Basic Electrical Principles

for Self Winding Clocks

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NAWCC Chapter 15

Objective

- To de-mystify electrical principles
- Enrich Understanding
  - Technical
  - How self-winding technology came into being
- Offer solid *technical* foundation for working on Self-winding Clocks
- This is NOT a course on self winding clock repair (that one is next!)

Approach

- Start with Historical Perspective
- Explain simple mathematical relationships
- Apply them with a mini lab
- Discussion, answer questions

Agenda

- **Historical**
- **Basic Electricity**
- **Ohm's Law**
- **Power Law**
  - **Double the voltage, quadruple the trouble**
- **Components**
  - Resistors
  - Batteries
  - Coils and Electromagnets
  - Contacts
- **Making Basic Electrical Measurements**
  - Digital Multimeter Basics
- **Mini-Lab**

The 1700s

Benjamin Franklin, American inventor and politician. In 1752 he established that lightning and Static electricity were fundamentally the same. He also established the conventions of negatively charged electrons and positively charged protons.

Alessandra Volta, Italian mathematician. In 1792 he proved that brine-(saltwater) saturated paper sandwiched in between disks of silver and zinc would produce an electrical potential (electrical pressure). This was the origin of the BATTERY! The unit of electrical potential or pressure was named in his honor.

Early 1800s

Andre-Marie Ampere, French Mathematician. In 1826, he published the results of his studies that related electric current flow to magnetism (but gave credit for it to Michael Faraday). The unit of electrical current flow was named after him.

George Ohm, German Physicist and mathematician. In 1827 he published "The Galvanic Circuit Investigated Mathematically," quantifying the relationships between electrical potential, electric current flow, and resistance. The unit of resistance was named after him.

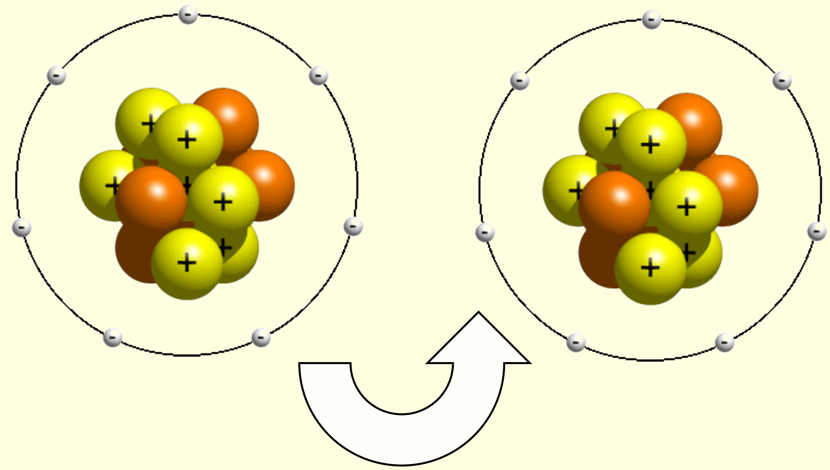
Significant Advances

Georges Leclanché, French Scientist and Engineer. In 1866 Leclanché developed the first practical 1.5 volt wet cell. Over 20,000 were produced to power telegraphs, clocks, doorbells. Was the forerunner of the Dry Battery (first realized by Carl Gassner and later E. M. Jewett) or modern carbon-zinc cell.

Thomas Alva Edison, American Inventor: Between 1850 and well into the early 1900's, Edison applied the theories of many predecessors to the invention or refinement of the incandescent light, DC motor, DC generator, and first practical storage battery.

The Atom

- Composed of:
  - Protons
  - Neutrons
  - Electrons
- Protons and neutrons are tightly bound into a nucleus
- *Electrons are relatively loosely held and can be moved in and out of atomic shells*



Electrons can be moved from atom to atom by electrical pressure

Electrons can also be freed by chemical reactions, creating electrical pressure

Insulators and Conductors

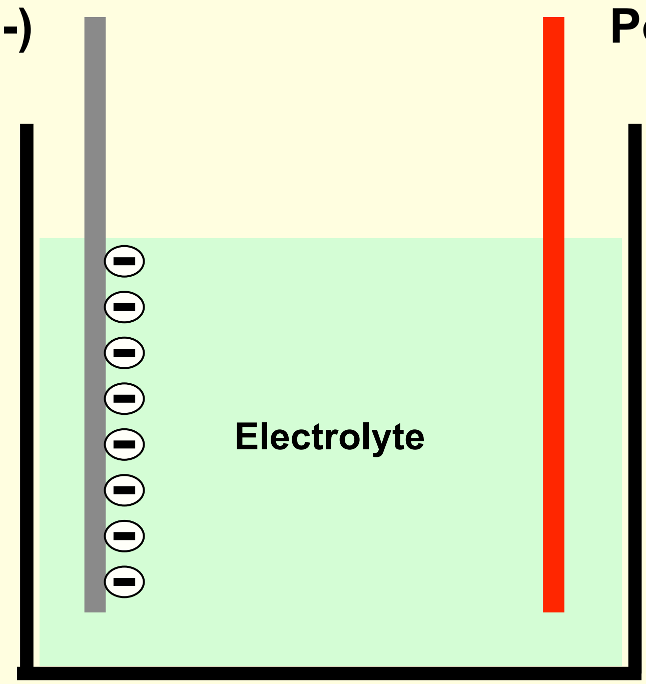
Insulators are materials that do not readily allow the electrons in their atoms to move freely from atom to atom. Examples are glass, wood, air.

Conductors are materials that freely allow movement of electrons between the individual atoms. Metals are the primary example.

