How to use this presentation

Slides 43-46 are a bit tricky. The last bullet in slide 48 refers to flipping the battery over. The next slide (49) will do that by pressing the down arrow on your remote presenter (or the keyboard). Pressing the up arrow flips it again, and so forth. Since this changes the poles on the nail, the nail would be repelled when the battery is flipped.

Now, with the mouse, left click the green circle on the upper right side of slide 49, and the next slide (49) shows the nail rotating as the battery is flipped. Notice that the wires cross when the battery is flipped and explain that if we were to keep doing it, the wires would eventually get hopelessly tangled. (Show demo of this now.)

While the demo is being shown, return momentarily to slide 48 by either pressing the esc key, or the reverse arrow on slide 49. Then press the red triangle on slide 48 (bottom right) to advance to slide 50 to carry on.

Please practice this before you present it. It's easier than it sounds.

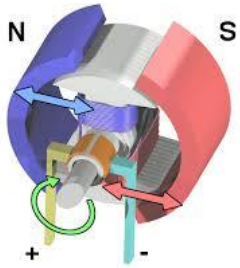
Motors Demos

- Show some motors – big and small (slide 9)
- Build a circuit with students (slide 16)
- Show Meter (slide 23)
- Experiment: Circuit Boards (slide 25-26)
- Show magnets (slide 28)
- Show compass (slide 30)
- Show field w/compasses (slide 32)
- Show electromagnetism field (slide 35)
- Show big motor w/switch (slide 50)
- Build motor with students (slide 51-62)

ARIZONA SCIENCE LAB

ALL ABOUT ELECTRIC MOTORS:

Creating Rotating Force from Electricity!



Institute Of Electrical And Electronic Engineers, Phoenix Section

Teacher In Service Program / Engineers In The Classroom (TISP/EIC)

“Helping Students Transfer What Is Learned In The Classroom To The World Beyond”

Our Sponsors

The AZ Science Lab is supported through very generous donations from corporations, non-profit organizations, and individuals, including:

Stuff on Magnetic Fields and Motors

Howstuffworks “How Electric Motors Work,”
http://www.howstuffworks.com/motor.htm

Wikipedia – Electric Motor:
https://www.wikipedia.org/wiki/electric-motor

Wikipedia – Magnetic Field:
https://www.wikipedia.org/wiki/magnetic-field

Videos,
http://www.youtube.com

Workshop Outline

- Uses of Electricity
- Electricity – What is it?
- Circuits – experiment & measurement
- Magnetism – What is it?
- Electromagnetism – Electricity + Magnetism
- Motors – How they work
- Building your own motor!
- Summary – what have we learned

What Do We Use Electricity For?

- Lighting
- Heating
- Power Electronics
- Power Electric Motors
- Combinations of the above

Let's Find All the Motors in Our Houses

- Kitchen:
  - Can opener, blender, mixer, disposal, refrigerator, …
- Utility room:
  - Washing machine, dryer, electric drill, vacuum cleaner, …
- Bathroom:
  - Toothbrush, shaver, hair dryer, …
- Bedroom:
  - Disk player, clocks, computer disk, toys, …
- Car:
  - Windows, wipers, seats, fan, …

Motors Come in All Sizes and Shapes

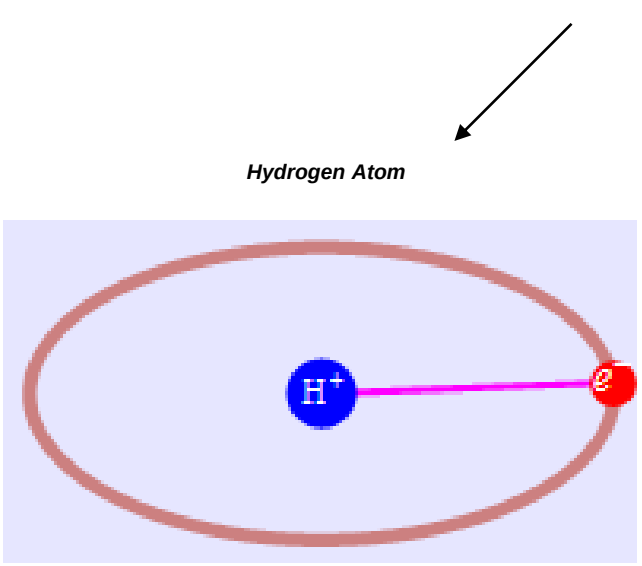
- Common Nine-volt battery in the middle front
- Largest motor: Three phase AC induction motor rated with 1 Hp (750 W)
- Next largest: 25 W
- Small motors:
  - CD player motor
  - Brushed DC Electric Motor common as toy motors
  - Stepper motor with worm gear for CD pickup-head

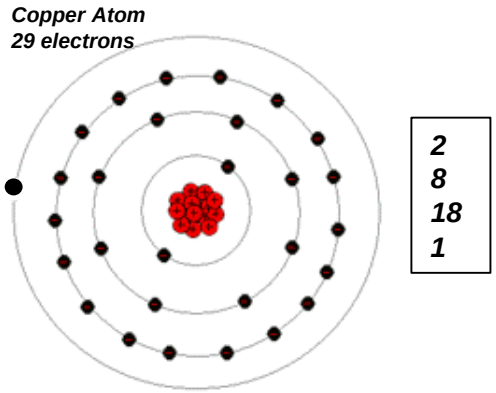
Electricity:

What Is It?

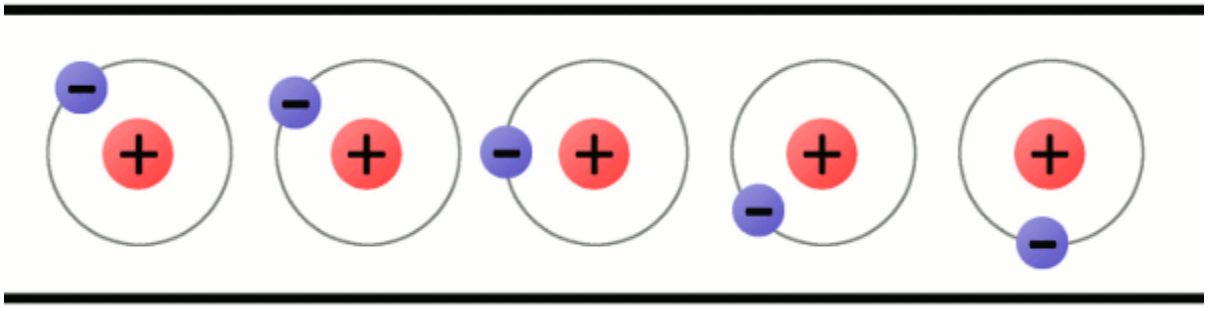
Electricity – The Flow of Electrons

This occurs best when the material is made up of atoms with “free” outer electrons





The Flow of Electrons



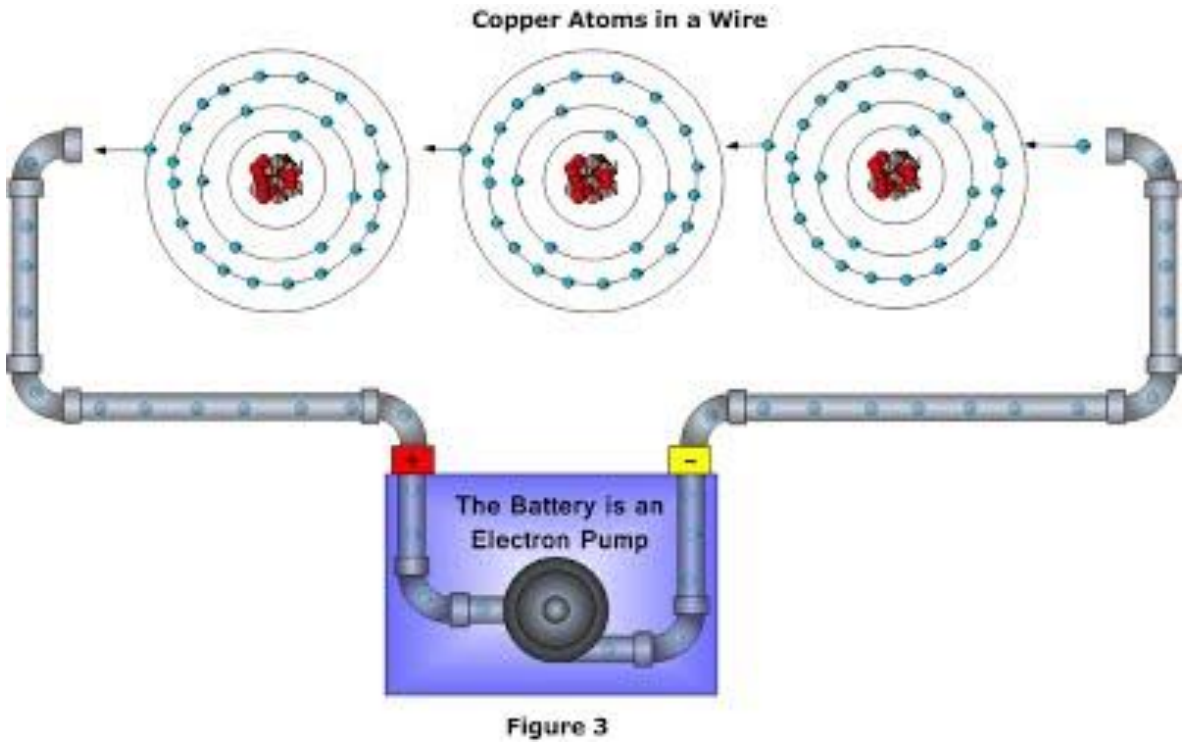
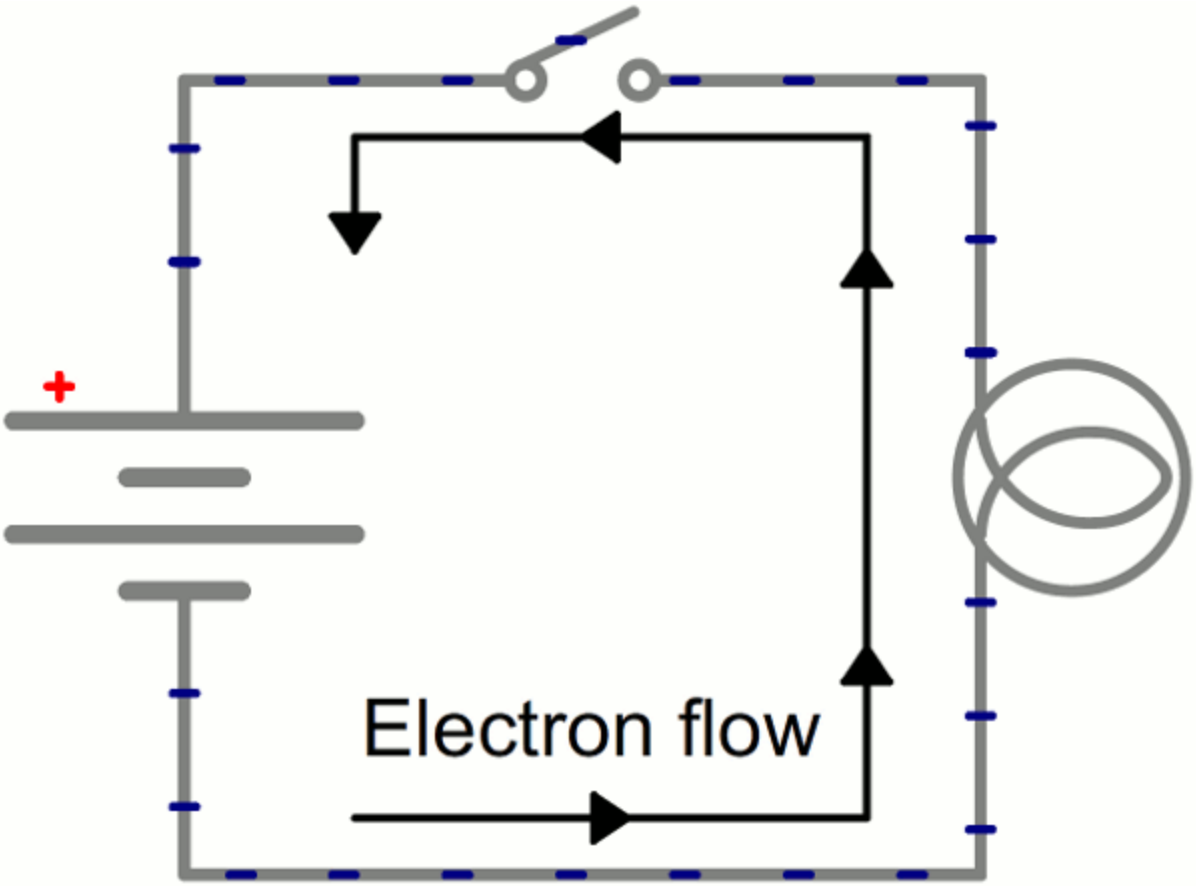
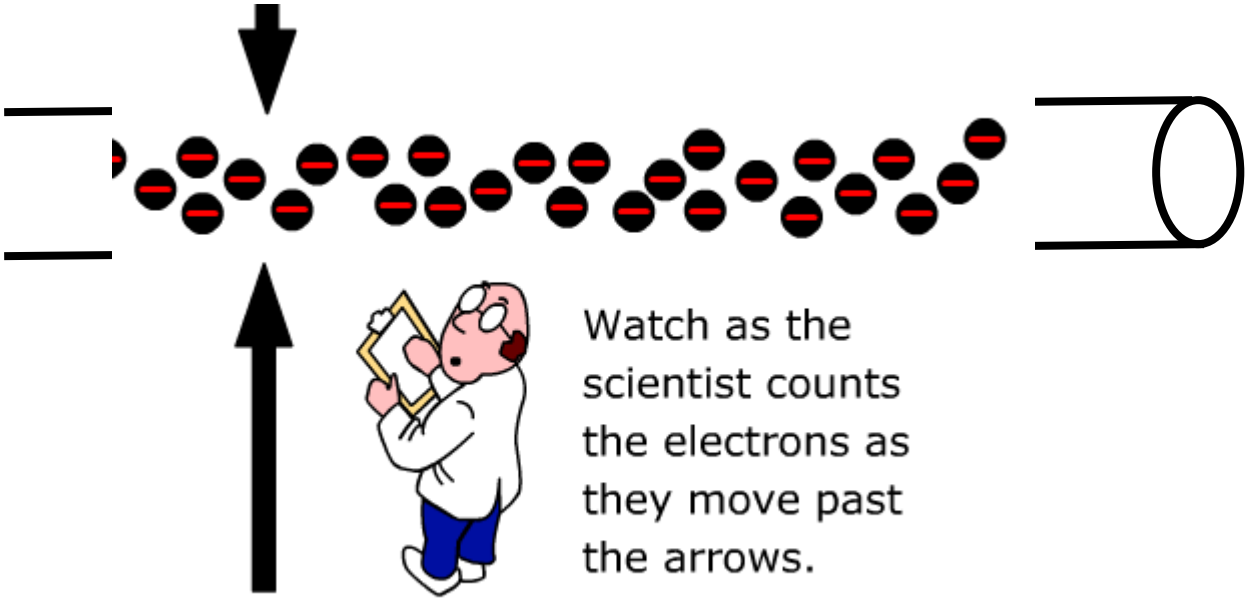


Figure 3


+
Electron flow

How do we measure electricity?



Billions and billions per second

We measure these using an electric meter

- An old electric multimeter (voltmeter, ampmeter):

Electrical Nature of Matter

Materials that permit the motion of free electrons are called ***Conductors***.

Materials that oppose the motion of electrons are called ***Insulators***

Conductors are said to have **low resistance** while **insulators** have high **resistance**

