Physics 1B

Lecture 18A

"We live in a truly magical time. With a flick of a finger, the power of ten horses flows from a small wire in the wall of our homes to clean our carpets."

--Steven Chu

Power

- Why do electric companies make power lines with very high voltages to deliver electricity to your house?
- Let's make some estimations:
- R = 10Ω, V = 100,000V to deliver 100kW of power.
- First, don't make a common mistake:

$$P_{dis} = \frac{V^2}{R} = \frac{(100{,}000\text{V})^2}{10\Omega} = 1.0\times10^9\text{W}$$ <-no!

- This equation can only be used with a potential difference (ΔV) across a resistor.

Power

- Instead we will find the current by the power transfer equation.

$$P = IV$$

$$I = \frac{P}{V} = \frac{100\text{kW}}{100{,}000\text{V}} = 1\text{A}$$

- Now we can input this current in the proper power dissipation equations.

$$P_{dis} = I^2R = (1A)^2 10\Omega = 10\text{W}$$

- This only represents a 0.01% loss of power transferred to resistive effects (not bad!).

Power

- What if power companies used lower potential for their transmission lines (say 2,000V)?

$$P = IV$$

$$I = \frac{P}{V} = \frac{100\text{kW}}{2{,}000\text{V}} = 50\,\text{A}$$

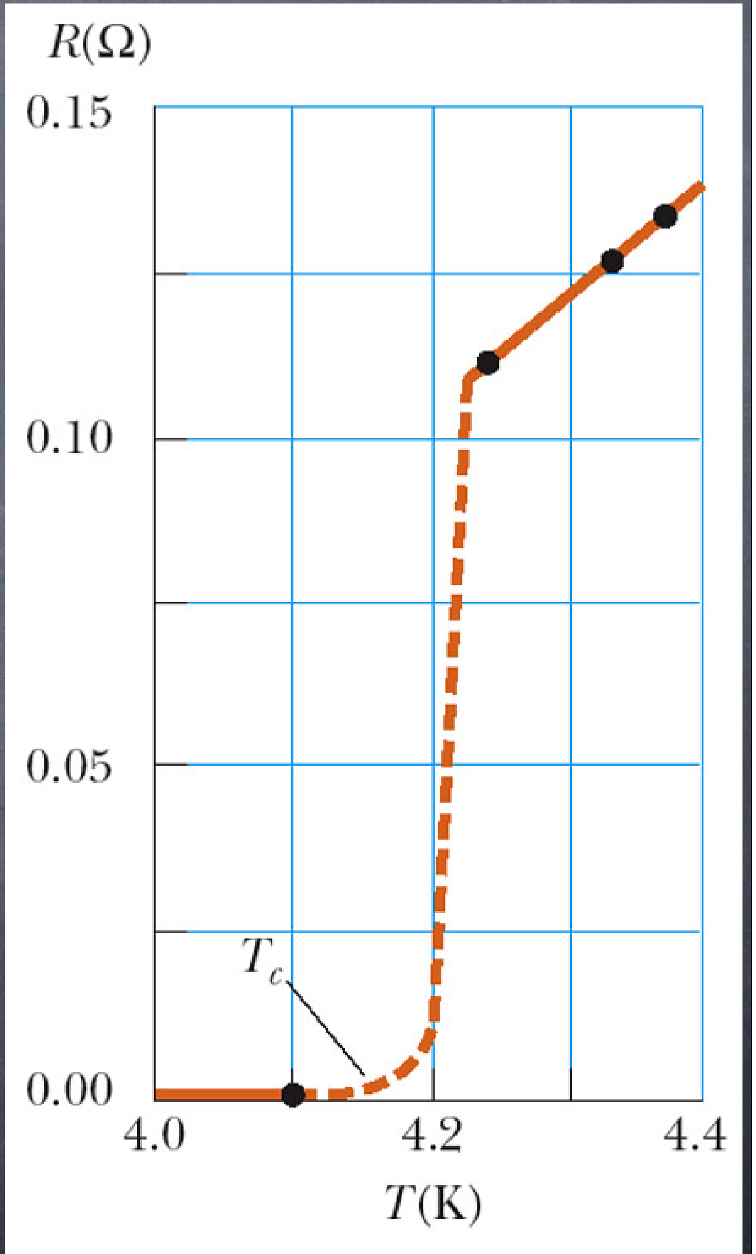
- Now we can input this current in the proper power dissipation equations.

$$P_{dis} = I^2R = (50\,A)^2 10\Omega = 25{,}000\text{W}$$

- 25% of power is lost to heat. That isn't good business.

