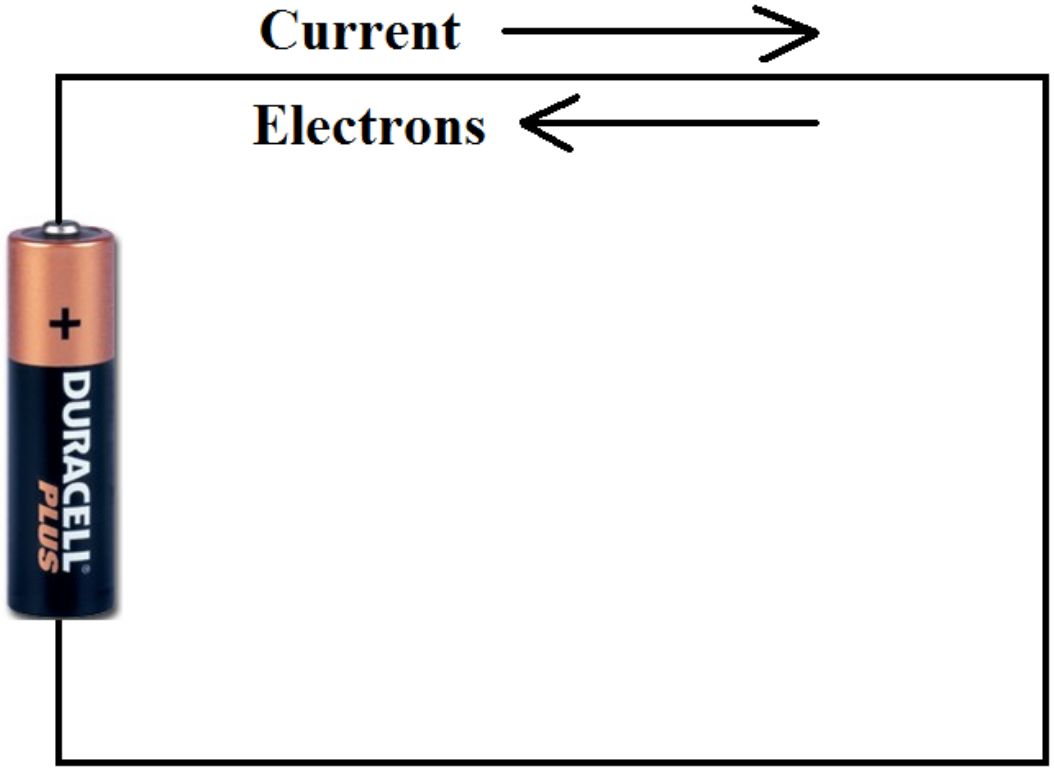
# Themed: 06-01

Basic circuit example, schematic, Resistors, batteries & symbols/units, series resistors, current, voltage, Ohm's law

# Basic circuit example

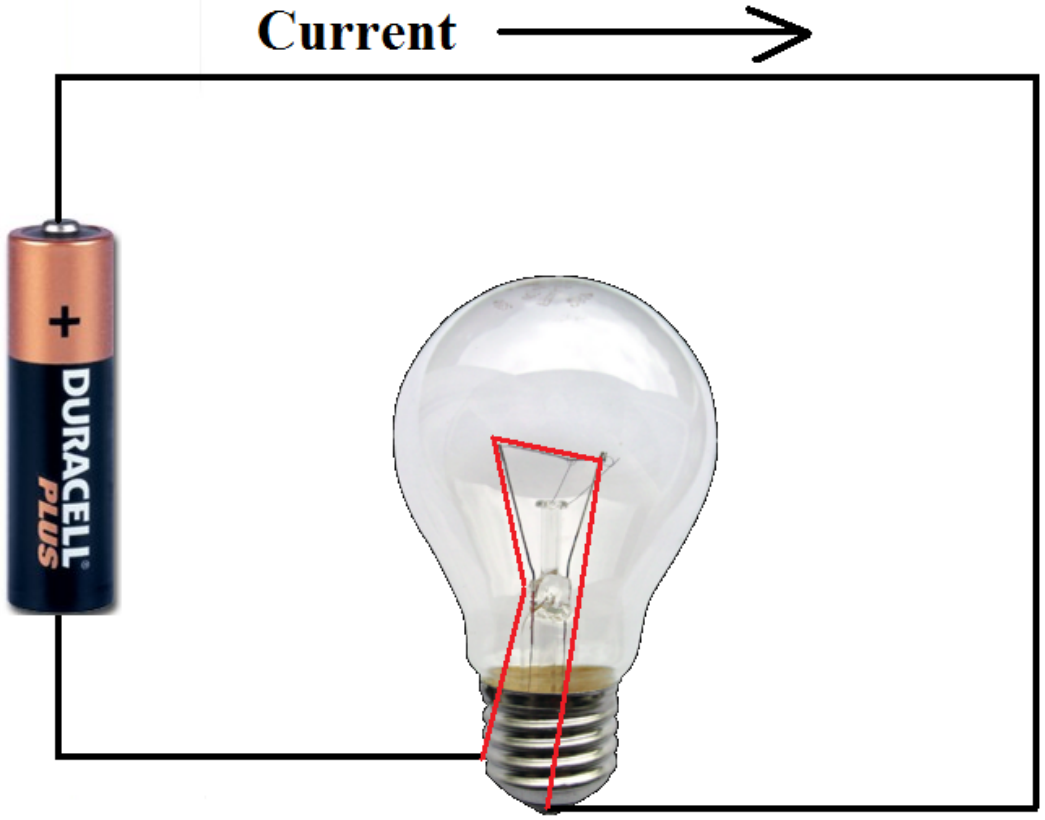
- Voltage source shorted with a wire
- Current: Flow of positive charge (opposite of what's really flowing (electrons))
- Electrical conductors (metals) have loosely bound valence electrons, which move charge freely




When we say charge flows from one point to another, we really mean the anti-flow of electrons, don't let this confuse you! (keep in the back of your mind)

# Basic circuit example - Bulb

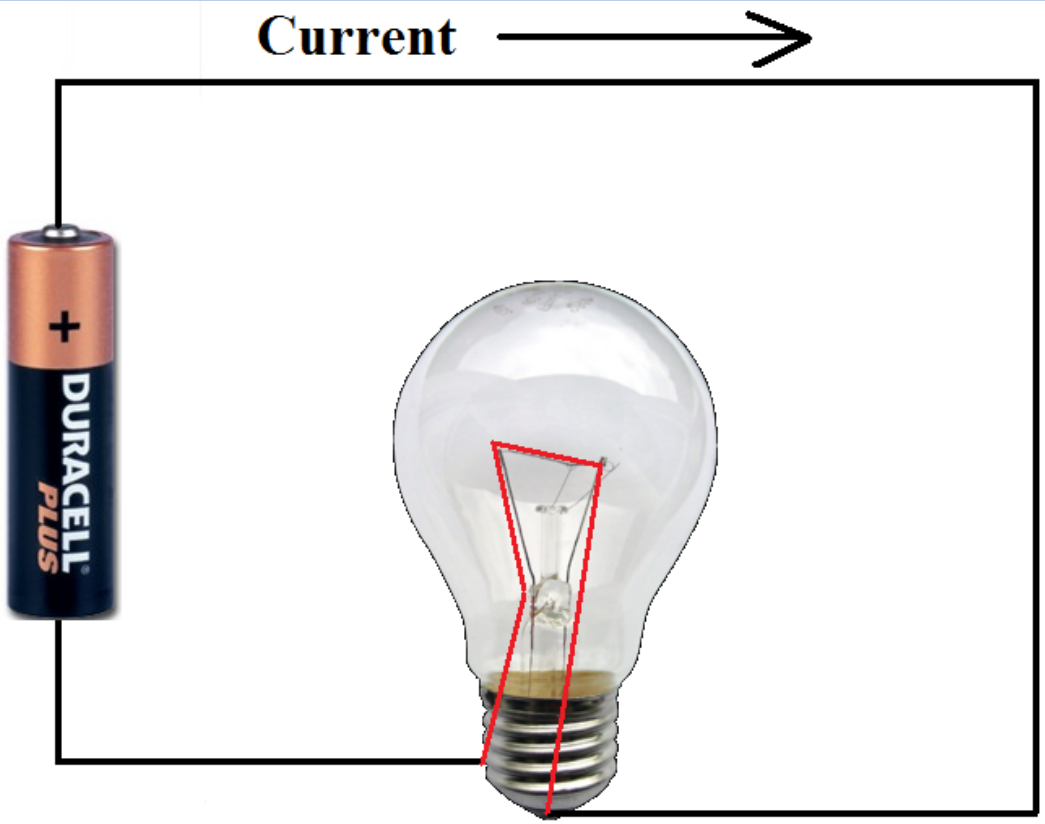
- Voltage source pushes electrons through resistance
- Bulb is a resistor you'll use for six days.
- Understand charge flows through bulb going in the bottom and out the side




Without resistance, electrons flow too fast and wire heats up a "short circuit" (previous picture of "simplest circuit")

