Unit - I
Introduction to Electricity

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Wireless power transmission

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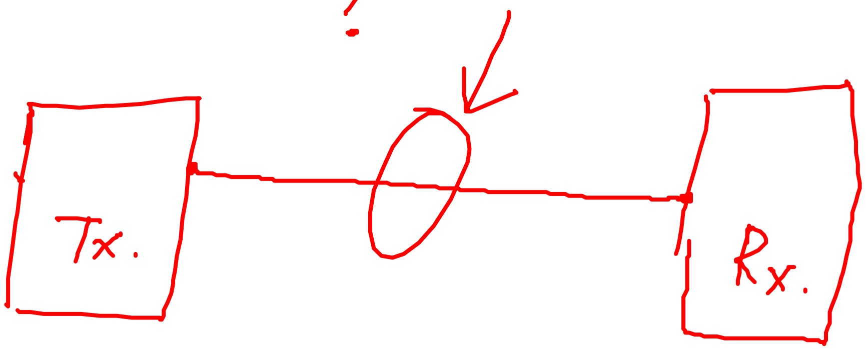

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Syllabus

UNIT – I **10 Periods**

Introduction and Basic Concepts: Concept of Potential difference, voltage, current - Fundamental linear passive and active elements to their functional current-voltage relation - Terminology and symbols in order to describe electric networks - Concept of work, power, energy and conversion of energy- Principle of batteries and application.

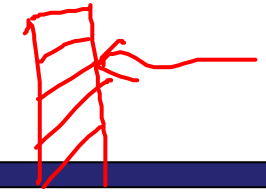
Principles of Electrostatics: Electrostatic field - electric field intensity - electric field strength - absolute permittivity - relative permittivity - capacitor composite – dielectric capacitors - capacitors in series & parallel - energy stored in capacitors - charging and discharging of capacitors.

Charge

V & I

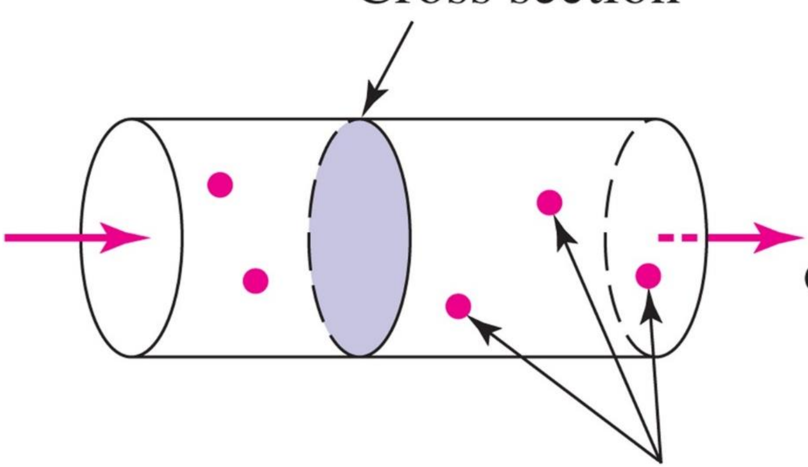
- Charge is *conserved*: it is neither created nor destroyed
- Symbol: Q or *q;* units are coulomb (C)
- The smallest charge, the *electronic charge*, is carried by an electron (-1.602×10^{-19} C) or a proton ($+1.602 \times 10^{-19}$ C)
- In most circuits, the charges in motion are electrons

Current and Charge

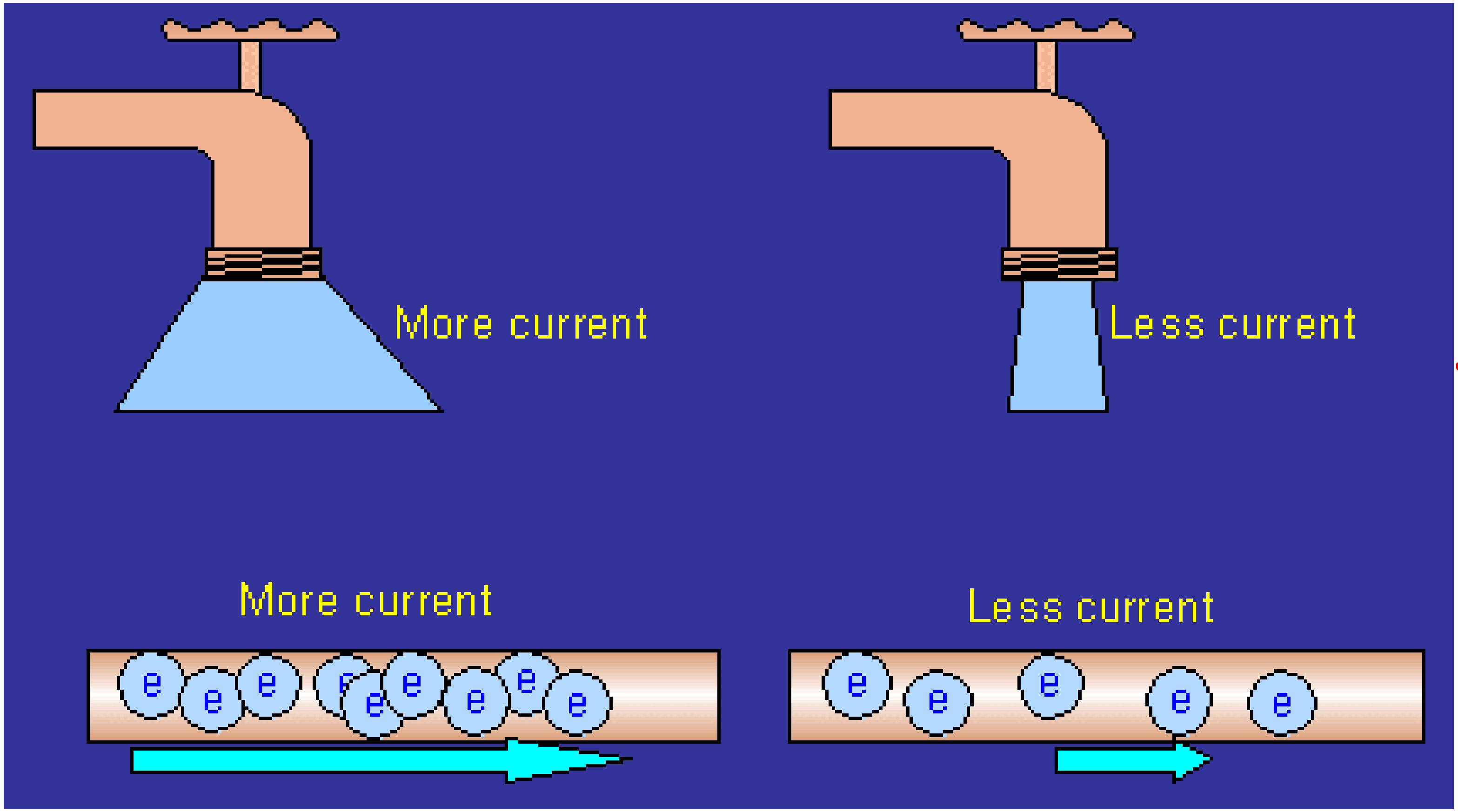


Current is the rate of charge flow:

1 ampere = 1 coulomb/second (or 1 A = 1 C/s)

