ESc201, Lecture 3: Power dissipation

Power Dissipation of Resistors: $P(t) = v(t)\,i(t)$

At steady state P=VI and by Ohm's Law V=RI. Therefore $P = RI.I = RI^2$.

One only looks at time average of power dissipation.

$$P_{av} = \frac{W}{(t_2 - t_1)} = \frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} P(t)\,dt$$

Resistors have *safe power ratings such as* common values of : 1/8 W, 1/4 W, 1/2 W, 1 W, 2 W and 5W. Resistors can have kWs of power rating also.

Tolerances of Resistors:

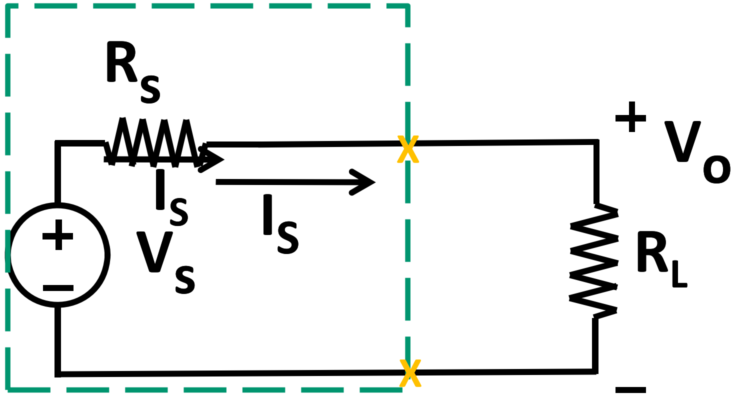
The 4th Band is the tolerance band:

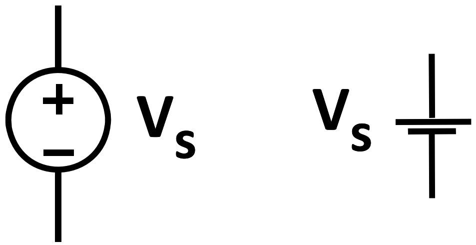
Violet - 0.1%,
Blue - 0.25%,
Green - 0.5%,
Brown - 1%,
Red - 2%,
Gold - 5%,
Silver - 10%,
None - 20%

Note that ideal capacitors and inductors at steady state should not have any power dissipation. Note that at steady state d.c. there is zero current through the capacitor although there is a voltage and there is zero voltage across an inductor although there is a finite current through it. In either case VI=0.

But Non-Ideal Capacitors & Inductors have inherent resistances and therefore does dissipate power. In a.c. conditions there could be other sources of dissipation in these elements, which can also be represented by equivalent resistors.

Independent Voltage Source:





V_S: Rated Voltage

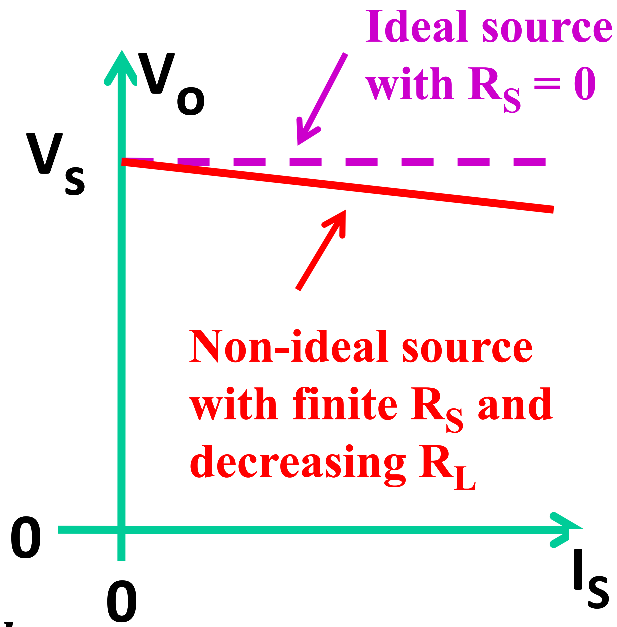
R_S: Series Resistance of Source

R_L: Connected Load Resistance

V_o: Output supply Voltage

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

$$V_O = I_S R_L = \frac{R_L}{R_S + R_L} V_S$$



For $V_o = V_S$, R_S must be zero --- *Ideal Voltage Source => lossless*

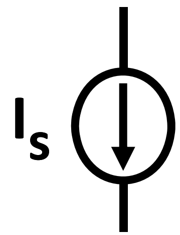
An important requirement for a good voltage source is to approach this ideality. For well designed sources, it may be less than 100 Ω.

