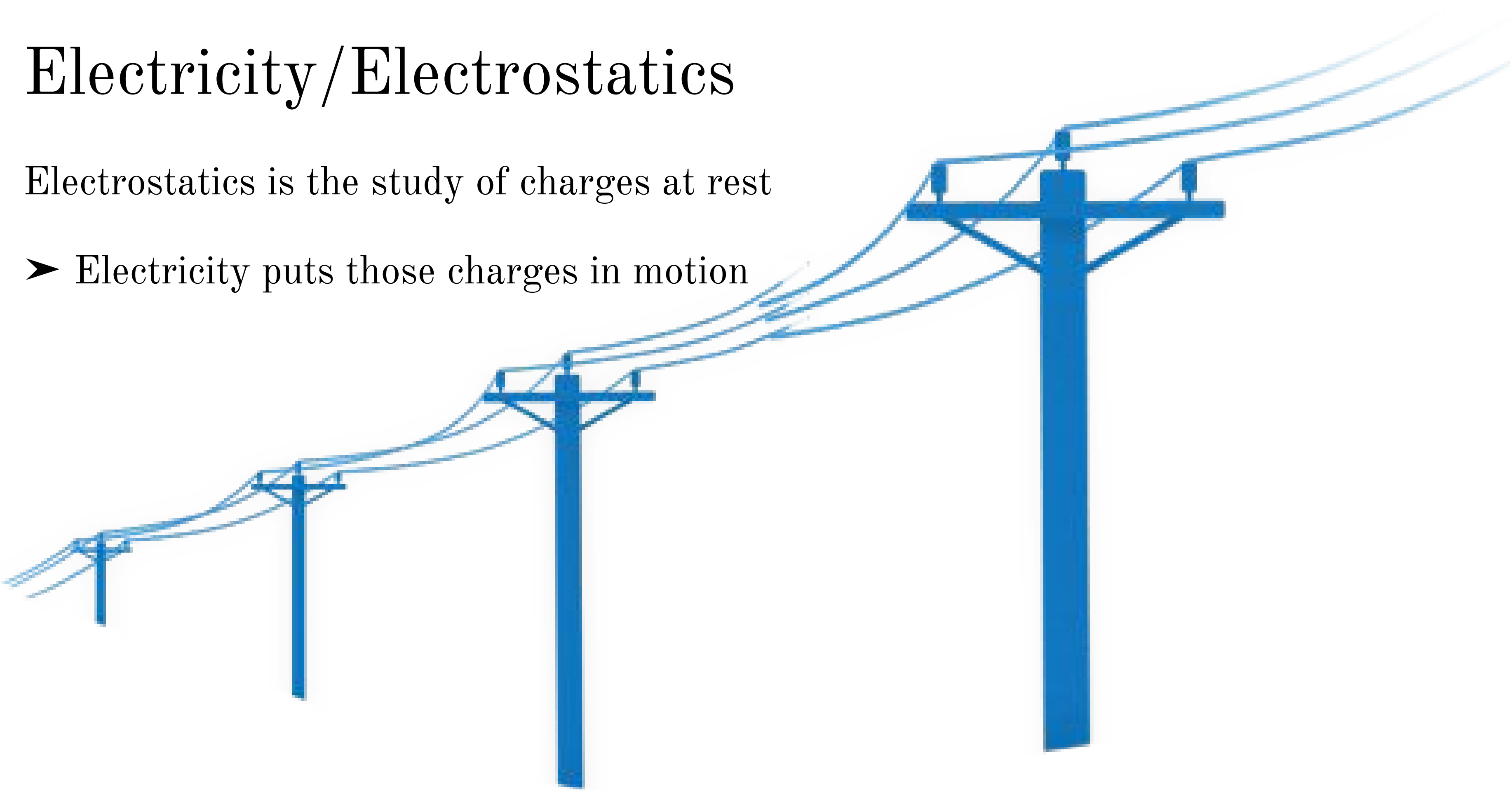
ELECTRICITY

Electricity/Electrostatics

Electrostatics is the study of charges at rest

➢ Electricity puts those charges in motion



Batteries/Voltage

- Batteries supply electric energy to a system
- Batteries use a chemical reaction to create a potential difference across its positive and negative terminals