How Batteries Work

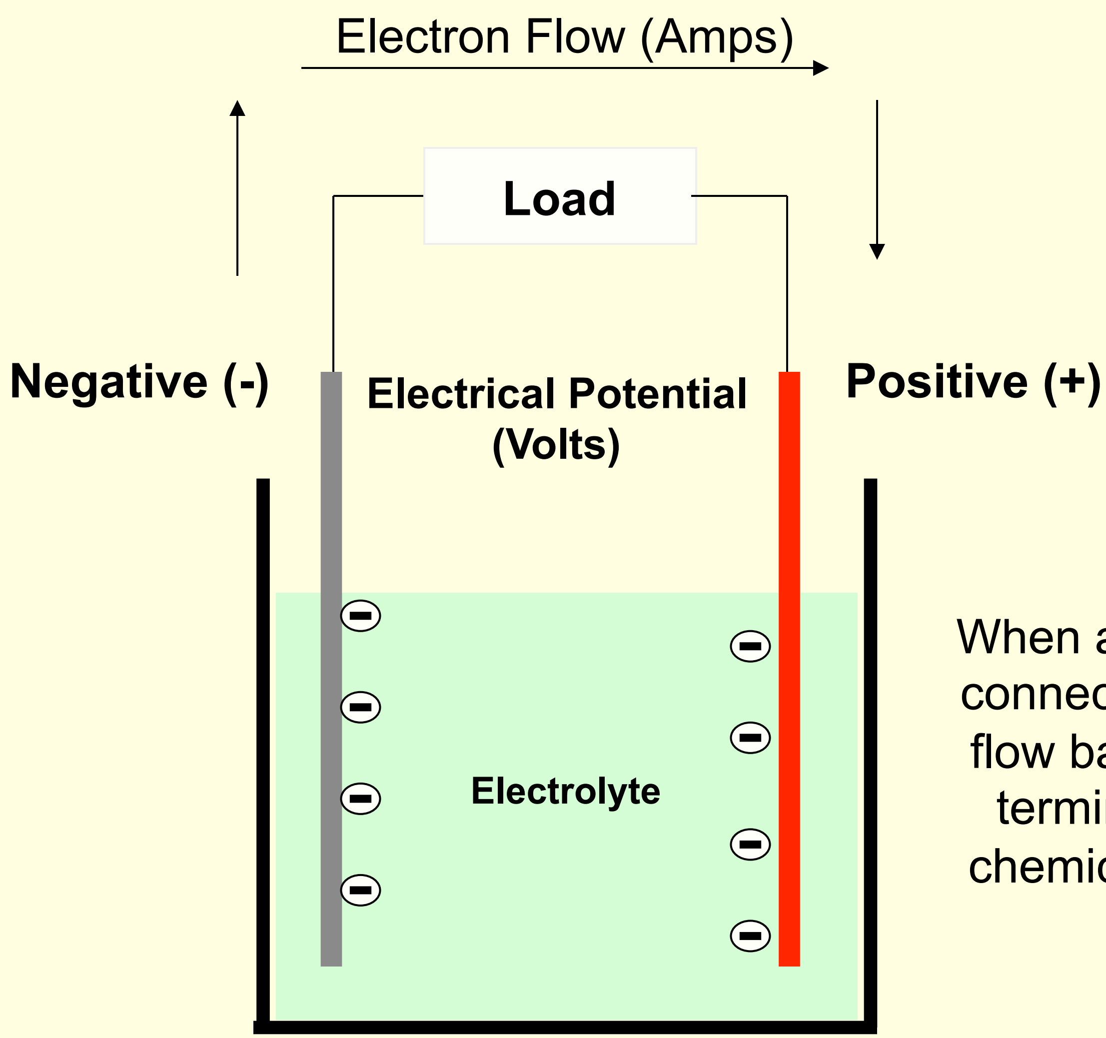
- A device for storing electrical pressure or potential
- Consists of 2 conducting plates and an electrolyte

The electrolyte and a conductor react chemically, releasing an abundance of electrons



This abundance of free electrons results in electrical pressure or potential, measured as voltage

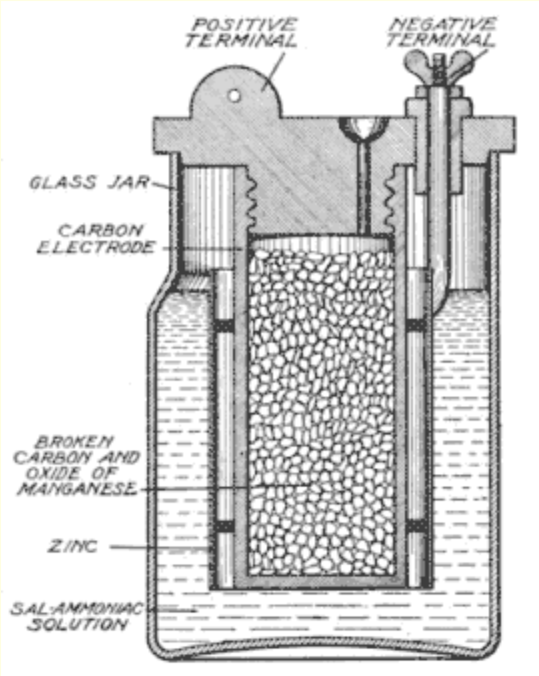
Battery Connected



When an external path is connected, the electrons flow back towards the + terminal and create a chemical reaction at the anode.