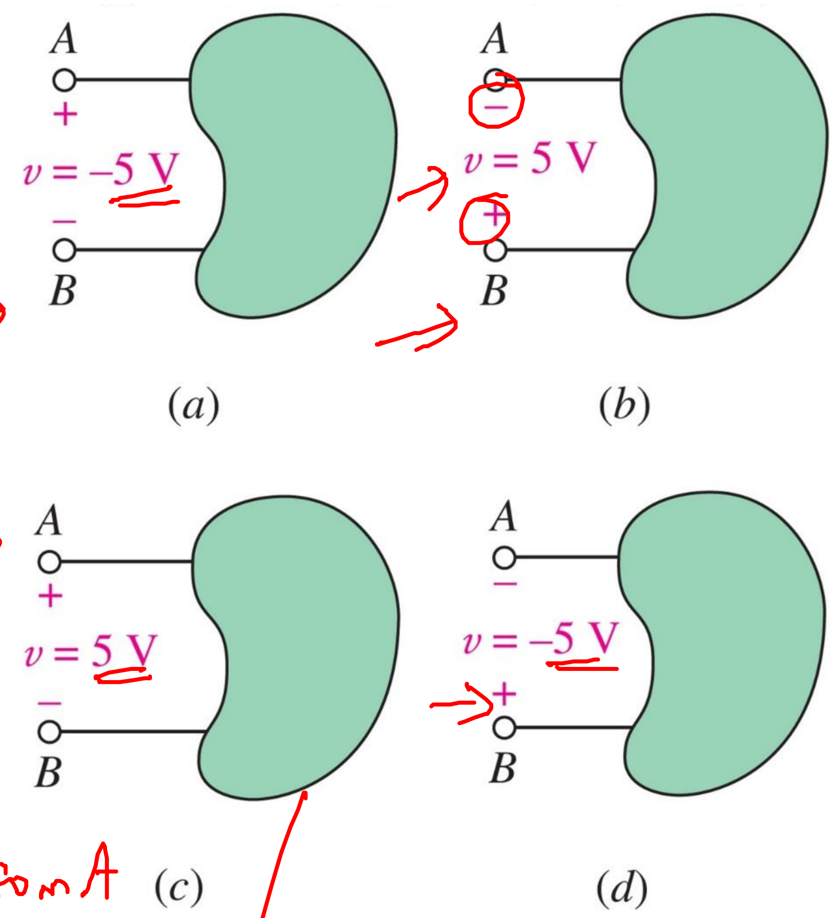


Current-Water Analogy



Voltage

- Symbol: V
- Unit: Volt



– Potential difference across two terminals in a circuit "across variable."

– In order to move charge from point A to point B, work needs to be done.

– Like potential energy at a water fall.

