FLORIDA'S TESLA TALES

CARLOS R. VILLA

DIRECTOR OF K-12 EDUCATION PROGRAMS

NATIONAL HIGH MAGNETIC FIELD LABORATORY

2018 NSTA DISTINGUISHED INFORMAL SCIENCE EDUCATOR

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FAST Annual Conference
Tamps, FL; October 2023

NATIONAL MAGLAB

The National High Magnetic Field Laboratory is supported by National Science Foundation through NSF/DMR-2128556 and the State of Florida.

THIS PRESENTATION IS AVAILABLE TO DOWNLOAD AT:

NATIONALMAGLAB.ORG/EDUCATION/

ABOUT US

NATIONAL MAGNET LAB

- ONE OF 7 HIGH MAGNETIC FIELD LABS IN THE WORLD
- ONLY ONE IN WESTERN HEMISPHERE
- LARGEST AND HIGHEST POWERED IN THE WORLD

National Magnet Lab

- User laboratory
  - Over 2,096 user visits (2019)
  - NSF & State of Florida funded
    - $58 Million Budget
  - Research free to scientist:
    - Must share research

NATIONAL MAGNET LAB

- RESEARCH IN MANY FIELDS (NOT JUST MAGNETS)
- MATERIALS – ENERGY – LIFE
  - INCLUDES MATERIALS SCIENCE, PHYSICS, ENGINEERING, CHEMISTRY, BIOLOGY, BIOMEDICAL, GEOCHEMISTRY, ETC…

CENTER FOR INTEGRATING RESEARCH & LEARNING

- MENTORING & RESEARCH
- FIELD TRIPS & TOURS
- SUMMER CAMPS

SciGirls wfsu PUBLIC MEDIA NATIONAL MAGLAB

NATIONAL MAGLAB CAMP TESLA Technology, Engineering, & Science in a Lab Atmosphere

- PROFESSIONAL DEVELOPMENT
- WORKSHOPS AND CONFERENCES
- RET PROGRAMS (MORE ON THAT LATER…)

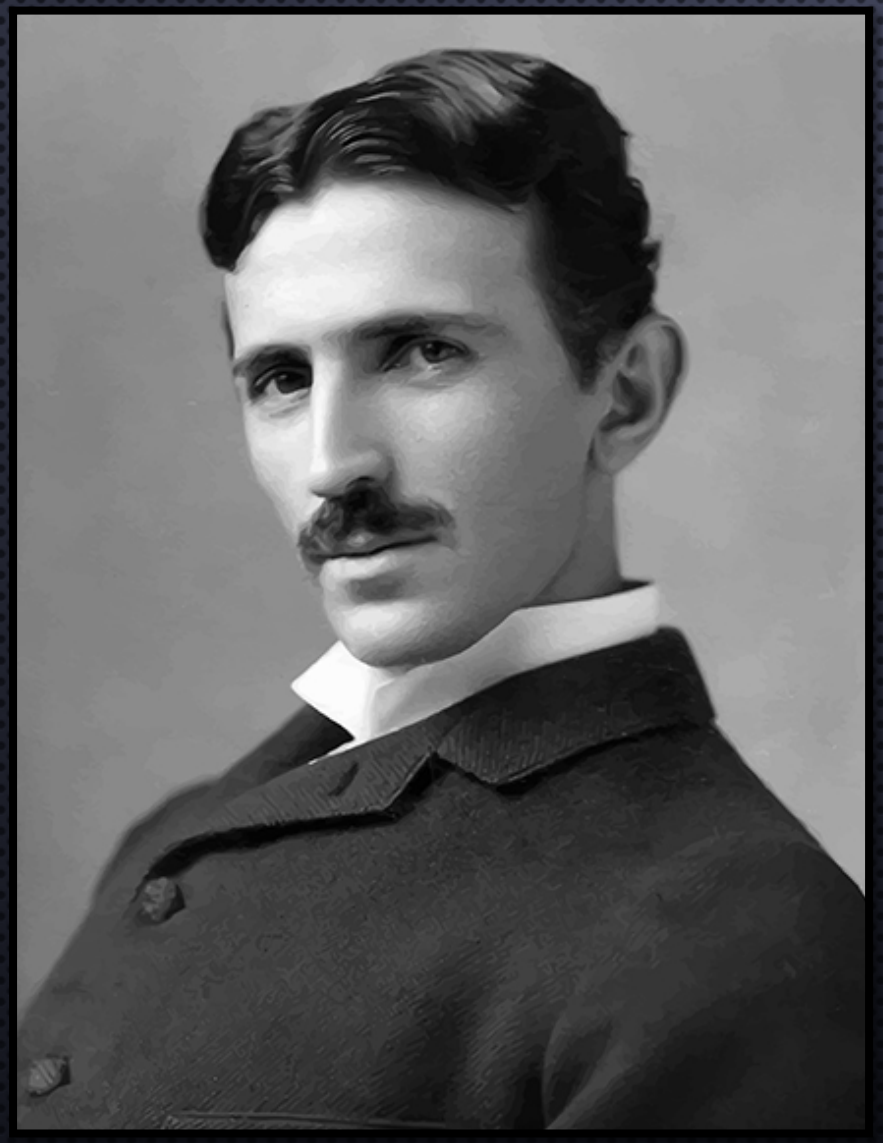
NATIONAL HIGH MAGNETIC FIELD LABORATORY

The National MagLab is taxpayer-funded by
the **National Science Foundation**
and the **State of Florida** making
you a stakeholder in this facility.

So, on behalf of all of us, thank you for supporting our science.

ABOUT MAGNETS

TESLA



- Tesla
  - Measurement of magnetic fields
- Named for Serbian Scientist Nikola Tesla

MAGNETIC FIELDS AROUND US (IN TESLA)

Refrigerator magnet:	.03 T
Earth's magnetic field:	.000045 T
Person's magnetic field:	3×10^{-13} T
Junkyard magnet:	1 T
Magnetic Resonance Imaging (MRI) magnet:	1.5 – 2 T

MAGNETIC FIELDS AT THE MAGLAB (IN TESLA)

WORLD RECORDS IN BLUE

McKnight Brain Institute MRI	3 T (60 mm)
Ion Cyclotron Resonance magnet (ICR)	**21 T**
900 Mhz Nuclear Magnetic Resonance (NMR)	21 T (100 mm)
Typical resistive magnet (ResMag)	24-31 T
Split cell ResMag	**25 T**
Water Cooled ResMag	**41 T**
Hybrid magnet (33 MW)	**45.2 T**
Series Connected Hybrid (14 MW)	35 T
NHMFL Pulse Magnet (Los Alamos)	**100.7 T**

THE HISTORY OF MAGNETS

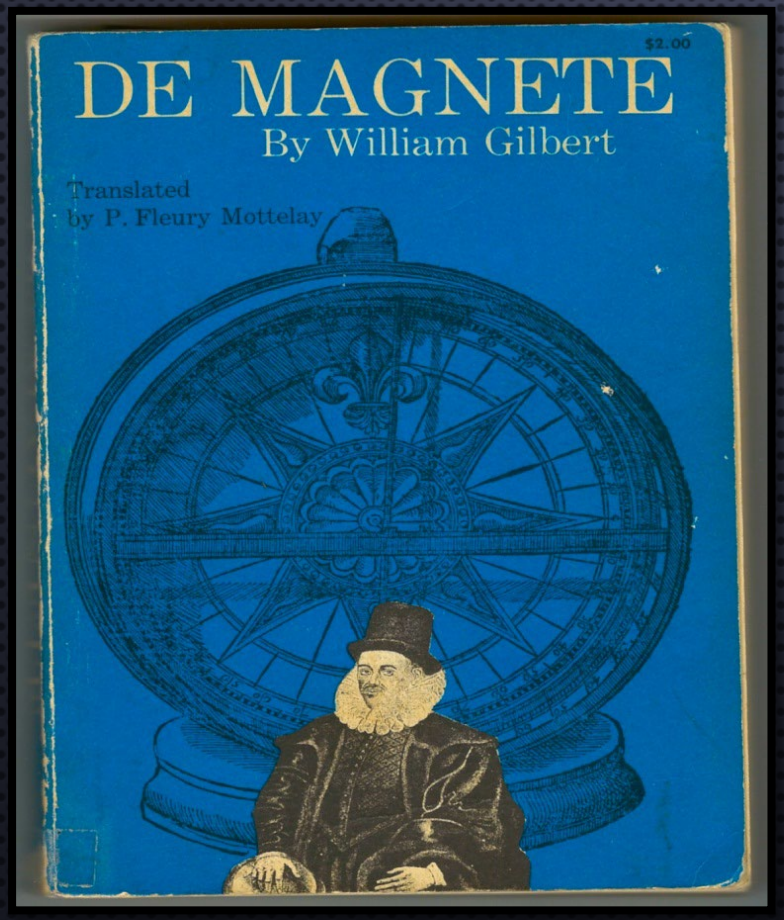
First Magnet Discoveries

- In Greece, 2000 BC
  - Magnes the shepherd
- In China, 400 BC
  - Feng shui
  - The south pointer
- In Rome, 50 AD
  - Pliny the Elder
  - Naturalist and researcher
  - "Magic" with healing properties

1269: PETRUS PEREGRINUS DE MARICOURT

- Epistola de magnete
  - Part 1 discusses the physical (not occult) properties of magnets
    - Magnetic fields can act at a distance
    - Magnets can only act on other magnetic materials
    - Opposite poles attract and like poles repel
    - When suspended, north poles point North and south poles point South.
- Part 2 discusses the use of magnets in devices
  - Wet and dry compass

1600: William Gilbert



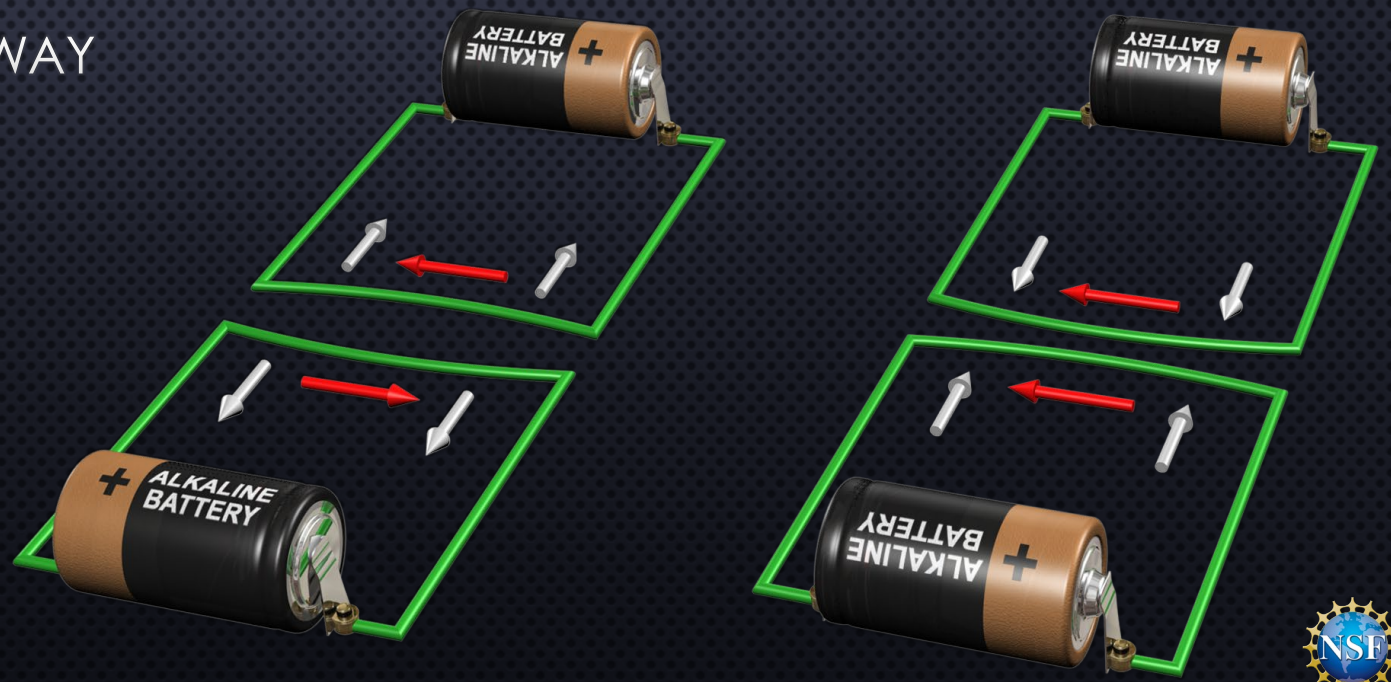
- Published De Magnete
  - Earth is a magnet
- First critical research on magnets
  - Used lodestone
  - Dispelled superstitions and myths

1820: Hans Christian Ørsted

- An electrical current can create a magnetic field
- Oersted set up lecture demonstration
  - Used battery to supply current
  - Showed compass needle deflecting near the wire