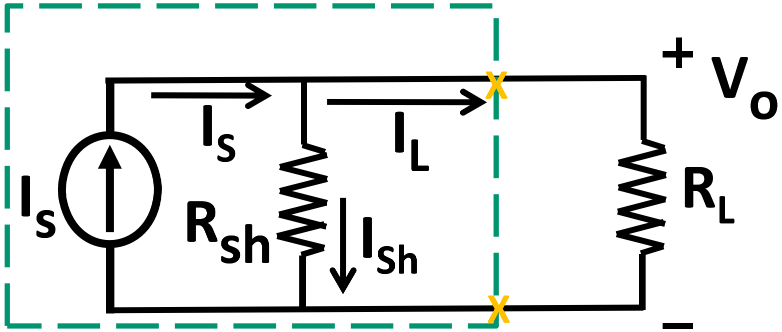
For finite R_S, V_o will drop with decreasing R_L , known as *loading effect.* Practical voltage sources have series resistance of ~ few kΩ.

Effect of loading becomes more pronounced as R_L and R_S start to become comparable

ESc201, Lecture 3: Sources and circuits

Independent Current Source:



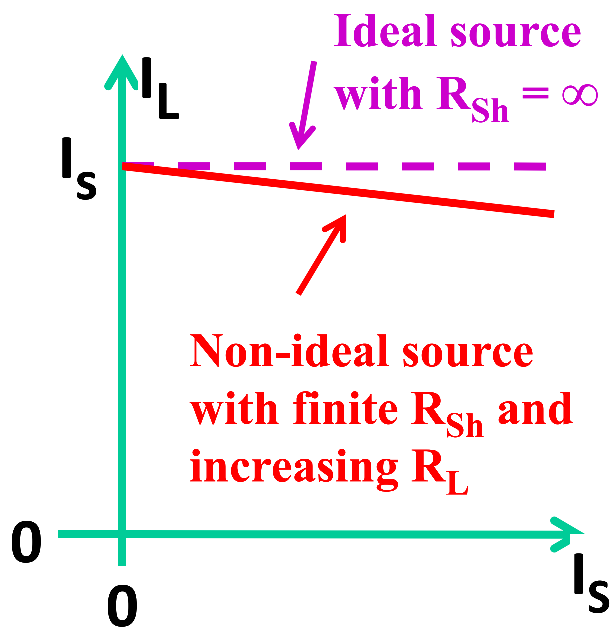


I_L: Current delivered by source to load.
I_{Sh}: Current lost in the internal resistance of source.

$I_{Sh} = I_S - I_L$ $\quad$ $R_{Sh} I_{Sh} = V_o = R_L I_L$

$$I_L = \frac{R_{Sh}}{R_{Sh} + R_L} I_S \qquad V_o = I_L R_L = \frac{R_{Sh} R_L}{R_{Sh} + R_L} I_S$$

I_S: Rated Current
R_{Sh}: Shunt Resistance of the Source
R_L: Connected Load Resistance
V_o: Output supply Voltage



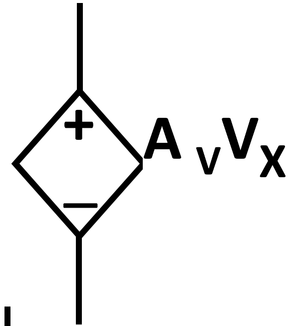
For $I_L = I_S$, R_{Sh} must be infinite - Required for a good current source, known as *Ideal Current Source => lossless*

