

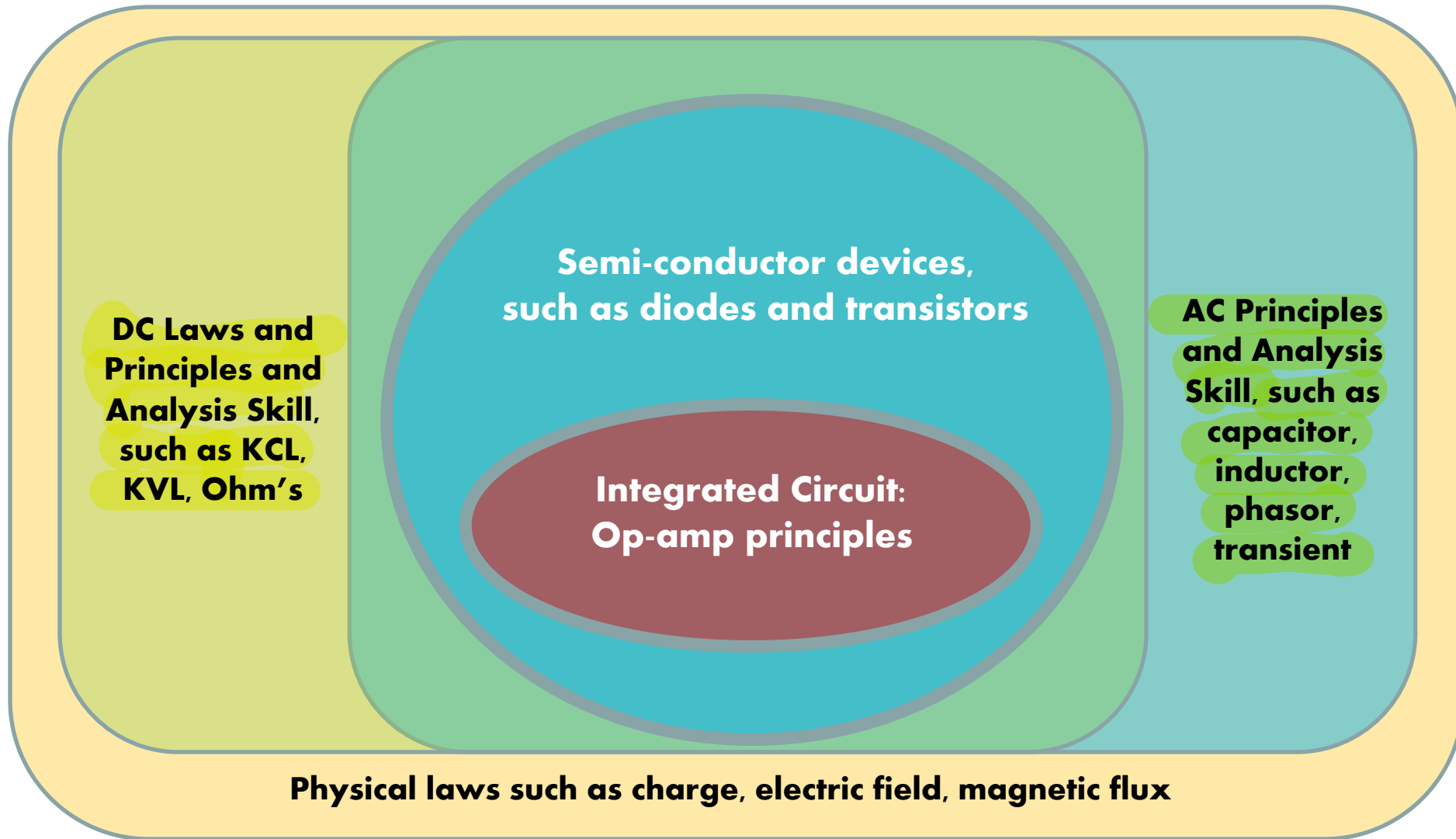
Overview of EE2005

Electronic Circuits and Devices

Week	Lecture		
	Date	Instructor	Coverage
01	2/09	Dr. Andy Chan	Review of DC circuit analysis methods
02	9/09		Equivalent circuit transformation and dependent sources
03 (Lab 1)	16/09		Diode circuits
04	23/09		Transistor devices; Basic transistor amplifiers
05	30/09		Capacitors and Inductors; Transient solutions
06 (Lab 2)	7/10		TEST 1
07	14/10	Public Holiday (Chung Yeung Festival)	
08	21/10	Dr. Rosa Chan	Impedance; Phasors
09	28/10		AC circuit analysis
10	4/11		Frequency response
11 (Lab 3)	11/11		Basics of operational amplifiers (Op Amp)
12 (Lab 4)	18/11		TEST 2
13	25/11		Op Amp circuit design and applications; Active filters (Lab Report Deadline)

Overview of EE2005

Electronic Circuits and Devices



1. Review of DC Circuit Analysis

- 1.1 Basic circuit laws and resistor networks
- 1.2 Circuit analysis methods
- 1.3 Equivalent circuit transformation and dependent sources

1.1 Basic circuit laws and resistor networks

- This unit is organized into 6 sections. The two sections cover the 3 basic laws in circuits:

I. Kirchhoff's Current and Voltage Law

II. Ohm's Law

- The remaining sections of this unit are just applications of these 3 laws together.

III. Electrical Power

IV. Sources, Short Circuit, Open Circuit

V. Resistive Networks

VI. Measuring Instruments

Alexander & Sadiku, "Fundamentals of Electric Circuits" 6th Edition Ch 1 & 2

Analogy between electricity and water

Electricity is like a water hose

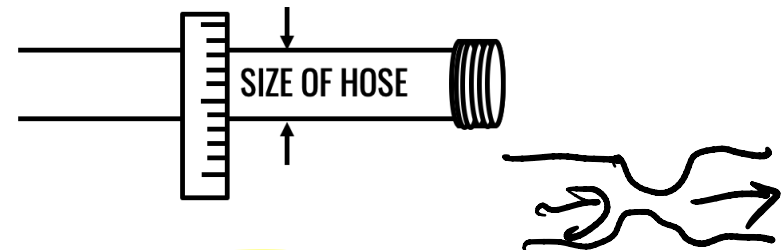
Voltage

Volts (V)



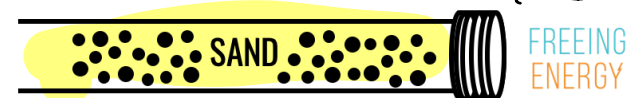
Current

Amps (A or I)



Resistance

Ohms (R or Ω)

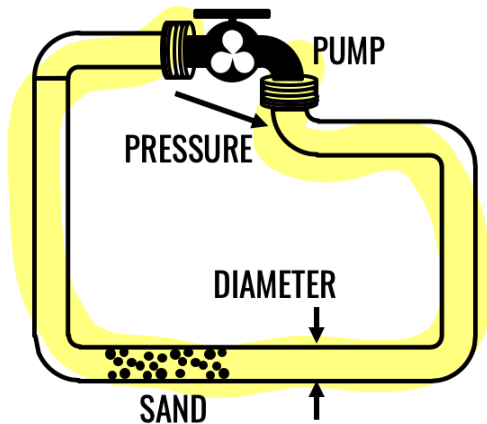


<https://www.freeingenergy.com/understanding-the-basics-of-electricity-by-thinking-of-it-as-water/>

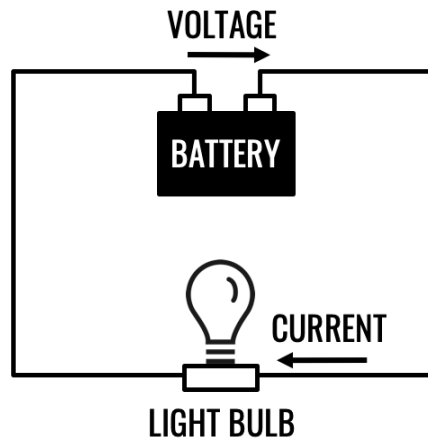
Analogy between electricity and water

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$
$$(V = I \times R)$$

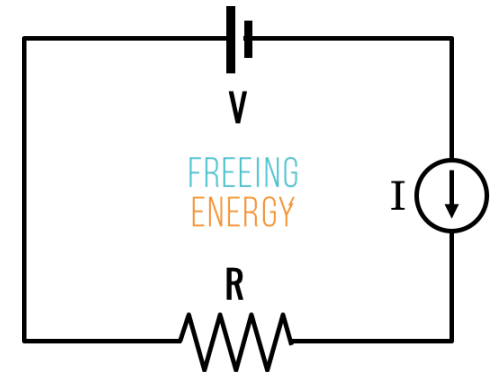
Water



Electricity



Circuit Diagram



<https://www.freeingenergy.com/understanding-the-basics-of-electricity-by-thinking-of-it-as-water/>

