EE1002
Introduction to Circuits and Systems

Part 1 : Lecture 2

Announcement

- LT Spice lab next week
- Safety Quiz:
  - http://my.ece.nus.edu.sg/safety/quiz/
  - Need to take this online quiz, pass it and submit the printed passing certificate when you come for lab 2.
  - It is a must to be able to work in the lab.

Rules for the lab

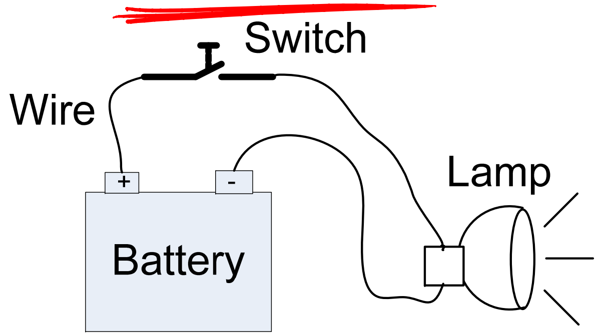
- Proper Attire
  - No flip-flop allowed
  - Covered-toe shoes only allowed

- Do not put water bottles on working tables

- Be punctual else you will miss the briefing

Current

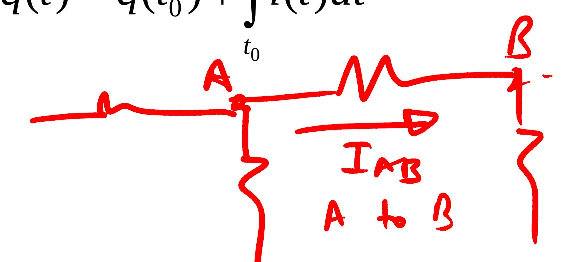
- Electric current is the time rate of flow of electrical charge through an element



$$i(t) = \frac{dq(t)}{dt}$$

$$q(t) = q(t_0) + \int_{t_0}^{t} i(t)dt$$

$V_{AB} = V_A - V_B$



- Unit – Ampere, symbol - *I*
- Current has a direction (that of positive charge)
- DC – direct current (unidirectional)
- AC – alternating current (bidirectional and periodic)

Voltage

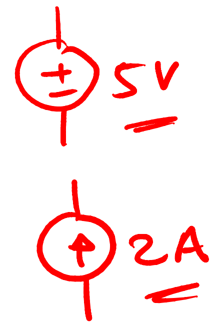
- Voltage is electrical potential difference (is a measure of the energy transferred per unit charge between two points.
- Unit – Volt, symbol - *V*
- Energy can be gained or lost, thus voltage has polarity: positive and negative
  - $V_{ab} = -V_{ba}$

