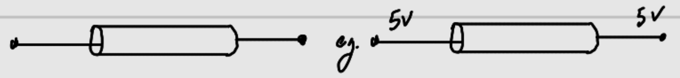
YT [SDS Sir]

L-2

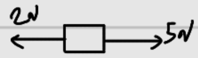
23/11/2024
Saturday

Circuits & ~~Electronics~~ → CSE 251
Electronics → made of semiconductor

Power (or wattage) → 1 Watt
Current (whenever a charge moves) → 1 Ampere
Electric Potential / Voltage → 1 Volt



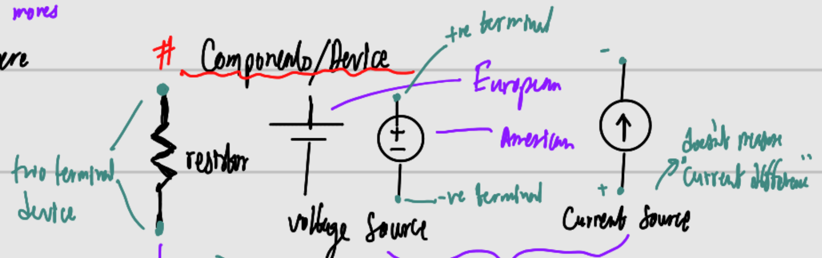
$I \propto V$ $\Delta V = 0$

$\Delta V = IR$
↑
Just like Force


$(5-2)N = 3N$ →

Conventional Current direction is from high Voltage to low voltage

Components/Device



Passive Component (Consumes power)
eg Inductor, capacitor, diode, LED

Resistor has no direction.

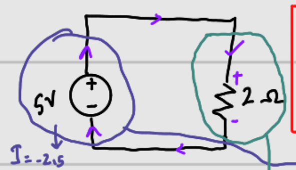
Active Components (Supplies power)

↗ Assuming passive element's power to +ve
Passive Sign Convention
- Current passes from +ve to -ve

voltage can be +ve/-ve as charge can be +ve/-ve

Currents +ve/-ve means opposite direction.
Power of Resistor is positive as it consumes power

Power → +5W → Consume
Power → -5W → Supply



$P = \Delta V \cdot I$ $P = I^2R$ → for resistor only

***$P = VI$ works only for passive sign convention

$\Delta V = IR$
$I = \frac{\Delta V}{R} = \frac{5}{2} = 2.5A$

Current from +ve to -ve
$P = \Delta V \cdot I$
$= 5 \times 2.5 = 12.5W$ (consuming)

Current should be from +ve to -ve (passive sign convention)

$\therefore P = \Delta V I$
$= 5 \times -2.5$
$= -12.5W$ (supplying)

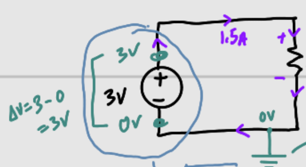
$$\boxed{F = -\frac{dV}{dx},\ P = \frac{W}{t} = \frac{Q \times V}{t}\quad P = VI,\ W = QV}$$

L-3

24/11/2024
Sunday

Q) What do we mean when we want to find power?

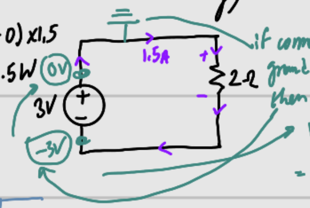
= It is not about the power of the whole circuit. Usually, we talk about the power of an appliance/component.



$P = (\Delta V) I$ of 2Ω $(V_+ - V_-) I$

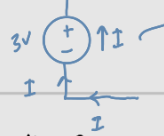
ground/earth: At zero volt

$(3-0) \times 1.5$
$= 4.5W$

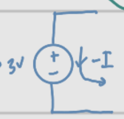


if connected to ground here then

$V_+ - V_-$ maintained
$= 0 - (-3) = 3V$



doesn't follow passive sign convention



Now it follows

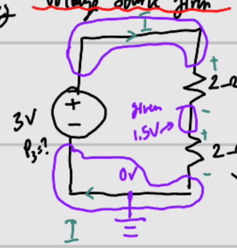
$P_{\text{of source}} = 3 \times (-1.5)$
$= -4.5W$ (supplying)

[From L-14]

Q) What is the node voltage?

= no voltage, no current hence so no node voltage

eg Voltage Source given



$I = \frac{3}{2+2} = 0.75$
$P_1 = (\Delta V) I$
$= (3-1.5) \times 0.75$
$= +1.125\ W$

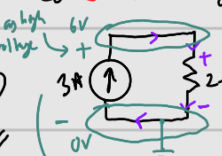
$P_2 = (1.5-0) \times 0.75$
$= +1.125\ W$

$P_3 = 3 \times (-0.75)$
$= -2.25W$

OR

$P_3 = -(P_1 + P_2)$
$= -2.25W$

eg Current Source given

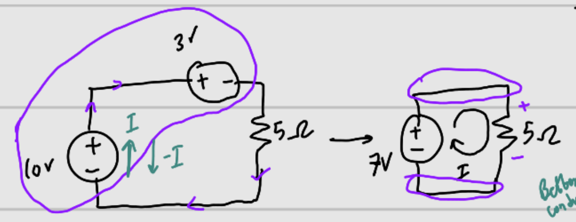


$\Delta V = IR$
$= 3 \times 2$
$= 6V$

$P = (6-0) \times -3$
$= -18W$

eg Source always won't have -ve Power

L-4

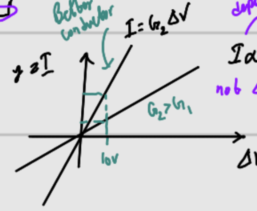


$I = \frac{7}{5} = 1.4A$

$P_{10V} = (\Delta V) I = 10 \times -1.4 = -14W$ (supplying)

$P_{5\Omega} = (\Delta V) I = (V_+ - V_-) I = (7-0) \times 1.4 = 9.8W$ (consuming)

$P_{3V} = 14 - 9.8 = +4.2W$ (consuming) OR $(\Delta V) I = 3 \times 1.4 = +4.2W$ — here voltage source is consuming power



dependent on

$I \propto \Delta V \longrightarrow I = G \Delta V$

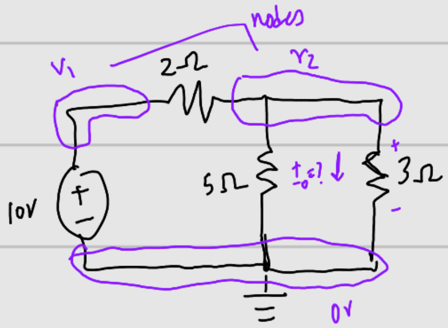
not $\Delta V \propto I$

G = Conductance, how much current it allows

how much current it resists → $R = \frac{1}{G}$

$\boxed{\begin{aligned} &\therefore I \propto \Delta V \\ &I = G \Delta V \\ &I = \tfrac{1}{R} \Delta V \\ &IR = \Delta V \end{aligned} \quad \therefore \Delta V = IR}$

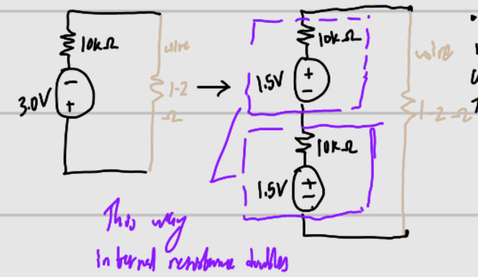
Ohm's story → Orsted, I means intensity
↓
Wheatstone



$I = \frac{\Delta V}{R} = \frac{10}{3}$ (wrong) # $I = \frac{\Delta V}{R} = \frac{V_2 - 0}{3} = \frac{V_2}{3} A$

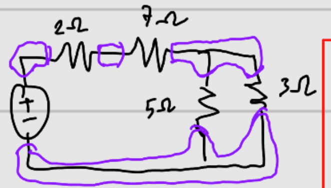
For Source, $\Delta V = 10 = V_1 - 0 = 10V$

V_0, I_0 — output Not zero



• Wire has very low resistance. Thus affects current flow insignificantly. Thus can be ignored

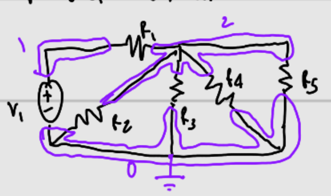
4 Nodes.



$\boxed{\text{How to Identify nodes? = Put opposite brackets on the terminal of every component. Then connect them without crossing a junction}}$

Parallel Connection

L-5

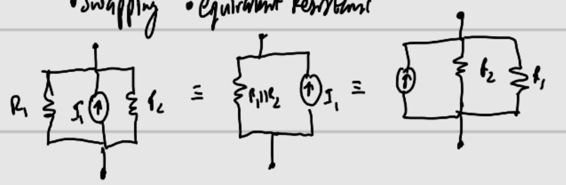


$R_4 \parallel R_5$? $(2,0) \equiv (2,0)$ same nodes — yes

$R_1 \parallel R_5$? $(1,2) \neq (2,0)$ different Nodes $\therefore$ NO

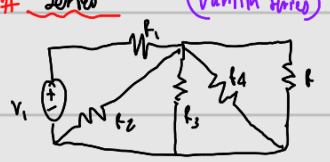
Series/Parallel Connection Advantages

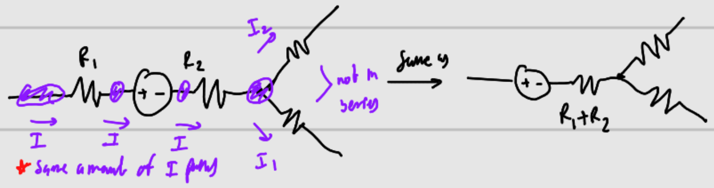
• Swapping • equivalent Resistance



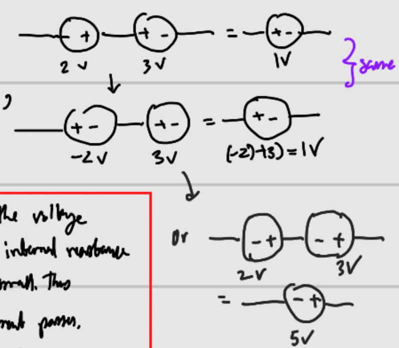
$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_2} + \frac{1}{R_1}$

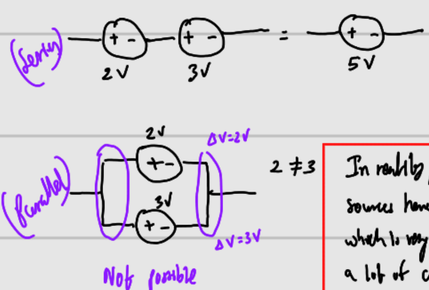
Series (vanilla series)





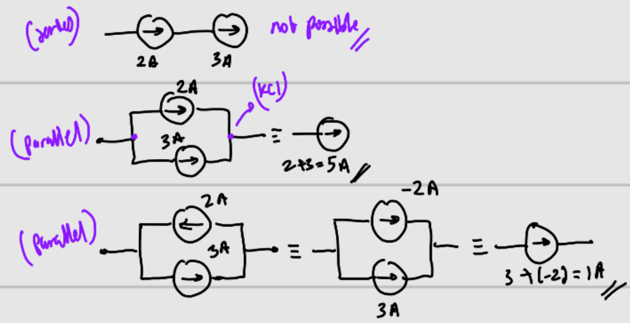
Voltage Source





$\boxed{\text{In reality, the voltage sources have internal resistance which is very small. Thus a lot of current passes. Thus affecting the sources}}$

Current Source

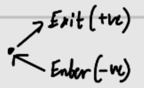


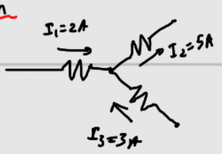
Kirchoff's Current Law (KCL)

- Applied at a Node/Supernode
- Algebraic Sum
- Currents
- $\Sigma I = 0$

$$\boxed{\begin{aligned}&\Sigma I_{Enter} = \Sigma I_{exit}\\ &0 = -\Sigma I_{enter} + \Sigma_{exit}\\ &\Sigma I_{exit} + \Sigma(-I_{enter}) = 0\\ &\Sigma I = 0\end{aligned}}$$

KCL Current Convention

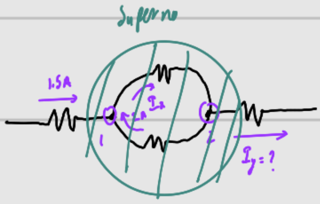




$I_1 + I_3 = I_2$

$-I_1 - I_3 + I_2 = 0$

eg



KCL @ Node 1

$-1.5 - 2 + I_x = 0$

$\therefore I_x = 2 + 1.5 = 3.5A$

KCL @ Node 2

$-I_x + 2 + I_y = 0$

$-3.5 + 2 + I_y = 0$

$I_y = 1.5A$

$-1.5 + I_y = 0$

$I_y = 1.5A$

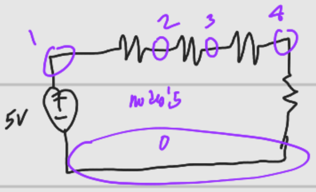
actually what happening:

Node 2! $-I_x + 2 + I_y = 0$

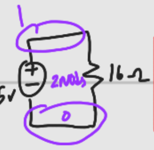
Node 1! $-1.5 - 2 + I_x = 0$

$-1.5 + I_y = 0$

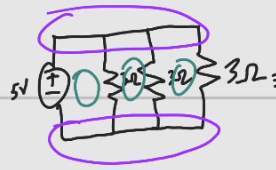
$I_y = 1.5A$



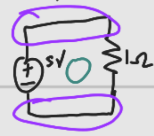
$\equiv$



$\boxed{\text{∴ The no. of nodes decreases when resistors are in series}}$



$\equiv$



3 loops, 2 nodes (mesh) 1 Loop, 2 loops

$\boxed{\text{The no. of mesh decreasing but nodes remain same in parallel connection of resistors}}$

L-5.5

as they're in series

KCL

1. Node/supernode
2. Algebraic sum
3. Current
4. zero

$\Sigma I = 0$

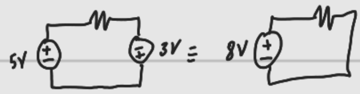
KVL

1. Mesh/Supermesh
2. Algebraic sum
3. voltage
4. zero

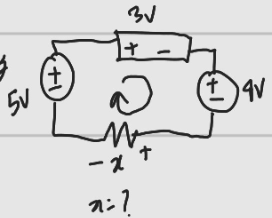
$\Sigma V = 0$

$\boxed{V, k\Omega, mA}$

eg



eg

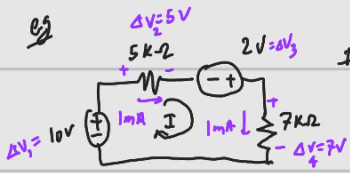


$x = ?$

$+3 + 4 + x - 5 = 0$

$x = -2V$

eg



$I = \frac{12}{12 \times 10^3} = 1mA$

\# Mesh (Loop)

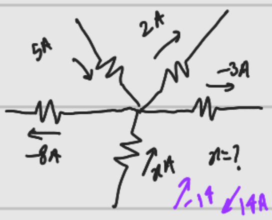
$\Sigma(\Delta V) = 0$

(Algebraic sum)

\# $-\Delta V_1 + \Delta V_2 - \Delta V_3 + \Delta V_4 = 0$

$\Rightarrow -(10) + (5) - (2) + (7) = 0$

$\Rightarrow 0 = 0$

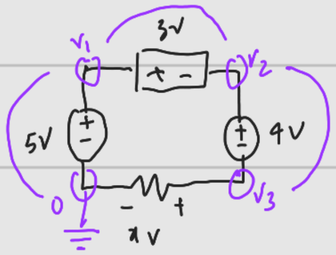


KCl enter (-ve), exit (+ve)

$-x + (-3) + 2 - (5) + (-8) = 0$

$x = -14A$

$\boxed{\begin{array}{l}\text{Voltage is of a node [1 Node = 1 Voltage]}\\ \text{voltage Difference is bet}^{n}\text{ two nodes [1 Element (Terminal) = 1 current]}\\ \text{Current is of an element}\end{array}}$



$V_1 - 0 = 5$

$V_1 - V_2 = 3$

$V_2 - V_3 = 4$

$V_3 - 0 = x$

$-4 - 3 + 5 - x = 0$

$V_3 - V_2 = -4$

$V_2 - V_1 = -3$

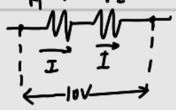
$V_1 - 0 = 5$

$0 - V_3 = -x$

$0 = -4 - 3 + 5 - x$

Voltage Divider Rule (only applicable for 2 resistors)

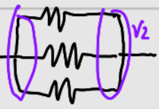
$R_1 = ?$ $R_2 = ?$



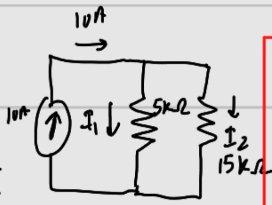
Series: 1) I same
2) V divide $\propto R$

$$\boxed{\Delta V_1 = 10V \times \frac{R_1}{R_1+R_2} \qquad \Delta V_2 = 10V \times \frac{R_2}{R_1+R_2}}$$

$\Delta V = V_1 - V_2$

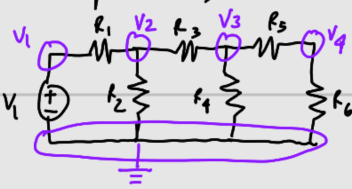


Parallel: 1) V same
2) I divide $\propto \frac{1}{R}$



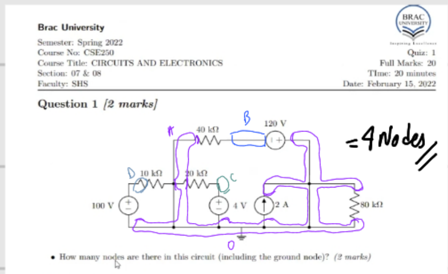
$$\boxed{I_1 : I_2 = \frac{1}{R_1} : \frac{1}{R_2} \qquad I_1 = 10 \times \frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}} \qquad I_2 = 10 \times \frac{\frac{1}{R_2}}{\frac{1}{R_1}+\frac{1}{R_2}}}$$

Lab Exp 5 : Series - Parallel



$\rightarrow$

$\rightarrow \cdots$


Brac University

Semester: Spring 2022
Course No: CSE250
Course Title: CIRCUITS AND ELECTRONICS
Section: 07 & 08
Faculty: SHS

Quiz: 1
Full Marks: 20
Time: 20 minutes
Date: February 15, 2022

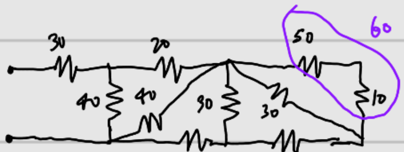
Question 1 *[2 marks]*

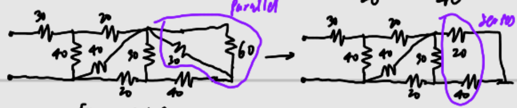
- How many nodes are there in this circuit (including the ground node)? *(2 marks)*

= 4 Nodes

L-6

Q3) [10marks]



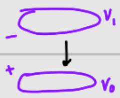


$50+10 = 60k\Omega$ (series)

$30 \parallel 60$

$\frac{1}{30}+\frac{1}{60} = \frac{1}{R}$ $R = 20k\Omega$

$\cdots$ $30+20 = 50$

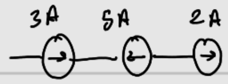


$\uparrow -10mA$

(i) $P = \Delta V I = V_+ - V_- = V_0 - V_1$
$= -25 \times 10 \times 10^{-3}$ W

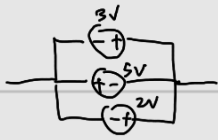
(ii) $P = \Delta V I = V_+ - V_- = V_0 - V_1$
$= (-25) \times (-10 \times 10^{-3})$ W

Q) 1)



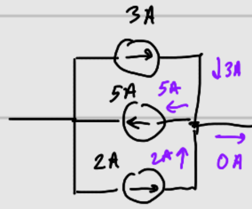
Illegal. Current sources can't be in series

2)



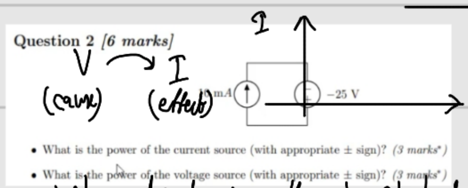
Illegal. Voltage source can't be in parallel

3)



Legal

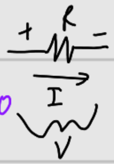
I-V Characteristics


Question 2 *[6 marks]*

- What is the power of the current source (with appropriate ± sign)? *(3 marks*)*
- What is the power of the voltage source (with appropriate ± sign)? *(3 marks*)*

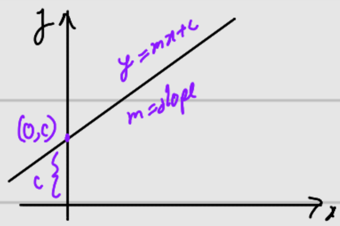
We've already seen this in Ohm's Law. $V = IR$

Ohm's Law



$I = \frac{1}{R} V + 0$

$y = mx + c$

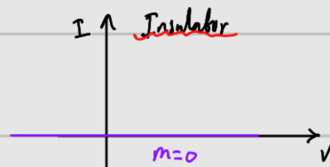


Resistor → I-V Characteristics

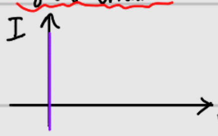
↳ ① Straight Line
② $m = \text{slope} = \frac{1}{R}$
③ $c = 0 \Rightarrow$ Origin