I. Current and Kirchhoff's Current Law

- Charge is a fundamental electrical quantity
- Typically denoted by the symbol Q , and its SI unit is the Coulomb (C)
- The smallest amount of charge that exists is the charge that is carried by an electron:

$$Q_e = 1.602 \times 10^{-19} \text{ C}$$



Always include units, otherwise there is no meaning

Current: Free electrons on the move

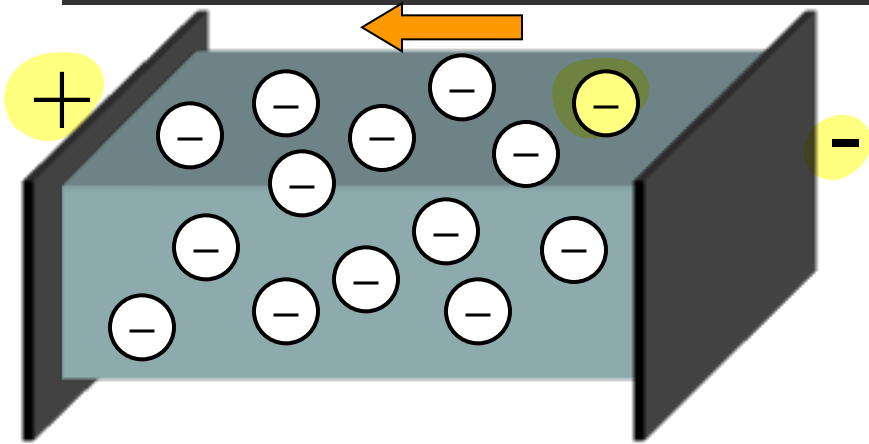


Fig 2a. A voltage is applied to move the charges

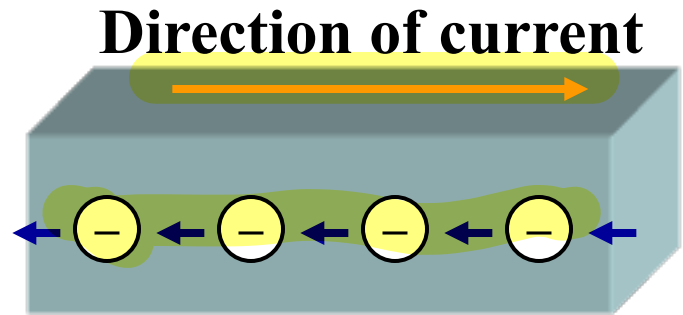


Fig 2b. Movement of electrons gives rise to current

Key Concept 1
For current to flow, there must be mobile charges

- Direction of electron flows is from negative to positive
- Direction of current flows (positive charges) is from positive to negative
- Typically denoted by the symbol, I
- SI unit is the Ampere (A)

Current must run in loops

- If a current flows out of a given point, then it must return to that point with the same amount
- Current must flow in loops
- What goes around comes around

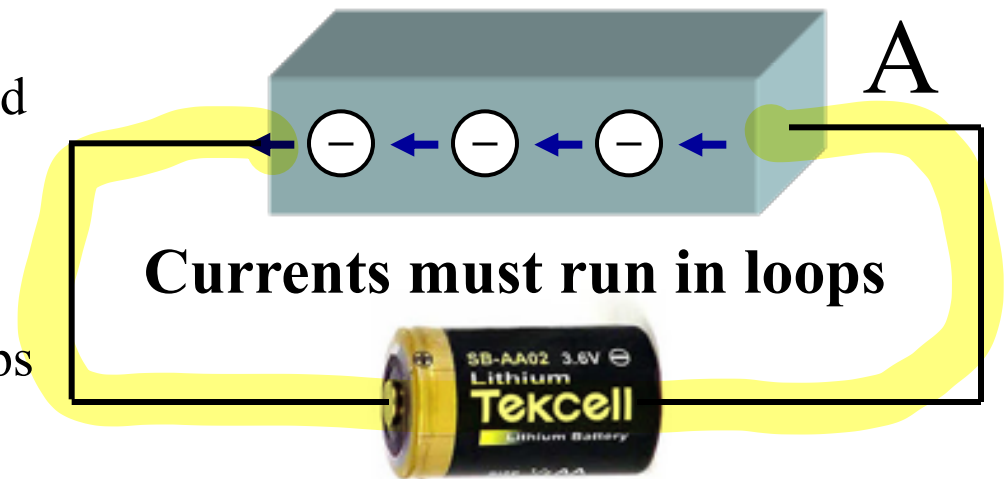


Fig 3. Current must run in loops

Key Concept 2

Currents must run in loops (otherwise charge is either destroyed or created which cannot happen)

Fundamental law for charge

- Current has to flow in closed loop
- No current flows if there is a break in the path
- Underlying physical law: Charge cannot be created or destroyed (“what goes in must also come out”)
- This is the basis of Kirchhoff’s Current Law

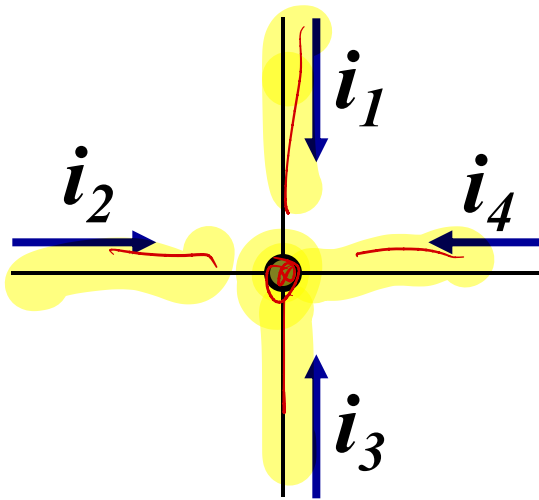


Fig 4.

Kirchhoff's current law

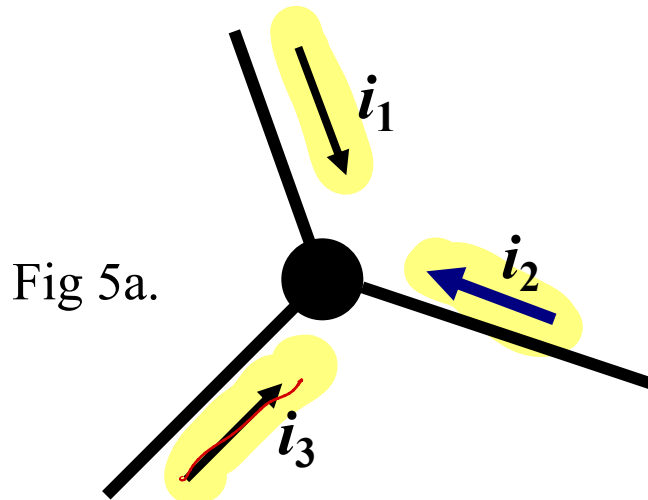
Sum of currents at a node must equal to zero:

$$i_1 + i_2 + i_3 + i_4 = 0$$

Kirchhoff's current law

Does the direction of current matter? **YES!!**

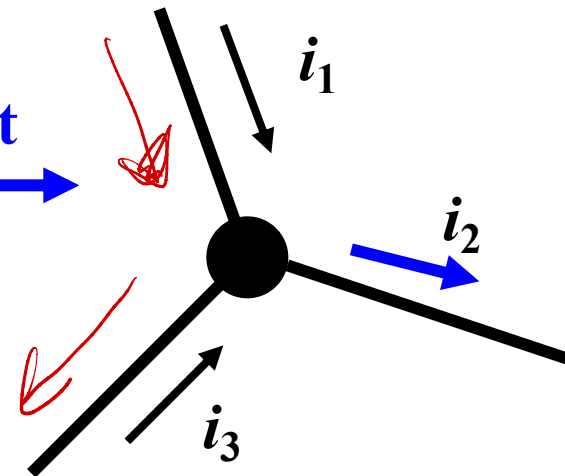
I_2 running into node



$$i_1 + i_2 + i_3 = 0$$

Handwritten red '+' and '-' signs are placed below the terms i_2 and i_3 respectively.