$\simeq 20$ mA

> 50 mA $\simeq 80$ mA

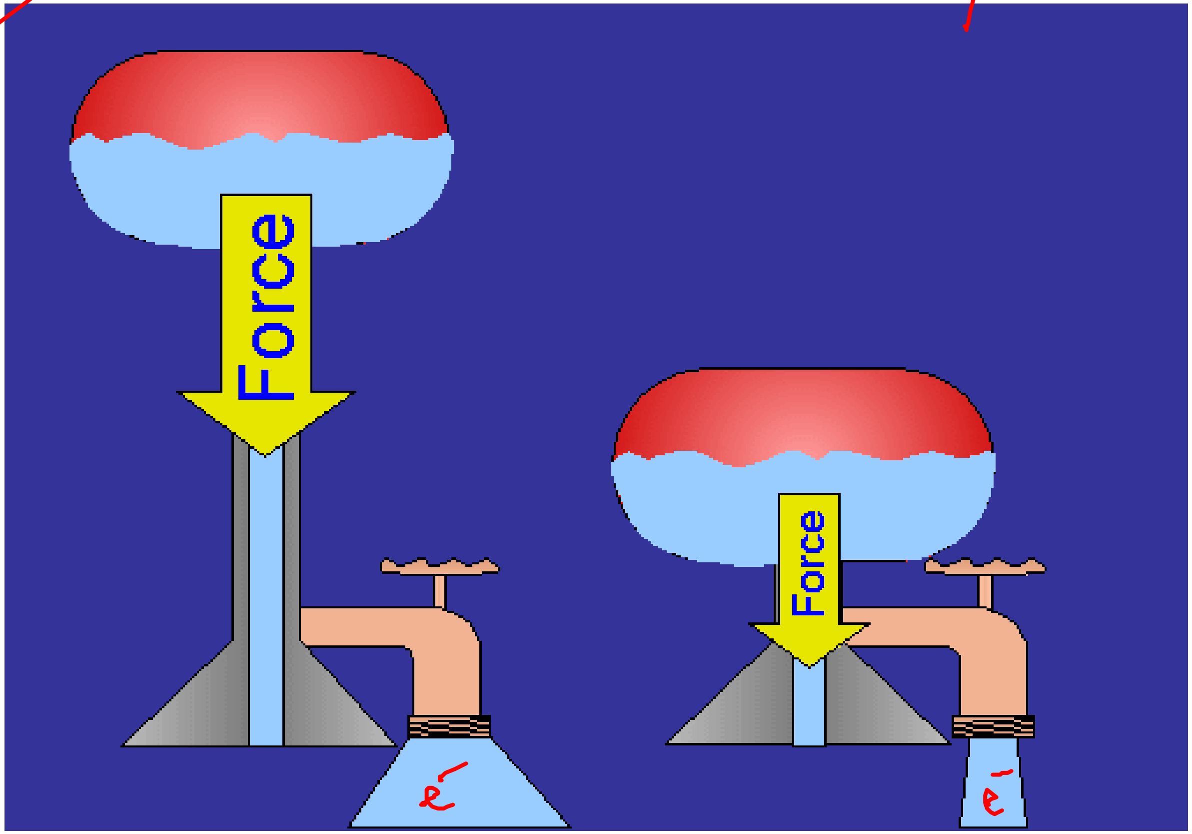
Voltage-Water Analogy

1ϕ → 230V, 50Hz → IND

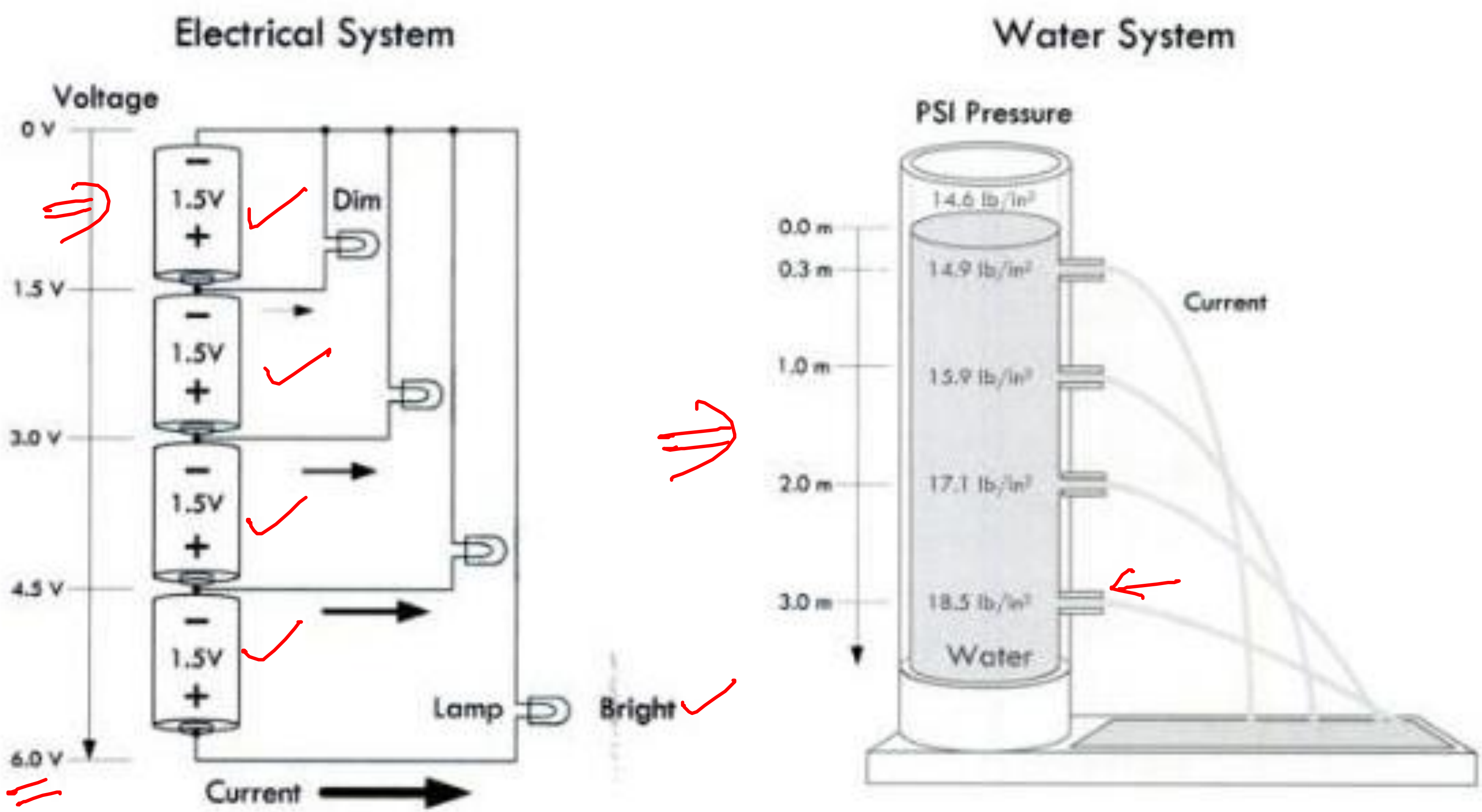
→ 110V, 60Hz → NA

1ϕ

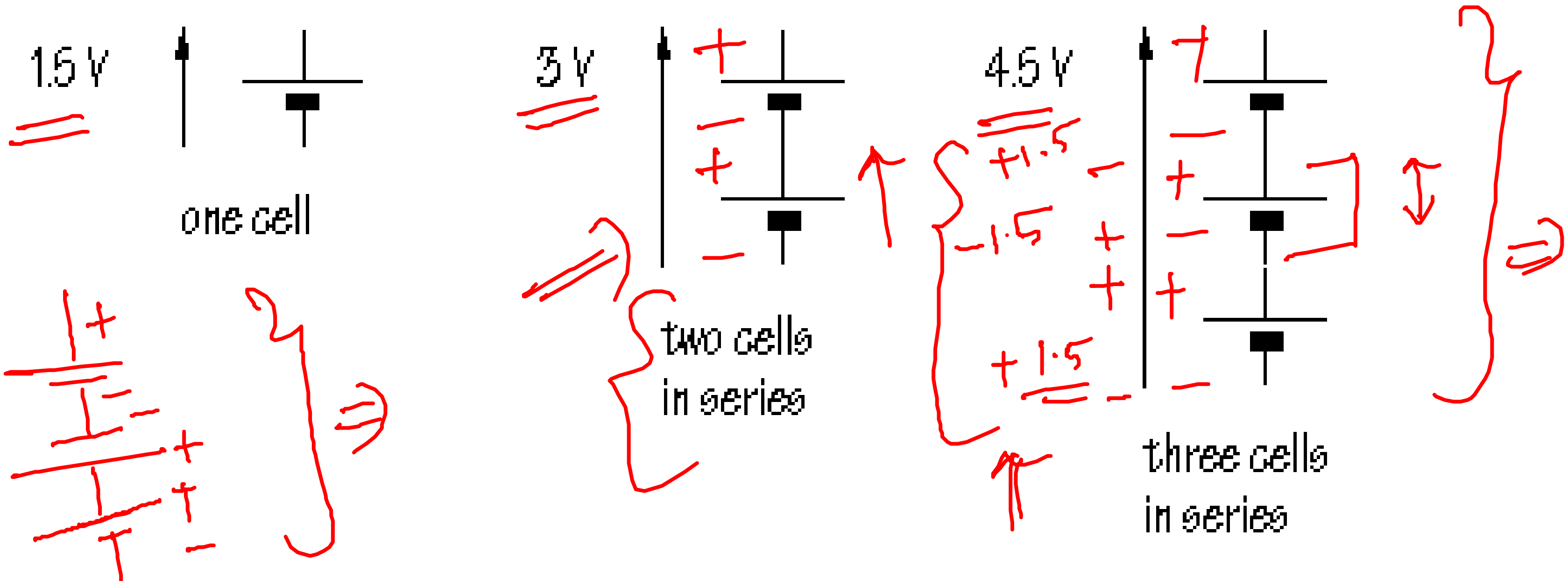
3ϕ



Voltage/Current-Water Analogy

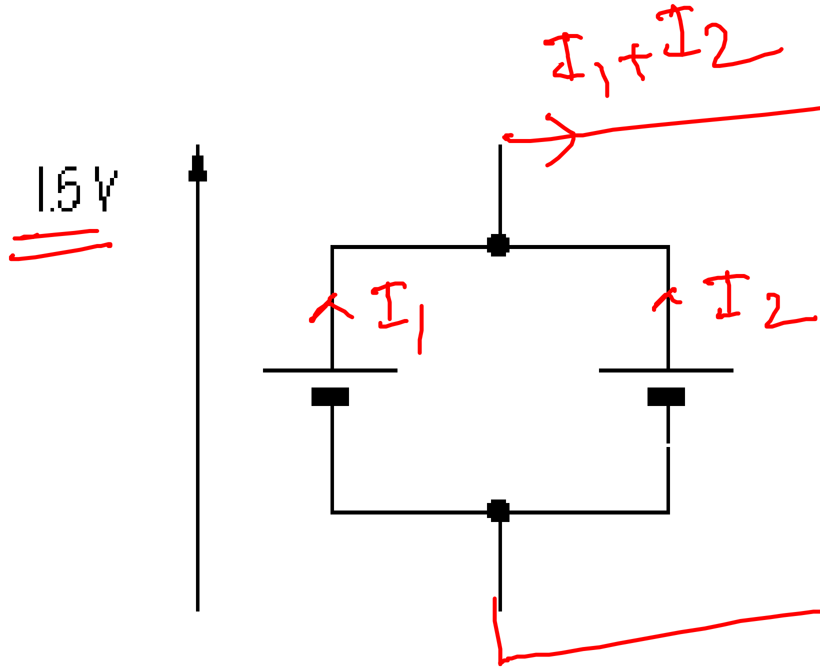


Series Connection



- Each cell provides 1.5 V
- Two cells connected one after another, **in series**, provide 3 V, while three cells would provide 4.5 V
- Polarities matter

Parallel Connection



- If the cells are connected in parallel, the voltage stays at 1.5 V, but now a larger current can be drawn.

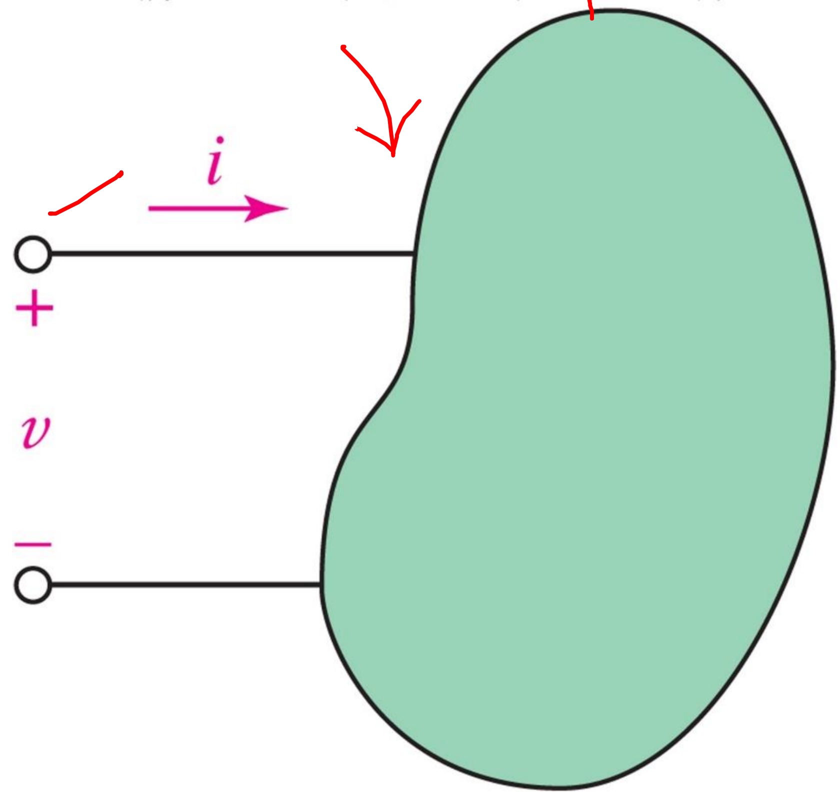
Power: $p = v\, i$

The power required to push a current i (C/s) into a voltage v (J/C) is $p = vi$ (J/s = W).