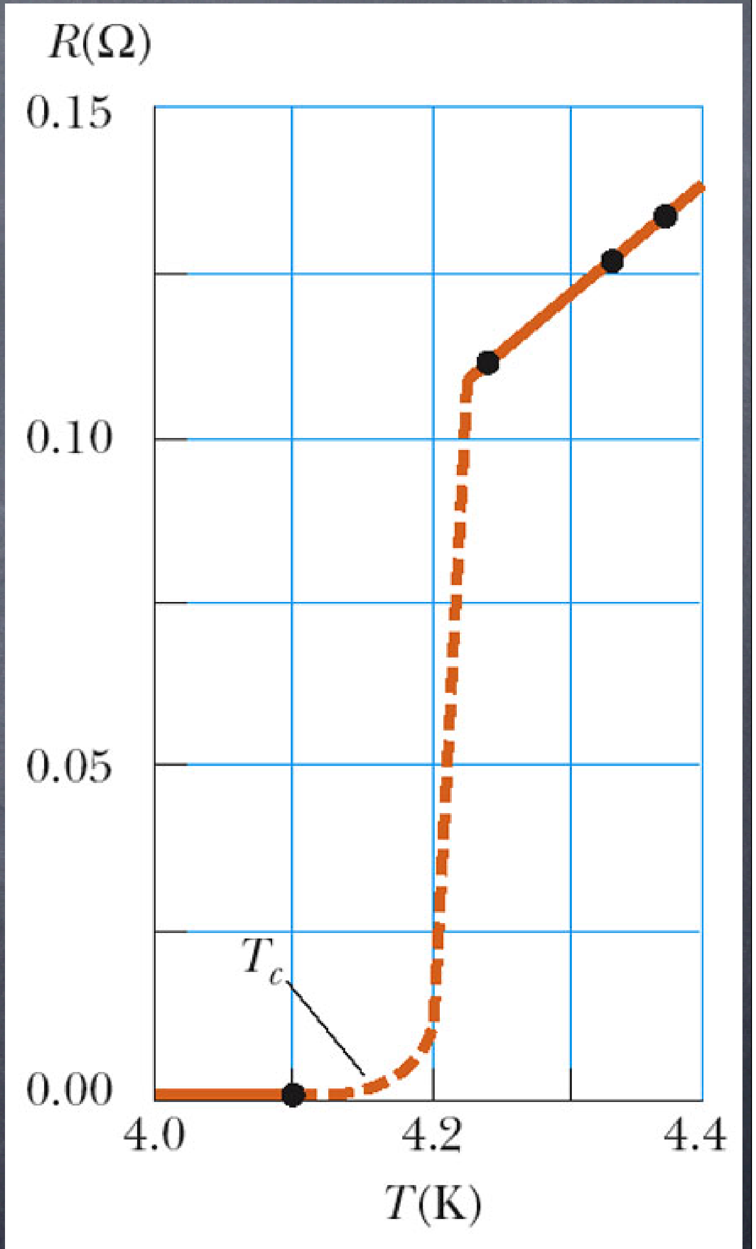
Superconductors

- Supercondutors can help solve these problems.
- Superconductors are materials whose resistance falls to virtually zero below a certain critical temperature, T_C.
- Once a current is set up in a superconductor, it persists without any applied potential difference.



Superconductors

- Above T_c, the superconductor acts as a normal metal.
- Unfortunately superconductors currently only exist at low temperatures (highest ~150K) [-123°C].
- But we are getting closer to room temperature superconductivity. In the mid-80's the highest was near 30K [-243°C].



Circuits

- Light bulbs are resistors that you can measure the power dissipated by them with their brightness.
- The brighter the bulb, the more power dissipation of the light bulb.
- I have two light bulbs, one 100W and one 60W. If I hook them up separately to the a given battery which one will be brighter?
- Correct, the 100W bulb was brighter!
- What if I hook them up in series to the same battery, which one will be brighter then?