The Leclanché Cell

- Earliest practical battery (1866-1900)
- Forerunner of Dry Battery
- Patented; over 20,000 built
- Had a tendency to spill
- 1.5 volt cell



Gonda™ Leclanché Cells

Self Winding Clock Co. Wet Cell

$180 on Ebay

The Columbia Battery

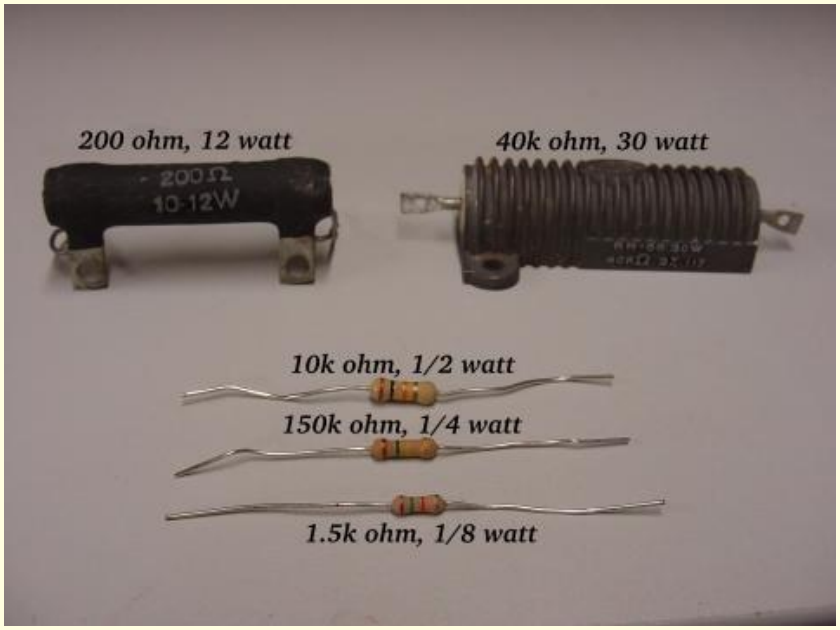
- National Carbon Co. of Lakewood, OH
  - Founded in 1894
  - Originally manufactured Leclanché cells
  - Decades later became Eveready and then Energizer
- E. M. Jewett and George Little
  - Developed a zinc can-based cell in 1896
  - Used carbon as the center cathode (+)
  - Acidic paste electrolyte with a cardboard separator
  - Powered telephone, doorbells, automobiles (ignitor), self-winding clocks, lanterns, etc.
  - Transformed the industry!

The Columbia Battery

http://acswebcontent.acs.org/landmarks/drycell/columbia.html

Resistors

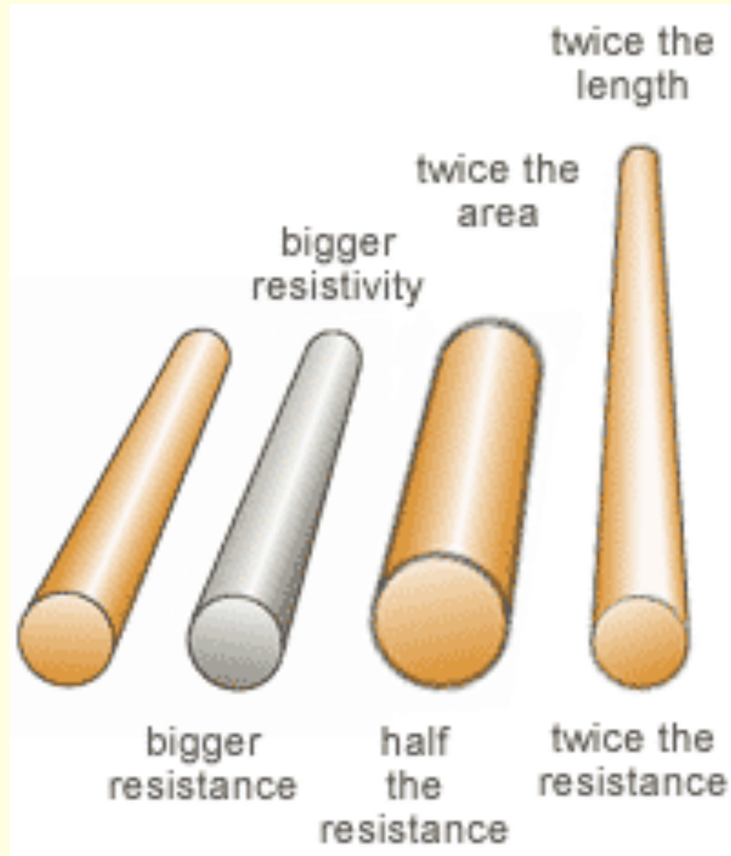
- Many electrical loads are resistive (at least partially)
  - Motors, light bulbs, electromagnets, etc.
- Other examples of resistors:



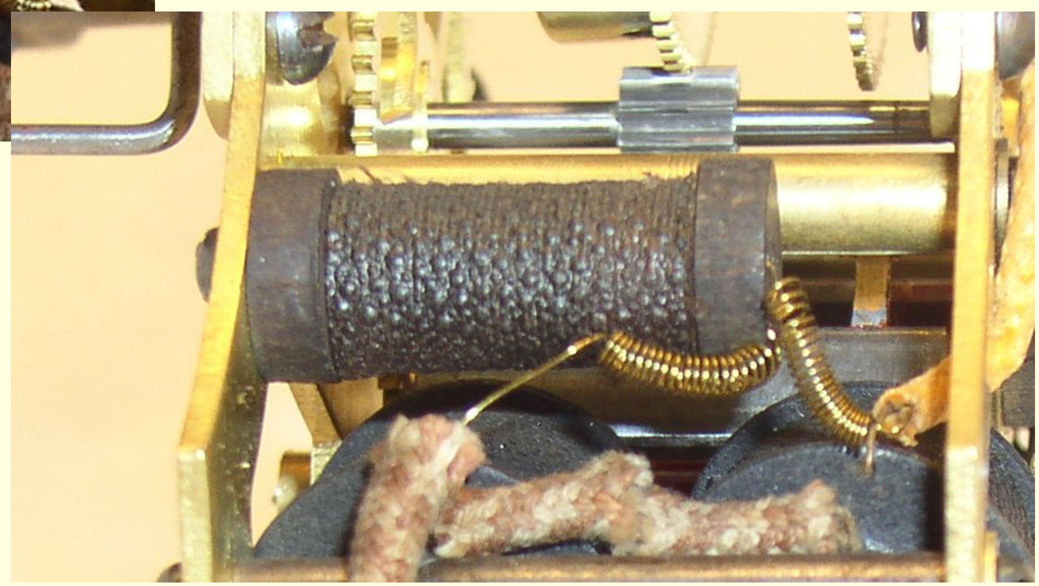
Resistors are measured in Ohms (Ω)