# Basic circuit example - Filament

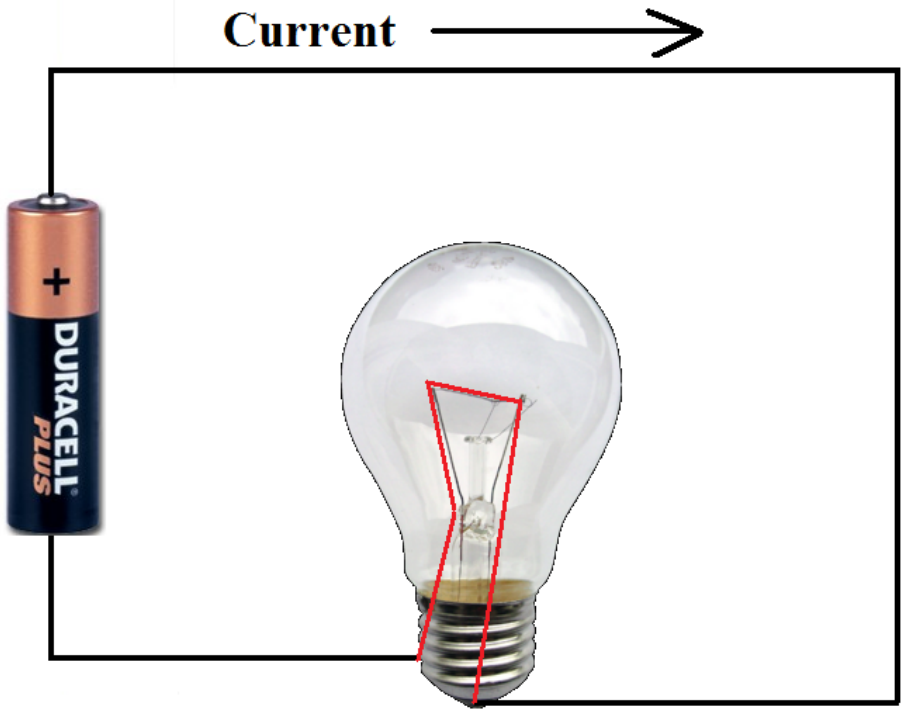
- Thin wire in bulb is called the filament
- Wire bulbs are incandescent, meaning they are so hot they glow – most energy is wasted in heat

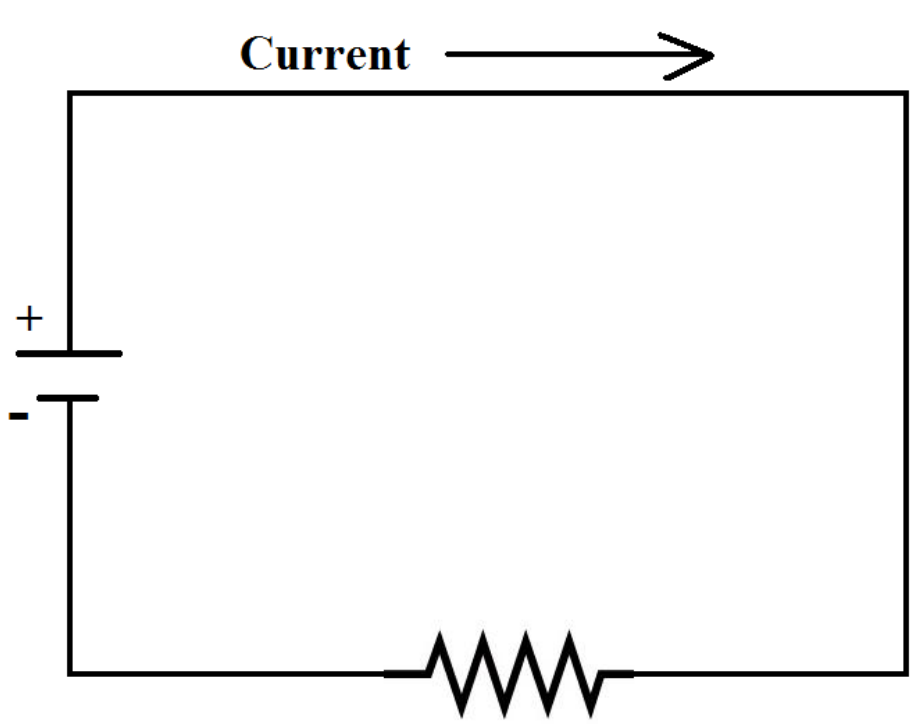



•Thick filaments are bright (lots of room for many electrons)
•Thin filaments are dim (narrow, few electrons can flow)

# Schematic

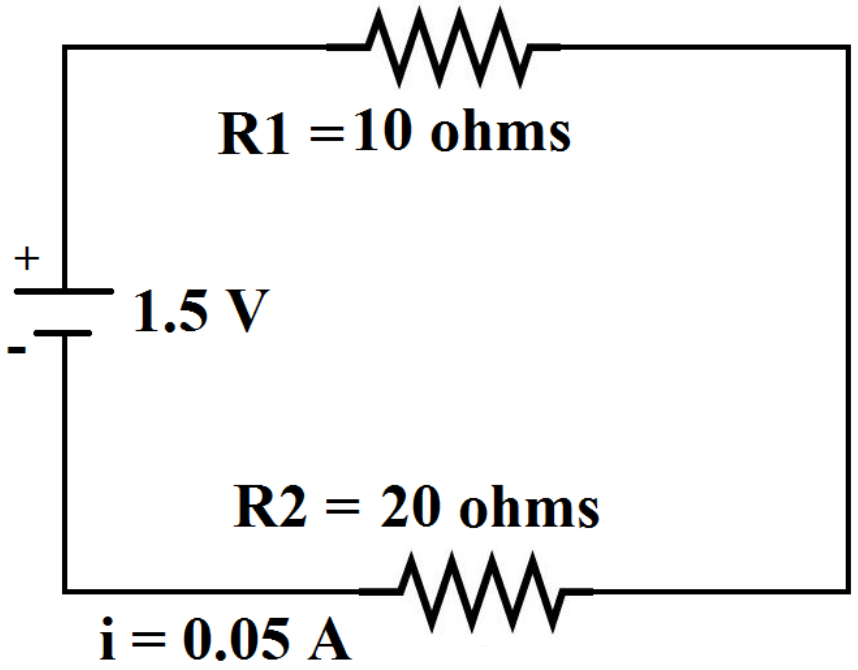
- Rather than drawing realistic-looking bulbs and batteries, we use symbols
- Batteries, or voltage sources have a wide positive and a narrow negative
- Resistors have a sawtooth symbol, sometimes put a circle around resistor symbol to symbolize a bulb



# Resistors, batteries & symbols/units

- Resistors resist flow of charge
- Resistance (R) is measured in ohms (Ω)
- More ohms = more resistance to flow of charge
- Battery "push" voltage (V) measured in volts (V)
- Current (i) measure in amps (A)

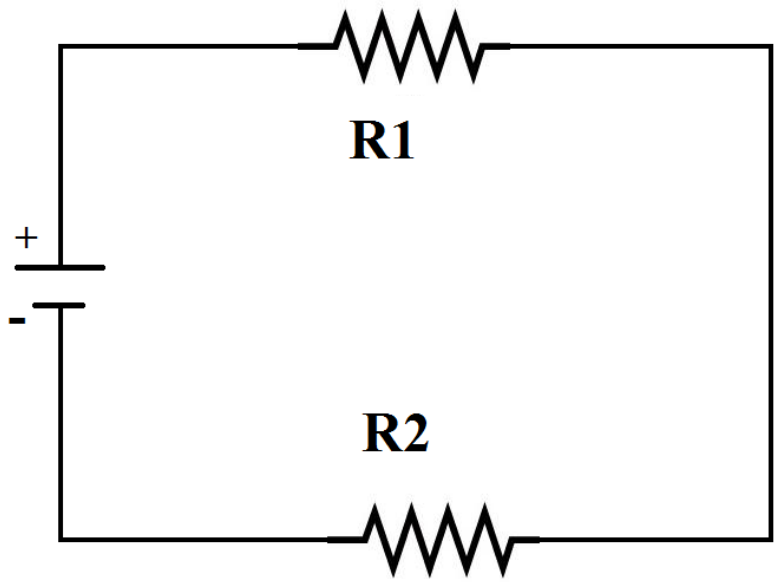



- 1 amp = 1 coulomb of charge flowing by any particular point in a wire each second

