Intro to ECSE Class 07: Electric Circuit Fundamentals

I| Terminology & Basic Quantities

1. **Charge**: what flows through a circuit.
   electrons have "-" charge.
   - → units: Coulombs (C)
   - → Variable: Q or q
   - → most fundamental quantity in a circuit

2. **Current**: flow of charge
   - → definition: Charge passing a point / time
   - → units: Amperes (A) = $\frac{\text{Coulombs (C)}}{\text{second (s)}} = C/s$
   - → Variable: I
   - → Terminology: Current **flows**
     - through an element (i.e. resistor)
     - into or out of a location (i.e. node)
     - Mathematical def.: $I = \frac{\Delta \text{Charge}}{\Delta \text{time}} = \frac{dQ}{dt}$

3. Voltage : an electrical potential difference

→ units : Volts (V)

→ variable : V

→ Terminology : voltage

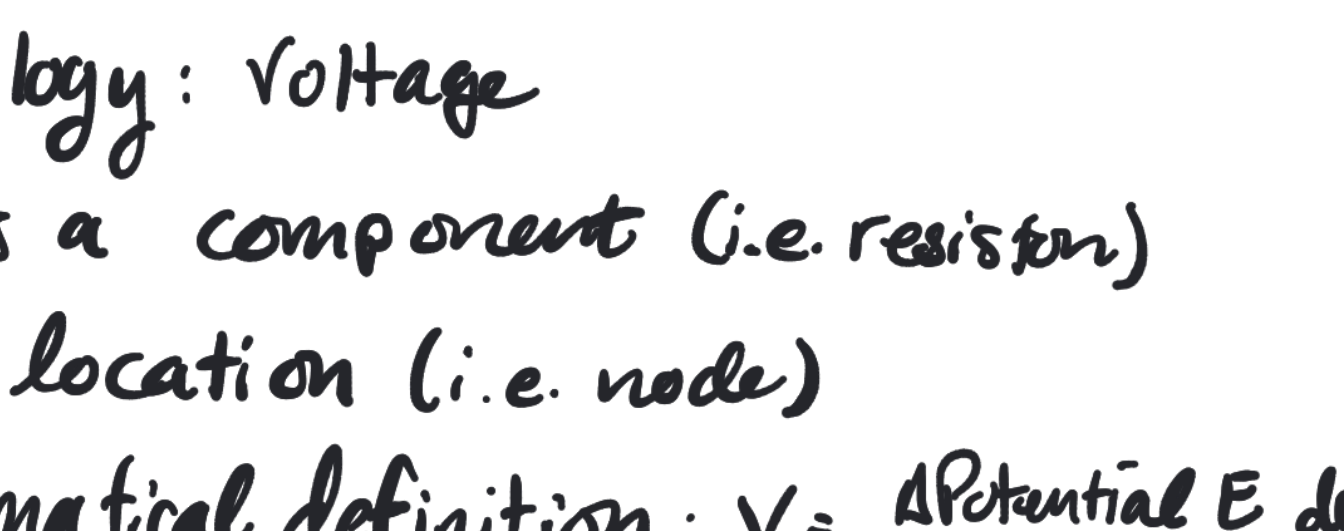
- across a component (i.e. resistor)
- at a location (i.e. node)
- mathematical definition : $V = \frac{\Delta \text{Potential Energy}}{\Delta \text{Charge}} = \frac{dU}{dQ}$

→ Note : voltage is always measured between 2 points : differential measurement

4. Ground : our standard reference pt. for all voltages : $V_{gnd} = 0$

→ Symbol: ⏚ ▽

→ Examples:



$V_A = 5V - 0V = 5V$

$V_B = -5V$

5. Power: Work done by a circuit

→ Units: Watts (W) = $\frac{\text{energy}}{\text{time}}$ = J/s

→ Variable: P

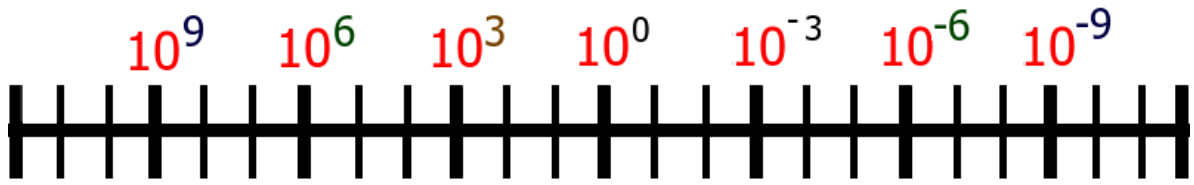
→ Terminology: power is

- dissipated by a component (ie resistor)
- delivered to an element (i.e. resistor)
- mathematical definition: $P = \frac{\Delta \text{energy}}{\Delta \text{time}} = \frac{dE}{dt}$

→ Note: power is always in reference to a circuit element. Something must be using it.