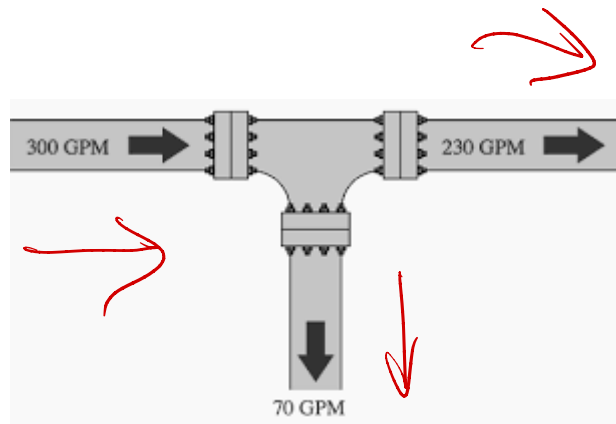
I_2 running out of node



$$i_1 + i_2 + i_3 = 0 \text{ (WRONG)}$$

$$i_1 + i_3 = i_2 \text{ (CORRECT)}$$

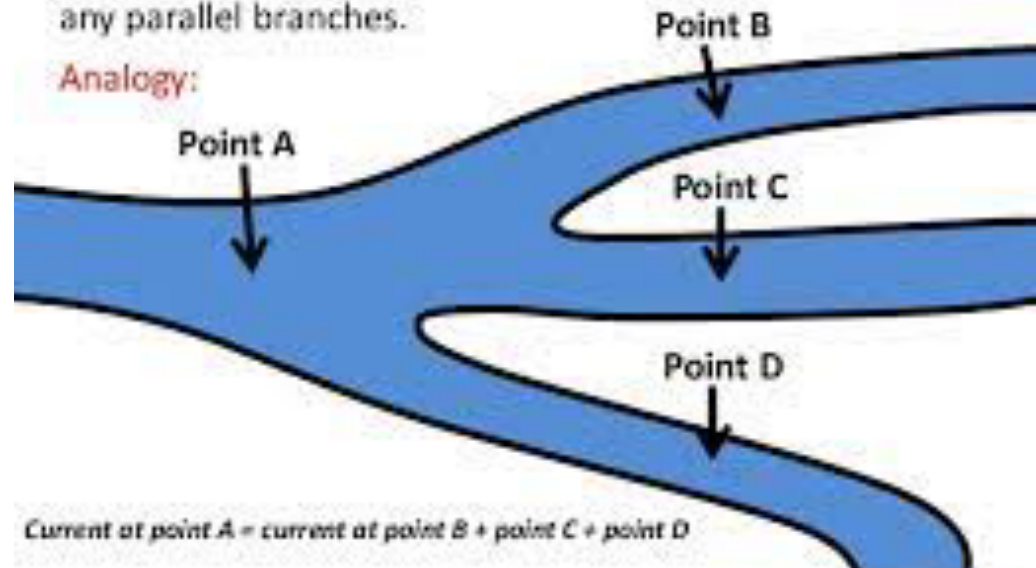
Analogy between water and current flow



Kirchhoff's Law

Kirchhoff's Current Law: In a **parallel** circuit, the total current flowing through the circuit is divided up among any parallel branches.

Analogy:

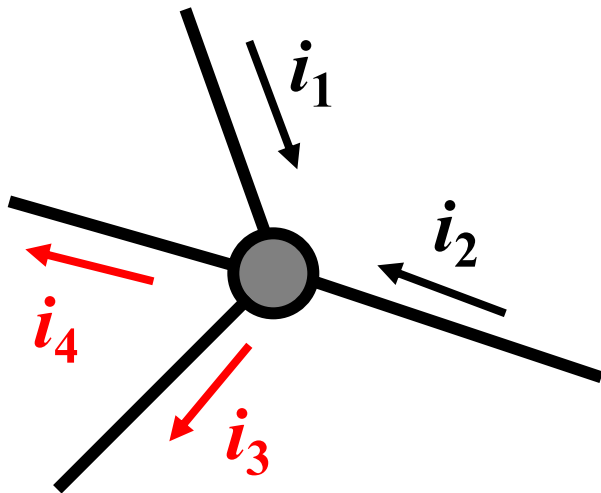


Kirchhoff's current law

Sign convention when applying KCL

Currents flowing IN - Positive

Currents flowing OUT - Negative



Entering: i_1 & i_2 (+ve)

Exiting: i_3 & i_4 (-ve)

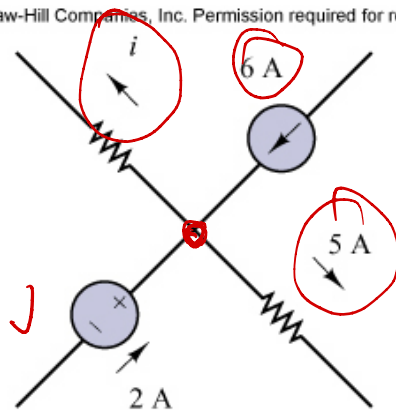
$$i_1 + i_2 - i_3 - i_4 = 0$$

$\underbrace{+ve} \quad \underbrace{+ve} \quad \underbrace{-ve} \quad \underbrace{-ve}$

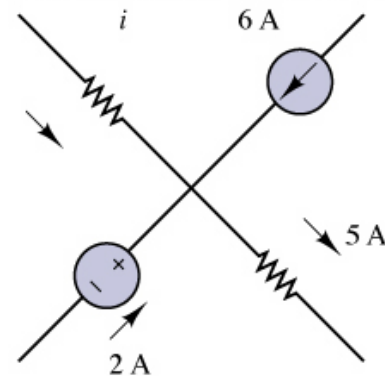
Worked Example on KCL

Find the unknown current within each of the following circuit networks

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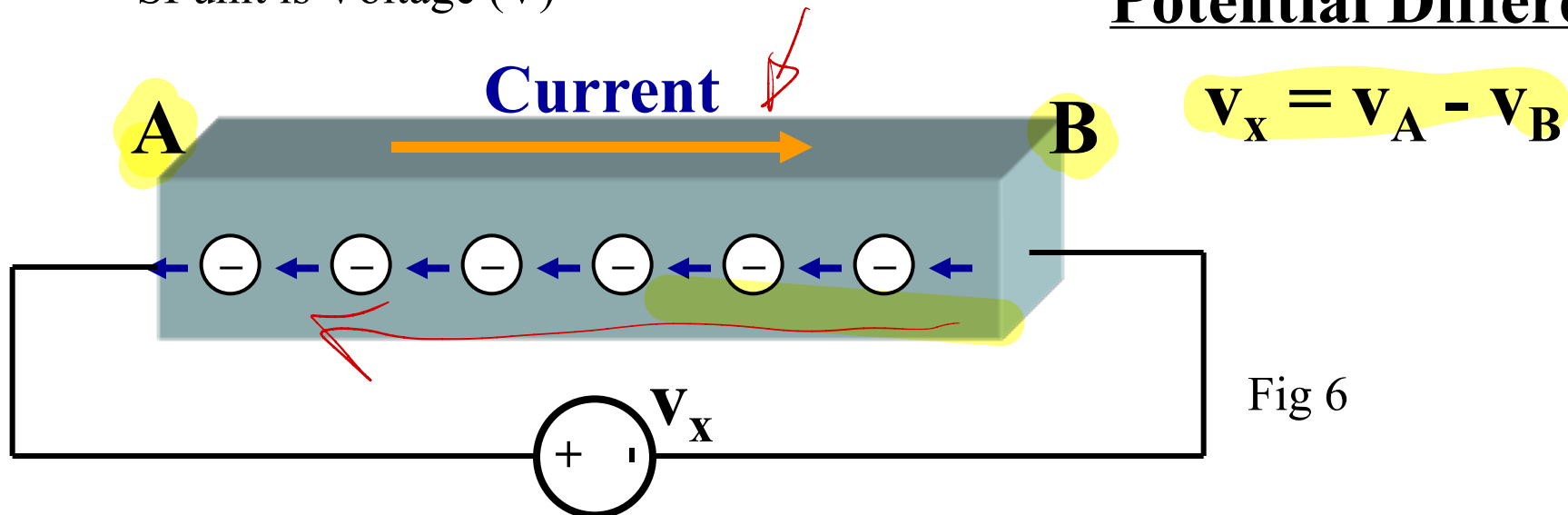


$$2 + 6 - 5 - i = 0$$
$$i = 2 + 6 - 5 = 3 \text{ A}$$

Voltage and Kirchhoff's Voltage Law

- Energy is required to move electrons between 2 points
- This energy could come from the battery cell connected to the circuit
- As the current goes across the cell, energy is pumped in
- As the current goes through a light bulb, energy is consumed
- The amount of energy required to move a unit charge is given by the voltage
- SI unit is Voltage (V)