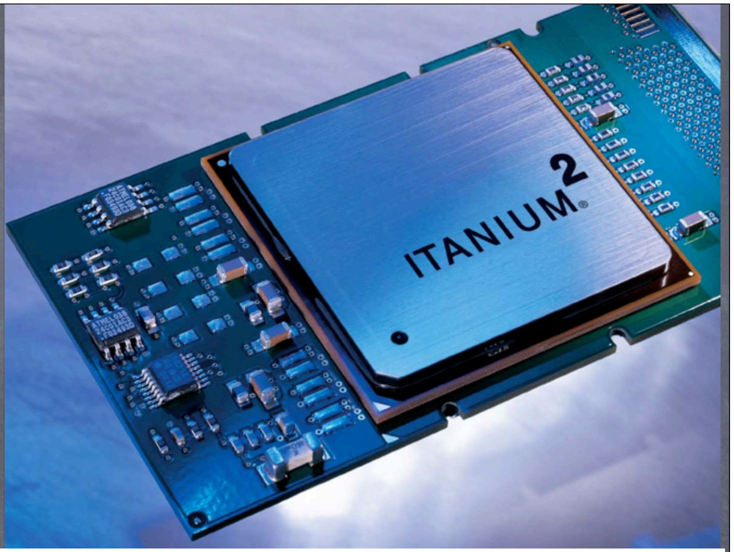
Conceptual Question

- I have two light bulbs, one 100W and one 60W. If I hook them up in series to the same battery, which one will be brighter?
- A) The 100W bulb.
- B) The 60W bulb.
- C) They will have the same brightness.
- D) It doesn't matter what power rating they have it will always be the one that is closest to the positive terminal of the battery.

Circuits

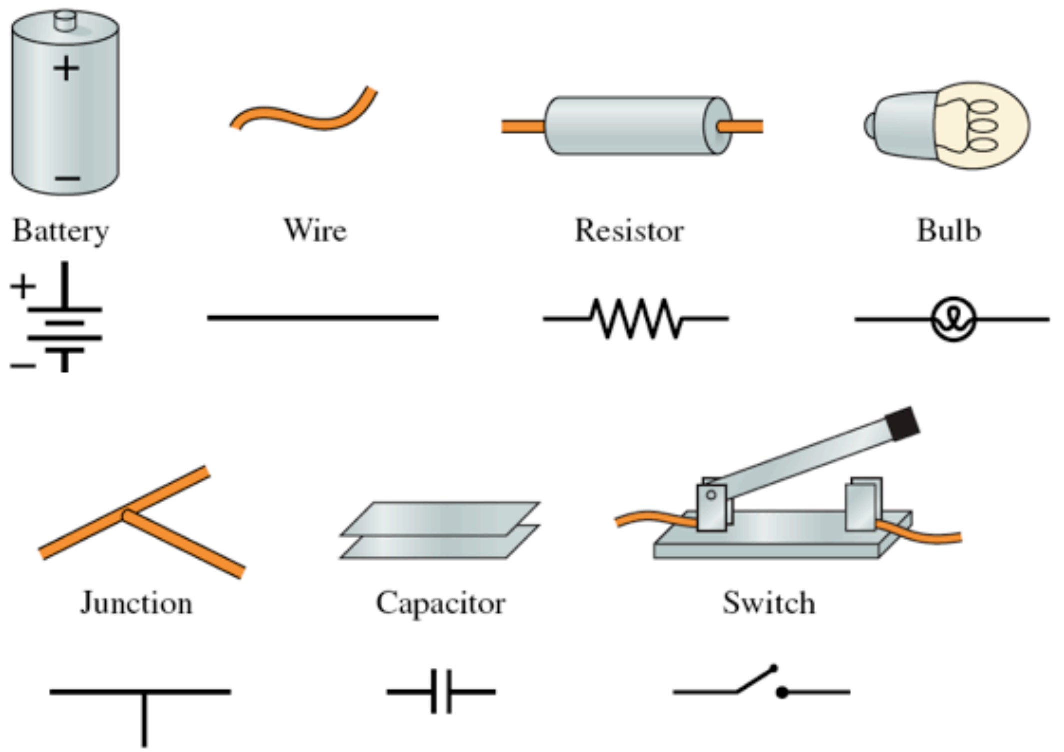
- The 60W?????????????????
- Realize that the power rating on light bulbs only represent the power dissipated when they are plugged into the wall.
- A 100W bulb will not always put out 100W of power dissipation.
- You have to know what the potential difference source is and what other elements are in the circuit.
- When examining a circuit you need to know all of the elements in the circuit (think globally).