– **For finite R_{Sh}, I_L will drop with increasing R_L, known as *loading effect.***
– **Practical current sources have shunt resistance ~ a few hundreds of kΩ**
– **For well designed sources, it may even be >1 MΩ**

Effect of loading becomes more pronounced as R_L and R_{Sh} start to become comparable

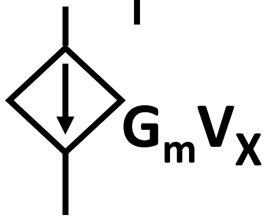
Dependent (or controlled) Sources (Four posibilites):

Very useful for the description of active devices



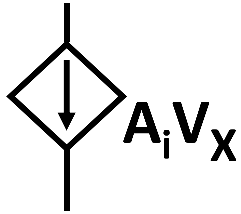
(a) ***VCVS (Voltage-Controlled Voltage Source)***

Where $V = A_vV_x$, A_v: ***voltage gain, V_X: controlling voltage.***



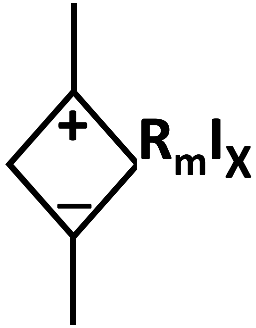
(b) ***VCCS (Voltage-Controlled Current Source)***

Where $I = G_mV_x$, G_m: ***transconductance.***



(c) ***CCCS (Current-Controlled Current Source)***

Where $I = A_iI_x$, A_i: ***current gain, I_X: controlling current.***



(d) ***CCVS (Current-Controlled Voltage Source)***

WhereV $= R_mI_x$, R_m: ***transresistance.***

ESc201, Lecture 3: Sources and circuits

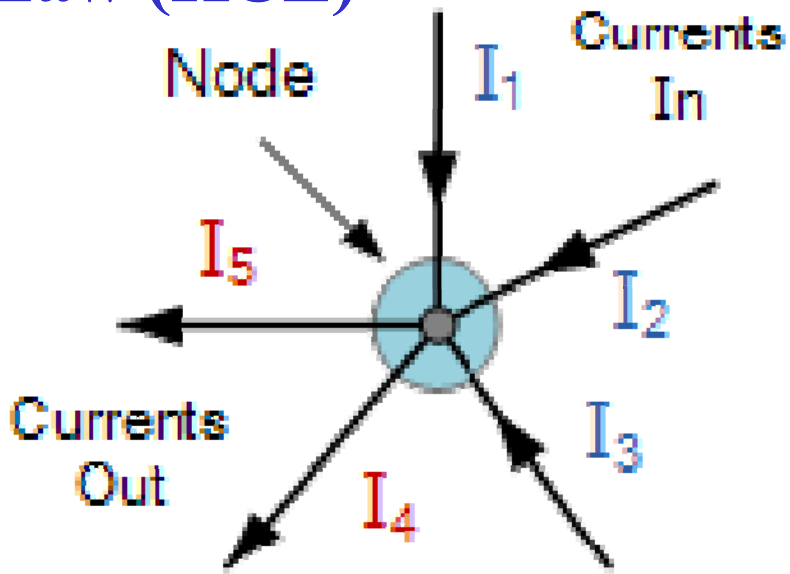
Electrical Network: **Connection of elements through *Nodes* to form a closed path through which current flows.**

Nodes : The connection point of two or more components in a network

Branch: **Any portion of a circuit with two terminals (Nodes) connected to it. May contain one or more circuit elements.**

Kirchhoffs Current Law (KCL)

KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero.



