



The National MagLab Presents: Tesla Tales

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2018 NSTA Distinguished Informal Science Educator

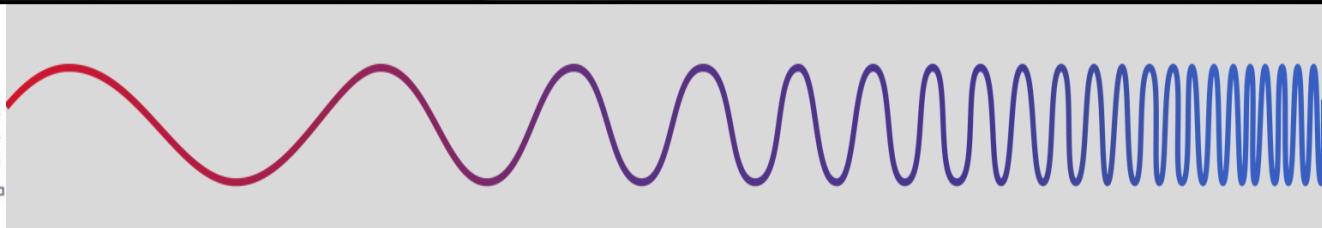
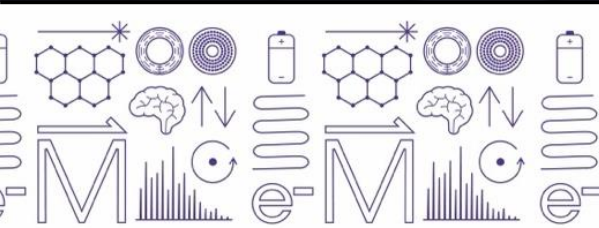
2021 Tallahassee Scientific Society Gold Medal Recipient



U.S. National
Science Foundation



About the National High Magnetic Field Laboratory



National MagLab

One of 7 high magnetic field labs in the world

Only one in western hemisphere

Largest and highest powered in the world



National MagLab

User Laboratory



Over 1,826
user visits in
2023

NSF & State
of Florida
funded

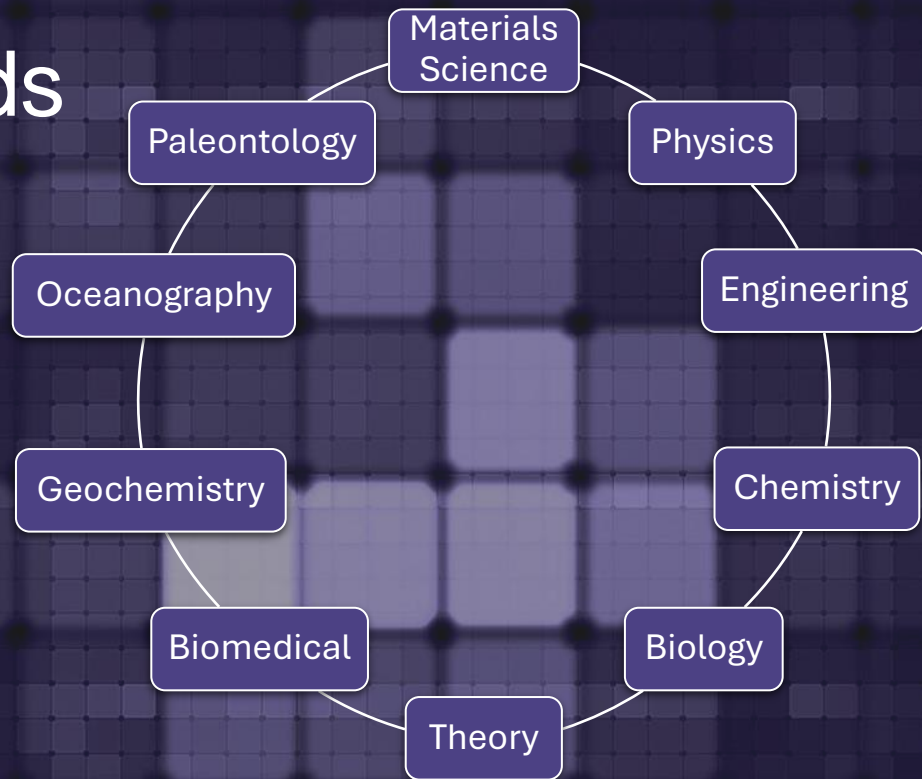
Research free
to scientist

\$41 Million
Budget

Must share
research

National MagLab

Research in many fields
(Not just magnets)