Circuits



- We will now start discussing how current, resistance, power, and devices work together as a circuit.

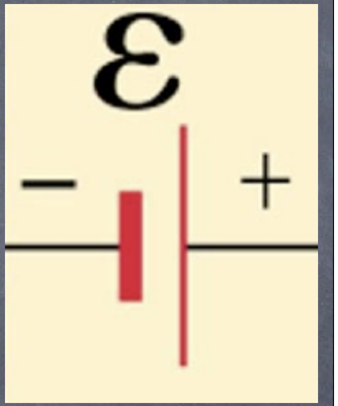
FIGURE 32.2 A library of basic symbols used for electric circuit drawings.



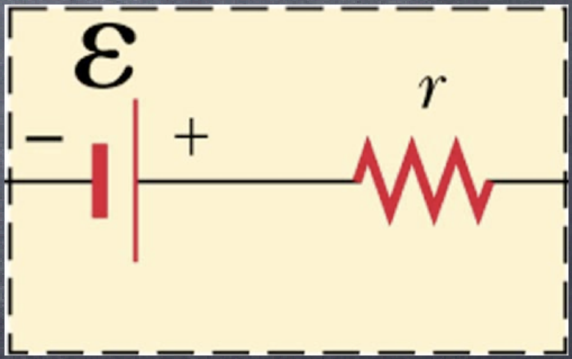
- First, become familiar with the following symbols that make circuit diagrams easy to draw.

Batteries

- There are three basic types of emf:
- 1) Ideal Battery: a battery that lacks internal resistance.



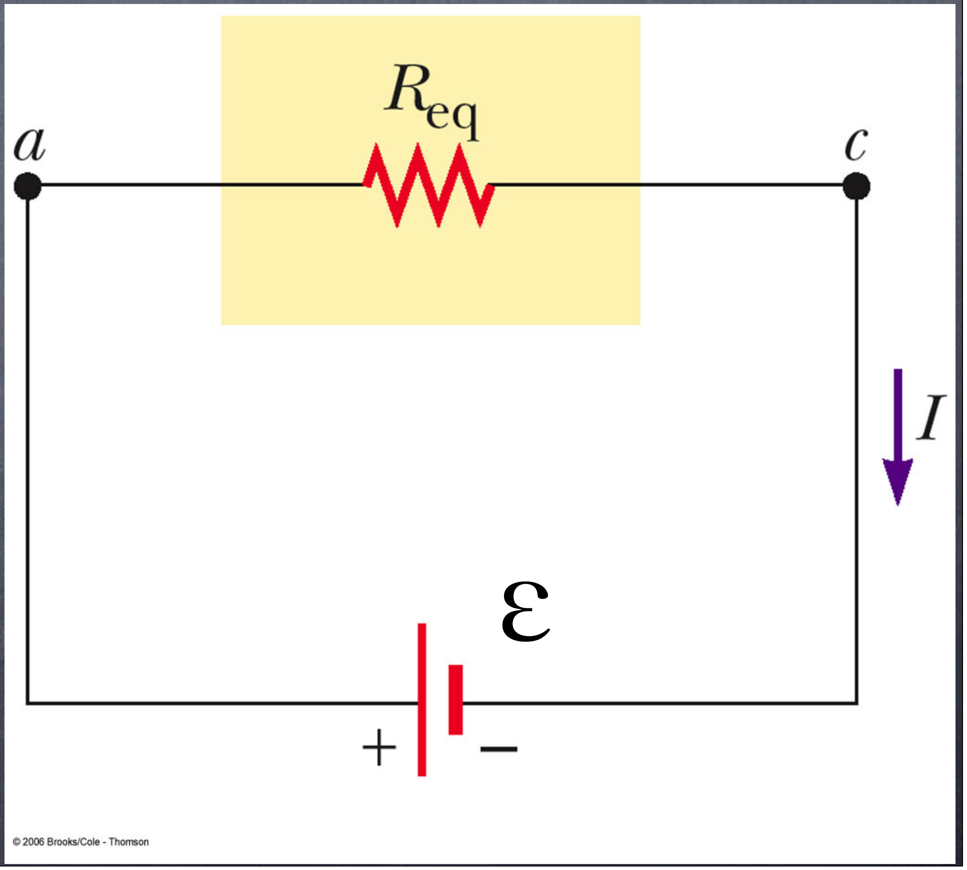
- 2) Real Battery: a battery that contains internal resistance, r, that hampers current flow.
  - Note the internal resistance is in series with the battery.