Potential Difference



Sign Convention

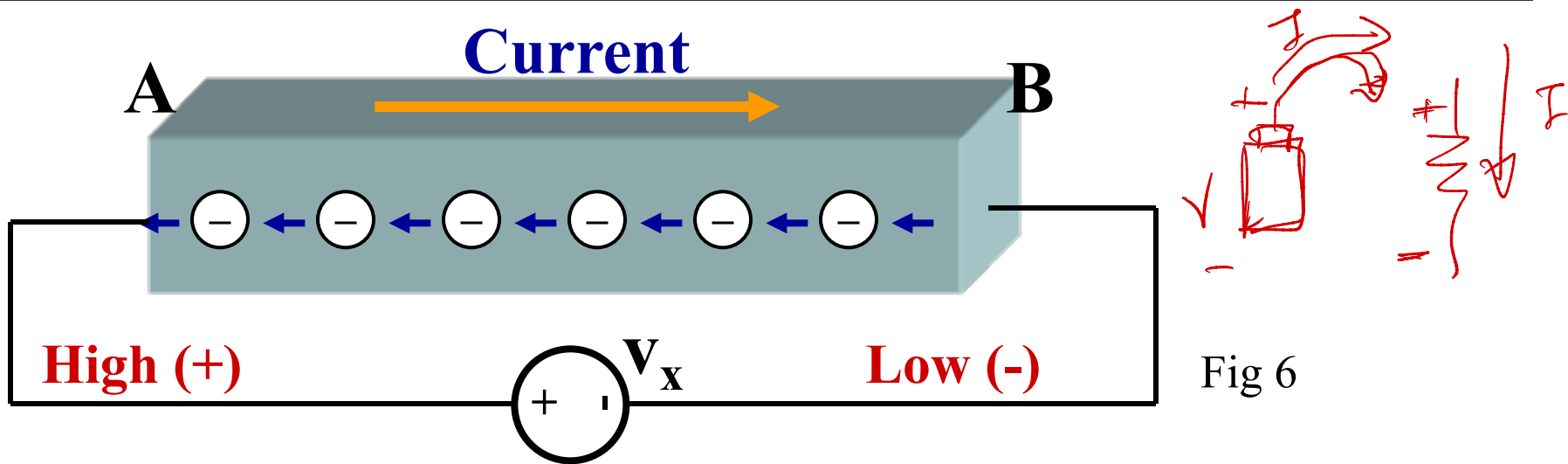


Fig 6

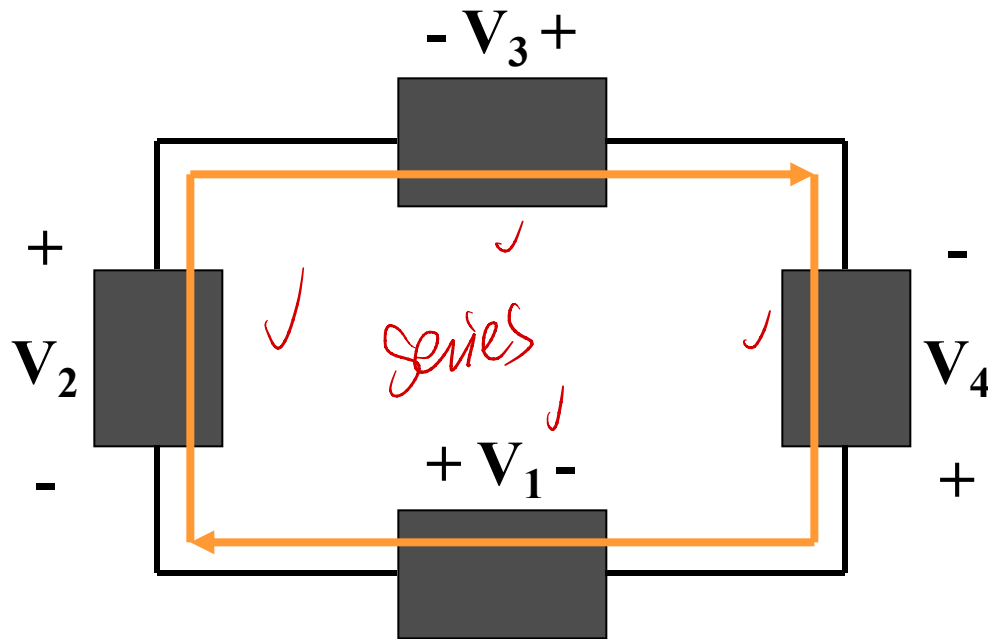
Sign Convention for Voltage

Voltage rises (negative to positive) along the direction of the current for an element that is generating power

Voltage drop (positive to negative) along the direction of the current for an element that is consuming power

Kirchhoff's Voltage Law (KVL)

- KVL states that the sum of voltages around a loop must equal to zero
- If a voltage starts at any given point, no gain or loss of any voltage when it returns to the same point
- Whatever energy is pumped into the loop must also be consumed



Kirchhoff's voltage law

Net voltage around a closed circuit is zero:

$$v_1 + v_2 + v_3 + v_4 = 0$$

Fig 7: Voltages around a closed loop

Kirchhoff's voltage law

- First, you need to define the direction
 - V_1 and V_3 are voltage rises (positive) while V_2 is a voltage drop (negative)
 - In the other direction, V_2 is voltage rise (positive), while V_1 and V_3 are voltage drops (negative)
- $V_2 - V_1 - V_3 = 0$

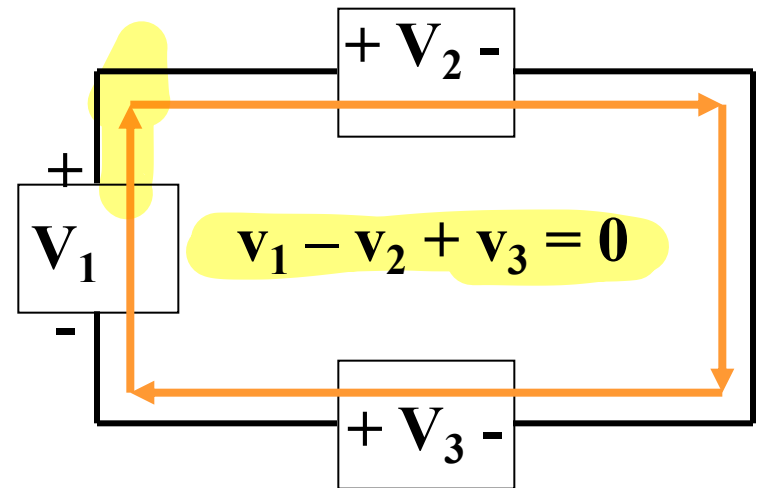


Fig 8: Defined voltage drops and rises

Sign Convention for KVL
Voltage RISE – Positive
Voltage DROP – Negative

Analogy between height and voltage

Kirchhoff's Law



Kirchhoff's Voltage Law: In a **series** circuit, the total voltage supplied by the source must equal the total voltage used by all of the loads in that path.

