

$V_p = 508V$

$I_p = 381A$

$V_L = 880V$

$I_L = 381A$

Load 1

$V_p = 508V$

$I_p = 127A$

$V_L = 880V$

$I_L = 127A$

Load 2

$V_p = 880V$

$I_p = 146.7A$

$V_L = 880V$

$I_L = 254A$

$V_{Line} = \sqrt{3}(V_{phase}) \rightarrow$ For Wye

$I_{Line} = \sqrt{3}\, I_{phase} \rightarrow$ For Delta

$I_p = \frac{V_p}{Z}$

$I_{Line} = 254 + 127$

Power $= 580{,}644W$

Power $= (V_p)(I_p)(3) = 193{,}548W$

Power $= (V_p)(I_p)(3) = 387{,}288$ watts