$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

$$I_1 + I_2 + I_3 = I_4 + I_5$$

Kirchhoff's Voltage Law:

- Net voltage around a closed circuit must be zero
- Origin: *Law of energy conservation:*

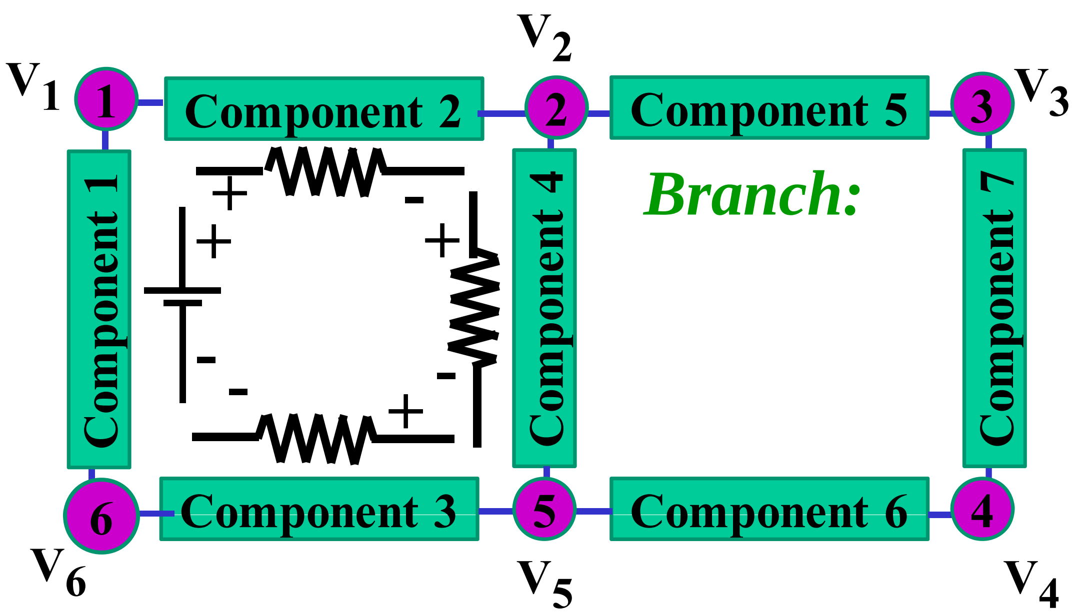
– Total energy generated in a circuit must equal total energy dissipated in the circuit

$(V_2 - V_1) + (V_5 - V_2) + (V_6 - V_5) + (V_1 - V_6) = 0$

Similarly:

$(V_2 - V_1) + (V_3 - V_2) + (V_4 - V_3) + (V_5 - V_4) + (V_6 - V_5) + (V_1 - V_6) = 0$

Quite easy to show above that the V_i's cross out to give zero. Then how does a circuit work?



Take care of the polarities of the potentials while applying this law

Arbitrary direction of voltage drop can be taken to start with. However, if any of the assumptions of the voltage drop was incorrect, the the value will turn out after analysis to be negative. One definitely needs to be consistent in assigning the sign of the voltage. i.e. If a generator of power is there then its polarity would be opposite from that of a resistor for the same current flow direction.

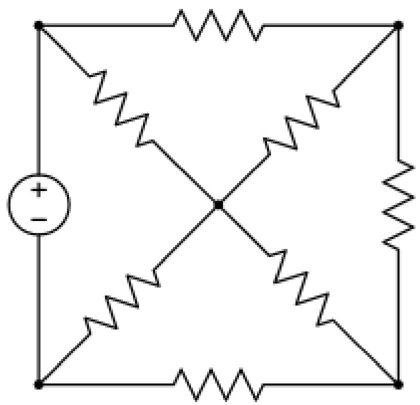
ESc201, Lecture 3: Sources and circuits

Planar vs. Non-planar

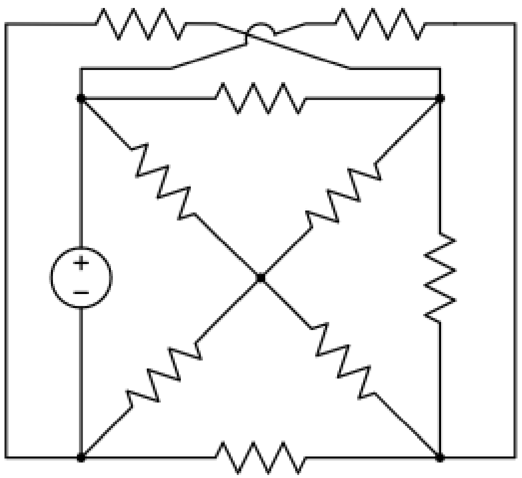
A circuit is *planar* if it can be drawn on a flat surface without crossing wires. The schematic below on the left is planar. For planar circuits, the Mesh Current Method is good and equations are based on *meshes*. This always works for planar circuits.

