Electric Circuits

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Charge

Measured in coulombs (C)

Denoted by q or Q

Electron

$$e^- = 1.6 \times 10^{-19} C$$

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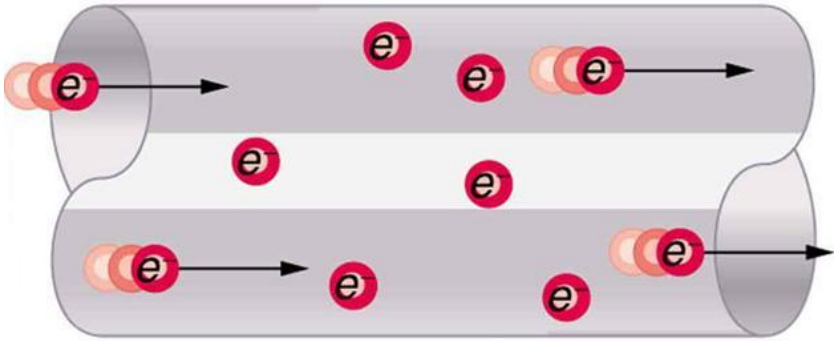
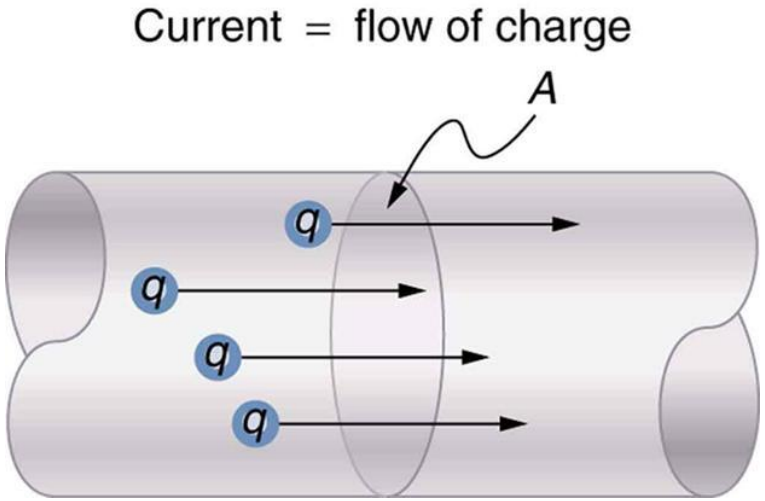


Current

Charge per unit time

measured in amperes (A)

denoted by I



$$I = \frac{Q}{t}$$

Current Practice Problem

Over the course of 8 hours, 3.8 x 10^4 C of charge pass through a typical computer. What is the current for such computer?

Answer: Current Practice Problem

Q = 3.8 x 10^4 C = 38000 C

t = 8 hr * 60 min/hr * 60 sec/min = 28800 sec

I = Q/t = 38000 C / 28800 sec

I = 1.3 A

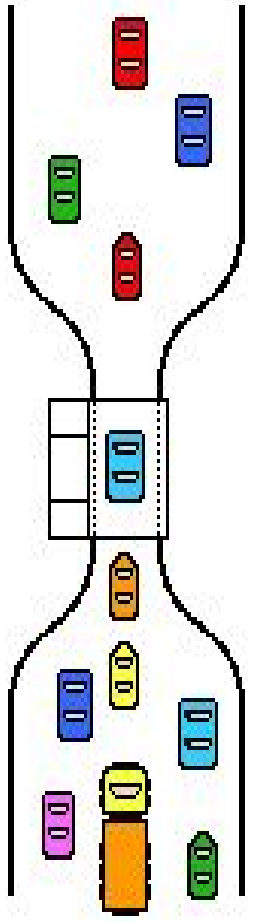
Resistance

Resists current (charge flow)

- Energy dissipation
- “constricts” the flow of electrons
- creates a voltage drop

Measured in ohms (Ω)

- denoted by R



A Single Resistor

Resistivity

Measure of tendency of material to resist current

NOT how much resistance

ohm-meters

denoted by ϱ

$$R = \frac{\rho L}{A}$$

- L = length
- A = cross sectional area
- ϱ = resistivity
- R = resistance

Resistance Practice Problem

The heating element of an electric toaster is typically made of nichrome wire (an alloy of nickel and chromium). As current passes through the wires, the wires heat up, thus toasting the toast. Estimate the overall resistance of a heating element which is 220 cm long and consists of nichrome wire with a diameter of 0.56 mm. The resistivity of nichrome is 110x10-8 Ω•m.