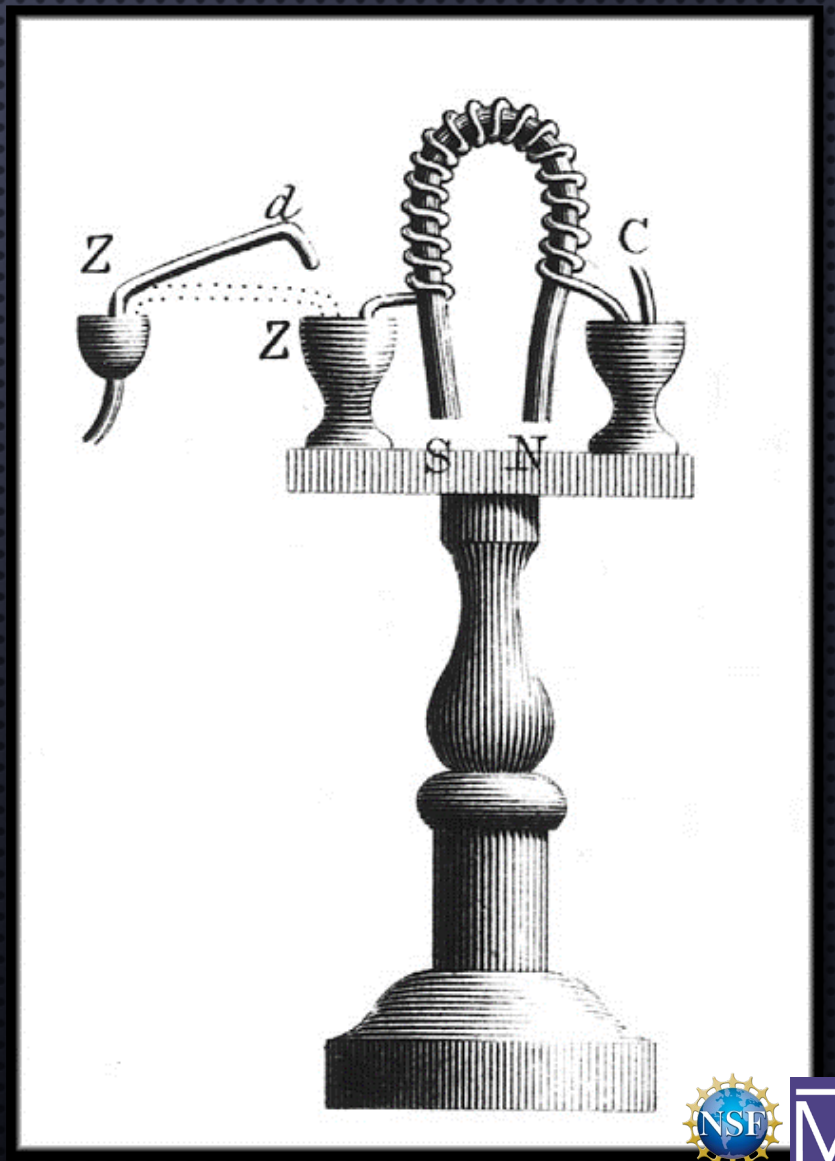
1820: André-Marie Ampère

- Moving electrical charges produce magnetic fields
- Simple experiment
  - Two straight wires with current passed through
  - Wires bowed toward or away
- Led to electromagnets



1824: William Sturgeon

- First electromagnet
  - Curved iron rod
  - Bare copper wire
  - Electricity
  - 18 total turns of wire
- Lifted 9 pounds
  - Magnet weighed 7 ounces

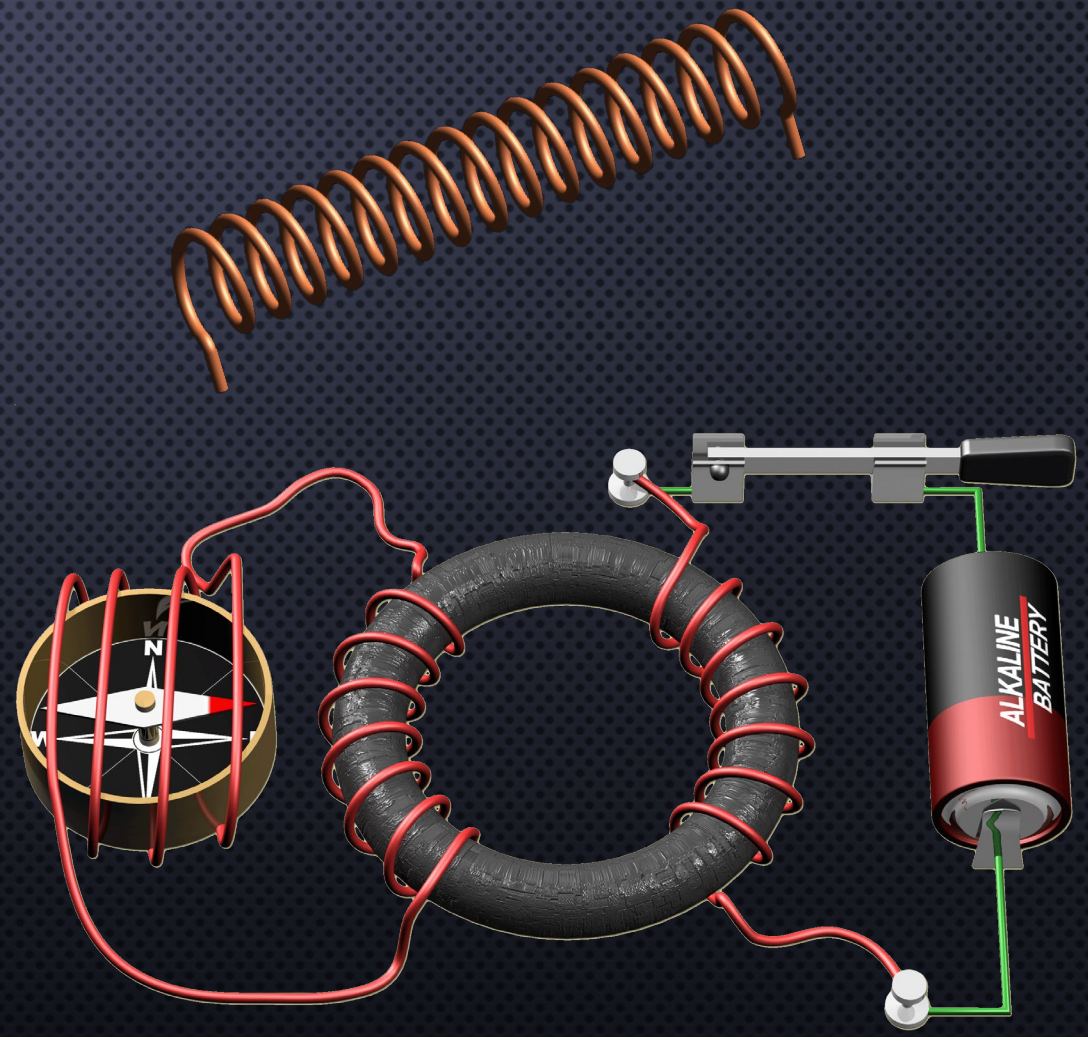


1827: Joseph Henry

- Improved the electromagnet
  - Larger iron rod
  - Copper wire
    - Insulated with silk
  - Electricity
- An electromagnet using two electrodes attached to a battery, best to wind coils of wire in parallel
- But an electromagnet using with multiple batteries, should use only one single coil

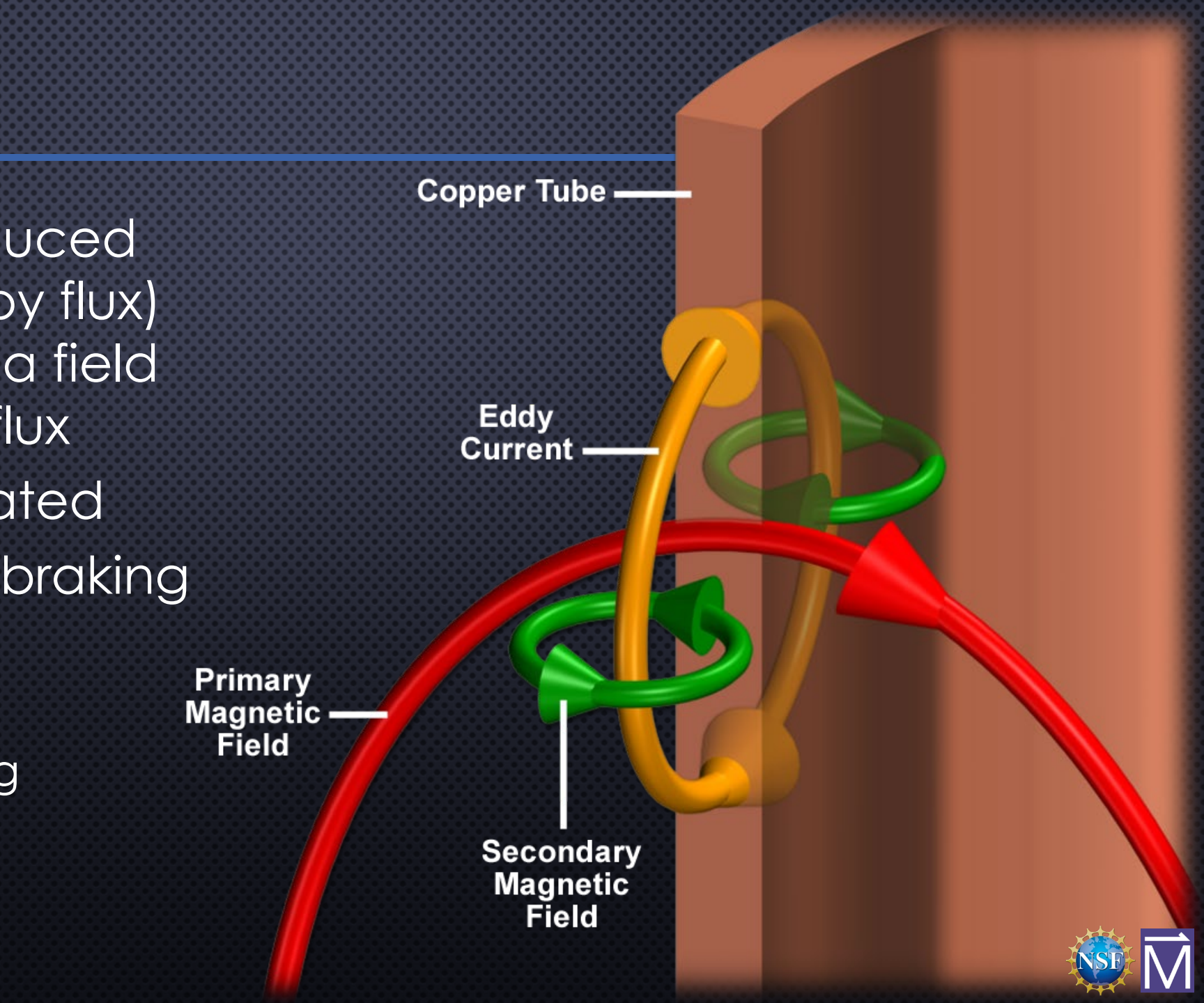
1831: Michael Faraday

- Wrapped wires around opposite sides of an iron ring
  - Change in magnetic field produces an electric current
  - Induction
- Magnetic Flux: The change needed to induce current
  - Move a magnet in and out of a coil of wires
- Originally rejected: Not formulated mathematically
  - James Clerk Maxwell (1862): Maxwell-Faraday equation

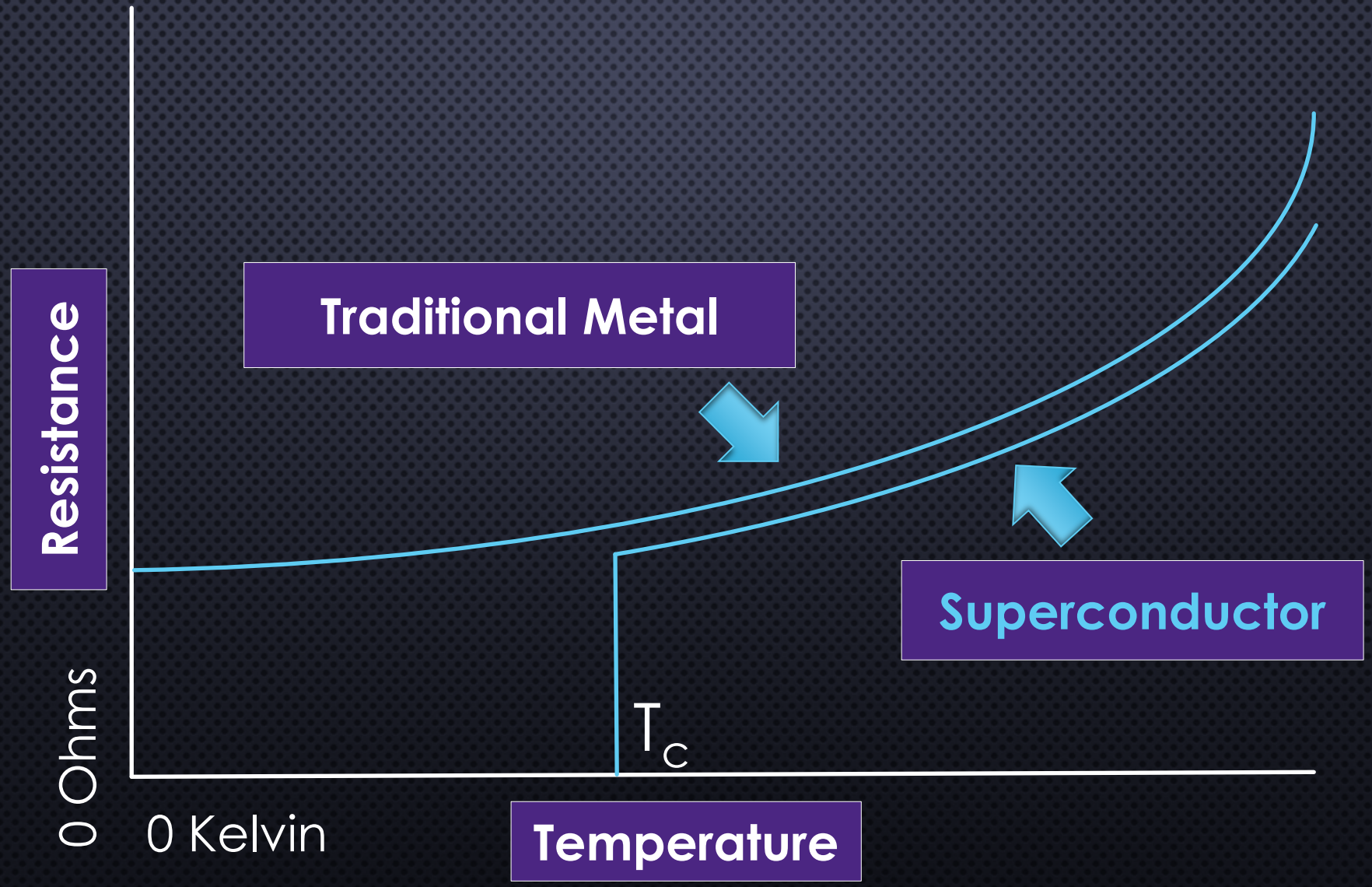


1834: EMIL LENZ

- Lenz's Law: An induced current in a wire (by flux) will flow to create a field that opposes the flux
- Eddy currents created
- Used in magnetic braking systems
  - Rollercoasters
  - Electric car braking feedback