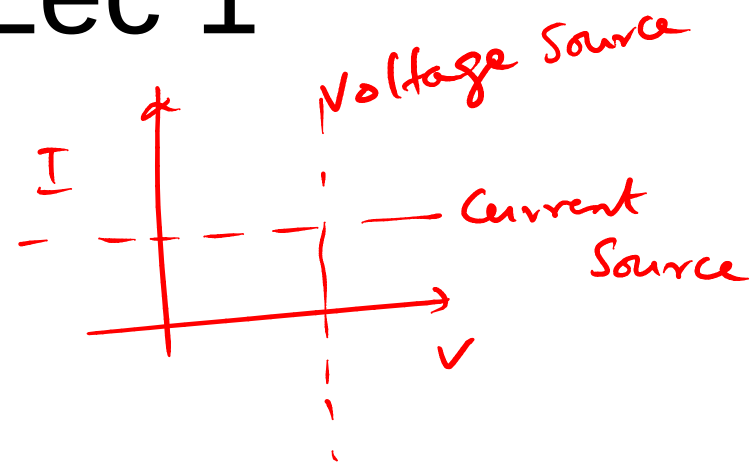
$V_{ab} = P_a - P_b$

$= V_a - V_b$

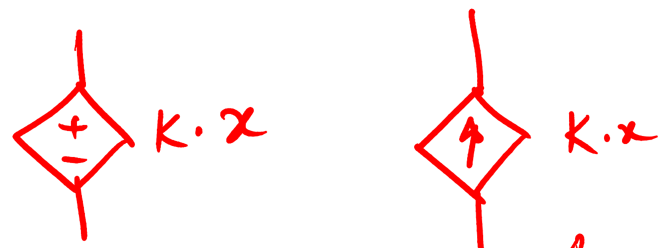
Review of Lec 1

- Voltage Source
- Current Source

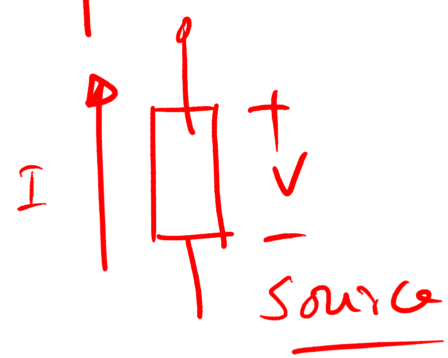




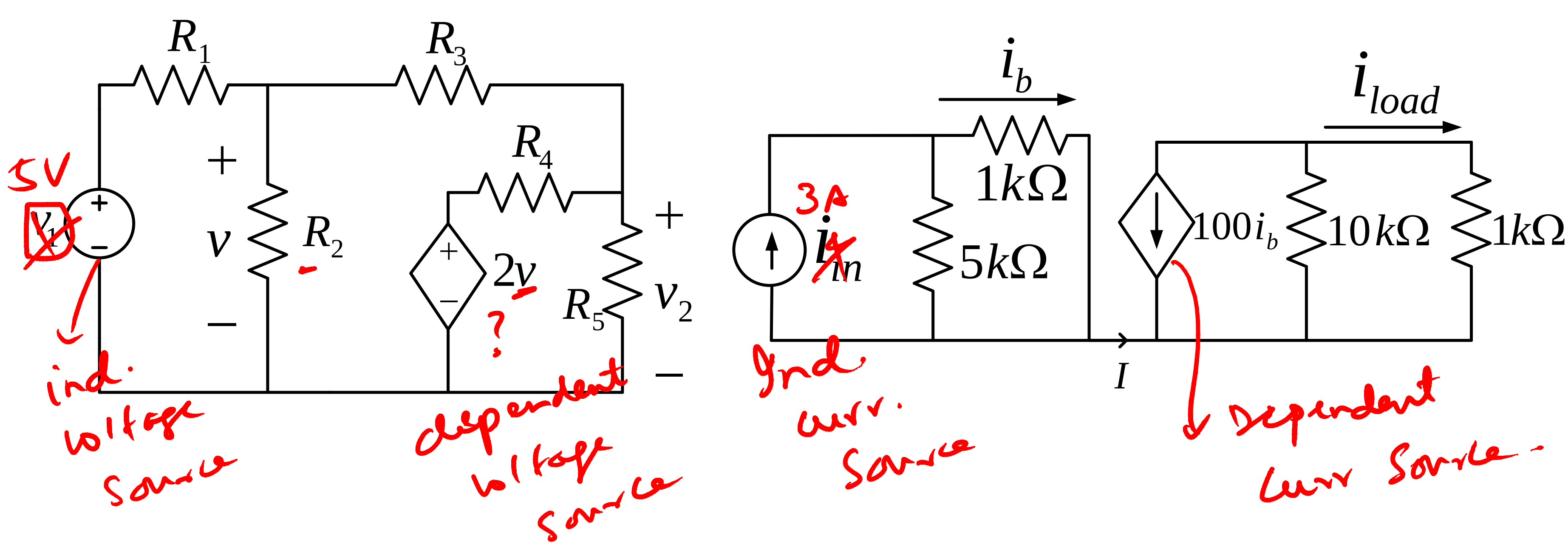
- Independent Source
- Dependent Source



- Active Element (Source)
- Passive Element (Load)



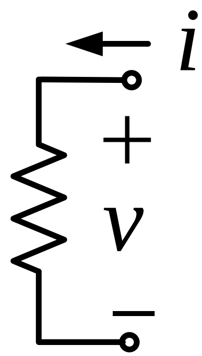
Examples of Dependent source

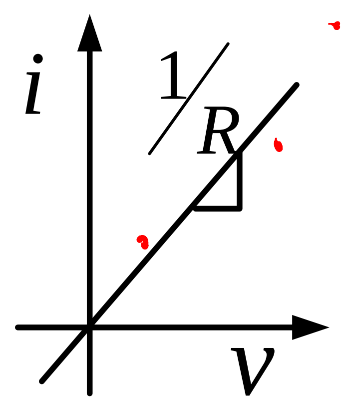


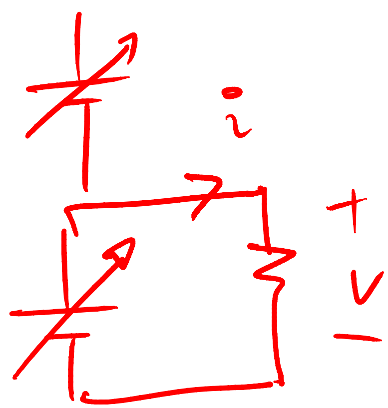
Resistance – R

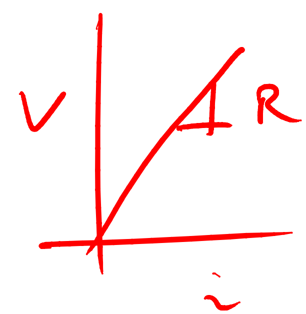
Resistance and Ohm's Law

- Current flows through a metal wire or other circuit elements, it encounters some resistance





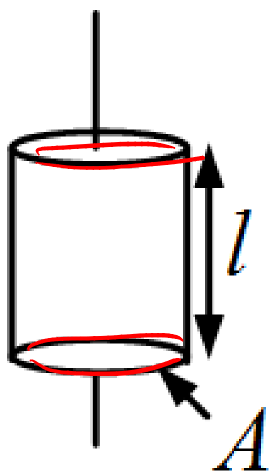




Ohm's law : $v = iR$

Resistance and Ohm’s Law

- This resistance is related to the material and size of the element



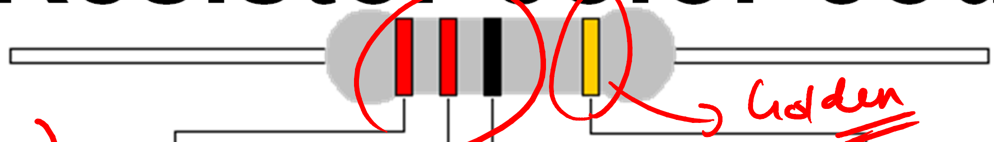
resistivity

$$\boxed{R = \frac{\rho l}{A}}$$

Material	Resistivity (Ohm-meter)
Silver	1.629×10^{-8}
Copper	1.725×10^{-8}
Gold	2.271×10^{-8}
Aluminium	2.733×10^{-8}
Iron	9.98×10^{-8}
Carbon	3.5×10^{-5}