National MagLab

Center for Integrating Research & Learning



Mentoring
& Research



Field Trips
& Tours



Summer
Camps



Professional
development



Workshops
and
Conferences



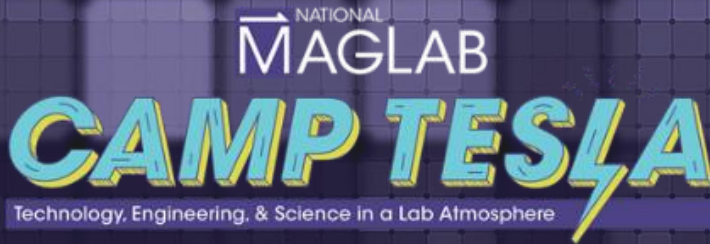
High
School
Externship



RET
program

National MagLab

Center for Integrating Research & Learning



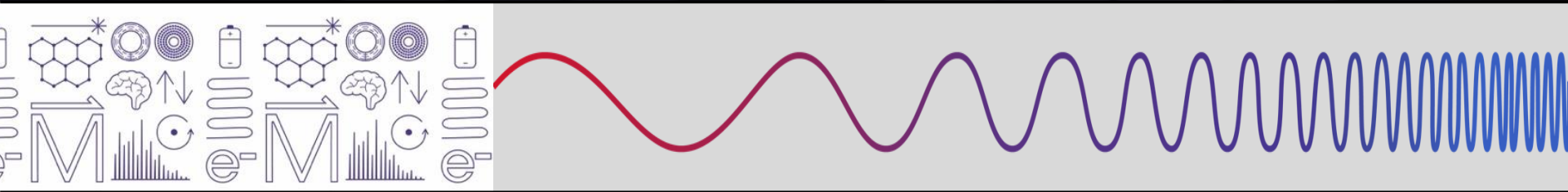
National MagLab

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

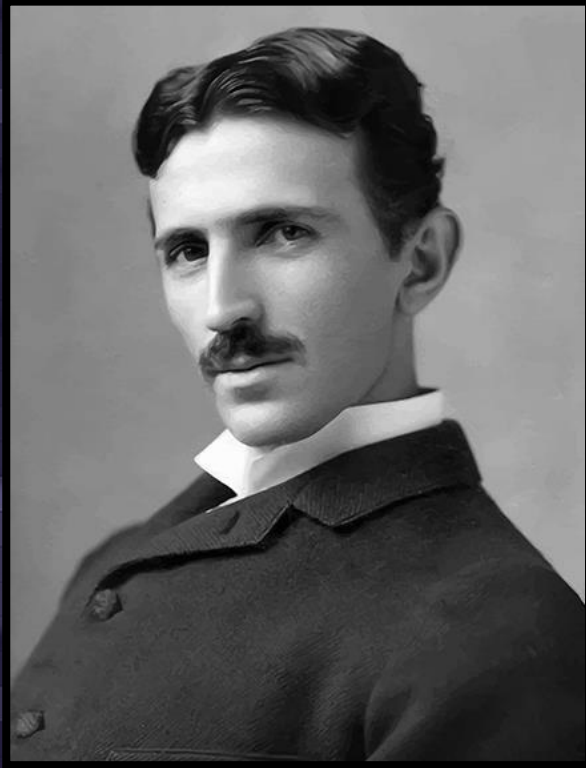
So, on behalf of all of us, thank you for supporting our science.



About the Magnets



Nicola Tesla



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

Magnetic Fields around us (In Tesla)

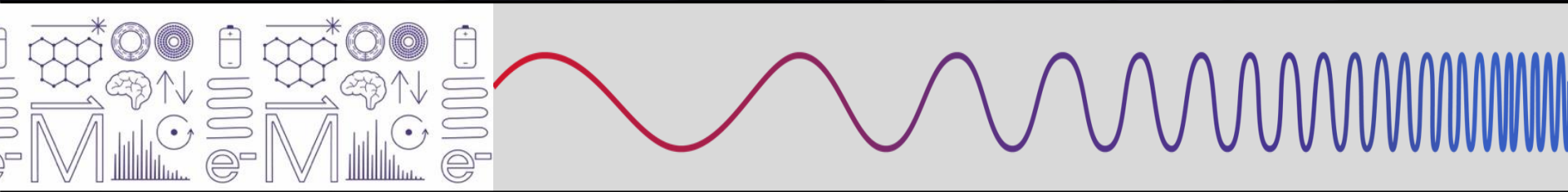
Refrigerator magnet:	.03 T
Earth's magnetic field:	.000045 T
Person's magnetic field:	3×10^{-13} T
Junkyard magnet:	1 T
Magnetic Resonance Imaging (MRI) magnet:	1.5 – 2 T

Magnetic Fields at the MagLab (In Tesla)

World Record Magnets in Red

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

Magnetism Throughout History



First Magnet Discoveries



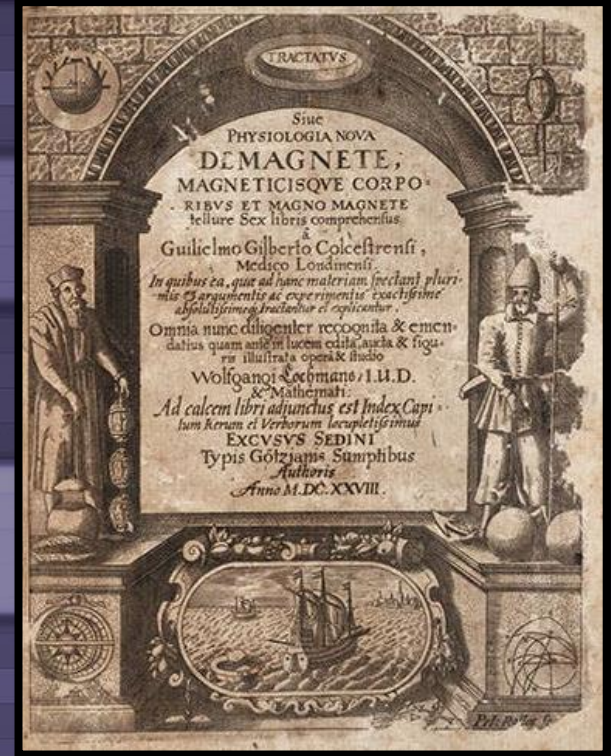
- In Greece, 2000 BC
 - Magnes the shepherd
- In China, 400 BC
 - Feng shui
 - The south pointer
- In Rome, 50 AD
 - Pliny the Elder
 - Naturalist and researcher
 - “Magic” with healing properties