II | Metric Prefixes

- Appear before units and correspond to a power of 10.

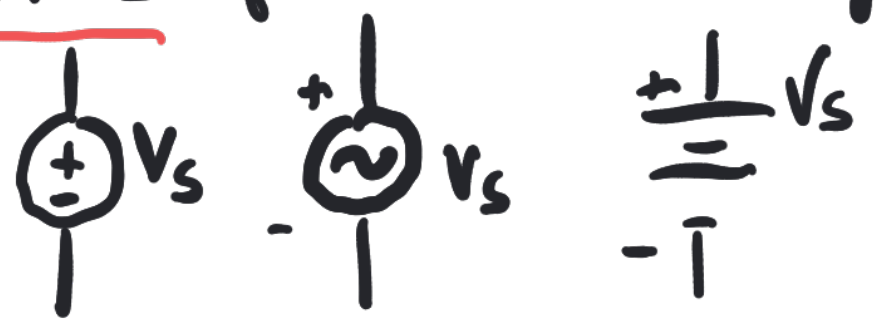


Power	Prefix	Example ECSE Unit	Example ECSE Use
10^{-9}	nano-	meters	IC dimensions (transistors)
10^{-6}	micro-	Henries	inductors (standard)
10^{-3}	milli-	amperes	typical circuit current
10^{-2}	centi-	meter	scale (semiconductor physics)
10^{0}	—	volts	typical voltage
10^{3}	kilo-	ohms	(standard) resistors
10^{6}	mega-	watts	power (power plant)
10^{9}	giga-	bytes	computer storage (standard)
10^{12}	tera-	flops	processing power
10^{-12}	pico-	farads	capacitors (standard)
10^{-15}	femto-	seconds	timescale for radiation (lasers)
10^{18}	exa-	bytes	big storage
10^{15}	peta-	bytes	"

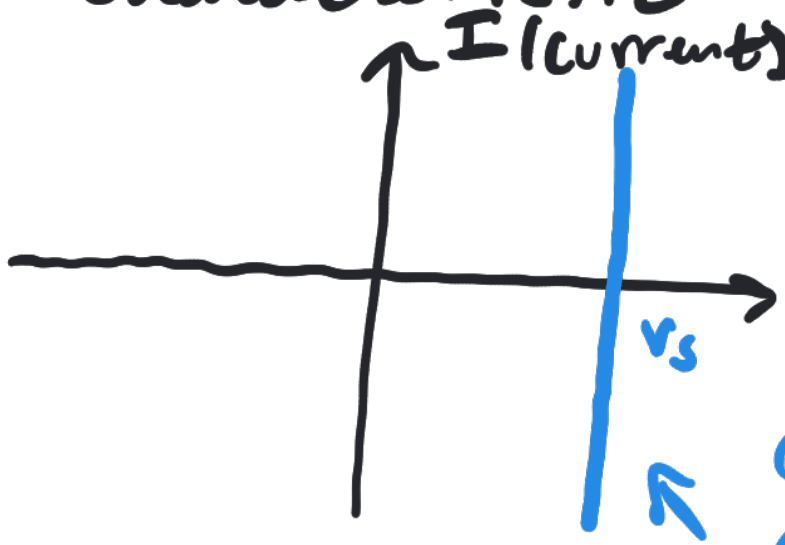
III. Basic Circuit Elements

1. Voltage Source: provides a voltage to circuit

→ Symbol:



→ I-V Characteristic: fingerprint of circuit component



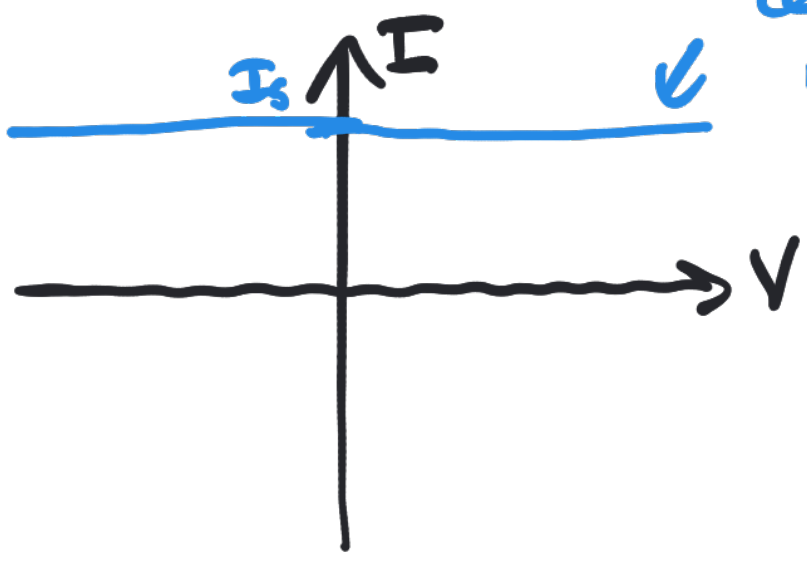
constant voltage regardless of current value