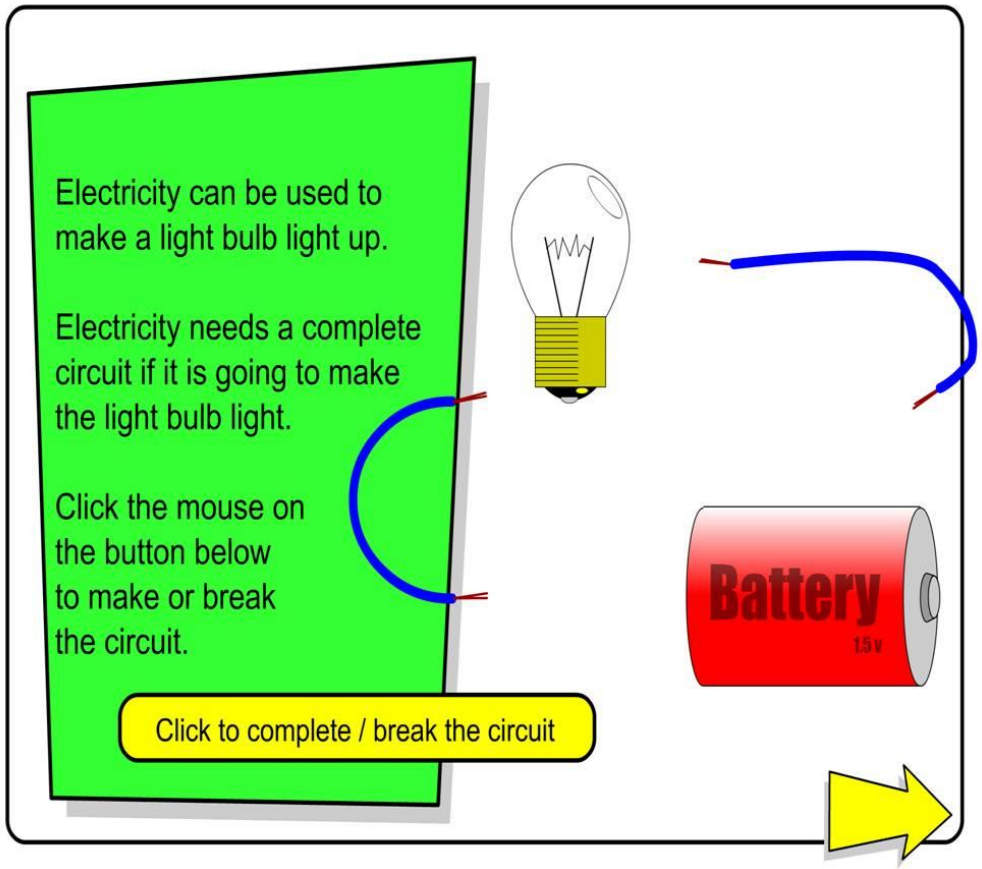
CONDUCTORS

Silver
Copper
Gold
Aluminum
Brass
Zinc
Iron

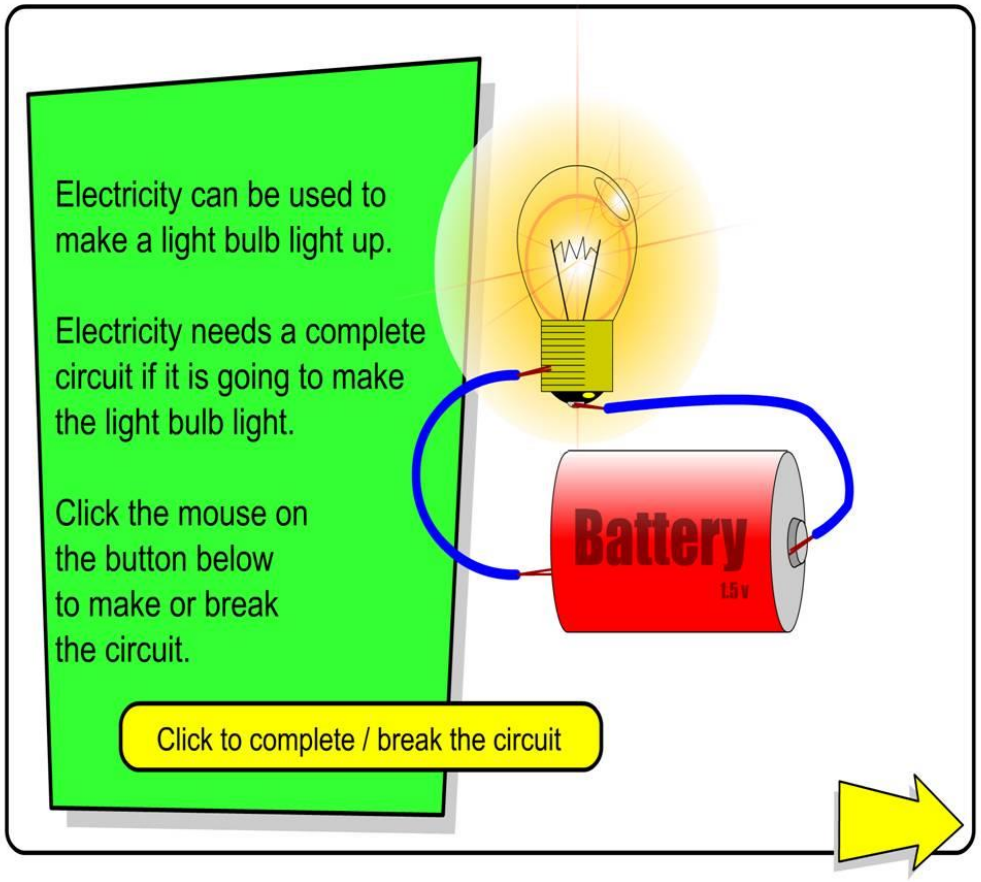
INSULATORS

Dry Air
Glass
Mica
Rubber
Asbestos
Bakelite
PVC
Teflon
Plastics

Non Connected Electrical Circuit



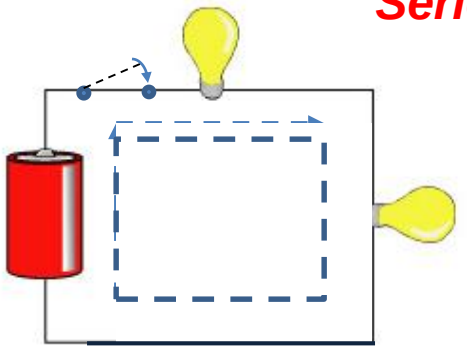
Connected Electrical Circuit

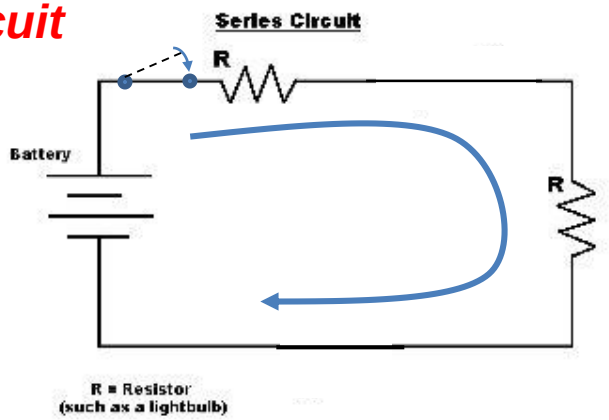


How to connect circuits

Connecting *Loads* (resistance/*resistors*)

Series Circuit

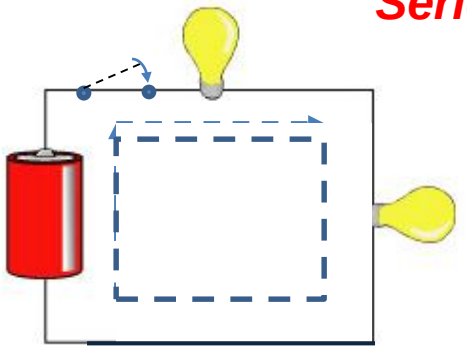


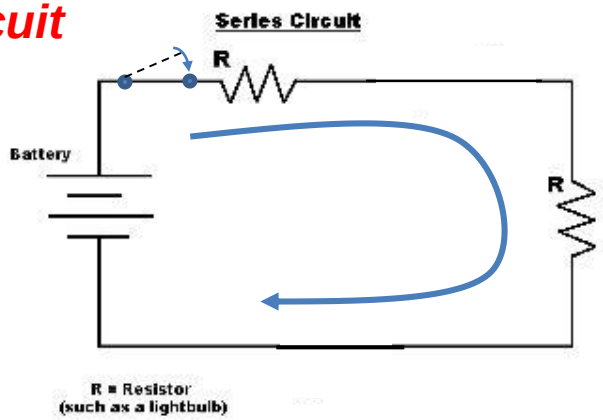


How to connect circuits

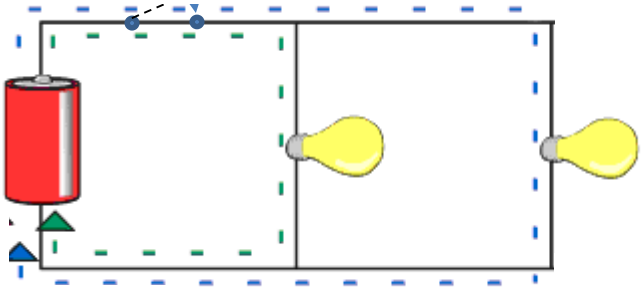
Connecting *Loads* (resistance/*resistors*)

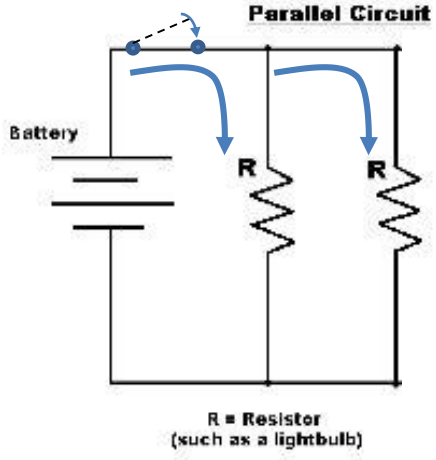
Series Circuit



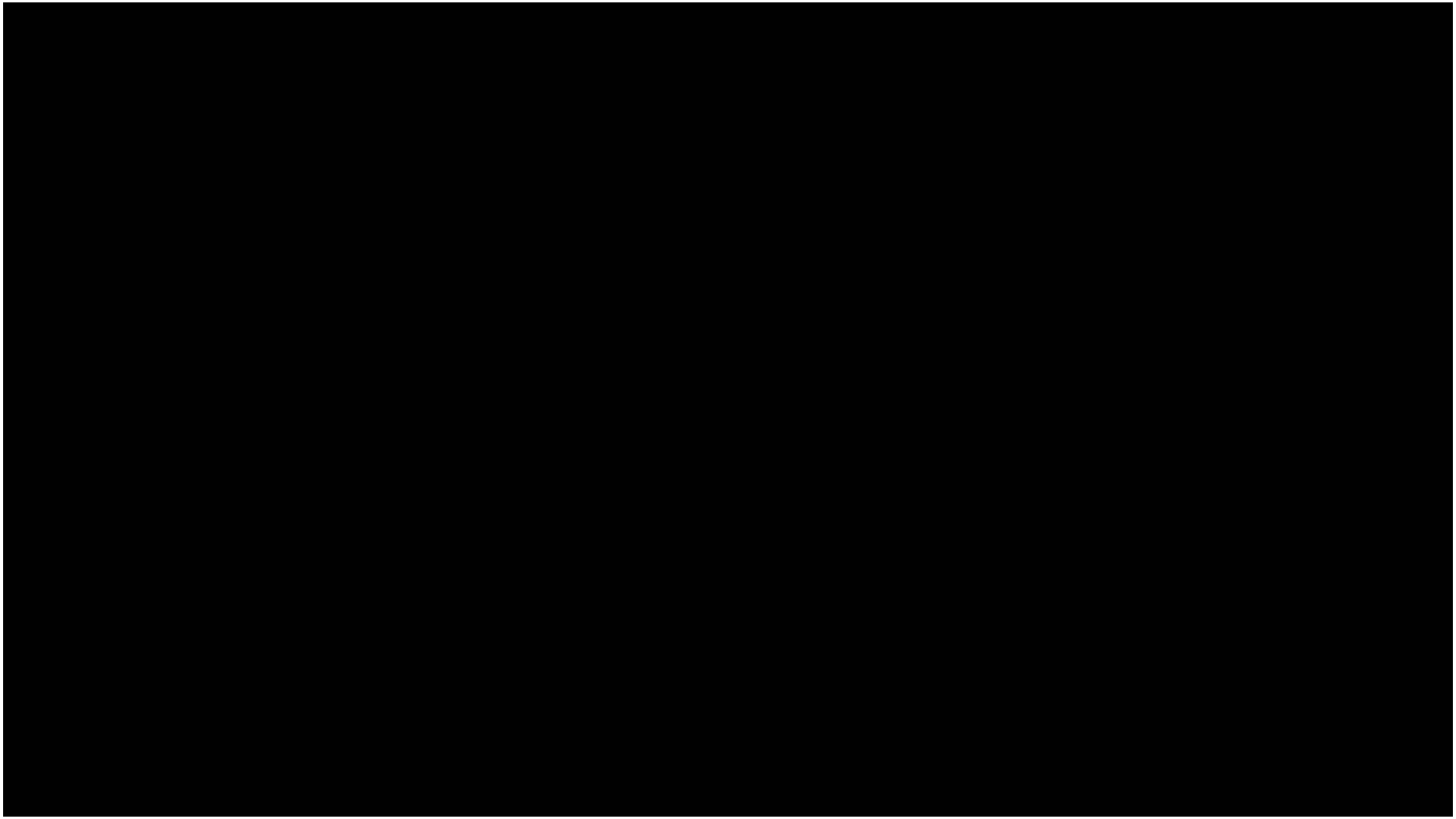


Parallel Circuit



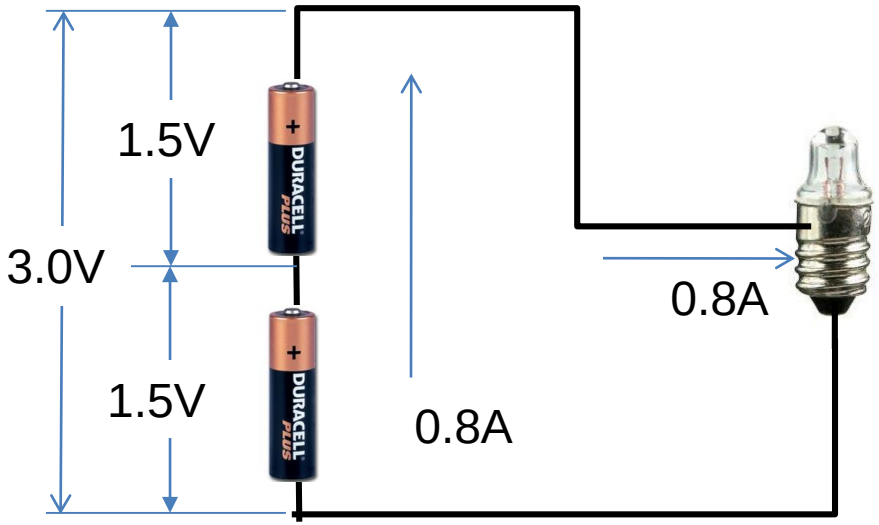


Circuits



How to connect circuits

Connecting *Sources* (batteries)



Series Circuit

Electrical Flow Characteristics

The pressure or push force that excites the electrons to "flow" in a circuit is called: **Voltage (volts, V) V**

The quantity or amount of electrons flowing in circuit or “current” is called: **Amperes (amps, A) I**

The opposition to movement of free electrons is called: **Resistance (ohms, Ω) R**

The rate at which electrical energy is used is called: **Power (watts, W) P**

Relationship of Electrical Terms

V – voltage or volts

I – amps or amperage

R – resistance or ohms

Ohms Law: V = I x R or R = V / I

Power: P = V * I (measured in watts) –

So, we can use the same power by altering V, I, and R

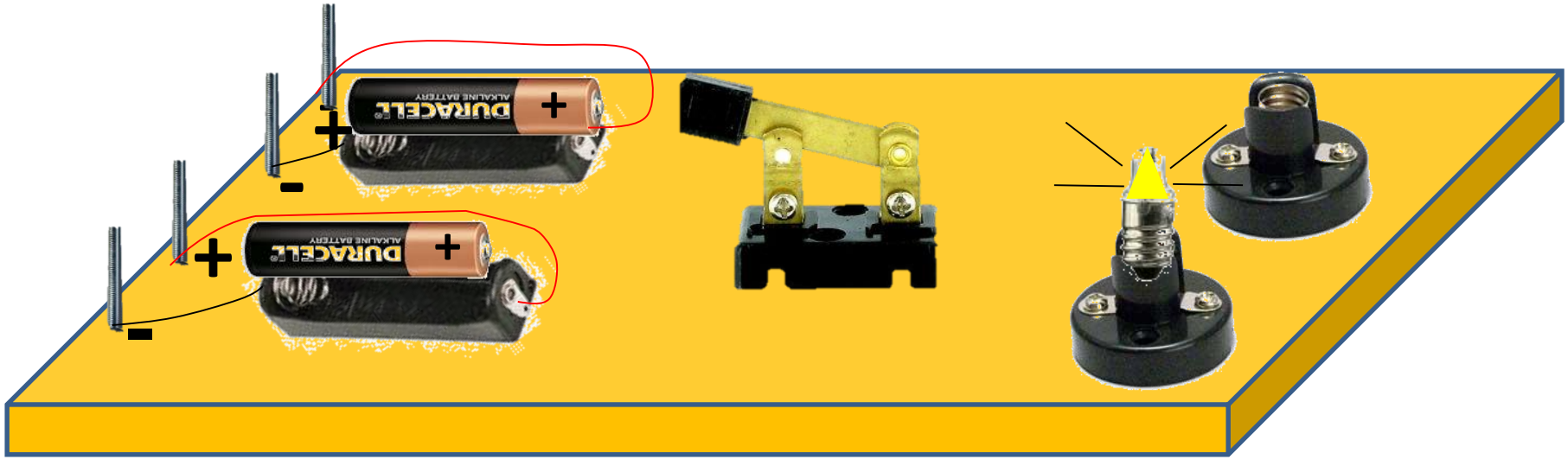
Creating, Connecting, and Measuring Circuits

Using a Breadboard
An Experiment

We measure these using an electric meter

A new electric multimeter (voltmeter, ammeter, ohmmeter):

Our Breadboard



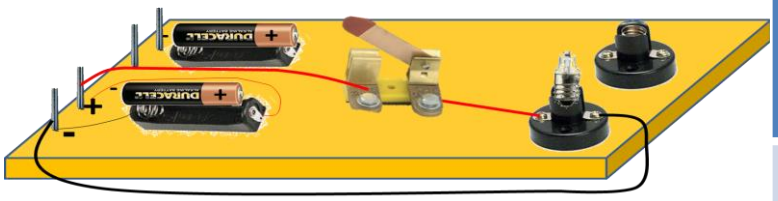
Components of our breadboard:

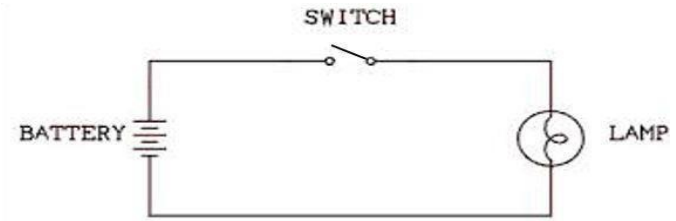
- Batteries (in holders)
- Switch
- Lightbulbs (in holders)
- Wires w/alligator clips

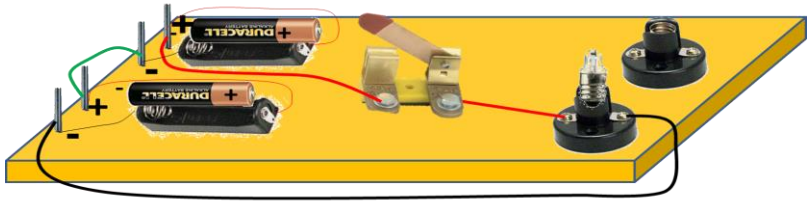
Circuit Worksheet

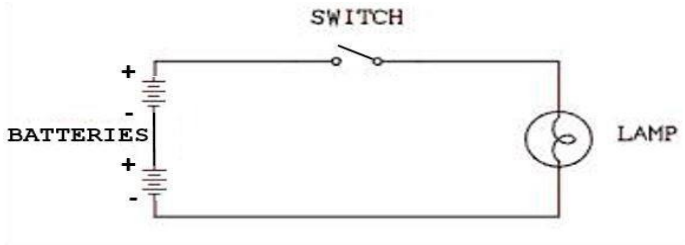
P = V*I, I = V/R, so we can also write:

$P = V^2/R$









Circuit	Open Circuit Battery Voltage (V) volts	Dim Bright Very Bright	Light Bulb Voltage (V) volts	Circuit Current (I) amps	Power (P= V*I) watts	Resistance (R=V/I) ohms
1 Battery, 1 light bulb	1.60	Dim	1.42	.22	.31	6.7
2 Batteries in series, 1 light bulb	3.12	Very Bright	2.80	.30	.84	9.2

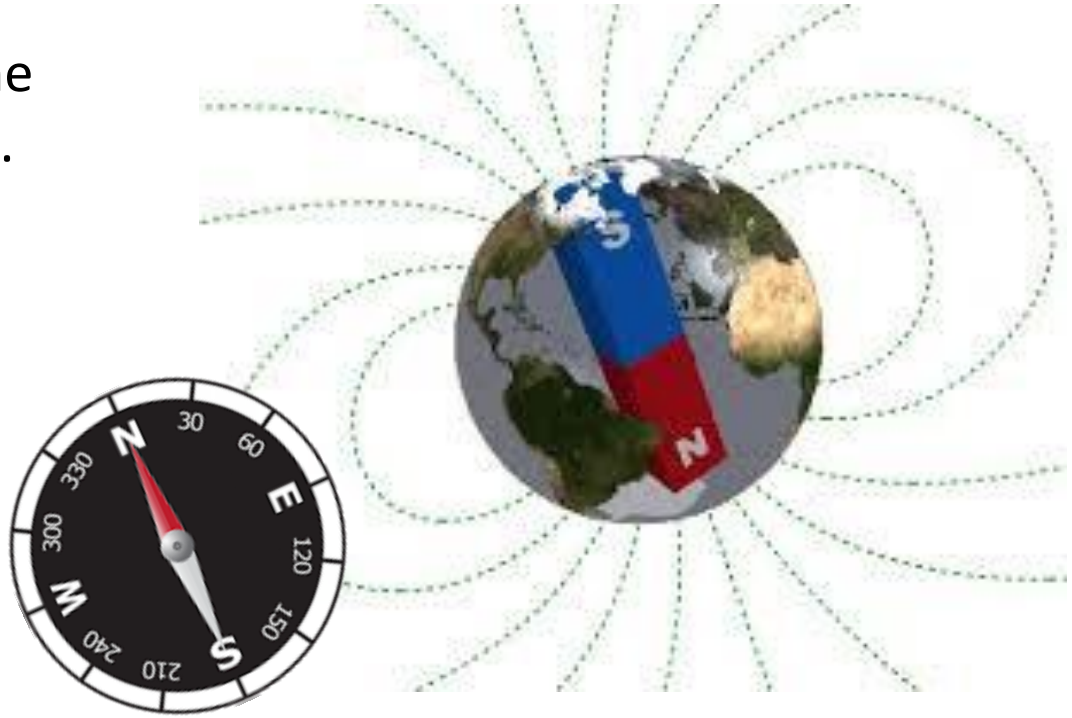
MAGNETS AND MAGNETISM

“Lodestones”: Naturally Occurring Magnets

- The ancient Greeks knew about strange and rare stones with the power to attract iron.
- A steel needle stroked with such a "lodestone" became "magnetic" as well.
- Around 1000 AD the Chinese found that such a needle, when freely suspended, pointed north-south.
- The magnetic compass soon spread to Europe.