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



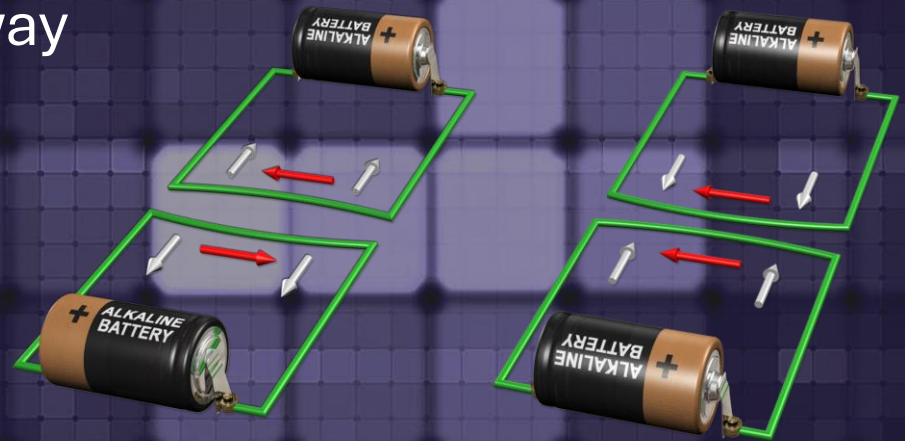
1820: Hans Christian Ørsted

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

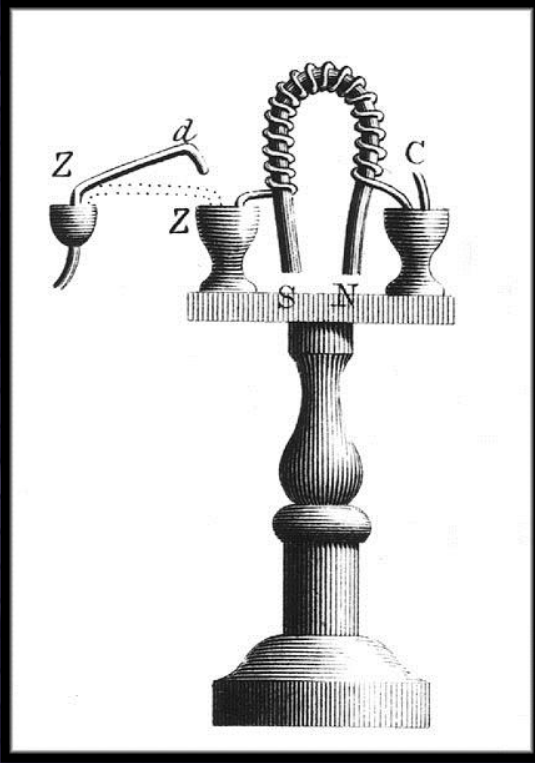


1820: André-Marie Ampère

- 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



An electromagnet using two electrodes attached
to a battery, best to wind coils of wire in parallel

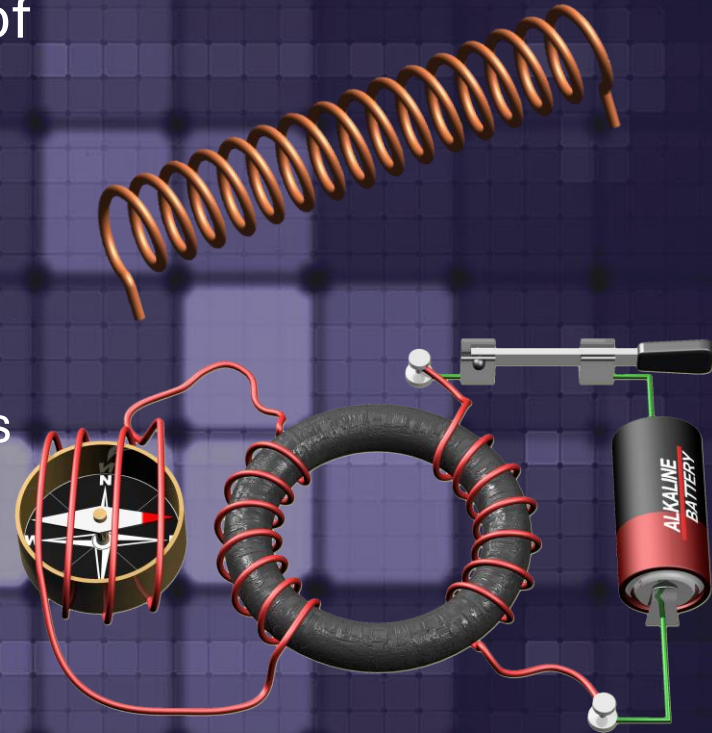


But an electromagnet using with multiple
batteries, should use only one single coil