$R = \infty \ \Omega$
(Insulator)

$m = \frac{1}{R} = \frac{1}{\lim_{R\to\infty} R} = 0$



$m = 0$
for Insulator
↓
also Open circuit



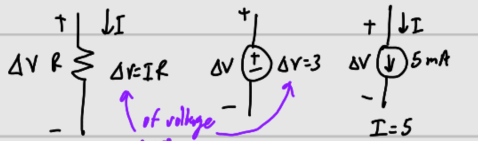
$R = 0 \ \Omega$

$m = \frac{1}{R} = \frac{1}{\lim_{R\to 0} R} = \infty$

L-7

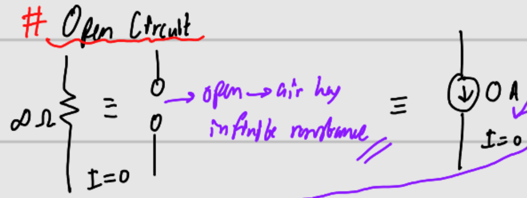
Characteristic eqn of Ohm's Law: $V = IR$ $[I \propto V]$

only for resistor

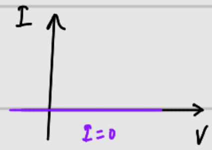


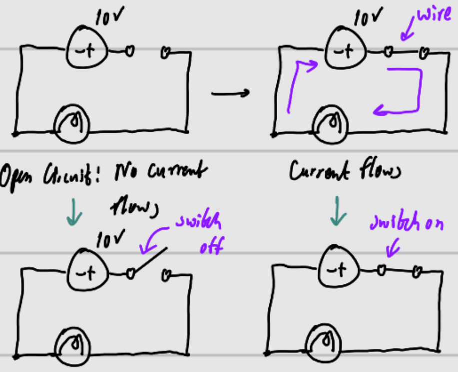
of voltage source — Characteristic eqn — of current source

Open Circuit



open → air has infinite resistance





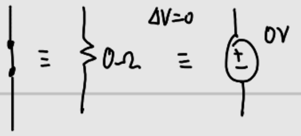
Open Circuit: No current flows

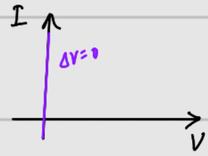
Current flows

switch off

switch on

Short Circuit

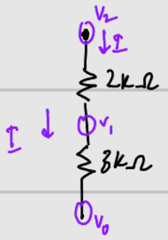




switch: switches bet^n open & closed circuit. Thus the name "switch"

Equivalent Circuit has same characteristic eqn

Series



$I \leftrightarrow \Delta V$

$V_2 - V_1 = 2I$

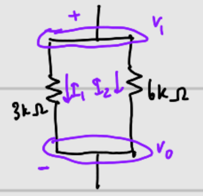
$V_1 - V_0 = 3I$

$(V_2 - V_0) = 5I$

$\therefore \Delta V = 5I$

$\Delta V = RI$

Parallel



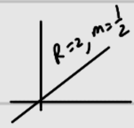
$V \leftrightarrow I$

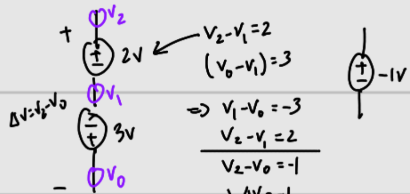
$I = I_1 + I_2$

$I = \frac{V}{3} + \frac{V}{6}$

$I = V\left(\frac{1}{3} + \frac{1}{6}\right) \Rightarrow \frac{1}{R} = \frac{1}{2}$

$I = V \times \frac{1}{R}$





$V_2 - V_1 = 2$

$(V_0 - V_1) = 3$

$\Rightarrow V_1 - V_0 = -3$

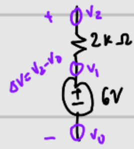
$V_2 - V_1 = 2$

$V_2 - V_0 = -1$

$\therefore \Delta V = -1$

Source Transformation

Voltage Source & Resistor in Series



$V_2 - V_1 = 2I$

$V_1 - V_0 = 6$

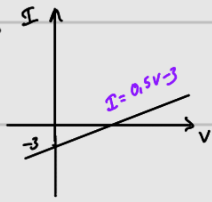
$V_2 - V_0 = 2I + 6$

$\Delta V = 2I + 6$

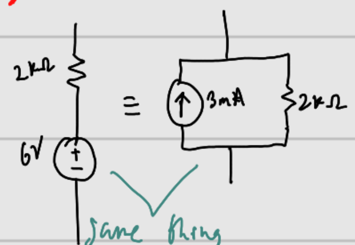
(characteristic eqn)

$I = 0.5\Delta V - 3$

$y = mx + c$

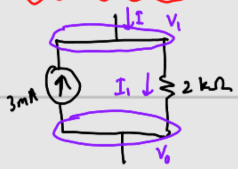


★★★



Same thing

Current Source & Resistor in Parallel



$-I - 3 + I_1 = 0$

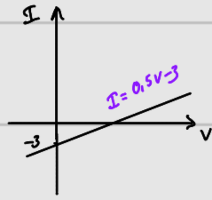
$I_1 = I + 3$

$\frac{V}{2} = I + 3$

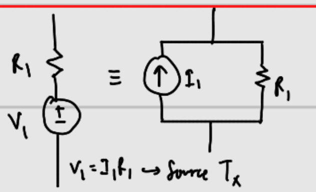
$\therefore V = 2I + 6$

(characteristic eqn)

same eqn $\therefore$ equivalent circuit

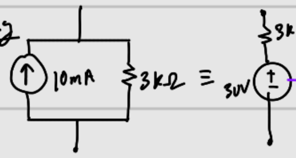


★★★ Source Transformation (T_x) as series circuit transformed to parallel circuit



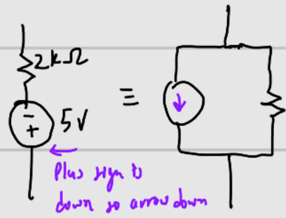
$V_1 = I_1 R_1 \rightarrow$ Source T_x

eg



opposite of passive sign

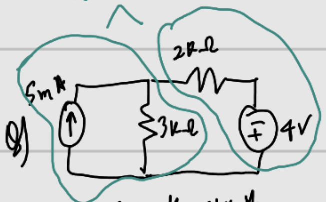
eg



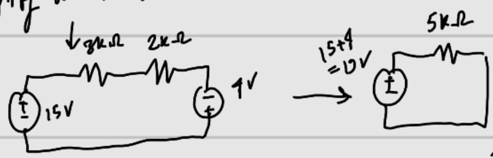
Plus sign is down so arrow down

both combo source T_x

Q)

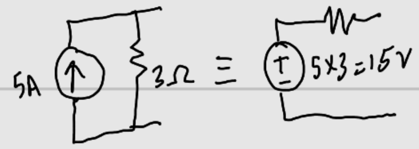


simplify the circuit

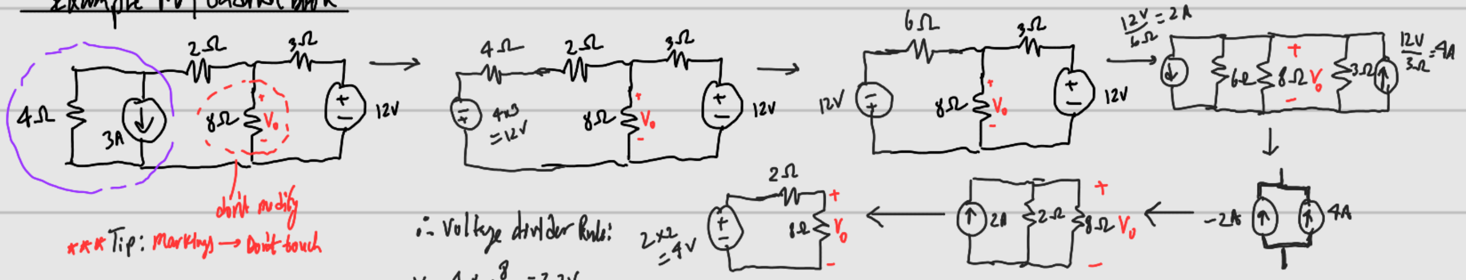


L-8

25/11/2024
Monday



Example 4.6 | Sadiku book



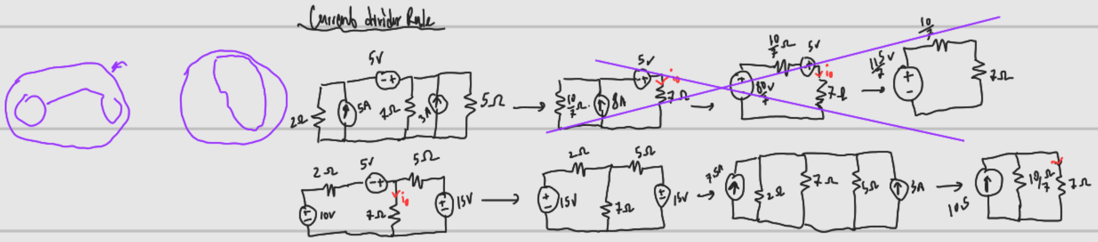
$\star\star$ Tip: marking → Don't touch

∴ Voltage divider Rule:

$V_0 = 4 \times \frac{8}{2+8} = 3.2V$

Practice Problem - 6

Current divider Rule



Current divider Rule

$i_0 = 10.5 \times \frac{10/7}{10/7 + 7}$

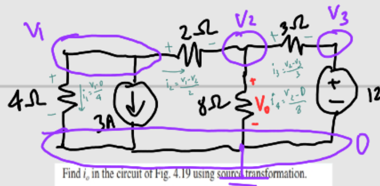
$\approx 1.79 A$

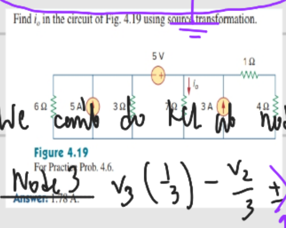
Drawback of Source Transformation

work only when:

- Current Source & resistor parallel
- Voltage source & resistor in series

Nodal Analysis (using KCL)





We can do KCL at node 3

Node 3: $V_3\left(\frac{1}{3}\right) - \frac{V_2}{3} \cancel{+12} - I$

Voltage

extra variable so no need

Step 1: Node Identification

0 (ground)

Step 2: Voltage Source eqn $\Delta V = V_3 - 0 = 12$

Step 3: Resistance Current (Ohm)

Step 4: Node 1

$i_1 + i_2 + i_3 = 0$

$\Rightarrow \frac{V_1}{4} + \frac{V_1 - V_2}{2} + 3 = 0$

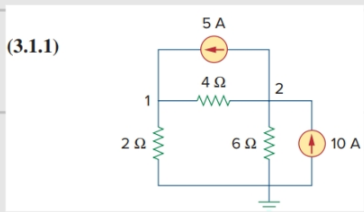
$\Rightarrow V_1\left(\frac{1}{4}+\frac{1}{2}\right) - \frac{V_2}{2} + 3 = 0$

Step 5: Solve eqn

(no need for RREF)

Node 2: $V_2\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{8}\right) - \frac{V_1}{2} - \frac{V_3}{3} - \frac{0}{8} = 0$

2 eqn, 2 variables

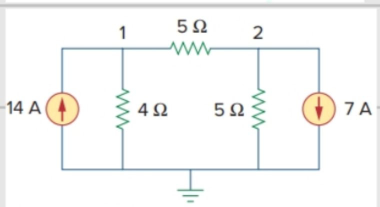


Step 1) Identify nodes

Step 2) Voltage source eqn. Here is None

Step 3) Step 4) Node 1: $V_1\left(\frac{1}{2}+\frac{1}{4}\right) - \frac{0}{2} - \frac{V_2}{4} - 5 = 0$

Node 2: $V_2\left(\frac{1}{4}+\frac{1}{6}\right) - \frac{V_1}{4} - \frac{0}{6} - 10 + 5 = 0$



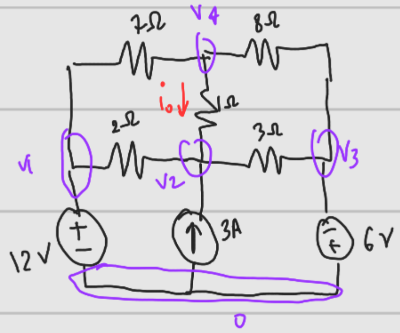
Node 1

$V_1\left(\frac{1}{5}+\frac{1}{4}\right) - \frac{V_2}{5} - \frac{0}{4} - 14 = 0$

$V_2\left(\frac{1}{5}+\frac{1}{5}\right) - \frac{V_1}{5} - \frac{0}{5} + 7 = 0$

$V_1 = 30V,\ V_2 = -2.5V$

L-9



Voltage source eq!: $V_1=12$, $V_3=6V$

No KCL at 1 and 3 as there's voltage source

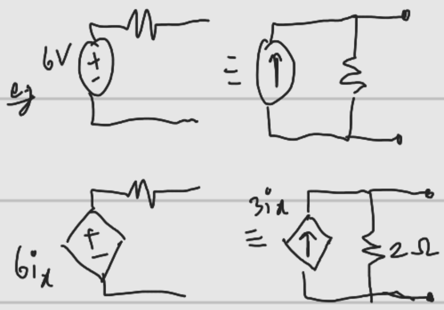
KCL at 4: $\left(\frac{1}{7}+\frac{1}{1}+\frac{1}{8}\right)-\frac{V_1}{7}-\frac{V_2}{1}-\frac{V_3}{8}=0$

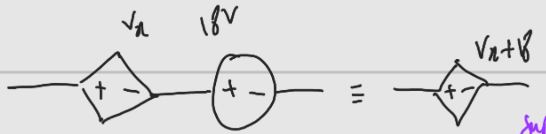
KCL at 2: $V_2\left(\frac{1}{2}+\frac{1}{3}+\frac{1}{1}\right)-\frac{V_1}{2}-\frac{V_3}{3}-\frac{V_4}{1}-3=0$

Independent Vs Dependent Source

Current Controlled Voltage source	Current Controlled Current Source	Voltage Controlled Voltage Source	Voltage Controlled Current Source
CCVS	CCCS	VCVS	VCCS

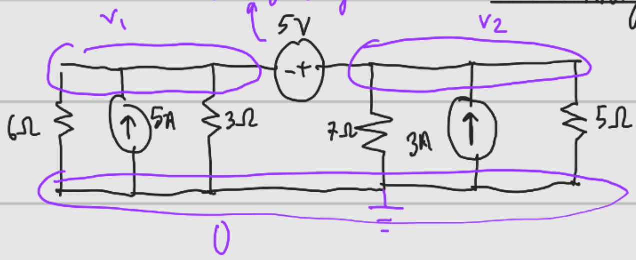
eg





floating Voltage source → supernode

Nodal Analysis Part-2

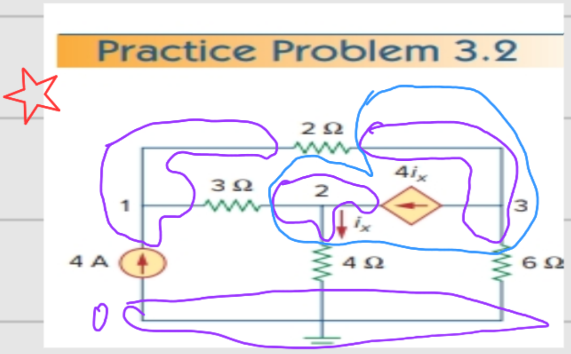


$V_2-V_1=5$

supernode at V_1 & V_2

Step 3&4: Super Node at 1,2: $V_1\left(\frac{1}{6}+\frac{1}{3}\right)-\frac{0}{6}-\frac{0}{3}+V_2\left(\frac{1}{7}+\frac{1}{5}\right)-\frac{0}{7}-\frac{0}{3}-5-3=0$

Node 1 + Node 2



wrong. It's a current source Not voltage source//

$4i_x = V_3 - V_2$

$V_2 - 0 = i_x \times 4$ ~~$\Rightarrow V_2 = 4i_x = V_3 - V_2$ ∴ $2V_2 = V_3$~~

KCL at 1: $V_1\left(\frac{1}{2}+\frac{1}{3}\right)-\frac{V_3}{2}-\frac{V_2}{3}-4=0$

~~KCL at Supernode 2+3: $\left\{V_2\left(\frac{1}{3}+\frac{1}{4}\right)-\frac{V_1}{3}-\frac{0}{4}\right\}+\left\{V_3\left(\frac{1}{2}+\frac{1}{6}\right)-\frac{V_1}{2}-\frac{0}{6}\right\}=0$~~

~~$= V_2\left(\frac{1}{3}+\frac{1}{4}\right)+V_1\left(-\frac{1}{3}-\frac{1}{2}\right)+V_3\left(\frac{1}{2}+\frac{1}{6}\right)=0$~~

$i_x=\frac{V_2}{4}$

$V_2\left(\frac{1}{3}+\frac{1}{4}\right)-\frac{V_1}{3}-\frac{0}{4}-\overbrace{4i_x}^{-V_2}=0$

$V_3\left(\frac{1}{2}+\frac{1}{6}\right)-\frac{V_1}{2}-\frac{0}{6}+\overbrace{4i_x}^{V_2}=0$

~~$V_1=15.70$, $V_2=26.6$, $V_3=13.7$~~

∴ $V_1=32$, $V_2=-25.6$, $V_3=62.4$ //

no need for super node as there is no voltage source. It's dependent current source//

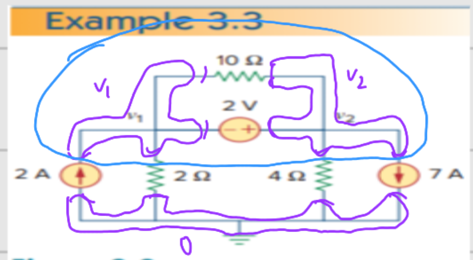


Figure 3.9
For Example 3.3.

$V_2 - V_1 = 2$

(1+2) $\left\{V_1\left(\frac{1}{10}+\frac{1}{2}\right)-\frac{V_2}{10}-\frac{0}{2}-2\right\}+\left\{V_2\left(\frac{1}{10}+\frac{1}{4}\right)-\frac{V_1}{10}-\frac{0}{4}+7\right\}=0$

$V_1\left(\frac{1}{10}+\frac{1}{2}-\frac{1}{10}\right)+V_2\left(-\frac{1}{10}+\frac{1}{10}+\frac{1}{4}\right)+5=0$

$V_1=-7.33V$ // $V_2=-5.33V$ //

Practice Problem 3.3

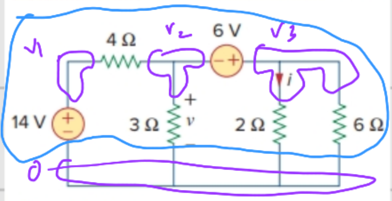


Figure 3.11
For Practice Prob. 3.3.

$v_3 - v_2 = 6$

$v_1 - 0 = 14 \Rightarrow v_1 = 14$

$\left\{v_1\left(\frac{1}{4}\right) - \frac{v_2}{4}\right\} + \left\{v_2\left(\frac{1}{4}+\frac{1}{3}\right) - \frac{v_1}{4} - \cancel{\frac{0}{3}}\right\} + v_3\left(\frac{1}{2}+\frac{1}{6}\right) - \cancel{\frac{0}{2}} - \cancel{\frac{0}{6}} = 0$

$\cancel{\frac{14}{4}} + v_2\left(-\cancel{\frac{1}{4}} + \cancel{\frac{1}{4}} + \frac{1}{3}\right) - \cancel{\frac{14}{4}} + v_3\left(\frac{1}{2}+\frac{1}{6}\right) = 0$

$v_2 = -4V$

$v_3 = 2V$

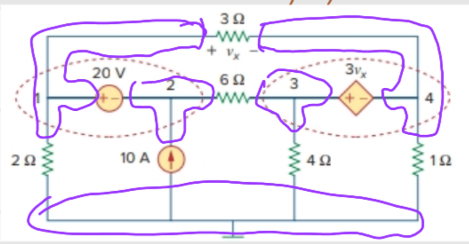
$V = v_2 - 0 = -4V$

$i = \frac{v_3 - 0}{2} = \frac{2}{2} = 1A$

Ans doesn't match

Q) Find v and i.

Ans: −400 mV, 2.8 A



Step 2: $v_1 - v_2 = 20$

$v_3 - v_4 = 3v_x = 3(v_1 - v_4)$

$v_x = v_1 - v_4$

Supernode at 1,2: $v_1\left(\frac{1}{2}+\frac{1}{3}\right) - \frac{0}{2} - \frac{v_4}{3} + v_2\left(\frac{1}{6}\right) - \frac{v_3}{6} - 10 = 0$

Supernode at 3,4: $v_3\left(\frac{1}{4}+\frac{1}{6}\right) - \frac{0}{4} - \frac{v_2}{6} + v_4\left(\frac{1}{1}+\frac{1}{3}\right) - \frac{0}{1} - \frac{v_1}{3} = 0$

4 eqⁿ, 4 variables → solve

L-10

Mesh Analysis

Nodal Analysis	Mesh Analysis
① v_1, v_2, v_3 .. (Node voltage)	① i_1, i_2, i_3, .. (mesh current)
② KCL eqⁿ	② KVL eqⁿ
③ Step 2: voltage source	③ Step 2: Current Source
④ Supernode [if there is floating voltage source]	④ Supermesh [if there is/are common current source]

Take Mesh (Loop) direction clockwise always

Example 3.5

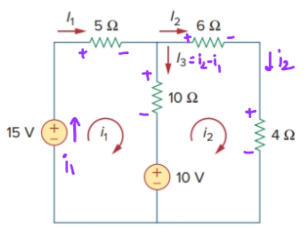


Figure 3.18
For Example 3.5.