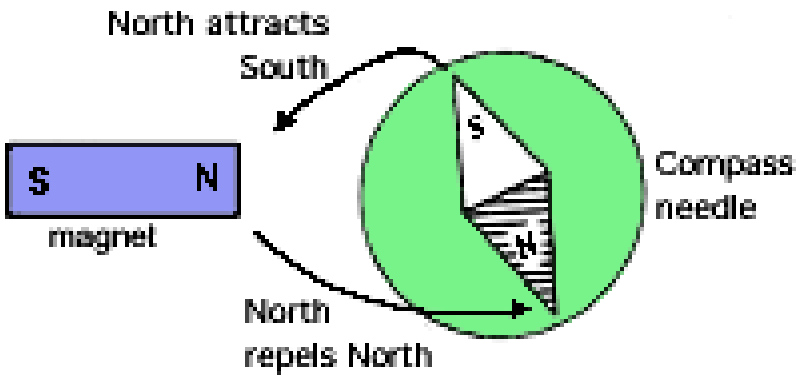
The Magnetic Compass

- Columbus used the early magnetic compass when he crossed the Atlantic ocean.



Magnetic Fields

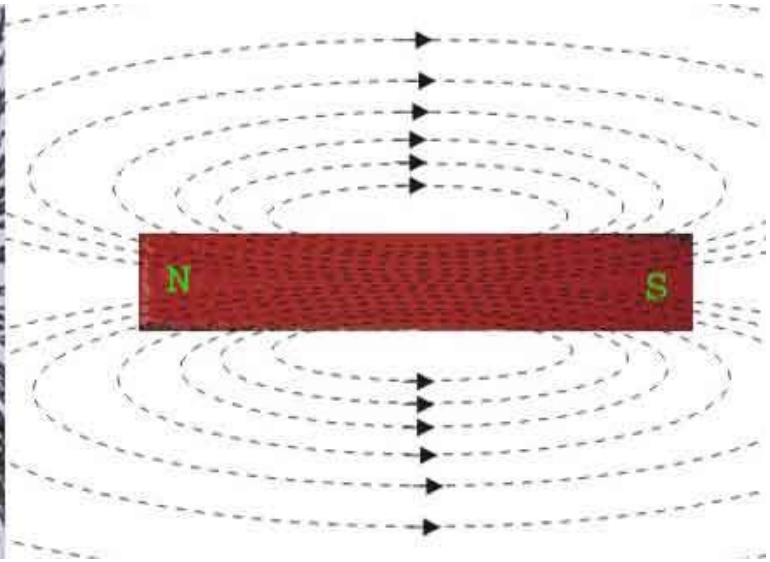
- A magnetized bar has its power concentrated at two ends, its *poles*.
- They are known as its north (N) and south (S) poles, because if the bar is hung by its middle from a string, its N end tends to point northwards and its S end southwards.



The N end will repel the N end of another magnet, S will repel S, but N and S attract each other.

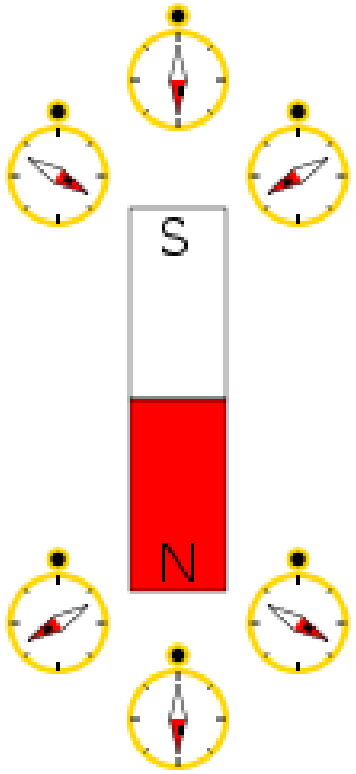
Magnetic Fields (cont'd)

- The region where this is observed is called a *magnetic field*
- This field is represented by magnetic lines of force.
- Either pole can also attract iron objects such as pins,



Magnets & Magnetic Fields

Compasses reveal the direction of the local magnetic field. As seen here, the magnetic field points towards a magnet's south pole and away from its north pole.



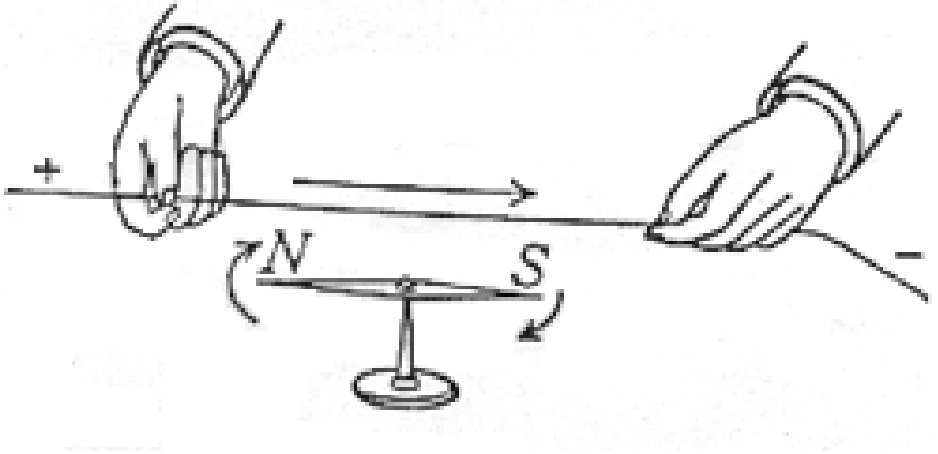
Permanent magnets are made from magnetic materials such as:
Iron, nickel, cobalt, and neodymium OR combinations of these elements.

ELECTROMAGNETISM:

ELECTRICITY + MAGNETISM

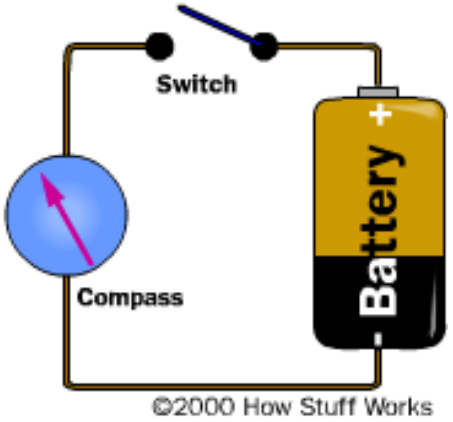
What Is ElectroMagnetism?

- Until 1821, only one kind of magnetism was known, the one produced by iron magnets.
- Then a Danish scientist, Hans Christian Oersted, while demonstrating to friends the flow of an electric current in a wire, noticed that the current caused a nearby compass needle to move!



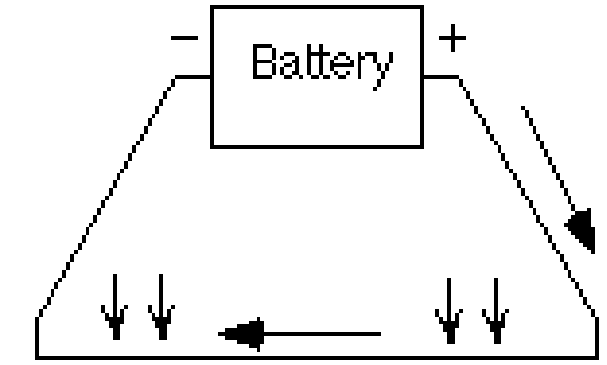
The Magnetic Field Generated By An Electric Current

- **This happens in all wires carrying electricity!**
- Let's try an experiment. We need:
  - A battery
  - A piece of wire
  - A compass
- Put the compass on the table and, with the wire near the compass, connect the wire between the positive and negative ends of the battery for a few seconds
- What you will notice is that the compass needle swings

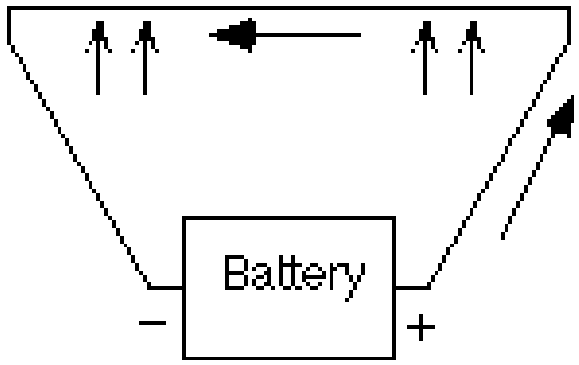


The Magnetic Field Generated By An Electric Current (cont'd)

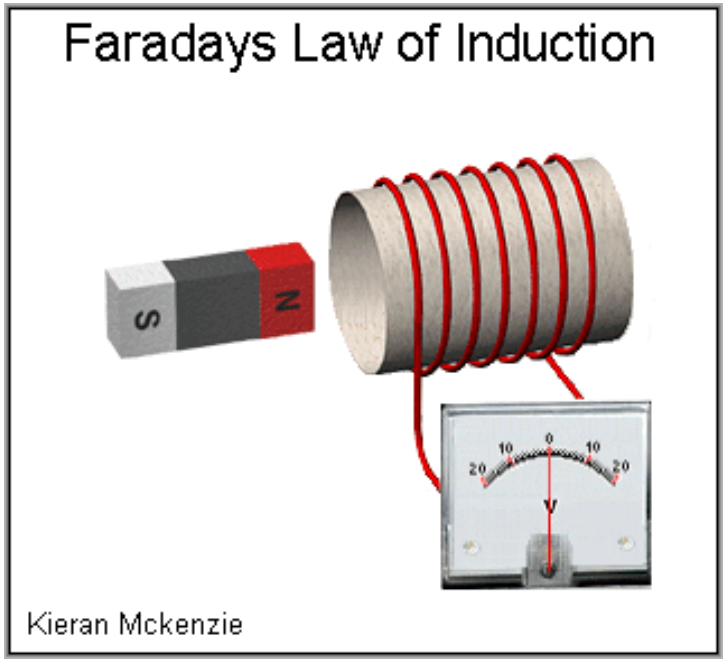
- The new phenomenon was studied in France by Andre-Marie Ampere, who concluded that magnetism was basically a **force between electric currents**:
- Two parallel currents in the same direction **attract**, in opposite directions **repel.**



Parallel currents attract each other



Faraday's Law

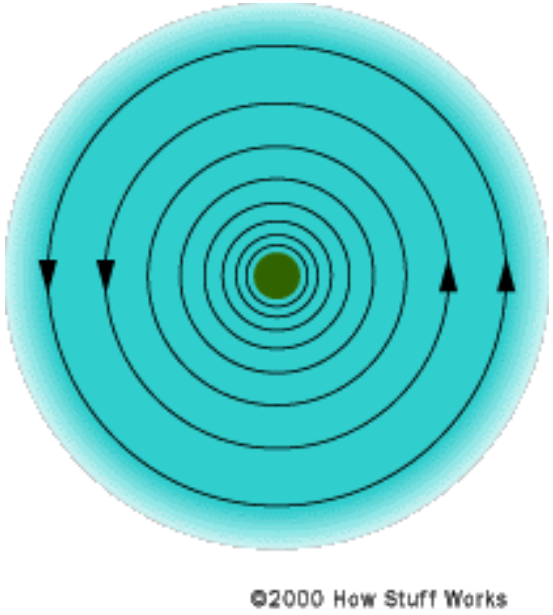


Any change in *the magnetic environment* of a coil of wire will cause a voltage to be "induced" in the coil.

This is how we make an electric generator

Coiling A Wire To Strengthen The Magnetic Field

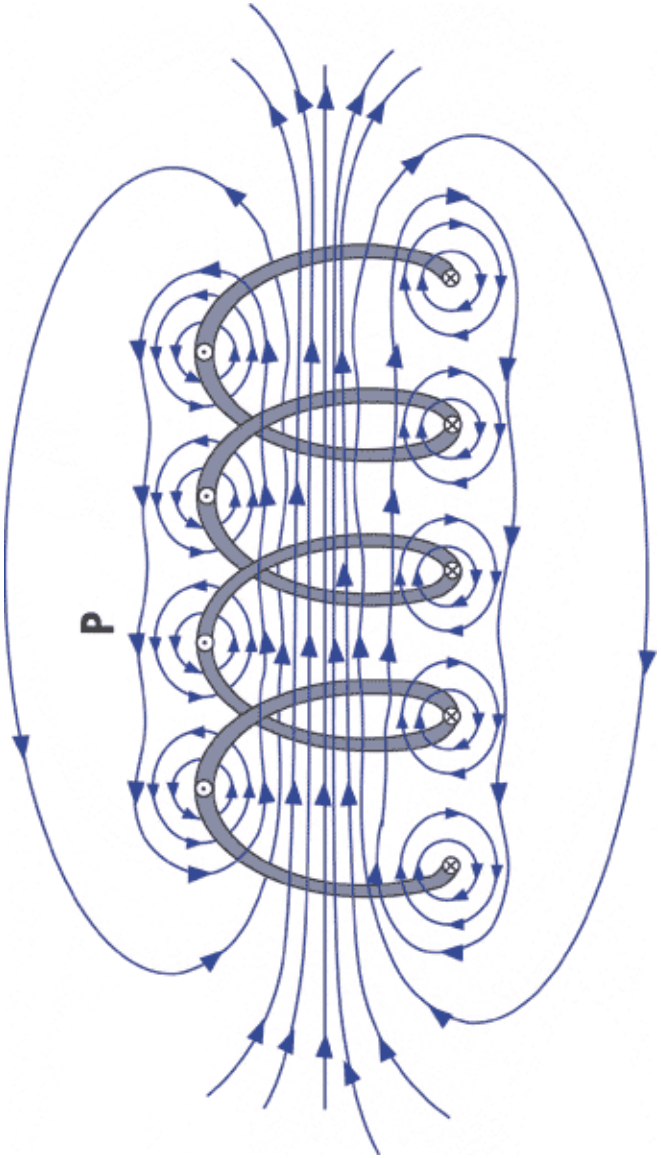
- Let's look at the shape of the magnetic field around the wire.
- Imagine that you have cut the wire and are looking at it end-on.
- The green circle in the figure is the cross-section of the wire itself.
- A **circular magnetic field** develops around the wire, as shown by the circular lines in the illustration.
- The field weakens as you move away from the wire (so the lines are farther apart as they get farther from the wire).



Magnetic field of a wire

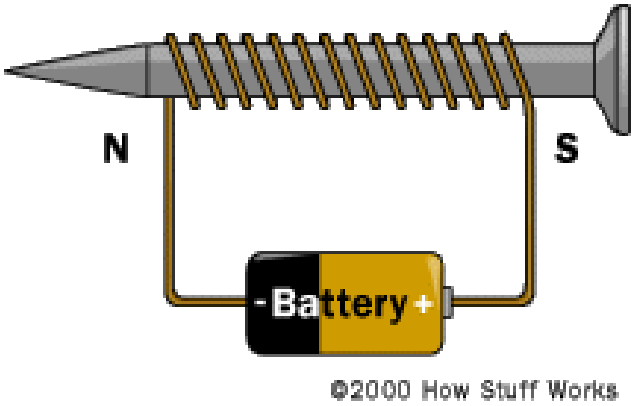
Magnetic Field Produced By A Coil

- The magnetic field circling each loop of wire combines with the fields from the other loops to produce a concentrated field down the center of the coil
- A loosely wound coil is illustrated to the right to show the interaction of the magnetic field
- The strength of a coil's magnetic field increases not only with increasing current but also with each loop that is added to the coil



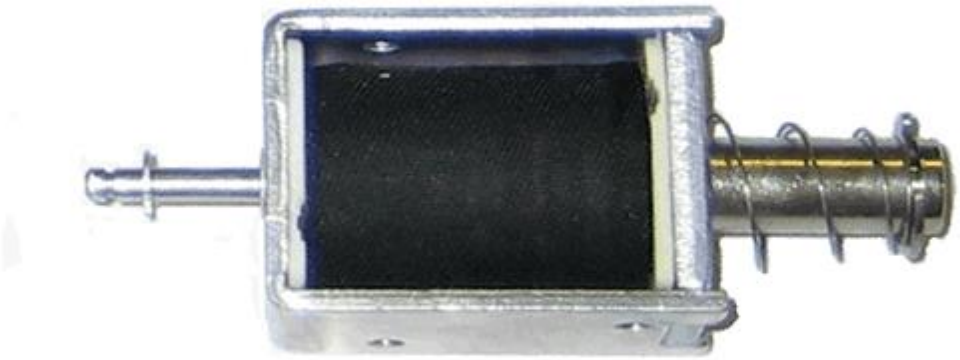
An Electromagnet

- If you wrap your wire around a nail 10 times, connect the wire to the battery and bring one end of the nail near the compass, you will find that it has a much larger effect on the compass
- In fact, the nail behaves just like a bar magnet
- However, the magnet exists only when the current is flowing from the battery
- What you have created is an electromagnet!
- You will find that this magnet is able to pick up small steel things like paper clips, staples and thumb tacks