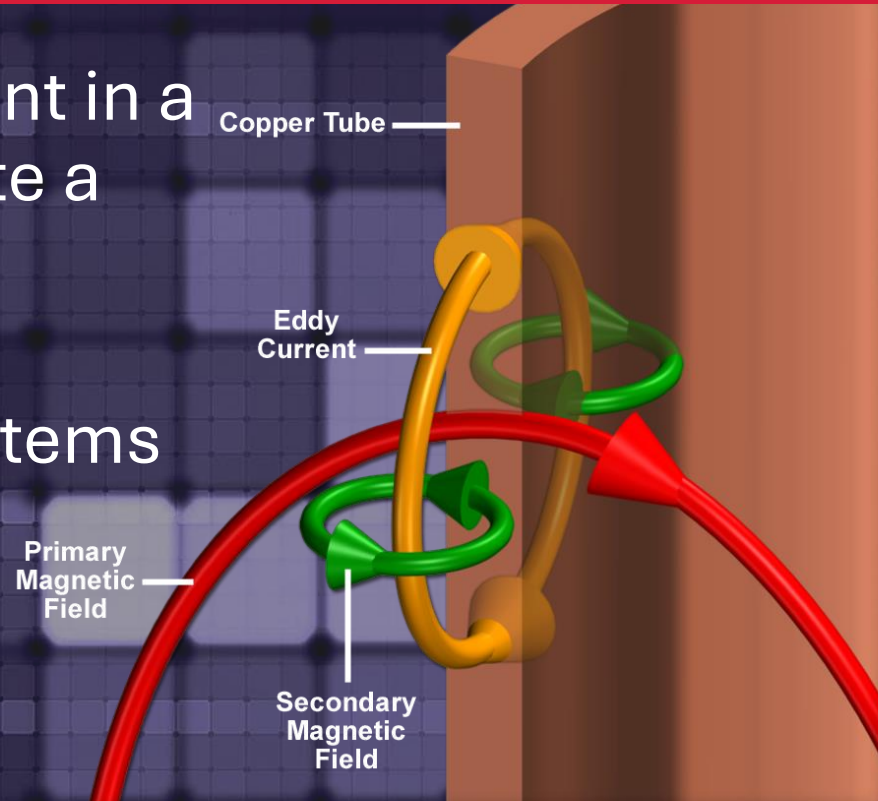
1831: Michael Faraday

- 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

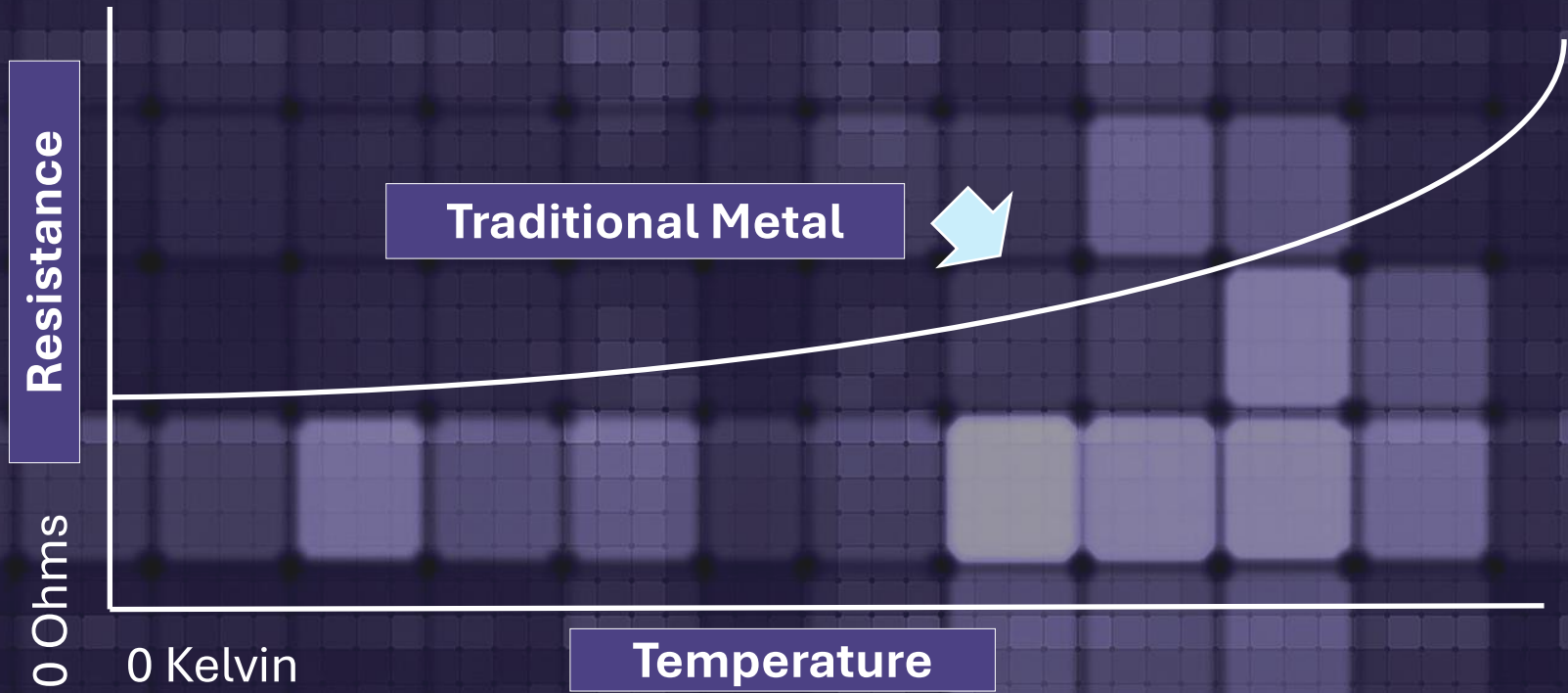


1834: Emil Lenz

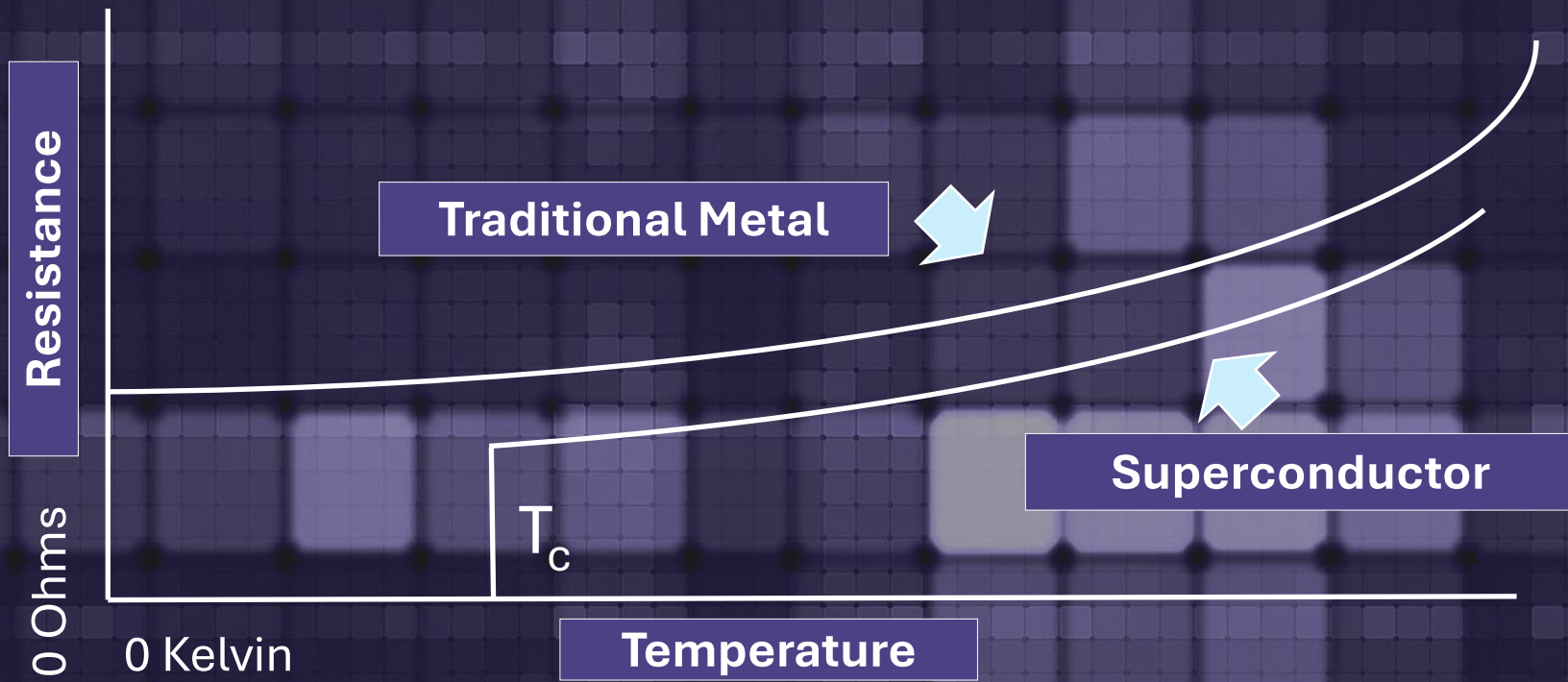
- Lenz's Law: An induced current in a wire (by flux) will flow to create a field that opposes the flux
 - Eddy currents created
- Used in magnetic braking systems
 - Rollercoasters
 - Electric car braking feedback



1900: Superconductivity