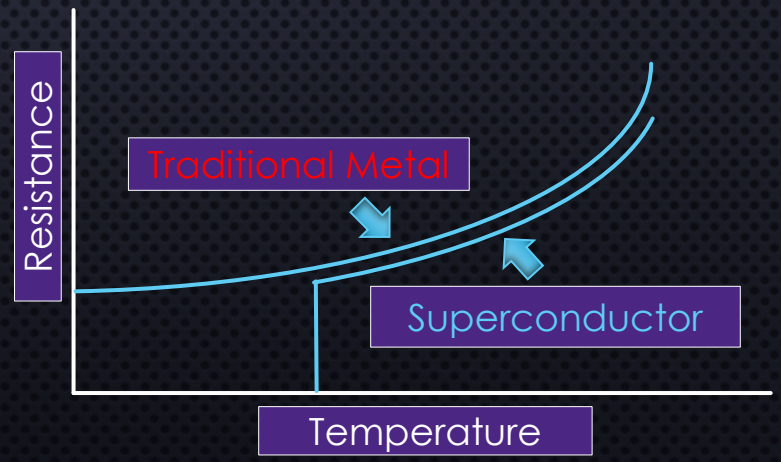


1900: SUPERCONDUCTIVITY



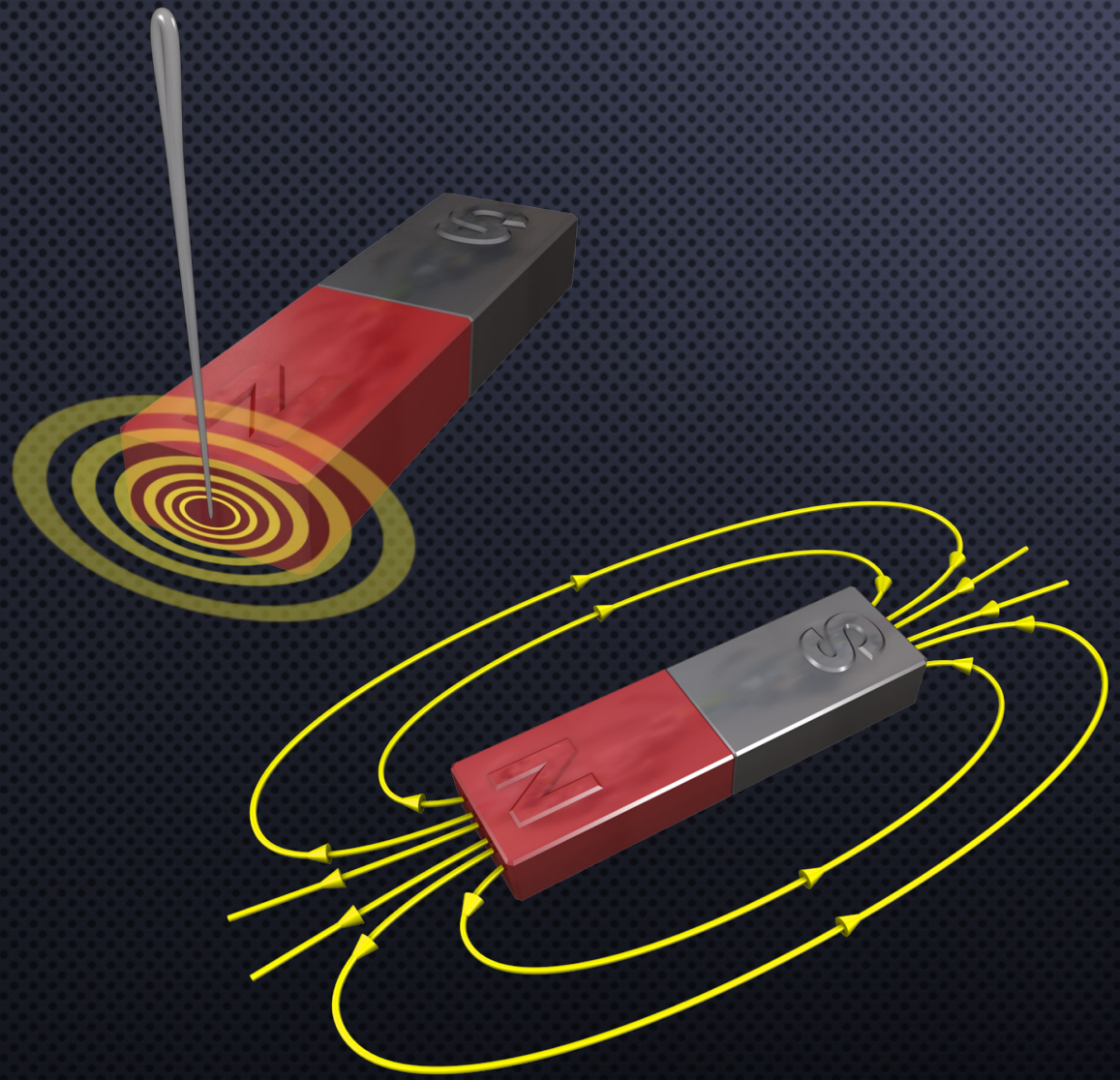
1957: BCS THEORY

- BCS: BARDEEN, COOPER, SCHREIFFER
- AT LOW TEMPERATURES, SOME METALS LOSE RESISTANCE
  - ATOMS NEARLY STATIONARY
- SUPERCONDUCTIVITY RESULTS FROM THE FORMATION OF COOPER PAIRS
  - TWO ELECTRONS PARTNERED
  - ONE FOLLOWS THE OTHER
- RESULTS IN FRICTIONLESS FLOW OF ELECTRONS



THE SCIENCE OF MAGNETISM

MAGNETS & MAGNETIC FIELDS

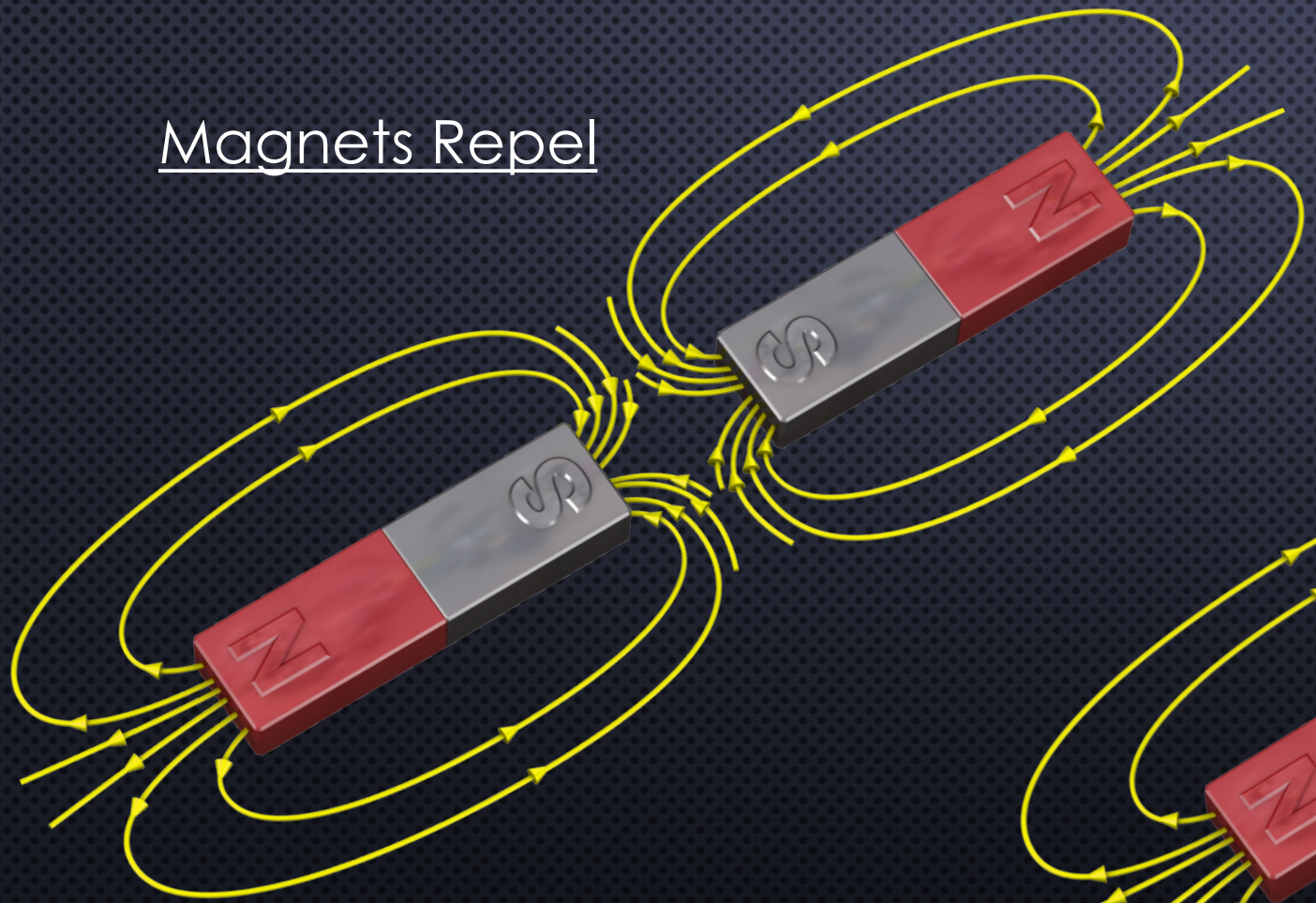


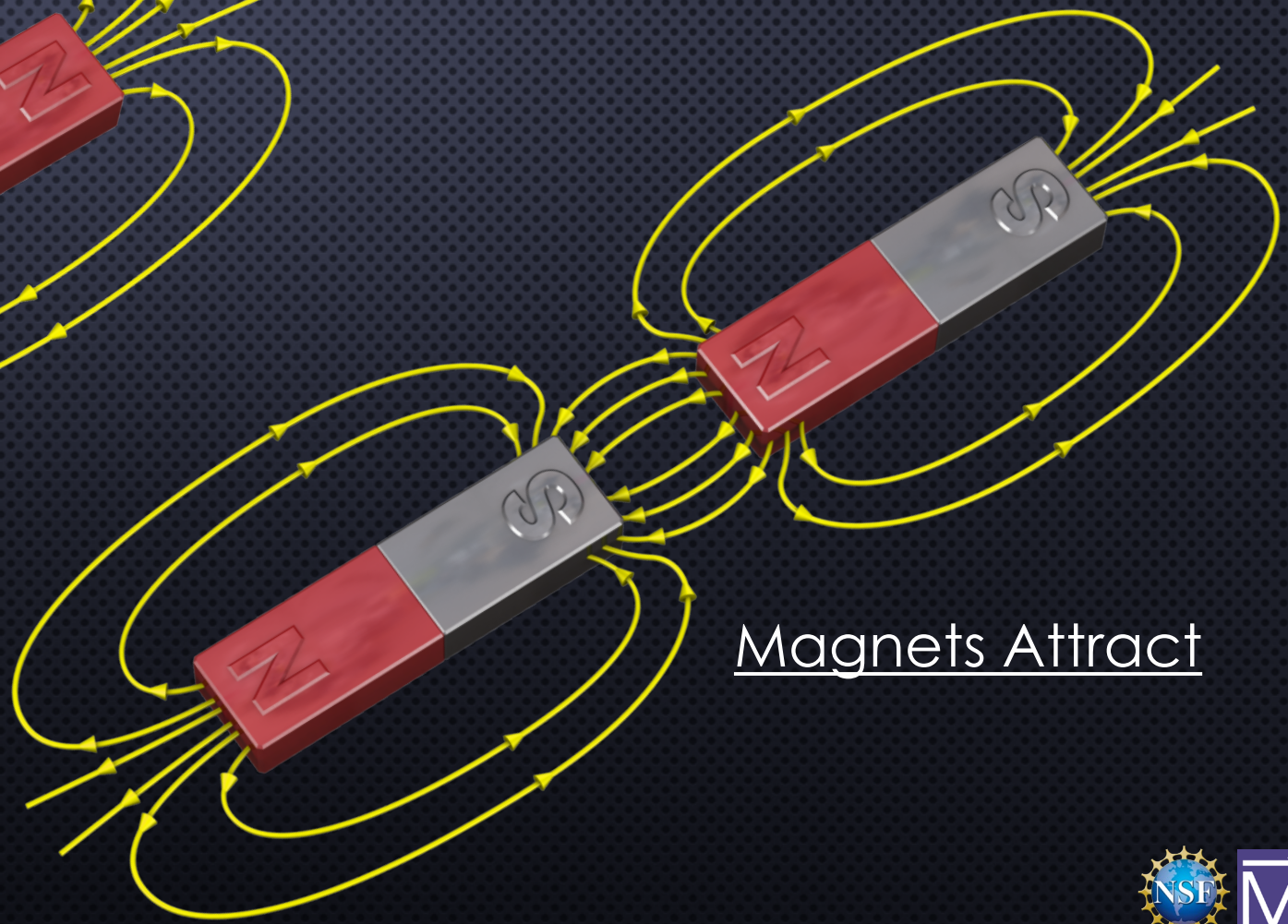
- All magnets have poles
  - North & South
  - Opposites attract; Like repels
- But not really: Magnetic monopole
  - Ongoing research