Electric Current

➢ Electric current is the flow of electric charge

➢ It's how much charge passes through in a given

amount of time

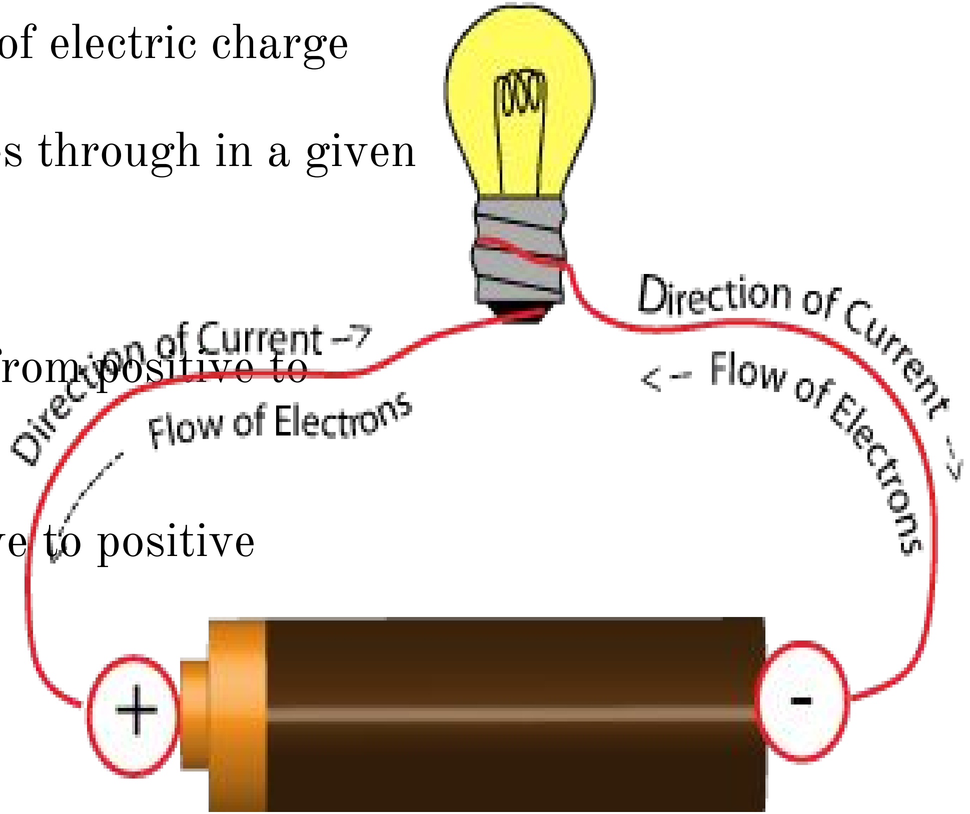
➢ Conventional current runs from positive to negative

➢ Electrons flow from negative to positive

➢ $I = \Delta Q/\Delta t$

➢ Measured in amperes (A)

➢ $1\ A = 1\ C/s$



Ohm's Law

In the early 19th Century, Georg Simon Ohm established through experiments that the current in a wire is proportional to the potential difference applied to its ends