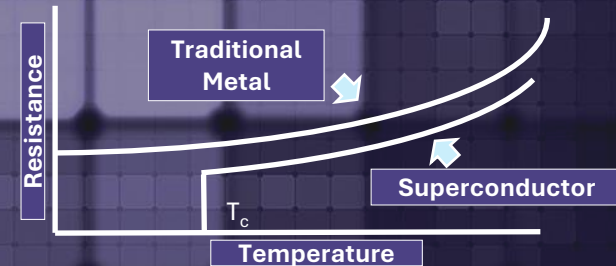


1900: Superconductivity

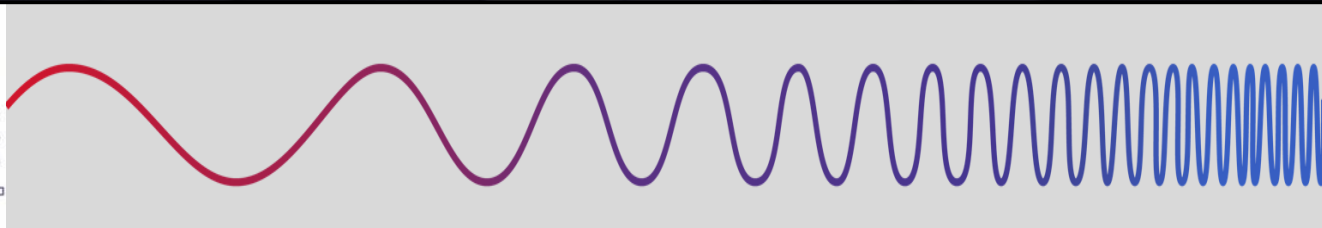
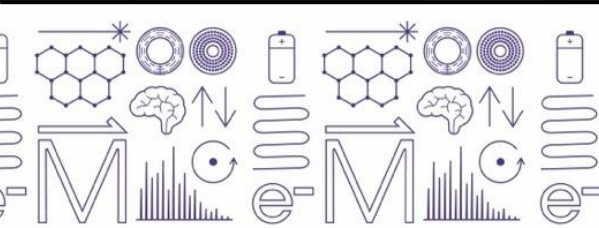


1900: Superconductivity

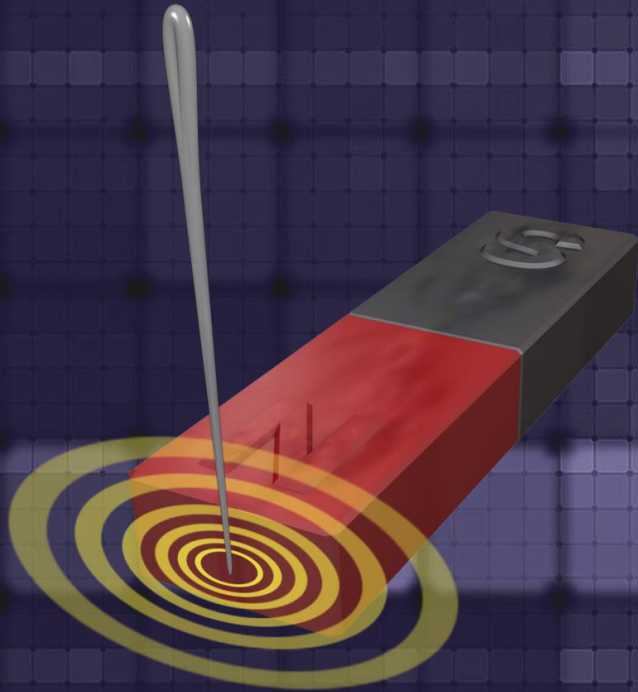
- BCS: Bardeen, Cooper, Schreiffer
 - At low temperatures, some metals lose resistance
 - Nucleus nearly stationary
- Superconductivity results from the formation of Cooper pairs
- Two electrons partnered
 - One follows the other
 - Results in frictionless flow of electrons