$$R = \frac{\rho L}{A}$$

- L = length
- A = cross sectional area
- ϱ = resistivity
- R = resistance

Conductance

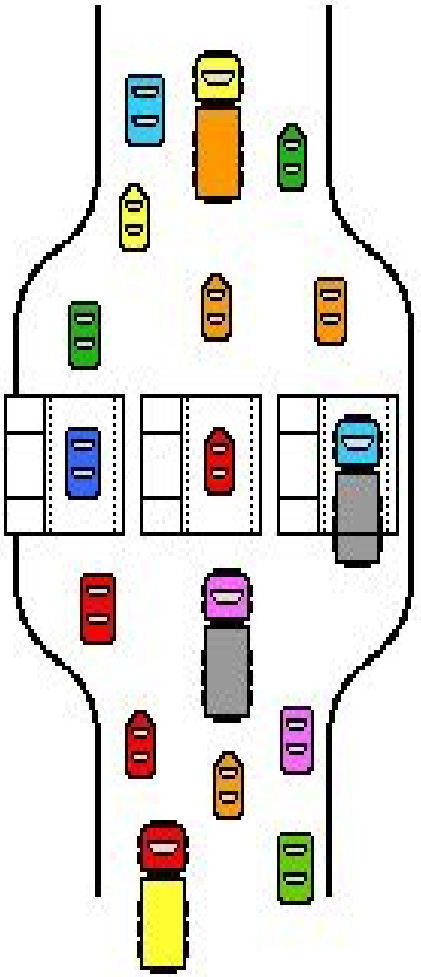
Inverse of resistance

Measured in siemens (S)

denoted by G

Measure of ease of charge flow

$$G = \frac{1}{R}$$



Conductivity

Inverse of resistivity

tendency of material to let charge flow

Measured in Siemens per meter (S/m)

denoted by σ

$$\sigma = \frac{1}{\rho}$$

Practice Problem

A 13 in long 12 AWG copper wire's resistance is 1.12 x 10^-12 Ω. What is the conductivity of the wire?

$$d_n = 0.005 \text{ inch} \times 92^{\frac{36-n}{39}}$$

Equation for the diameter of n gauge wire

Voltage

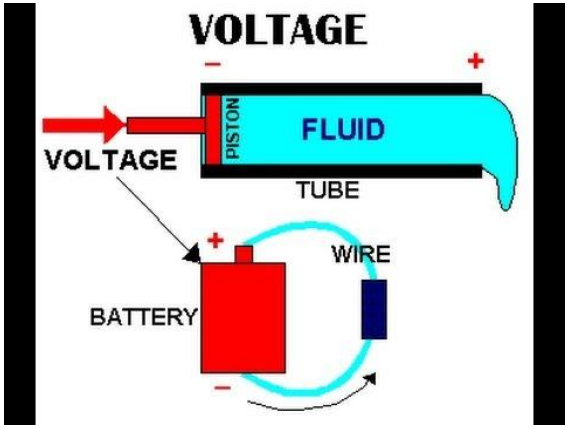
Electrical “pressure”

aka. Potential difference

forces electrons to move

Measured in volts (V)

denoted by V



Ohm's Law

$$V = IR$$

Relationship of voltage, current, and resistance

- I and R inverse
- V is directly proportional to I and R

Ohm’s Law Practice Problem

A coffee cup immersion heater utilizes a heating coil with a resistance of 8.5 Ω. Determine the current through the coil when operated at 110 V.

Power

$$P = VI$$

"Strength" of motor / mechanism

Units:

- $kg(m^2/s^3)$
- J/s (joules per second)
- W (watts)
- VI (volt-amps)

Power Practice Problem

The power of a 1.5-volt alkaline cell varies with the number of hours of operation. A brand new D-cell can deliver as much as 13 A through a copper wire connected between terminals. Determine the power of a brand new D-cell.