Wire Resistance

- Wire resistance varies by length and thickness
- Also depends on the type of wire e.g., copper or NiCr



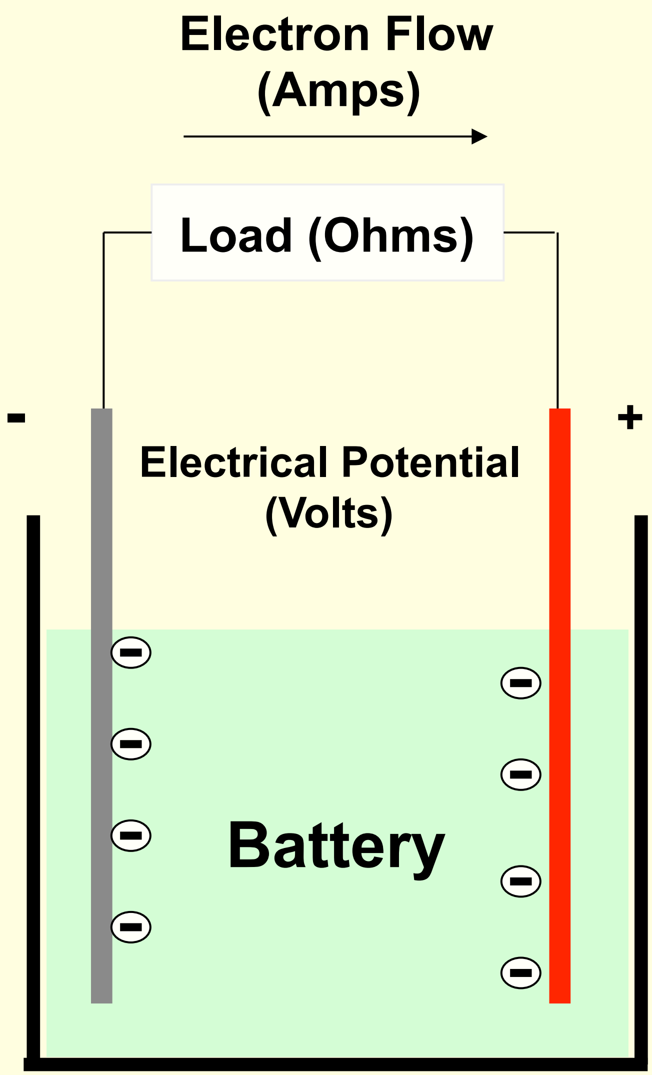
SWCC Damping Resistors



Elements of Electricity

- Voltage
  - Electrical Pressure or Potential
  - Batteries are an example of a voltage source
- Current
  - A measure of the FLOW of electricity
  - Measured in Amps
- Resistance
  - A measure of the restriction to FLOW
  - Measured in Ohms

Elements of Electricity



Ohm's Law:

Voltage = Amps x Ohms

Also,

Amps = Voltage/Ohms

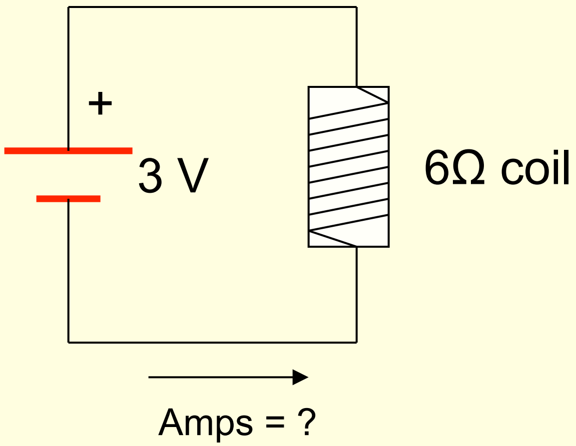
Power (Watts) = Amps x Volts

Power (Watts) = Volts^2/Ohms

Power is a measure of energy

Example Application of Ohm's Law

Coil resistance = 6Ω
Battery voltage = 3 volts



How many amps will be needed from battery?

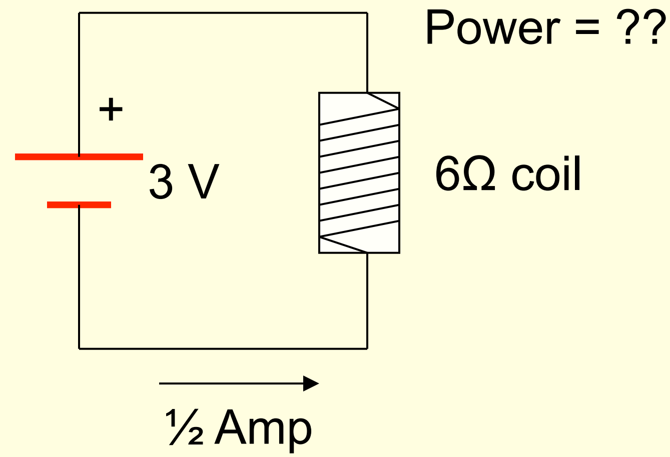
Answer:

$$\text{Amps} = \text{Volts/Ohms} = 3\text{ volts}/\ 6\Omega = \tfrac{1}{2}\ \textbf{Amp}$$

Let' s keep going…..

- For the same circuit:

How much power is dissipated in the coil?