- In calculations, Copper wire is usually assumed to have no resistance

# Series resistors– shopping analogy

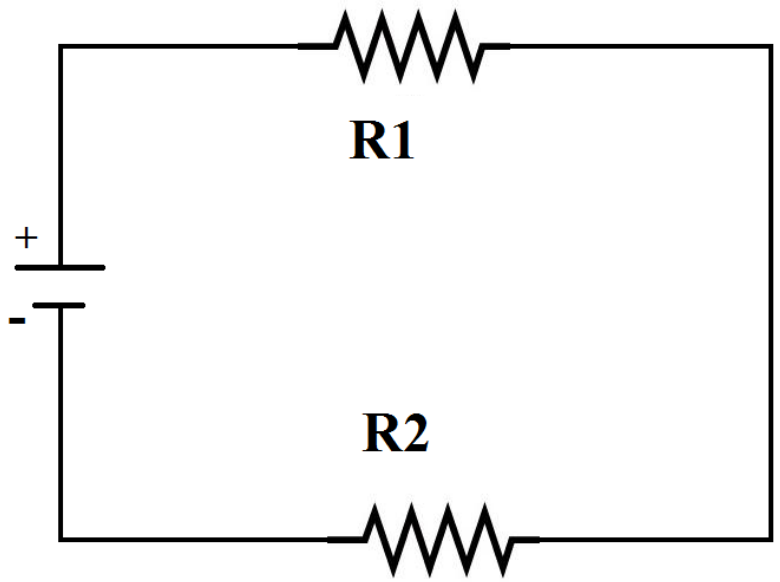
- Imagine you're doing holiday shopping
- First: Wait in check out line
- Second: Wait in gift box line
- Do two consecutive lines speed flow of shoppers?
- Two consecutive resistors are in "series"




- Resistors in series have more resistance
- We'll learn the math for series and parallel resistors later

# What is current?

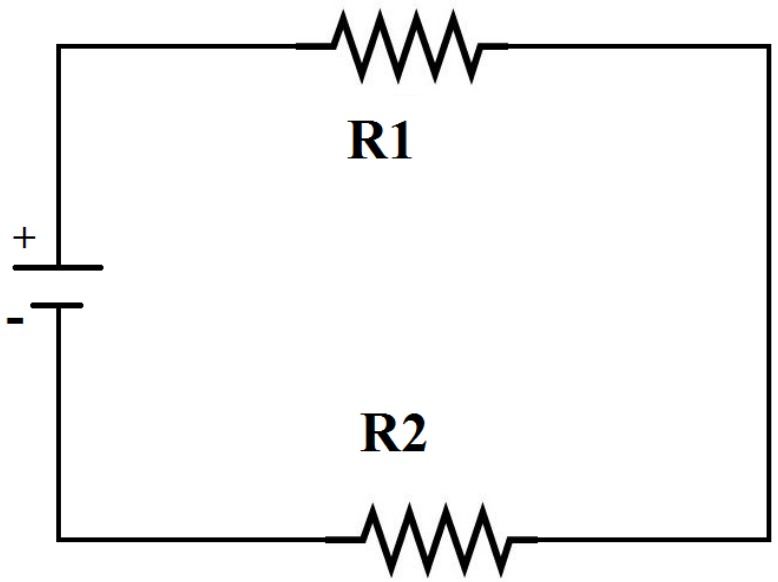
- Conventional Current is the flow of positive charge
- Electrons flow the opposite way
- Measure in Amps, short for amperes
- Symbol for current is I
- I = Q/t




- What direction does current flow?
- What direction do electrons flow?

# What is voltage?

- Voltage is the push of charge toward lower voltage
- Think of +/- as elevation, charge goes downhill
- AKA: emf (electromotive force)
- Schematic shows wide end as +, narrow as –
- Voltage drops across resistance ONLY
- In calculations, we assume wire has zero resistance




- Which has higher voltage, left of R1 or right of R1?
- Which has higher voltage, left of R2 or right of R2?

# Ohm's law

- The relationship between voltage, current and resistance is called Ohm's law and is the cornerstone of current electricity:

$\Delta V = iR$ (voltage drop = current flow x resistance to current flow)

Example: how much current flows when a 12 volt battery is wired to a 4 ohm resistor? (draw a schematic & solve)

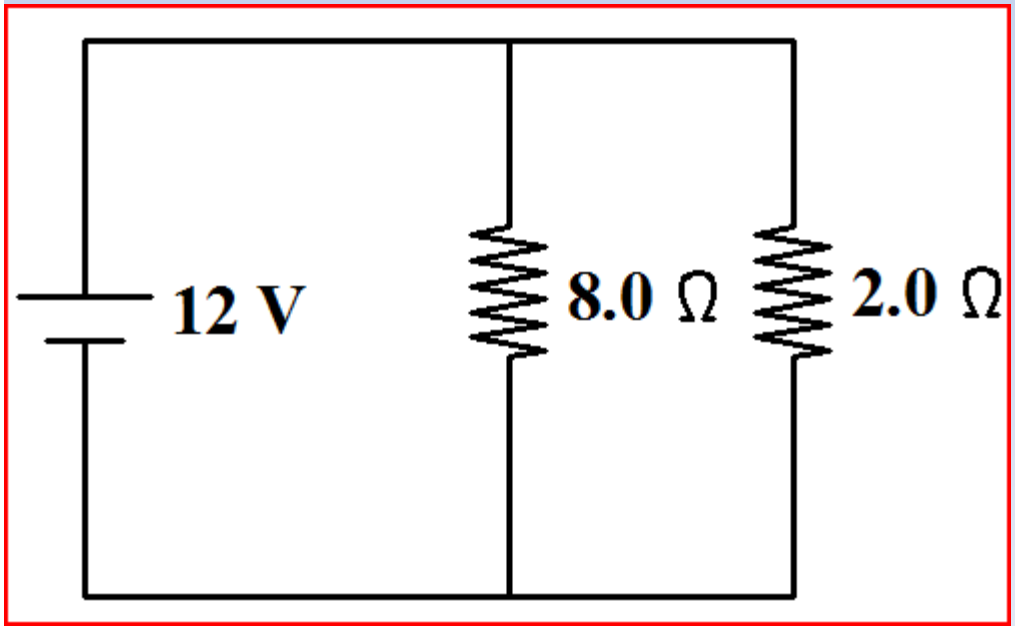
*(3A)*

# Themed: 06-02

Parallel resistors, Cost of electricity, Wire resistance/drift velocity

# Parallel resistors

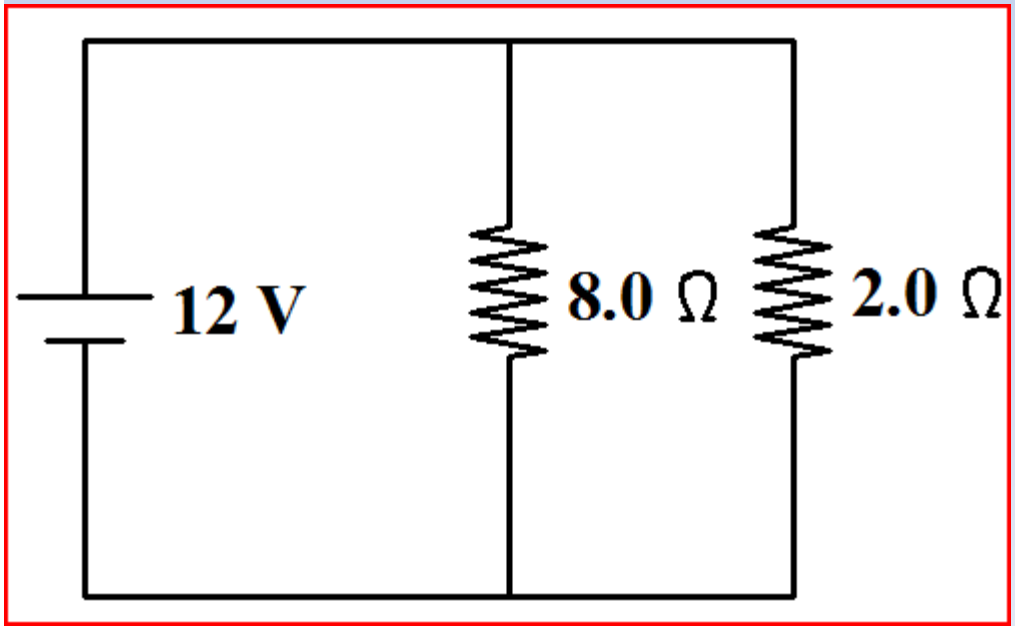
- You leave your car to go shopping
- To return to your car, must check out
- One cashier is really slow; the other is fast
- Which has the most resistance to the flow of shoppers?




- Would it speed things up if there were only one cashier?
- Does opening another traffic lane help?
- Do you see how parallel is a fork in the road? Would a third parallel resistor help?