- 3) Generator: a device that uses mechanical energy to create electrical energy.

Circuits

- A typical circuit problem is to solve for the power/voltage/current at a specific point (like at a resistor).
- This simplest circuit to calculate the current for is the following:
  - Using Ohm's Law we find that:
  - $\Delta V = IR$
  - $\varepsilon = IR$
  - $I = \varepsilon/R$

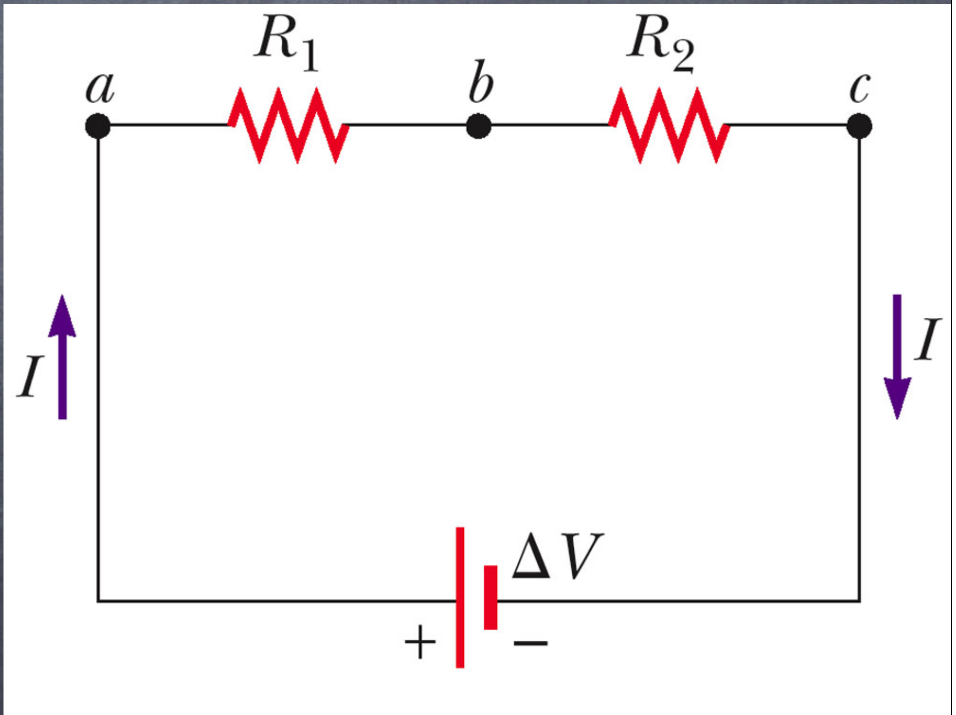


Circuits

- Technically, this is the only circuit you can use Ohm's Law to solve for the current through the resistor.
- But we can take more complicated circuits and reduce them down this simple circuit and then apply Ohm's Law.
- A typical task is to find the current in a circuit and, maybe, then find the power dissipated by various circuit elements.
- We will use the same ideas that we developed when finding out the equivalent capacitance for a given circuit.

Circuits

- Let's say we have a circuit with two resistors in series.
- When these two resistors are hooked up to the battery, a current is then established.
- In this circuit, the amount of current moving through R_1 equals the amount of current moving through R_2 (and the same as the battery as well).