Mesh-1: $-15 + 5i_1 + 10(i_1 - i_2) + 10 = 0$

$\Rightarrow i_1(5+10) - 10i_2 - 15 + 10 = 0$

Mesh-2: $-10 - 10(i_1 - i_2) + 6i_2 + 4i_2 = 0$

$i_2(10+6+4) - 10i_1 - 10 = 0$

$i_1 = \square, i_2 = \square$

Stepwise:

Step 1) Mesh Identification

Step 2) Current source eqⁿ

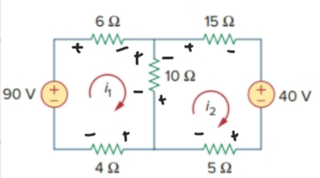
Step 3/4: KVL at mesh

Mesh-1 $i_1(5+10) - 10(i_2) - 15 + 10 = 0$

Mesh-2 $i_2(6+4+10) - 10i_1 - 10 = 0$

Step-5: Solve

Practice Problem 3.5



Mesh 1) $i_1(6+10+4) - 6\times0 - 10\times(\cancel{-i_2}) - 4\times0 - 90 = 0$ $(+i_2)$ $\Rightarrow i_1(20) - 10i_2 = 90$

Mesh 2) $i_2(15+5+10) - 15\times0 - 5\times0 - 10\times(\cancel{-i_1}) + 40 = 0$ $(+i_1)$ $\Rightarrow i_2(30) - 10i_1 = -40$

$i_1 = 6.2$ A, $i_2 = -3.4$ A

$i_1 = 4.6A$, $i_2 = 0.2A$

Example 3.6

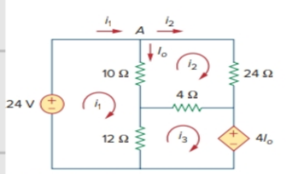


Figure 3.20
For Example 3.6.

Step 1: Mesh Identification

Step 2: Current source eqⁿ $i_3 = 4I_o$

Step 3/4: Mesh 1: $i_1(10+12) - 10\times\underline{i_2} - 12\times\underline{i_3} - 24 = 0$

Mesh 2: $i_2(24+4+10) - 24\times\underline{0} - 4\times\underline{i_3} - 10\times\underline{i_1} = 0$

Mesh 3: $i_3(4+12) - 4\times\underline{i_2} - 12\times\underline{i_1} + 4I_o = 0$

3 eqⁿ, 3 variables

Practice Problem 3.6

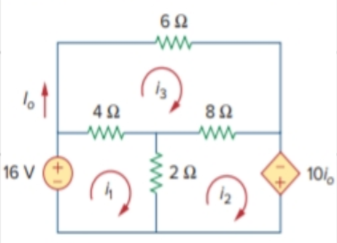


Figure 3.21
For Practice Prob. 3.6.

$i_o = i_3$

$i_1(4+2) - 4(i_3) - 2(i_2) - 16 = 0$

$i_2(2+8) - 2(i_1) - 8(i_3) - 10i_o = 0$

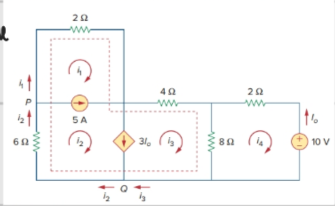
$i_3(6+4+8) - 4(i_1) - 8(i_2) = 0$

$i_1 = -2.53$, $i_2 = -7.71$

$i_3 = -4A = i_o$

For the circuit in Fig. 3.24, find i_1 to i_4 using mesh analysis.

Example 3.7



Step 2: $i_2 - i_1 = 5$

$i_2 - i_3 = 3I_0$

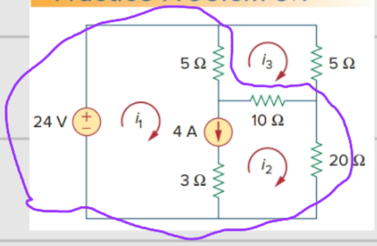
$i_0 = -i_4$

Step 3 & 4:

mesh 4: $i_4(2+8) - 2(0) - 8(i_3) + 10 = 0$

Supernode 1,2,3: $\{i_1(2) - 0\} + \{i_2(6)\} + \{i_3(4+8) - 4\times 0 - 8\times i_4\} = 0$

Practice Problem 3.7



$i_1 - i_2 = 4 \Rightarrow i_1 = 4 + i_2$

mesh 3: $i_3(5+10+5) - 5\times i_1 - 5\times 0 - 10\times i_2 = 0$

$\Rightarrow i_3(20) - 5(4+i_2) - 10i_2 = 0 \Rightarrow -15i_2 + i_3(20) = 20$ (i)

Supernode 1,2: $\{i_1(5+3) - 5\times i_3 - 3\times i_2 - 24\} + \{i_2(10+20+3) - 10\times i_3 - 20(0) - 3(i_1)\} = 0$

$i_1(5) + i_2(30) + i_3(-15) = 24$

$5(4+i_2) + 30i_2 - 15i_3 = 24 \Rightarrow 35i_2 - 15i_3 = 4$ (ii)

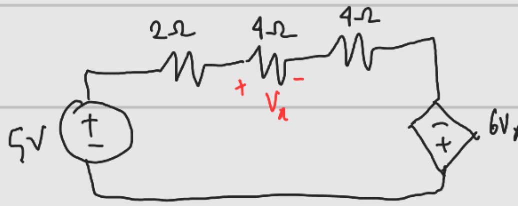
$i_1 = 4.8,\ i_2 = 0.8,\ i_3 = 1.6$

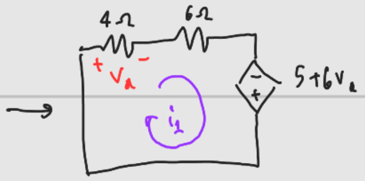
Ans: $i_1 = 12.379$, $i_2 = 574.9\,mA$, $i_3 = 3.284\,A$

(Wrong ans in book)

26/11/2024
Tuesday

Mid Review





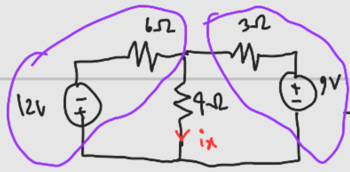
$V_x = 4i_1$ # $i_1(4+6) - (5+6V_x) = 0$

$\Rightarrow i_1 = \frac{V_x}{4}$ $\Rightarrow \frac{V_x}{4}(10) - (5+6V_x) = 0$

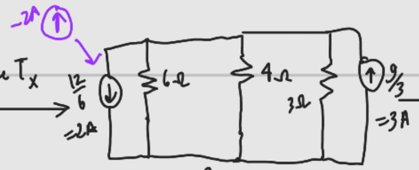
$\Rightarrow -3.5V_x - 5 = 0$

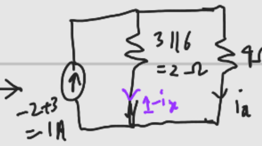
$\therefore V_x = \frac{5}{-3.5} = -\frac{10}{7} \approx -1.43\,V$

Q1)



Source Tx





(current divider rule)

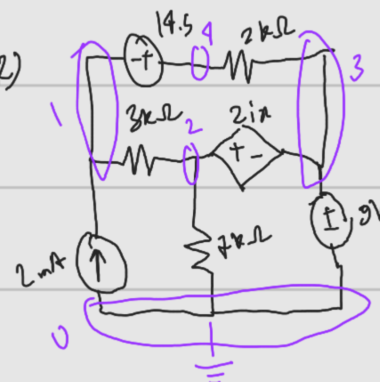
$\therefore i_x = 1\times\frac{2}{2+4} = \frac{1}{3} \approx 0.33\,A$

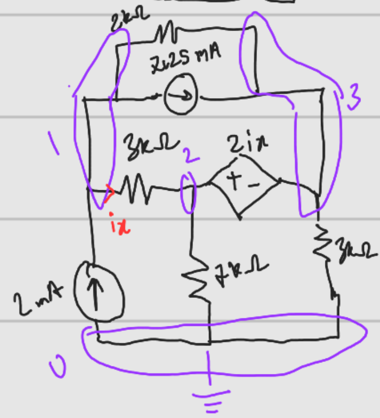
OR $(1-i_x)\times 2 = i_x \times 4 \Rightarrow \therefore i_x = \frac{1}{3}A$

$1 - i_x = 2i_x$

$1 = 3i_x$

Q2)





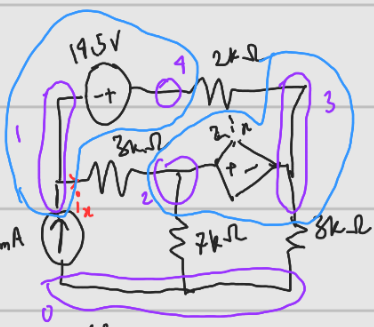
$i_x = \frac{V_1 - V_2}{3}$ (mA)

$V_2 - V_3 = 2i_x$

$V_1\left(\frac{1}{3}+\frac{1}{2}\right) - \frac{V_2}{3} - \frac{V_3}{2} + 7.25 - 2 = 0$

$\left\{V_2\left(\frac{1}{3}+\frac{1}{7}\right) - \frac{V_1}{3} - \frac{0}{7}\right\} + \left\{V_3\left(\frac{1}{2}+\frac{1}{3}\right) - \frac{V_1}{2} - \frac{0}{3} - 7.25\right\} = 0$

eg



Nodal Analysis

$i_x = \frac{V_1 - V_2}{3}$

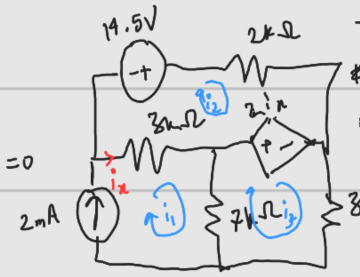
$2i_x = V_2 - V_3$

Supernode 1+4

$\left\{V_1\left(\frac{1}{3}\right) - \frac{V_2}{3} - 2\right\} + \left\{V_4\left(\frac{1}{2}\right)\right\} = 0$

Supernode at 2+3

Mesh Analysis



$i_x = i_1 - i_2$

$i_1 = 2\,mA$

Mesh at 2

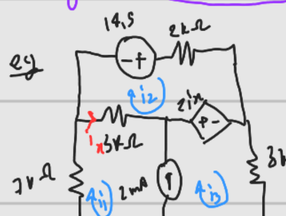
$i_2(2+3) - 2\times 0 - 3\times i_1 - 14.5 - 2i_x = 0$

Mesh at 3

$i_3(3+7) - 3\times 0 - 7\times i_1 + 2i_x = 0$

No need for super mesh as there's no common current source

eg



$i_3 - i_1 = 2\,mA$

$i_2(2+3) - 2\times 0 - 3\times(i_1) - 14.5 - 2i_x = 0$

Supermesh at 1&3:

$\{i_1(7+3) - 7\times 0 - 3\times i_2\} + \{i_3(3) - 3\times 0 + 2i_x\} = 0$

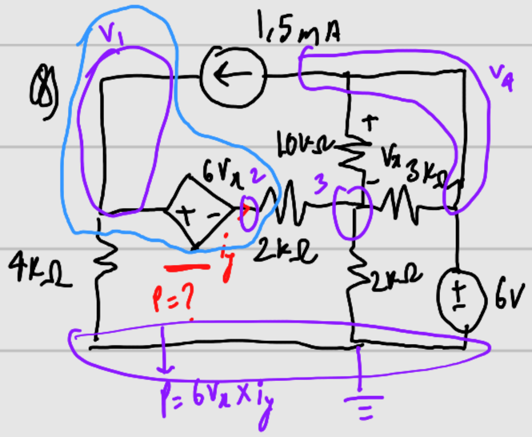
Practice Problem 3.7

$i_1 - i_2 = 4A$

$i_3(5+5+10) - 5\times 0 - 5\times i_1 - 10\times i_2 = 0$

$\{i_1(5+3) - 5\times i_3 - 3\times i_2 - 24\} + \{i_2(3+10+20) - 3i_1 - 10i_3\} = 0$

8)



Using Nodal Analysis

$V_4 - 0 = 6 \Rightarrow V_4 = 6$

$V_4 - V_3 = V_x \Rightarrow V_3 = 6 - V_x$

$V_3\left(\frac{1}{3}+\frac{1}{10}+\frac{1}{2}+\frac{1}{2}\right) - \frac{V_4}{3} - \frac{V_4}{10} - \frac{V_2}{2} - \frac{0}{2} = 0$

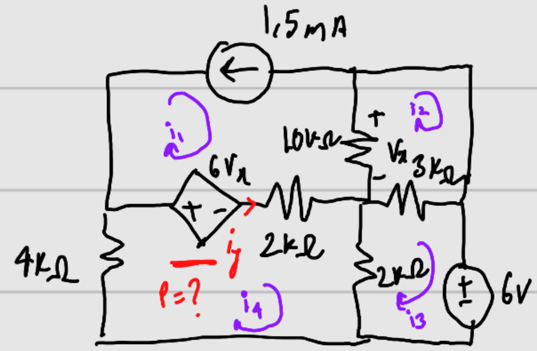
$\left\{V_1\left(\frac{1}{4}\right) - 1.5\right\} + \left\{V_2\left(\frac{1}{2}\right) - \frac{V_3}{2}\right\} = 0$

$V_2 - V_3 = i_y \times 2$

$i_y = \boxed{}\ mA$

$\therefore P = 6V_x \times i_y$

$= \boxed{}$



$-i_1 = 1.5\ mA$

$i_y = i_4 - i_1$

$V_x = (i_2 - i_1) \times 10\ V$

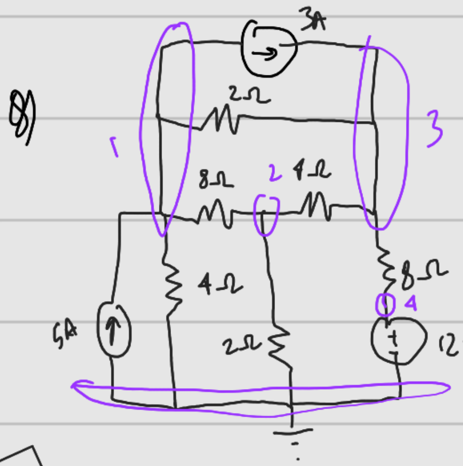
$i_2(3+10) - 3 \times i_3 - 10\, i_1 = 0$

$i_3(2+3) - 2(i_4) - 3(i_2) + 6 = 0$

$i_4(4+2+2) - 2(i_3) - 2(i_1) + 6V_x = 0$

$P = (6V_x) i_y$

8)



$V_4 = 12V$

Node1 : $V_1\left(\frac{1}{2}+\frac{1}{8}+\frac{1}{4}\right) - \frac{V_3}{2} - \frac{V_2}{8} - \frac{0}{4} - 5 + 3 = 0$

Node2! $V_2\left(\frac{1}{8}+\frac{1}{4}+\frac{1}{2}\right) - \frac{V_1}{8} - \frac{V_3}{4} - \frac{0}{2} = 0$

Node3: $V_3\left(\frac{1}{2}+\frac{1}{4}+\frac{1}{8}\right) - \frac{V_1}{2} - \frac{V_4}{8} - \frac{V_2}{4} - 3 = 0$

$-\frac{12}{8}$

$V_1 = 10,\ V_2 = 4.73$

$V_3 = 12.27$

PDS Str

L-1

Practice Problems

Problem 1) (i) $1e^- \rightarrow -1.602 \times 10^{-19} C$

$\therefore 1C \rightarrow \frac{1}{1.602 \times 10^{-19}} = 6.25 \times 10^{18}$ electrons

(ii) (a) $1e^- \rightarrow -1.6 \times 10^{-19} C$

$1.24 \times 10^{18} \rightarrow (1.24 \times 10^{18} \times -1.602 \times 10^{-19}) = -0.198648\ C \approx -198.65\ mC$

(b) $2.46 \times 10^{19} \rightarrow 2.46 \times 10^{19} \times (-1.602 \times 10^{-19}) = -3.94092\ C \approx -3.941\ C$

(iii) $V = \frac{W}{q} = \frac{1.2}{20 \times 10^{-6}} = 60{,}000\ V = 60\ kV$

Problem 2) (i) $W = q(V_B - V_A)$ $(V_{final} - V_{initial})$

$-10 = -2(V_B - 22)$

work done by the charge is -ve

$\therefore V_B = 27V$

(ii) $V_B = (-11) - (-1) = -12$

$V_A = (-7) - (-1) = -8$

$V_B - A_A = -12 - (-8) = -4$

$W = -4 \times (-5) = 20J$

Problem-3

$V_B - V_A = \frac{W}{q}$

$-30 - (20) = \frac{W}{-6 \times 10^{-3}}$

$\therefore W = 0.3J$

Problem 4)

$P_1 = VI = 15 \times (-10)$

$= -150\,W$ (supplying)

$P_2 = 15 \times 4 = 60\,W$

$P_3 = 9(-(-6)) = 54\,W$ (absorbing)

$P_4 = -6(-6) = 36\,W$

Problem-5)

$P_{5V} = 5 \times (-7)$

$= -35\,W$ (supplying)

$P_{3V} = 3 \times (-3) = -9\,W$ (supplying)

$P_{1V} = 1 \times (-4) = -4\,W$ (supplying)

$P_{-6V} = (-6) \times (-2) = 12\,W$ (absorbing)

$P_{2V} = 2 \times (-2) = -4\,W$ (supplying)

$P_{-8V} = -8 \times (-5) = 40\,W$ (absorbing)

Problem-6

$\boxed{\begin{array}{l} -ve \to \text{Supplying} \\ +ve \to \text{absorbing} \end{array}}$

$P_1 = 5 \times (-9) = -45\,W$

$P_2 = 2 \times 9 = 18\,W$

$P_3 = 3 \times (-(-5)) = 15\,W$

$P_4 = 0.6I \times (-4) = 0.6(-5) \times (-4) = 12\,W$ //

Problem-7

$P_1 = 30(-10) = -300\,W$

$P_2 = 10(10) = 100\,W$

$P_3 = 20(14) = 280\,W$

$P_4 = 8 \times (-0.4I) = 8 \times (-0.4 \times 10) = -32\,W$

$P_5 = 12 \times (-0.4I) = 12 \times (-0.4 \times 10) = -48\,W$ //

Problem-8

(a) $R = \frac{4}{2} = 2\,\Omega$

$A\, i_a = 2$

$A = \frac{2}{-0.5} = -4$

(b) $P_{2V} = (2) \times (-(-0.5))$
$= 1\,W$

$P_R = 4 \times (-(-2)) = 8\,W$

$P_{10V} = 10 \times 2.5 = 25\,W$

$P_{14V} = 14 \times 1.5 = 21\,W$

$P_{12V} = 12 \times (-4) = 48\,W$

Problem-1

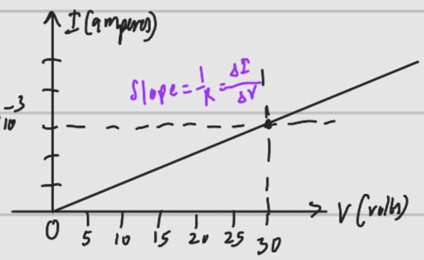
(i) $V = 3 \times 10^{-3} \times 10 \times 10^{3} = 30\,V$

$G = \frac{1}{R} = \frac{1}{10 \times 10^3} = 1 \times 10^{-4}\,S = 100\,mS$

$P = VI = 30 \times 3 \times 10^{-3} = 0.09\,W = 90\,mW$ //

(ii)

L-2



Problem-2

$P = VI$

$I = \frac{60}{120} = 0.5\,A$

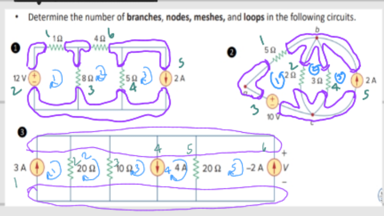
$R = \frac{V}{I} = \frac{120}{0.5}$
$= 240\,\Omega$ //

Problem-3

(a) $i = \frac{40}{100}$
$= 0.4\,A$ //

(b) $i = \frac{40}{250}$
$= 0.16\,A$ //

Problem-5



1) Branches = 6
nodes = 4
meshes = 3
loops = 6

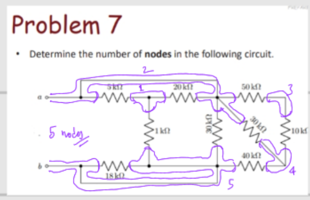
2) b = 5
n = 3
m = 3
l = 6

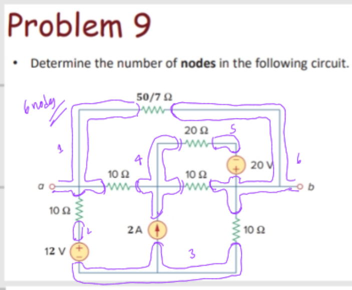
3) b = 6
n = 2
m = 5
L = 15

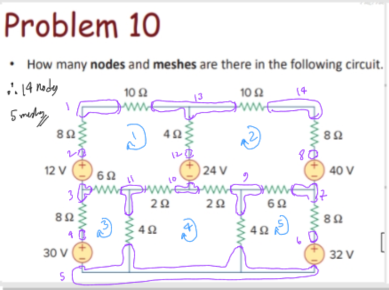
Problem 6, 8

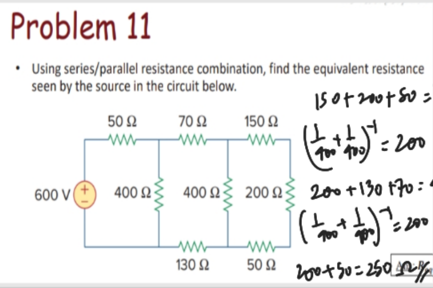
[Sol^n given]