Answer:

Power = Voltage^2/Ohms

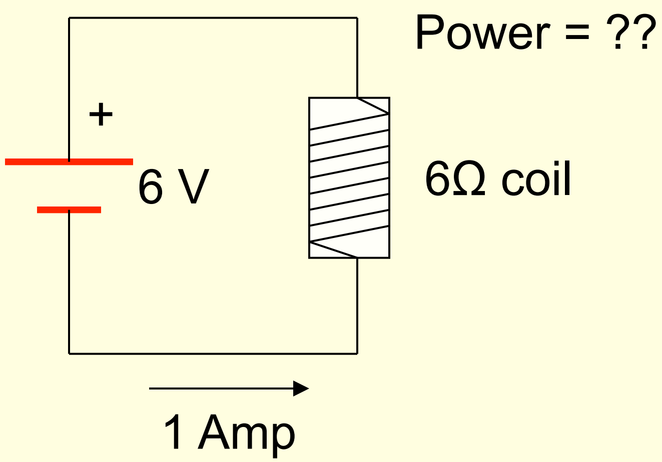
= 3^2 volts/6Ω

= 1.5 watts

One more time…

- For the same circuit:

How much more power is dissipated in the coil if we use a Lantern battery which is 6 volts???



Answer:

Power = $Voltage^2/Ohms$

$= 6^2$ volts/6Ω

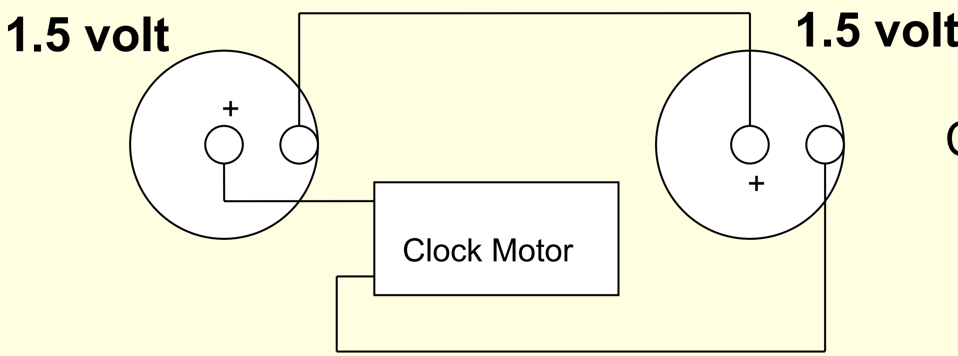
= 6 watts or 4x more!!

Lesson Learned…..

- Double the voltage (6V) forces 4x the energy into the electrical components
- DO NOT USE in 3V clocks
  - Unless you use a voltage converter

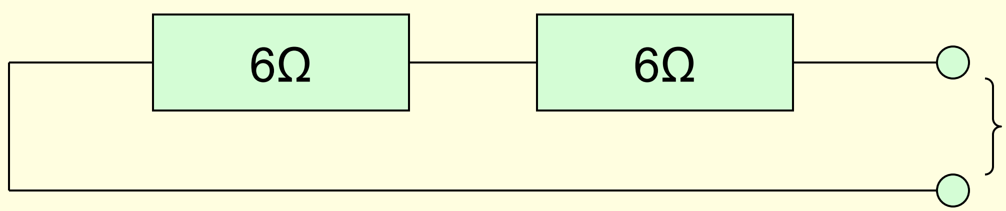
Series Circuits

- Batteries in SERIES add:



Clock motor "sees" 3 volts

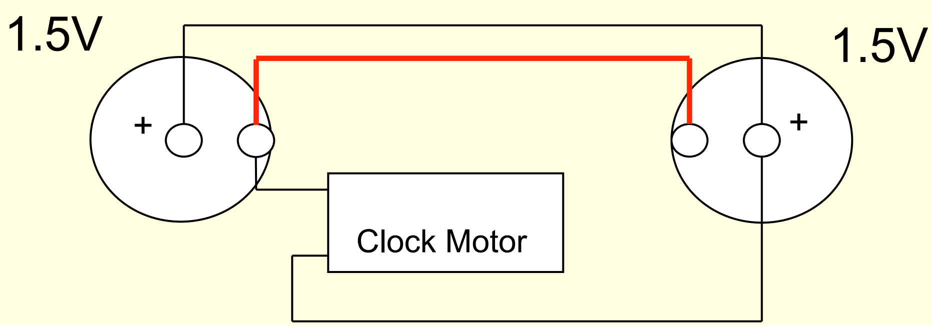
- Resistors in SERIES also add:



Total Resistance = 12Ω

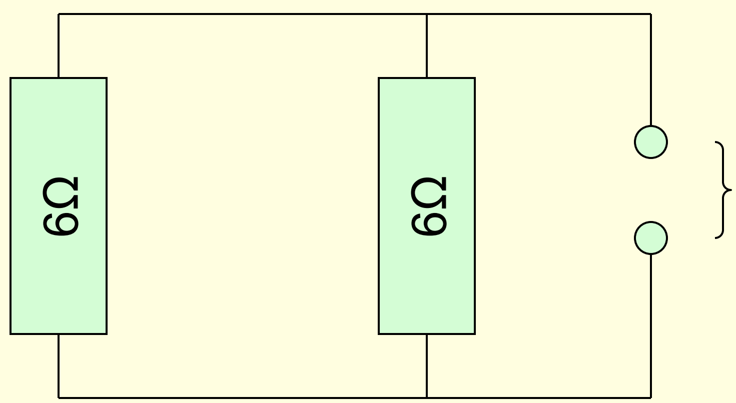
Parallel Circuits

- Batteries in PARALLEL of same voltage will output that voltage, but increase Amperage capacity



Clock motor "sees" 1.5 volts which may not be sufficient

If each battery can supply 2 amps, two in parallel can supply 4 amps.