Resistor

Resistor color code



Golden

$22 \times (1 \pm 0.05)$

$22 \times 1 =$
$= 22\,\Omega$

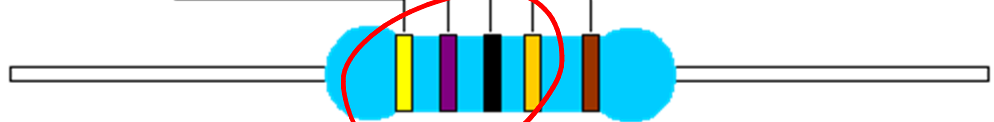
COLOR	1ST BAND	2ND BAND	3TH BAND	MULTIPLIER	TOLERANCE	
BLACK	0	0	0	1		
BROWN	1	1	1	10	± 1%	F
RED	2	2	2	100	± 2%	G
ORANGE	3	3	3	1K		
YELLOW	4	4	4	10K		
GREEN	5	5	5	100K	± 0.5%	D
BLUE	6	6	6	1M	± 0.25%	C
VIOLET	7	7	7	10M	± 0.10%	B
GREY	8	8	8		± 0.05%	A
WHITE	9	9	9			
GOLD				0.1	± 5%	J
SILVER				0.01	± 10%	K
PLAIN					± 20%	M

B
B
R
O
Y
G
B
V
G
W

Brown	Red	Yellow
1	2	4

10^4

$12 \times 10K$
$= 120K.$



Power in resistors

- Power is product of voltage and current.

$$p = vi$$

R = 22Ω.

Pmax = 0.25W

what is Vmax? Imax?

$$v = iR$$ ohm's law

$$p = i^2R$$

power is always +ve for a resistor.

$$i = \frac{v}{R}$$

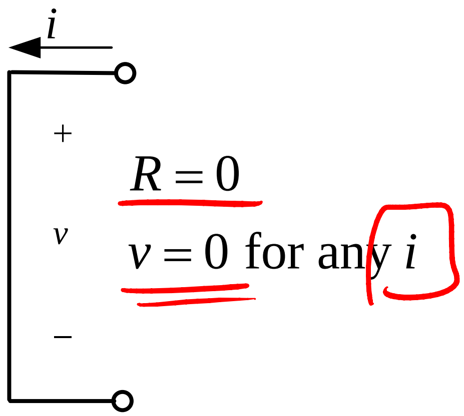
Load or passive element.

$$\boxed{p = \frac{v^2}{R}} \longrightarrow$$ $V_{max} = \sqrt{P_{max} \times R} = \sqrt{0.25 \times 22}$

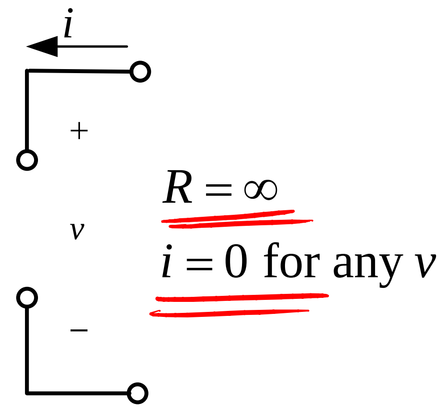
$\simeq 2.2V$.

- Thus, power in resistor is always positive

Short Circuit and Open Circuit



Short Circuit



Open Circuit

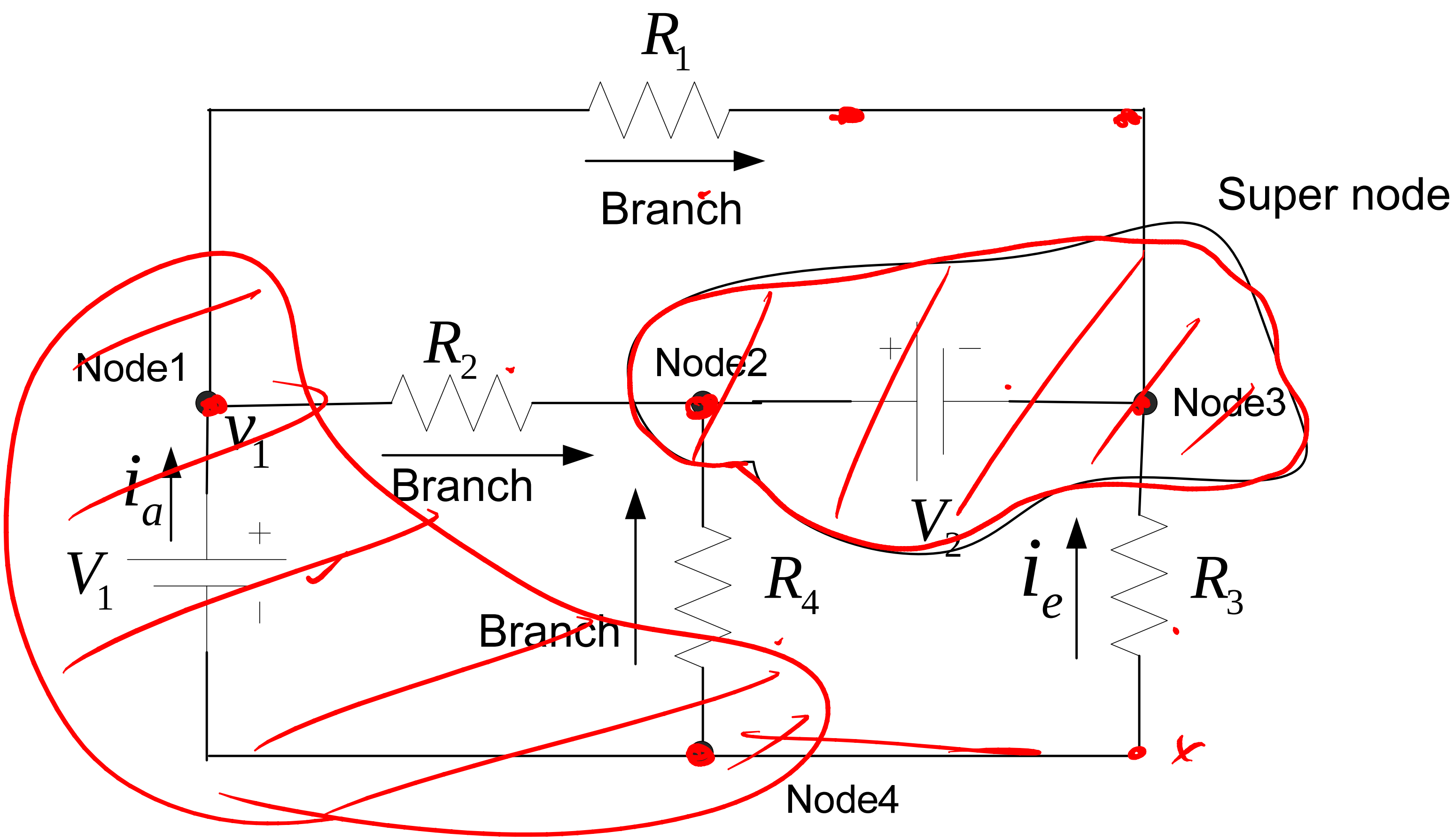
- These are idealization only.