- $V/I = \text{constant}$
- Resistance (R) is measured in ohms (Ω)
- $V = IR$

Resistance

All electronic devices offer resistance to the flow of current

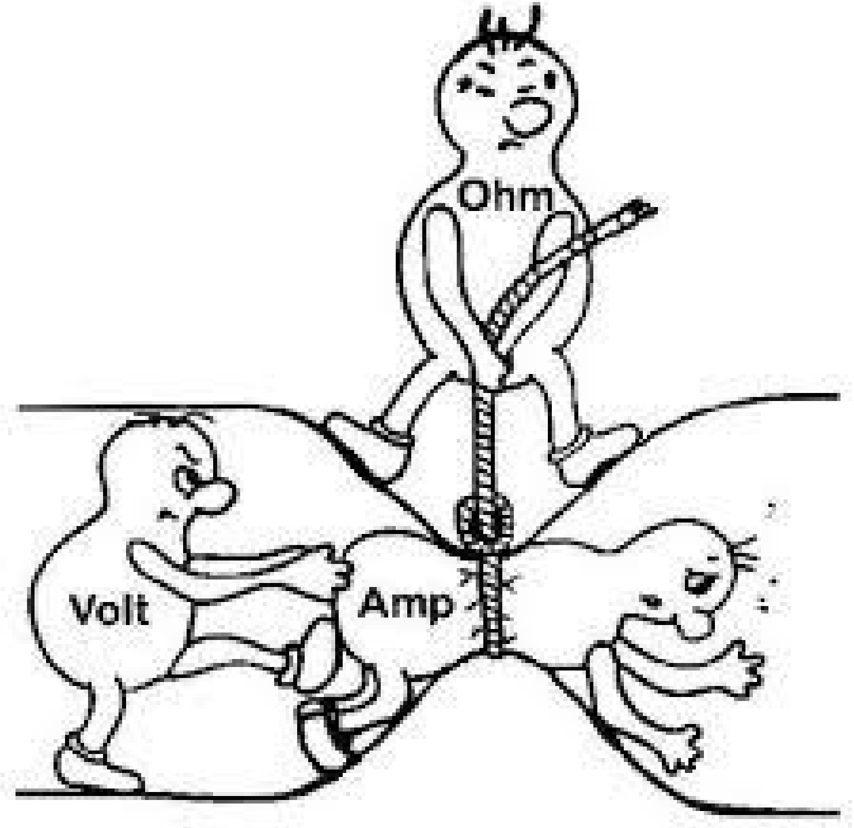
➢ Anything that offers resistance "eats up" electric energy

➢ It can also be seen as converting electric energy to heat energy

➢ $R = \rho L/A$

➢ ρ is the resistivity of the material

➢ Measured in Ωm



Superconductors and Resistivity

All regular conductors put up some electrical resistance

➢ The resistivity of a material can depend on temperature, and resistivity usually increases with temperature

➢ Some materials, once cooled below a particular critical temperature, will offer exactly zero resistance

➢Materials acting like this are considered superconductors

Power

Electric energy is useful because it can be easily transformed into other forms of energy

- motors turn it into mechanical work
- electric heaters, stoves, toasters, and hair dryers turn it into thermal energy
- lightbulbs turn it into light and thermal energy
- $P = IV = I^2R = V^2/R$

Series Circuit: Current

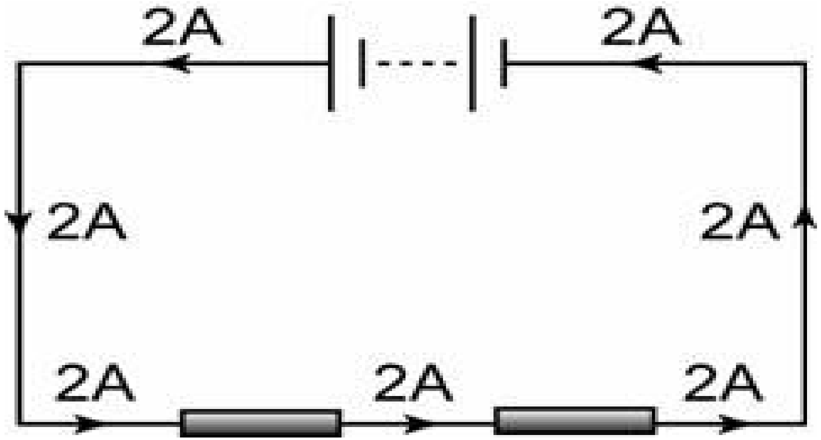
When two or more resistors are connected end to end, they are said to be connected in series

➤ Any charge that passes through R1 will also pass through R2 and then R3, etc.