- All magnets have magnetic fields
- Magnetic field is a vector field
  - Has direction and magnitude

MAGNETS & MAGNETIC FIELDS

Magnets Repel





Magnets Attract

Magnets & Magnetic Fields

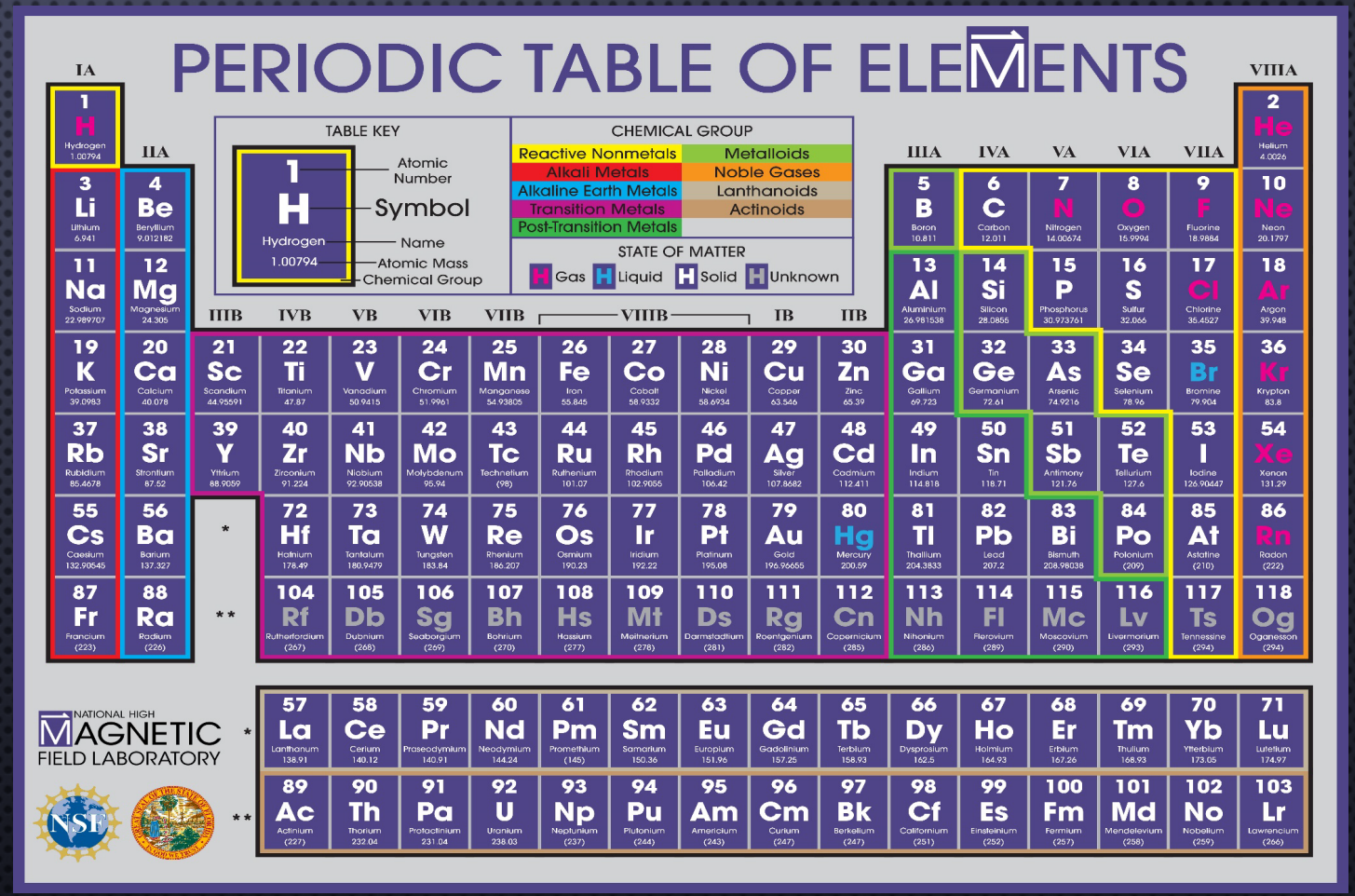
- Magnetic fields invisible to humans
- Many animals can sense magnetism
  - Sea turtles
  - Migratory birds
  - Sharks

MAGNETS & MAGNETIC FIELDS

- Rare animals can see magnetism
  - Robins
    - Only in bright settings
    - Right eye and the left half of brain
  - Family Canidae
    - Wolves, foxes, coyotes, dogs

MAGNETS & MAGNETIC FIELDS

- 3 METALS ARE NATURALLY MAGNETIC AT ROOM TEMPERATURE
  - IRON, NICKEL, COBALT
- TWO MORE ARE MAGNETIC AT LOWER TEMPERATURES
  - GADOLINIUM (65 F AND BELOW), DYSPROSIUM (-301 F AND BELOW)
- ONE MORE MAGNETIC AT ABNORMAL CONDITIONS
  - RUTHENIUM (IN UNNATURAL FORM)
- MANY ARE MAGNETIC AS ALLOYS
  - RARE-EARTH ELEMENTS



DO YOU LIKE MOVIES?

MAGNETS & MAGNETIC FIELDS

~~MONSTERS, INC.~~

MAGNETS, INC.

INC. = IRON, NICKEL, COBALT

Magnets & Magnetic Fields

- Magnetite
  - Iron rich mineral
  - Lodestone is magnetized piece of magnetite
  - led to first compass

MAGNETS & MAGNETIC FIELDS

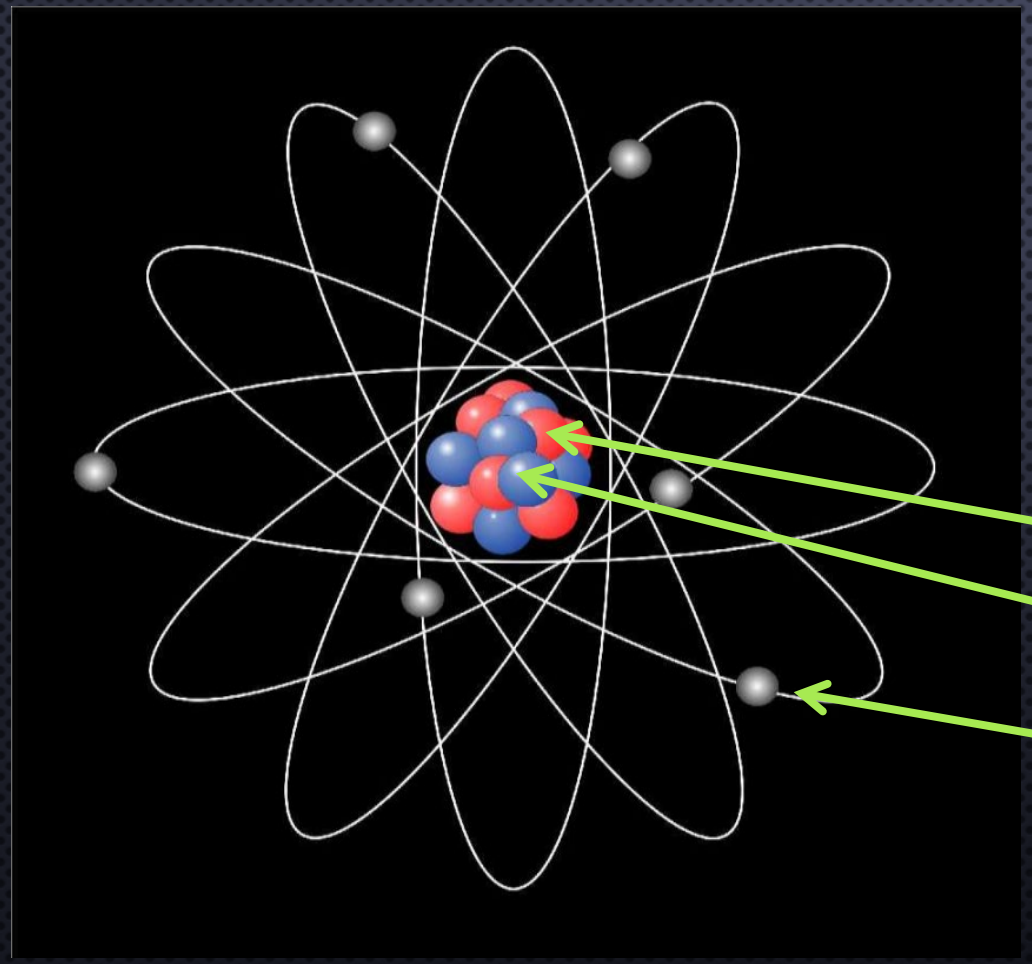
PERMANENT MAGNETS

- ALMOST ALWAYS KEEP THEIR FIELD
- FIELDS CAN BE LOST
  - CURIE POINT (HEAT)
  - ELECTRIC CURRENT (DEGAUSS)
  - HITTING IT (BLUNT FORCE)

TEMPORARY MAGNETS

- WILL KEEP MAGNETIC FIELD UNTIL TAMPERED WITH
- EXAMPLES: PAPERCLIPS, SCISSORS, STAPLES, THUMB TACKS, PINS, SCREWDRIVERS, REFRIGERATOR DOOR, CAR DOORS, ETC…
- ANYTHING THAT IS MAGNETIC, BUT WILL NOT KEEP ITS FIELD

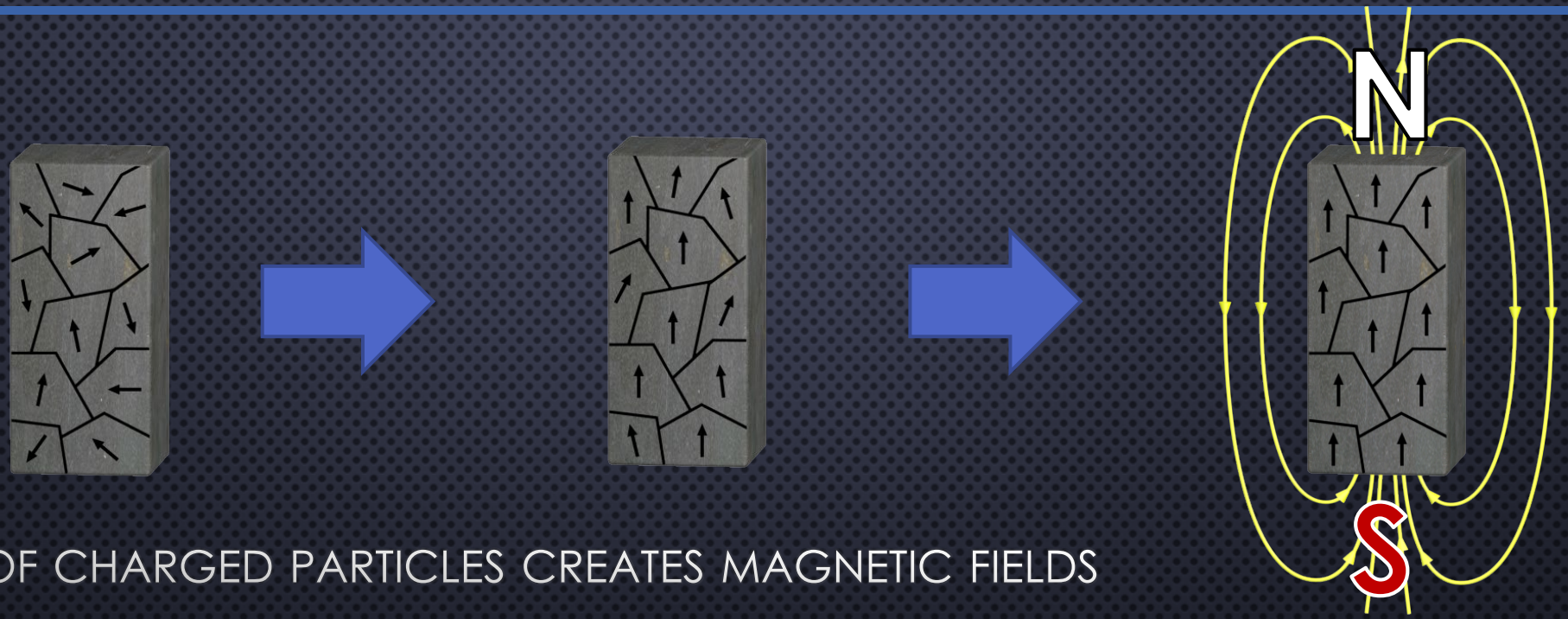
MAGNETS & MAGNETIC FIELDS



- Name atom comes from *Atomos,* Greek for Indestructible
  - But not really
- The atom is divisible