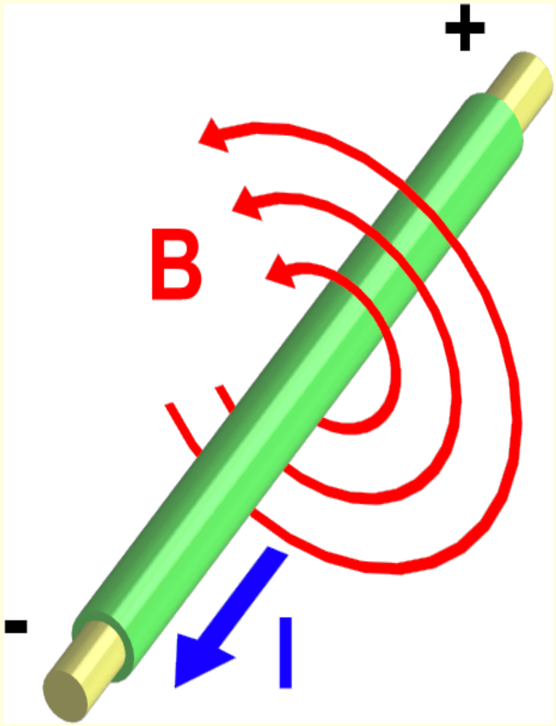
N like value resistors in parallel reduce by:

$R_p = R/N$

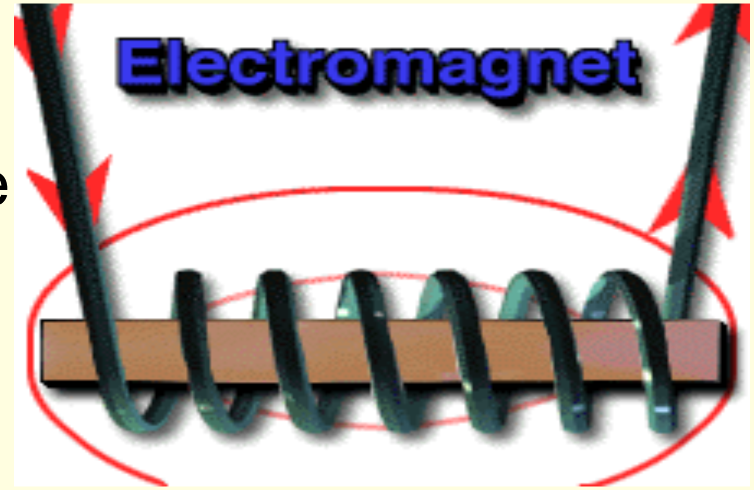
$6\Omega // 6\Omega = 3\Omega$

Coils and Electromagnets

- If a current is passed through a wire, a magnetic field results
- This magnetic field encircles the wire as shown.
- The magnetic field will form around magnetic materials if we let it



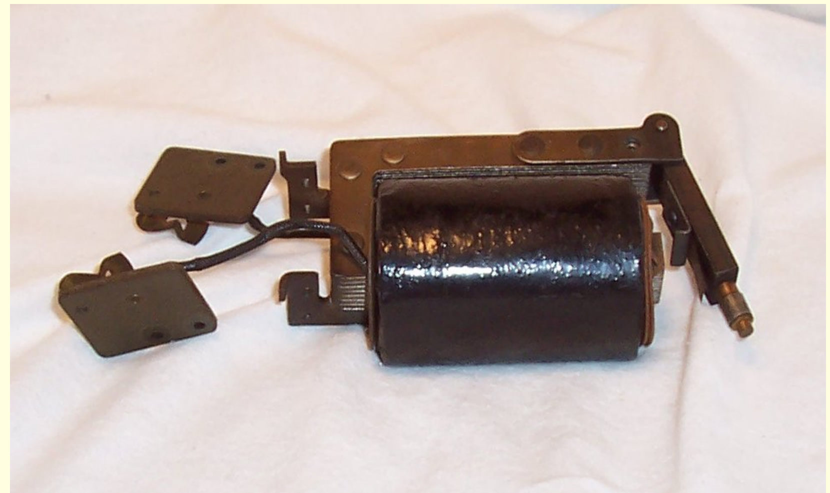
Coils and Electromagnets



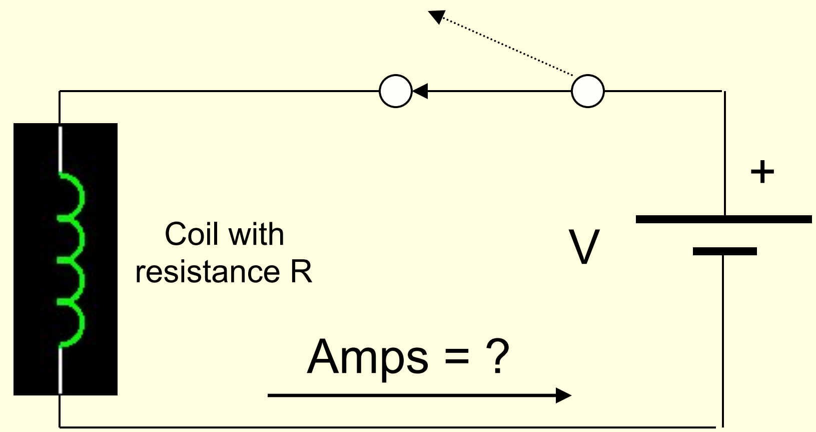
- Winding multiple turns around a core will concentrate the magnetic field as shown.
- An example of a simple electromagnet can be made using enameled wire wrapped around a nail!
- All coils have some winding resistance resulting from the copper

Challenges with Coils

- What happens when I energize this synchronizer coil?