A *non-planar* circuit is shown below on the right. It has to be drawn with at least one crossing wire, meaning it cannot be drawn flat. Since there is no way to redraw the circuit to avoid a crossing wire, the circuit on the right is non-planar.

When faced with a non-planar circuit, one *must* use the Loop Current Method



Planar



Non-planar

Introduction to Electronics (Esc 201A)-- 2019-20-I.

ESc201, Lecture 3: Sources and circuits

Techniques: **(1)** ***Node Voltage Method,*** **(2)** ***Mesh Current Method*** **(3)** ***Superposition Principle,*** **(4)** ***Thevenin Equivalent,*** **(5)** ***Norton Equivalent***

To solve a circuit the voltage and current for each element need to be known. This means need twice as many independent equations are needed as there are elements in the circuit.

These equations come from three places:

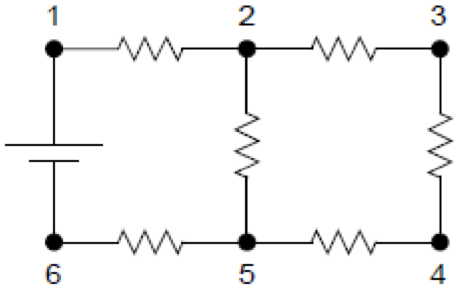
- **Half of the equations come from the element laws for each component.**
- **Kirchhoff's Current Law (KCL) : N−1 where N is the number of nodes.**
- **Kirchhoff's Voltage Law (KVL) : E−(N−1) independent equations, where E is the number of elements.**

Putting these together, one ends up with the right no. of equations.

Node Voltage Method:

– By far, the simplest and the most widely used.

– Consider a circuit having Non-trivial nodes.



Out of nodes 1- 6,
1, 3, 4, and 6 are trivial nodes,
as the same current flows through all the components connected to these nodes.

– Pick a reference node, and define all other node voltages with respect to this reference node.

– Apply Ohm's Law between any two adjacent nodes, and write the current equations.

– Thus, we arrive at a set of (N – 1) equations.