➤ Hence, the same current (I) will pass

through each resistor

Measured in Amps (A) or (C/s)



Series Circuits: Voltage

Each resistor eats up some of the energy supplied by the battery

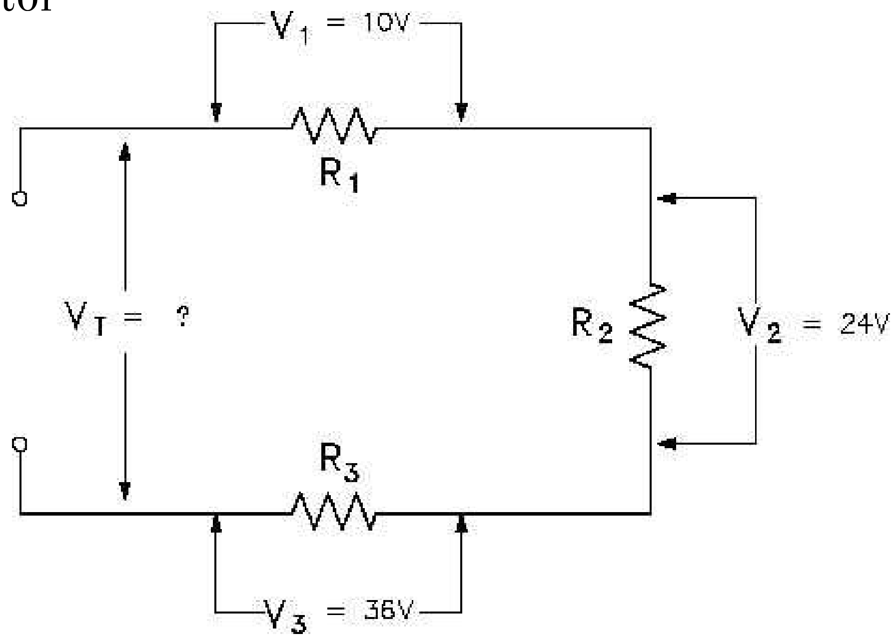
- ➤ i.e. the voltage will drop across each resistor
- ➤ Ohm's Law tells us how much the

voltage will drop:

$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$, etc.

- ➤ $V = V_1 + V_2 + V_3 + V_4$

Measured in Volts (V)