Circuit Elements

Node, branch, etc. defined

- A node in an electrical circuit is a point at which two or more elements are joined together.
- A super node is a closed surface enclosing part of a circuit. It may contain some sources and other nodes.

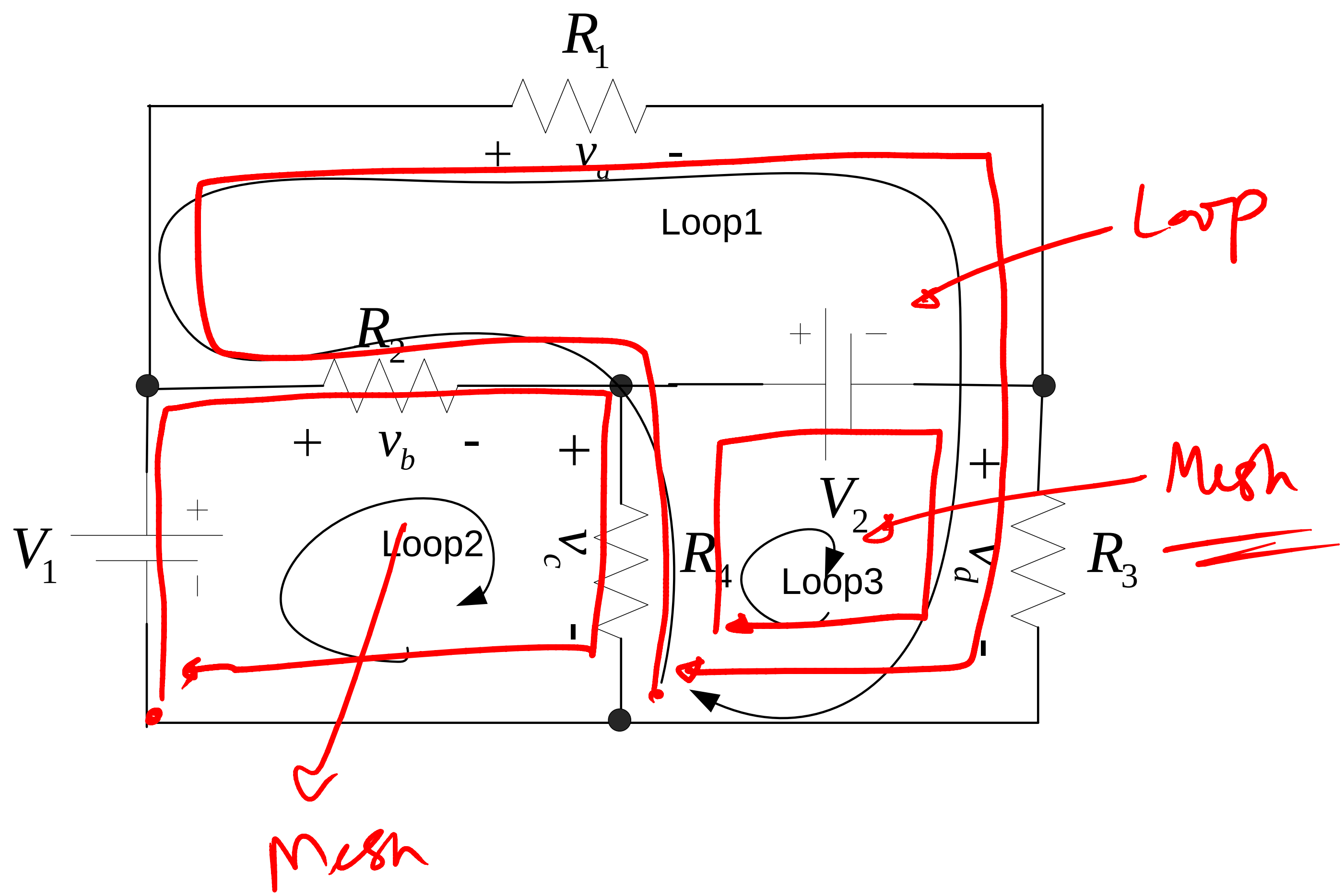
Terms of Circuit/Network Analysis



Mesh, Loop

- A mesh is a closed path in the circuit.
- A loop is also a closed path in the circuit.
- A mesh cannot have any other mesh or loop inside it.
- A loop can have meshes inside it.