– Rearrange the in terms of node voltages V_1 to V_{N-1}

– $[G][V] = [C]$ or $[V] = [G]^{-1}[C]$

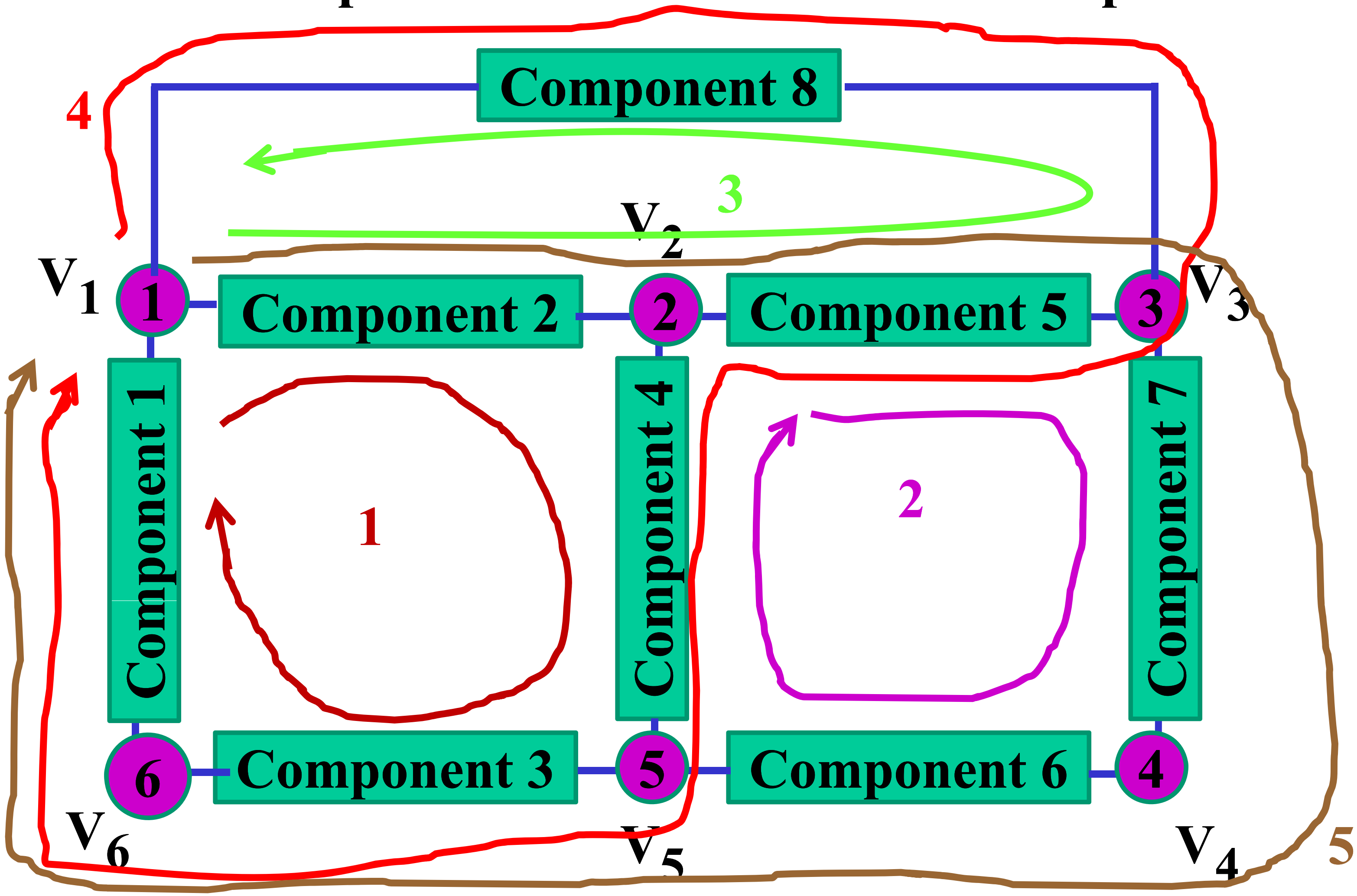
– Note that the final set of equations does not contain any current variable.

– Solve them to find the node voltages and currents.

Loop: **Closed connection of branches**

– Different loops in the same circuit may include some of the same elements or branches

- ***Mesh:*** **A loop that does not contain other loops**



Loops 1, 2 and 3 are meshes, but Loops 4 and 5 are not meshes, since 4 includes Loops 1 and 3, and Loop 5 includes Loops 1 and 2.

Mesh Current Method:

• Known as the complement of node voltage method

– Branch currents are taken to be independent variables.

– Find the min. number of independent meshes in the network

– Using KVL, write the mesh equations in terms of the voltage drop across each element.

– Repeat for all the meshes

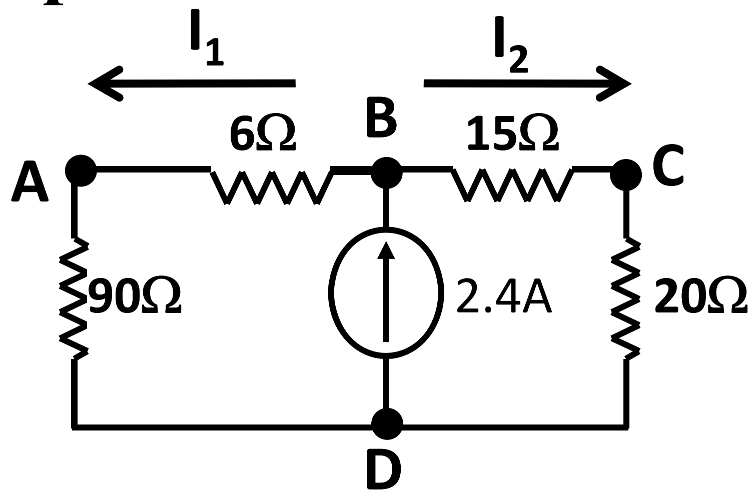
– Number of equations would equal the number of independent meshes. (becomes quite involved for networks for > 3 independent meshes). Therefore not much used as few nodes may have many meshes.

$$[Z]\,[I]_{mesh} = [B] \text{ or } [I]_{mesh} = [Z]^{-1}[B]$$

– Once the mesh currents are known, all the node voltages can be evaluated.