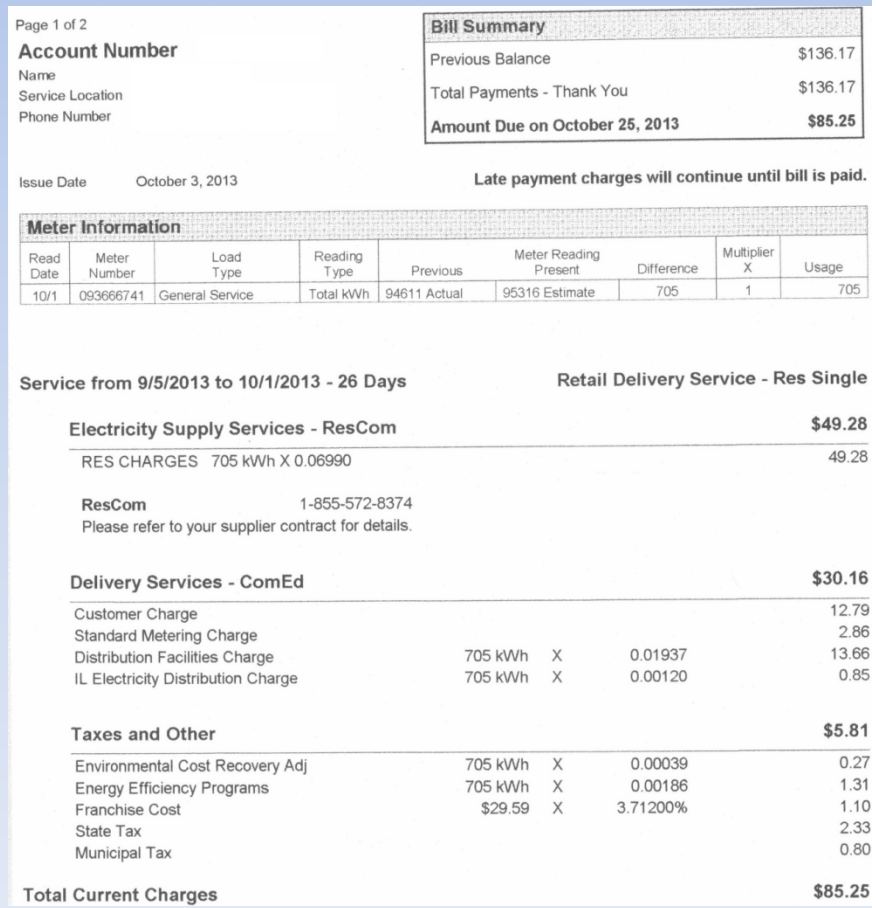
# Parallel resistors – overall resistance

- What can you say about the overall resistance below in ohms? (>8, >2, <2, between 2 and 8)?
- There's math to figure this out, we'll do that later



# Cost of electricity

- This is my ComEd bill from Fall 2013
- Using 705 kw-hrs cost me $85.25
- To nearest penny this is **12** cents/kw-hr (you'll memorize this)
- 5 yrs ago we used 10 cents!



Page 1 of 2

**Account Number**
Name
Service Location
Phone Number

| Bill Summary | |
|---|---|
| Previous Balance | $136.17 |
| Total Payments - Thank You | $136.17 |
| **Amount Due on October 25, 2013** | **$85.25** |

Issue Date October 3, 2013

**Late payment charges will continue until bill is paid.**

**Meter Information**

| Read Date | Meter Number | Load Type | Reading Type | Meter Reading Previous | Meter Reading Present | Difference | Multiplier X | Usage |
|---|---|---|---|---|---|---|---|---|
| 10/1 | 093666741 | General Service | Total kWh | 94611 Actual | 95316 Estimate | 705 | 1 | 705 |

**Service from 9/5/2013 to 10/1/2013 - 26 Days** **Retail Delivery Service - Res Single**

| | | | | |
|---|---|---|---|---|
| **Electricity Supply Services - ResCom** | | | | **$49.28** |
| RES CHARGES 705 kWh X 0.06990 | | | | 49.28 |
| **ResCom** 1-855-572-8374 | | | | |
| Please refer to your supplier contract for details. | | | | |
| **Delivery Services - ComEd** | | | | **$30.16** |
| Customer Charge | | | | 12.79 |
| Standard Metering Charge | | | | 2.86 |
| Distribution Facilities Charge | 705 kWh | X | 0.01937 | 13.66 |
| IL Electricity Distribution Charge | 705 kWh | X | 0.00120 | 0.85 |
| **Taxes and Other** | | | | **$5.81** |
| Environmental Cost Recovery Adj | 705 kWh | X | 0.00039 | 0.27 |
| Energy Efficiency Programs | 705 kWh | X | 0.00186 | 1.31 |
| Franchise Cost | $29.59 | X | 3.71200% | 1.10 |
| State Tax | | | | 2.33 |
| Municipal Tax | | | | 0.80 |
| **Total Current Charges** | | | | **$85.25** |

# Cost of electricity

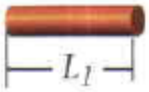
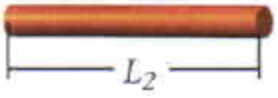
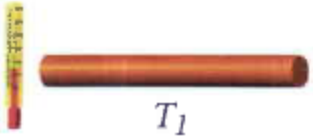
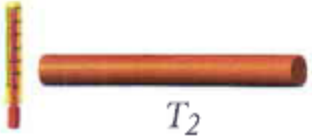
Equations to use:

- P = iV (power in watts = current in amps x voltage)
- P = E/t (power = energy/time)
- E = P t (same equation above, solved for energy)
- **Do you pay for power or energy? How much does it cost to run a 100 W light bulb? What's missing (or Watt's missing!)?**
- Use E = P t where E is kilowatt-hours (convert time to hours and power to kilowatts)
- Example: How much does it cost to run a 40 watt night light 12 hrs every night for 365 days?
- Example 2: To light a tennis court indoors at my club takes eight bright lights. I think they're 1000 watt lights. Assuming that's right and assuming my club gets an industrial rate half of mine, how much does it cost them to light up a tennis court for an hour?

# Drift Velocity & Factors affecting wire resistance

- Drift velocity: Average speed of electrons in circuit…Electrons move slow, current sets up at light speed
- Yes, assume resistance for calculations, but…..
- Know what affect wire resistance
- Harder to move charge = more resistance

**Table 2 Factors That Affect Resistance**

| Factor | Less resistance | Greater resistance |
|---|---|---|
| Length |   |   |
| Cross-sectional area |  $A_1$ |  $A_2$ |
| Material |  Copper |  Iron |
| Temperature |  $T_1$ |  $T_2$ |

- Has farther to go
- Has fewer electrons to help move charge
- Material property

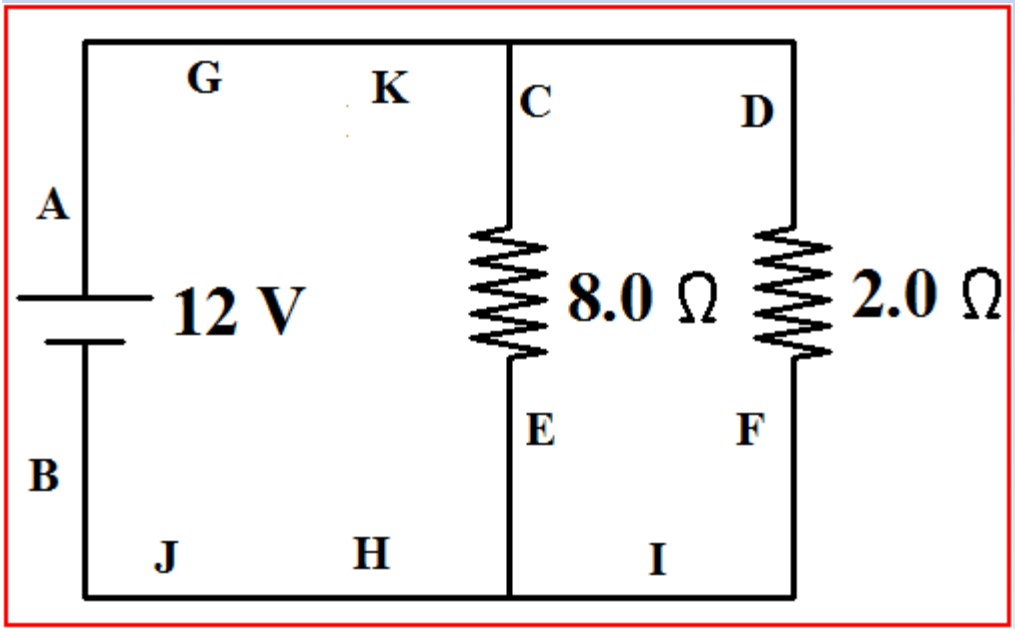
- Hotter = more atomic vibration = more R

# Themed: 06-03

Solving Simple Circuits Mathematically, Wire paths make voltages same!, examples, Circuit strategies, Finding power& cost