A simple electromagnet

Solenoid

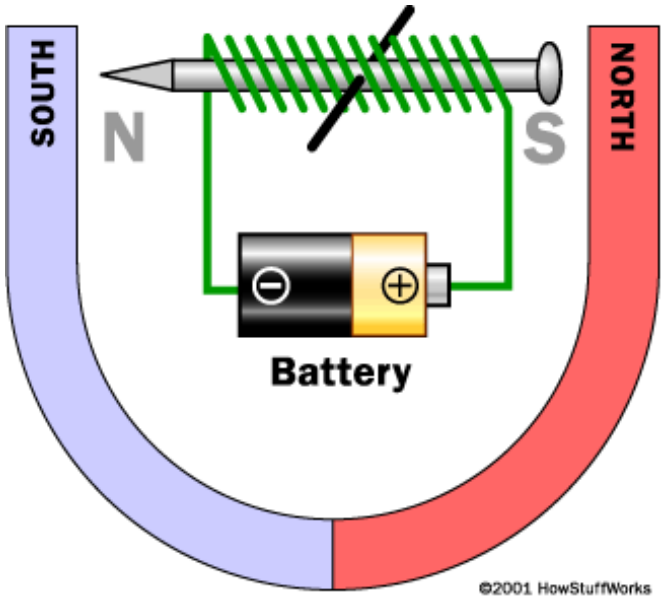


A Powerful Electromagnet

ELECTRIC MOTORS:
How They Work

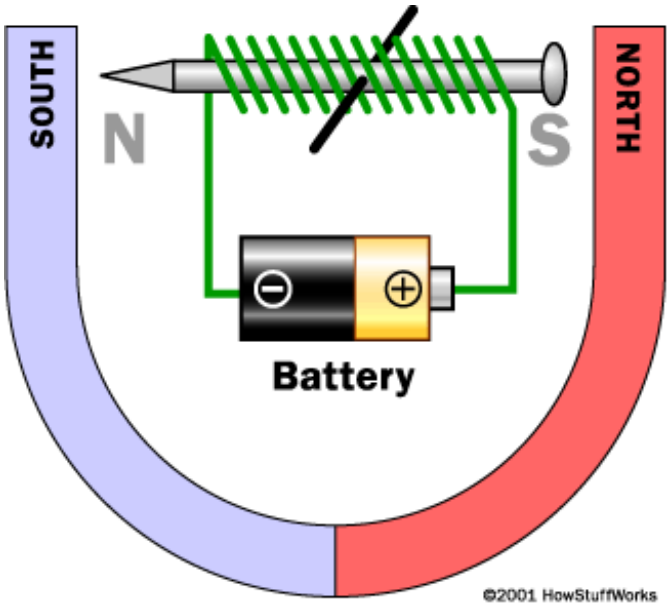
Electromagnets and Motors

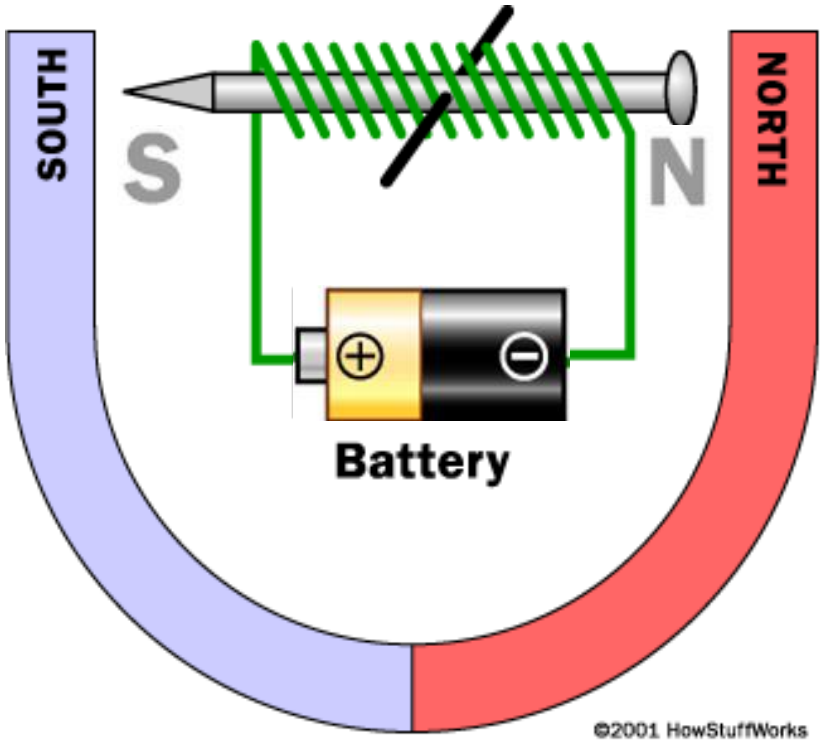
- An electromagnet is the basis of an electric motor
- Say that you created a simple electromagnet by wrapping 100 loops of wire around a nail and connecting it to a battery
- The nail would become a magnet and have a north and south pole while the battery is connected.
- Now say that you take your nail electromagnet, run an axle through the middle of it and suspend it in the middle of a horseshoe magnet as shown in the figure to the right



Electromagnets and Motors (cont'd)

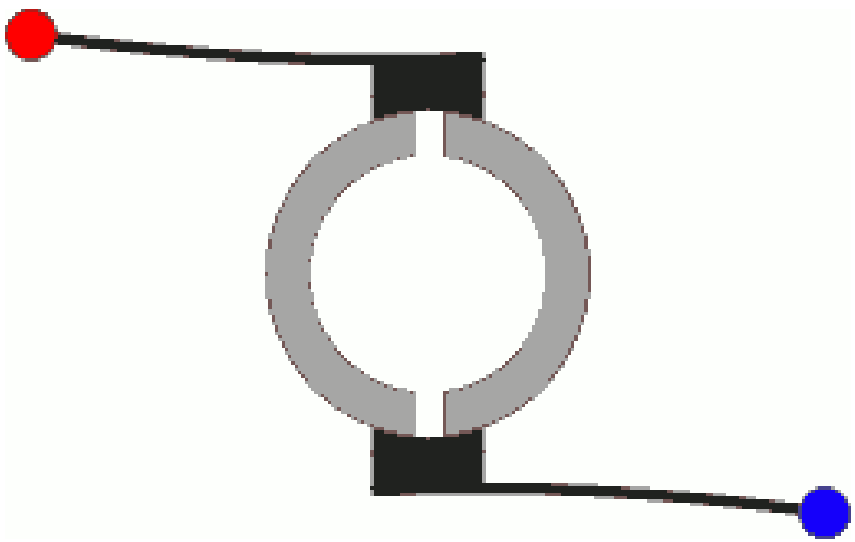
- With the battery attached:
  - The south end of the electromagnet would be attracted to the north end of the horseshoe magnet and repelled from the south end
  - The nail would move about half a turn and then stop in the position shown
  - The key to an electric motor is to then go one step further so that, at the moment that this half-turn of motion completes, the field of the electromagnet flips
  - One way to flip the magnetic field is to change the direction of the electrons flowing in the wire which you could do by flipping the battery over




SOUTH
NORTH
S
N
Battery
©2001 HowStuffWorks

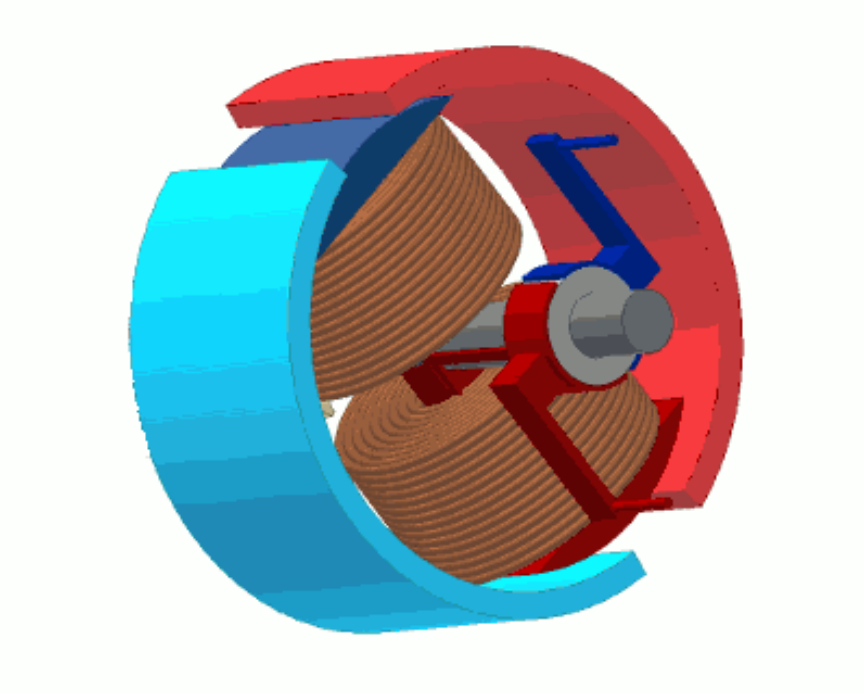
The Commutator and Brushes

- As the armature turns, the electric current direction changes to the opposite part of the commutator – the commutator is a switch!

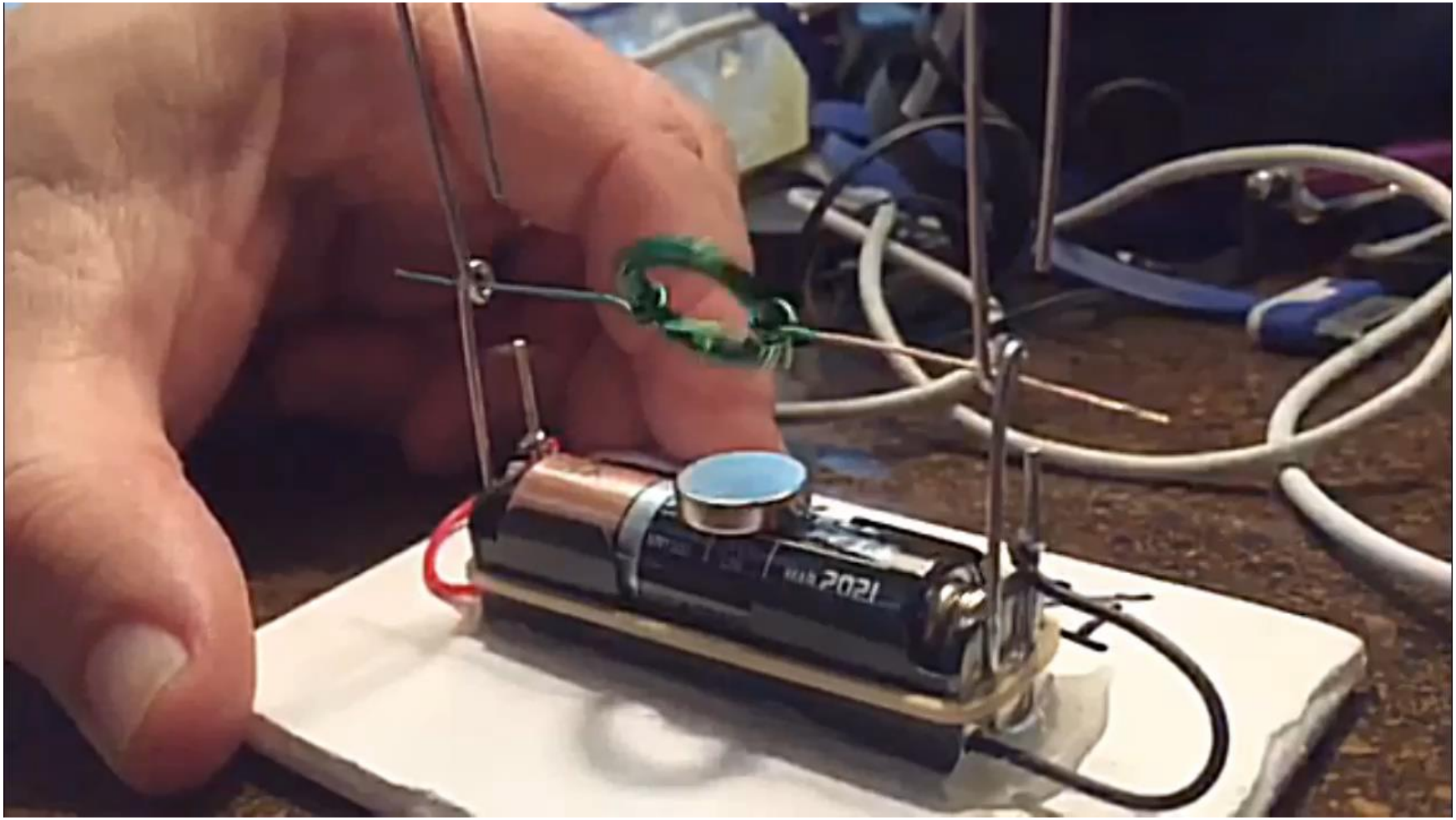


A Two Pole DC Motor

- As the armature turns ½ way into each field magnet the current is switched so the armature is now repelled to the other field magnet.

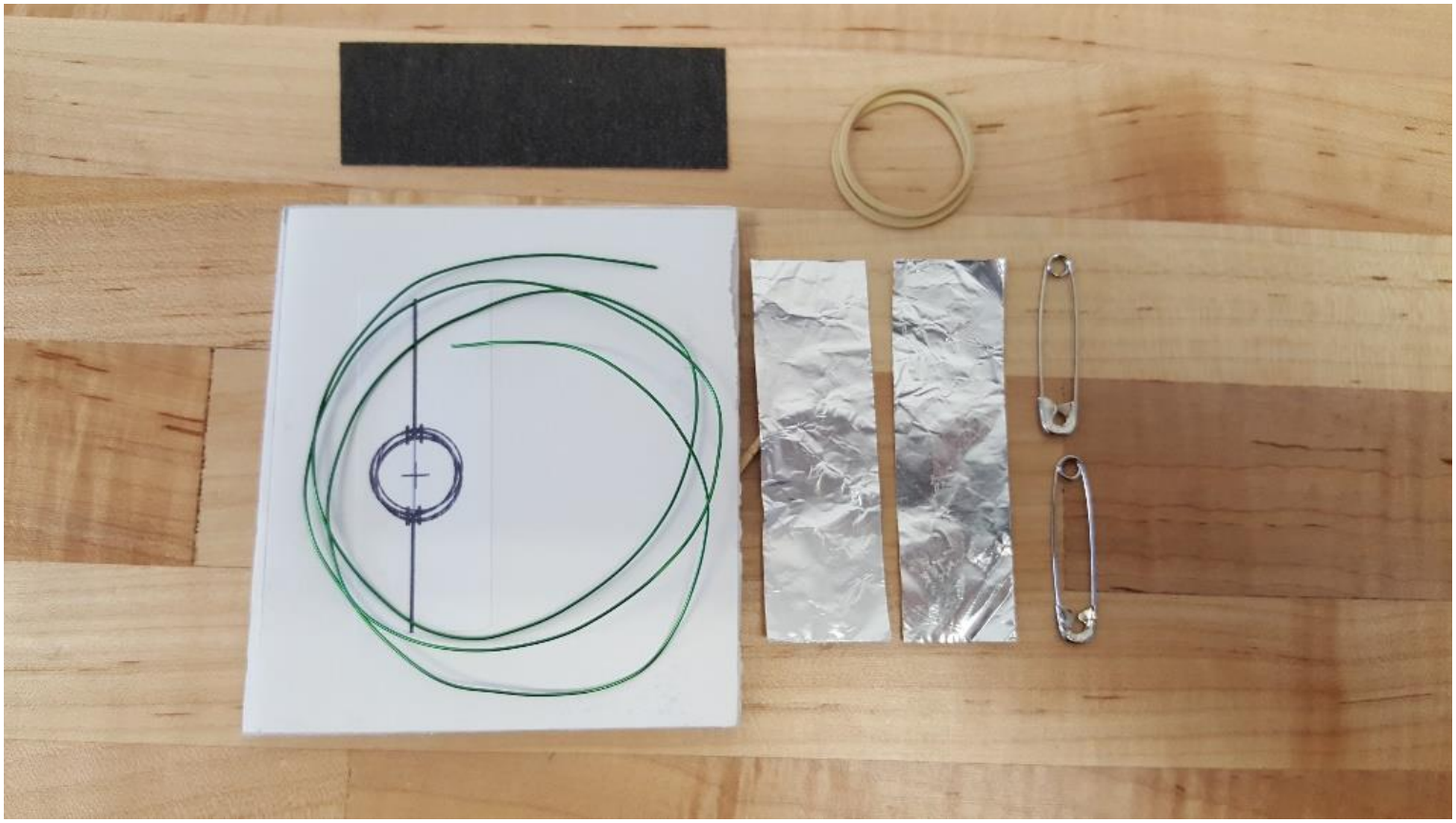


The Paperclip Motor

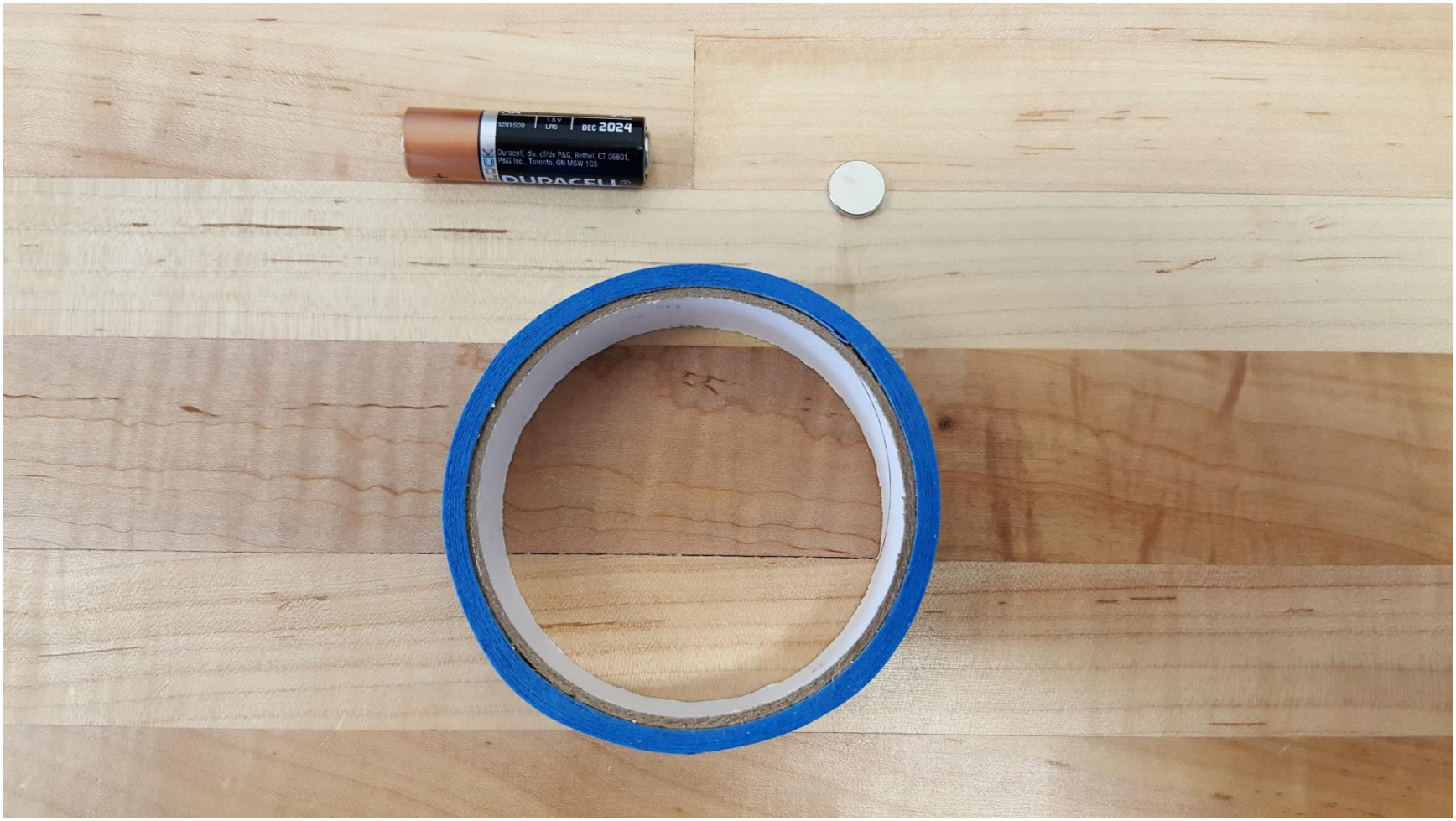


Let’s build a Paperclip Motor!