When power is positive, the element is *absorbing* energy.

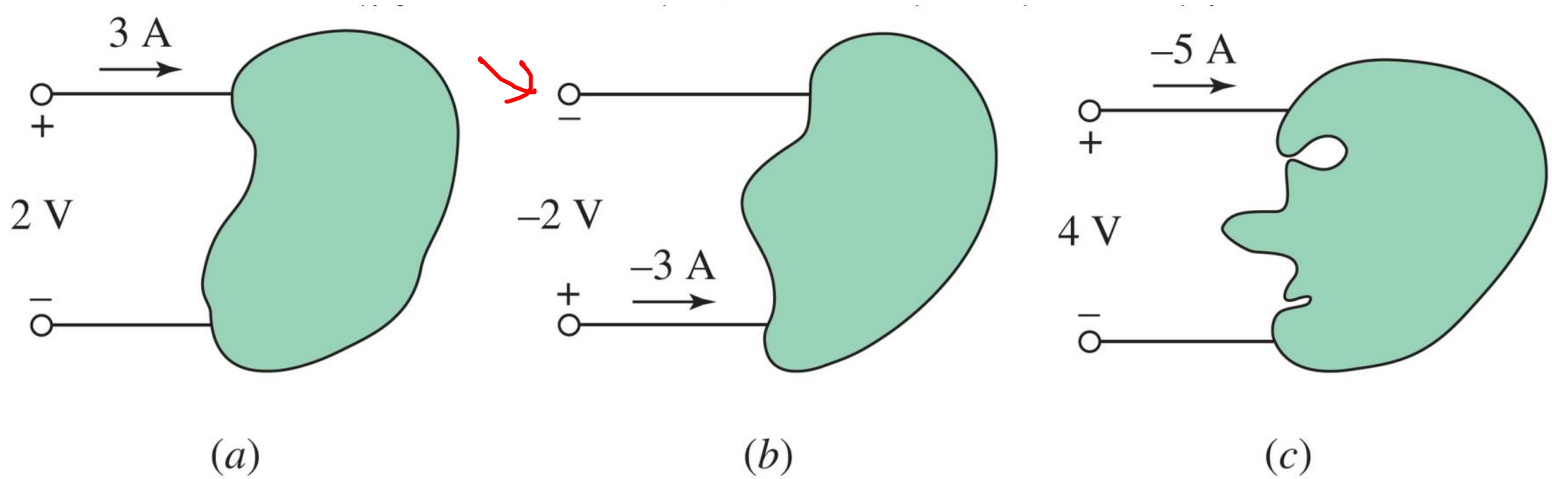
When power is negative, the element is *supplying* energy.

Linear abstraction



Example: Power

$2 \times 3 = 6W$ $\quad -2 \times -3 = 6W$ $\quad +4 \times -5 = -20W.$



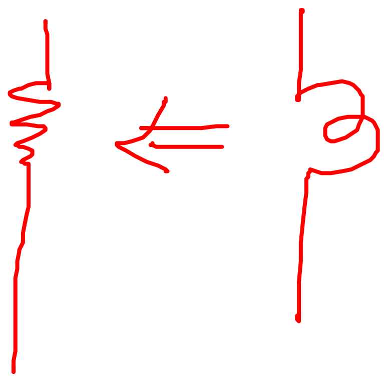
How much power is absorbed by the three elements above?

R L C

$P_a = +6$ W, $P_b = +6$ W, $P_c = -20$ W.
(Note: (c) is actually supplying power)