- Current will flow through the coil
- Amps = V/(coil R)
- Example: If V =3 volts and R is 6 Ω, then:

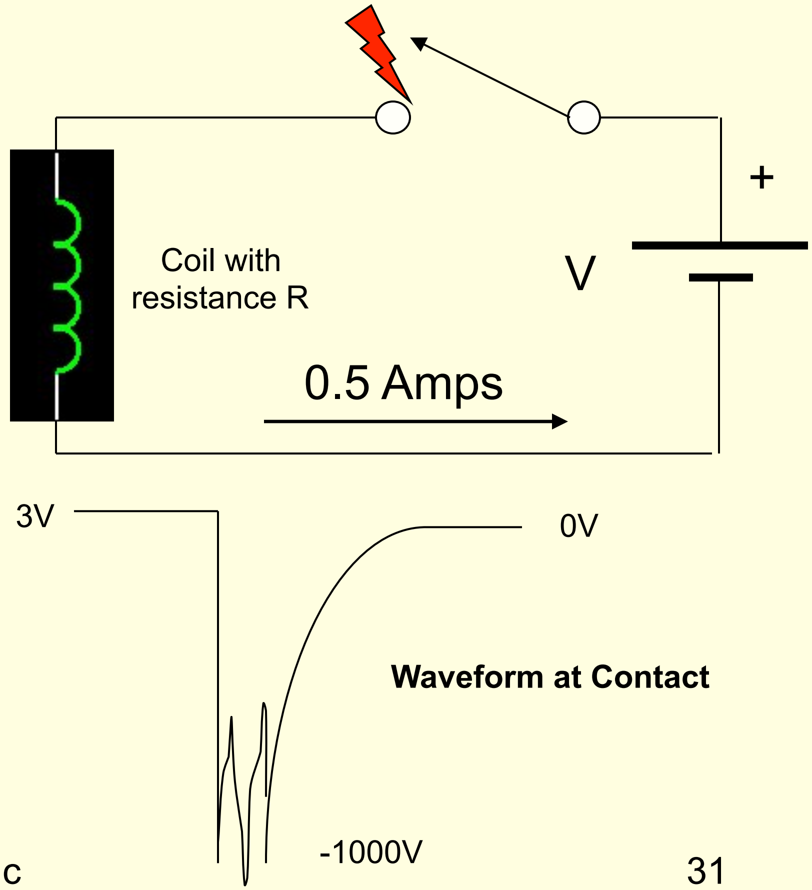


Amps = 3V/6Ω = 0.5 Amp

Challenges with Coils

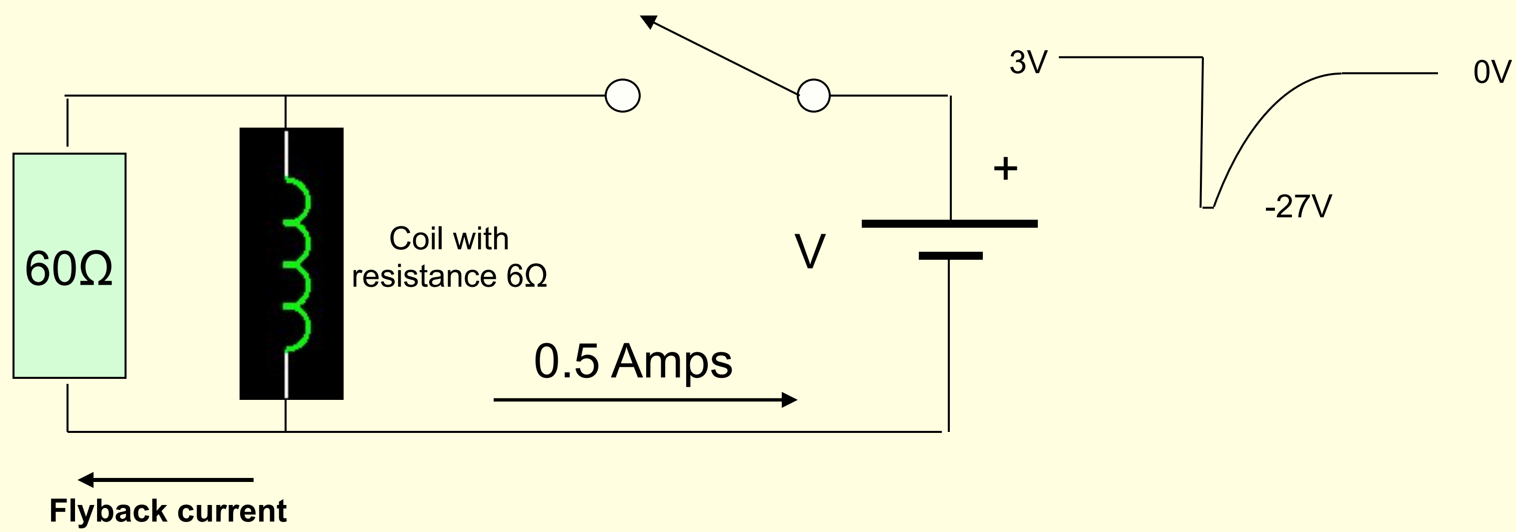
- What happens when we disconnect the coil?

1. **Energy is stored in the coil as an electromagnetic field. That's the nature of a coil.**
2. **So, when the switch is opened, the current will want to keep flowing in the coil.**
3. **It will increase its voltage until the contact arcs over (100's or 1000's of volts).**
4. **The "spot" temperature from this arc is hot enough to melt metal, thus pitting and damaging the contacts.**