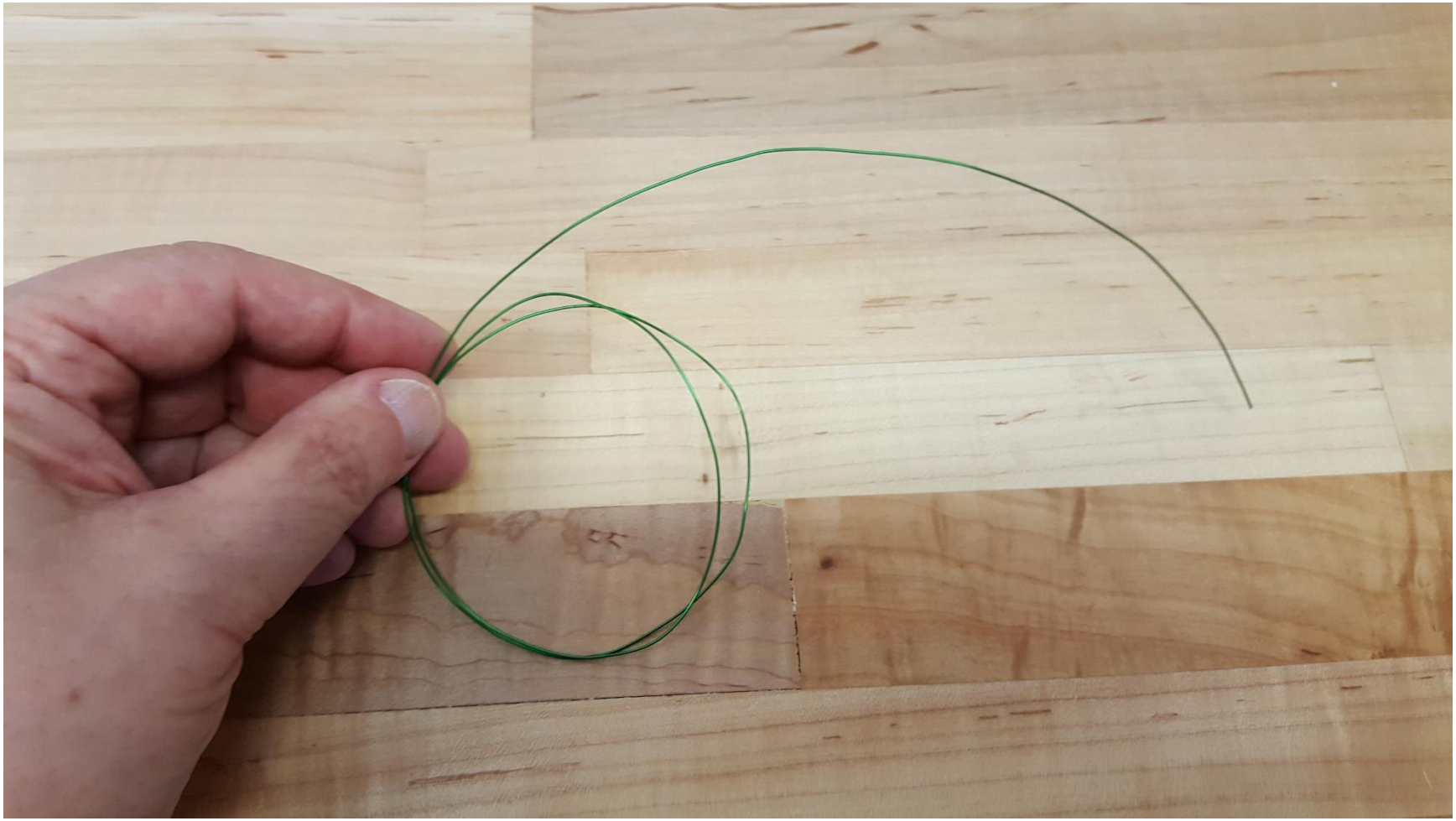
Parts Envelope



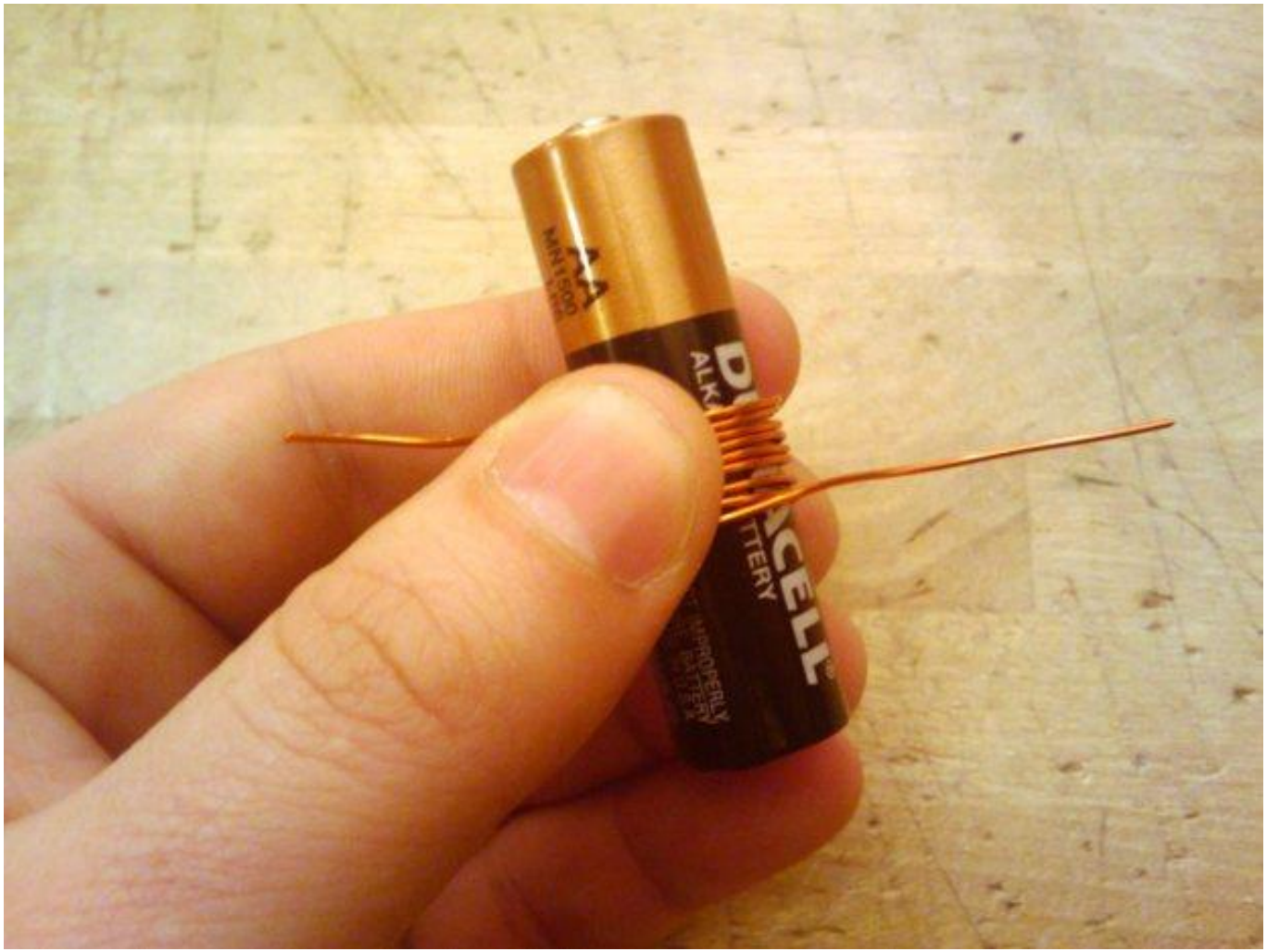
Other Parts



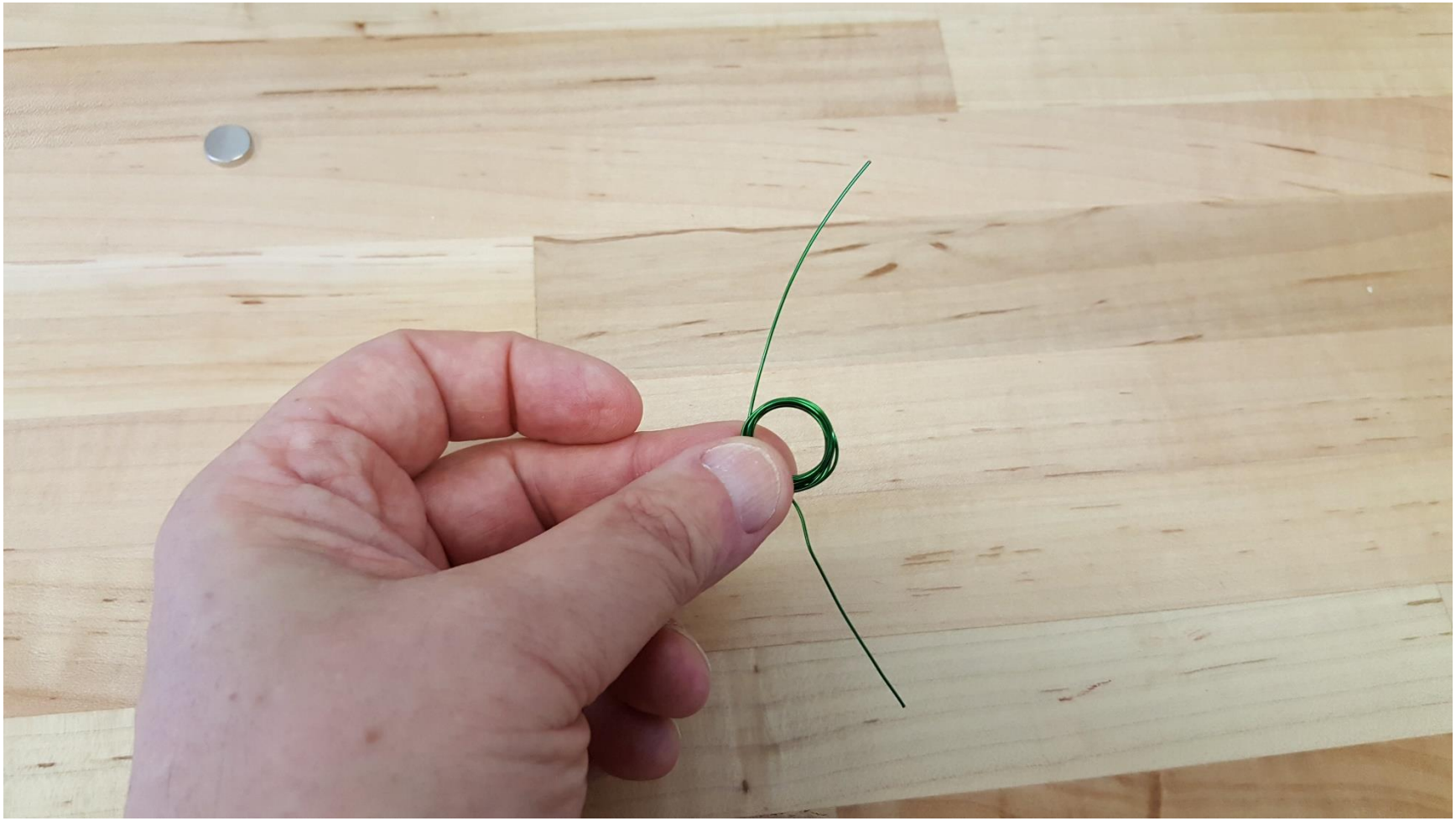
Unwind the wire carefully!



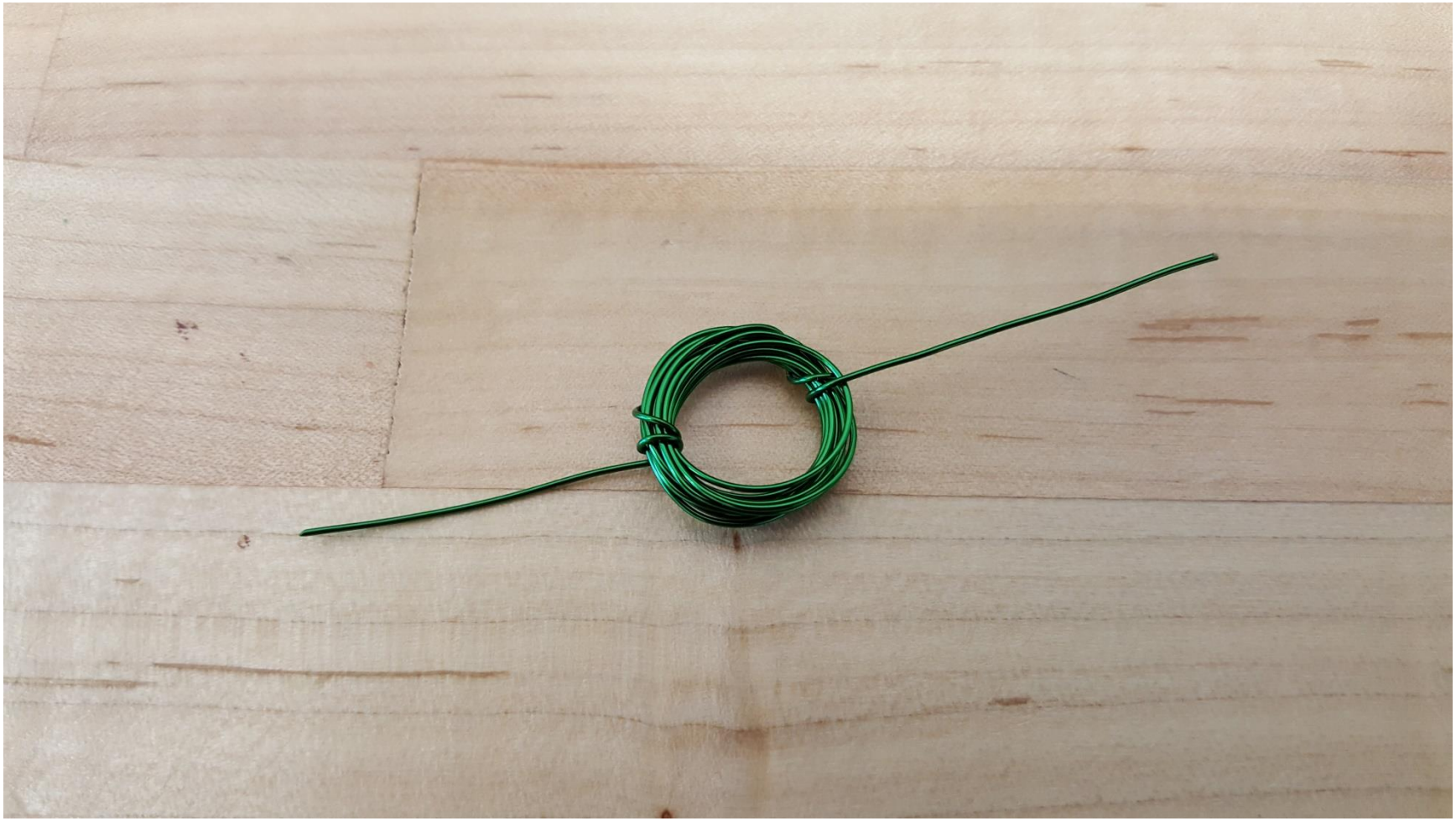
Wind Tightly Around Battery – Leave about 2” at Ends