Problem-7









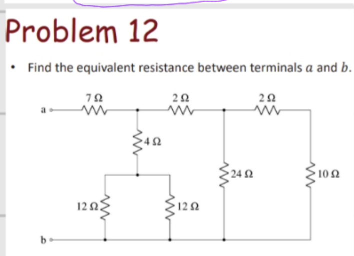
$150 + 200 + 50 = 400\,\Omega$

$\left(\frac{1}{400} + \frac{1}{400}\right)^{-1} = 200$

$200 + 130 + 70 = 400$

$\left(\frac{1}{400} + \frac{1}{400}\right)^{-1} = 200$

$200 + 50 = 250\,\Omega$ //

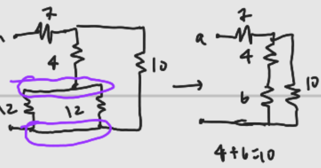


$2 + 10 = 12$

$\left(\frac{1}{12} + \frac{1}{24}\right)^{-1} = 8$

$8 + 2 = 10$

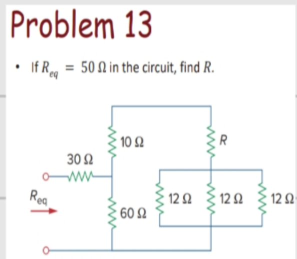
$\left(\frac{1}{12} + \frac{1}{12}\right)^{-1} = 6$



$4 + 6 = 10$

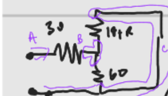
$\left(\frac{1}{10} + \frac{1}{10}\right)^{-1} = 5$

$7 + 5 = 12\,\Omega$ //



$\left(\frac{1}{12} + \frac{1}{12} + \frac{1}{12}\right)^{-1} = 4$

$4 + R + 10 = 14 + R$



$\frac{1}{14+R} + \frac{1}{60} = \frac{1}{R_1}$

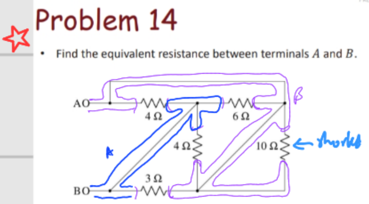
$R_1 = \frac{60(14+R)}{60 + 14 + R}$

$\therefore R_{eq} = 50 = 30 + R_1$

$20 = \frac{840 + 60R}{74 + R}$

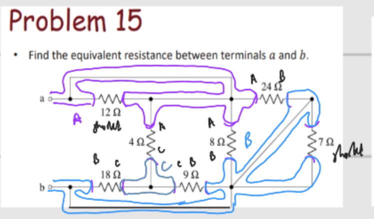
$1480 + 20R = 840 + 60R$

$\therefore R = 16\,\Omega$ //

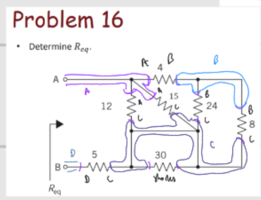


All parallel with each other

$\left(\frac{1}{4} + \frac{1}{6} + \frac{1}{4} + \frac{1}{3}\right)^{-1} = 1\,\Omega$ //



$\therefore R_{ab} = \left(\frac{1}{10} + \frac{1}{6}\right)^{-1} = 3.75$ //

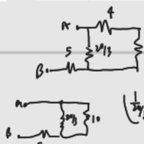


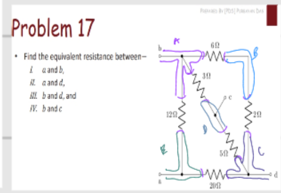
$\left(\frac{1}{12} + \frac{1}{15}\right)^{-1} = \frac{20}{3}$

$\left(\frac{1}{24} + \frac{1}{8}\right)^{-1} = 6$

$\left(\frac{1}{20/3} + \frac{1}{10}\right)^{-1} = 4$

$\therefore R_{ab} = 5 + 4 = 9$ //





(i)

$\left(\frac{1}{6+2} + \frac{1}{5+3}\right)^{-1} + 20 = 24$

$\left(\frac{1}{24} + \frac{1}{12}\right)^{-1} = 8\,\Omega$ //

(iii)

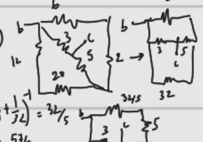
$\left(\frac{1}{12+20} + \frac{1}{3+5} + \frac{1}{6+2}\right)^{-1} = \frac{32}{9}\,\Omega$ //

(ii)

$\left(\frac{1}{8} + \frac{1}{8}\right)^{-1} + 12 = 16$

$\left(\frac{1}{16} + \frac{1}{20}\right)^{-1} = \frac{80}{9}\,\Omega$ //

(iv)



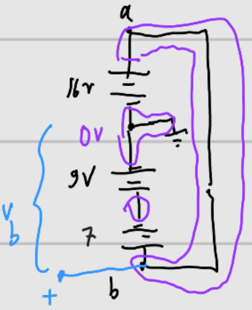
$\left(\frac{1}{8} + \frac{1}{32}\right)^{-1} = \frac{32}{5}$

$\frac{32}{5} + 5 = \frac{57}{5}$

$\left(\frac{1}{57/5} + \frac{1}{3}\right)^{-1} = \frac{19}{8}\,\Omega$ //

L-6

Problem-1



(i) V_a (w.r.t ground) $= 16V$

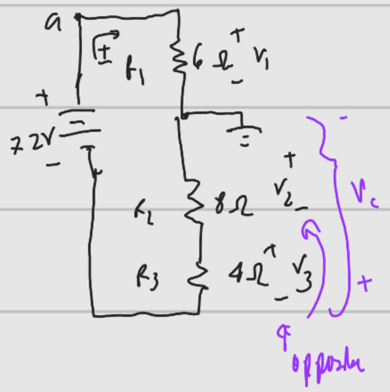
(ii) KVL $V_b - 9 - 7 = 0$

$V_b = 16V$

V_a and V_b are shorted

(iii) $V_a - V_b = 16 - 16 = 0V$

Problem-2



(i) $V_a = 72 \times \frac{6}{6+8+4}$

$= 24V$

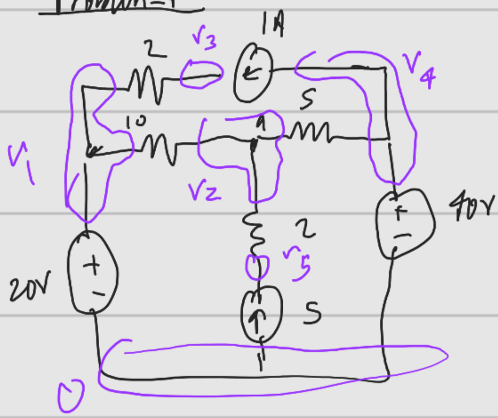
(ii) $V_b = -V_2 = -72 \times \frac{8}{8+6+4} = -32V$

$V_c = -(V_2 + V_3) - \left(32 + \frac{72 \times 4}{8+4+6}\right)$

$= -48V$

$V_{ab} = V_a - V_b = 24 - (-32) = 46V$

Problem-4

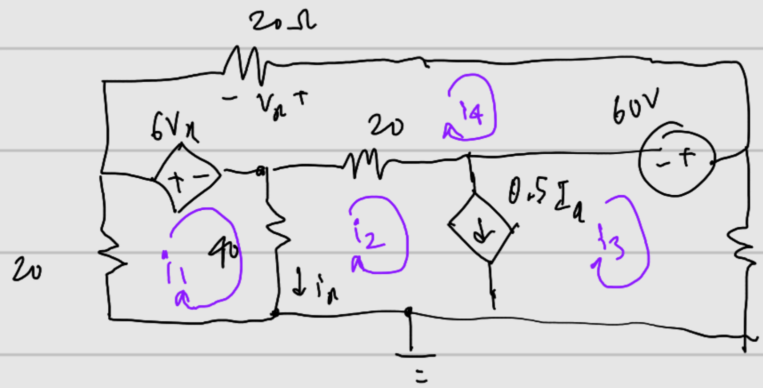


$V_1 - 0 = 20$

$V_4 - 0 = 40$

$V_3\left(\frac{1}{2}\right) - \frac{V_1}{2} - 1 = 0$

$V_2\left(\frac{1}{5} + \frac{1}{10} + \frac{1}{2}\right) - \frac{V_4}{5} - \frac{V_1}{10} - \frac{V_5}{2} = 0$



$i_2 - i_3 = 0.5 I_x$

$i_1 - i_2 = i_x$

$V_x = -i_4 \times 20$

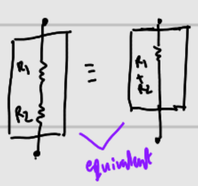
mesh at i_1: $i_1(20+40) - 20(0) - 40(i_2) + 6V_x = 0$

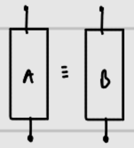
mesh at i_4: $i_1(20+20) - 20(0) - 20(i_2) + 60 - 6V_x = 0$

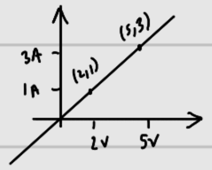
Super mesh at i_2 & i_3: $\{i_2(40+20) - 40(i_1) - 20(i_4)\} + \{i_3(10) - 10(0) - 60\} = 0$

01/01/2025
Wednesday

Equivalent Circuit

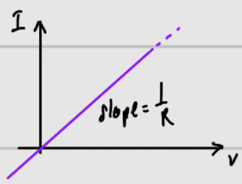


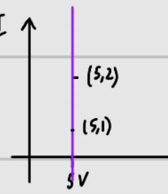


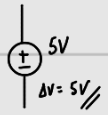


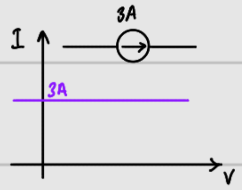
Here I-V characteristics of A & B are same.
Thus A & B are equivalent

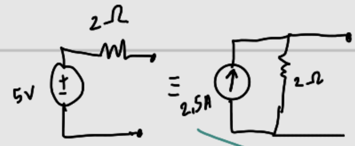
In this course, we'll deal with Linear Devices only.
These give straight line I-V characteristics

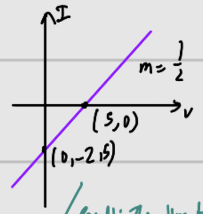




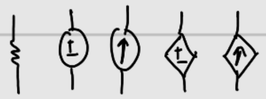






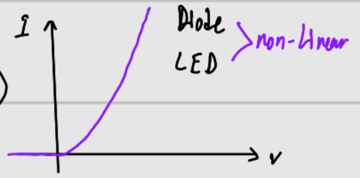


Recall: The direction is opposite of passive sign convention.



Dependent sources will also give a st. line.

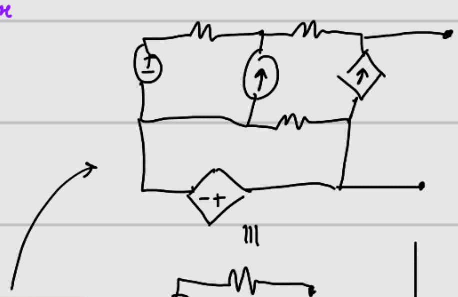
Not necessarily a positive slope every time



Diode
LED
non-Linear

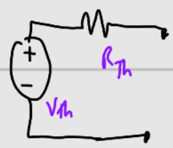
CSE251

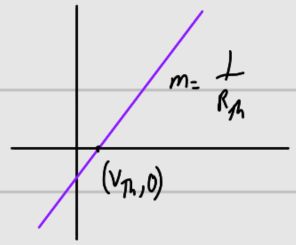
Logic gates are made using non-Linear circuits



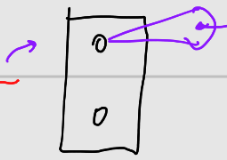
Thevenin's Theorem

According to Thevenin any complicated (Linear) circuit can be reduced and be equivalent to a volage source and a resistor in series



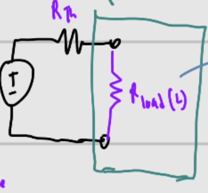


[Practically]
Socket Testing



Lights up for the terminal

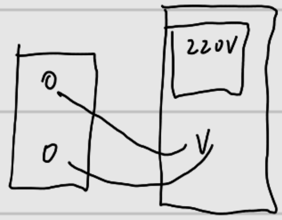
whole system/country equivalent



wastage power

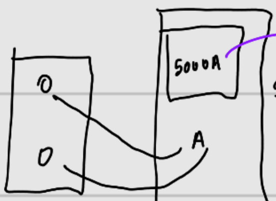
(Recall: Load shedding)

→ house



multimeter

$V_{Th} = 220V$
$= V_{open\ circuit}$



Dangerous. Don't try at home

$I = 5000A$ short circuit

$\therefore R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{220V}{5000} = 0.044\ \Omega$

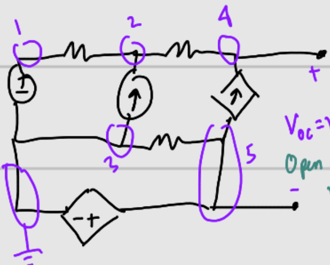
very small

This is not the resistance of the house but of the whole system (eg. whole BD)

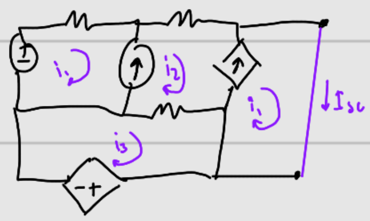
There is no open circuit current, no short circuit voltage

Voltmeter works in open circuit mode

Ammeter works in short circuit mode



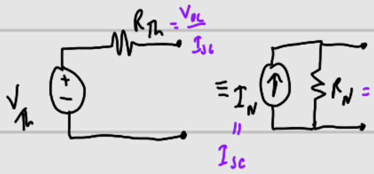
$V_{oc} = V_4 - V_c$
Open circuit to find V_{Th}

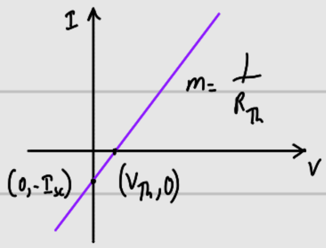


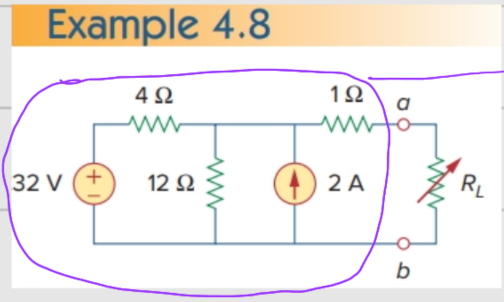
$V_{Th} = V_{oc}$

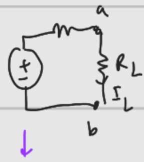
$R_{Th} = \frac{V_{oc}}{I_{sc}}$

Norton's Theorem







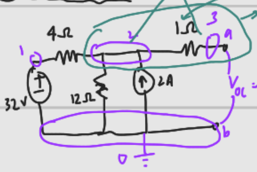


This way we don't need to do mesh analysis every time for new values of R_L

Part 1: V_{oc} / V_{Th}

same node as open circuit → no current passes

One node



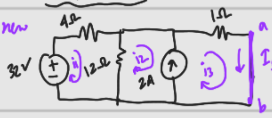
$V_{oc} = v_3 - 0 = v_3$

$$v_2\left(\frac{1}{4}+\frac{1}{12}+\frac{1}{1}\right) - \frac{32}{4} - \frac{v_3}{1} - 2 = 0$$

$V_3 = V_2$

$\therefore V_{Th} = V_{oc} = V_3 - 0 = 30V$

Part-2: I_{sc}



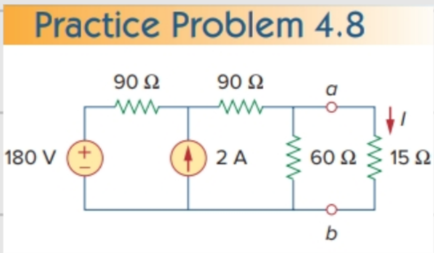
$i_3 - i_2 = 2$

$i_2(12) + i_3(1) - i_1(12) = 0$

$i_1(4+12) - 12 i_2 - 32 = 0$

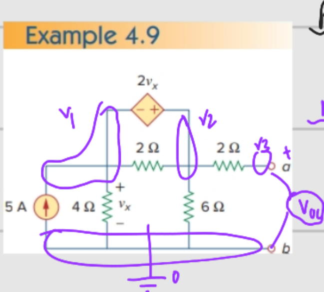
$\therefore I_{sc} = i_3 = 7.5A$

$\therefore R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{30}{7.5} = 4$



$V_{Th} = 90V,\ R_{Th} = 45\Omega$

$I = 1.5A$



Part 1: V_{oc}

$V_2 = V_3$

Node 1,2:

$V_2 - V_1 = 2V_x$

$V_x = V_1$ (Node 1,2)

$\therefore V_2 - V_1 = 2V_1$

$3V_1 = V_2$

$\therefore$ solving these eqn

$v_1 = 6.67$ V

$v_2 = 20V$

L-12

Superode 1,2

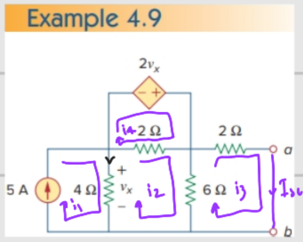
$$v_1\left(\frac{1}{4}+\frac{1}{2}\right) - \frac{0}{4} - \frac{v_2}{2} - 5 + v_2\left(\frac{1}{2}+\frac{1}{6}+\frac{1}{2}\right) - \frac{v_1}{2} - \frac{v_3}{2} = 0$$

no need. As common in supernode

Node 3 $\quad v_3\left(\frac{1}{2}\right) - \frac{v_2}{2} = 0$

$v_3 = 20V$

$\therefore V_{oc} = V_3 - 0 = 20V = V_{Th}$



$I_{sc} = i_3$

Step 1: 4 meshes. No supermesh

Step 2: mesh 1: $i_1 = 5$

Step 3/4:

mesh 2: $i_2(4+2+6) - 4i_1 - 2i_4 - 6i_3 = 0$

mesh 3: $i_3(6+2) - 6(i_2) = 0$

mesh 4: $i_4(2) - 2(i_2) - 2V_x = 0$

$V_x = (i_1 - i_2) \times 4$

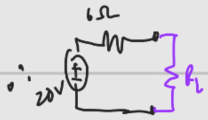
$i_1 = 5A,\ i_2 = 4.44A,\ i_3 = 3.33A,\ i_4 = 6.67A$

$\therefore R_{Th} = \frac{V_{oc}}{I_{sc}} = \frac{20}{3.33} = 6\Omega$

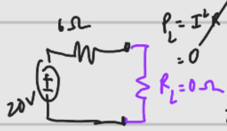
$\therefore$

Maximum Power Transfer Theorem

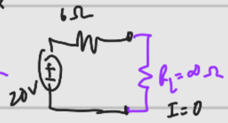
$\therefore$



happens when $\boxed{R_L = R_{Th}}$

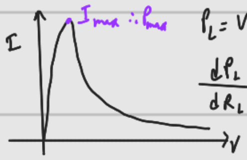


$P_L = I^2 R$
$= 0$
0



$$\boxed{P_L = V_L I_L \qquad I_L = \frac{V_{Th}}{R_{Th}+R_L} \qquad V_L = V_{Th} \times \frac{R_L}{R_{Th}+R_L}}$$

So max current is somewhere
In b/w $R=0$ & $R=\infty$
This is when $R_L = R_{Th}$



$P_L = V_L I_L$

$\frac{dP_L}{dR_L} = 0 \quad \left(\frac{dy}{dx} = 0\right)$

$\therefore R_{Th} = R_L$

12/01/2025

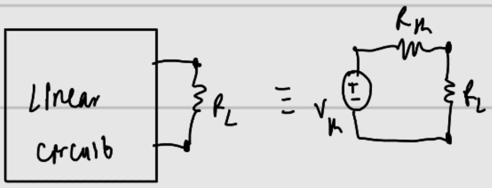
Sunday

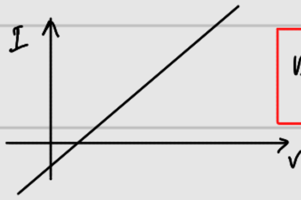
L-13

Thevenin's Theorem (+ Norton's Theorem)

In real life $R = 0\,\Omega$ and $R = -ve\ \Omega$ is not possible

We are able to do equivalent circuit of complicated circuit because they are Linear and have same characteristic eqn



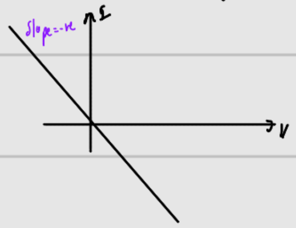


$$\boxed{V_{Th} = V_{open\ circuit},\ R_{Th} = \frac{V_{oc}}{I_{sc}}}$$

Maximum Power Transfer Condition

$R_{Th} = R_L$

R_{Th} can be negative



$P = I^2 R = \frac{V^2}{R}$

$= (+ve)(+ve) = \frac{(+ve)}{(+ve)}$

$= (+ve)$

(Power consuming)