MAGNETS & MAGNETIC FIELDS

MAGNETS & MAGNETIC FIELDS



- MOTION OF CHARGED PARTICLES CREATES MAGNETIC FIELDS
- IN MOST ATOMS, DISORGANIZED SPINS CANCEL OUT
  - MAGNETIC DOMAINS: WHEN ELECTRONS LINE UP
- MAGNETIC FIELD IS PRODUCED WHEN ALL ELECTRONS SPIN THE SAME DIRECTION:
  - MORE ELECTRONS LINED UP: MORE MAGNETISM

THE SCIENCE OF ELECTROMAGNETISM

Electromagnetism

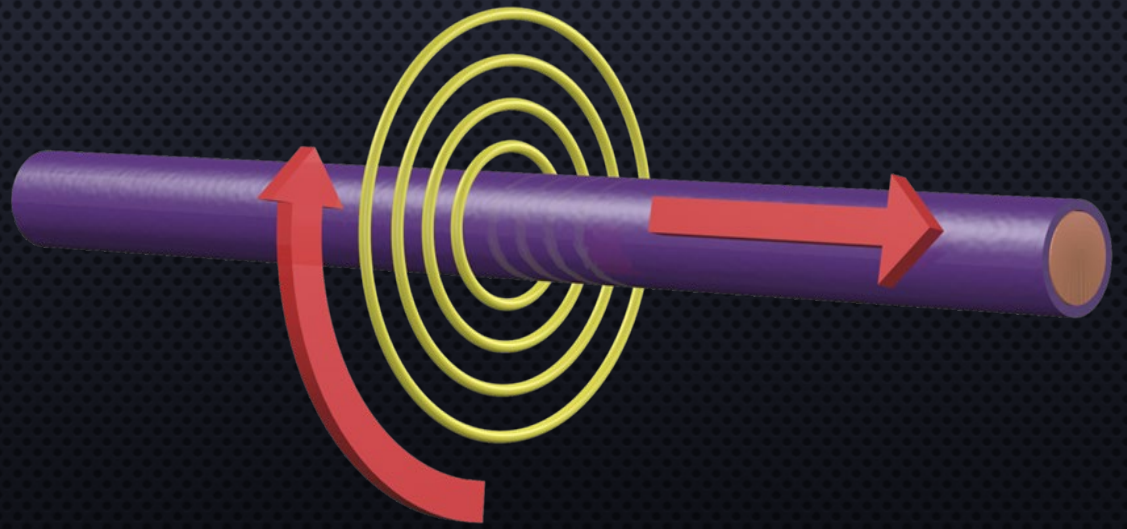
- Electrons Make Magnetism Work
  - Spin of Electrons
- Electrons Make Electricity Work
  - Movement of electrons

Electromagnetism

- The two are so closely related
- Where there is electricity, there is a magnetic field
  - When electrons flow, they line up (Ørsted)
- Where there is a magnetic field, electricity can be created (Faraday)
  - Magnetic flux can create movement of electrons

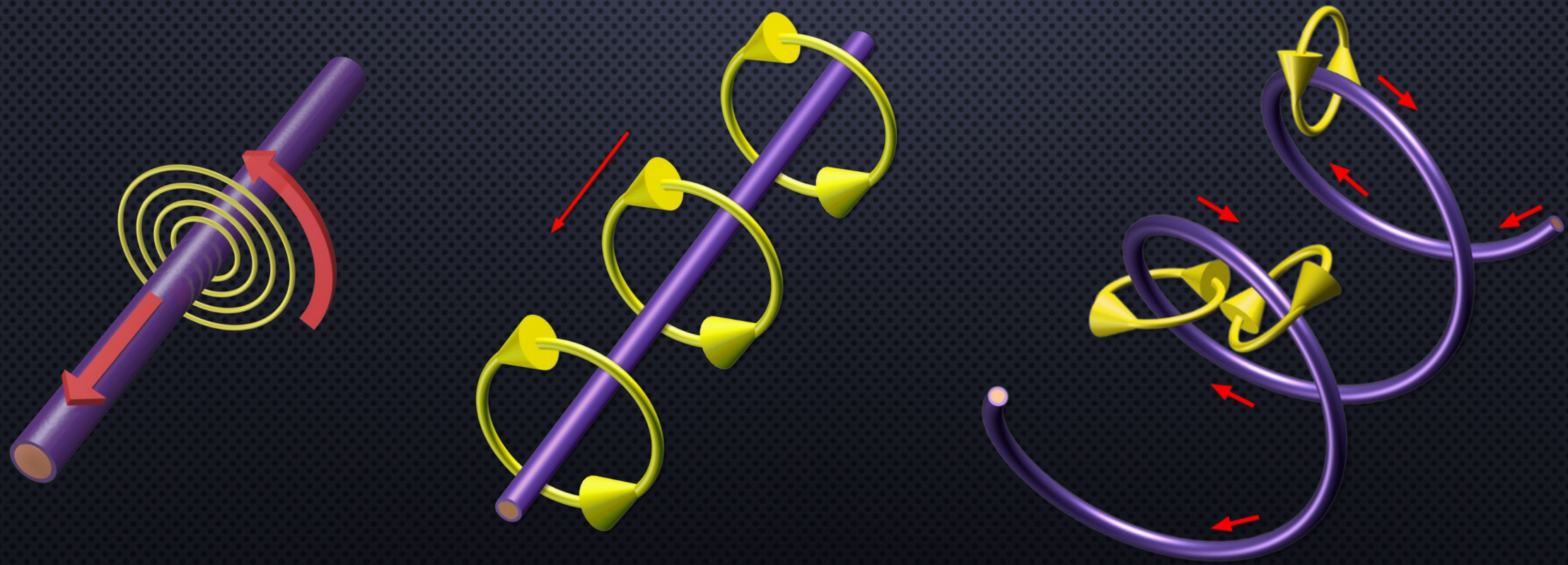
ELECTROMAGNETISM

- ELECTRICITY IS THE FLOW OF ELECTRONS
  - ELECTRONS FLOW IN SAME DIRECTION
- THIS ALIGNMENT OF ELECTRONS CREATES A MAGNETIC FIELD AROUND THE CONDUCTOR
  - SIMILAR TO ELECTRONS LINING UP IN A PERMANENT MAGNET
  - SO *EVERY* WIRE CARRYING ELECTRICITY HAS A WEAK MAGNETIC FIELD AROUND IT



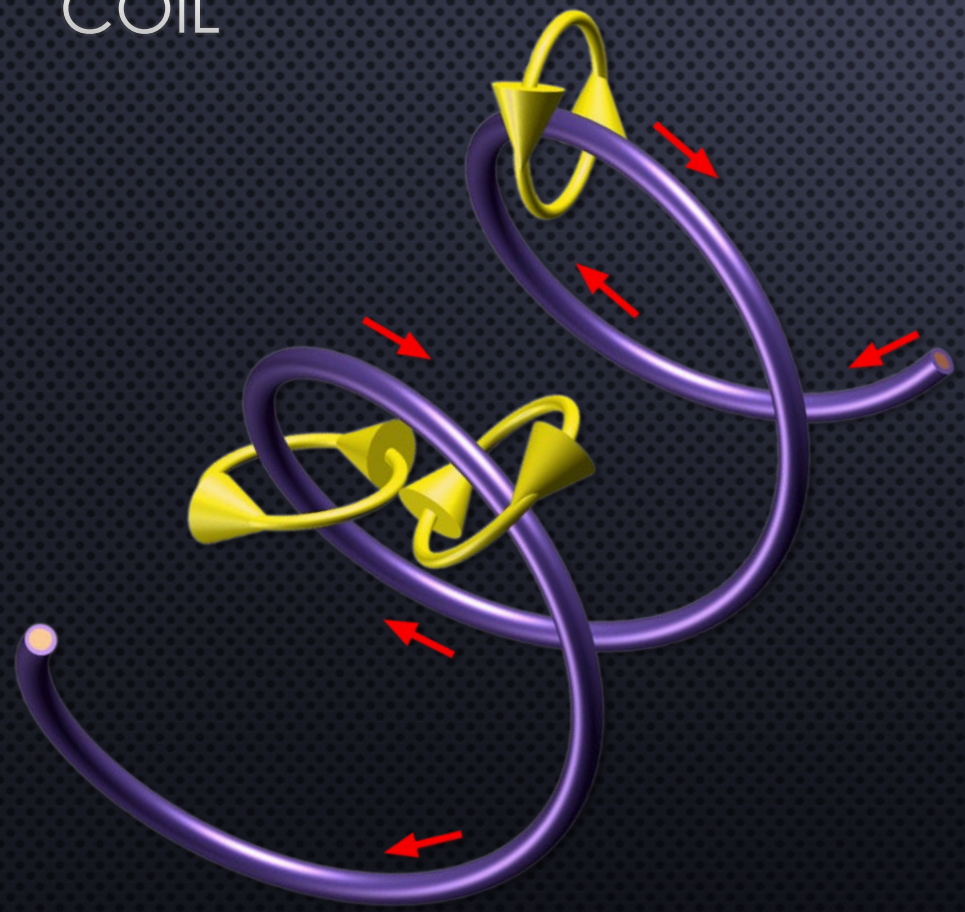
ELECTROMAGNETISM

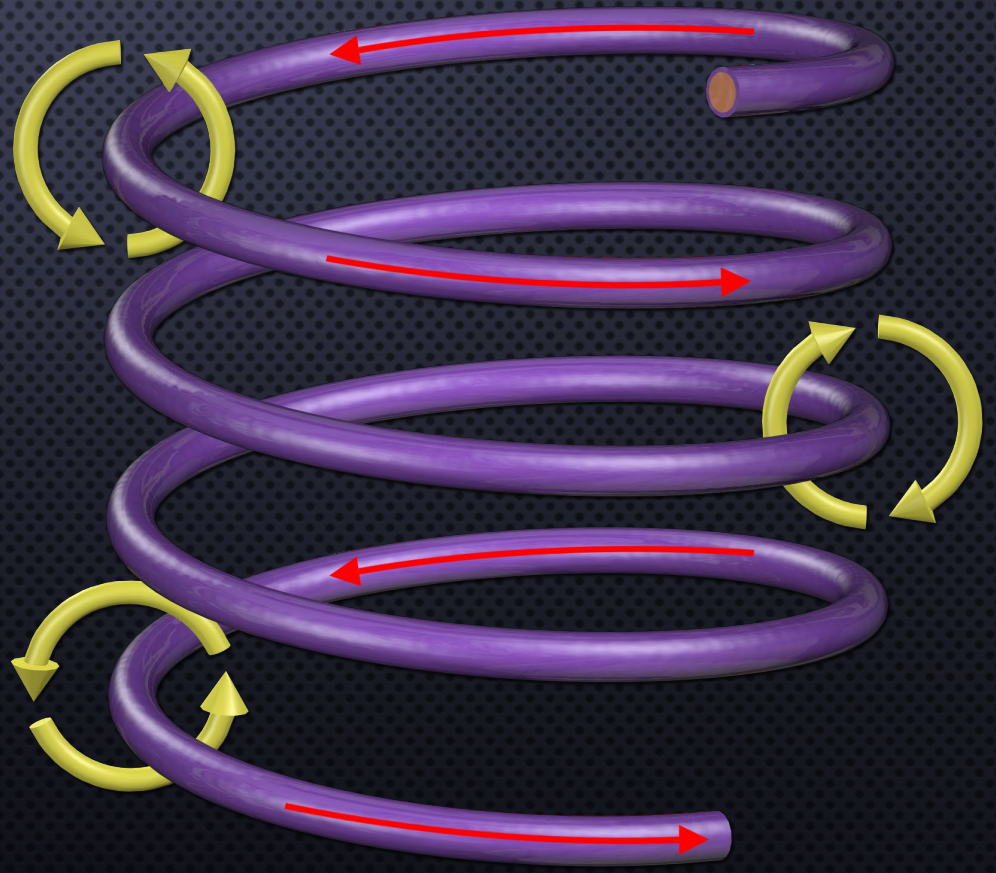
- THE FIELD EXISTS AT ALL POINTS ALONG THE WIRE
- COILING THE WIRE CONCENTRATES THE MAGNETIC FIELD INSIDE THE COIL