# Solving Simple Circuits Mathematically

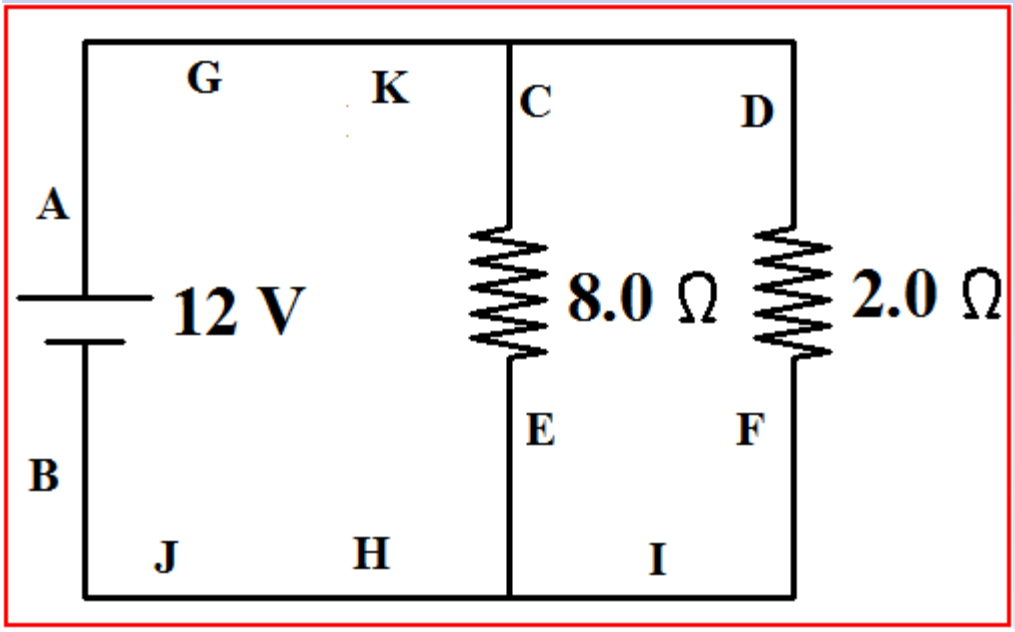
- Combine resistors & solve via Ohm's law
- Realize voltage drops only take place over resistors
- Combine in series: $R_e = R_1 + R_2$
- Combine in parallel: Parallel $1/R_e = 1/R_1 + 1/R_2$




- Which pts have 12 V? 0 V?
- How much current goes
  - Through 8Ω resistor?
  - Through 2Ω resistor?
  - In/out of battery?
- What's $R_e$ for this circuit?
- How much current does that $R_e$ predict?

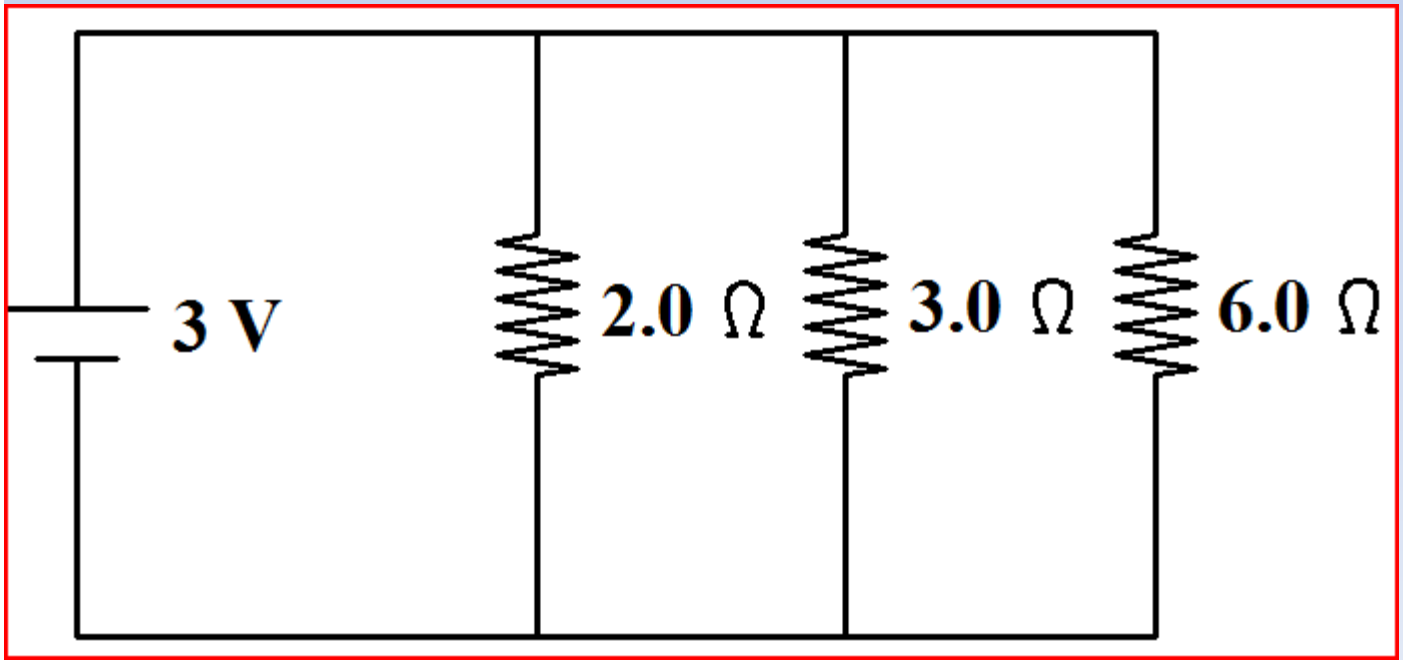
# Wire paths make voltages same!

- Remember: For any calculation, assume no resistance in copper wires
- V = iR says that: No voltage drop occurs over wire
- Voltage only drops across resistors!
- Which voltages are the same?



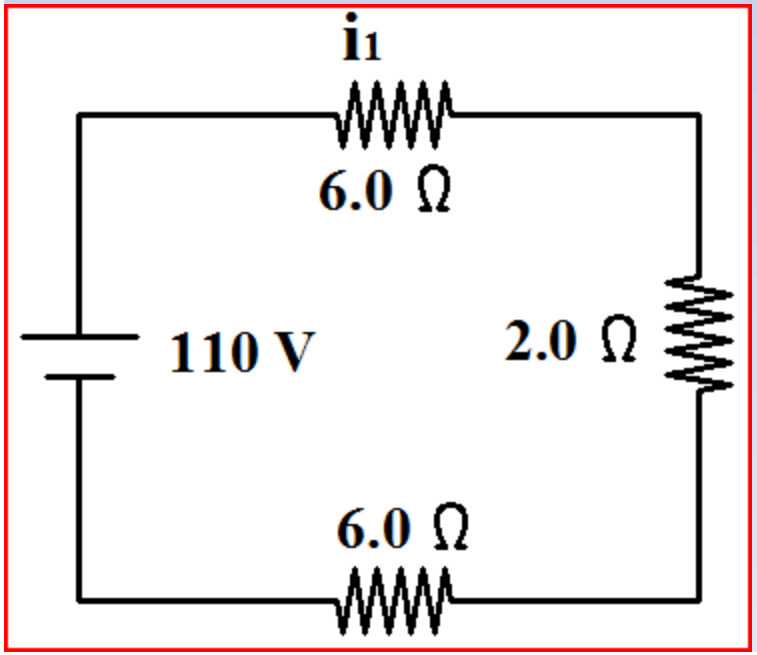
# Example 1: Resistors in parallel

- Resistors in parallel have the same voltage drop across them
- What would be the equivalent resistance for this circuit?
- Now you can find the current entering/leaving battery



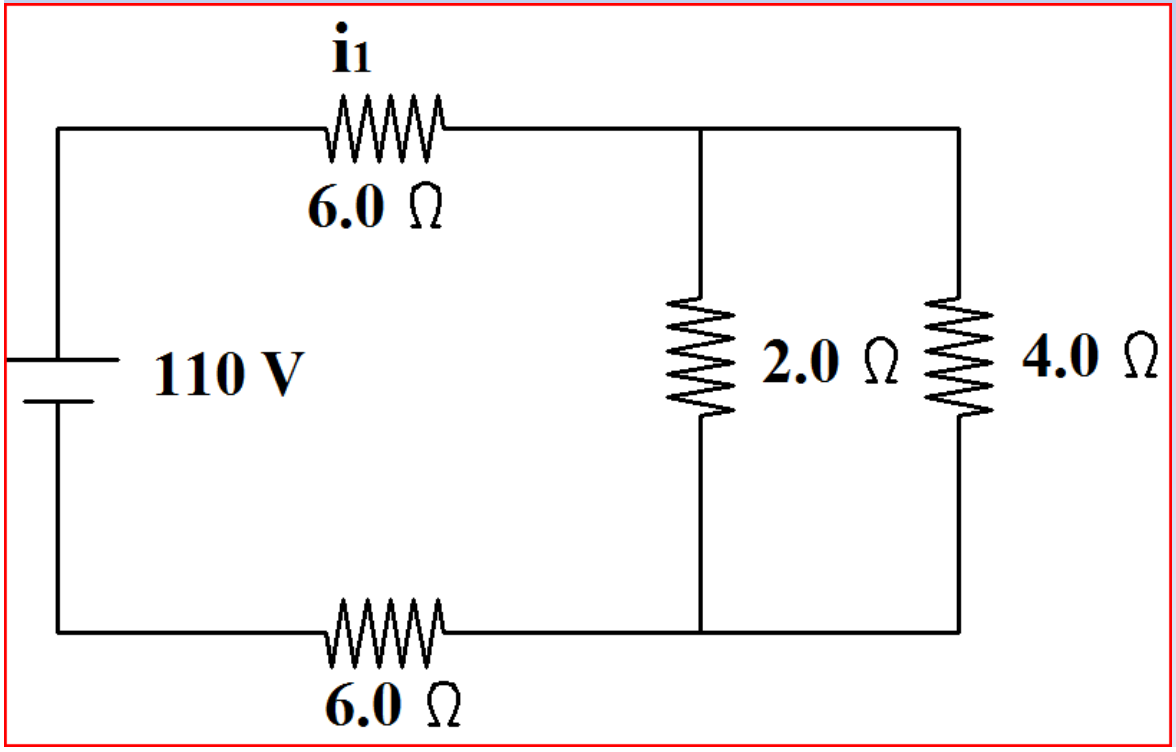
# Example 2: Resistors in series

- Resistors in series have the same current passing through them
- Where could current possibly split off?
- What would be the equivalent resistance for this circuit?