Resistance / Linear circuit abstraction

10Ω



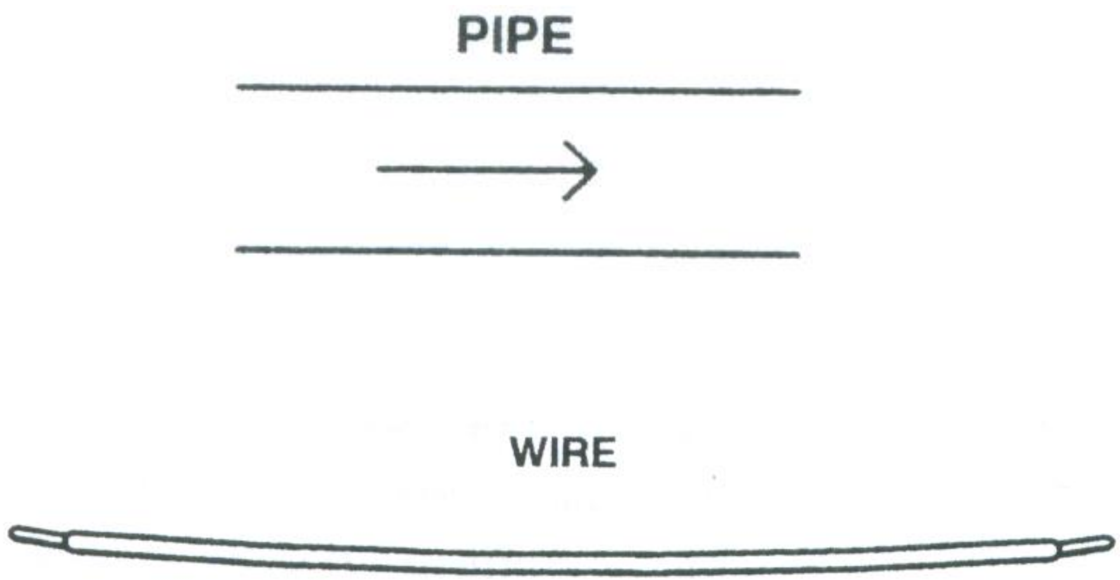
Material

Structure

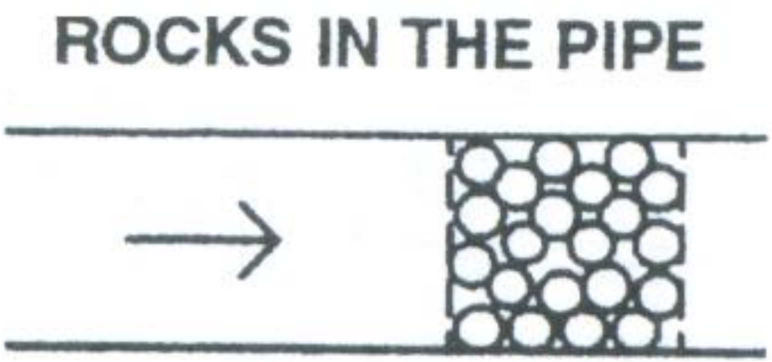
Environment

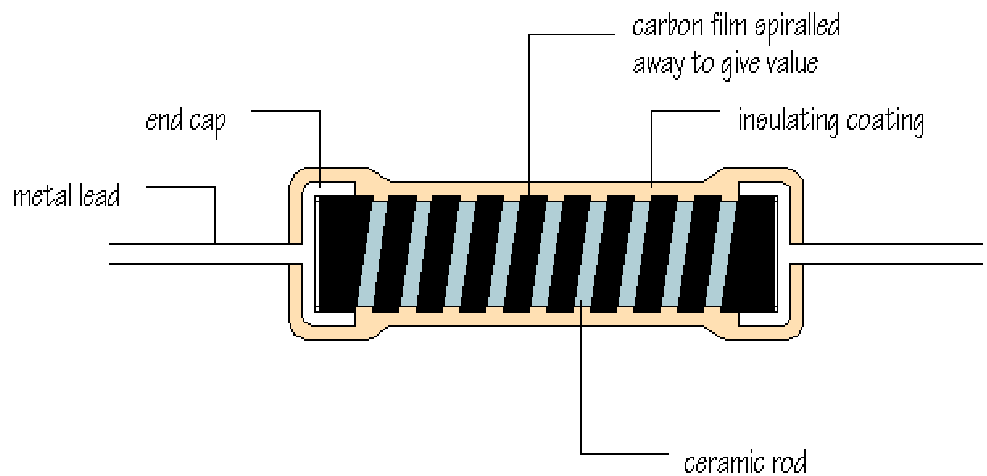
Digital twin

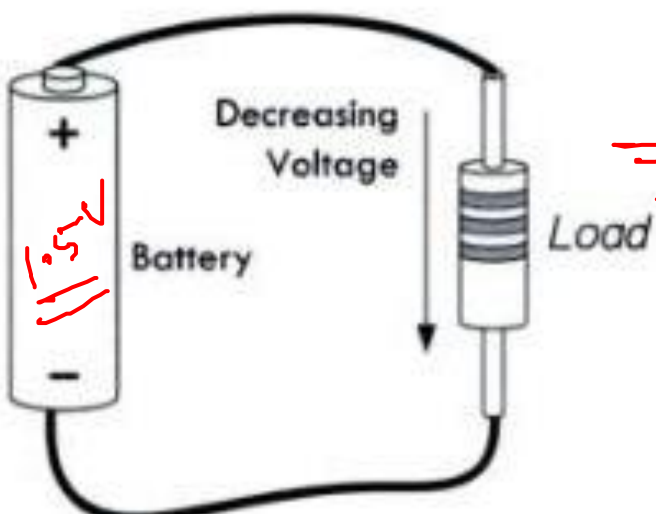
Wire-Water Analogy

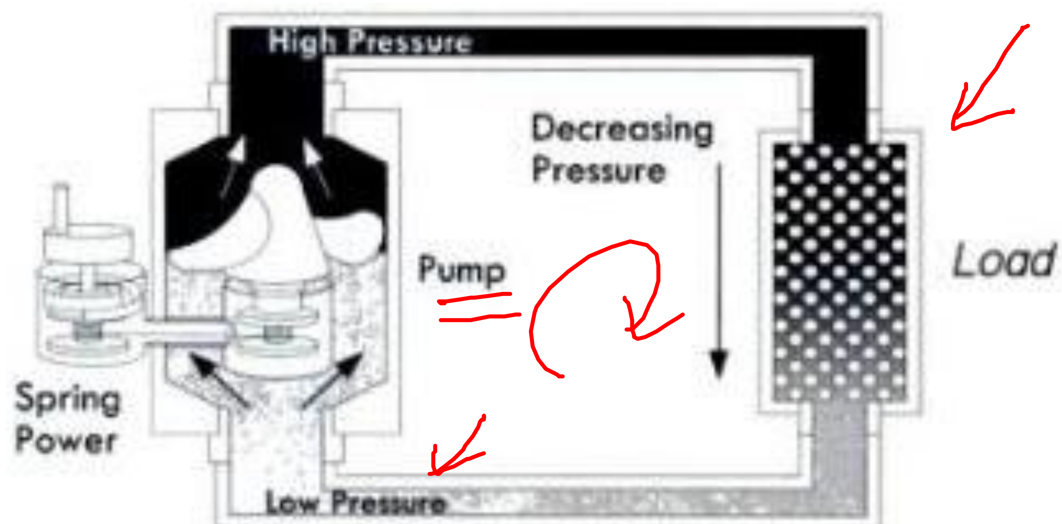


Resistors-Water Analogy









Resistor V-I Characteristic

- In a typical resistor, a conducting element displays linear voltage-current relationship. (i.e., current through a resistor is directly proportional to the voltage across it).

$$\mathbf{I} \propto \mathbf{V}$$

- Using G as a constant of proportionality, we obtain:

$$I = GV$$

- Equivalently,

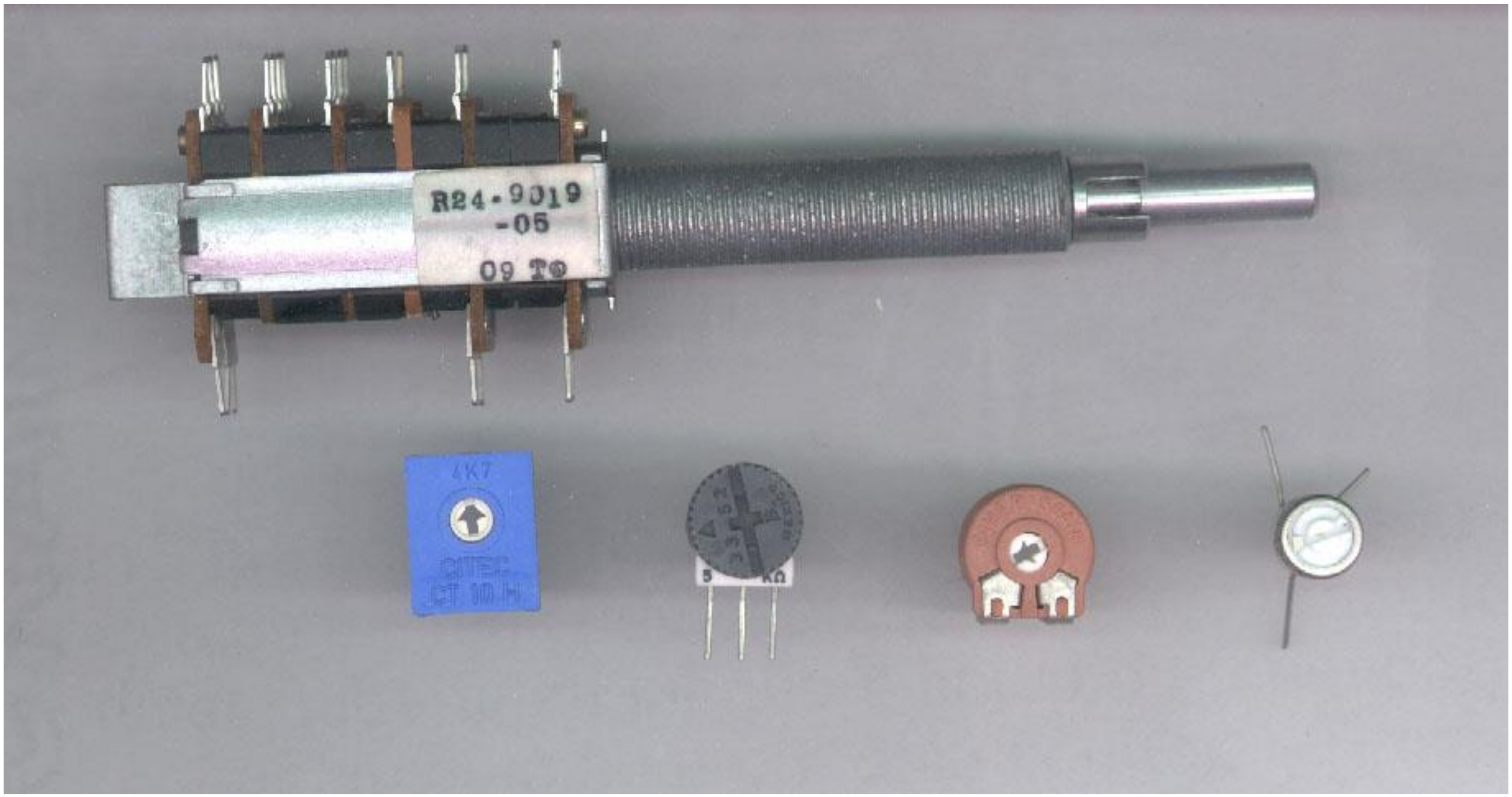
$$V = RI \quad (\text{or } V = IR)$$

where R = 1/G.