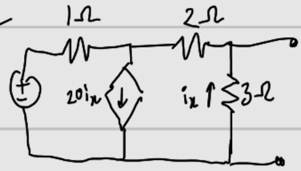
$= (+ve)(-ve) = \frac{(+ve)}{(-ve)}$

$= (-ve)$

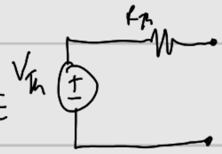
(Power supplying)

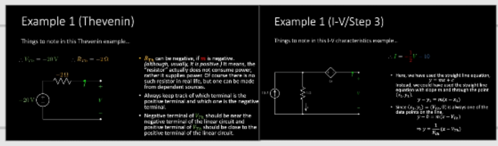
Thevenin's Eqn

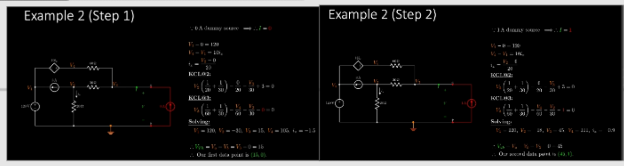
with −ve R_{Th}

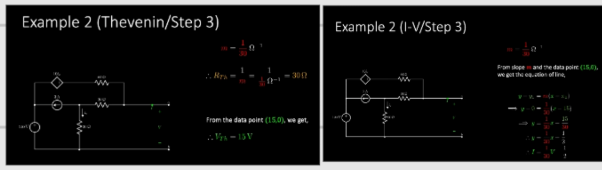


$\equiv$

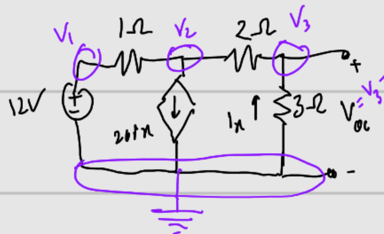








Part 1: V_{oc}



Step 1: ground + 3 nodes. No supernode

Step 2: $V_1 - 0 = 12 \Rightarrow V_1 = 12$ [Node 1]

Step 3: $V_2\left(\frac{1}{1}+\frac{1}{2}\right) - \frac{V_1}{1} - \frac{V_3}{2} + 20(i_x) = $; $i_x = \frac{(0-V_3)}{3}$

$-\frac{V_1}{1} + V_2\left(\frac{1}{1}+\frac{1}{2}\right) - V_3\left(\frac{1}{2}+\frac{20}{3}\right) = 0$ [Node 2]

$V_3\left(\frac{1}{2}+\frac{1}{3}\right) - \frac{V_2}{2} - \frac{0}{3} = 0$ [Node 3]

Solving them:

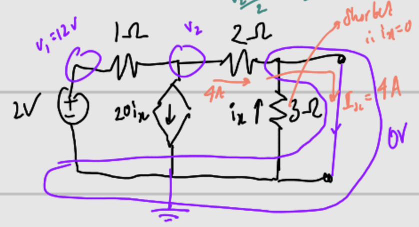
$V_1 = 12V$

$V_2 = -4.286V$

$V_3 = -2.571V$

$V_{oc} = -2.571V$

Part 2: I_{sc}

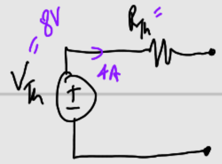


$V_2\left(\frac{1}{1}+\frac{1}{2}\right) - \frac{V_1}{1} - \frac{0}{2} + 20 \times i_x = 0$; $V_1 = 12V$, $i_x = 0$

$V_2 \times 1.5 = 12$

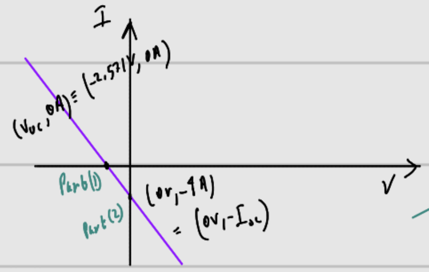
$V_2 = \frac{4 \times 2}{3} \cdot \frac{12}{1} = 8V$

$\boxed{R_{Th} = \frac{V_{oc}}{I_{sc}}}$

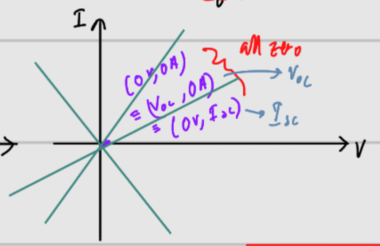


$= \frac{-2.571V}{4A} = -0.643\ \Omega$

negative resistance



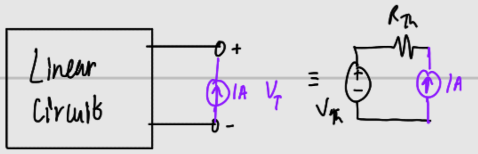
Edge Case



$\boxed{R_{th} = \frac{V_{oc}}{I_{sc}} = \frac{0}{0}}$

When we get V_{oc} or I_{sc} zero, the other will definitely be zero. So use another data point

Better use 1A. Easy to calculate



Part 1: V_{oc}

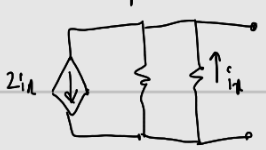
$V_{oc} = 0V$?

Yes → Test voltage / current source (1A / 1mA)

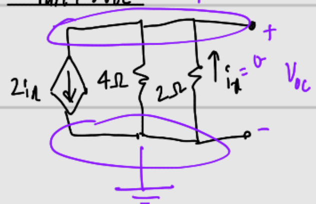
No → I_{sc}

$\boxed{V \times A = W}$

Example 4.10



Part 1: V_{oc}



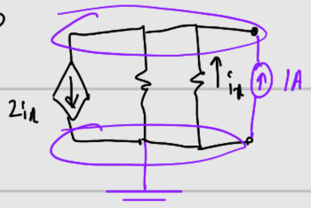
$V_1\left(\frac{1}{4}+\frac{1}{2}\right) + 2\left(\frac{-V_1}{2}\right) = 0$

$V_1(\ldots) = 0$

$V_1 = 0V$

$V_{oc} = 0V$

Part 2: Test Source



$V_1\left(\frac{1}{4}+\frac{1}{2}\right) + 2\left(\frac{-V_1}{2}\right) - 1 = 0$

$V_1 = 4V$

$V_T = V_1 - 0 = -4V$

$R_{th} = \frac{V_T}{1A} = \frac{-4}{1} = -4\ \Omega$

13/01/2025

Monday

Superposition Theorem → Only with Linear elements — L-14

Tools

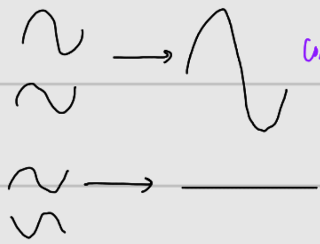
Nodal Analysis,
Mesh Analysis,
Source Transformation

→ Thevenin, Superposition

Transient Analysis, AC Analysis

Capacitor, Inductor

\# In waves!



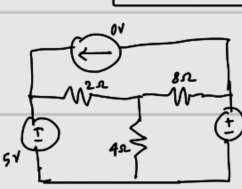
Constructive Superposition

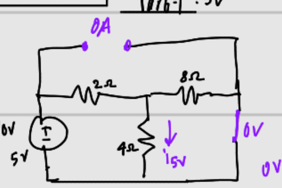
Destructive Superposition

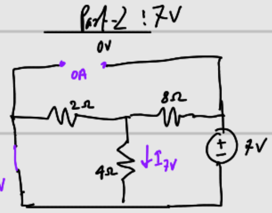
Part 1: 5V

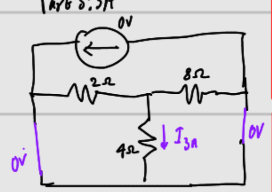
Part 2: 7V

Part 3: 3A









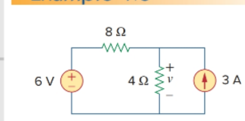
Superposition is really impt when using AC source. Sources might have different frequency

\# Fact: USA, Canada uses 60Hz, UK uses 50Hz

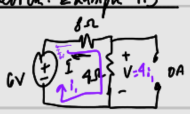
How to Kill
- ↳ Current source → Open
- ↳ Voltage source → Short

Chapter 4.3: Superposition Theorem. Example 4.3

Example 4.3



Part 1: 6V



$i_1(8+4)-6=0$

$i_1 = 0.5A$

$I_{6V} = -I_1 = -0.5A$

$V_{6V} = 4i_1 = (4\times0.5)v = 2V$

Do not kill the Dependent Sources

Part 2: 3A

$I_{3A} = 3A \times \frac{4}{4+8} = 3A \times \frac{4}{12} = 1A$

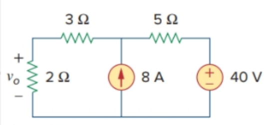
$V_{3A} = 2A \times 4\Omega = 8V$

Using Superposition Theorem,

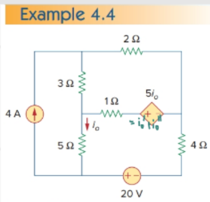
$V = V_{6V} + V_{3A} = 2V + 8V = 10V$

$I = I_{6V} + I_{3A} = -0.5 + 1 = 0.5A$

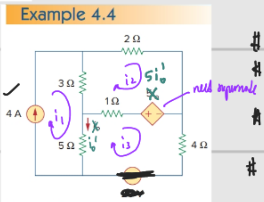
Practice Problem 4.3



Example 4.4



Example 4.4



$i_1 = 4A$ (mesh 1)

$i_2(3+2+1) - i_3 - 3i_1 - 5i_0' = 0$ (mesh 2)

$i_0' = i_1 - i_3$ $\quad -5(i_1-i_2)$

$i_3(5+1+4) - 5i_1 - i_2 + 5i_0 = 0$ (mesh 3) $\quad 5(i_1-i_2)$

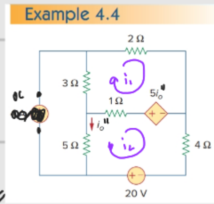
$i_1 = 4A$

$i_2 = 4.706A$

$i_3 = 0.941A$

$\therefore i_0 = 4 - 0.941 = 3.059A$

Example 4.4



$i_0'' = -i_2$ $\quad -5(-i_2)$

$i_1(3+2+1) - i_2 - 5i_0'' = 0$ (mesh 1)

$i_2(5+1+4) - i_1 + 5(-i_2) - 20 = 0$ (mesh 2)

$i_1 = -2.353A$

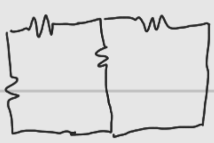
$i_2 = 3.534A$

$i_0'' = -i_2 = -3.534A$

$i_0 = i_0' + i_0''$

$= 3.06A + (-3.534)A$

$i_0 = -0.47A$



Q) What is the node voltage?

= no voltage, no current flow so no node voltage

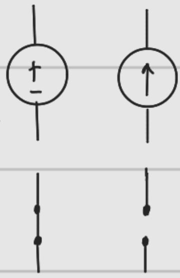
As no independent source.

=0 so dependent source behaves like resistor

Summary

• kill only Independent Source

• How to kill:



Superposition Theorem can be applied to find

↳ Voltage ✓

↳ Current ✓

↳ Power ✗

$P \neq P_{4A} + P_{20V}$

$I^2 \neq I_{4A}^2 + I_{20V}^2$

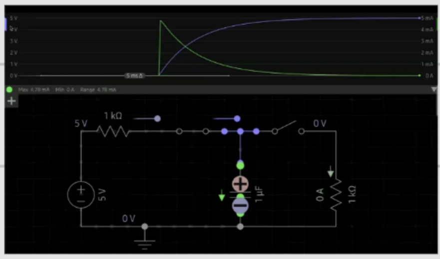
$(I_{4A} + I_{20V})^2 \neq I_{4A}^2 + I_{20V}^2$

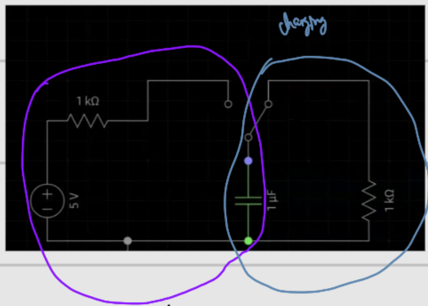
Online class

RC Circuit Intuition

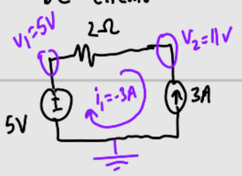
20/12/2024

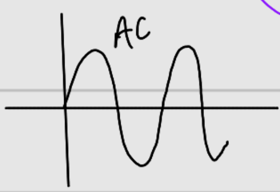
Friday

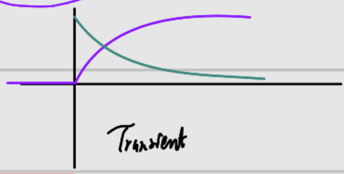




DC Circuit



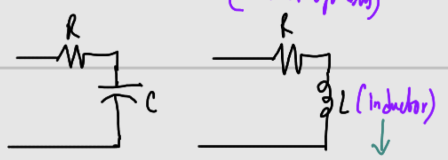




A lot of transient circuit is used inside RAM

Infact every bit is a transient circuit: resistance & capacitance circuit.

(out of syllabus)



RC Circuit $\quad$ RL Circuit

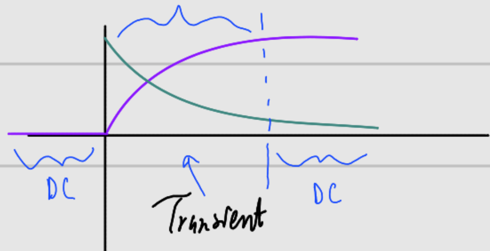
• Power hungry

• Requires high maintenance

↳ Speed at which CPU can work, is determined by the values of R and C.

* 5G Hz → One of the fastest in today's time

5RC → To fully charge & discharge a capacitor



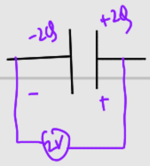
$5RC = 5 \times 1k\Omega \times 1\mu F$

$= 15\,ms$

To fully charge & discharge 1uF

Capacitor

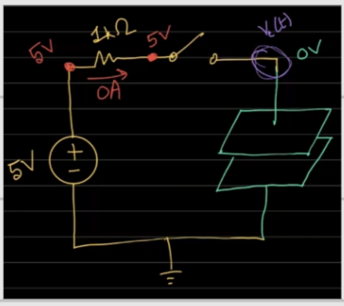
two metal plates



$Q = CV$

Capacitor wants to be an open circuit but takes time to open. This time is transient behaviour

↳ Capacitor finally becomes open
↳ Capacitor's voltage always changes gradually



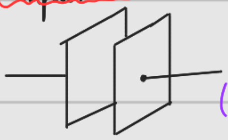
L-15

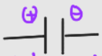
14/01/2025
Tuesday

↳ DC Analysis
↳ Transient Analysis — Capacitor, Inductor
↳ AC Analysis

Transient → Temporary

Capacitor





(finally becomes open)

$V = RI$

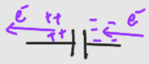
resistor resists current

$Q = CV$

$\Rightarrow \frac{dQ}{dt} = C\frac{dV}{dt}$

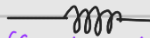
$I = C\frac{dV}{dt}$

capacitor resists the change in voltage



C [F or μF]

Inductor



(finally becomes short circuit)

SI Unit: H (Henry)

*** Whenever current through Inductor is changed, a voltage difference is created

Here $V \propto \frac{dI}{dt}$

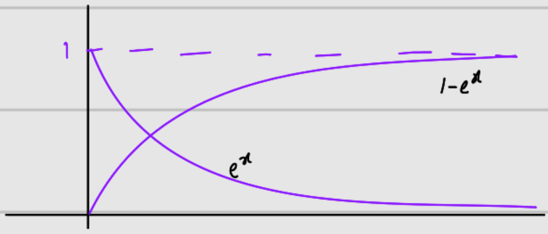
$V = L\frac{dI}{dt}$

Inductance resists change in current

$\tau = \frac{L}{R}$ $\quad 1s = \frac{1H}{1\Omega}$

*** Inductor tries to hold current and Capacitor tries to hold voltage

*** Capacitor basically works like a battery. When we charge a battery, it charges quick in the beginning, but slows down when close to 95% - 100%.



$V(t) = (V_f - V_i)(1 - e^{-t}) + V_i$

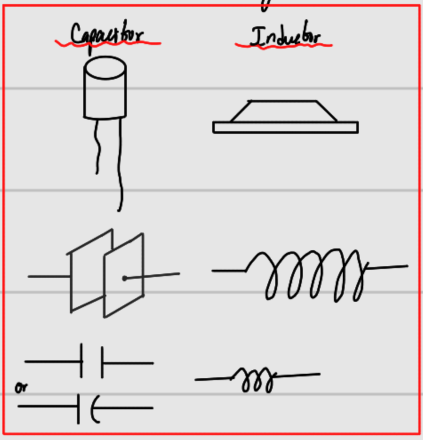
$\tau = RC$

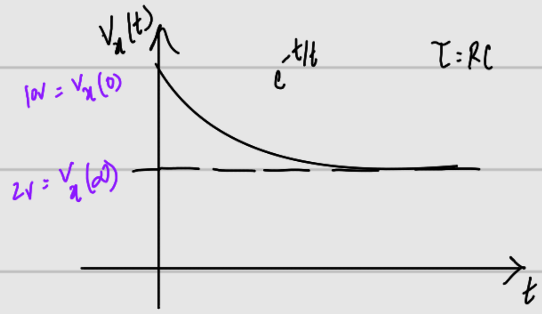
$\therefore V(t) = (V_f - V_i)(1 - e^{-t/\tau}) + V_i$

$I(t) = (I_f - I_i)(1 - e^{-t/\tau}) + I_i$

Transient Analysis

L-16





$\tau = RC$

Chapter 7: First-Order Circuits

RC / RL ~~RLC~~

Practice Problem 7.1 Refer to the circuit in Fig. 7.7. Let $v_C(0) = 60$ V. Determine v_C, v_x, and i_o for $t \geq 0$.

Answer: $60e^{-0.25t}$ V, $20e^{-0.25t}$ V, $-5e^{-0.25t}$ A.

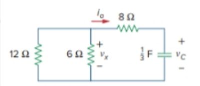
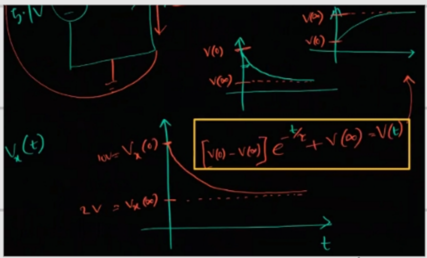
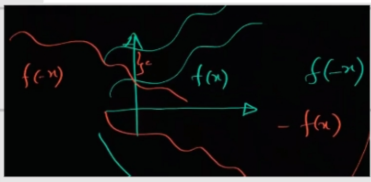


Figure 7.7 For Practice Prob. 7.1.

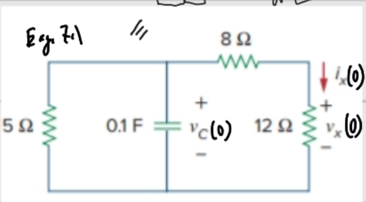




$V_c(t) = V_c(\infty) + [V_c(0) - V_c(\infty)]e^{-t/\tau}$

$i_x(t) = i_x(\infty) + [i_x(0) - i_x(\infty)]e^{-t/\tau}$

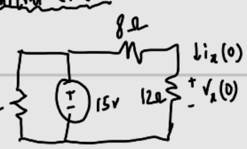
$V_x(t) = V_x(\infty) + [V_x(0) - V_x(\infty)]e^{-t/\tau}$



In this circuit, let $V_c(0) = 15V$

Find V_c, V_x, i_x

Initial Circuit

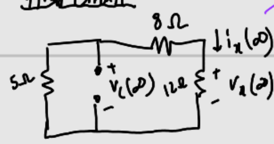


$\# V_c(0) = 15V$

$i_x(0) = \frac{15V}{8+12} = 0.75A$

$V_x = 12 \times i_x(0) = 12 \times \frac{3}{4} = 9V$

Final Circuit



$V_c(\infty) = 0V$

$i_x(\infty) = 0A$

$V_x(\infty) = 0V$

after infinite time

Complete Eqn

$V_c(t) = [V_c(0) - V(\infty)]e^{-t/\tau} + V_c(\infty)$

$= [15 - 0]e^{-t/0.4} + 0$

$= 15e^{-t/0.4}$ V

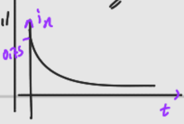
$= 15e^{-2.5t}$ V

$\tau = RC$
$= 4 \times 0.1$
$= 0.4s$

$i_x(t) = [i_x(0) - i_x(\infty)]e^{-t/\tau} + i_x(\infty)$

$= [0.75 - 0]e^{-t/0.4} + 0$ A

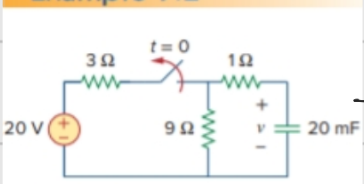
$= 0.75e^{-2.5t}$ A



$V_x(t) = V_x(\infty) + [V_x(0) - V_x(\infty)]e^{-t/\tau}$

$= 9e^{-2.5t}$ V

Example 7.2



As closed initially
$V(0) = 15V$

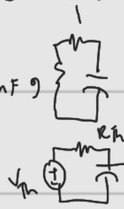
replace capacitor / inductor with proper element

$$\boxed{\begin{array}{l} \text{Initial Circuit} \rightarrow x(0) \rightarrow \text{actually } x(0^-) \\ \text{Intermediate Situation} \rightarrow \tau = R_{Th}C \,/\, \frac{L}{R_{Th}} \\ \text{Final Circuit} \rightarrow x(\infty) \\ x(t) = [x(0) - x(\infty)]e^{-\frac{t-0}{\tau}} + x(\infty) \end{array}}$$

Initial Circuit

$-\infty < t < 0$

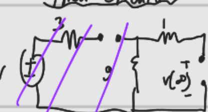
Intermediate Circuit



$\therefore \tau = R_{Th} \times C = 10 \times 20 \times 10^{-3}$

$= 0.2s$

Final Circuit



$v(\infty) = 0V$

Eqn: $v(t) = 0 + [15 - 0]e^{-t/0.2} + 0$

$= 15e^{-5t}$ V

L-17

$$\boxed{\begin{array}{l} \text{Capacitor stores energy as electrical energy} \rightarrow \text{Electrostatic energy} \\ \text{Inductor stores energy magnetically.} \rightarrow \text{Magnetic energy} \end{array}}$$

Energy stored initially $= \frac{1}{2}CV(0^-)^2$

(Capacitor) $\boxed{\frac{1}{2}CV^2}$

$= \frac{1}{2} \times 20mF \times (15V)^2$

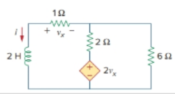
$= 2.25J$

Energy stored $= \frac{1}{2}LI^2$

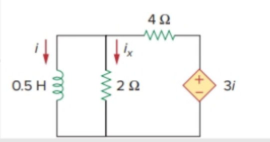
(Inductor) $\boxed{\frac{1}{2}LI^2}$

Find i and v_x in the circuit of Fig. 7.15. Let $i(0) = 7$ A. **Practice Problem 7.3**

Answer: $7e^{-2t}$ A, $-7e^{-2t}$ V, $t > 0$.