Mesh and Loop



- Circuit Analysis
  – Kirchoff’s Laws
  – Analysis techniques

Circuit Analysis

- To find the unknown voltage and current for various elements in the circuit
- We need to find the voltage polarity and current direction along with the magnitude
- Some elements in the circuits may be either giving power or taking power: can be known only after solving the circuit
- For unknown elements, we need to have reference polarity and direction first.

Reference direction and polarity

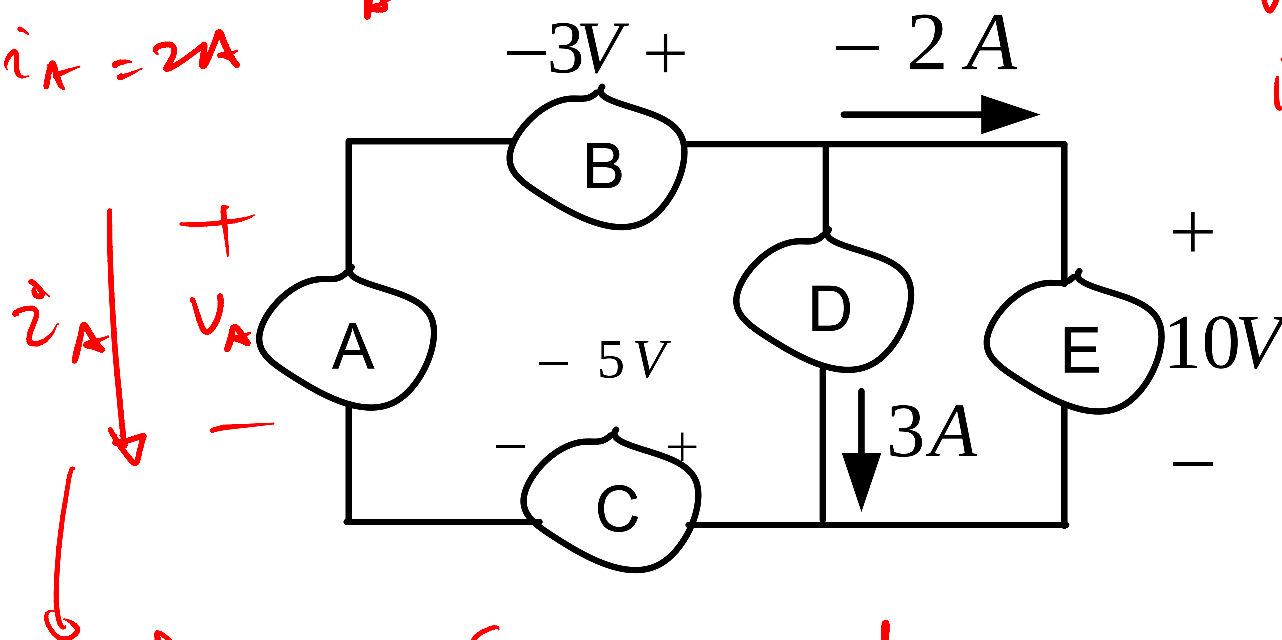
$v_A = 10V$ $\quad$ $p_A = 10 \times 2 = 20\,W$

$i_A = 2A$

$v_A = -10V$

$i_A = -2A$

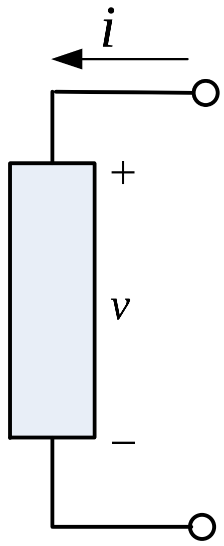
$p = 20\,W.$



passive sign convention

Passive sign convention

- Reference direction (positive current direction) for current is to enter into the positive voltage terminal of the element
- If power is positive, the element is passive (dissipating energy)
- i-v characteristics of for various circuit elements will follow this sign convention