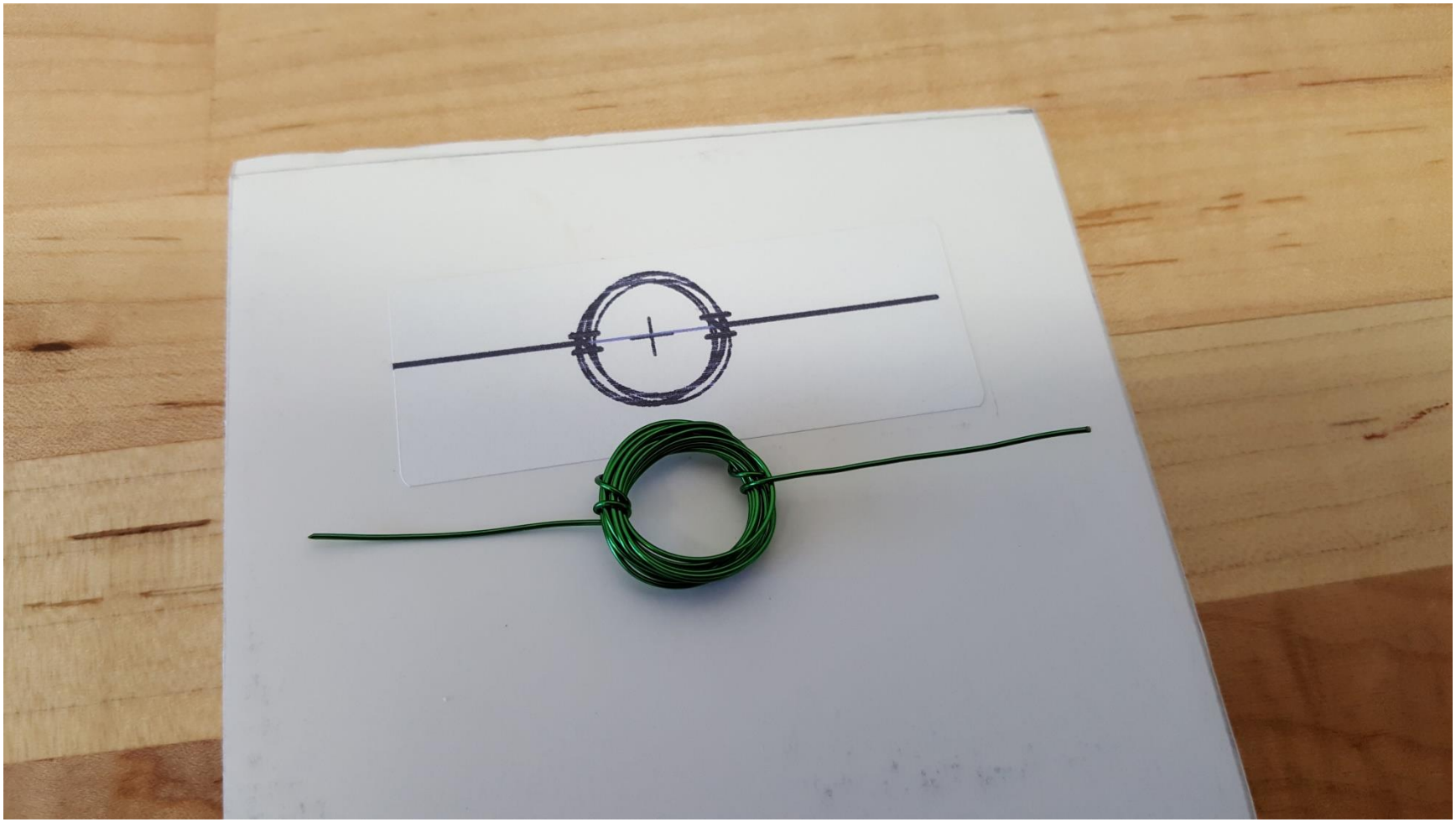
The Motor “Armature” or Coil



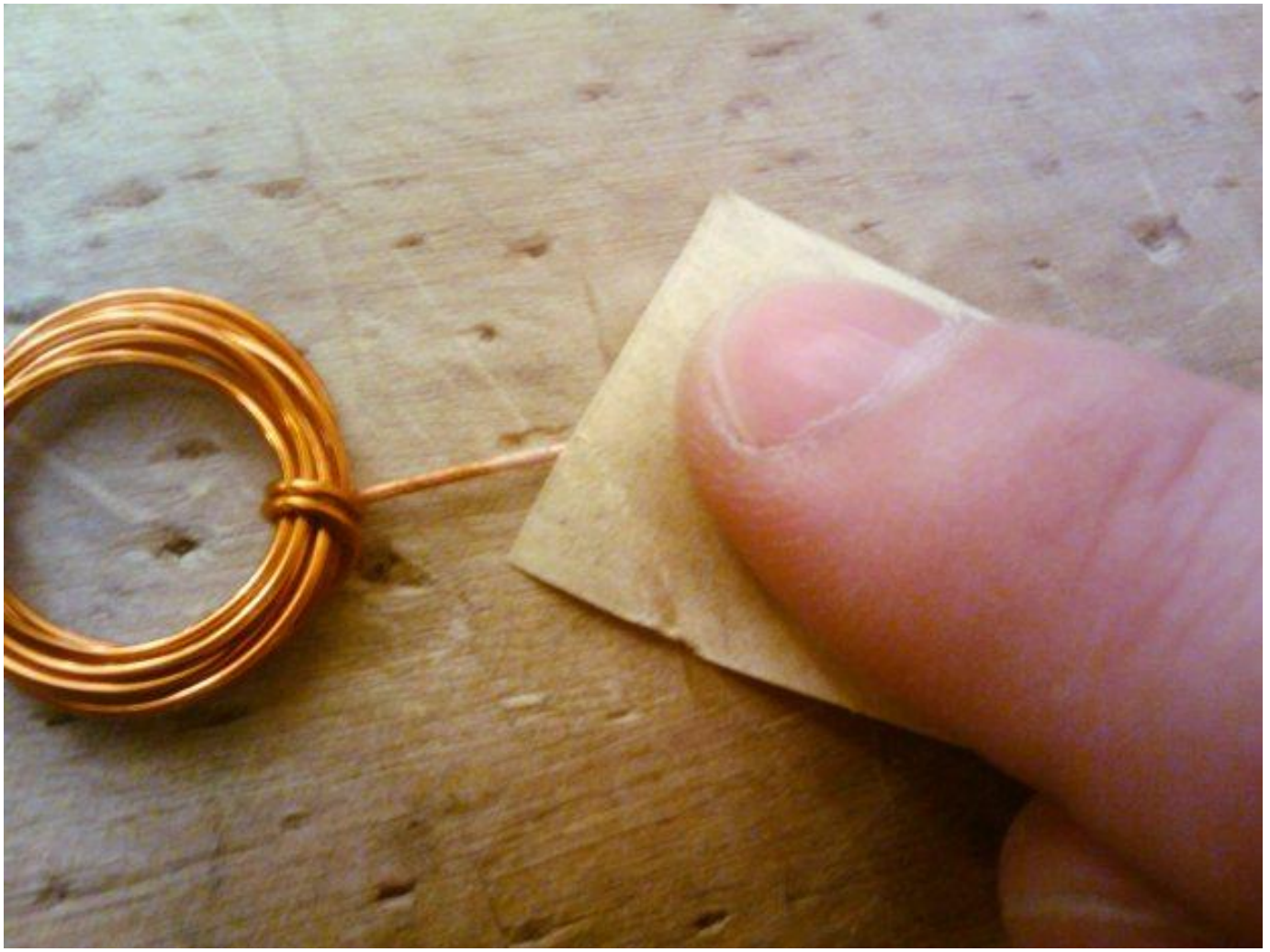
Wind Wire In and Out of Coil



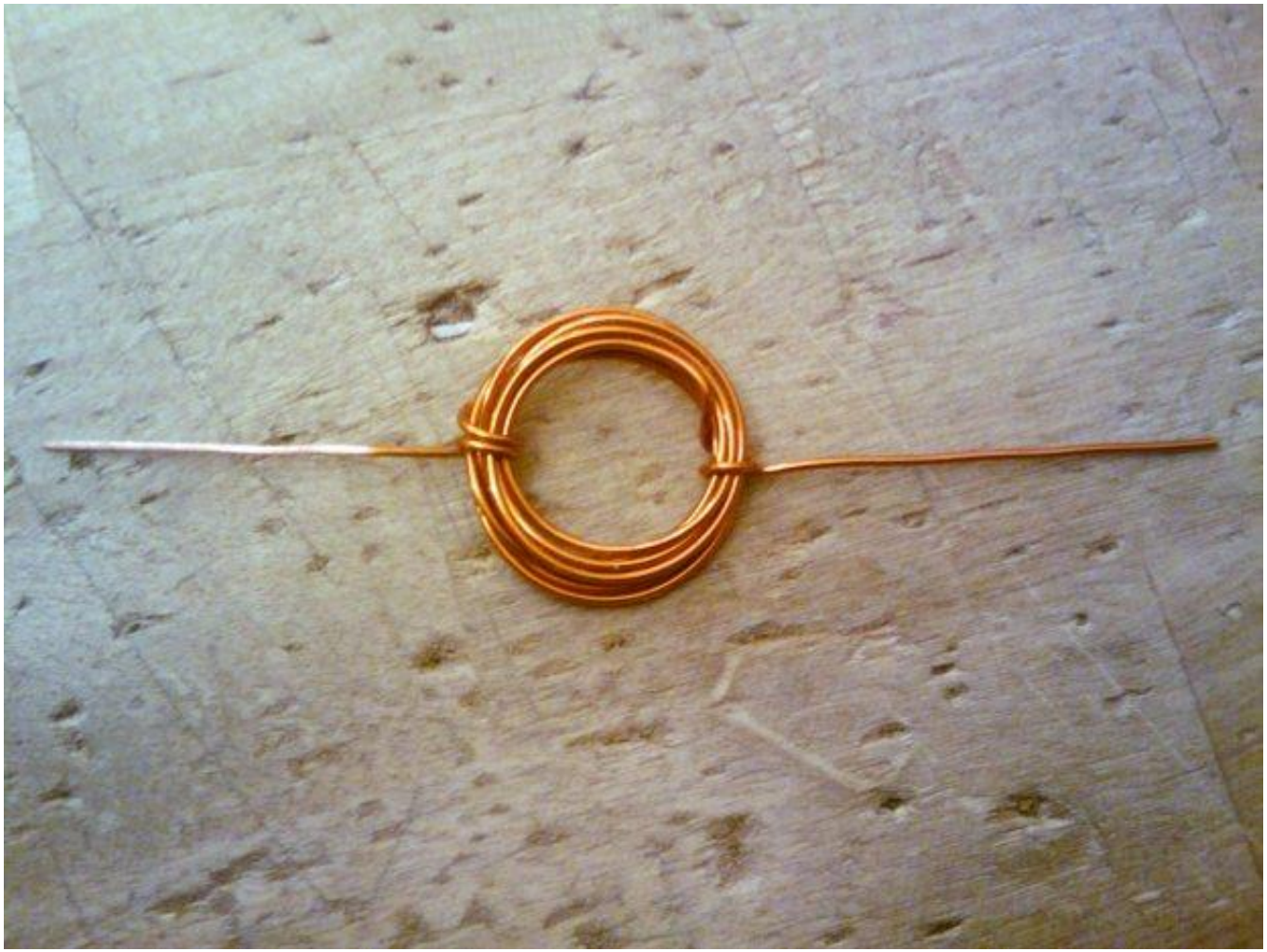
Leave Enough at Ends – Use Template



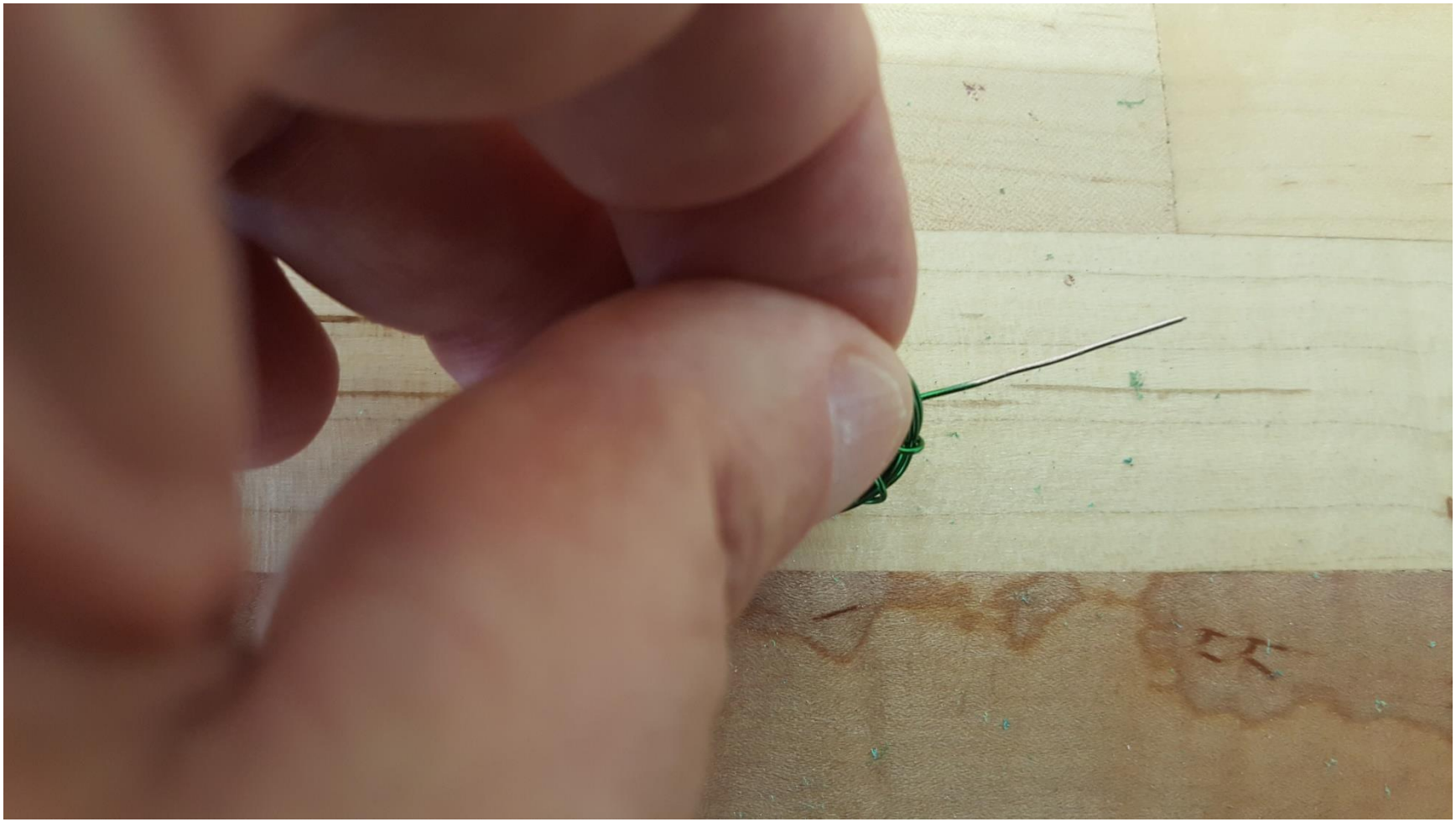
Clean Off One Wire End Completely!



Cleaned End



Clean Other Wire ONLY ½!