Example 7.3



$i(0) = 10A$

Find $i(t)$ & $i_x(t)$

initial:

$i_2 = -10A$

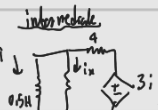
$i_1(2+4) - 2i_2 + 30 = 0$

$i_1 = -\frac{20+30}{6} = \frac{-50}{6} = -8.33$

$i_x(0^-) = i_2 - i_1 = (-10) - (-8.33)$

$= i_x(0) = 1.67A$

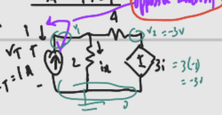
intermediate



$\tau = \frac{L}{R_{Th}}$

V_{oc}:

$R_{Th} = V_T / I_T$ (opposite direction)



$V_1\left[\frac{1}{2} + \frac{1}{4}\right] - \frac{0}{2} - \frac{(-3)}{4} - 1 = 0$

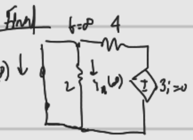
$V_1 = 0.33 = V_T$

$R_{Th} = \frac{V_T}{I_T} = \frac{0.5}{0.33} = 1.5$

$\tau = \frac{L}{R_{Th}} = \frac{0.5}{0.33} = 1.5s$

Final

$t \to \infty$



$i(\infty) = 0A$ $i_x(\infty) = 0A$

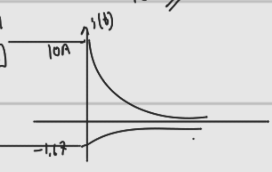
[No Independent source]

Eqn: $i(t) = [i(0) - i(\infty)]e^{-t/\tau} + i(\infty)$

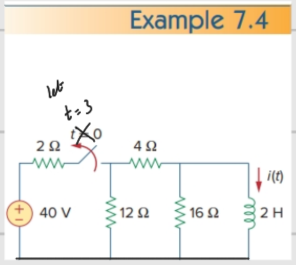
$= [10 - 0]e^{-t/\tau} = 10e^{-t/1.5}$

$i_x(t) = [(-1.67) - 0]e^{-t/1.5} + 0$

$= -1.67e^{-t/1.5}$



Example 7.4



Initially

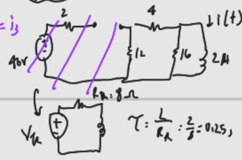
$i_1(2+12) - 12i_2 - 40 = 0$

$i_2\ 4+12+16 - 12i_1 - 16i_3 = 0$

$i_3(16) - i_2(16) = 0\ (i_2 = i_3)$

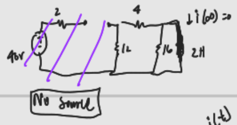
$i_3 = 6A$ $\quad i(3^-) = 6A$ //

Intermediate



$\tau = \frac{L}{R_{th}} = \frac{2}{8} = 0.25,$

final

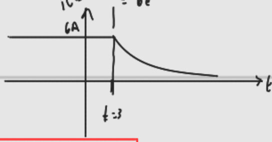


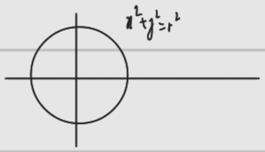
$\not{\text{E}}$

$i(t) = \left[i(3^-) - i(\infty)\right] e^{-\frac{(t-3)}{\tau}} + i(\infty)$

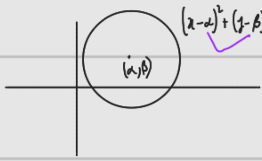
$= \left[6 - 0\right] e^{-\frac{t-3}{0.25}} + 0$

$i(t) = 6e^{-4(t-3)}$



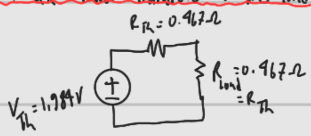


$x^2 + y^2 = r^2$



$(x-\alpha)^2 + (y-\beta)^2 = r^2$ //

Max^m Power Transferred to the load → when $R_L = R_{Th}$



$$\boxed{P = \left(\frac{V_{Th}}{2R_{Th}}\right)^2 \times R_{Th} = \frac{V_{Th}^2}{4R_{Th}}}$$

L-18

$1, 2, 3, 4, \ldots \rightarrow \mathbb{N}$ (Natural numbers)

$\ldots -2, -1, 0, 1, 2, 3 \ldots \rightarrow \mathbb{Z}$ (Whole numbers)

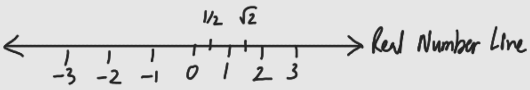
$\ldots -\frac{8}{3}, 0, \frac{1}{2}, \frac{4}{2} \ldots \rightarrow \mathbb{Q}$ (rational numbers)

$\ldots -\frac{1}{\sqrt{2}}, 0, \sqrt{2}, \sqrt[3]{3}, \pi, e \rightarrow \mathbb{R}$ (real numbers)

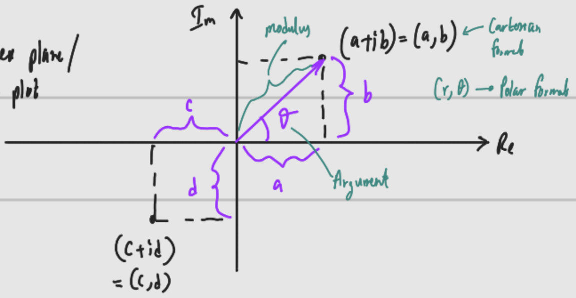
$\ldots -\sqrt{3}i, i, 2i, 2.5i \ldots \rightarrow$ Imaginary numbers

$\ldots, \sqrt{2} - \sqrt{3}i \longrightarrow \mathbb{C}$ (Complex numbers)

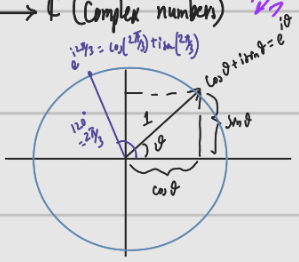
$\underbrace{a}_{\text{real part}} + \underbrace{bi}_{\text{imaginary part}}$



Complex plane / Argand plot



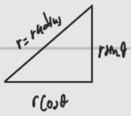
$$\boxed{e^{i\theta} = \cos\theta + i\sin\theta}$$



$|\cos\theta + i\sin\theta|$

$= \sqrt{\cos^2\theta + \sin^2\theta}$

$= 1$ //



$re^{i\theta} = r\cos\theta + ir\sin\theta$

$z = a + ib = re^{i\theta} = r\angle\theta$

$$\boxed{i^2 = -1}$$

$z_1 = r_1 e^{i\theta_1} = r_1 \angle\theta_1$

$z_2 = r_2 e^{i\theta_2} = r_2 \angle\theta_2$

$z_1 z_2 = \left(r_1 e^{i\theta_1}\right)\left(r_2 e^{i\theta_2}\right)$

$= (r_1 r_2)\, e^{i(\theta_1 + \theta_2)}$

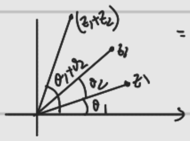
$z_1 / z_2 = r_1/r_2\, e^{i(\theta_1 - \theta_2)}$

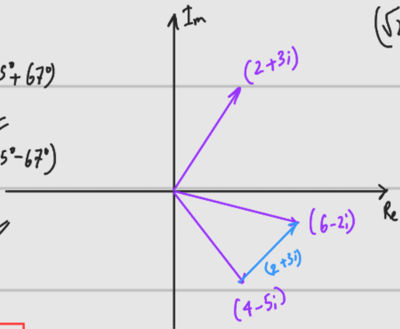
e.g. $\sqrt{2}\angle 45° \times 7\angle 67° = 7\sqrt{2}\angle(45° + 67°)$

$= 7\sqrt{2}\angle 102°$ //

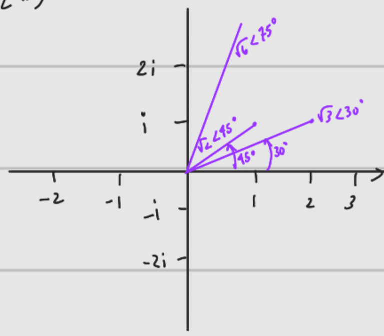
$\sqrt{2}\angle 45° \div 7\angle 67° = \frac{\sqrt{2}}{7}\angle(45° - 67°)$

$= \frac{\sqrt{2}}{7}\angle -22°$ //

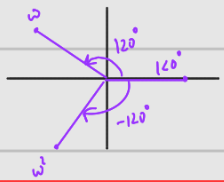




$(\sqrt{2}\angle 45°)(\sqrt{3}\angle 30°)$



$$\boxed{\begin{aligned} &\sqrt[3]{1} = \omega = 1\angle 120° \\ &\omega^3 = \omega \times \omega \times \omega \\ &= 1\angle 120° \times 1\angle 120° \times 1\angle 120° \\ &= 1\angle 360° = 1\angle 0° = 1 \end{aligned}}$$



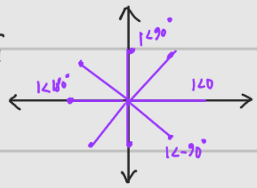
$1\angle 0°$

$1\angle 120°$

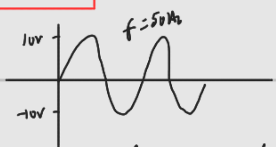
$1\angle -120°$

$-180° \angle \theta \leq 180°$

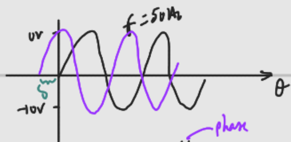
e.g. $\sqrt[3]{64}$



$$\boxed{\begin{aligned} &e^{i(A+B)} = \cos(A+B) + i\sin(A+B) \\ \text{or } &e^{iA} \cdot e^{iB} = (\cos A + i\sin A)\cdot(\cos B + i\sin B) \\ &= \cos A\cos B - \sin A\sin B + i(\cos A\sin B + \sin A\cos B) \end{aligned}}$$



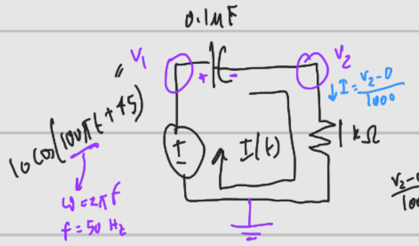
$10\sin(2\pi f t) = 10\sin(2\pi \times 50 \times t)$



$10\sin(2\pi f t + \underbrace{\delta}_{\text{phase}}) = 10\sin(2\pi \times 50 \times t + \delta)$

15/01/2025
wednesday

L-19



$I = C \frac{dv}{dt}$

$= 0.1 \times 10^{-6} \times \frac{d}{dt}(v_1 - v_2)$

$\frac{V_2 - 0}{1000} = 10^{-7} \frac{d}{dt}(v_1 - v_2)$

$10^{-7} \frac{d}{dt} v_1 - 10^{-7} \frac{d}{dt} v_2 = \frac{v_2}{100}$

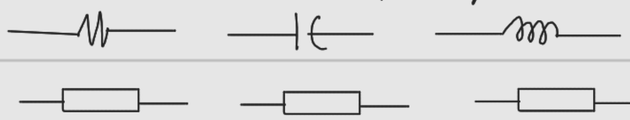
$10^{-7}(10\cos(100\pi t + 45)) - 10^{-7} \frac{dv_2}{dt} = \frac{v_2}{100}$

⋮

Difficult approach

Quarternion
$a + ib + jc + kd$
• higher dimension

Impedance, Z (Ω): In AC analysis capacitor, resistor, inductor produces impedance. They work like complex resistor.



→ All 3 treated the same

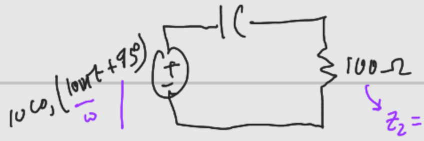
$Z = R = R\angle 0°$

$Z = \frac{1}{j\omega C} = \frac{-j}{\omega C} = \frac{1}{\omega C}\angle -90°$

$Z = j\omega L = \omega L\angle 90°$

$j: \angle 90°$

* shift → 2: CMPLX
* Shift + mode
* 3: Deg
* go down
* +3: Complex
* Complex result?
1: a+bi 2: r∠θ ✓

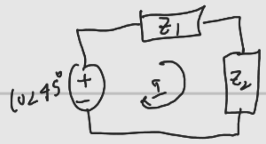


$0.1\mu F \rightarrow Z_1 = \frac{1}{\omega C}\angle -90° = \frac{1\angle -90°}{100\pi \times 0.1 \times 10^{-6}}$

$= \frac{10^5}{\pi}\angle -90°$ Ω

$Z_2 = 100\angle 0°$ Ω

phasor form



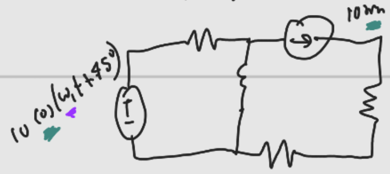
$I = \frac{V}{Z_1 + Z_2} = \frac{10\angle 45°}{\frac{10^5}{\pi}\angle -90° + 1000\angle 0°}$ A

$= 3.14 \times 10^{-4}\angle 133.2°$ A

$= 0.314\angle 133.2°$ mA (Complex format)

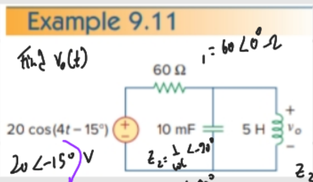
$I(t) = 0.314\cos(100\pi t + 133.2°)$ mA

When frequency is different we've to do superposition



$= -10\cos(\omega t + 45 - 90)$
$= -10\cos(\omega t - 45°)$
$\downarrow$ $10\angle -45°$

$\sin(\theta + 90°) = -\cos\theta$
$\cos\theta = \sin(90° - \theta)$



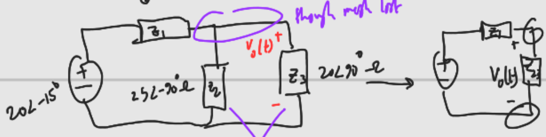
$Z_1 = 60\angle 0°$ Ω

$20\angle -15°$ V, $\omega = 4$

$Z_2 = \frac{1}{\omega C}\angle -90° = \frac{1\angle -90°}{4 \times 10 \times 10^{-3}} = 25\angle -90°$ Ω

$Z_3 = \omega L\angle 90° = 4 \times 5\angle 90° = 20\angle 90°$ Ω

* Phasor (Impedance) circuit
* DC-like Calculation



The node is not lost though most lost

parallel (like resistor)

$Z_{23} = \frac{Z_2 \cdot Z_3}{Z_2 + Z_3} = \frac{25\angle -90° \cdot 20\angle 90°}{25\angle -90° + 20\angle 90°}$

$= 100\angle 90°$ Ω

$V_o(t) = V \times \frac{Z_{23}}{Z_1 + Z_{23}} = 20\angle -15 \times \frac{100\angle 90°}{60\angle 0° + 100\angle 90°}$

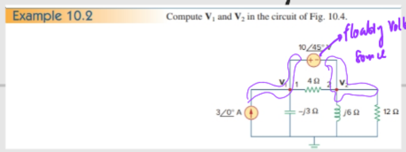
$= 17.14\angle 15.96°$

$V_o(t) = 17.14\cos(4t + 15.96)$ V

AC Analysis

Chapter 10: Sinusoidal Steady State Analysis

L-20



$r_1\angle\theta_1 \times r_2\angle\theta_2 = r_1 r_2\angle(\theta_1 + \theta_2)$

$V_1 - V_2 = 10\angle 45°$ Supernode @ 1&2

$v_1\left(\frac{1}{4} + \frac{1}{3\angle -90°}\right) - \frac{V_2}{4} - \frac{0}{3\angle -90°} - 3\angle 0° + V_2\left(\frac{1}{4} + \frac{1}{6\angle 90°} + \frac{1}{12}\right) - \frac{V_1}{4} = 0$ ... $V_2 = 31.72\angle -86.7°$

$V_1 = V_2 + 10\angle 45° = 26.2\angle -69.7°$

$V_1 + 0.33\angle 90° + V_2 + 0.186\angle -63.4° = 3\angle 0°$

can't solve in calculator (casio). So solve without

OR

$a_1 x + b_1 y = c_1$
$a_2 x + b_2 y = c_2$

$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}}$ $y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}}$

$V_1 + 0.33\angle 90° + V_2 + 0.186\angle -63.4° = 3\angle 0°$

$V_1 - V_2 = 10\angle 45°$

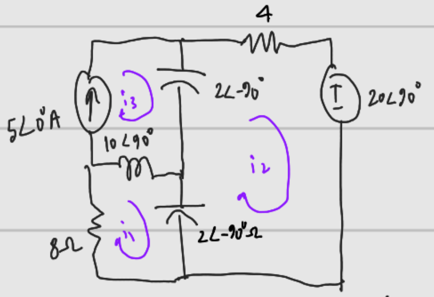
$V_1 = \frac{\begin{vmatrix} 10\angle 45° & -1 \\ 3\angle 0° & 0.186 \end{vmatrix}}{\begin{vmatrix} 1 & -1 \\ 0.33\angle 90° & 0.186\angle -63.4 \end{vmatrix}} = \frac{10\angle 45° \times 0.186\angle -63.4° - 3\angle 0° \times (-1)}{1 \times 0.186\angle -63.4° - (-1) \times 0.33\angle 90°}$

$= 26.14\angle -70°$

$a_1 x + b_1 y + c_1 z = d_1$
$a_2 x + b_2 y + c_2 z = d_2$
$a_3 x + b_3 y + c_3 z = d_3$

$y = \frac{\begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}$

$\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} = a_1(b_2 c_3 - b_3 c_2) - b_1(a_2 c_3 - a_3 c_2) + c_1(a_2 b_3 - a_3 b_2)$



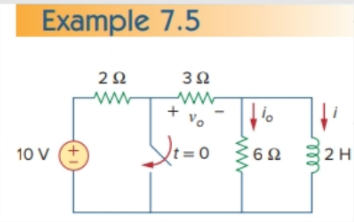
$i_3 = 5\angle 0^\circ$ [mesh 3]

$i_1(8+10\angle 90^\circ + 2\angle -90^\circ) - i_3(10\angle 90^\circ) - i_2(2\angle -90^\circ) = 0$

$i_2(4+2\angle -90^\circ + 2\angle -90^\circ) - i_1(2\angle -90^\circ) - i_3(2\angle -90^\circ) + 20\angle 90 = 0$