– The unknown mesh currents, by convention, are considered to be positive in the *clockwise* direction. But need not be so.

Node Voltage Method Example:



Here A and C are trivial nodes.
D can be considered as a reference node.

As only one current source powers the circuit it is very easy for nodal analysis.

$I_1+I_2-2.4=0$ or $I_1+I_2 = 2.4$

So $V_B=96xI_1=V_B=35xI_2$

$I_1/I_2=35/96$, and $I_1/I_2+1=2.4/I_2$

Which gives $I_2=(0.5686)^{-1}=1.759A$

Or $I_1=2.4-1.759=0.641$

$V_A=90x0.641$ V, $V_B=96x0.641$ V,

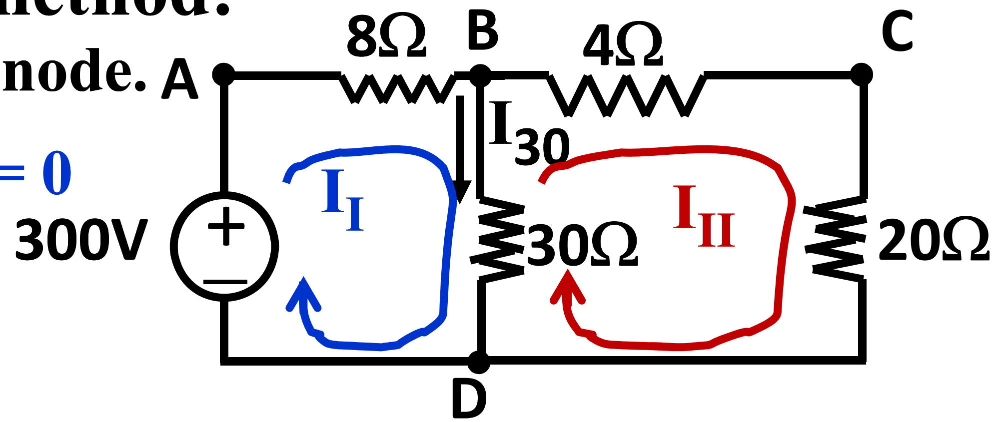
$V_C=35x1.759$ V

Now consider the current source is replaced with a 10V battery, with $V_B= 10$ V. Even easier for this small circuit.

Then $I_1= 10/96 = 0.104$ A, and $I_2= 10/35 = 0.286$ A.

$V_A=90x\ 0.104 = 9.36$ V, and $V_C=20x\ 0.286 = 5.72$ V

Mesh current method:



D can easily be made the datum node.

In mesh I , $8\,I_I + 30(I_I - I_{II}) - 300 = 0$

$38I_I - 30I_{II} = 300$

In mesh II ,

$(4+20)\,I_{II} + 30(I_{II} - I_I) = 0$

OR $(4+20+30)\,I_{II} = 30(300/38)$

$+\ (30/38)\,I_{II}$

or $[54 - (30/38)]I_{II} = 236.8$

$I_{II} = 236.8/53.2 = 4.451$ A

$I_{20} = I_{II} = 4.451$ A

$I_8 = I_I = (300/38)+(30/38)I_{II} = 11.409$A

As voltage at B has to be higher than that of D. $I_{30} = I_I - I_{II}$.

$I_{30} = 11.409 - 4.451 = 6.958$ A

$V_A = 300$ V,

$V_B = 300$ V $- 11.409 \times 8$

$= 208.7$ V,

$V_C = 208.7 - 11.409 \times 4$

$= 163.1$ V