Kirchoff’s Laws

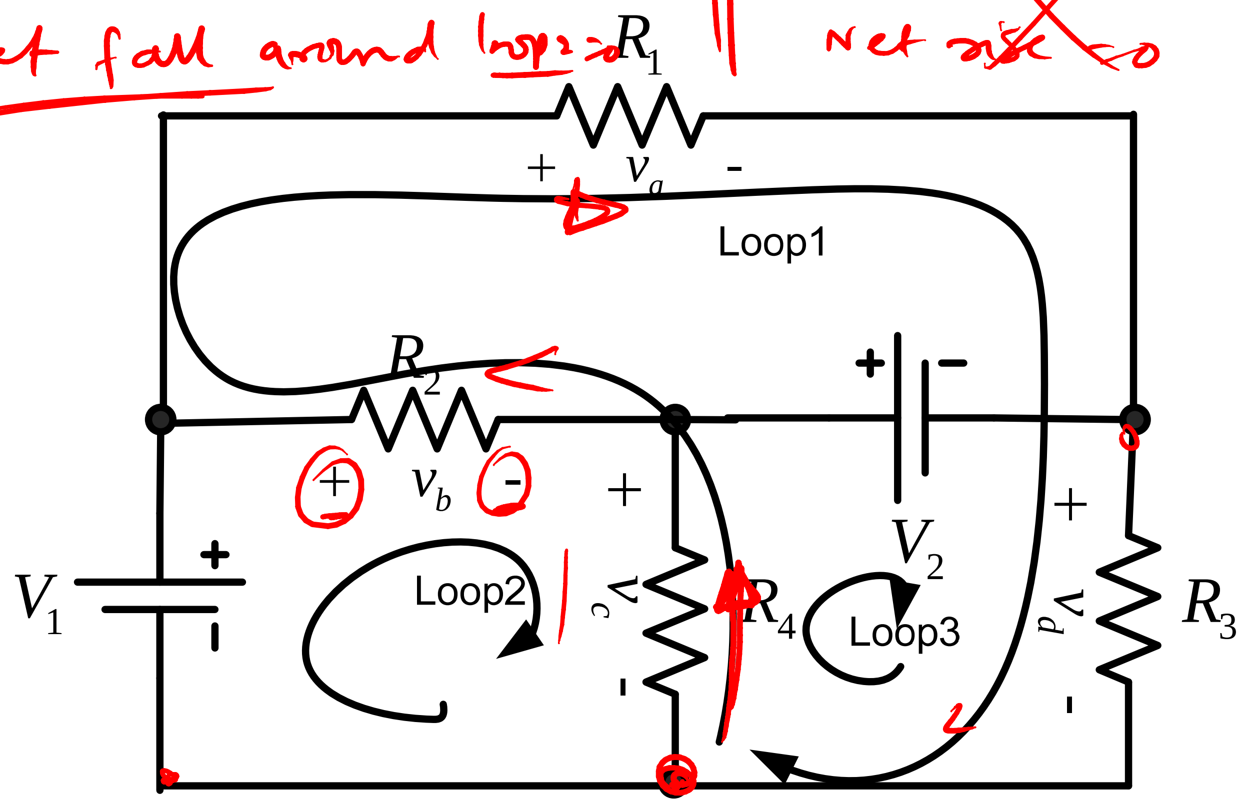
Kirchoff’s Voltage Law (KVL)

- Net voltage fall (or voltage rise) around a closed path (loop or mesh) is zero
  - Voltage rises when we go from negative polarity to positive polarity
  - Voltage falls when we go from positive polarity to negative polarity
- Imagine this law was violated!

KVL Example

$-V_1 + V_b + V_c = 0$ || $V_1 - V_b - V_c = 0$

Net fall around loop2 = 0 | Net rise = 0



Loop 3:

Net fall: $-V_c - V_b + V_a + V_d = 0$

KVL

Kirchoff's Current Law (KCL)

- Net current leaving (or entering) a node/supernode is zero
- Imagine if this law was violated!

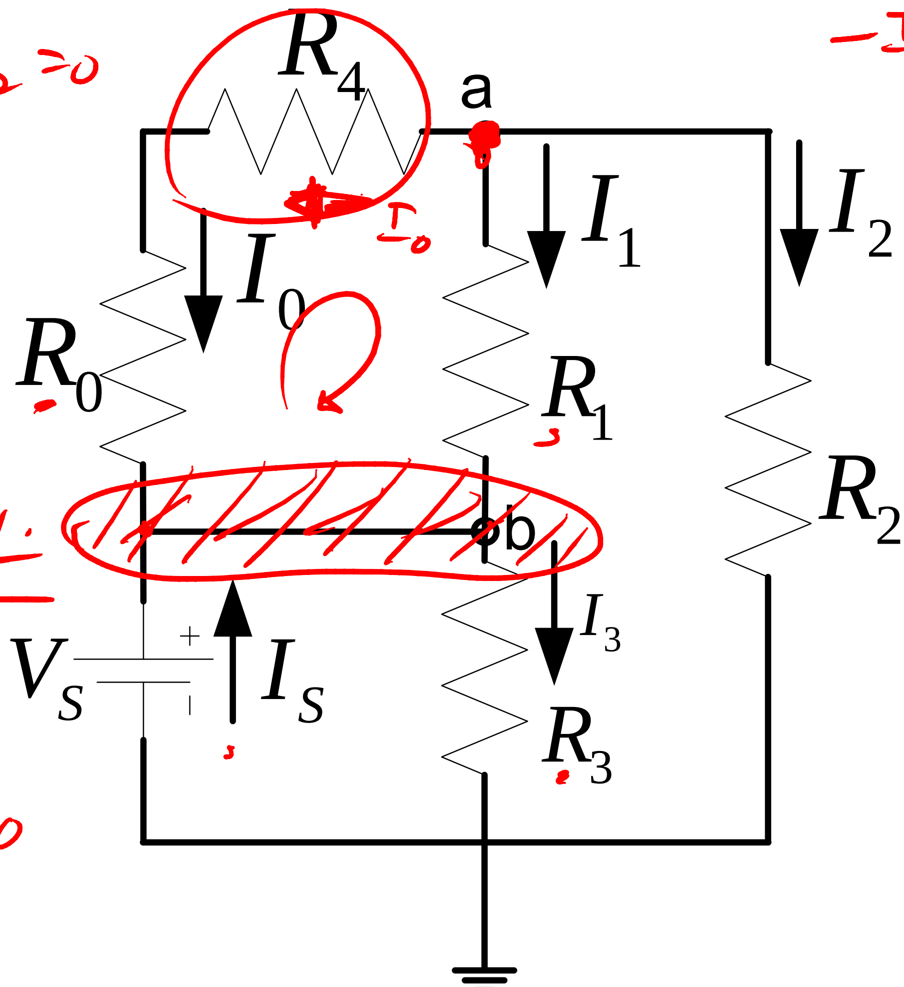
KCL Example

KCL: Leaving.