# Example 3: Mixed circuits

- How would you figure the equivalent resistance for this circuit?
- Two resistors in series: When current HAS to leave one and enter the next
- Two resistors in parallel: When they have the same entrance and exit voltages
- Do you see how neither the 2 or 4 ohm resistors are in series, but their equivalent is?




•Do it in two steps:

1) find Re for 2 and 4 ohm resistors

2) add all three now in series

# Themed: 06-04

Circuit board care, Multimeter: introduction, plug placement, dial setting, conductivity test, ammeter/voltmeter: circuit placement, examples

# Circuit board care

- Note your board number (same each time)
- Always paper underneath
- Battery voltage (ALL alkaline batteries are 1.5V DC…know this!)
- Weak solders sometimes, treat carefully, especially bulbs – NEVER pick up by battery holder!
- NEVER twist or bend a resistor!
- Show bulb side and bottom

# Multimeter – intro and plug placement

- Multimeter is 3-in-1 meter
  - Ohmmeter: measures resistance
  - Voltmeter: measures voltage drops (difference)
  - Ammeter: measures amps (current)


• Multimeter is a circuit itself, so must have a “return” lead – black lead into COM port

•Black port never changes

•Red port VΩ plug: Volt or ohmmeter

  •High resistance

•Red port 10A: ammeter

  •Low resistance

# Multimeter – Dial Setting

- Multimeter has three dial settings:

1. Voltage (DC voltage..what we're using)
2. Amps (ammeter)
3. Ohms (ohmmeter)


• We wont' use AC voltage region – this is for dangerous voltages we don't experiment with

•Top setting is OFF, leave here or battery drains

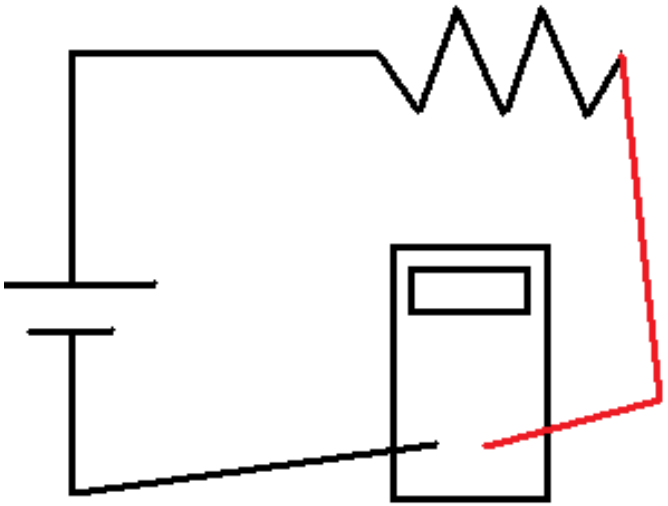
•Bottom setting is conductivity tester – sees two spots on board are SAME

# Multimeter – Conductivity Tester

- Beeps when leads are placed on conductive path (dial is set at “6:00”, pointed downward)
- Useful for testing if spring points are electrically the same
- Useful to check for burnt out bulb, break in circuit (de-soldered piece, etc.)
- Try checking all your bulbs now
- Check battery voltages are at least 1.1 V (let me know if below 1.25 V)
- Do Multimeter lab (2 pages)

# Ammeter/voltmeter: circuit placement

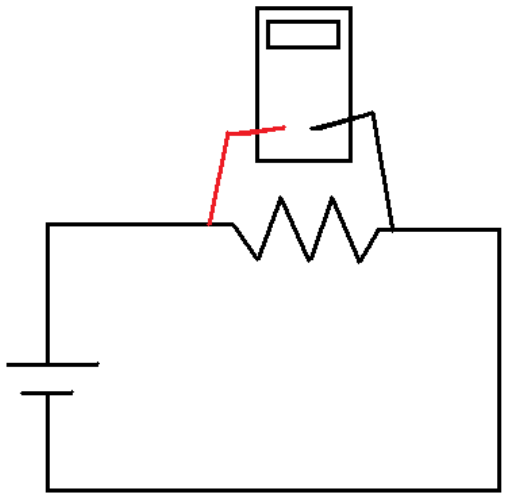
- Ammeter counts how many charges per second (this is what current is! – a charge CENSUS TAKER)
- All current must pass through ammeter for accurate count
- Ammeter can't have resistance, or would change circuit (would add resistance!)
- Ammeter must behave like wire – no resistance and be part of circuit (count all charges)



- Like always, red lead is on more positive side (though almost zero voltage drop)
- Reverse this & get negative current

# Ammeter/voltmeter: circuit placement

- Voltmeter compares voltage in two locations and subtracts black value from red value
- Voltmeter is high resistance device (**otherwise would short circuit what it's measuring**!)
- Not counting charges (want tiny amt. of current)



•Resistance like voltage (compare entrance to exit, not counting number of charges)
•For SAME REASON, want device to have huge resistance
•BOTTOM LINE: These devices are placed in parallel (opposite of ammeter)

# Multimeter – examples

- Set dial to max value you expect, if value too high, get error message (1 .  ?) and not a real value
  - Plug AND dial in correct locations? Red lead in right place?
  - Example: Measure two batteries in series with setting of 2 and setting of 20…which works? Any batteries <1.1 V?


• Place a resistor on board ….PLEASE DON'T TWIST!

•Find the resistance (dial and plug!)

•Connect via wire and measure current (dial and plug and part of circuit)

# Board and make wires

- Every pair make 3 or 4 wires
- Make wires 9”, strip ends enough to easily grasp
- Will help with robot project?

# Themed: 06-05

Resistor codes, Schematics & equivalent equipment diagrams, Consequences of bulb changes

# Resistor codes

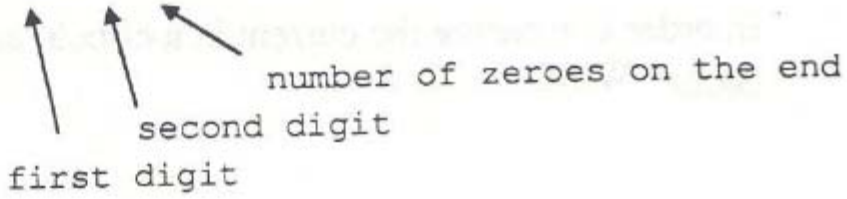
- Resistor codes use three colored stripes
- Fourth stripe is quality control codes (for accuracy, not for determining resistor value)

# Reading a resistor code

*Finding how many ohms a resistor is*

- First two stripes are first two digits
- Third stripe tells how many zeros go after second digit
- You won't have to memorize colors, just use them
- Try some examples……..

0 = black
1 = brown
2 = red
3 = orange
4 = yellow
5 = green
6 = blue
7 = violet
8 = gray
9 = white

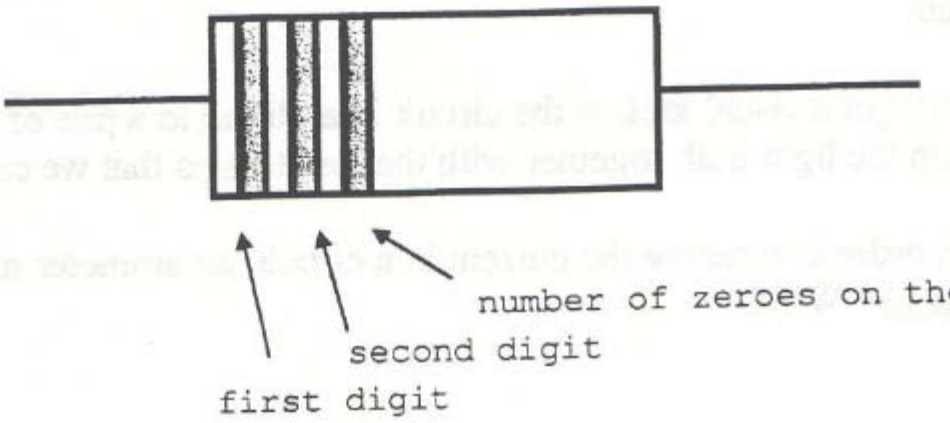


# Reading a resistor code

*Finding how many ohms a resistor is*

- 10 ohms, 100 ohms, 1000 ohms
- 730 ohms, 73 ohms
- Orange, black, black
- Violet, yellow, yellow
- Brown, black, black
- Brown, brown, black
- More practice available in packet!