  – R is termed as the resistance of conductor (ohm, Ω)

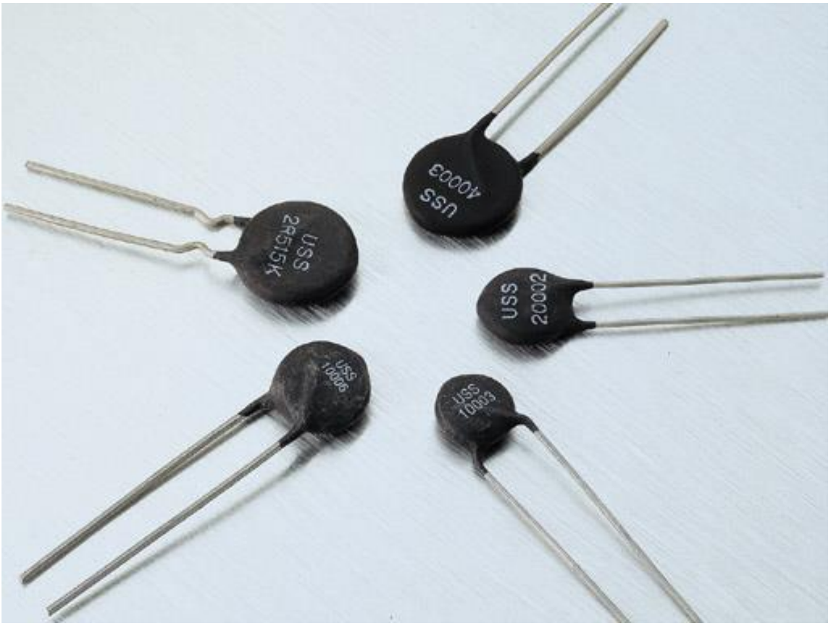
  – G is termed as the conductance of conductor (mho, ℧)