Analogy:

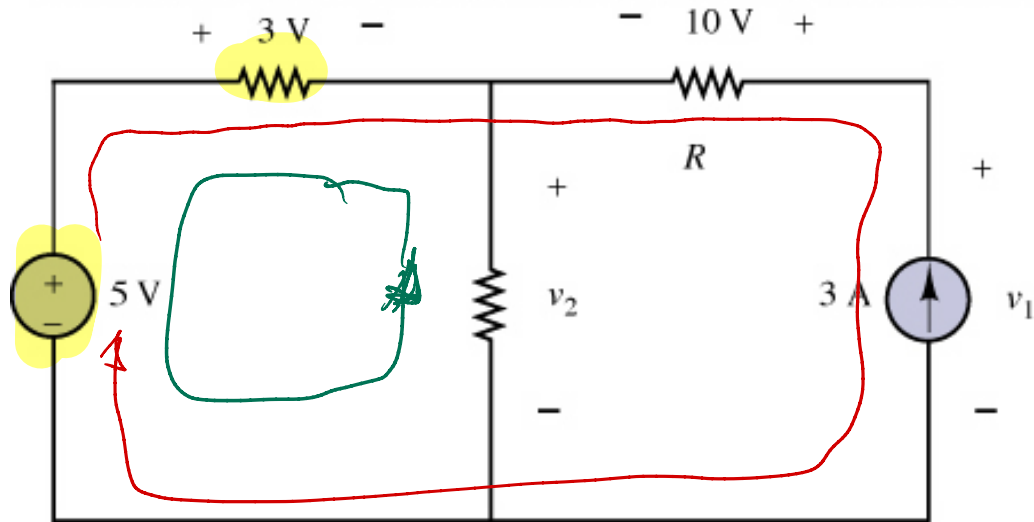


<https://www.slideshare.net/mrtangextrahelp/16-intro-to-kirchhoffs-law>

Worked Example on KVL

Apply KVL to find voltage V_1 and V_2

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To find V_1

$$5 + (-3) + (+10)$$

$$-V_1 = 0$$

$$5 - 3 + 10 - V_1 = 0$$

$$V_1 = 5 - 3 + 10 \\ = 12 \checkmark$$

$$-5V + V_2 + 3 = 0 \\ V_2 = 5 - 3 = 2 \checkmark$$

II. Resistance and Ohm's Law

- When current flows through a conductor, it will always experience some resistance
- Resistance is given by the change in voltage over change in current
- SI unit is Ohm (Ω)
- If the voltage is linear with current, then resistance is said to be linear and obeys Ohm's law

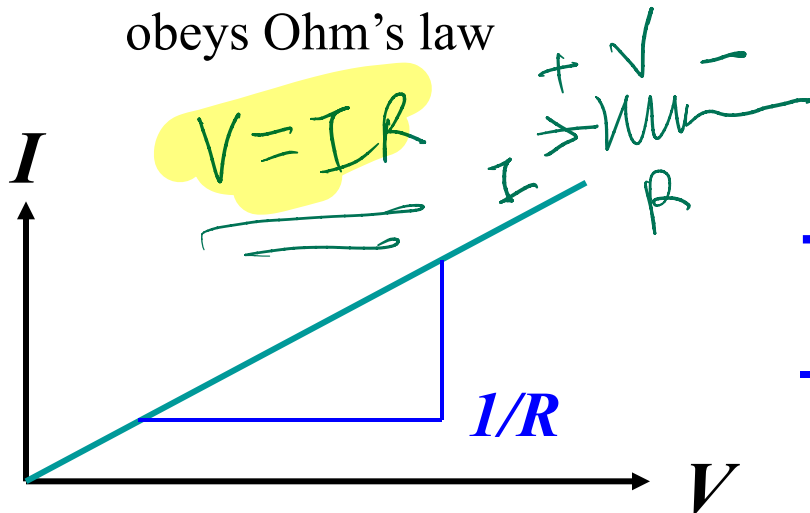


Fig 9a: Linear resistance that obeys Ohm's law

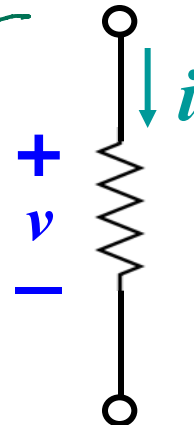


Fig 9b

Ohm's law is given as:

$$V = IR$$

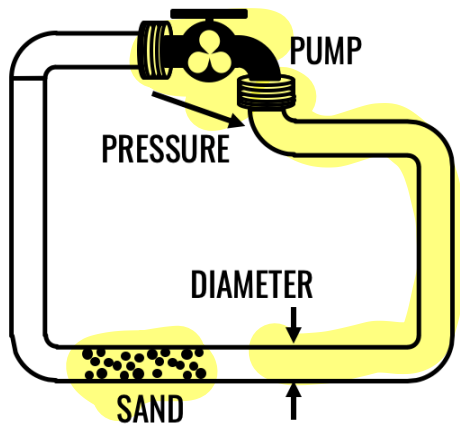
Important point to note:

If an unknown current is defined to flow from A to B, the voltage at A is assumed to be higher than B.

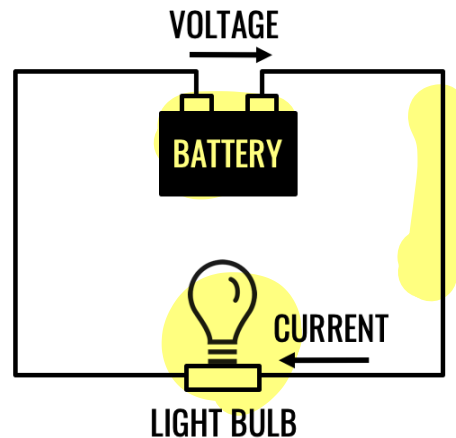
Recap: Analogy between electricity and water

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$
$$(V = I \times R)$$

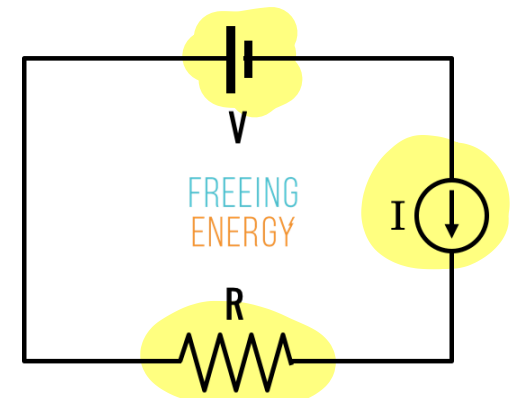
Water



Electricity



Circuit Diagram

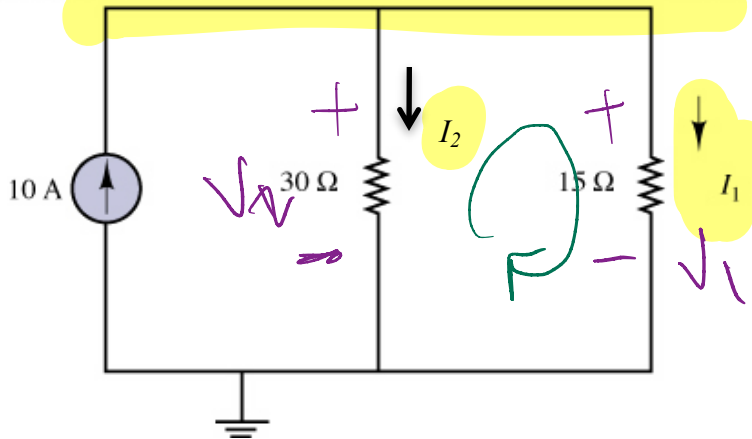


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Worked Example Applying 3 Laws

Find the current through the 15Ω resistor I_1

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KCL: $10 - I_2 - I_1 = 0$ (1)

KVL: $V_2 - V_1 = 0$

$V_2 = V_1$

$30I_2 = 15I_1$ (2)

ohm's law

superconductor

III. Electrical Power

- A voltage drop in the direction of the current indicates the power is consumed
- Conversely, a voltage rise in the direction of the current indicates that power is generated
- If the voltage across a resistor is V , and current through it is I , then the power consumed is given by:

$$P = VI$$

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

$$\text{Ohm's law} \rightarrow P = I^2 R$$

$$\text{Ohm's law} \rightarrow P = V^2 / R$$

Power generated by source

MUST EQUAL

Power dissipated in the load

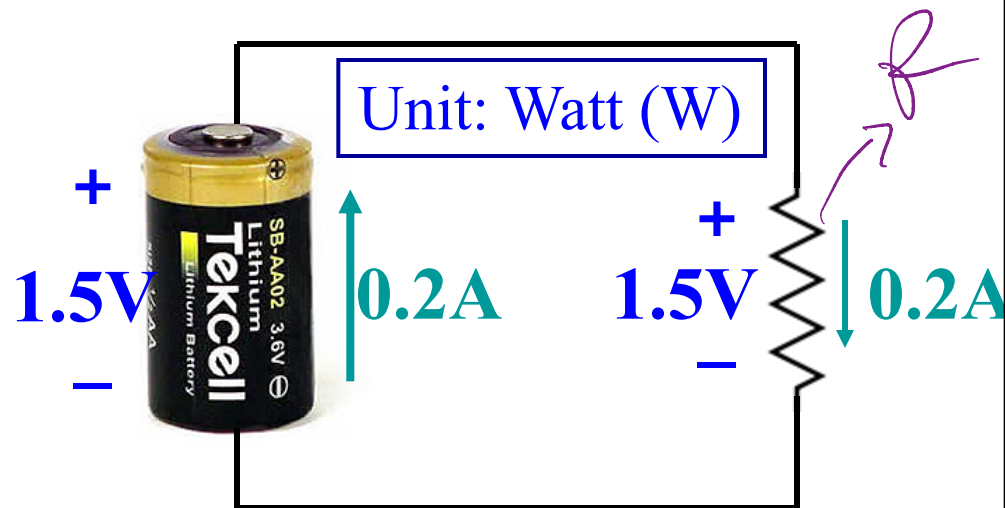
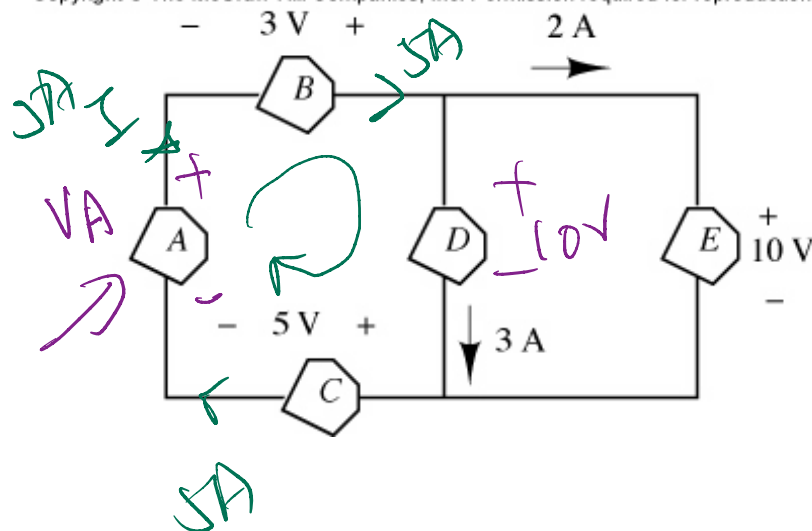


Fig 10: Power generated and consumed in a circuit

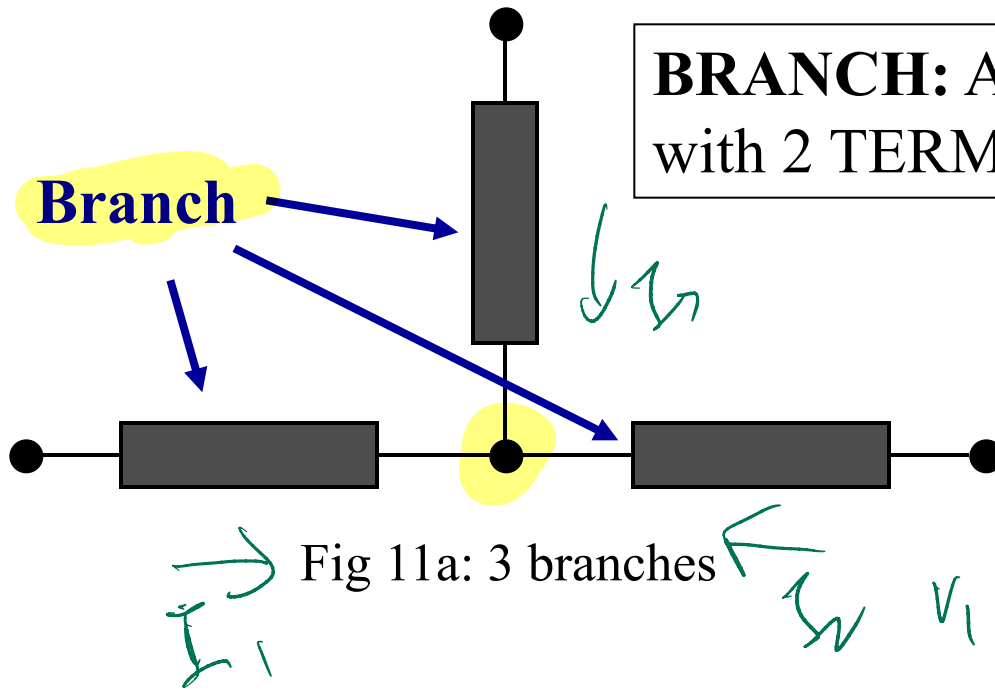
Worked Example on Power

Determine which components are absorbing power and which are delivering power

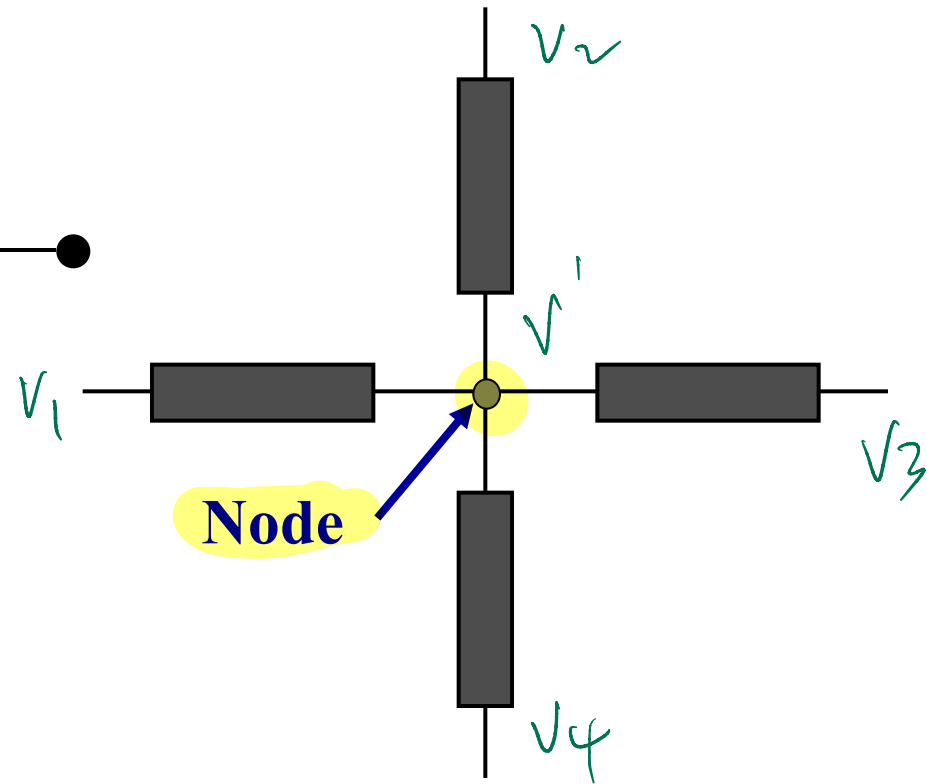
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Terminology: Branch and Node



BRANCH: Any path of a circuit with 2 TERMINALS connected to it



NODE: Junction of 2 or more branches

Fig 11b: 1 node

Terminology: Loop and Mesh

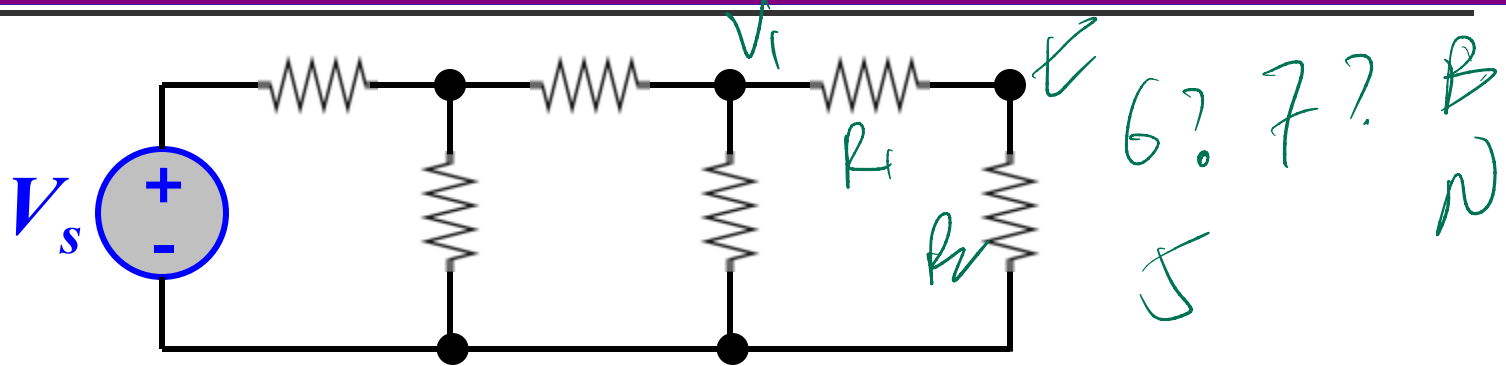


Fig 12: Loops (6) and meshes (3)