Challenges with Coils

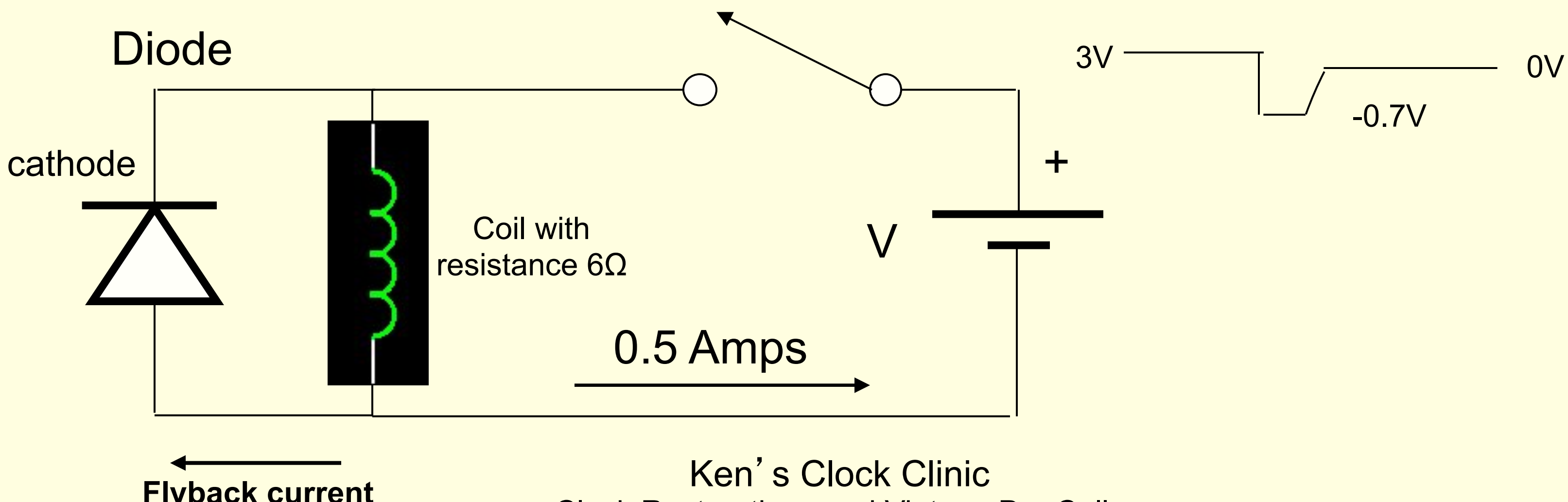
- Question: How do I prevent this?
- Answer: Create somewhere else for the coil current to go when the contact opens.



Challenges with Coils

- Most common option is a Damping resistor, usually selected to be 10x the value of the coil resistance.

- Another option is a diode, but this was obviously not used in vintage days.



Contacts

- What makes a good contact???
  - Largely depends on the application, but….

- Low contact resistance
- Resistant to oxidation
  - And, therefore, burning
  - Probably also means high melting temp
- Good hardness—wears well over time

Contacts

- What kind of materials offer these qualities?

Material	Low Contact R	Resistance to Surface Films	Hardness (wears well)
Gold	Better	Best	Poor
Platinum	Better	Best	Better (especially Platinum-Iridium)
Silver	Best (initially)	Fair	Good
Tungsten	Good	Good	Best
Copper	Best (initially)	Poor	Poor

Contacts

- Platinum is the best pure material (non alloy)
- Platinum-iridium is great because of additional hardness
- Unfortunately both are VERY EXPENSIVE
- But they are WORTH IT!
  - Clocks restored with platinum will run much longer

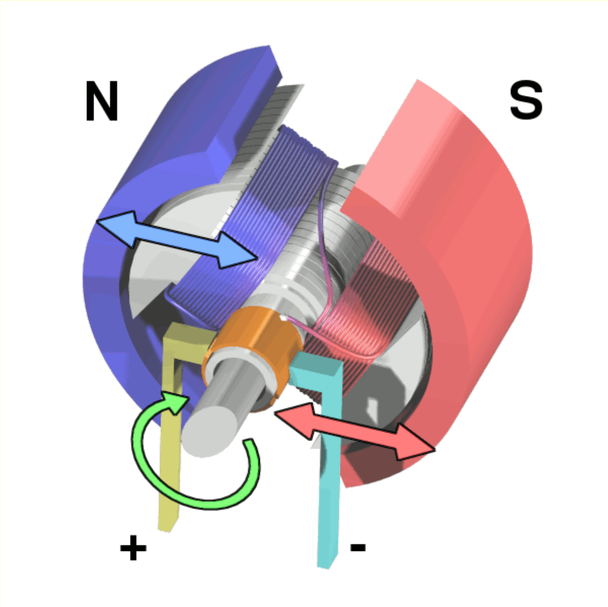
DeoxIT® and DeoxIT® Gold G100L

- Caig Laboratories
- Proven over 50 year history
- Unbelievable results
  - Examples

- Only a very small quantity needed on CLEAN contacts to preserve them indefinitely
  - Don’t flood contact with it
- Possible lubricant for Style A motor bearings and commutators
- http://store.caig.com

Electric Motors

- Electromagnetism is exploited
  - Opposite magnetic poles attract; like poles repel
- Rotation causes reversal of the electromagnetic field because of the commutator



Basic Electrical Measurements

- The standard instrument for basic electrical measurements is the DMM (**D**igital **M**ulti**M**eter)
- Multi Function
  - Volts
  - Ohms
  - Amps
  - Continuity
  - Diode Test
- Accuracy ~1%
  - Good enough for most if not all clock work

Important Aspects of DMM Measurements

- Know your DMM
  - Make sure the range is appropriate for what you expect to measure!!
  - Make sure the leads are in the right place
  - Make practice measurements before doing anything real

- Make sure you have a good zero
  - If you don't, subtract the offset from your measurement to obtain most accurate reading
  - Especially true with low voltages

Experiment 1: Measure the resistance of devices

- Set DMM to 200 ohm range

1. Touch both probe tips to a terminal
2. Record “offset”
3. Measure device of interest eg Terminal 3 and Terminal 4
4. Subtract value in Step 2 from value in Step 3.

Experiment 2: Measuring Voltage

- Set DMM to 20 Volts DC range

1. Measure battery terminal voltage.
2. Now, connect battery to light bulb (Terminals 5 and 6).
3. Measure battery terminal voltage again.
4. Compare result from 2 to result from 4.

Experiment 3: Stall Current of Motor

- Connect a wire between Terminal 2 and Terminal 6
- Connect battery (with test clips) between Terminal 1 and Terminal 5
- Stop motor with fingers
- What happens??? Why???

Experiment 4:
Coil Arcing

1. Connect one of the battery leads to Terminal 3 using test clip.
2. Touch other test clip to Terminal 4
3. As you do, notice the spark. Why is there a spark there?
4. Now, connect Terminal 3 to Terminal 7
5. Likewise connect Terminal 4 to Terminal 8.
6. Repeat the test in 1-2 above.
   - What happened? Why?