The Science of Magnetism

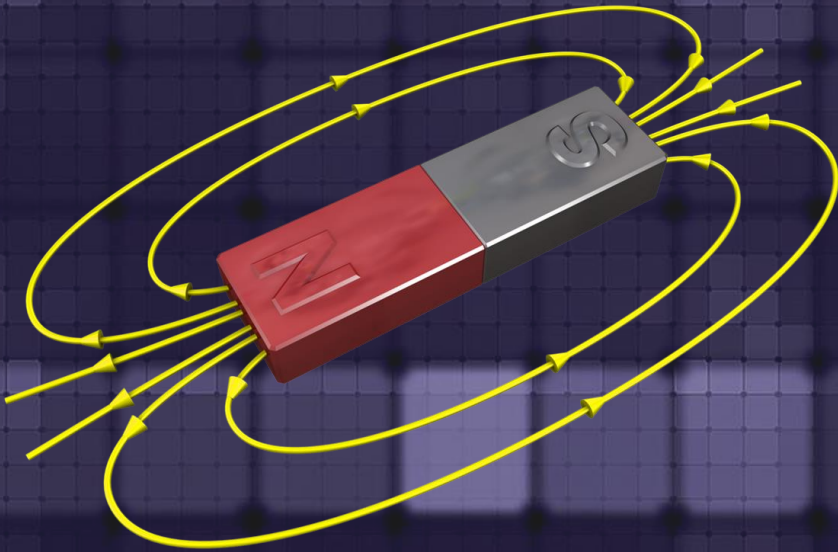


Magnets & Magnetic Fields



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

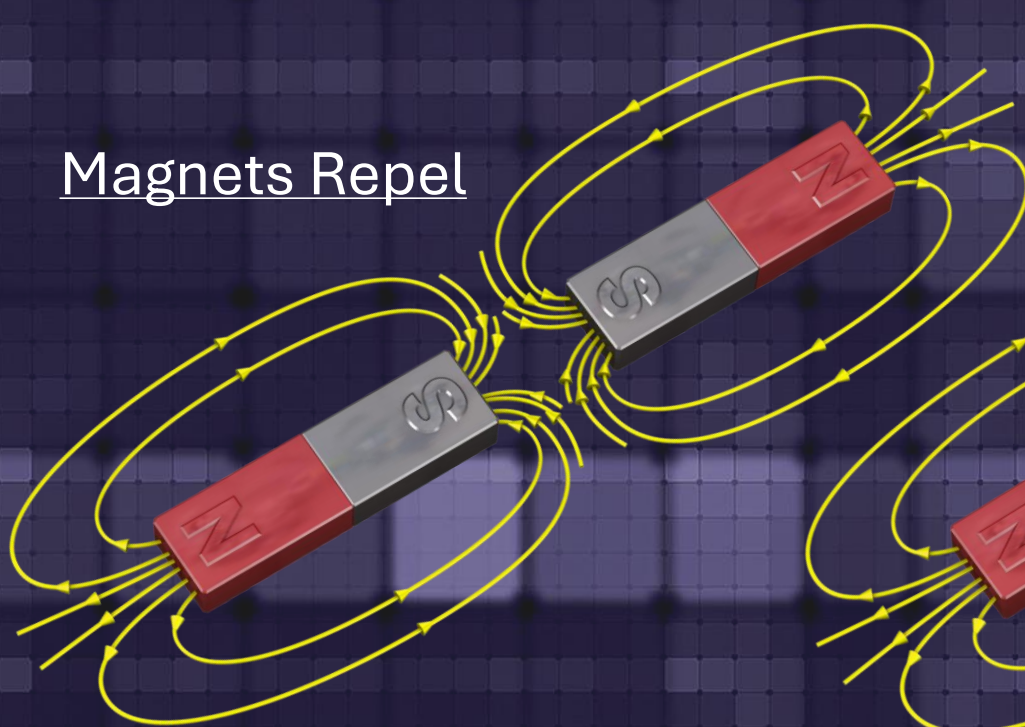
Magnets & Magnetic Fields



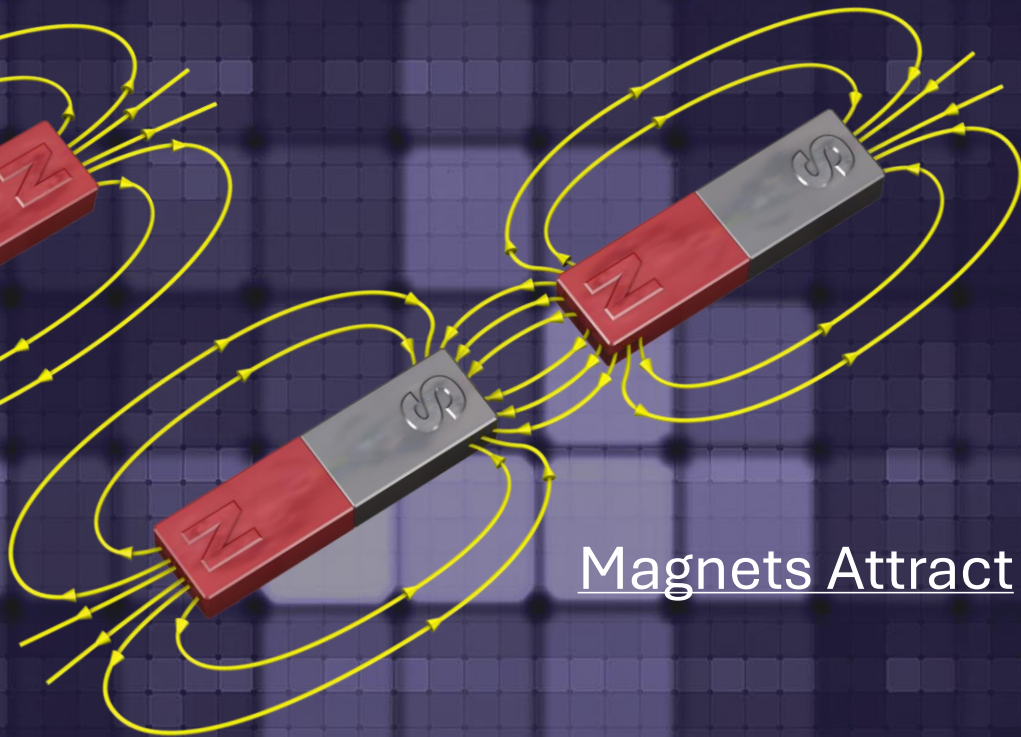
- All magnets have magnetic fields
 - Fields are responsible for attracting and repelling
- Magnetic field is a vector field
 - Has direction and magnitude

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

- Family Canidae
 - Foxes listen and aligns with the angle of the sound waves.
 - Protein in their eyes allows them to detect magnetic field.
 - When they align to the north, they successfully pounce on their prey 74% of the time.
 - If they align in any other direction, they are only successful 18% of the time.



Magnets & Magnetic Fields

- Rare animals can see magnetism
 - European Robins
 - Only in bright settings
 - Right eye and the left half of brain



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

PERIODIC TABLE OF ELEMENTS

IA		IIA										IIIB										IVB										VB										VIB										VIIA										VIII										IX										X										XI										XII										IIB										IIIA										IVA										VA										VIA										VIIA									