- **Loop:** Any closed connection of branches
- **Mesh:** Loop that does not contain any loops
- In Fig 12, there are 6 loops and 3 meshes.
- We will use the term mesh more than loop in this course

IV. Sources, Short Circuit and Open Circuit

- Loads (e.g. resistors) consume power
- Sources on the other hand deliver power

Ideal Voltage Source

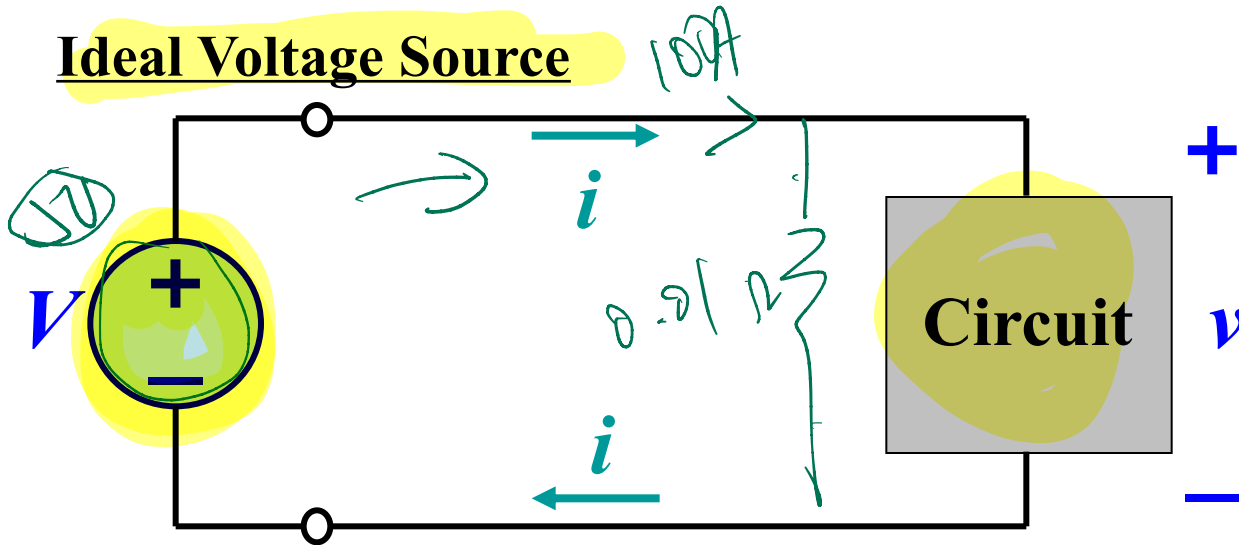


Fig 13a: Ideal voltage source in a circuit

- The purpose of a voltage source is to keep the voltage across its terminals unchanged
- Current through a voltage source is allowed to change in order to maintain the voltage at V with reference to Fig 13a

Ideal Current Source

Ideal Current Source

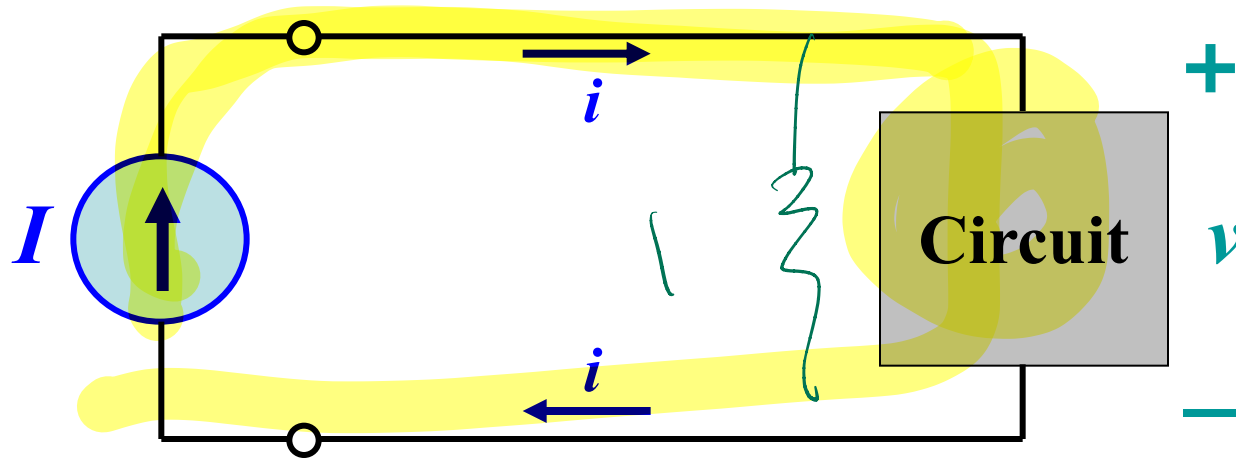


Fig 13b: Ideal current source in a circuit

- The purpose of a current source is to keep the current flowing through it unchanged
- Voltage across a current source is allowed to change in order to maintain the current at I with reference to Fig 13b

Recognize the differences between an ideal voltage and current source in their functions and symbols.

Short Circuit

- A short circuit means connecting 2 or more terminals together so that the voltage between them is zero
- It is typically associated with currents rather than voltage, e.g. short circuit current

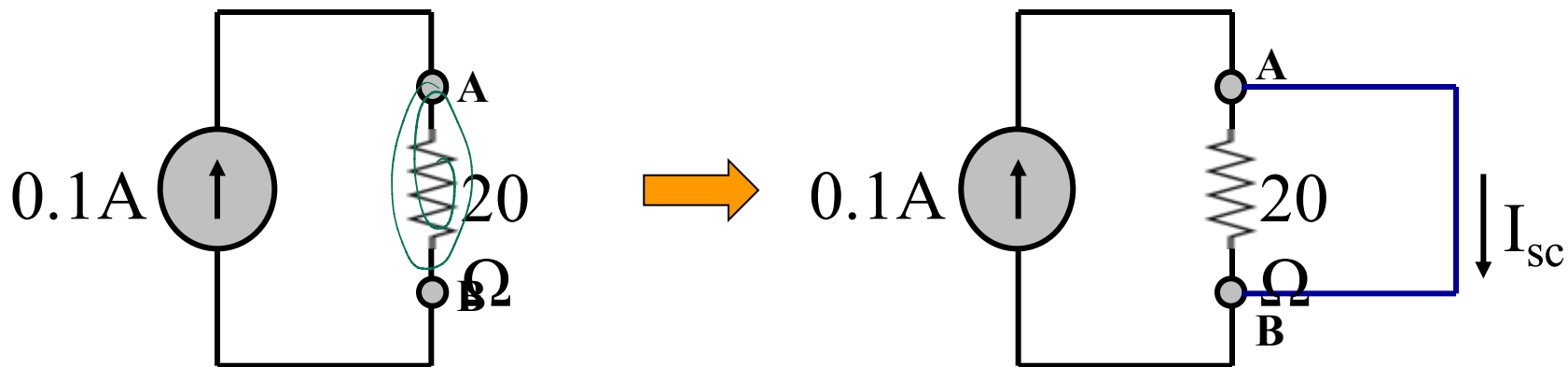


Fig 14a: Short circuiting the resistor

- All the current from the source flows through the short circuit, bypassing the resistor
- Short circuit current $I_{sc} = 0.1 \text{ A}$

Open Circuit

- A open circuit means no extra connections are imposed across two terminals
- It is typically associated with voltage rather than current, e.g. open circuit voltage