Power Practice Problem

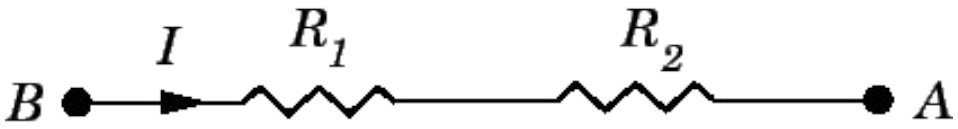
A 3-way light bulb for a 110-V lamp has two different filaments and three different power ratings. Turning the switch of the lamp toggles the light from OFF to low (50 W) to medium (100 W) to high (150 W) brightness. These three brightness settings are achieved by channeling current through the high resistance filament (50 W), the low resistance filament (100 W) or through both filaments. Determine the resistance of the 50 W and the 100 W filaments.

Hint: Utilize Ohm’s Law.

Equivalent Resistance

- Most circuits have more than one resistor
- Overall resistance is different than individual resistances
- Equivalent Resistance
  - total resistance of the circuit
  - resistance of single resistor that produces same overall effect
  - 3 resistors with equivalent resistance 25 ohms could be replaced by one 25 ohm resistor
- Two ways resistors can be connected
  - Series
  - Parallel

Series



Equivalent Resistance

$R_{eq} = R_1 + R_2 + R_3 + \ldots + R_n$

Current

same in the resistors as in the battery

$I_{battery} = I_1 = I_2 = I_3 = \ldots = I_n$

Voltage

as charge travels there is a drop in potential difference

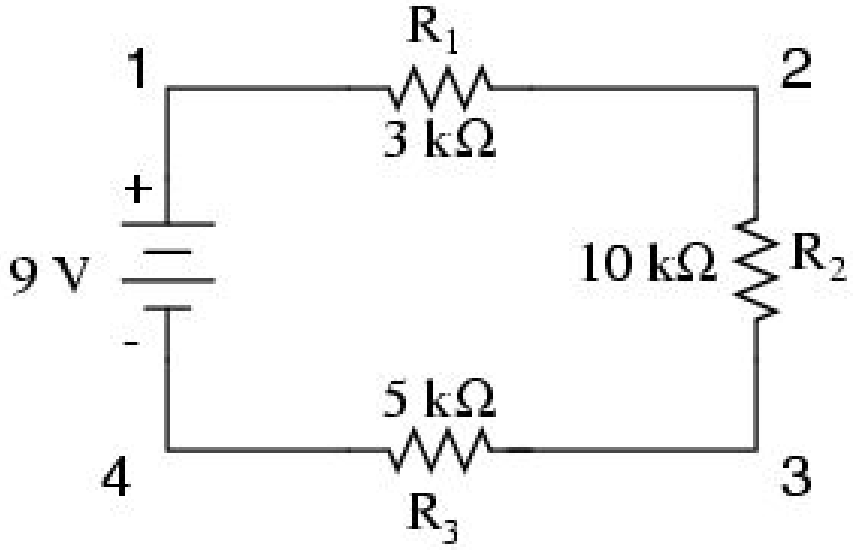
voltage drop

charge gains 12V passing through the battery

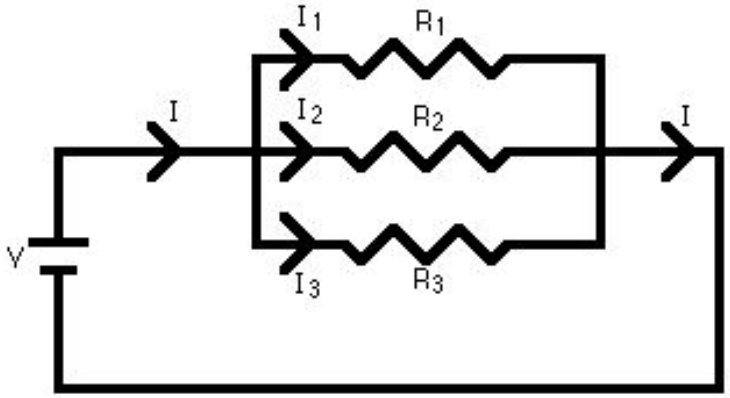
charge loses 12V passing through the external circuit

Series Resistors

1. What is the equivalent resistance?
2. What is the current through the entire circuit?
3. What is the current through
    a. R1?
    b. R2?
    c. R3?
4. What is the potential difference across
    a. R1?
    b. R2?
    c. R3?