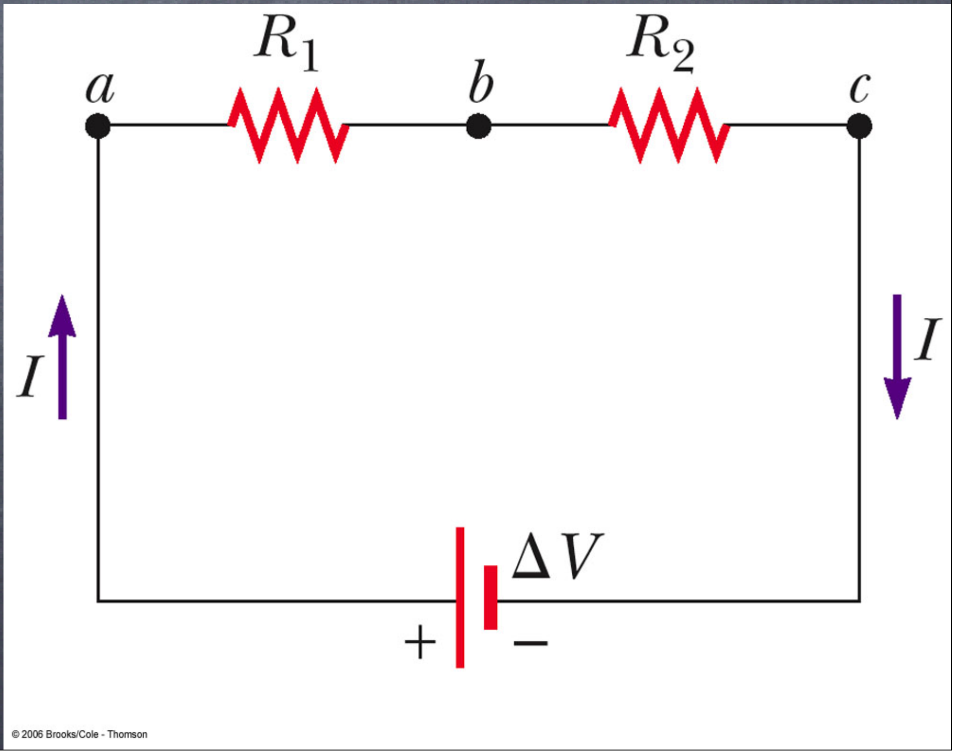


- $I_{bat} = I_{R1} = I_{R2} = I$

Circuits

- Each resistor will have a voltage drop across it.
- But the straight part of the wire will not have any potential differences.
- This means that: $\Delta V_{bat} = \Delta V_{ac}$

- The potential difference across either resistor will sum to be the potential difference across the battery.
- $\Delta V_{bat} = \Delta V_1 + \Delta V_2$



Circuits

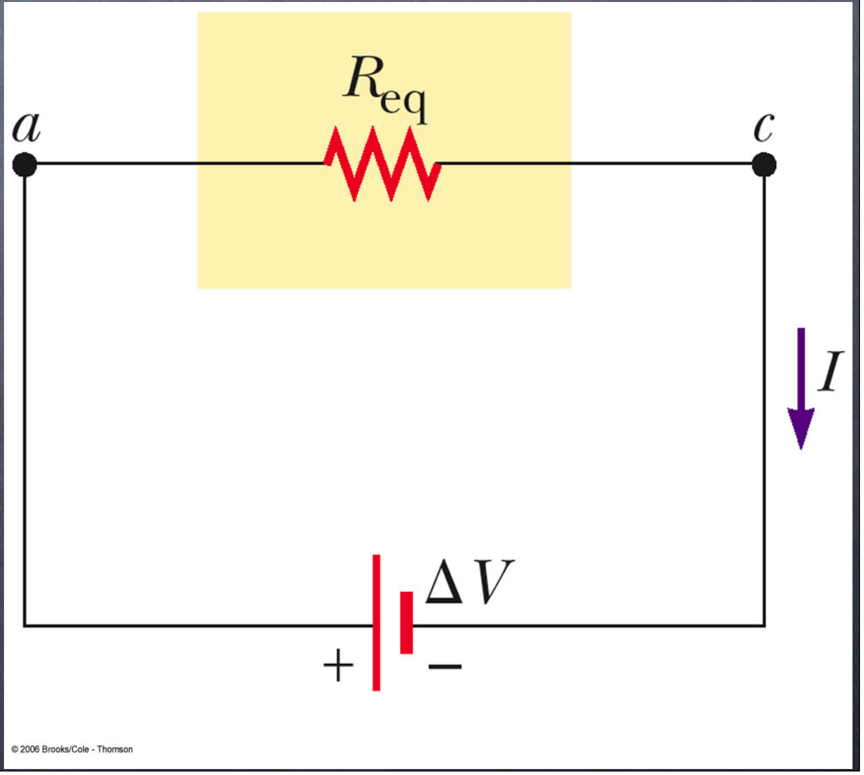
- We can essentially replace the two resistors in series with one equivalent resistor.