Variable Resistor: Rotary Potentiometers



Variable Resistor: Other Examples

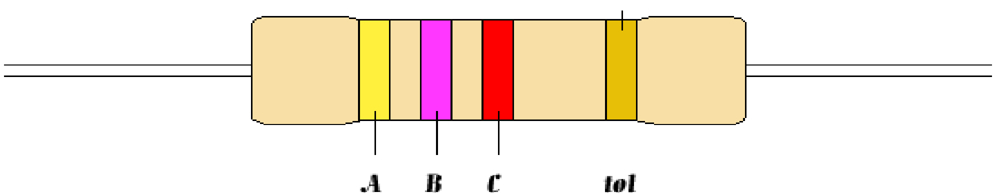
Photoresistor

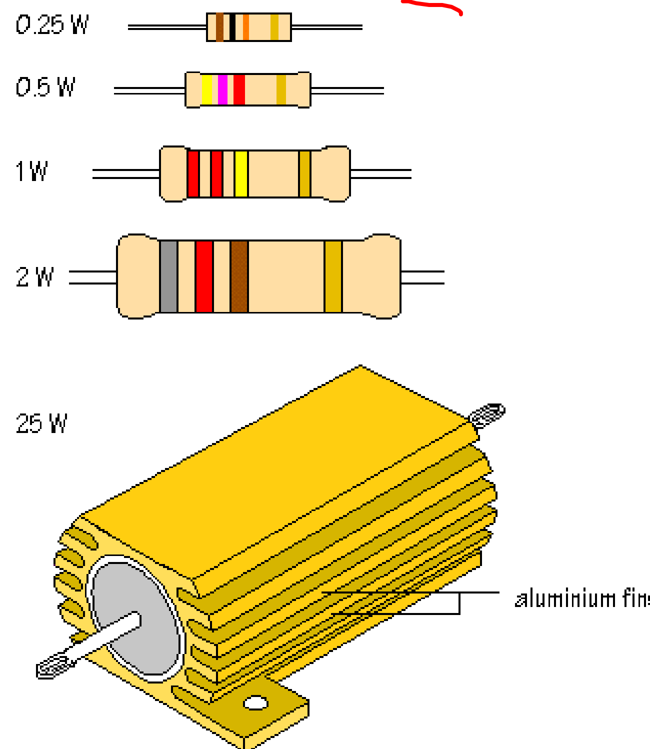


Thermistor

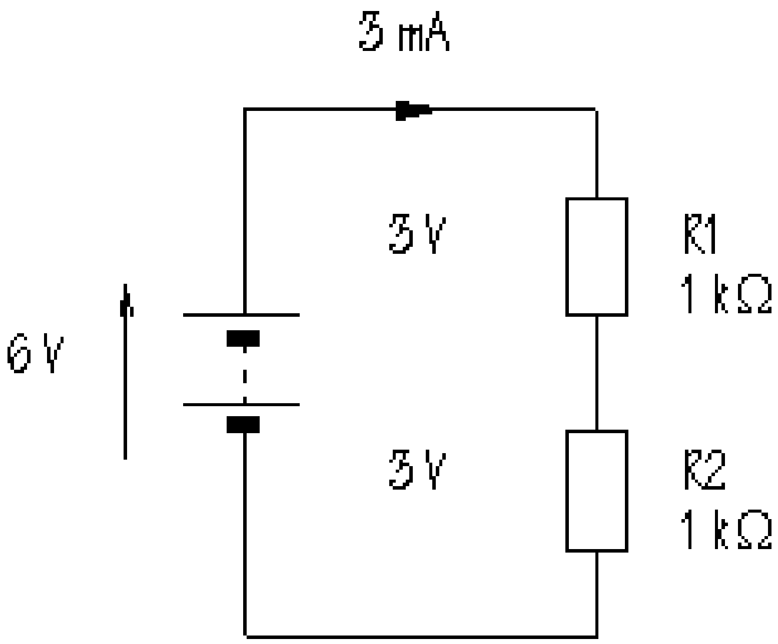
Resistor Examples

Resistor value = $AB \times 10^{C} \pm tol\%(\Omega)$





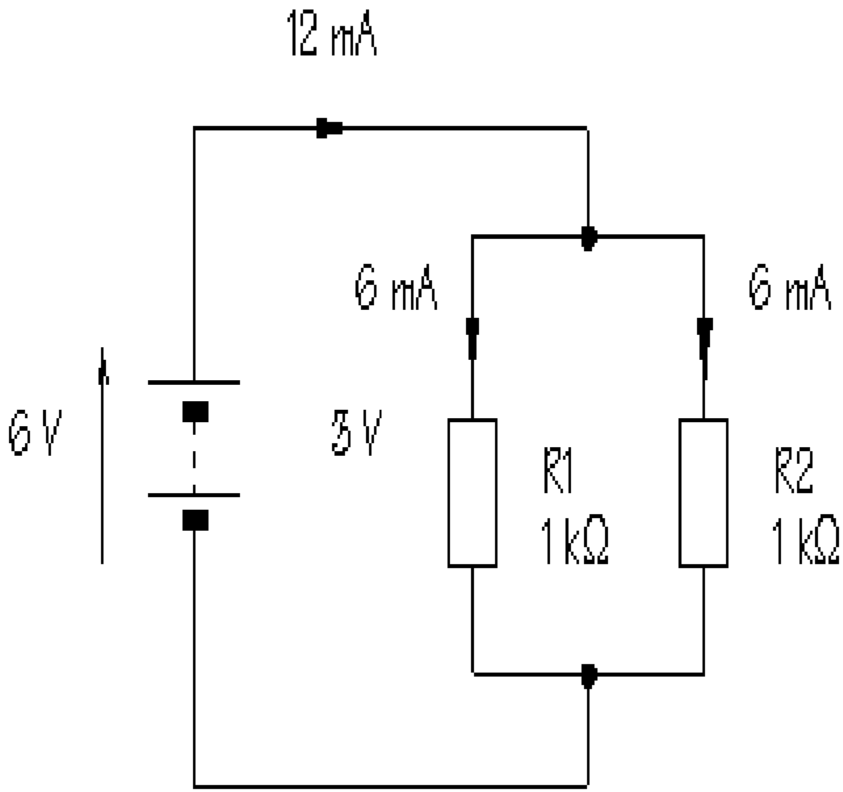
Resistors in Series



$$R_{total}=R_1+R_2$$

$$R_{total}=1+1=2k\Omega$$

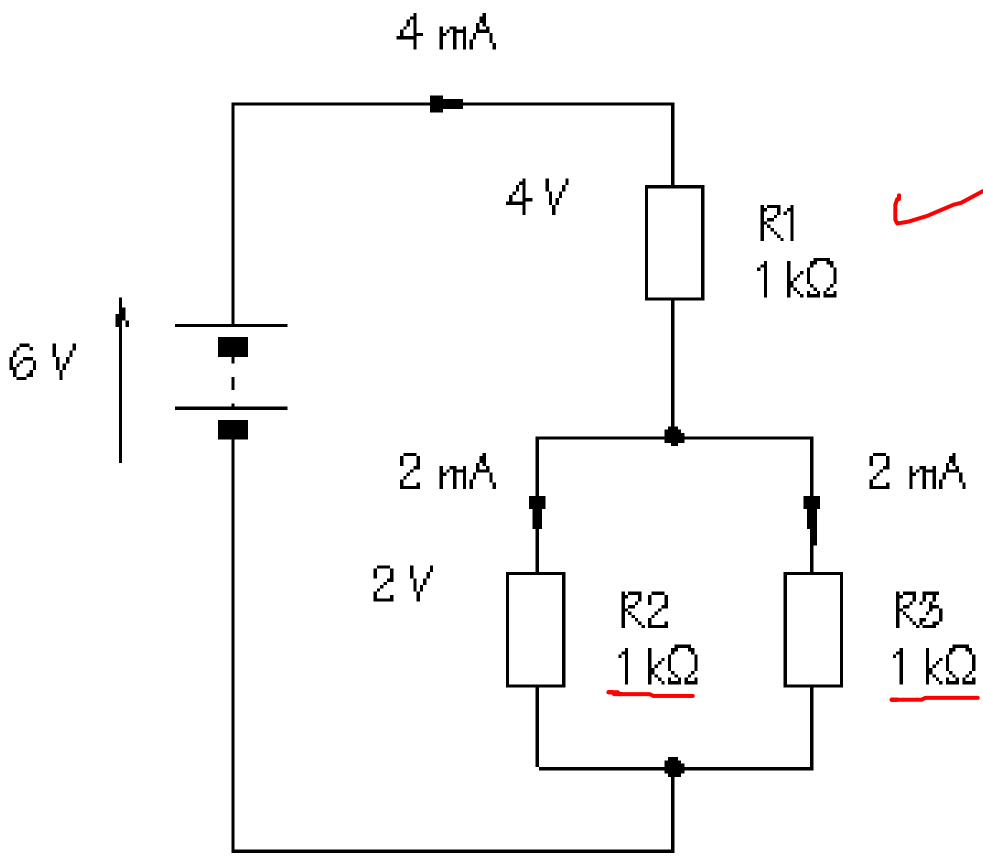
Resistors in Parallel



$$R_{total} = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_{total} = \frac{1 \times 1}{1+1} = \frac{1}{2} = 0.5k\Omega$$

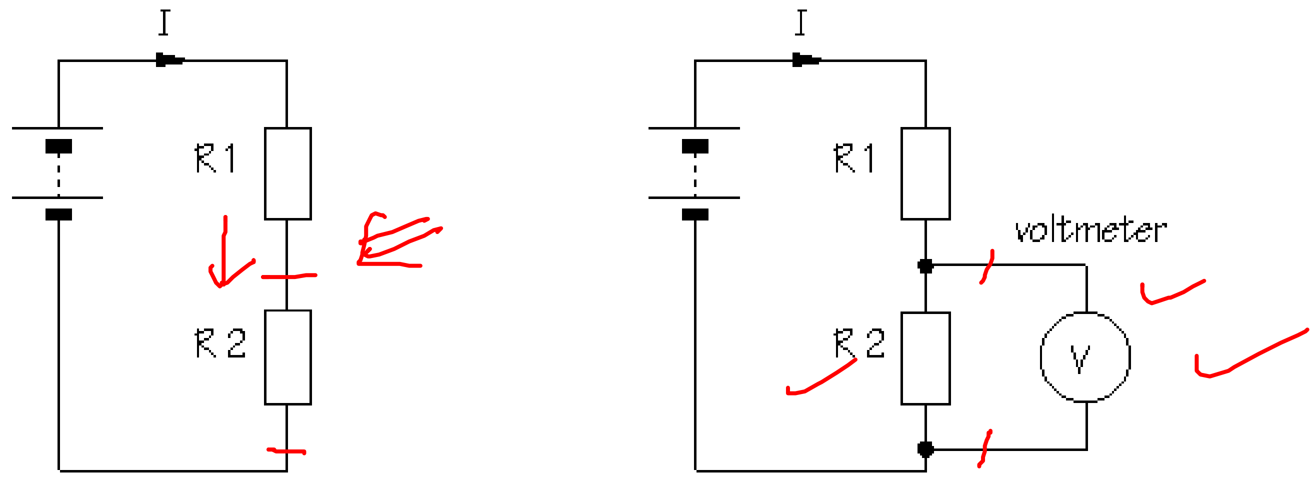
Exercise 1



$$R_{total} = R_1 + \frac{R_2 \times R_3}{R_2 + R_3}$$

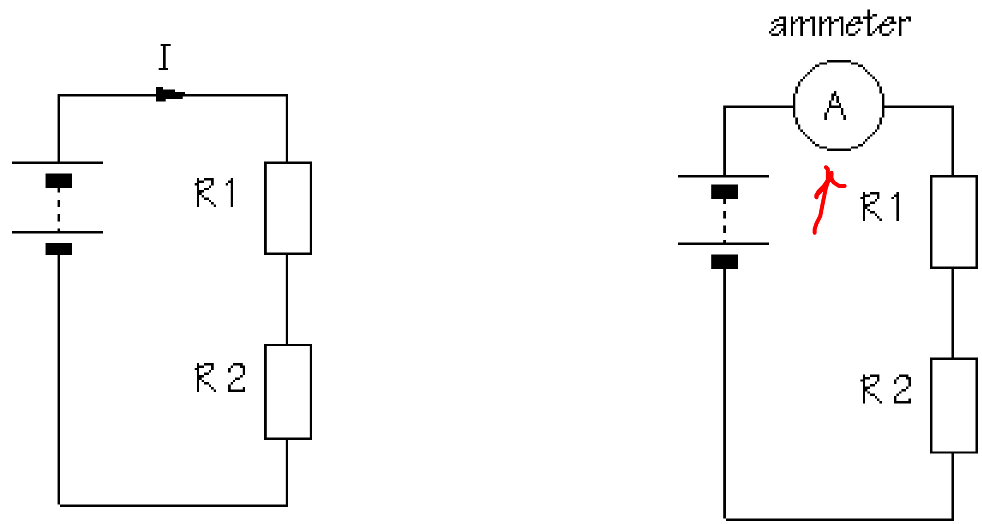
$$R_{total} = 1 + \frac{1 \times 1}{1+1} = \frac{3}{2} = 1.5k\Omega$$

Voltmeter Connection



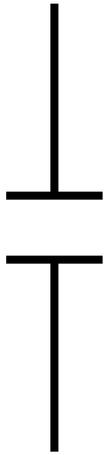
- The voltmeter is connected in parallel between two points of circuit
- A voltmeter should have a very HIGH input impedance

Ammeter Connection

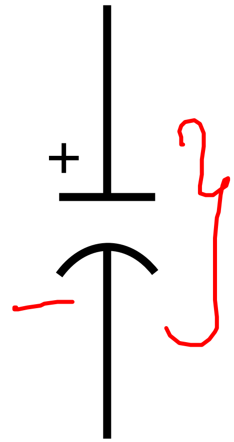


- Break the circuit so that the ammeter can be connected in series
- All the current flowing in the circuit must pass through the ammeter
- An ammeter must have a very LOW input impedance