→ Examples: DC power supply, battery, function generator

2. Current Source: provides a constant current

→ Symbol:

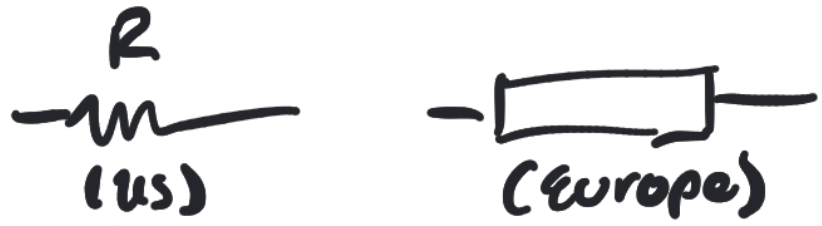
→ I-V Characteristic



constant current regardless of voltage value

→ Examples: photodiode, transistors

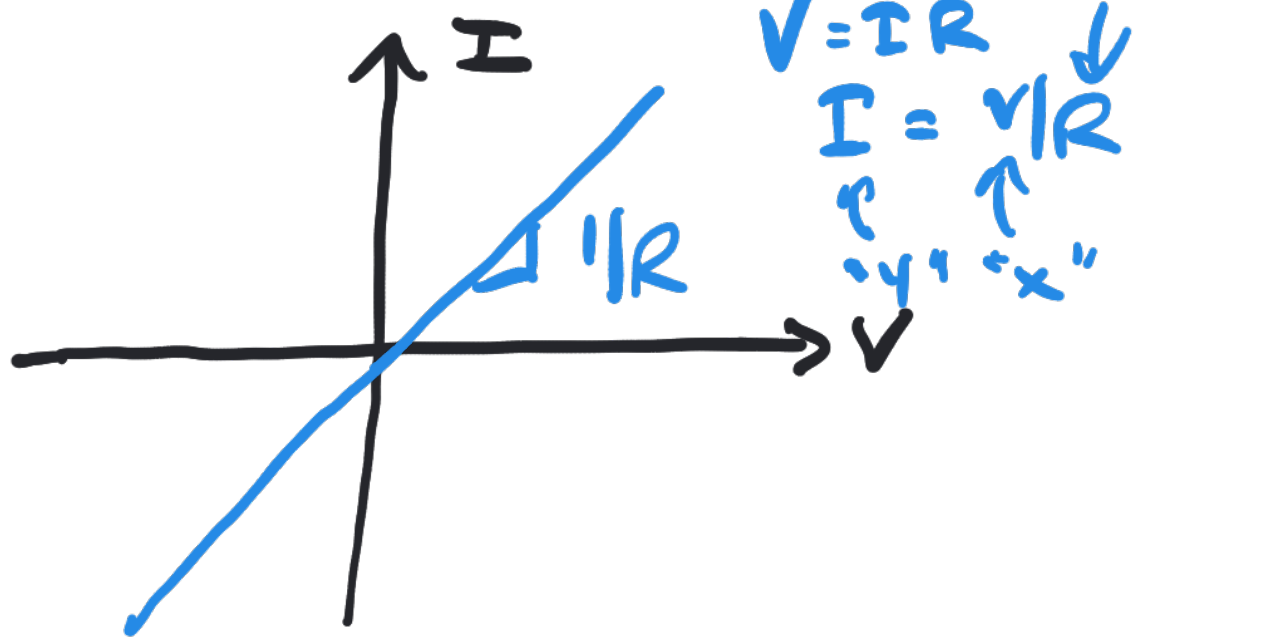
3. Resistor

→ Symbol: 

→ Variable: R

→ Units: Ohms (resistance) = $\frac{\text{Volts}}{\text{Amperes}} = \frac{V}{A}$ (Ω)