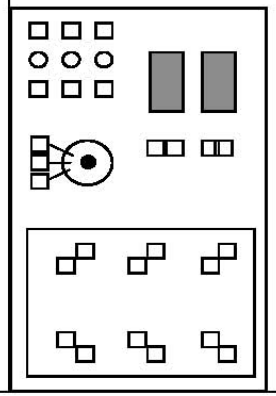
0 = black
1 = brown
2 = red
3 = orange
4 = yellow
5 = green
6 = blue
7 = violet
8 = gray
9 = white

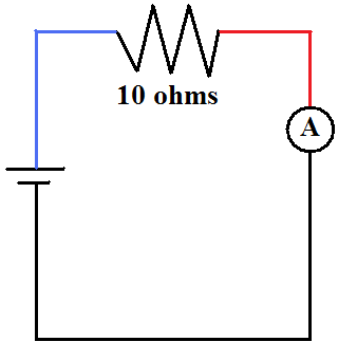
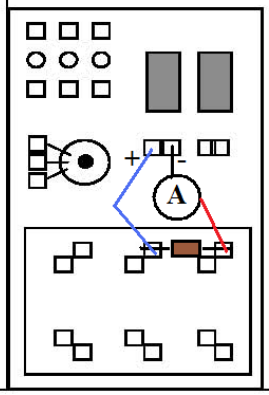


# Schematics & equivalent equipment diagrams

*Color coding helps, use colored pencils if handy*

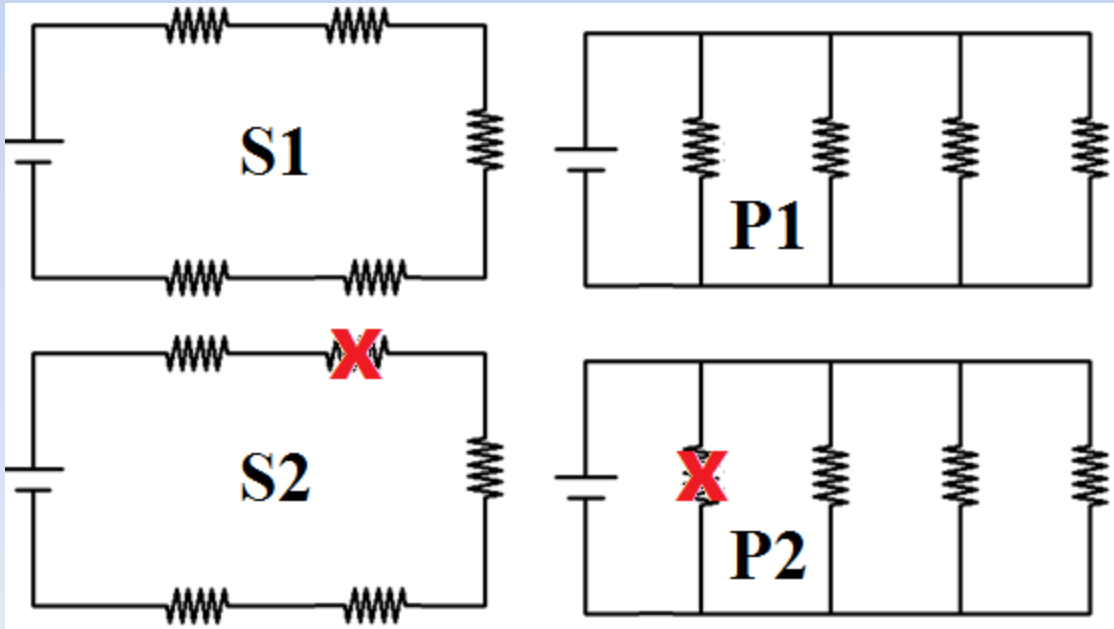
- Schematic uses symbols (sawtooth for resistor, etc.)
- Equipment diagrams: practical translation of schematic onto real circuit board model
- Example: Ammeter measuring current through circuit with 1.5V and single 10 ohm resistor
- Can you follow color-coding of like-parts in schematic and equipment? See how red lead is in more positive place?
- Try it and see if current is like theory predicts! ( i = V/R )
- Work on packets according to calendar

| Schematic Diagram | Equipment Diagram |
|---|---|
| |  |

| Schematic Diagram | Equipment Diagram |
|---|---|
|  |  |

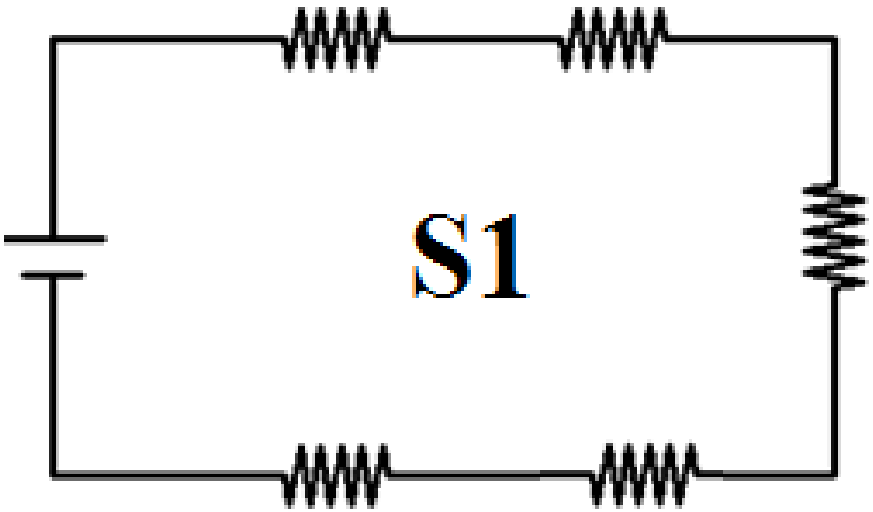
# *Consequences of bulb changes*

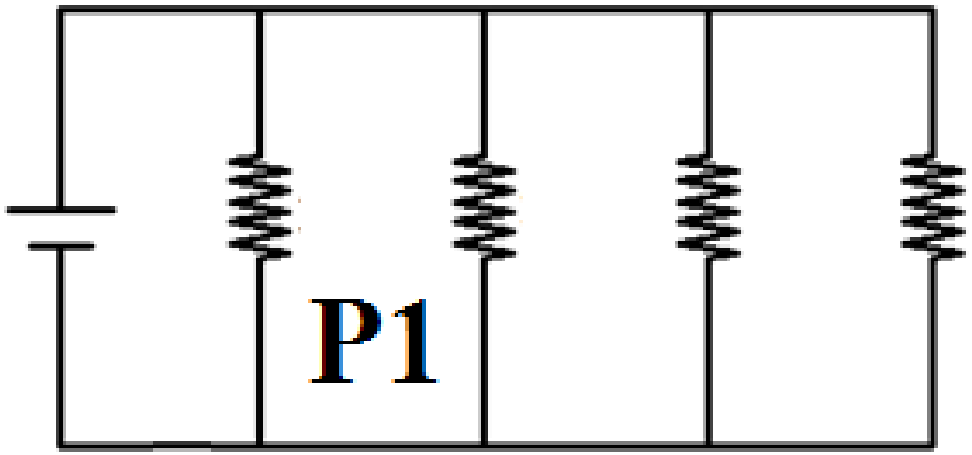
- Series circuit: Bulb out = circuit open, no light!
- Parallel circuit: Bulb out = remaining bulbs still get same voltage, burn just as bright!
- Added bulbs: Series, less voltage per bulb – dimmer!
- Added bulbs: Parallel, same volts per bulb, same brightness



# *Consequences of bulb changes*

- Power: more parallel resistors = less overall resistance = more current = more power
- Power: more series resistors = more overall resistance = less current = less power