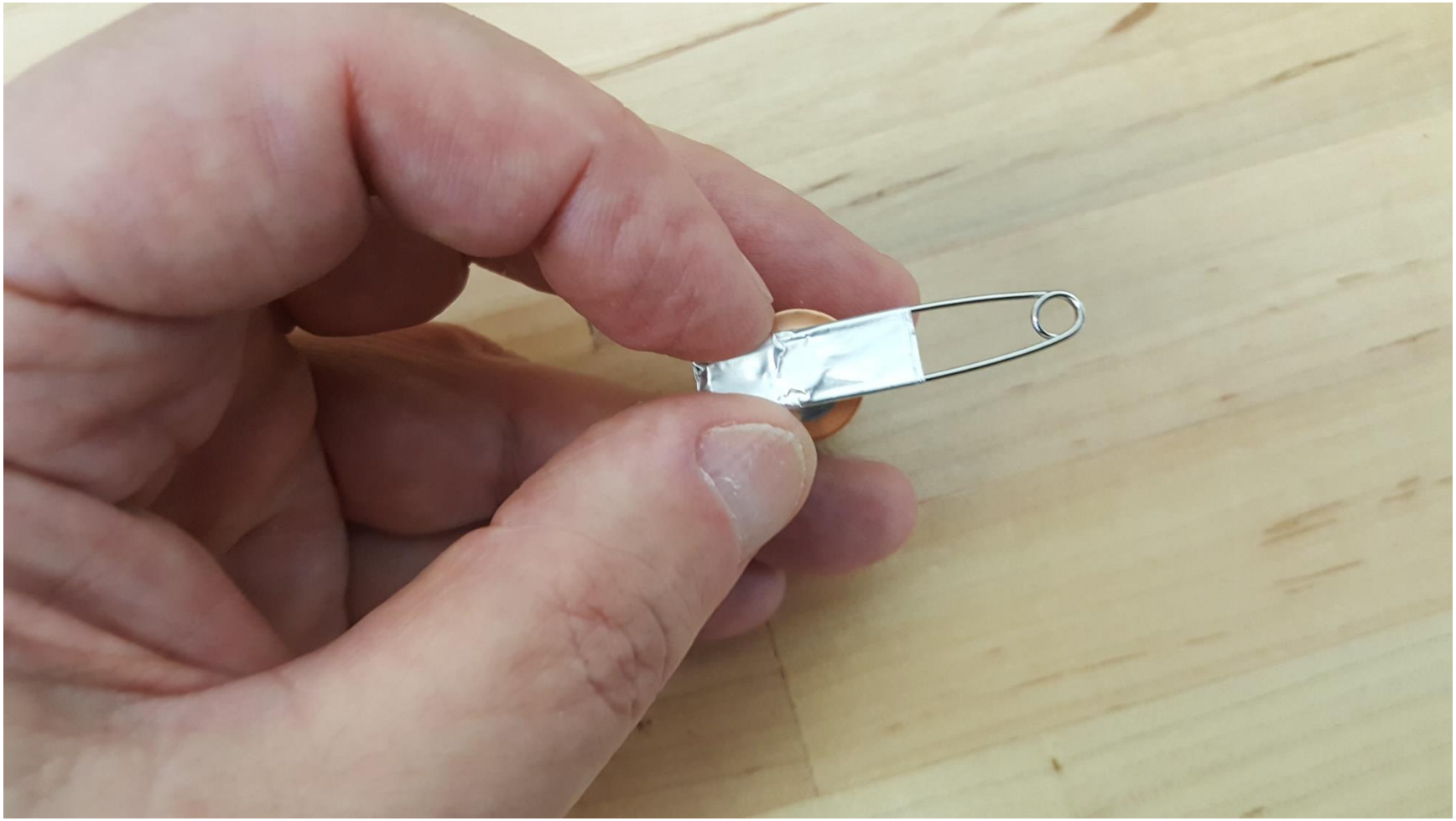


Make Contacts

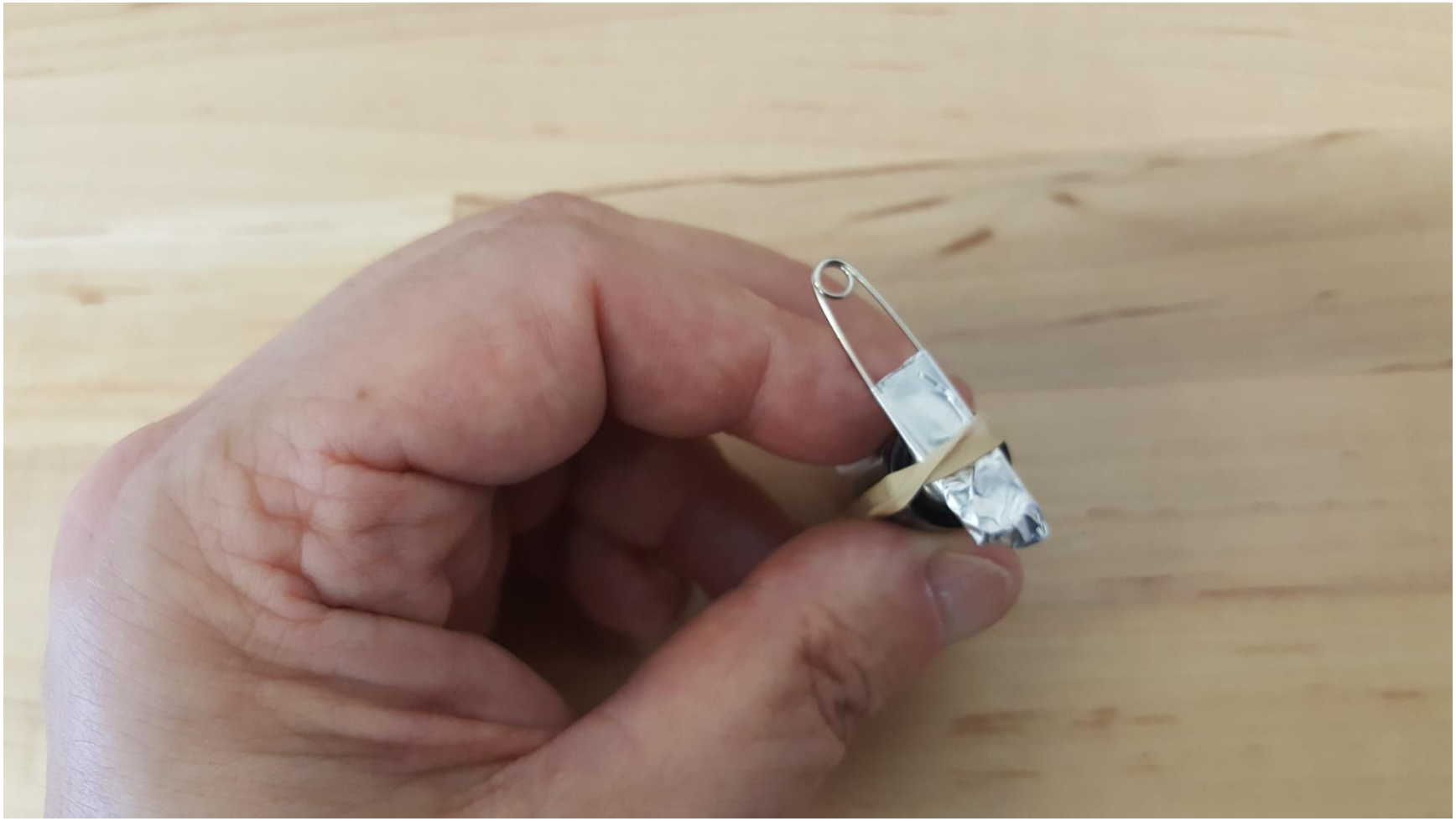
Wrap Foil Over End of Supports

Wrap Completely and Press Tight

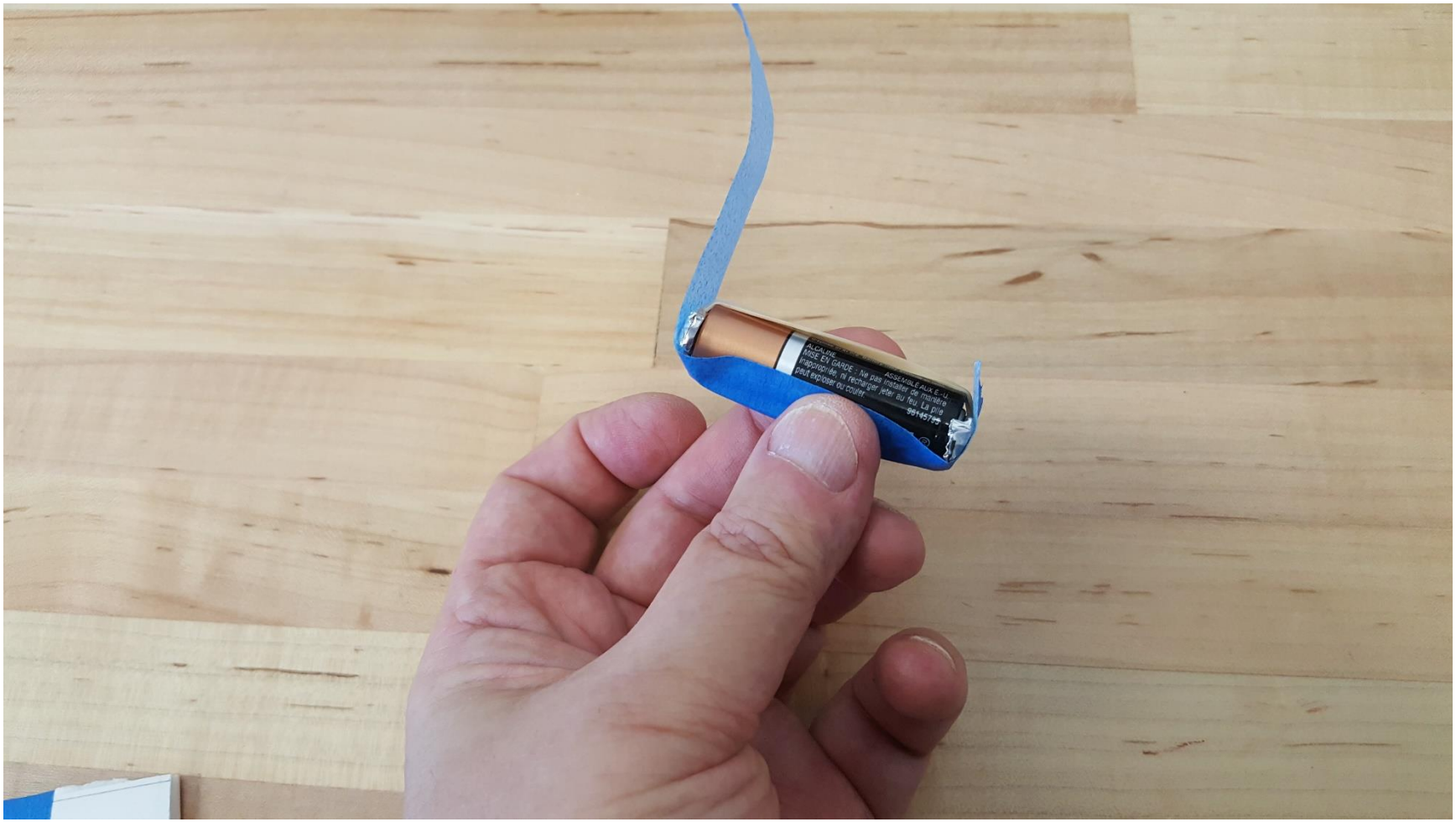
Put Support on Battery – Down Over Battery “Button”



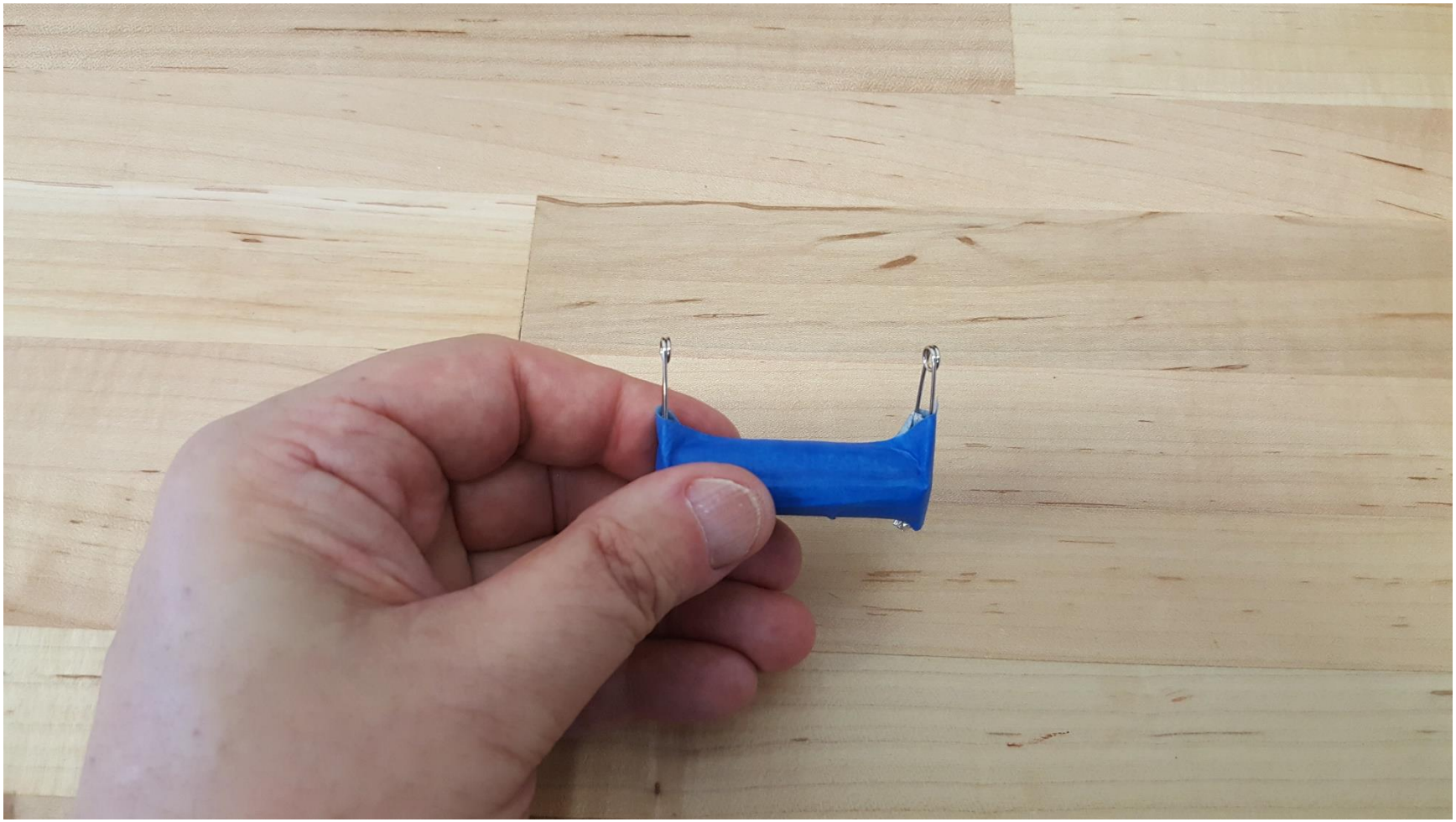
Hold in Place –
Use Two Rubber Bands



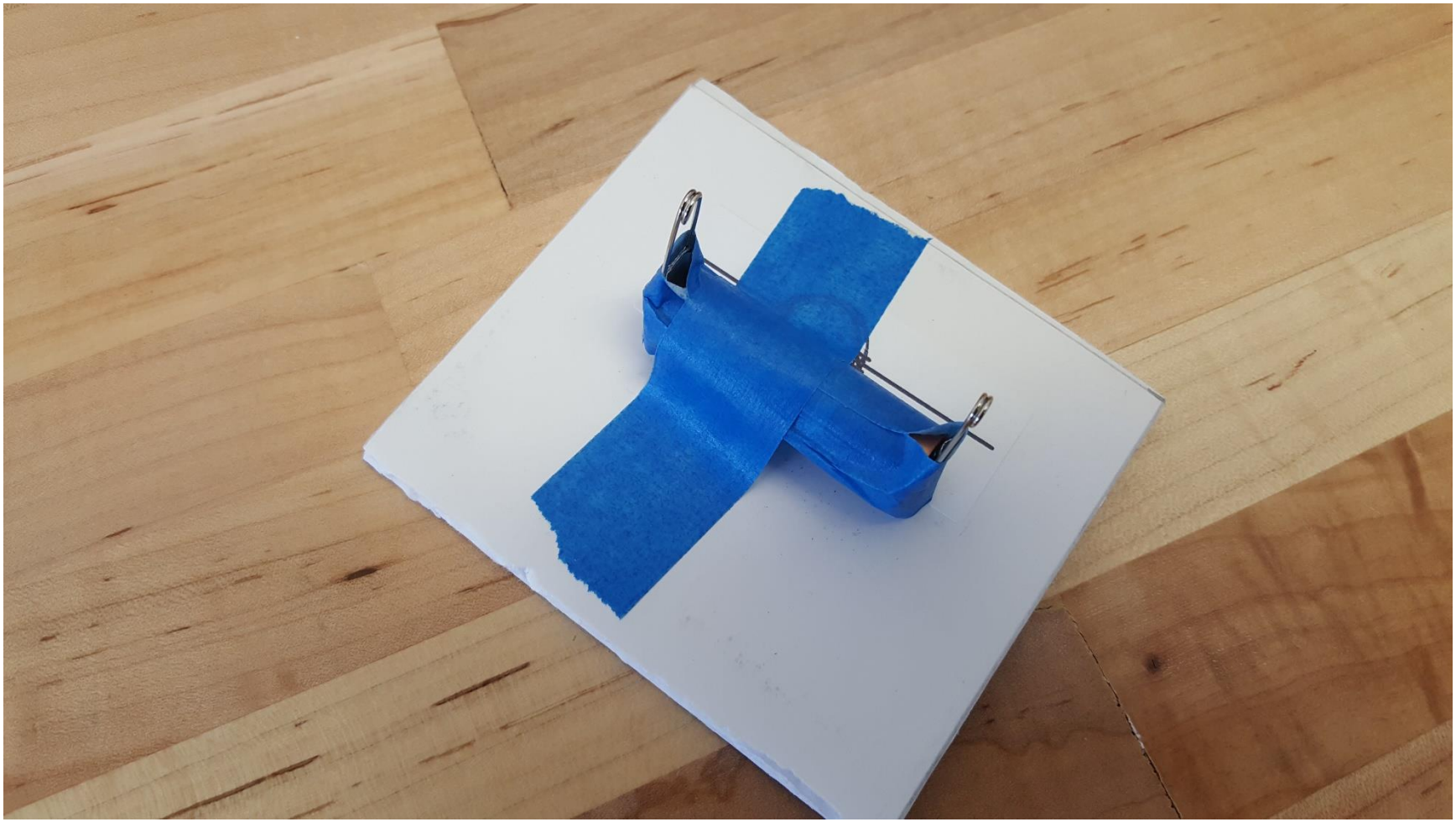
Tape Around Battery –
To Hold Rubber Bands in Place!



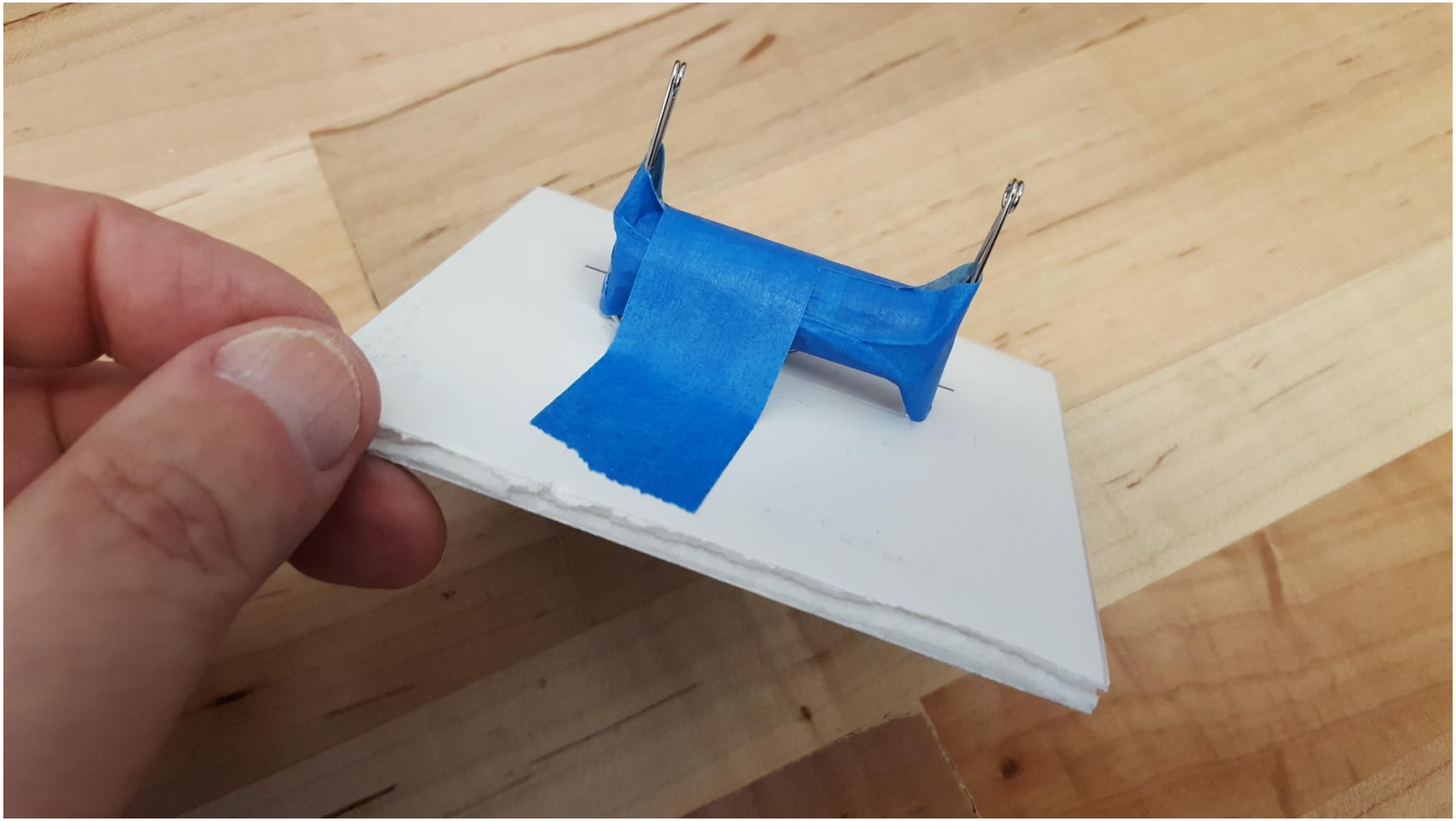
Press Down Tape –
Note Contacts Below Ends of Battery