1 H Hydrogen 1.00794	3 Li Lithium 6.941	4 Be Beryllium 9.012182	11 Na Sodium 22.989767	12 Mg Magnesium 24.305	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.87	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.93805	26 Fe Iron 55.845	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.8	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9058	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29	55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.905	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 192.22	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.96657	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	90 Th Thorium 232.0377	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (285)	111 Rg Roentgenium (282)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)																																																																			

TABLE KEY

- 1 **H** Atomic Number
- H** Symbol
- Hydrogen Name
- 1.00794 Atomic Mass
- Chemical Group


CHEMICAL GROUP

- Reactive Nonmetals
- Alkali Metals
- Alkaline Earth Metals
- Transition Metals
- Post-Transition Metals
- Metalloids
- Noble Gases
- Lanthanoids
- Actinoids

STATE OF MATTER

- Gas
- Liquid
- Solid
- Unknown

NATIONAL HIGH MAGNETIC FIELD LABORATORY





**DO YOU LIKE
MOVIES?**



WHAT IS THIS
ONE CALLED?

Magnets & Magnetic Fields

~~MONSTERS, INC.~~

MAGNETS, INC.

INC. = Iron, Nickel, Cobalt

Magnets & Magnetic Fields

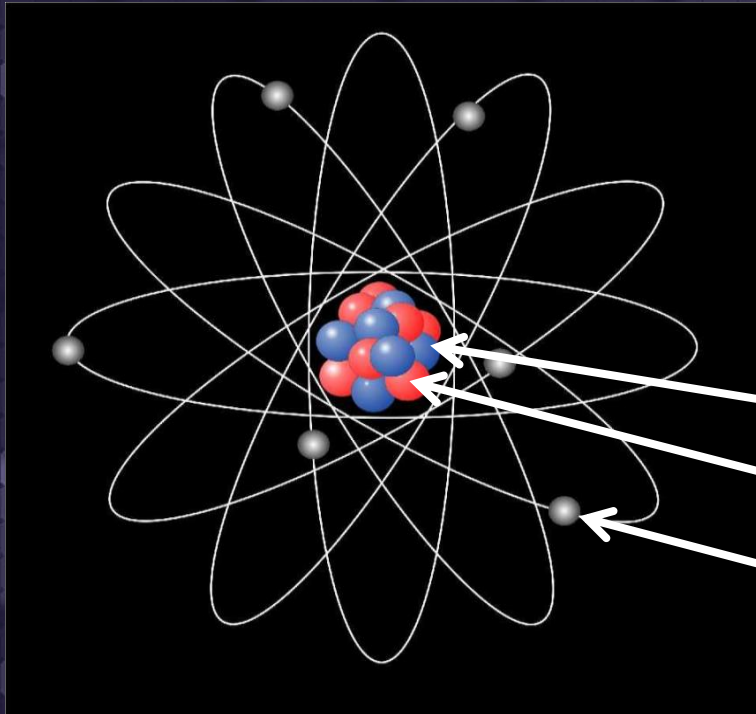
Permanent magnets

- Almost always keep their field
- Fields can be lost
 - Curie point (Heat)
 - Electric current (Degauss)
 - Hitting it (Blunt force)