⋮

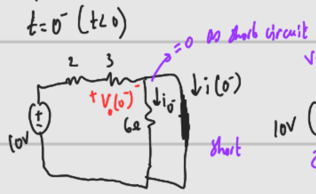
Example 7.5



$i(t) = [i(0^+) - i(\infty)]e^{-\frac{t}{\tau}} + i(\infty)$

$i(0^-) = i(0^+) \rightarrow$ same for Inductor

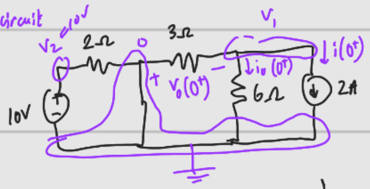
$t = 0^-$ $(t<0)$



$i_o(0^-) = 0A$

$i(0^-) = \frac{10}{2+3} = 2A$

$V_o(0^-) = 10 \times \frac{3}{2+3} = 6V$



$V_1\left(\frac{1}{6}+\frac{1}{3}\right) - \frac{0}{6} - \frac{0}{3} + 2 = 0$

$V_1 = \frac{-2}{1/6+1/3} = -4$

$V_o(0^+) = 0 - V_1 = 4V$, $i_o(0^+) = \frac{V_1}{6\Omega} = -0.67A$

$i_o(\infty) = 0A$

$\tau = 1s$

$i(t) = [i_o(0^+) - i_o(\infty)]e^{-\frac{t}{\tau}} + i_o(\infty)$

$= [-0.67 - 0]e^{-t} + 0$

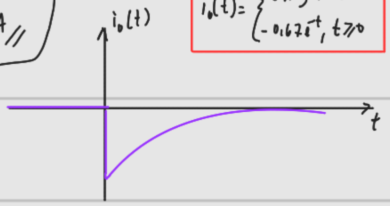
$= -0.67e^{-t}$ A

$i_o(0^-) = 0A$ $(t<0)$

$i_o(0^+) = -0.67A$ $(t=0^+)$

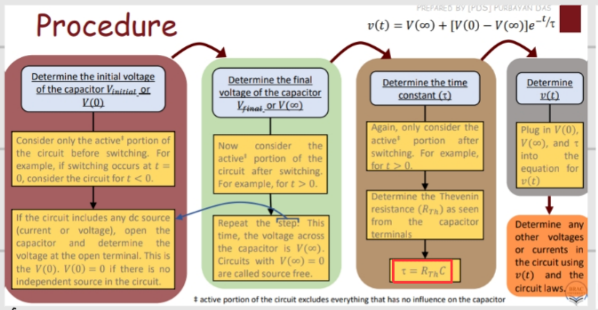
$i_o(\infty) = 0A$

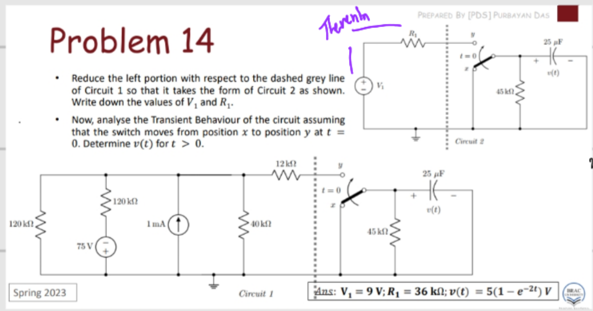
$\boxed{i_o(t) = \begin{cases} 0A; & t<0 \\ -0.67e^{-t}, & t\geq 0 \end{cases}}$

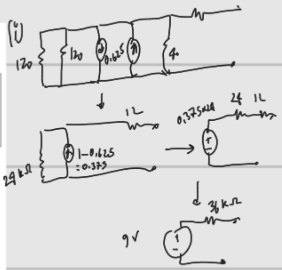


[SDS] YT

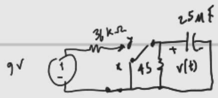
Transient Analysis Problem Solving



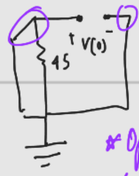




(ii)



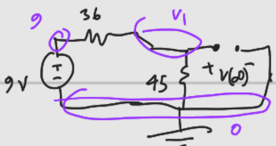
1] Initial Circuit $\xrightarrow{\text{capacitor open}}$ $V_c(0)$



$\therefore v(0) = 0V$

* Open the circuit and find the voltage across it

2] Final circuit $\xrightarrow{\text{Capacitor Open}}$ $v(\infty)$



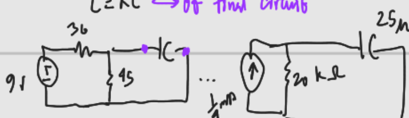
KCL@1: $V_1\left(\frac{1}{36}+\frac{1}{45}\right) - \frac{9}{36} = 0$

$V_1 = 5V$

$\therefore V_\infty = 5V$

3] Time Constant τ:

$\tau = RC \rightarrow$ of final circuit



$\boxed{\tau = R_{Th} \times C} = 20k\Omega \times 25mF = 0.5s$

$\boxed{\text{Full charge: } 5\tau} = 5 \times 0.5 = 2.5s$

4] $\boxed{v(t) = \begin{cases} v(0); & t<0 \\ v(\infty) + [v(0) - v(\infty)]e^{-t/\tau}; & t\geq 0 \end{cases}}$

$v(t) = \begin{cases} 0V; & t<0 \\ 5+[0-5]e^{-t/0.5} V; & t\geq 0 \\ = 5-5e^{-2t}; & t\geq 0 \end{cases}$

when $t = 5\tau$

$e^{-\frac{5\tau}{\tau}} = e^{-5}$

$= 0.0067$

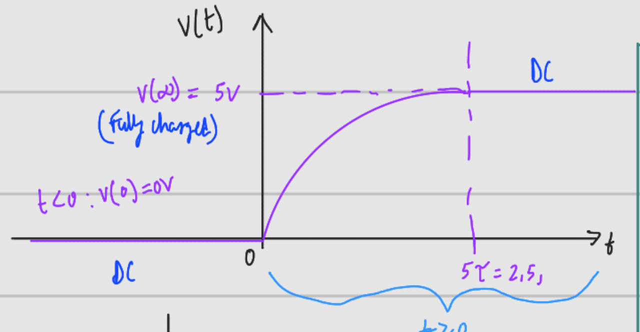
Only 0.67% error

$v(\infty) = 5-5e^{-2(\infty)} = 5V$

$v(1) = 5-5e^{-2(1)} = 4.323$ V

$v(2.5) = 4.966V \approx 99.3\%$

(almost 5)



$P(t) = v(t)i(t)$

5] $I(t) = C\frac{dV}{dt}$

$\boxed{\text{Initial and final current of capacitor is always zero except for transient period. As rest of the time it acts as an open circuit when it's stable.}}$

$t<0$

$I(t) = C\frac{d}{dt}(0)$

$= 0A$

$t\geq 0$

$I(t) = C\frac{d}{dt}(5-e^{-2t})$

$= C\cancel{\frac{d}{dt}(5)} - C\frac{d}{dt}e^{-2t}$

$= -C \times 5(-2)e^{-2t}$

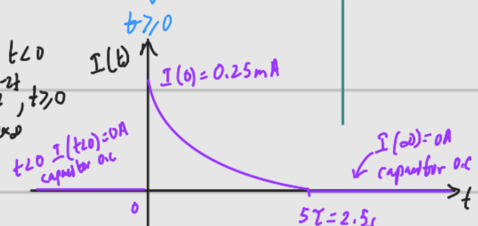
$= 10 \times 25 \times 10^{-6} e^{-2t}$ A

$= 0.25 \times 10^{-3} e^{-2t}$ A $= 0.25e^{-2t}$ mA

$I(t) = \begin{cases} 0A: & t<0 \\ 0.25e^{-2t}, & t\geq 0 \end{cases}$

$I(\infty) = 0.25e^{-2\infty}$

$= 0$



Final Review (Fall 2024)

1) Transient
2) Superposition / Source Transformation
3) I-V
4) AC Sinusoidal

→ No dependent Source
→ R_{th} by killing all sources (superposition) and find eqv resistance
→ Source Transformation

$A\sin(\omega t + \phi)$

$A > 0$ $\omega > 0$ $\boxed{-180° \le \phi \le 180°}$

$\sin\theta = \cos(90-\theta) = \cos(\theta - 90)$

$\sin(\theta + 90) = \cos\theta$, $\sin\theta$, $\sin(\theta-90)$, $\cos\alpha$

$\sin(-\theta) = -\sin\theta$

$\cos(-\theta) = \cos\theta$,

Always keep ϕ btw -180 & 180
(Add/subtract 360° when needed to adjust)

$\sin(180+\theta) = -\sin\theta$
$\cos(180+\theta) = -\cos\theta$

Problem 3

- Calculate amplitude, initial phase ($-180° \le \varphi \le 180°$), angular frequency, period, and frequency for the following sinusoids. What are the values of V_s and I_s at $t = 20\ ms$? [Both sin and cosine forms can be employed]
   - I. $V_s = 45\cos(5\pi t + 36°)\ (V)$
   - II. $I_s = 15\cos(25\pi t + 25°)\ (A)$
   - III. $I_s = -20\cos(314t - 30°)\ (A)$
   - IV. $V_s = -4\sin(628t + 55°)\ (V)$

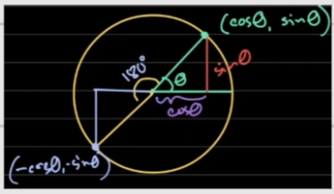
Ans: I. 45 V; 36° or 126°; $5\pi\ ^{rad}/_s$; 0.4 s; 2.5 Hz; 26.45 V
II. 15 A; 25° or 115°; $25\pi\ ^{rad}/_s$; 80 ms; 12.5 Hz; − 6.34 A
III. 20 A; 150° or 120°; $314\ ^{rad}/_s$; 20 ms; 50 Hz; − 17.29 A
IV. 4 V; − 125°; $628\ ^{rad}/_s$; 10 ms; 100 Hz; − 3.26 V

(i) $V_s = 45\cos(5\pi t + 36°)\ V$
$A = 45V$, $\omega = 45$, $\phi = 36$
OR
$V_s = 45\cos(5\pi t + 36 + 90)$
$= 45\sin(5\pi t + 126°)$
ϕ

(ii) $I_s = 15\cos(25\pi t + 25)\ A$
$A = 15A$, $\omega = 25\pi\ rad\ s^{-1}$, $\phi = 25$

(iii) $I_s = -20\cos(314t - 30°)\ A$
$= 20\cos(314t + 150)$ $[\cos(180+\theta) = -\cos\theta]$
$A = 20A$, $\omega = 314\ rad\ s^{-1}$, $\phi = 150°$
OR $I_s = 20\sin(314t + 150 + 90)$ out of range
$= 20\sin(314t + 240°)$
$= 20\sin(314t + 240 - 360)$
$= 20\sin(314t - 120°)$
$\therefore A = 20A$, $\omega = 314\ rad\ s^{-1}$, $\phi = -120°$

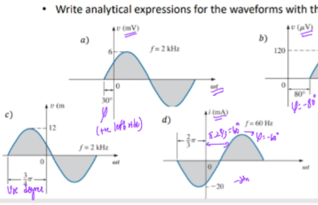
(iv) $V_s = -4\sin(628t + 55)\ V$
$= 4\sin(628t + 55 + 180)$
$= 4\sin(628t + 235 - 360)$
$= 4\sin(628t - 125°)$
$\therefore A = 4V$, $\omega = 628\ rad\ s^{-1}$, $\phi = -125°$



Problem 4

$\phi = \omega t$

- Write analytical expressions for the waveforms with the initial phase in degrees.

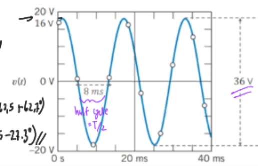


Ans:
a) $6 \times 10^{-3}\sin(2\pi 2000t + 30°)\ V$
b) $120 \times 10^{-6}\sin(2\pi 1000t - 80°)\ V$
c) $12 \times 10^{-3}\sin(2\pi 2000t + 135°)\ V$
d) $20 \times 10^{-3}\sin(2\pi 60t - 60°)\ A$

Problem 5

- The following figure shows a sinusoidal voltage $v(t)$, plotted as a function of time t. Represent $v(t)$ by a function of the form $A_m\cos(\omega t + \varphi)$ with φ in degrees.

$(0, A\sin\phi)$
$16 = 18\sin\phi$
$\phi = 62.7°$
$\therefore 18\sin(2\pi \times 62.5 + 62.7°)$
$18\cos(2\pi \times 62.5 - 27.3°)$



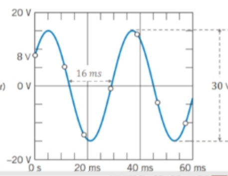
$T = 8 \times 2 = 16 \times 10^{-3}\ s$
$f = \frac{1}{T} = 62.5\ Hz$
$\omega = 2\pi f = 2\pi \times 62.5$

Ans: $v(t) = 18\cos(393t - 27°)\ V$

Problem 6

- The following figure shows a sinusoidal voltage $v(t)$, plotted as a function of time t. Represent $v(t)$ by a function of the form $A_m\sin(\omega t + \varphi)$ with φ in degrees.

$15\sin(\phi) = 8$
$\phi = 32.2°$



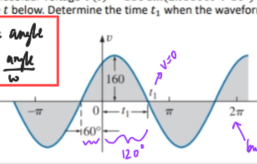
$A = \frac{30}{2} = 15V$
$T = 16 \times 2 = 32\ ms$
$f = \frac{1}{32} = 31.25\ Hz$
$\therefore 15\sin(2\pi \times 31.25 + 32°)\ V$

Ans: $v(t) = 15\sin(196t + 32°)\ V$

Problem 7

- A sinusoidal voltage $v(t) = 160\sin(2\pi 1000t + 60°)$ is plotted as a function of time t below. Determine the time t_1 when the waveform crosses the axis.

ωt = angle
$\therefore t = \frac{angle}{\omega}$



$v(t_1) = 0$
$\Rightarrow \sin(2\pi 1000t + 60°) = 0$
$T = \frac{1}{f} = \frac{1}{1000} = 1\ ms$
$360° \to 1\ ms$
$1° \to 1/360\ ms$
$\therefore 120° \to \frac{120}{360} = 0.33\ ms$

Ans: t_1 = ~~13.05 μs~~
1/3 ms

ω must be same for both

Problem 8

Consider the sinusoidal voltage $v(t) = 80\cos(1000\pi t - 30°)\ V$.

a) What is the first time after $t = 0$ that $v(t) = 80\ V$?
b) If the sinusoidal voltage is shifted $^2/_3\ ms$ to the left along the time axis, what will be the expression for $v(t)$?
c) What is the minimum number of milliseconds that the function must be shifted to the (right/left?) if the expression for $v(t)$ is $80\sin(1000\pi t)\ V$?

Ans:
(a) $t = 166.67\ \mu s$
(b) $-80\sin(1000\pi t)\ V$
(c) $t = 333.33\ \mu s$

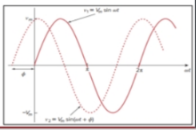
Problem 9

At $t = -2\ ms$, a sinusoidal voltage $v(t)$ is known to be zero and going positive. The voltage is next zero at $t = 8\ ms$. It is also known that the voltage is 80.9 V at $t = 0$. What is the expression fot $v(t)$?

Ans: $v(t) = 20\cos(400\pi t - 45°)\ V$

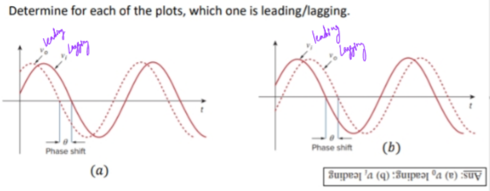
Leading and Lagging Sinusoids

- The equation for a sinusoid in more general form,
$$v(t) = V_m\sin(\omega t + \varphi)$$
where $(\omega t + \varphi)$ is the argument and φ is the initial phase. Both argument and phase can be in radians or degrees.
- Let's examine two sinusoids $v_1(t) = V_m\sin\omega t$ and $v_2(t) = V_m\sin(\omega t + \varphi)$
- The starting point of v_2 occurs first in time. Or v_2 passes the zero-crossing line first if compared between two same phase points of v_1 and v_2.
- Therefore, we say that v_2 leads v_1 by φ or that v_1 lags v_2 by φ.
- If $\varphi \ne 0$, v_1 and v_2 are out of phase.
- If $\varphi = 0$, v_1 and v_2 are in phase



Problem 10

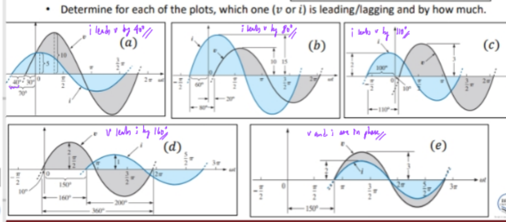
- Determine for each of the plots, which one is leading/lagging.



Ans: (a) v_2 leading; (b) v_1 leading

Problem 11

- Determine for each of the plots, which one (v or i) is leading/lagging and by how much.

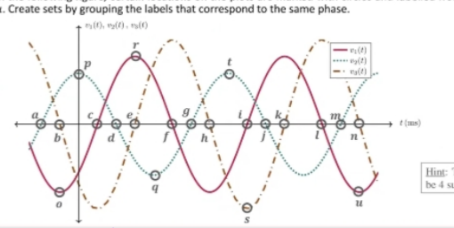


Q) Which one is leading and which one is lagging?
$V_s = 45\cos(5\pi t + 36°) = 45\sin(5\pi t + 126°)$
$I_s = 80\sin(5\pi t - 20°)$
✓ # V_s leads I_s by $(126 - (-20°)) = 146°$
✓ # I_s lags V_s by $146°$
I_s leads V_s by $(-20° - 126°) = -146°$
correct but not the convention

$-180° \le$ phase $(\phi) \le 180°$
phase difference $(\phi_A - \phi_B) \le 180°$
A leads B by $(\phi_A - \phi_B)$
>0, ≤ 180

Problem 12

- In the following figure, certain locations on the plots are marked with circles and labelled from a to u. Create sets by grouping the labels that correspond to the same phase.



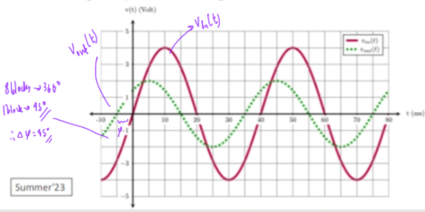
green wave
- a, g, m
- p, t
- d, j

yellow wave
- b, l, n
- e, k

red wave
- o, u
- c, i
- f, l

Problem 12

- Two ac voltages $v_{in}(t)$ and $v_{out}(t)$ from an ac circuit are plotted below. Which one is leading and by how much in degrees?



Ans: $\Delta\varphi = 45°$

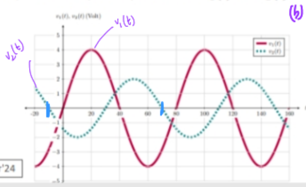
Problem 13

(a) 4 blocks → 360°, 1b → 90° ∴ 1.5b → 1.5×90 = 135° = Δφ

Two ac voltages $v_1(t)$ and $v_2(t)$ from an ac circuit are plotted below.

a) Which one is leading and by how much in degrees? → $V_1(t)$ leads $V_2(t)$ by $135°$

b) Write analytical expressions for $v_1(t)$ and $v_2(t)$.



(b) 1 b → 1000 ms, 100 ms → 1.25, ∴ 1000 ms → 12.5 cycles (f)

∴ $V_1(t) = 4\sin(2\pi \times 12.5\, t + 0)$
$= 4\sin(25\pi t)$ V

80 ms → 1 cycle, 1000 ms → $\frac{1}{80} \times 1000 = 12.5$ cycles (f)

∴ $V_2(t) = 2\sin(2\pi \times 12.5 t - 135°)$ V
$= 2\sin(25\pi t - 135°)$ V

Ans:
(a) $\Delta\varphi = 135°$
(b) $v_1(t) = 4\sin(25\pi t)$ V
$v_2(t) = 4\sin(25\pi t - 135°)$ V

Problem 17

8 block → 360, 1b → 45, ∴ 3 → 135°

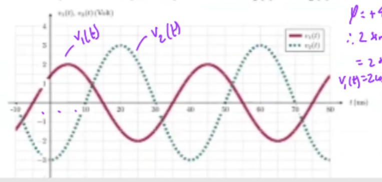
∴ (a) $V_1(t)$ leads $V_2(t)$ by $135°$

(b) 40 ms → 1 wave, 1000 ms → 25 (f)

Two ac voltages $v_1(t)$ and $v_2(t)$ from an ac circuit are plotted below.

a) Which one is leading and by how much in degrees?

b) Write analytical expressions for $v_1(t)$ and $v_2(t)$ in the format $A_m\cos(\omega t \pm \varphi)$.



$\varphi = +45°$

∴ $2\sin(2\pi \times 25 t + 45°)$
$= 2\cos(50\pi t + 45 - 90)$
$V_1(t) = 2\cos(50\pi t - 45°)$ V

40 ms → 1 w, 1000 ms → 25 (f)

φ = 2 block = $-90°$

∴ $3\sin(50\pi t - 90)$

∴ $V_2(t) = 3\cos(50\pi t - 180°)$ V

Ans:
(a) $\Delta\varphi = 135°$
(b) $v_1(t) = 2\cos(50\pi t - 45°)$ V
$v_2(t) = 3\cos(50\pi t - 180°)$ V

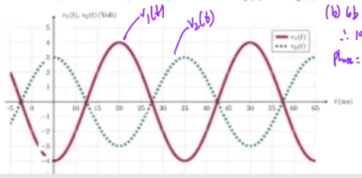
Problem 18

(a) 6b → 360°, 1b → 60°, Δφ = 3 blocks ∴ 3×60 = 180°, ∴ $V_2(t)$ leads $V_1(t)$ by 180°

Two ac voltages $v_1(t)$ and $v_2(t)$ from an ac circuit are plotted below.

a) Which one is leading and by how much in degrees?

b) Write analytical expressions for $v_1(t)$ and $v_2(t)$ in the format $A_m\sin(\omega t \pm \varphi)$.



(b) 6b = 6×5 = 30 ms → 1 wave ∴ 1000 ms → 33.3 (f)

Phase: − 1.5 block: (1.5×60) = −90

→ ∴ $V_1(t) = 4\sin(2\pi \times 33.3 - 90°)$
$= 4\sin(67\pi - 90°)$

4.5×60 = 270°

∴ $3\sin(67\pi - 270°)$

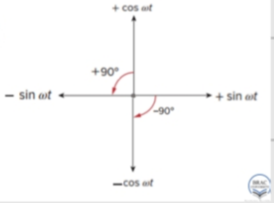
$3\sin(67\pi - 270 + 360)$

$V_2(t) = 3\sin(67\pi + 90°)$ V

Ans:
(a) $\Delta\varphi = 180°$
(b) $v_1(t) = 4\sin(57\pi t - 90°)$ V
$v_2(t) = 3\sin(57\pi t + 90°)$ V

Sine-Cosine Conversion

- A sinusoid can be expressed in either sine or cosine form. When comparing two sinusoids, it is expedient to express both as either sine or cosine with positive amplitudes.
- The following trigonometric identities can be used to convert from sine to cosine or vice versa.