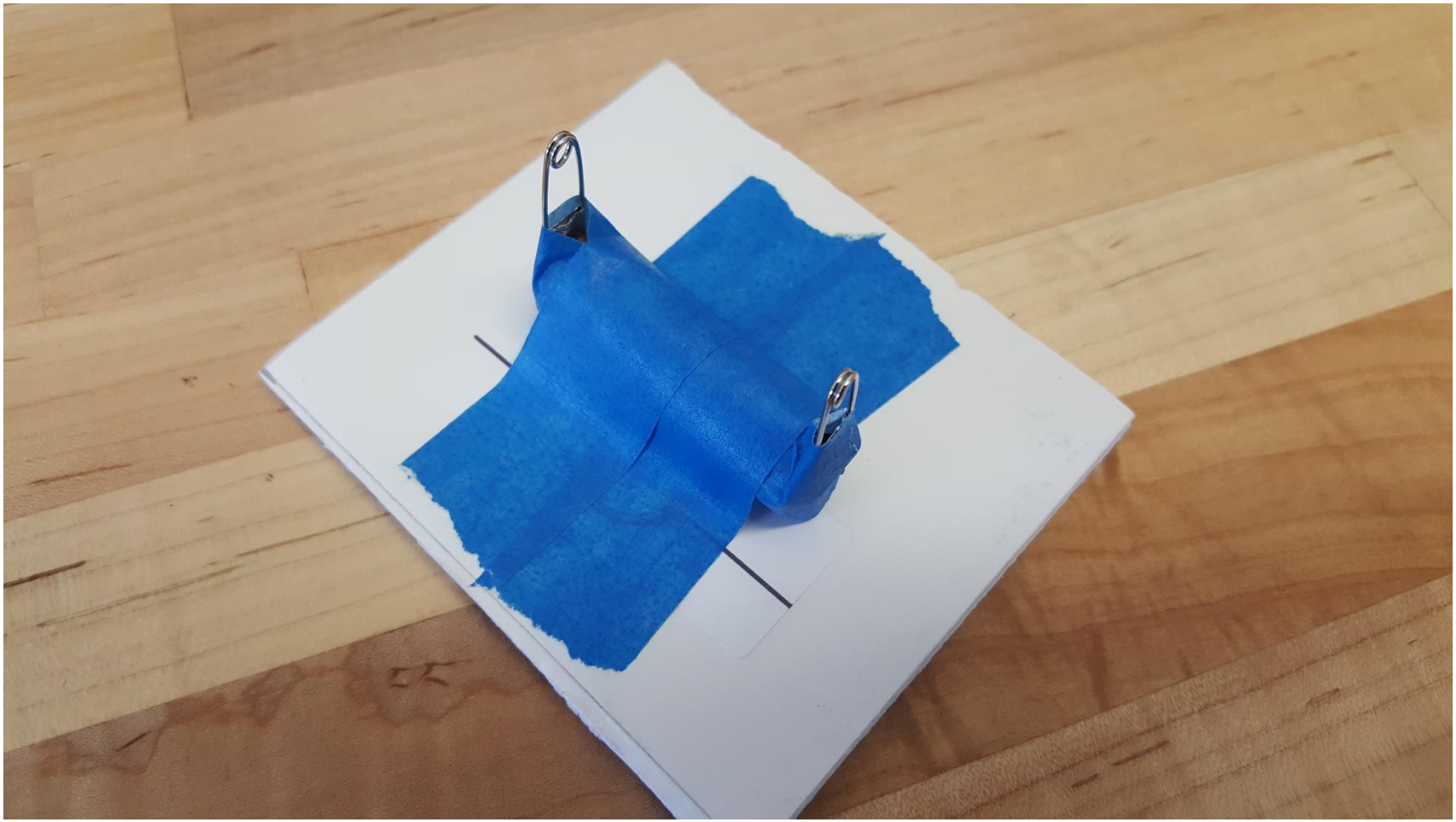
Tape Down to Base Plate



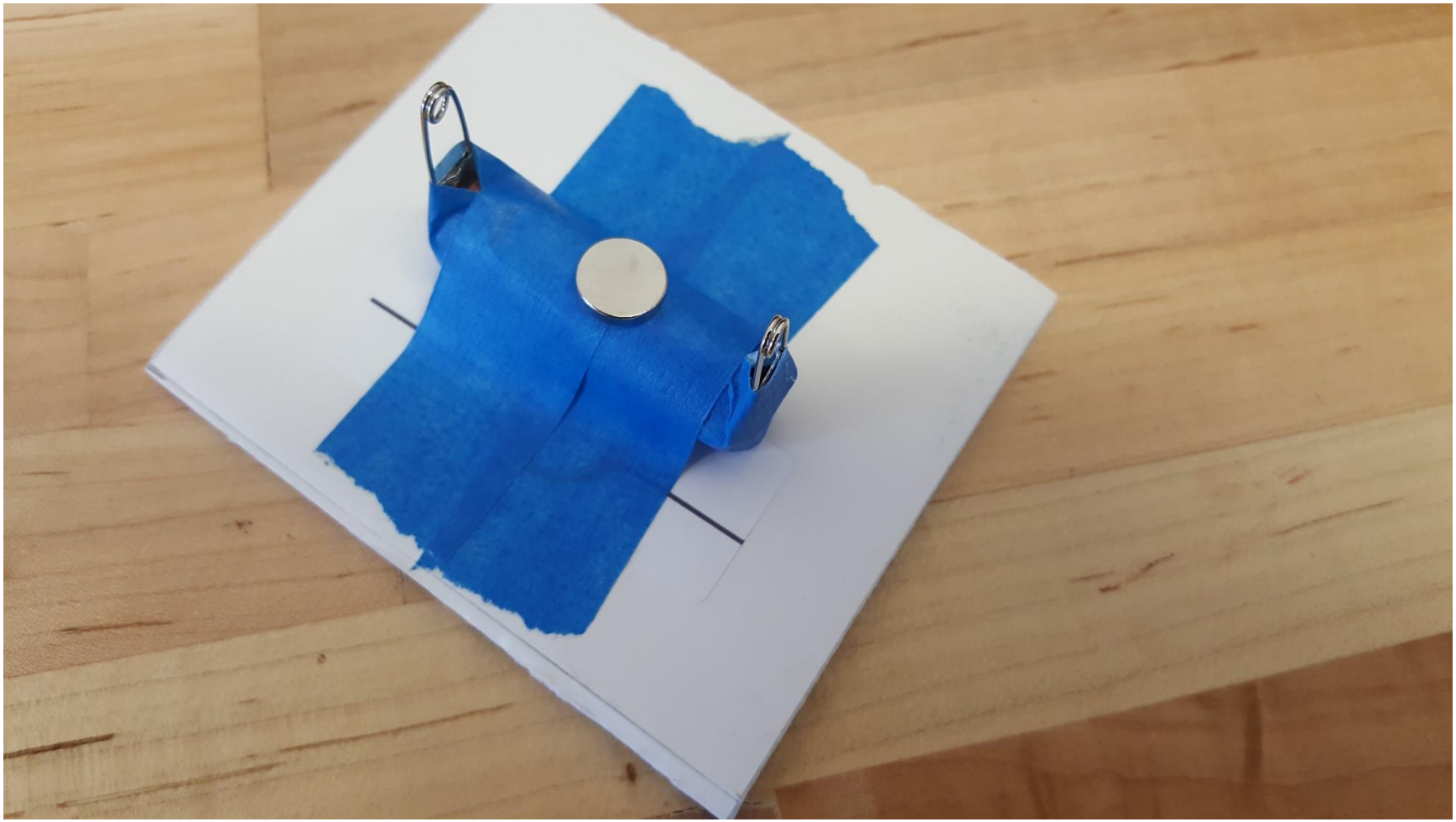
Note Space!



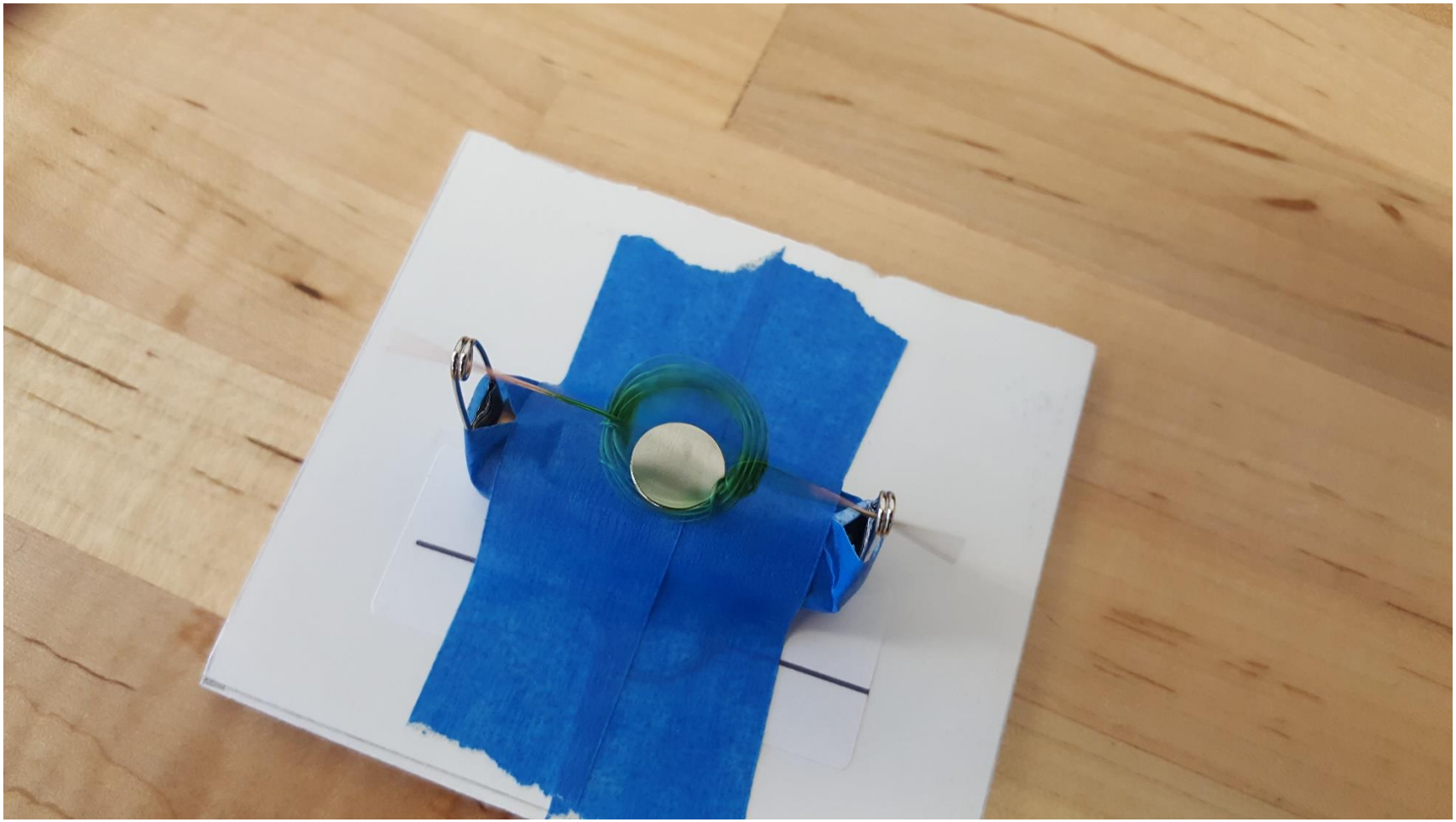
Finish Taping



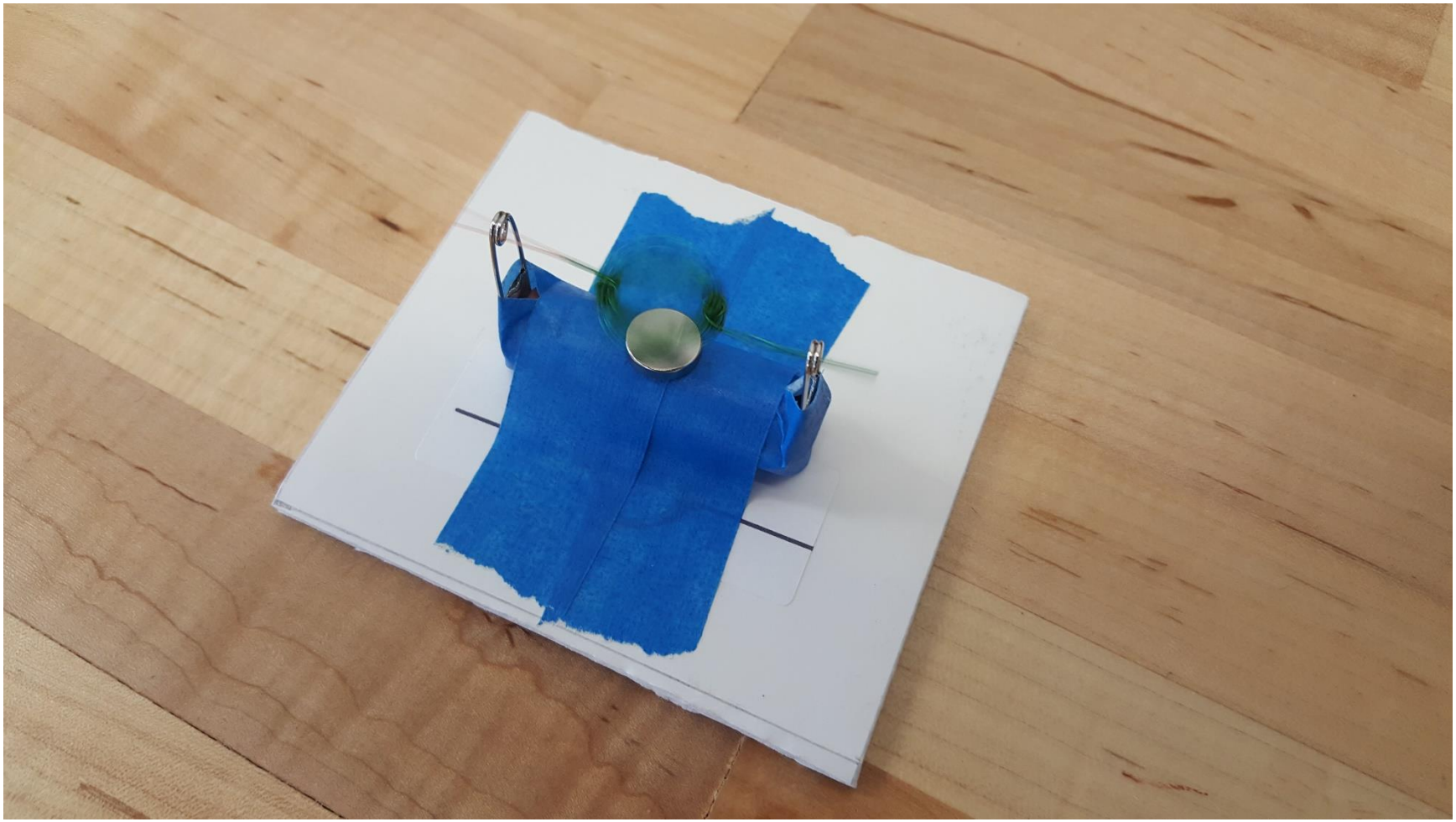
Add Button Magnet



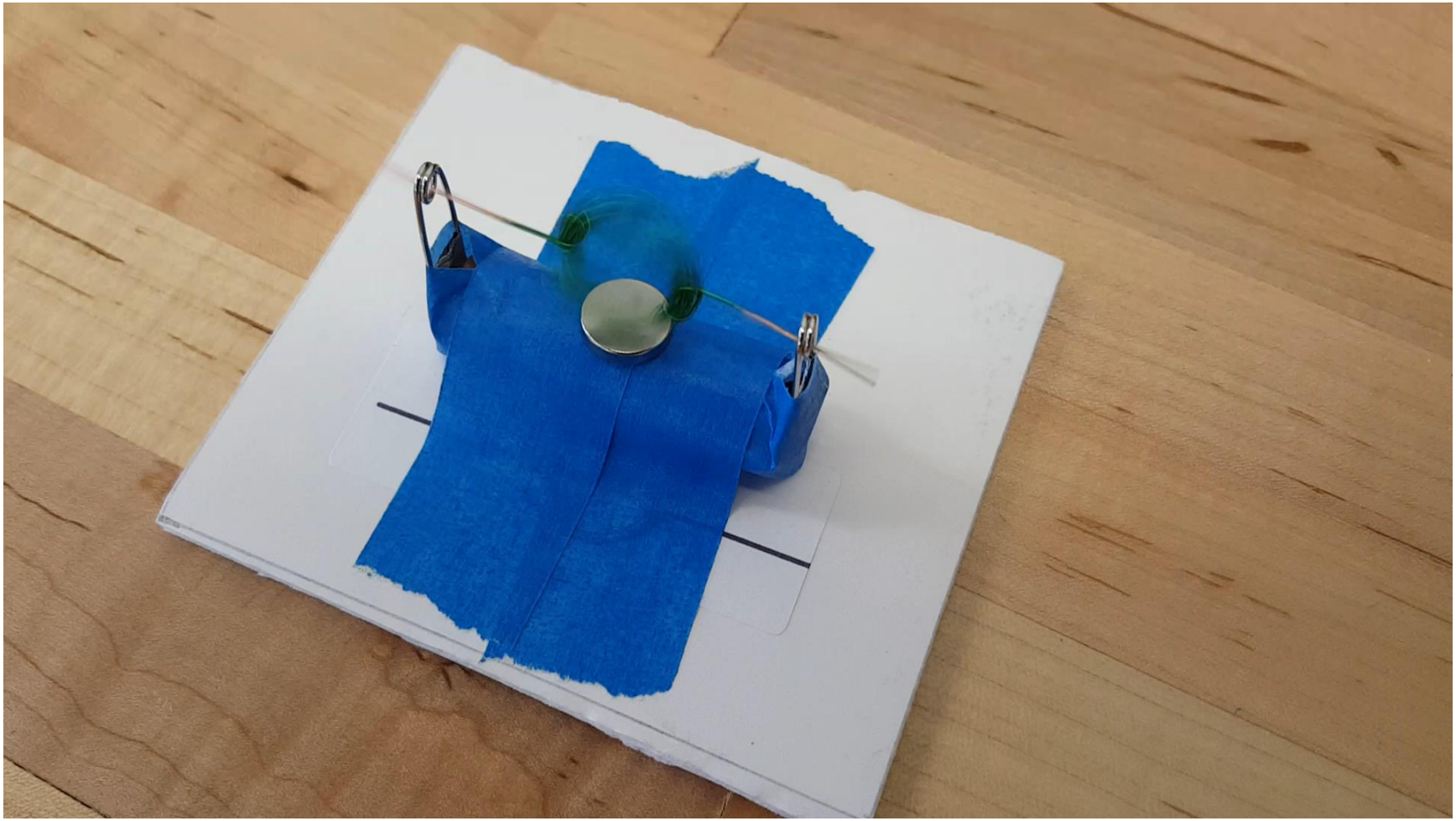
Carefully Put in Coil!



Away We Go!!!



GREAT JOB!!!



Reengineering the Motor

- We have built over 500 motors at these workshops.
- We have learned what works well and what fails in the motor engineering.
- Changes we have made now:
  - Poor contact with battery ends – add aluminum foil strips wrapped around supports.
  - Difficulty with rubber bands – get very short rubber bands that do not have to be doubled.
  - Paperclips hard to bend – change from paperclips to Safety Pins, better connection and openings.
  - Magnet too far away – readjust supports position to be closer.

Tuning Your Motor

Try the following to get your motor running faster:

- Balance the coil: make both axles tight, straight, even.
- Clean the axles (commutators): one side fully, one side ½ only for full length, check again if motor running for a while (oxidation).
- Use Safety Pin OR SMALL end of paperclips to battery.
- Contact battery with “foil” over Safety Pins OR Paperclips: make sure you get good contacts with battery ends, use two rubber bands.
- Try turning magnet over and changing position (top or over to one side), try turning coil around.
- Tuning can help, see ASL staff.
- Keep motor flat on table.

What did we learn today?

- Electricity – what is it?

  The flow of electrons/electric charge

- Circuits – components?

  Source, load, wiring, switch

- Magnetism – what is it?

  Force of attraction/repulsion between materials acting at a distance

- Electromagnetism – properties?

  A magnetic field created around a wire by an electric current flowing through the wire

- Motors – how do they work?

  Rotating force created by an electromagnetic attraction/repulsion switched via a commutator

Careers in STEM

- You must find your passion
- You can have a very rewarding career in science and engineering:
  - Financial, satisfaction, enjoyment
- Need learning and training (education)
- Maybe you will even become an engineer or scientist!

Careers in STEM

Have Fun Today?

Check out our website: www.azsciencelab.org click on the “For Students” tab!

Thanks for coming and exploring with us
the world of electricity, magnetism, and motors!