$I_0 + I_1 + I_2 = 0$

~~KCL entering~~

~~$-I_0 - I_1 - I_2 = 0$~~



S.N.

KCL at S.N. Leaving:

$-I_0 - I_1 + I_3 - I_S = 0$

R_4 and R_0 are in series

R_1 is not parallel with R_0.

Series, Parallel

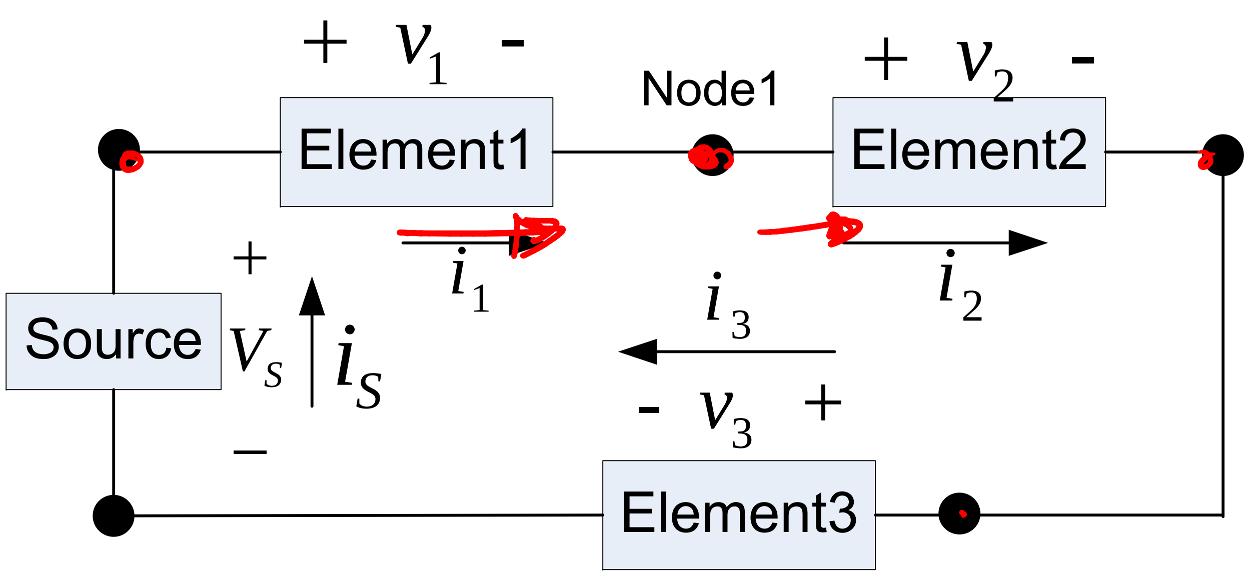
Series Conection

- When elements are connected end to end
- they carry the same current
  - Apply KCL at any node to find this

KCL at node1

$-i_1 + i_2 = 0$

$i_1 = i_2$

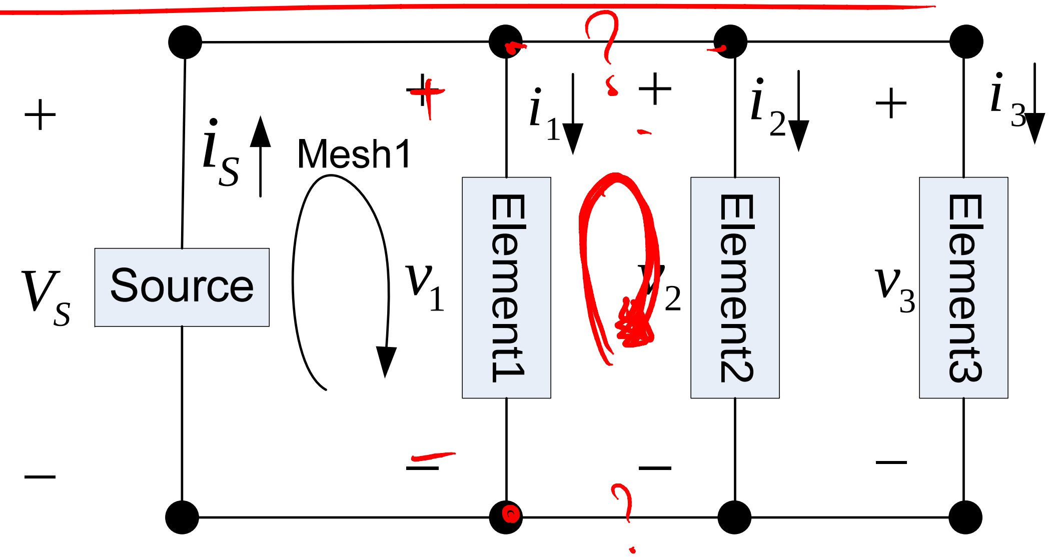


Parallel Circuit

- If both ends of one elements are connected to the corresponding ends of the other element
- Voltages across all the elements are identical
  - KVL