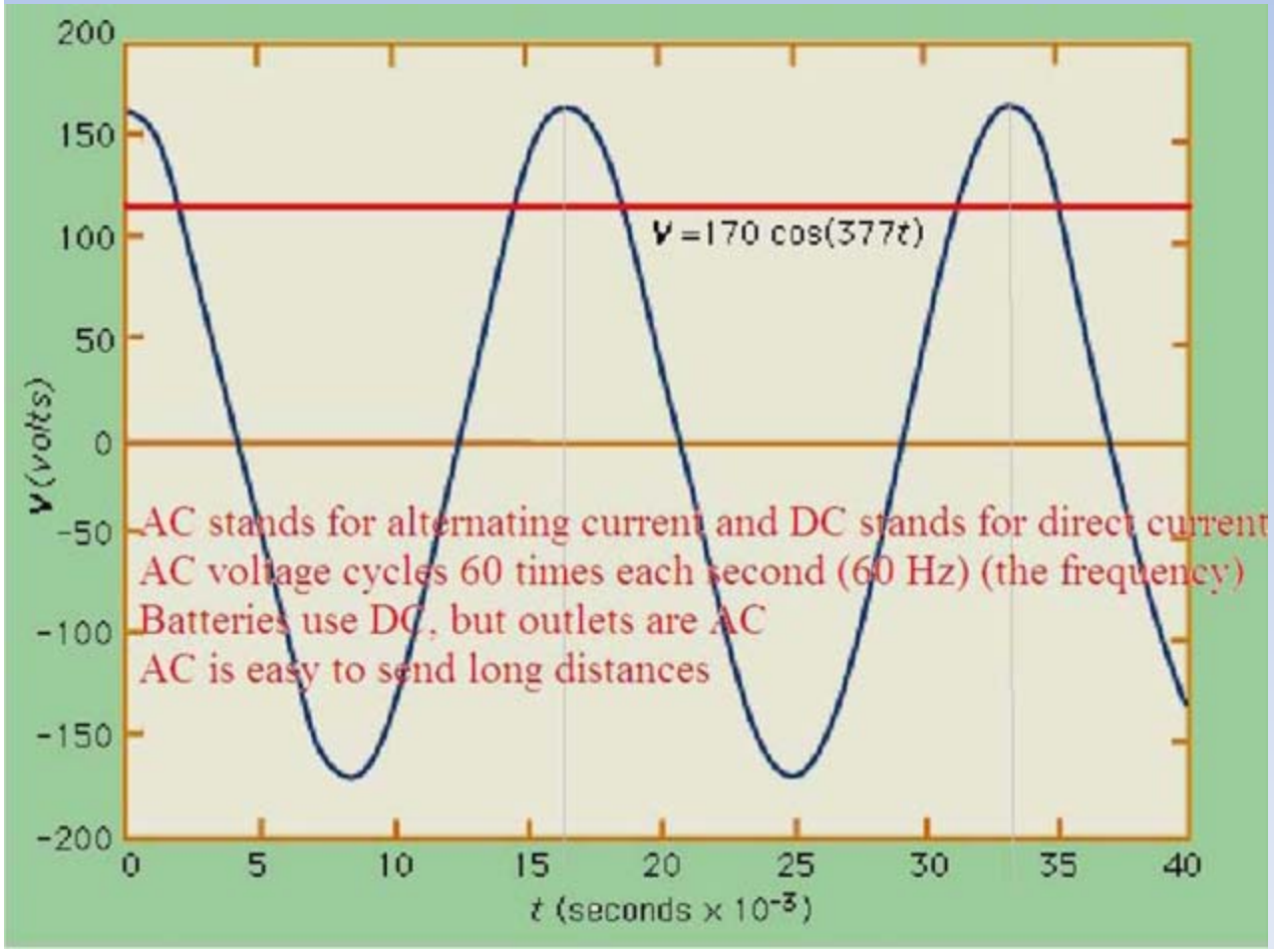



# Themed: 06-06

AC vs DC, Electricity kills, Circuit breakers/fuses

# AC vs. DC

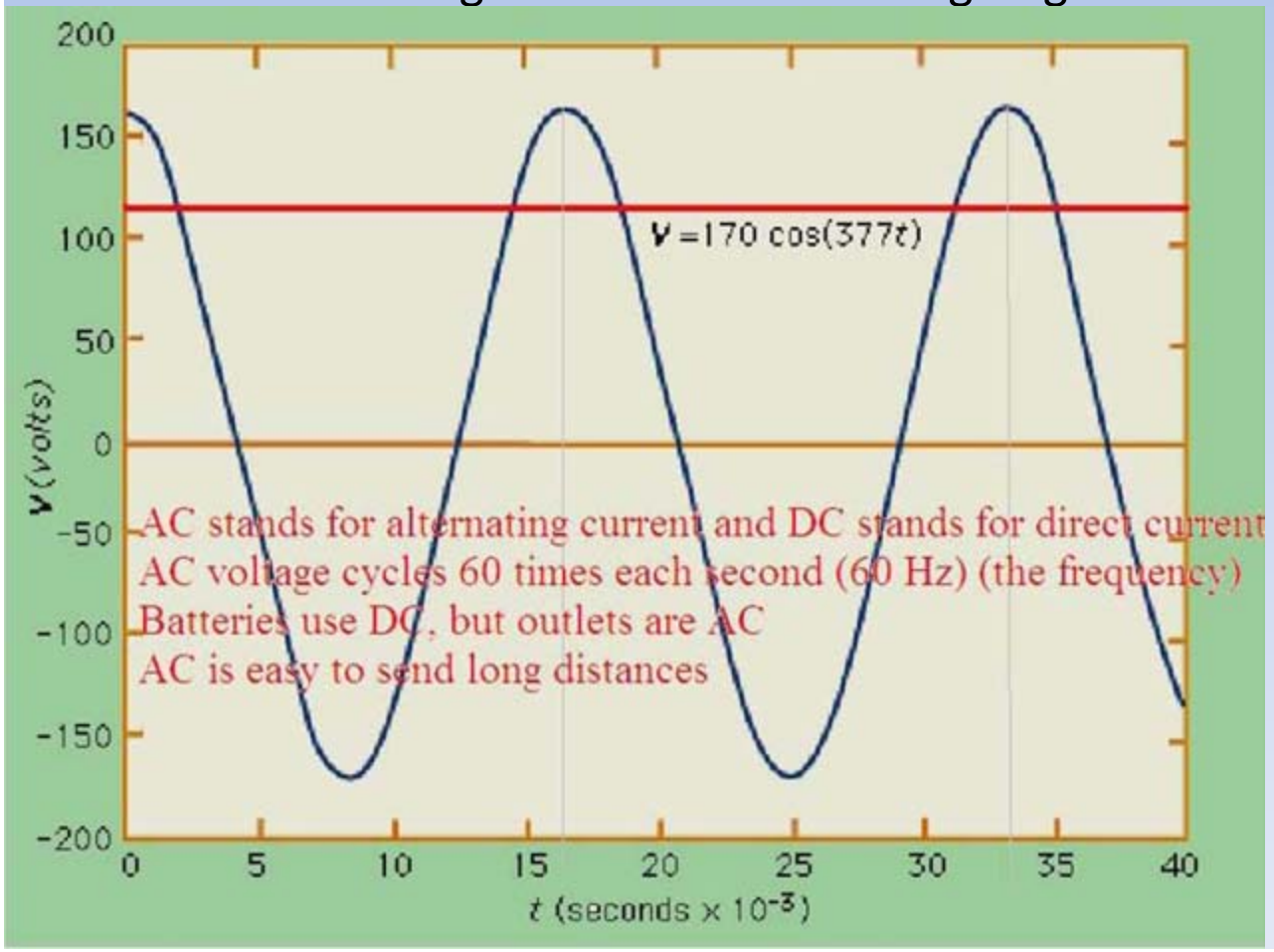
- AC stands for Alternating Current
- DC stands for Direct Current
- Tesla and Edison battled over which to use: Tesla won




- AC can go large distances without losing much energy; DC can't….this is why Tesla won!
- North American voltage is 120 V and frequency is 60 Hz (know this!)

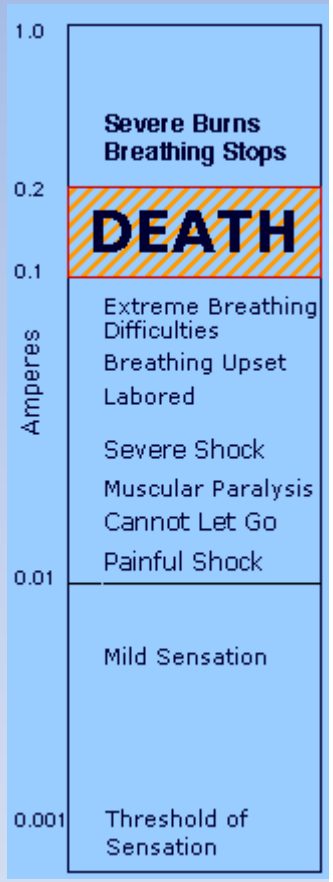
# AC vs. DC

- AC voltage varies continuously at 60 Hz
  - Push charges left at 170 volts, push charges right at 170 volts, repeat
  - Electrons don't move from power company to you – Power company only swishes them back and forth for you
  - Average *magnitude* of voltage is 120 volts
  - Bulb burn bright whether electrons go right or left



# Electricity kills

- High voltage produces high current…but: Current kills, not voltage
- Static shocks have high voltage, but little current
- Human resistance varies by 100x depending on dry skin vs. wet/salty (sweating)
- Wounds have extremely low resistance (insulating skin is gone, leaving salt water body directly exposed)
- Left pocket rule (keep current from heart)



# Circuit breakers/fuses

- Fuses and circuit breakers “open” when amps too big
- Breakers trip for a reason…Find the reason!
- Fuses melt when too many amps
- Circuit breakers can reset
- Shorting any fuse is dangerous! Wires get hot and cause fires!
- How do you get 240 V in your house for AC when only 120 V is delivered?...180° out of phase! (if you get this, you get AC)
- 240 V is much more dangerous than 120V