- $\sin(\omega t \pm 180°) = -\sin\omega t$
- $\cos(\omega t \pm 180°) = -\cos\omega t$
- $\sin(\omega t \pm 90°) = \pm\cos\omega t$
- $\cos(\omega t \pm 90°) = \mp\sin\omega t$

Problem 14

sin → cos, θ − 90

$\sin(180 + \theta) = -\sin\theta$
$\cos(180 + \theta) = -\cos\theta$

- For the following pairs of sinusoids, determine which one leads and by how much $(0 \le \theta \le 180°)$.

→ $10\cos(4t - 60 + 90) = 10\cos(4t + 30)$

I. $v(t) = 10\cos(4t - 60°)$ & $i(t) = 4\sin(4t + 50°)$ ∴ $i(t)$ leads $v(t)$ by $20°$

II. $v_1(t) = 4\cos(377t + 10°)$ & $v_2(t) = -20\cos 377t$ $= 20\cos(377t + 180)$ ∴ $180 - 10 = 170°$

$45\sin(\omega t + 30 - 90) = 45\sin(\omega t - 60)$

III. $v_1(t) = 45\sin(\omega t + 30°)$ V & $v_2(t) = 50\cos(\omega t - 30°)$

$4\sin(377t + 55 + 180) = 4\sin(377t + 235 - 90) = 4\cos(377t + 145)$

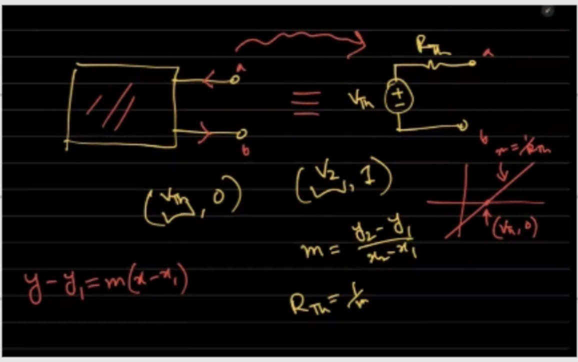
IV. $i_1(t) = -4\sin(377t + 55°)$ & $i_2(t) = 5\cos(377t - 65°)$ → i_1 leads i_2 by $145 - (-65) = 210°$

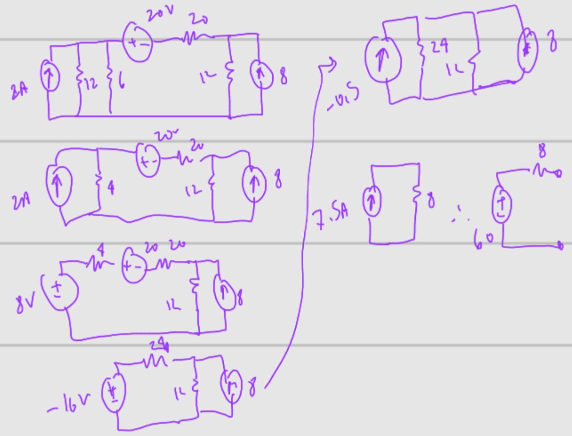
V. $x(t) = (13\cos 2t + 5\sin 2t)$ & $y(t) = 15\cos(2t - 11.8°)$

Ans:
I. i leads v by 20°
II. v_2 leads v_1 by 170°
III. v_2 leads v_1 by 30°
IV. i_2 leads i_1 by 150°
V. y leads x by 9.24°

Hint: convert both the sinusoids into sine or cosine form → convert them into phasors → add them in frequency domain → convert them back in the time domain and compare

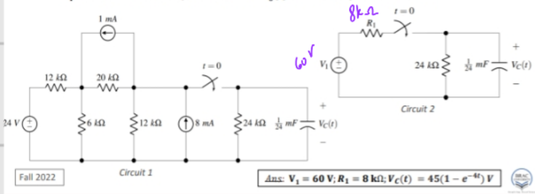
I-V characteristics





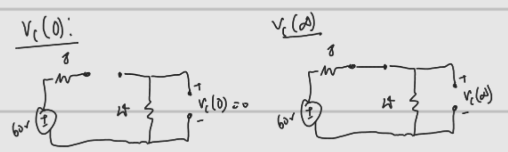
Problem 13

- Simplify the Circuit 1 below so that it takes the form of the Circuit 2. Determine the values of V_1 and R_1. Perform transient analysis to determine $V_C(t)$ across the capacitor for $t > 0$.



Ans: $V_1 = 60$ V; $R_1 = 8$ kΩ; $V_C(t) = 45(1 - e^{-4t})$ V

kill all the sources



$V_c(\infty)$

$\frac{24}{24+8} \times 60 = 45$ V

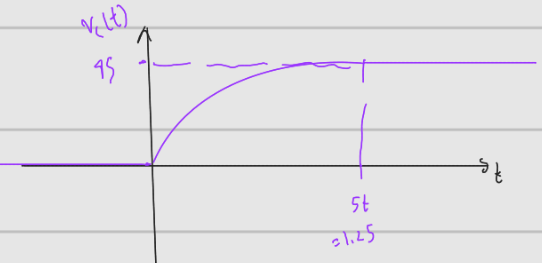
$T = R_{th} \times C$

short circuit

∴ $R_{th} = 8 \| 24 = 6$ kΩ

∴ $T = 6 \times 10^3 \times \frac{1}{24} \times 10^{-3} = 0.25$ s

∴ $V_c(t) = \begin{cases} 0\text{V}, & t < 0 \\ 45 + (0 - 45)e^{-t/0.25}, & t \ge 0 \\ = 45 - 45e^{-4t} & \end{cases}$

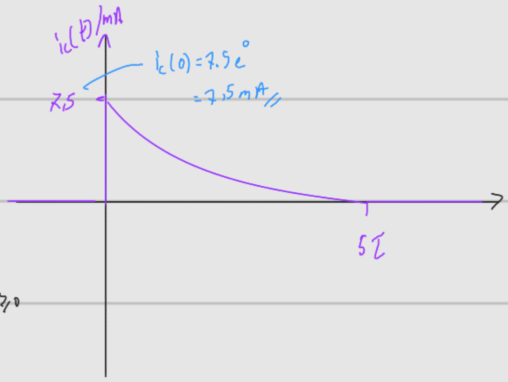


$i_c(t) = C\frac{dv_c}{dt}$ → $t < 0$, $V_c(t) = 0V$

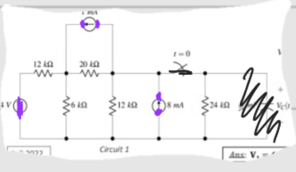
$= C(-45e^{-4t} \times -4)$ } $t \ge 0$

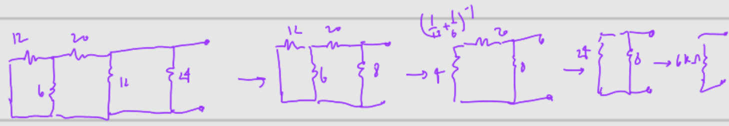
$= 180 \times \frac{1}{24} \times 10^{-3} e^{-4t}$

$= 7.5e^{-4t}$ mA ∴ $i_c(t) = \begin{cases} 0\text{mA}, & t < 0 \\ 7.5e^{-4t}\text{ mA}, & t \ge 0 \end{cases}$



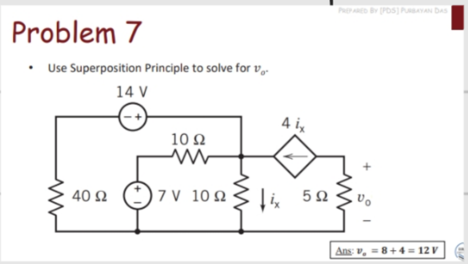
Process-2 of finding R_{th}



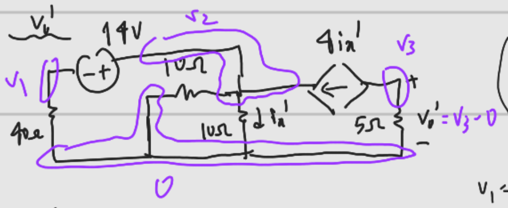


Superposition Theorem

* Do not kill dependent source



By superposition, $V_o = V_o' + V_o''$, $i_x = i_x' + i_x''$



$V_2 - V_1 = 14V$

$i_x' = V_2/10$

$V_o' = V_3$

$V_1 = V_2 - 14$

$V_3(\frac{1}{5}) - 0 + 4i_x' = 0$

$V_3(\frac{1}{5}) + 4(V_2/10) = 0$

$V_3(\frac{1}{5}) + 4(\frac{-2}{10}) = 0$

$\therefore V_3 = \frac{8}{10} \times 5 = 4V$

$(V_1 + V_2)$

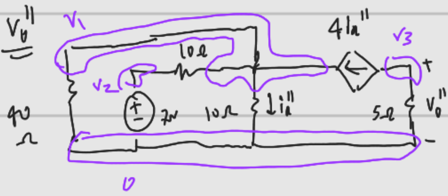
$V_1(\frac{1}{40}) + V_2(\frac{1}{10}+\frac{1}{10}) - 4i_x' = 0$

$(V_2 - 14)(\frac{1}{40}) + V_2(\frac{1}{10}+\frac{1}{10}) - 4(\frac{V_2}{10}) = 0$

$V_2(\frac{1}{40}+\frac{1}{10}+\frac{1}{10}-\frac{4}{10}) = \frac{14}{40}$

$V_2 = -2V$

$\therefore v_o' = 4V$



$V_2 - 0 = 7V$

$V_2 = 7$

$V_o'' = V_3$

$i_x'' = \frac{V_1}{10}$

$V_3(\frac{1}{5}) + 4i_x'' = 0$

$V_3(\frac{1}{5}) + 4(\frac{V_1}{10}) = 0$

$V_1(\frac{1}{40}+\frac{1}{10}+\frac{1}{10}) - \frac{V_2}{10} - 4i_x'' = 0$

$V_1(\frac{1}{40}+\frac{1}{10}+\frac{1}{10}) - \frac{7}{10} - 4(\frac{V_1}{10}) = 0$

$\therefore V_1(-\frac{7}{40}) = \frac{7}{10}$ $\therefore V_1 = -4V$

$\therefore V_3(\frac{1}{5}) + 4(\frac{-4}{10}) = 0$

$V_3(\frac{1}{5}) = \frac{16}{10}$

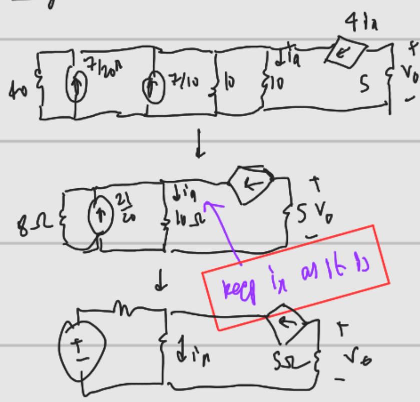
$V_3 = 8 = V_o''$

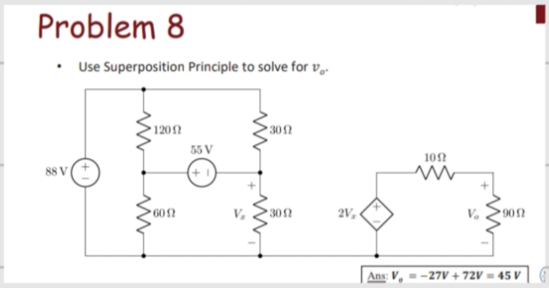
$\therefore V_o = v_o' + v_o''$

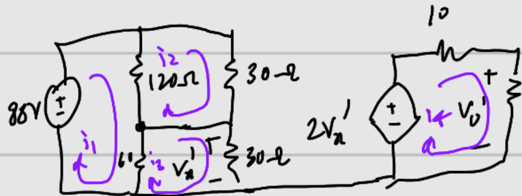
$= 4 + 8$

$= 12V$

Using Source Transformed







$i_4 = \frac{V_o'}{90}$, $i_3 = \frac{V_x'}{30}$

$i_1(120+60) - 120(i_2) - 60(i_3) - 88 = 0$

$i_2(120+30) - 120(i_1) = 0$

$i_3(60+30) - 60(i_1) = 0$

$i_1 = 2$, $i_2 = \frac{8}{5}$, $i_3 = \frac{4}{3}$

$i_4(10+90) - 2V_x' = 0$

$i_4(10+90) - 2(30\,i_3) = 0$

$i_4(100) - 2(30 \times \frac{4}{3}) = 0$

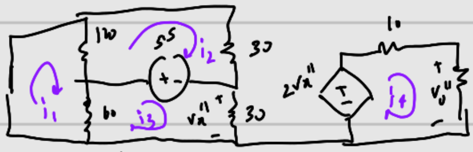
$i_4(100) - 80 = 0$

$i_4 = \frac{80}{100} = 0.8$

$V_o' = i_4 \times 90$

$= 0.8 \times 90$

$= 72V$



$i_4 = \frac{V_o''}{90}$, $i_3 = \frac{V_x''}{30}$

$i_1(120+60) - 120(i_2) - 60(i_3) = 0$

$i_2(120+30) - 120(i_1) - 55 = 0$

$i_3(60+30) - 60(i_1) + 55 = 0$

$i_4(10+90) - 2V_x'' = 0$

$i_4(100) - 2(i_3 \times 30) = 0$

$i_1 = \frac{1}{6}$, $i_2 = \frac{1}{2}$, $i_3 = -\frac{1}{2}$

$i_4(100) - 2(-\frac{1}{2} \times 30) = 0$

$i_4(100) + 30 = 0$

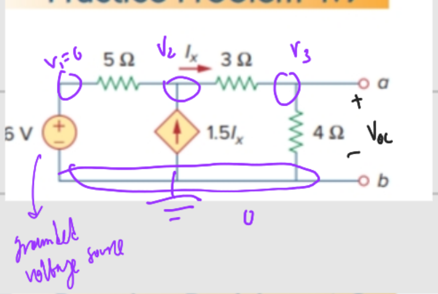
$i_4 = -0.3$

$\therefore V_o'' = -0.3 \times 90$

$= -27V$

$\therefore V_o = V_o' + V_o'' = -27 + 72 = \boxed{45V}$

Practice Problem 4.9



$V_{oc} = V_3 - 0 = V_3$, $i_x = \frac{V_2 - V_3}{3}$

$V_2\left(\frac{1}{5}+\frac{1}{3}\right) - \frac{6}{5} - \frac{V_3}{3} - 1.5 i_x = 0$

$V_2\left(\frac{1}{5}+\frac{1}{3}\right) - \frac{6}{5} - \frac{V_3}{3} - 1.5\left(\frac{V_2}{3} - \frac{V_3}{3}\right) = 0$

$V_2\left(\frac{1}{5}+\frac{1}{3} - \frac{1.5}{3}\right) + V_3\left(-\frac{1}{3} + \frac{1.5}{3}\right) = \frac{6}{5}$

$V_3\left(\frac{1}{3}+\frac{1}{4}\right) - \frac{V_2}{3} - \frac{0}{4} = 0$ ∴ $V_{OC} = 5.33V$

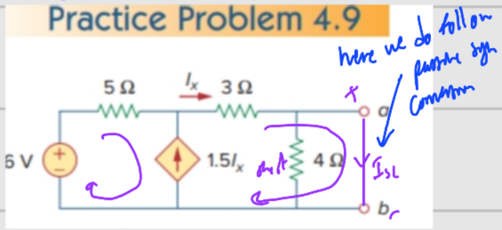
$V_3\left(\frac{1}{3}+\frac{1}{4}\right) + V_2\left(-\frac{1}{3}\right) = 0$

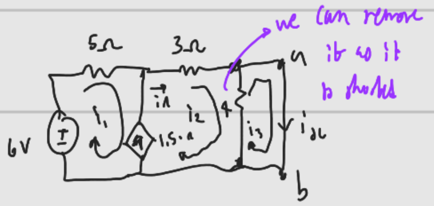
$V_2 = \frac{28}{3}$, $V_3 = \frac{16}{3}$

$= 9.33$ $= 5.33$

$(0, V_{Th}) = (0, 5.33)$

Practice Problem 4.9





3 mesh, 1 supermesh (1,2)

$i_2 - i_1 = 1.5 I_x$ #, $i_{sc} = i_3$,
$= 1.5 i_2 \longrightarrow 0.5 i_2 + i_1 = 0$

$\{i_1(5) - 6\} + \{i_2(3+4) - 4i_3\} = 0$

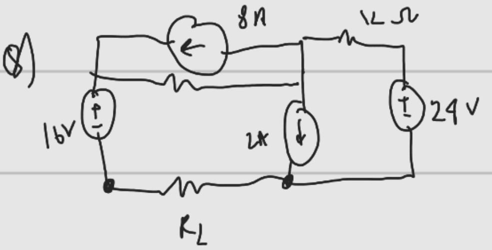
$i_3(4) - 4(i_2) = 0$

$i_1 = -6A$, $i_2 = 12$, $i_3 = 12$

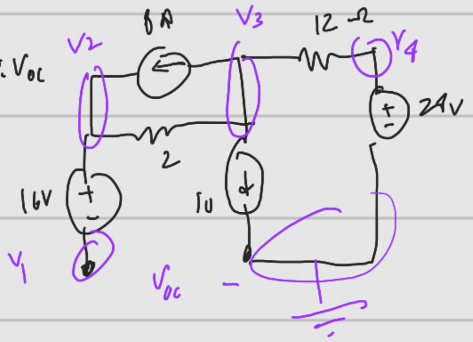
∴ $R_{Th} = \frac{5.33}{12} = 0.44\Omega$

We don't follow passive sign convention:
↳ During source transformation
↳ Test current source

Q)

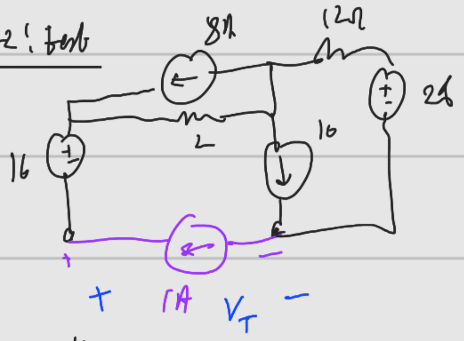


Step-1: V_{oc}



4 nodes & 1 supernode (1,2)

Step-2: test



$V_{OL} = V_1$

$16 = V_2 - V_1$

$V_1(0) + V_2\left(-\frac{1}{2}\right) - \frac{V_3}{-2} - 8 = 0$

$V_3\left(\frac{1}{12} + \frac{1}{2}\right) - \frac{V_4^{=24}}{12} - \frac{V_2}{2} + 10 = 0$

$V_4 = 24$

∴ $V_1 = 0V$, $V_2 = 16V$, $V_3 = 0$

∴ $V_{OC} = 0V$ → hence put test current source

same eqn but

$16 = V_2 - V_1$

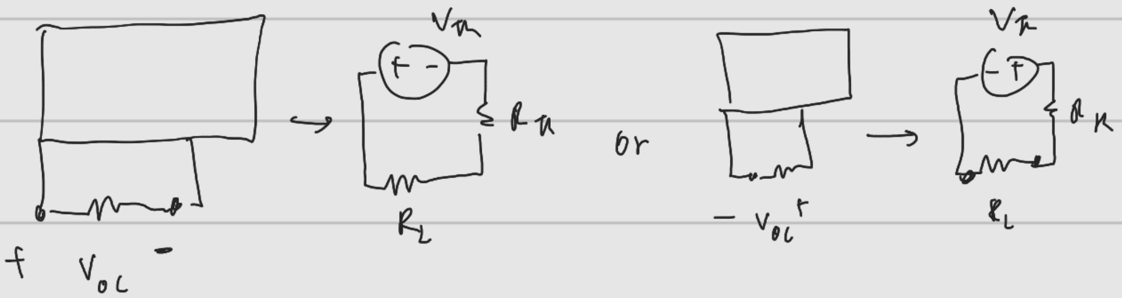
$V_1(0) - 1 + V_2\left(-\frac{1}{2}\right) - \frac{V_3}{-2} - 8 = 0$

$V_3\left(\frac{1}{12} + \frac{1}{2}\right) - \frac{V_4^{=24}}{12} - \frac{V_2}{2} + 10 = 0$

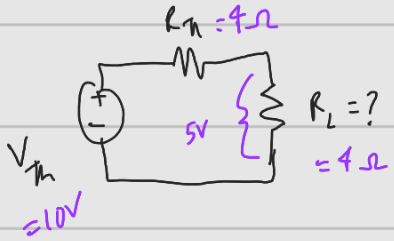
$V_4 = 24$

∴ $V_1 = V_T = 14V$

∴ $R_{Th} = \frac{14}{1} = 14\Omega$



Maximum Power Transfer Theorem



$\boxed{\text{It is when } R_L = R_{Th}}$

$P_{L_{max}} = ?$ $\quad P_{circuit} = ?$

$= \left(\frac{10}{2}\right)^2$

eg $P_{max} = \frac{V_L^2}{R_L} = \frac{5^2}{4} = 6.25W$ //

$$\boxed{P_{max}\ (\text{Load}) = \frac{(V_{Th}/2)^2}{R_{Th}} = \frac{V_{Th}^2}{4R_{Th}}}$$