ELECTROMAGNETISM

- COILING THE WIRE CONCENTRATES THE MAGNETIC FIELD INSIDE THE COIL





ELECTROMAGNETISM

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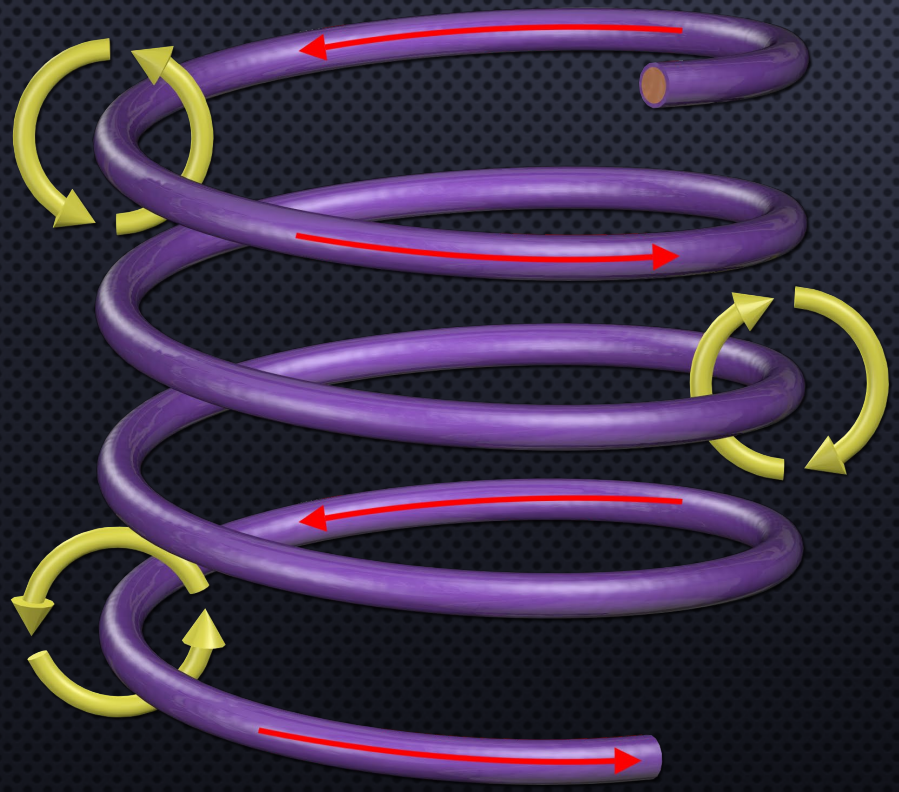
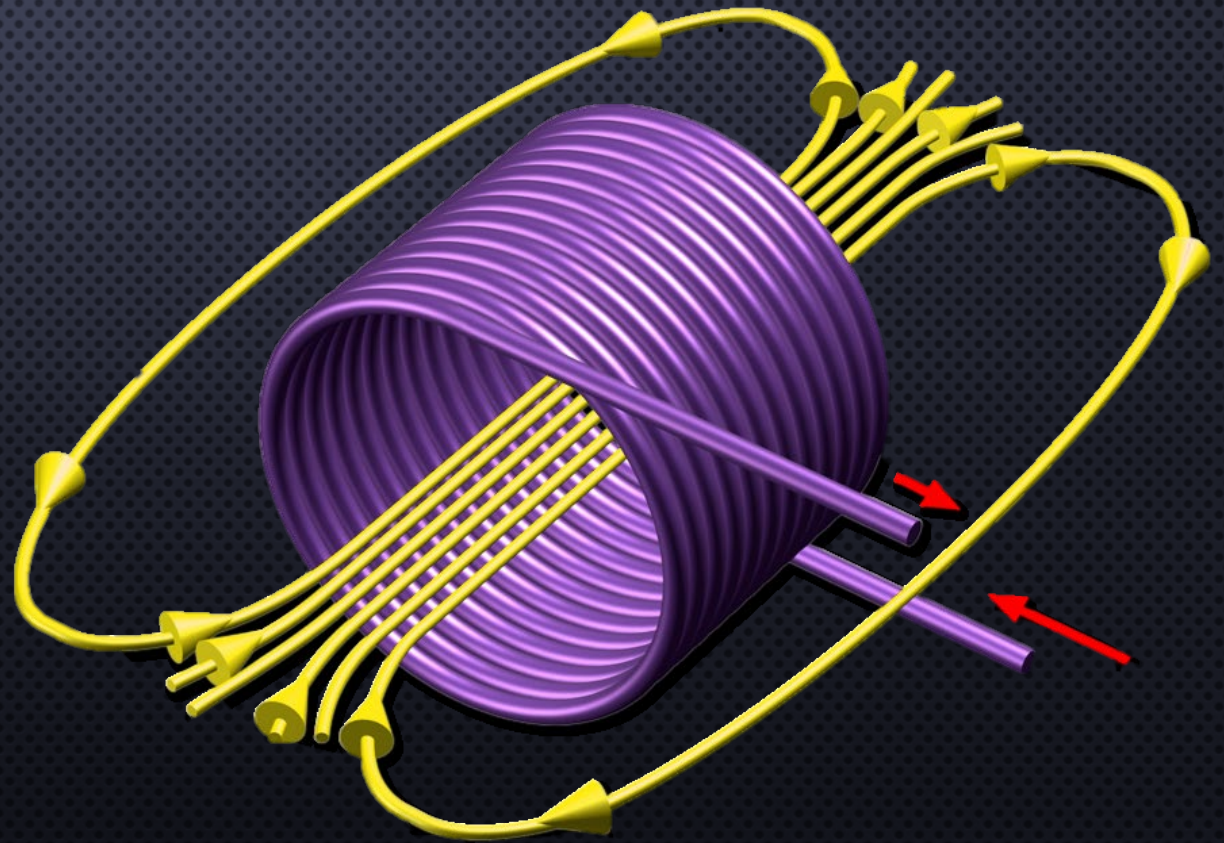
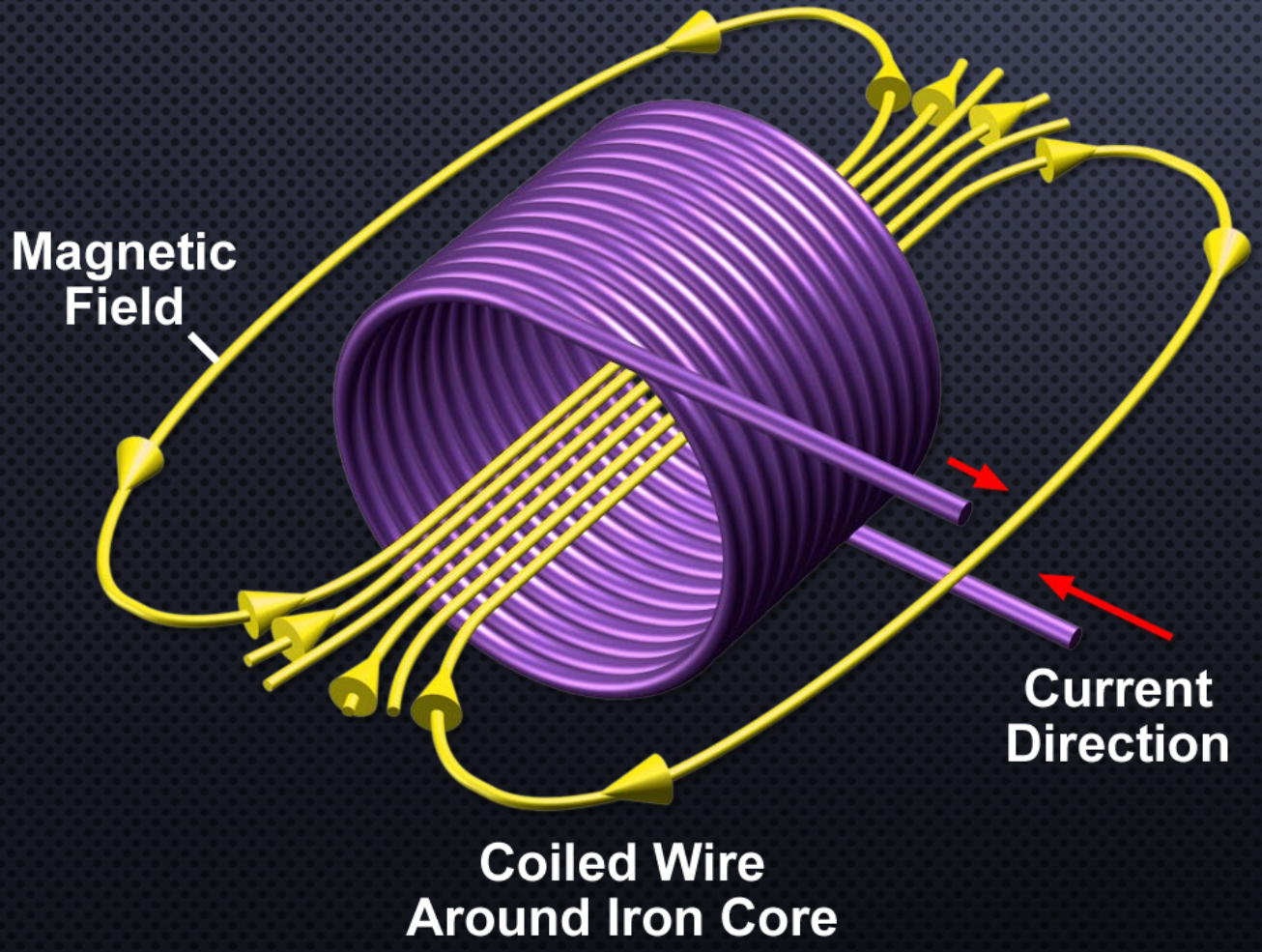




ELECTROMAGNETISM

- THE MAGNETIC FIELD IS STRONGEST INSIDE THE COIL



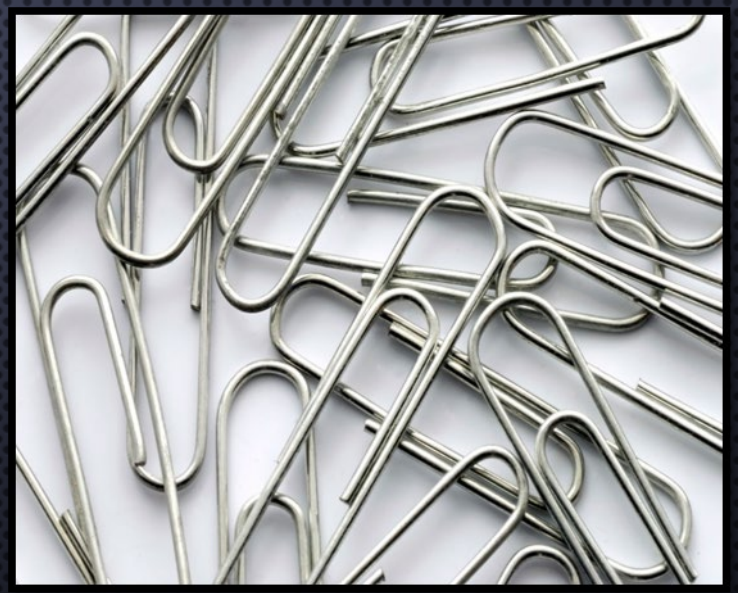
ELECTROMAGNETISM ACTIVITIES FOR YOUR CLASSROOM

Magnetism in Money

- Money is magnetic
  - Coins are copper-nickel alloy (not magnetic)
  - Pennies are copper-plated zinc (also not magnetic)
  - Dollars are printed with iron-rich ink (magnetic!)
- Foreign Coins
  - Canadian, British, Brazilian, Mexican (some)…

Permanent & Temporary Magnets

- No rubbing necessary
  - Magnetism happens almost instantly
- They are magnets
  - North and South
  - Attract and Repel
- Paper Clips remain magnetic
  - Until something tampers with their field
  - Field could last years



UNIVERSAL MAGNETISM

- HOLD A STRONG MAGNET OVER BEACH SAND
- IRON WILL ATTRACT TO THE MAGNET
  - EXCESS SAND WILL CLING TO THE MAGNET
  - PURIFY BY SPREADING IT ON A SHEET OF PAPER AND PASSING THE MAGNET OVER IT

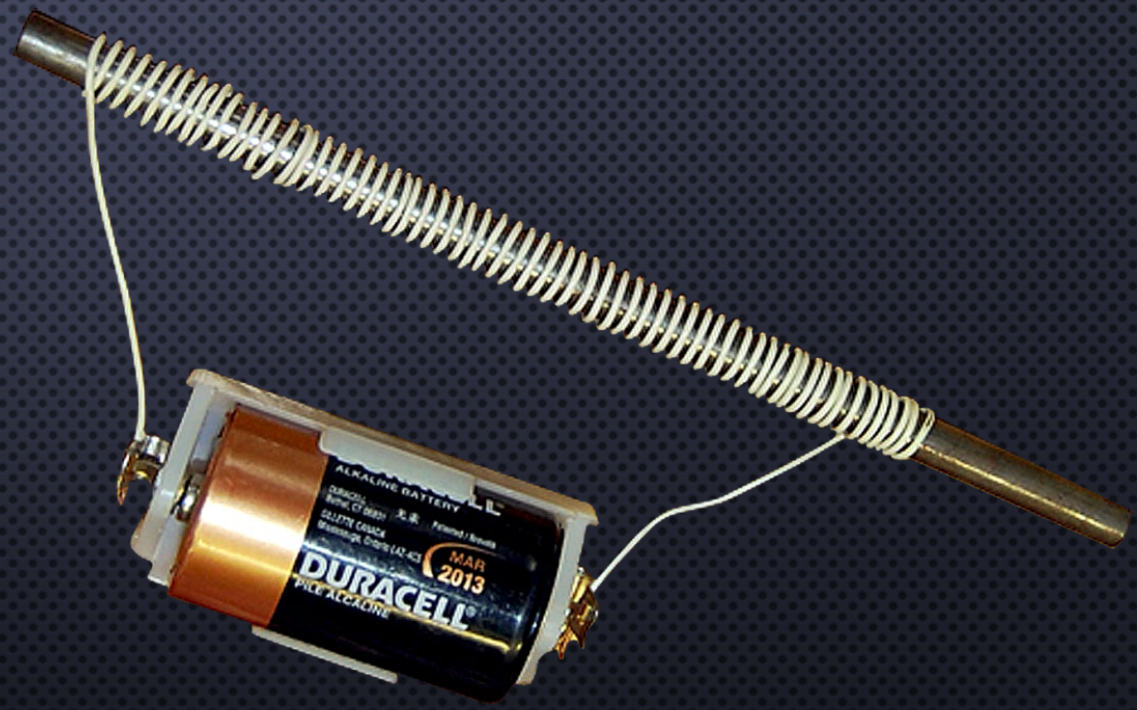
- METEORS ARE HIGH IN IRON CONTENT
- BURN UP IN ATMOSPHERE
- WAVES WASH THEM ASHORE

MUSICAL MAGNETS

- MAGNETS ARE MAGNETIZED SHORT LENGTH
- MADE OF STRONG BARIUM FERRITE
- THEY ATTRACT BUT BOUNCE UPON IMPACT AND SEPARATE
- PROCESS REPEATS WITH A LITTLE ENERGY LOST EACH TIME
- PITCH CHANGES
  - FREQUENCY INCREASES
  - AMPLITUDE DECREASES