Series Circuits: Resistance

$V = V_1 + V_2 + V_3 + V_4$

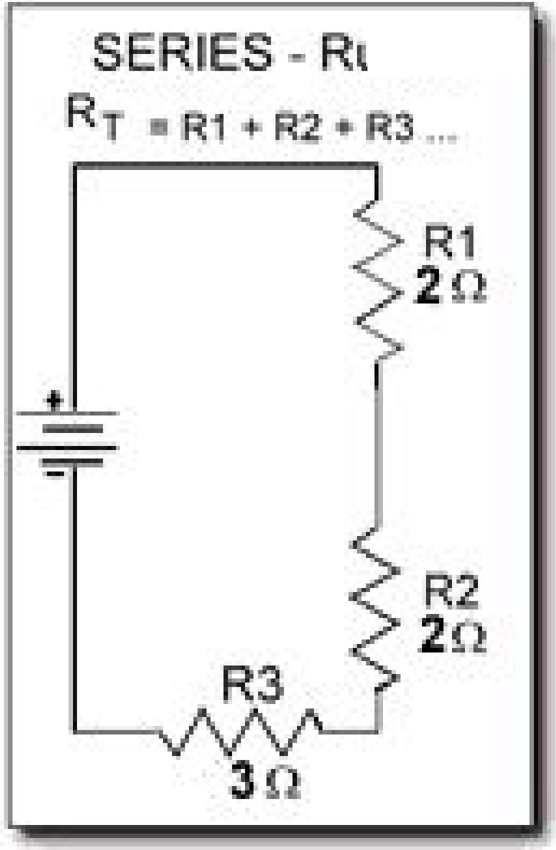
$= IR_1 + IR_2 + IR_3 + IR_4$

The battery doesn't know the difference between one

big resistor and several small resistors working in series

- ➤ $V = IR_{eq}$
- ➤ $R_{eq} = R_1 + R_2 + R_3 + R_4$

Measured in Ohms (Ω)



Parallel Circuits: Current / Voltage

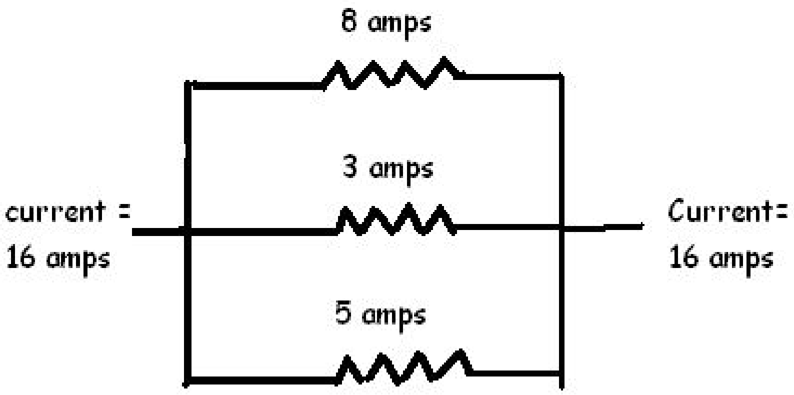
Resistors connected in parallel will split the current into separate branches

➢ The “forks in the road” where current can split off into multiple paths are called junctions

➢ $I = I_1 + I_2 + I_3$

Resistors are connected in parallel, each Experiences the same voltage

- $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$



Series/Parallel

	Series	**Parallel**
V	$V=V_1+V_2+V_3+...$	constant
I	Constant	$I=I_1+I_2+I_3+...$
R	$R_{eq}=R_1+R_2+R_3+...$	$(1\backslash R_T)=(1\backslash R_1)+(1\backslash R_2)+(1/R_3)+...$

Kirchhoff's Rules

The rules are really just convenient applications of conservations of charge and energy

1. Junction Rule: at any junction, the sum of currents in equals the sum of currents out

➢ (conservation of charge)

Loop Rule: the sum of the changes in potential around any closed path of a circuit must be zero

➢ (conservation of energy)

Capacitors in Circuits

Capacitors in parallel:

- ➢ The junction rule tells us that current in equals current out, and by extension, charge in equals charge out
- ➢ $Q = Q1 + Q2 + Q3$
- ➢ Combine with $Q = CV$
- ➢ $Ceq = C1 + C2 + C3$

Capacitors in Circuits

Capacitors in series:

➤ Conservation of energy tells us that electric potential supplied by the battery will equal the sum of the potentials used up by circuit components

➤ $V = V1 + V2 + V3$

➤ Combine with $Q = CV$

$(1/Ct)=(1/C)+(1/C2)+(1/C3)$ ←Series

Common Misconceptions

- Batteries do not create or even supply electric charge, all they do is push charge
- Electrical charges move quite slowly (about 1 meter per second), but in a circuit a light bulb will turn on as soon as a switch is turned on because when this happens, charge everywhere in the circuit begins to move.
- Charge does not become used up as it flows through a circuit, and the amount of charge that comes out of a light bulb is the same amount that enters the light bulb.

Question (Sanity Check)

A hair dryer draws 9.0 A when plugged into a 120-V line

a) What is its resistance?

b) How much charge passes through in 15 min?