→ I-V Characteristic



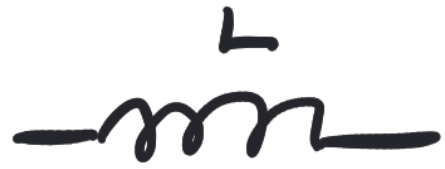
4. Capacitor

→ Symbol: 

→ Variable: C

→ Units: Capacitance : farads (F)

5. Inductor

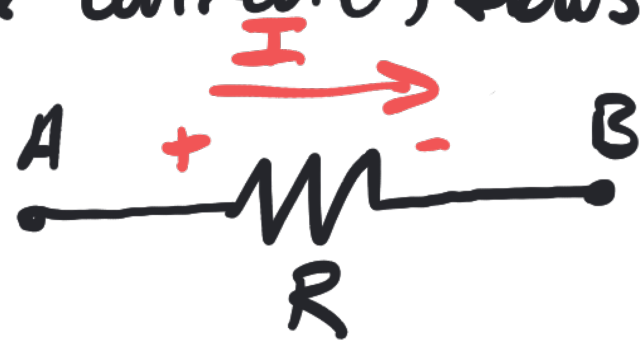
→ Symbols: 

→ Variable : L

→ Units : Inductance = Henries (H)

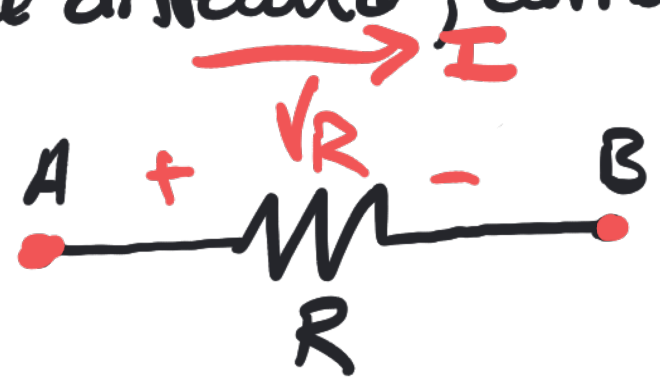
IV Fundamental Circuit Laws

1. **Passive Sign Convention**: In EE, current (conventional current) flows from "+" to "−"



2. **Ohm's Law**: relates voltage difference, current, and resistance

$$\Delta V = IR$$

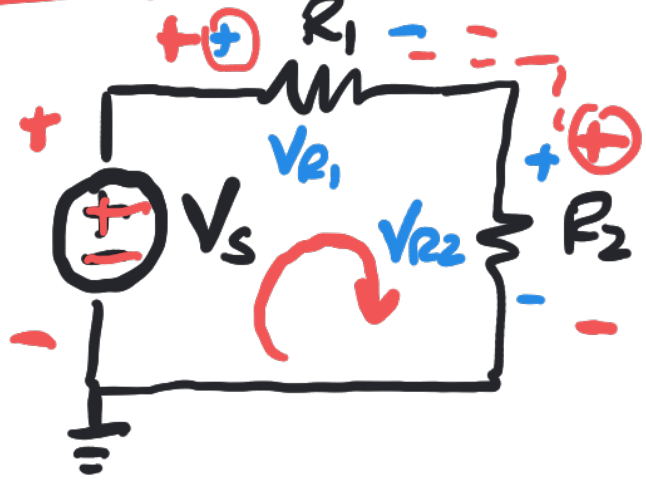


$$V_R = V_A - V_B = IR$$

3. **Kirchhoff's Voltage Law (KVL)**

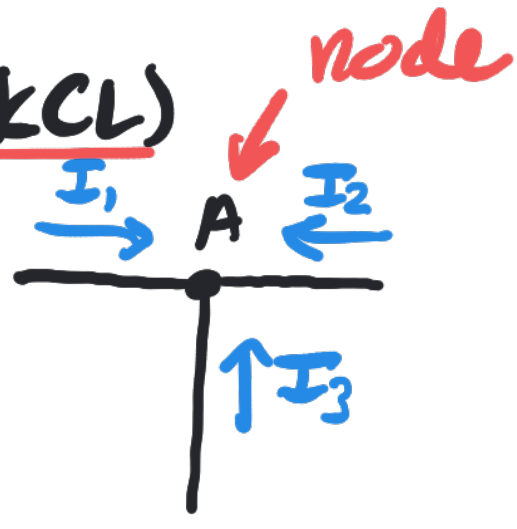
→ the sum of all voltages in a loop is zero

$$-V_S + V_{R1} + V_{R2} = 0$$



4. **Kirchhoff's Current Law (KCL)**

→ the sum of all currents at a node is zero



$$I_1 + I_2 + I_3 = 0$$