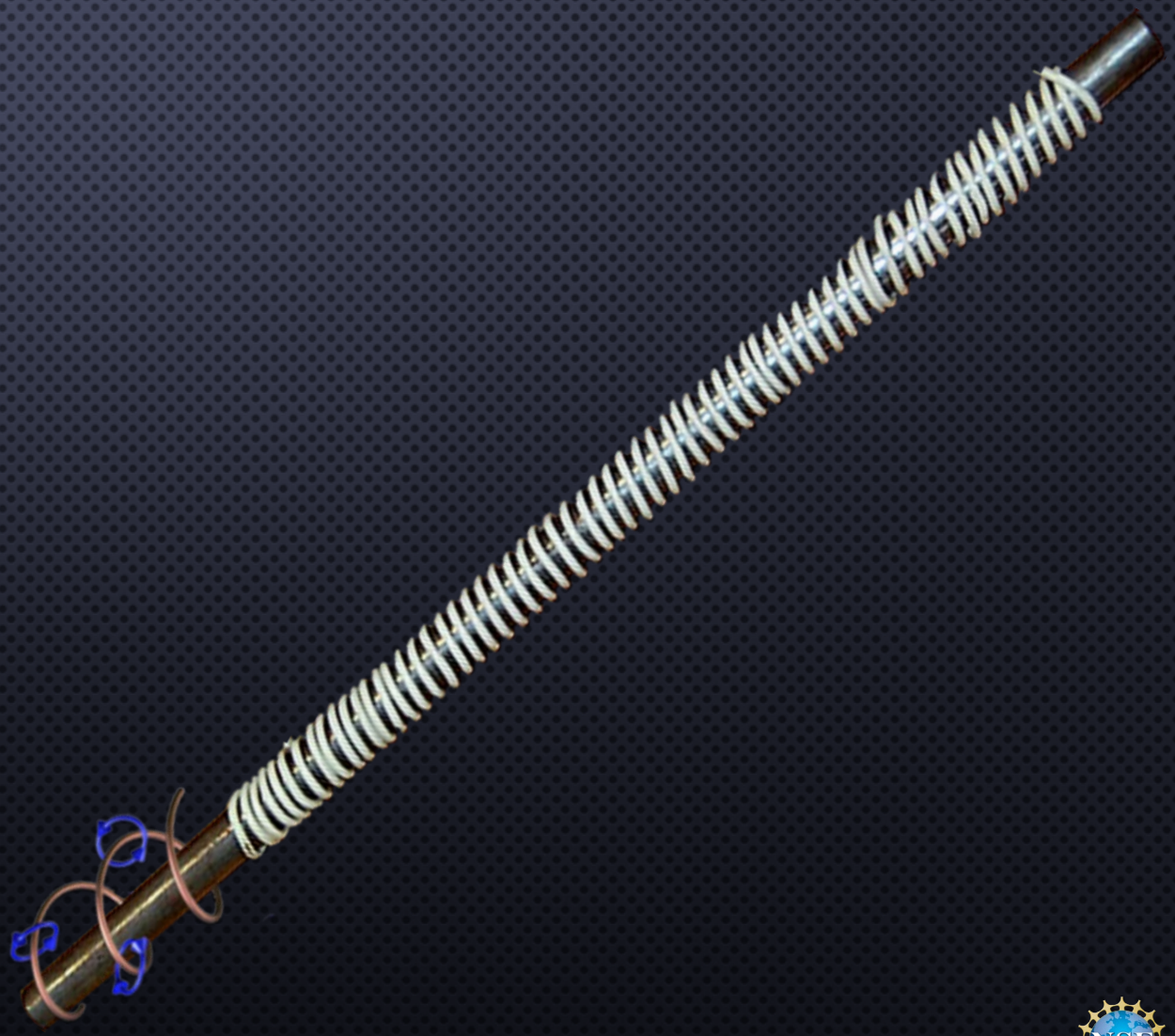
ELECTROMAGNETISM

- MATERIALS
  - COPPER WIRE
  - IRON ROD
  - BATTERY
- EXTENSIONS:
  - 2 BATTERIES
    - IN LINE?
  - ALUMINUM OR WOODEN ROD
    - WILL THEY WORK?

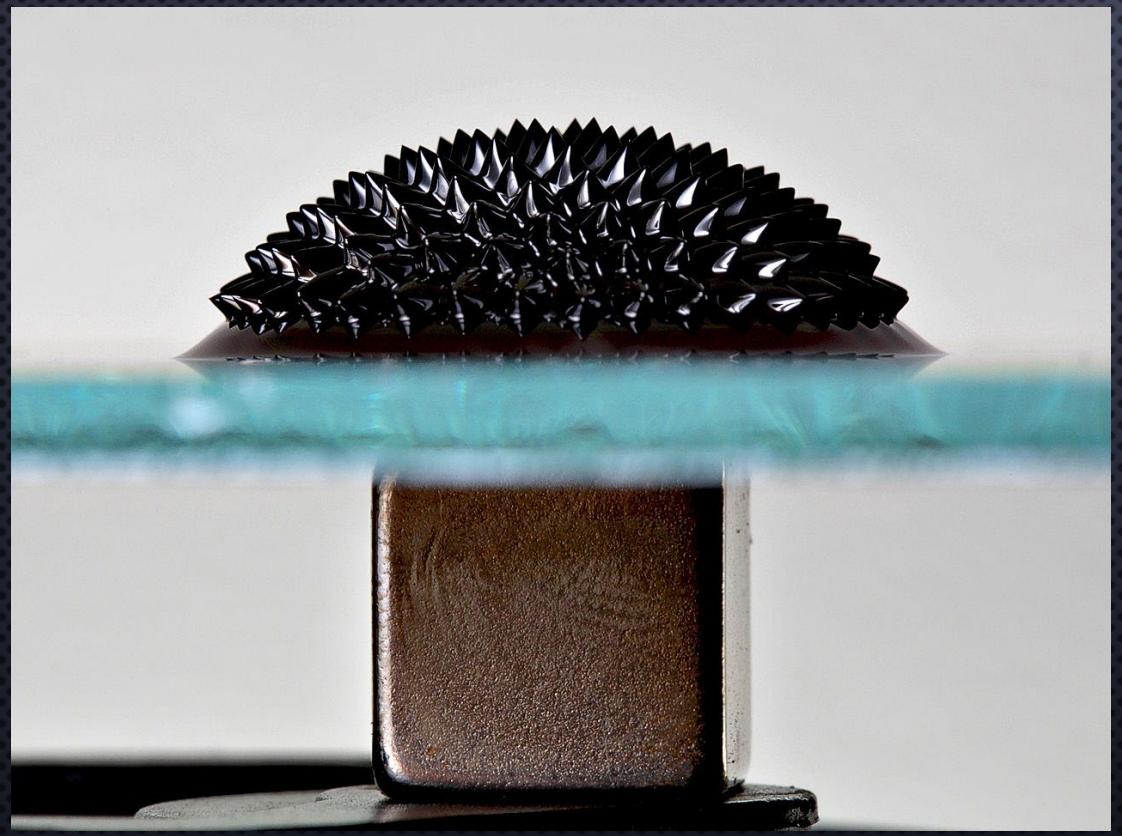


Electromagnetism Extensions

- Right hand rule
  - Direction of field
- Poles (Winding direction)
- Variables:
  - Neatness
  - Number of winds
  - Wire gauge
  - Battery strength
  - Temperature
  - Precision



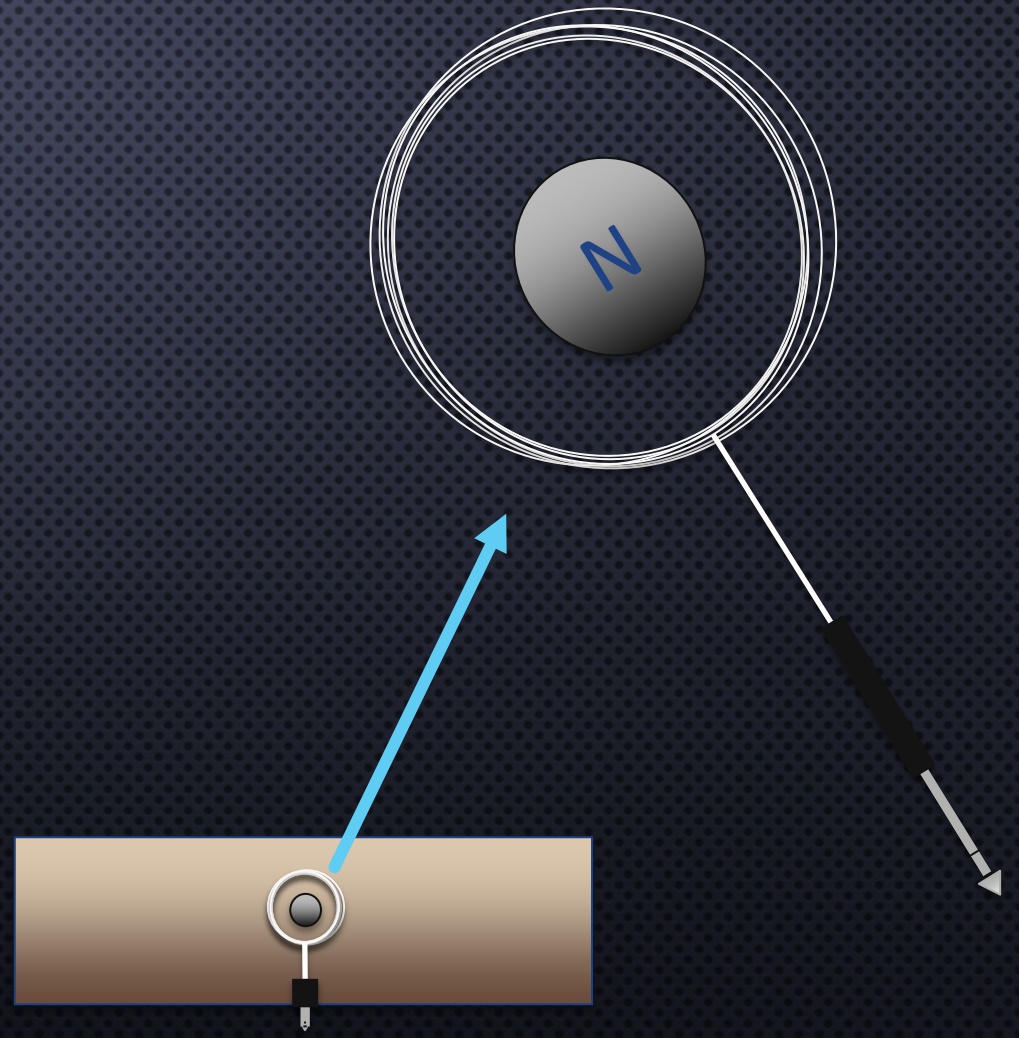
THE MAGNETIC HEDGEHOG



- FERROFLUIDS AKA LIQUID MAGNETS
  - SUSPENSION OF IRON NANOPARTICLES
- FLUID ADHERES TO MAGNETIC FIELD LINES
- INCREDIBLY ATTRACTIVE
  - **BE CAUTIOUS**

MAKE A SPEAKER

- SPEAKERS WORK WITH A PERMANENT MAGNET IN AN ELECTROMAGNET COIL
  - MUSIC SENT AS ELECTRICAL CURRENT CREATES FLUX IN THE COIL, CAUSING THE MAGNET TO VIBRATE
- VIBRATION CREATES THE SOUND WE HEAR

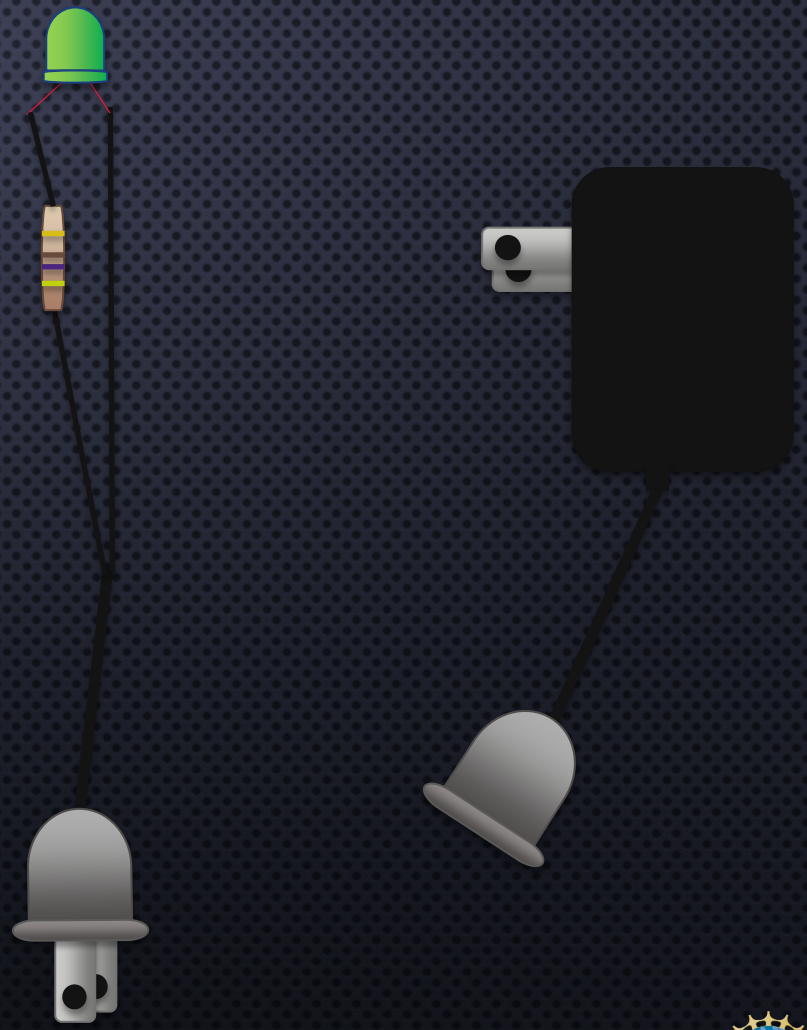


AC/DC CURRENT DETECTOR

Device shows AC current

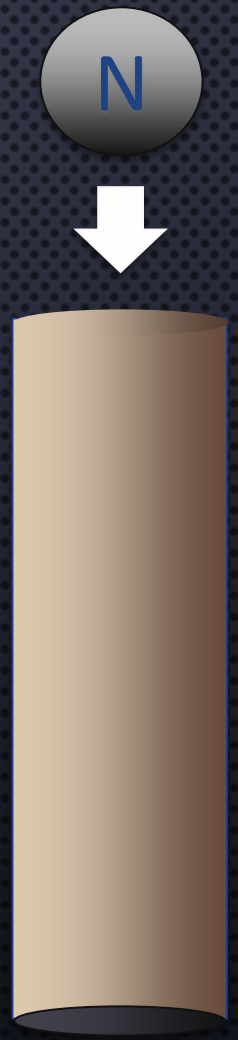
Materials

- Bi-color LED
- ½ Watt, 400-500 ohm resistor
- Lamp cord
- 2-prong plug
- 2-prong socket
- Electrical tape
- 9-volt AC adaptor/transformer