$-v_1 + v_2 = 0$

$v_1 = v_2$



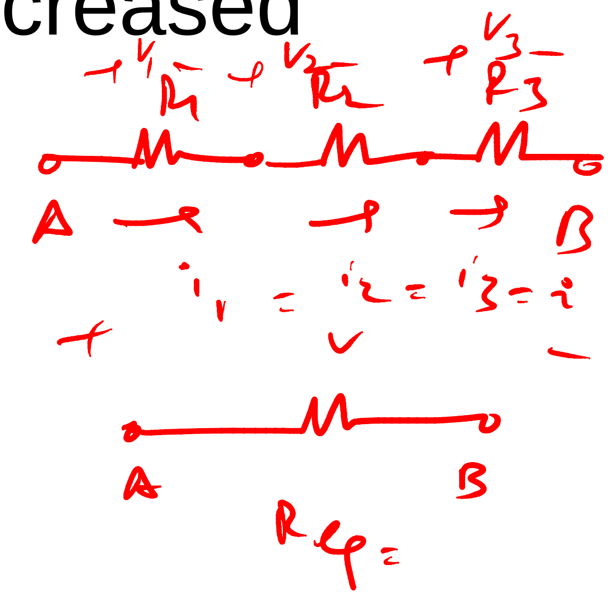
Resistances in series

- Resistors in series lead to increased resistance as they add up

$$v_1 = R_1 i, v_2 = R_2 i, v_3 = R_3 i$$

$$v = v_1 + v_2 + v_3 = \left(R_1 + R_2 + R_3\right) i = R_{eq} i$$

$$R_{eq} = R_1 + R_2 + R_3$$



- This can be used to simplify circuits

Resistances in parallel

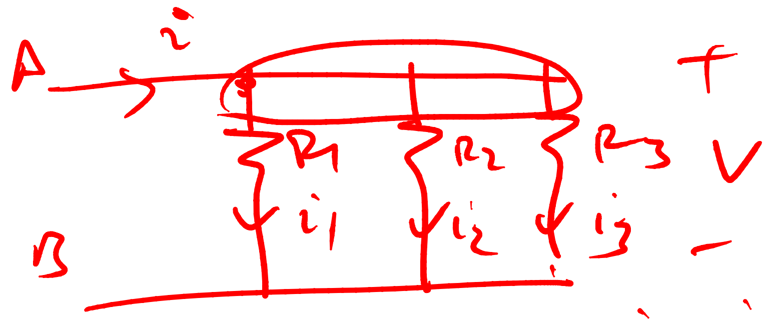
- Resistances in parallel reduce the equivalent resistance.

$$i_1 = \frac{v}{R_1}, i_2 = \frac{v}{R_2}, i_3 = \frac{v}{R_3}$$

$$i = i_1 + i_2 + i_3$$

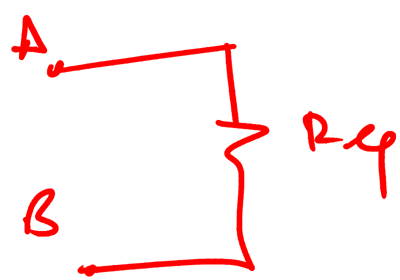
$$\frac{v}{R_{eq}} = \frac{v}{R_1} + \frac{v}{R_2} + \frac{v}{R_3}$$

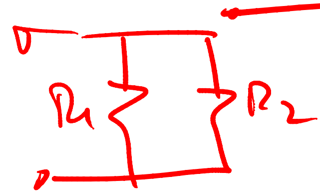
$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$



$i = i_1 + i_2 + i_3$

$\equiv$



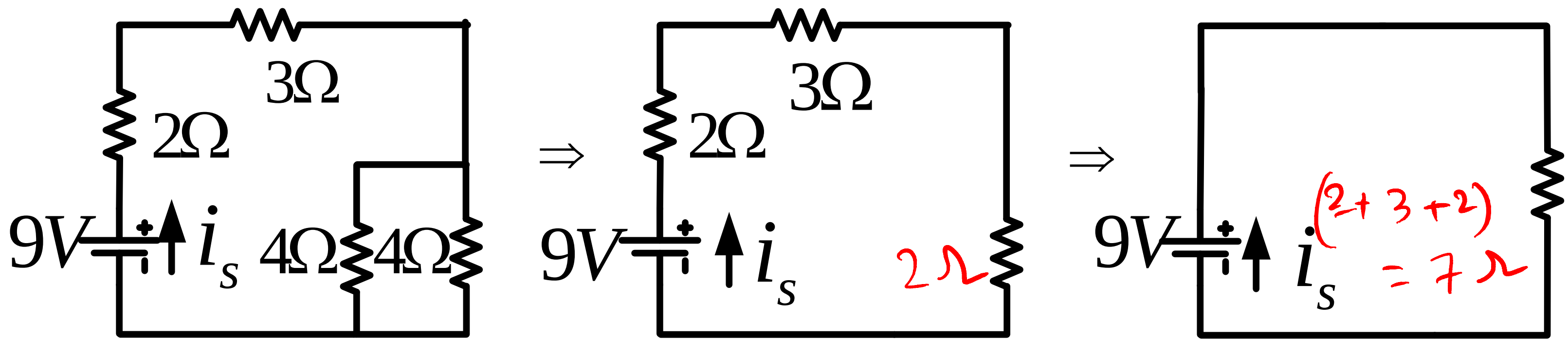


$\equiv$

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

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Network analysis by series and parallel rules for resistance



$$4\Omega \parallel 4\Omega = \frac{4\times 4}{4+4} = 2\Omega$$

$$i_s = \frac{9}{7}\ \text{A}$$