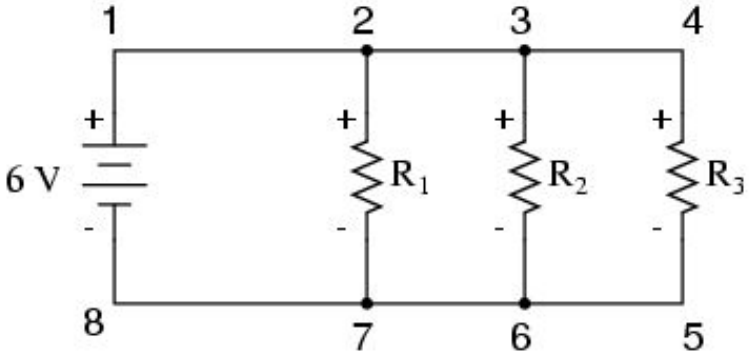


Parallel



Equivalent Resistance

$$1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n$$



Voltage

$$\Delta V_{battery} = \Delta V_1 = \Delta V_2 = \Delta V_3 = \ldots = \Delta V_n$$

Current

charge is splitting into separate pathways

current in individual pathway lower than outside the pathway

depends on two values

resistance of resistor

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

Parallel Resistor Practice Problems

2 conductors, wired in parallel, have conductances of 10S and 5S. What is the equivalent resistance the parallel circuit?

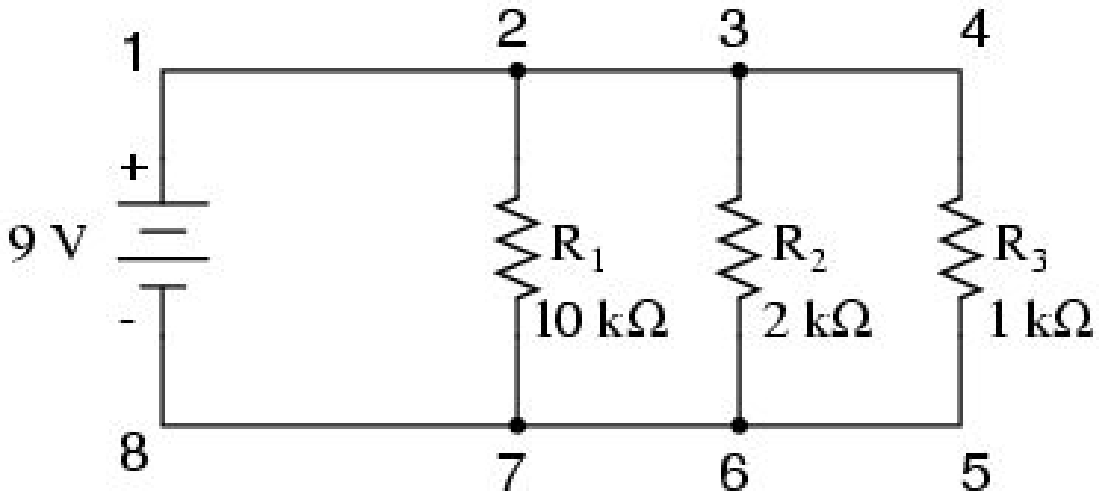
Remember:

$$G = \frac{1}{R}$$

G = Conductance (in Siemens)