Induction by Gravity Part 1

- Movement of magnetic field by a conductor creates motion of electrons
  - Current is induced
  - Basis of electric generators
- Gravity pulls magnet past conducting coil
- Induced current in copper tube created Eddy currents
  - Currents repel magnet



Induction by Gravity Part 2

- Movement of magnetic field by a conductor creates motion of electrons
  - Current is induced
  - Basis of electric generators
- Gravity pulls magnet past conducting coil
- Induced current lights LED

PLOTTING ELECTRIC FIELD LINES

MAGLAB HOME KIDS TEENS ADULTS / COLLEGE STUDENTS TEACHERS Search Magnet Academy or CUSTOM SEARCH

MAGNET ACADEMY
FROM THE NATIONAL HIGH MAGNETIC FIELD LABORATORY

EXPLORING THE WIDE WORLD OF ELECTRICITY AND MAGNETISM

WATCH & PLAY | LEARN THE BASICS | EXPLORE HISTORY | TRY THIS AT HOME | PLAN A LESSON | FOLLOW THE LINKS

Plotting Electric Field Lines

font size | Print | 1

Detailed instructions for teachers on conducting a hands-on lesson on plotting electric fields lines.

Concepts covered

- Electric fields
- Forces

Time

This activity requires about 1-1.5 hours to complete.

Background

There are four fundamental interactions that occur in nature; in physics they are referred to as fundamental forces. The four forces are gravitational, electromagnetic, strong nuclear and weak nuclear. For this lesson we will focus on the electromagnetic force, specifically the force produced by an electric field (E).

The concept of the electric field is a bit esoteric compared to, let's say, a gravitational field because we can interact much more easily with a gravitational field than we can with an electric field. If we take a ball (basketball, golf ball, baseball, etc.) and drop it, we see that it falls toward the Earth. This happens because the ball is in a gravitational field and the gravitational field produced by the Earth interacts with the mass of the ball. We assume, for the most part, that the gravitational field experienced by the ball is uniform, therefore, the ball falls straight from your hand to the ground. The force exerted by the field on the ball is **F** = m**g** (**force** =mass of the ball x **gravity**) **Figure 1**.

Uniform gravitational field, g

What's the MagLab?

Magnet Academy is brought to you by the National High Magnetic Field Laboratory — the largest, most high-powered magnet lab in the world.

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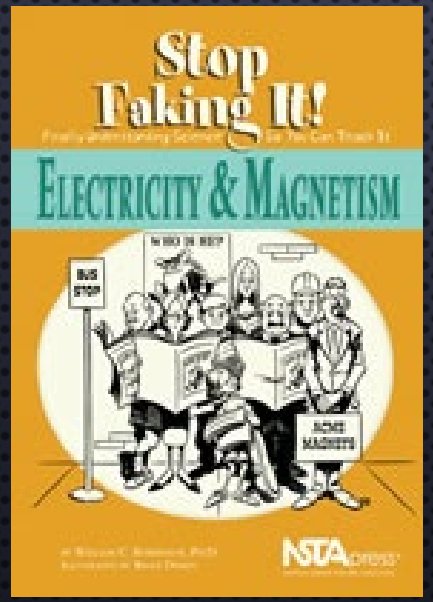
More Lesson Plan Ideas

- Electric Motors
- Ion Motors
- Making Microphones

MAGNETISM RESOURCES FOR FURTHER LEARNING

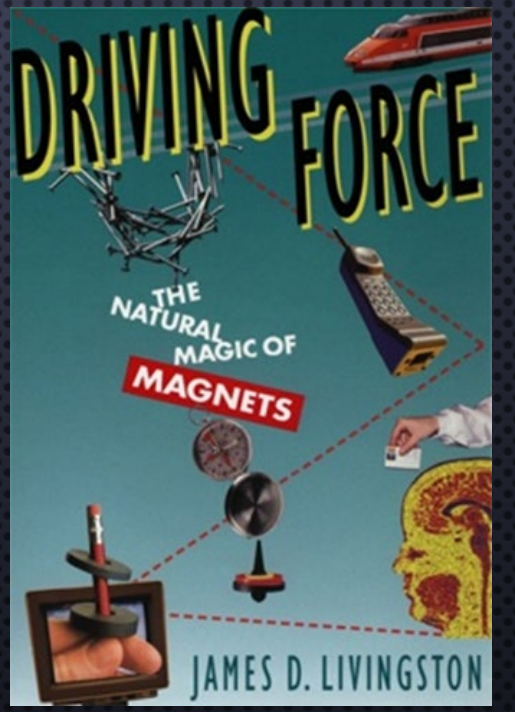
Stop Faking It

Bill Robertson



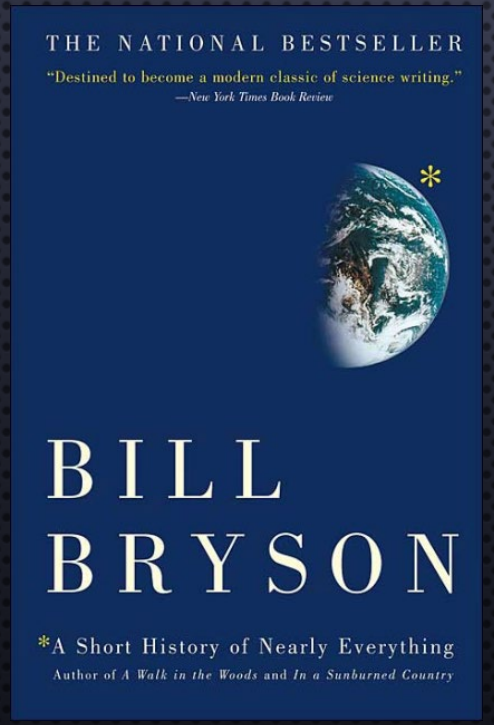
Driving Force

James D. Livingston



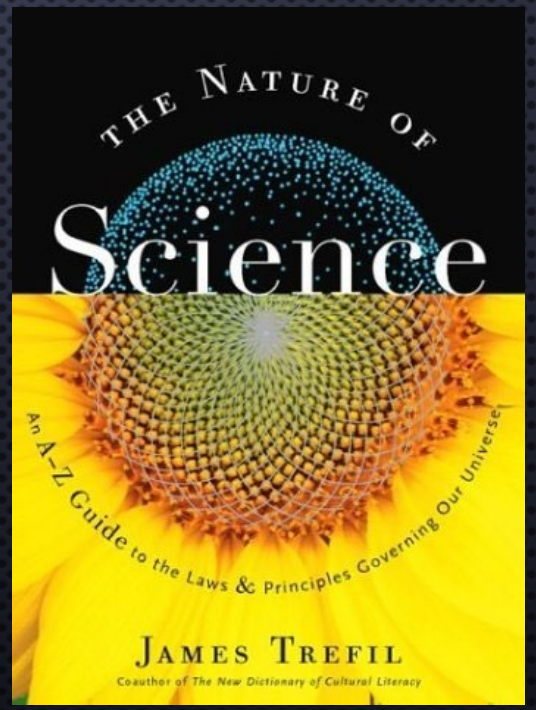
A Short History of Nearly Everything

Bill Bryson



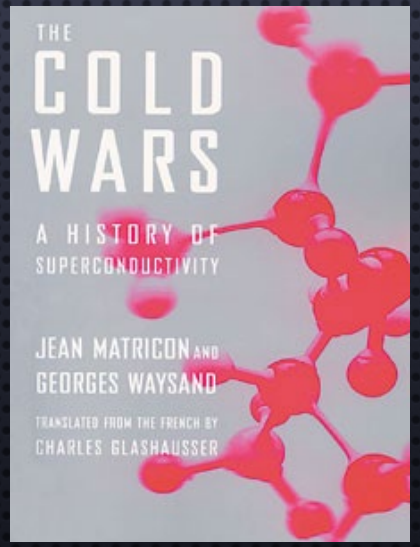
The Nature of Science

James Trefil



The Cold Wars

Jean Matricon & Georges Waysand



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NATIONAL HIGH MAGNETIC FIELD LABORATORY

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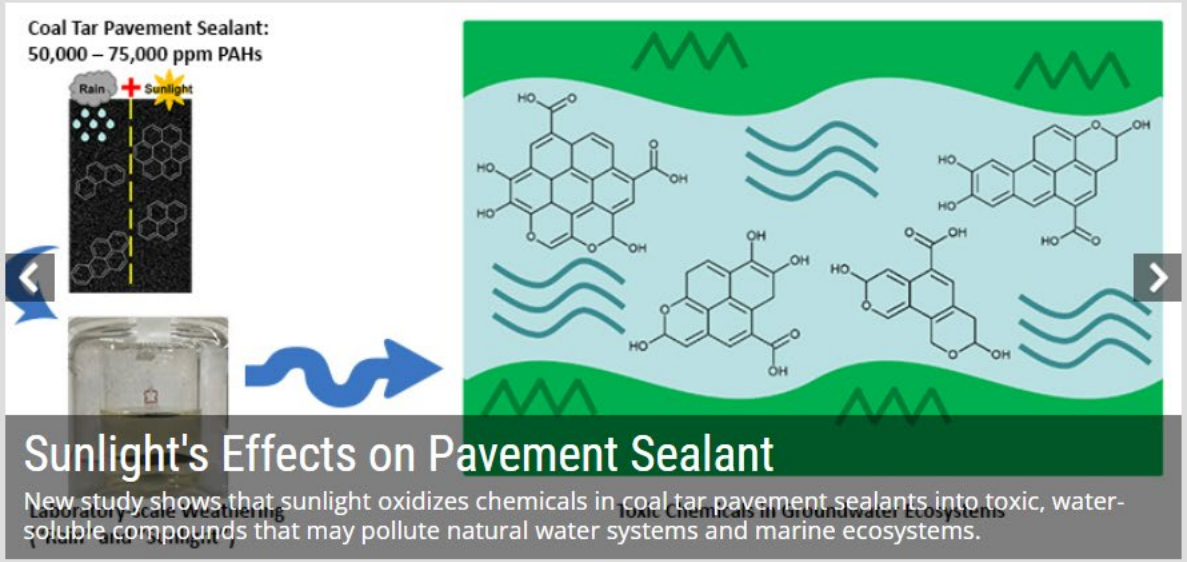
Message from the MagLab Director on Coronavirus (COVID-19)



Sunlight's Effects on Pavement Sealant

New study shows that sunlight oxidizes chemicals in coal tar pavement sealants into toxic, water-soluble compounds that may pollute natural water systems and marine ecosystems.

See-Thru Science

Popular YouTube See-Thru Science Series is now available En Español. Find out more.

Research Initiatives

User Facilities

- Advanced Magnetic Resonance Imaging and Spectroscopy
- DC Field
- Electron Magnetic Resonance
- High B/T

MAGLAB RESEARCH EXPERIENCE FOR TEACHERS (RET)

MAGLAB RET 2023

- Summer Program
  - 1 Week in Person
    - In the MagLab
  - 4 weeks virtual
    - Wherever Home Is
- $3600 stipend

What do you have to do?

- Complete online application
- Complete program surveys
- Submit lesson plan
- Send in supporting documents (letter of rec, etc.)

MAGLAB RET 2023

- Week in Tallahassee we supply
  - Housing
  - Travel stipend
- Program is open to Elementary, Middle, and High School teachers
- Pre-service teacher positions available
- Focus of the program
  - Nature of Science
  - Argument Driven Inquiry
  - Communicating in science
  - Experimental Design
  - Culturally Responsive Pedagogy
- Topics for Lesson Plan Research
  - Materials Engineering
  - Superconductivity
  - Electron Scanning Microscopy
  - Condensed Matter

Before you leave

- Business cards
  - Please do not hesitate to contact us with questions, ideas, suggestions, etc…
- RET applications:
  - https://nationalmaglab.org/education/

Thank You

NATIONAL MAGLAB

Carlos R. Villa
Director of K-12 Programs
villa@magnet.fsu.edu • 850-644-7191