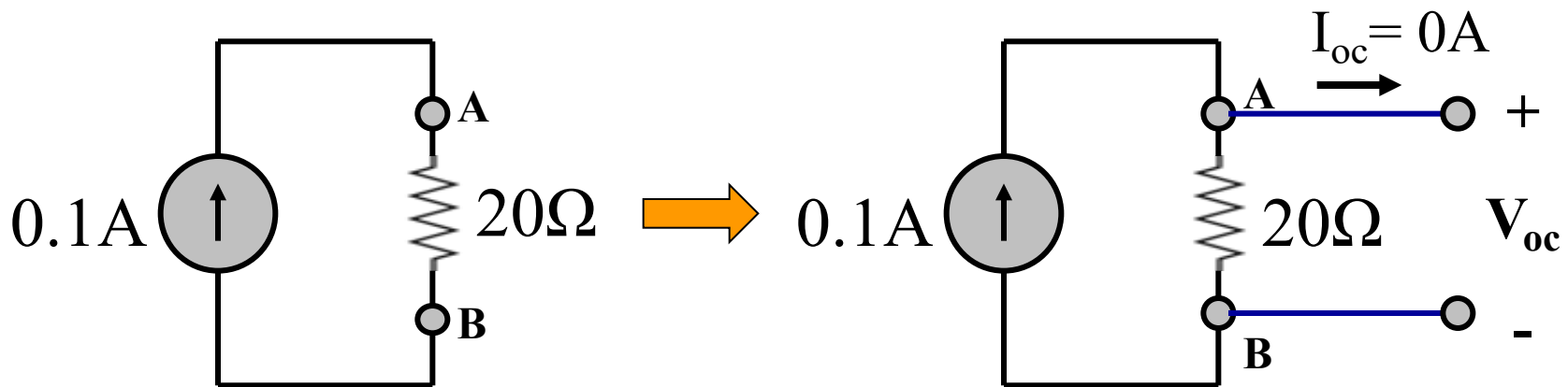
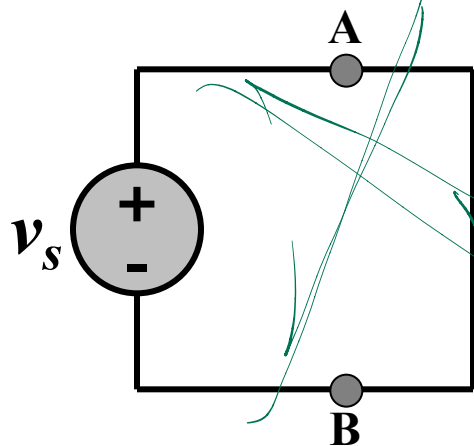


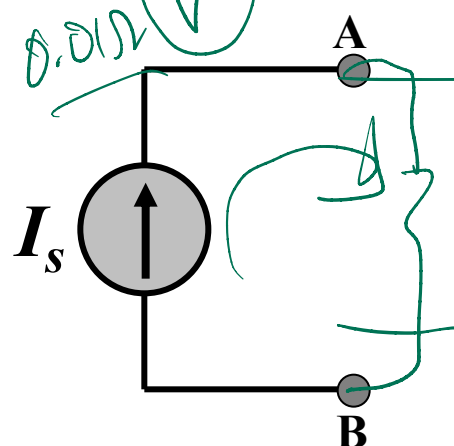
Fig 14b: Open circuiting the resistor

- In Fig 14b, the open circuit voltage of the resistor is simply the voltage across the resistor
- Open circuit Voltage $V_{oc} = 2\text{ V}$

Self-contradictory circuits??



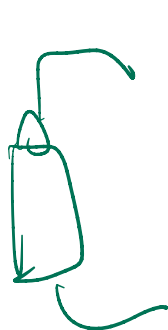
What is the voltage across A and B?



What is the current through the source?

Can battery
 $I = ?$
 0.01Ω
 V

AA 1.5V
 AAA



Prefixes

- As engineers, it is important that we replace exponents with prefixes
- For example:
0.00215 A $\rightarrow$ 2.15 mA
never 2.15×10^{-3} A
- Make sure you memorize the prefixes from nano (n) to mega (M)

Prefixes: Memorize and **apply** them!

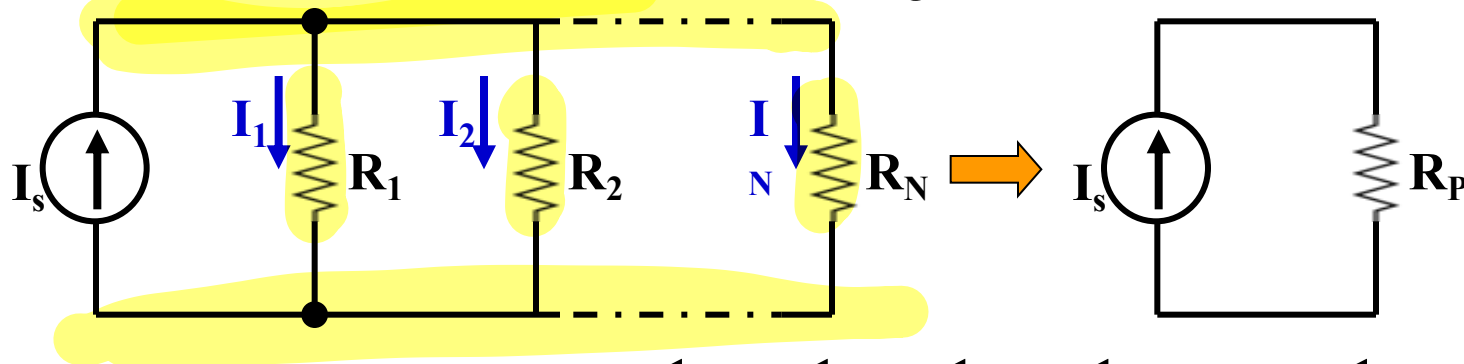
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

V. Resistive Networks

- Resistors are either arranged in parallel or in series or as combination of both

Parallel Network

Fig 15a: Parallel resistive network



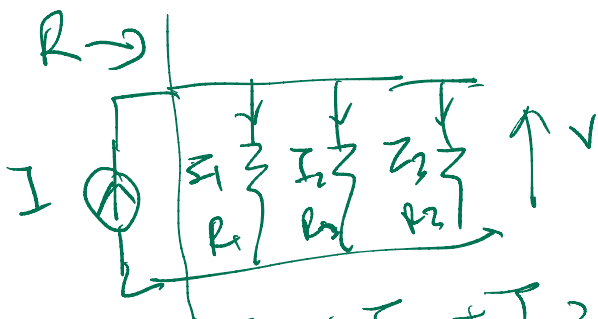
Equivalent Resistance R_P :

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_N}$$

Current Divider Rule

$$I_k = \frac{R_P}{R_k} I_s$$

- Current (I_s) from the source will have to be shared between the resistors (R_k) in each branch



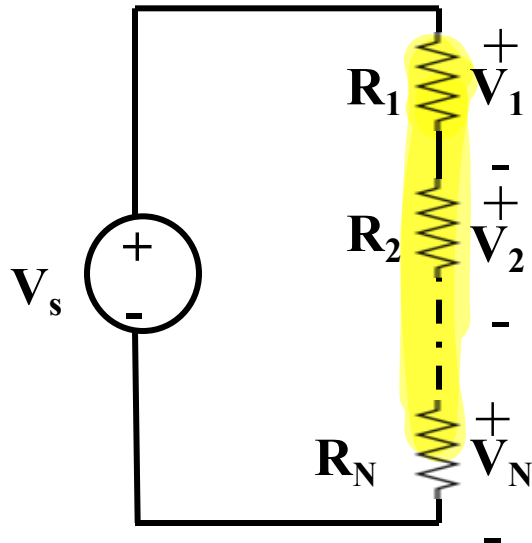
$$I = I_1 + I_2 + I_3 \quad \dots$$

$$\cancel{V} / R = \cancel{V} / R_1 + \cancel{V} / R_2 + \cancel{V} / R_3 \quad \dots$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \dots$$

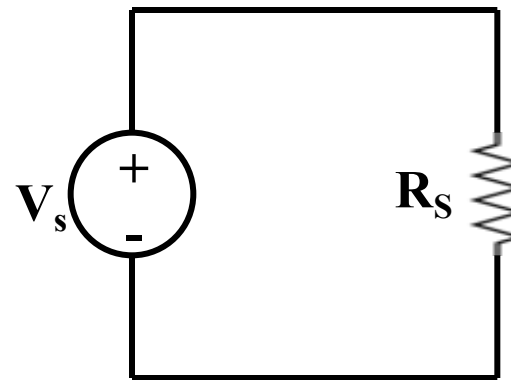
Series network (Highlights)

Series Network



Equivalent Resistance R_p :

Fig 15b: Series resistive network



$$R_S = R_1 + R_2 + \dots + R_N$$

Voltage Divider Rule

$$V_k = \frac{R_k}{R_S} V_S$$

- Total voltage drop across all the resistors (V_s) in series is the sum total of voltage (V_k) drops across each resistor