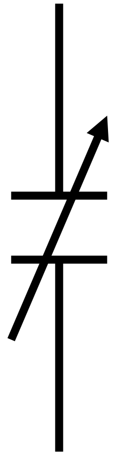
Capacitor Symbols



Fixed capacitor



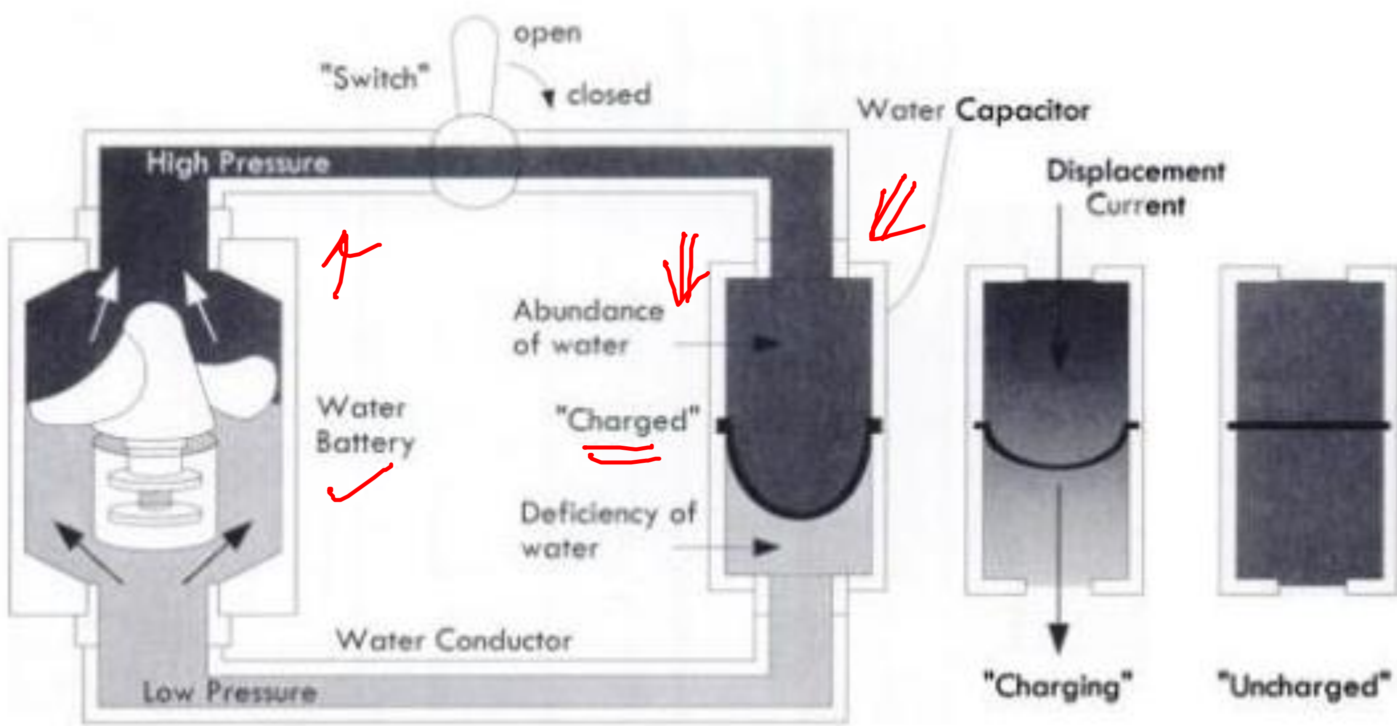
Polarized capacitor



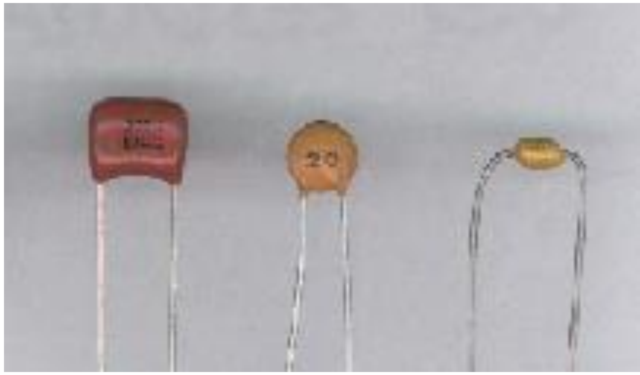
Variable capacitor

Capacitor Water Pipe Analogy

- Water capacitor: a tube with a rubber membrane in the middle
- Rubber membrane analogous to the dielectric, two chambers analogous to two capacitor plates
- When no water pressure is applied on the water capacitor, the two chambers contain same amount of water (uncharged)
- When pressure is applied on the top chamber, the membrane is pushed down causing the water to be displaced from the bottom chamber (appearance of current flow → displacement current)



Capacitor Variations



- Ceramic capacitors
  - –very popular nonpolarized capacitor
  - –small, inexpensive, but poor temperature stability and poor accuracy
  - –ceramic dielectric and a phenolic coating
  - –often used for bypass and coupling applications

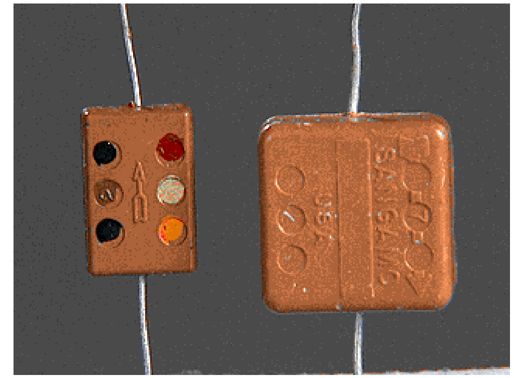
Axial lead

Radial lead

- Electrolytic
  - –Aluminum, tantalum electrolytic
  - –Tantalum electrolytic capacitor has a larger capacitance when compared to aluminum electrolytic capacitor
  - –Mostly polarized.
  - –Greater capacitance but poor tolerance when compared to nonelectrolytic capacitors.
  - –Bad temperature stability, high leakage, short lives

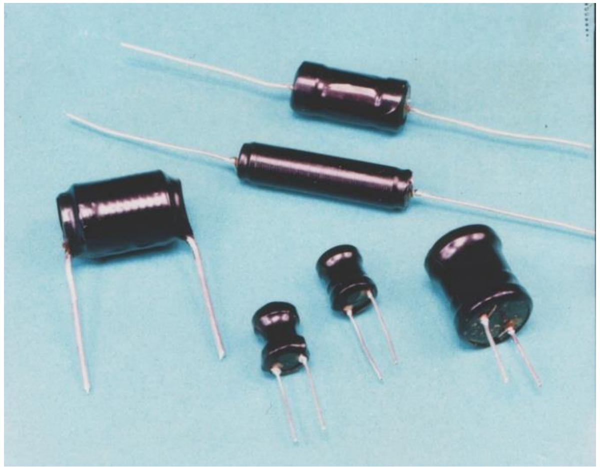
Capacitor Variations

- Mylar
  - –very popular, nonpolarized
  - –reliable, inexpensive, low leakage
  - –poor temperature stability



- Mica
  - –extremely accurate, low leakage current
  - –constructed with alternate layers of metal foil and mica insulation, stacked and encapsulated
  - –small capacitance
  - –often used in high-frequency circuits (i.e. RF circuits)

Inductor Variations



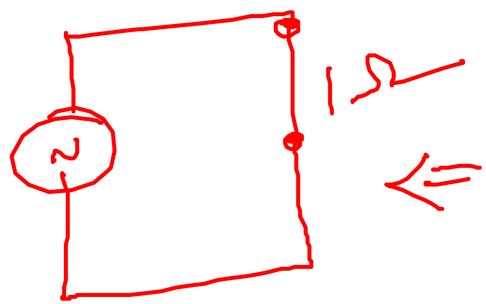
- Chokes
  - –general-purpose inductors that act to limit or suppress fluctuating current.
  - –some use a resistor-like color code to specify inductance values.
- Toroidal coil
  - –resembles a donut with a wire wrapping
  - –high inductance per volume ratios, high quality factors, self-shielding, can be operated at extremely high frequencies

Open and Short Circuits

- An open circuit between A and B means *i=0.*
- *Voltage across* an open circuit: any value.
- An open circuit is equivalent to R = ∞ Ω.

- A short circuit between A and B means *v=0.*
- *Current through* a short circuit: any value.
- A short circuit is equivalent to R = 0 Ω.

R => 1Ω / km



230V

15A

Summary

Basics

- charge
- Voltage / current / power
  - Voltage → Voltmeter
  - current → Ammeter
- R, L, C