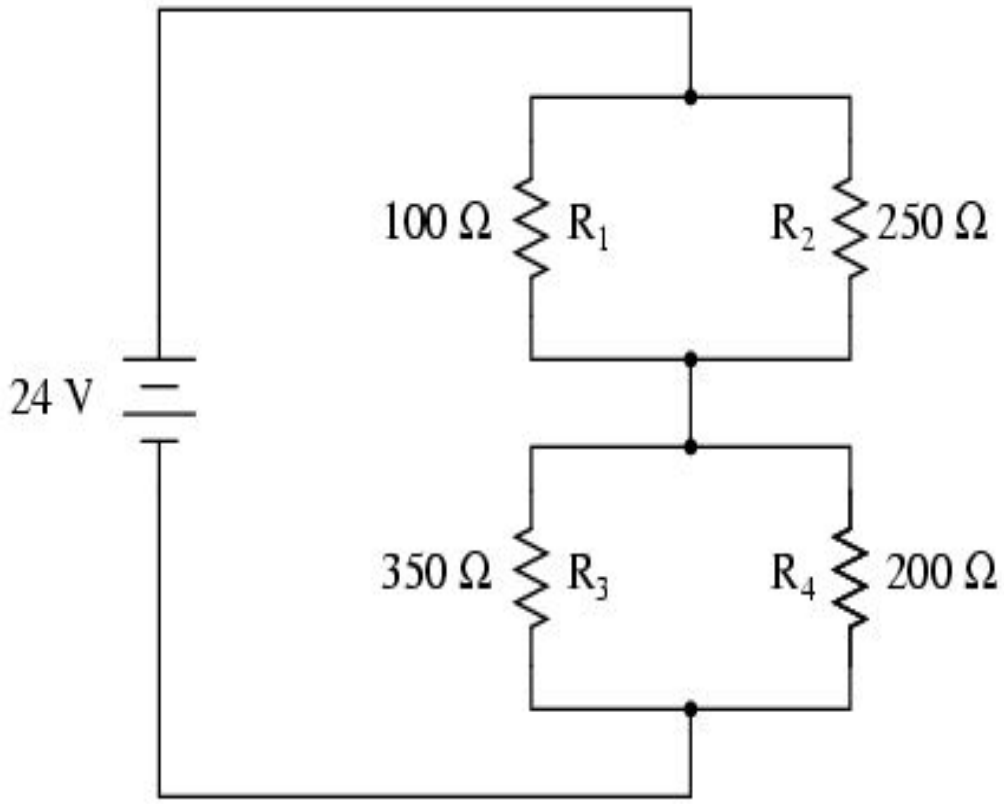
Parallel Resistor Practice Problems

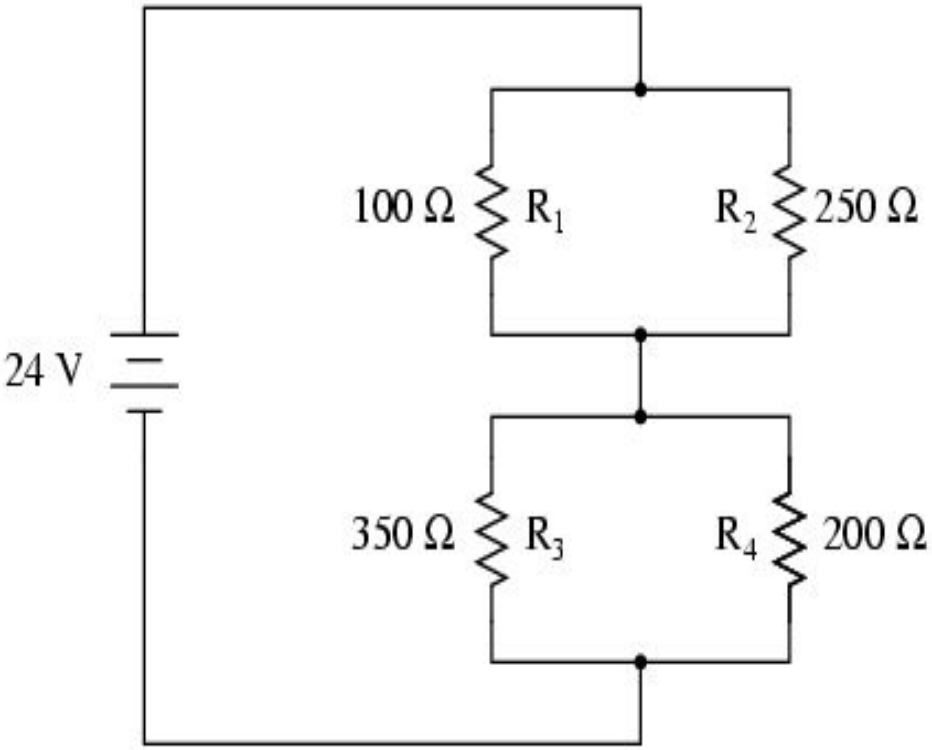
1. What is the equivalent resistance?
2. What is the current through the entire circuit?
3. What is the potential differer
    a. R1?
    b. R2?
    c. R3?
4. What is the current through
    a. R1?
    b. R2?
    c. R3?



Parallel and Series Practice Problem

1. What is the equivalent resistance?
2. What is the current through the entire circuit?
3. What is the potential difference across
    a. R1?
    b. R2?
    c. R3?
    d. R4?
4. What is the current through




24 V
100 Ω
R1
R2
250 Ω
350 Ω
R3
R4
200 Ω