- The battery sees current, I, passing through it and believes that the one equivalent resistor has a potential difference of ΔV_{bat}.

- So, to the battery the equivalent resistance is:

$$R_{eq} = \frac{\Delta V_{bat}}{I}$$

$$R_{eq} = \frac{\Delta V_1 + \Delta V_2}{I}$$



Circuits

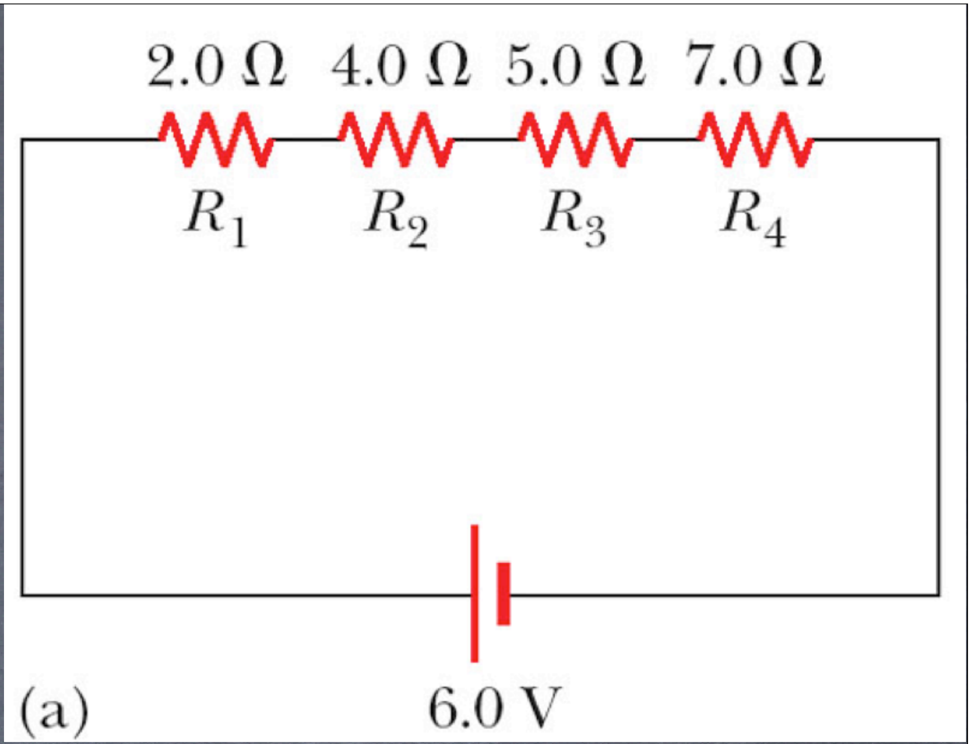
- This becomes:

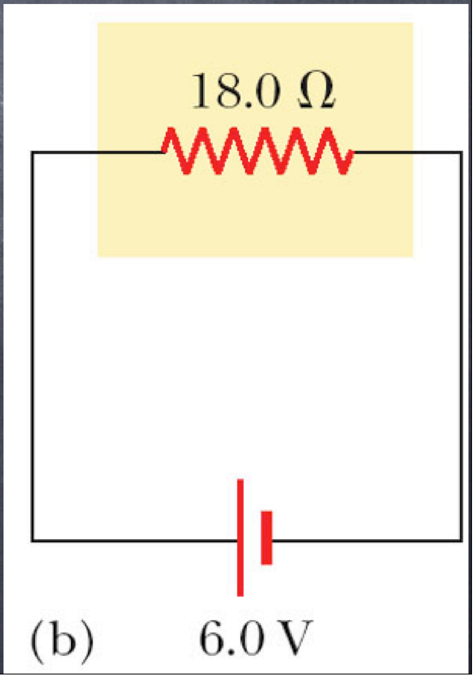
$$R_{eq} = \frac{\Delta V_1}{I} + \frac{\Delta V_2}{I}$$

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

- The equivalent resistance of resistors in series is greater than the individual resistors.
- In general, for series resistors:

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





For Next Time (FNT)

- Finish reading Chapter 18
- Start working on the homework for Chapter 18