Temporary magnets

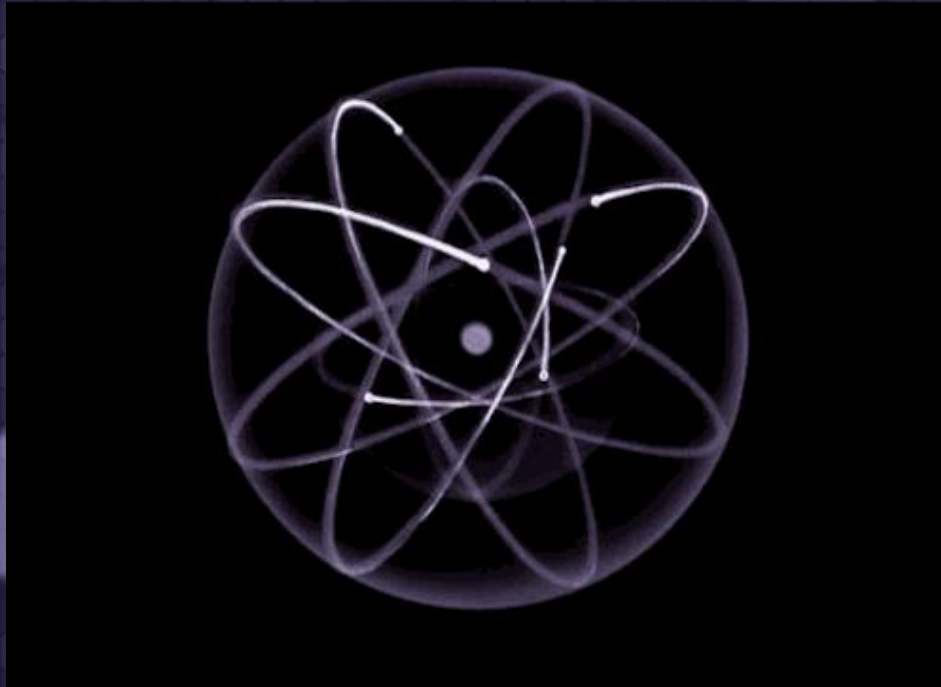
- Will keep magnetic field until tampered with
- Examples: Paperclips, scissors, staples, thumb tacks, pins, screwdrivers, refrigerator door, car doors, etc...
- Anything that is magnetic, but will not keep its field

Magnets & Magnetic Fields

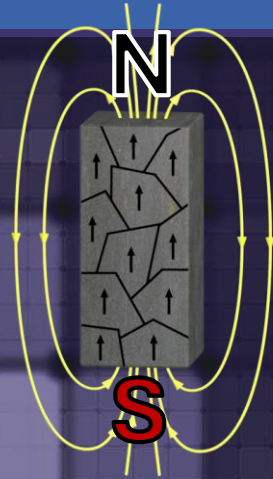
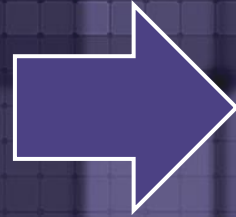
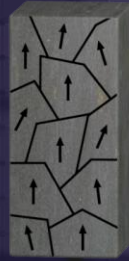
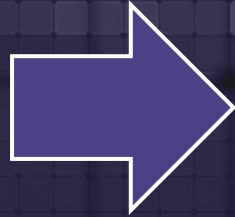


- Name atom comes from Atomos, Greek for Indestructible (not really)
- The atom is divisible
 - Proton
 - Neutron
 - Electron

Magnets & Magnetic Fields

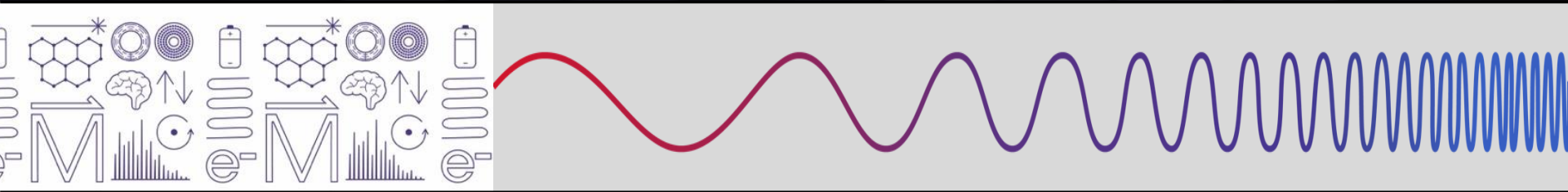


Magnets & Magnetic Fields



- 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

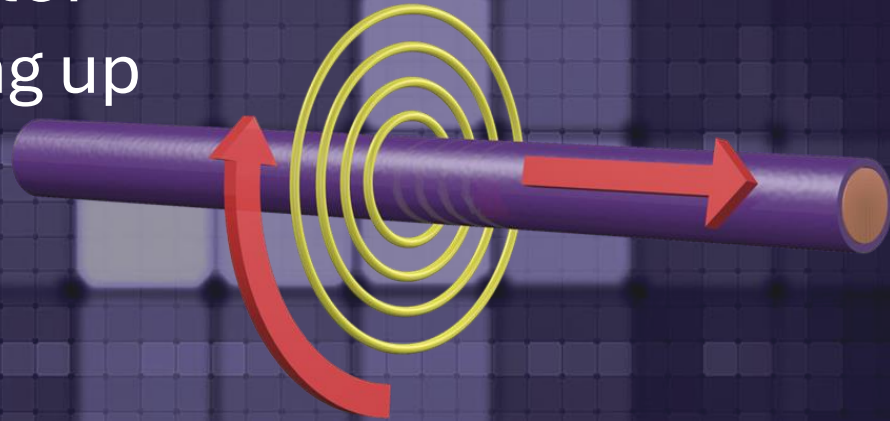
- Electrons make magnetism work
 - Spin of electrons
- Electrons make electricity work
 - Movement of electrons

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

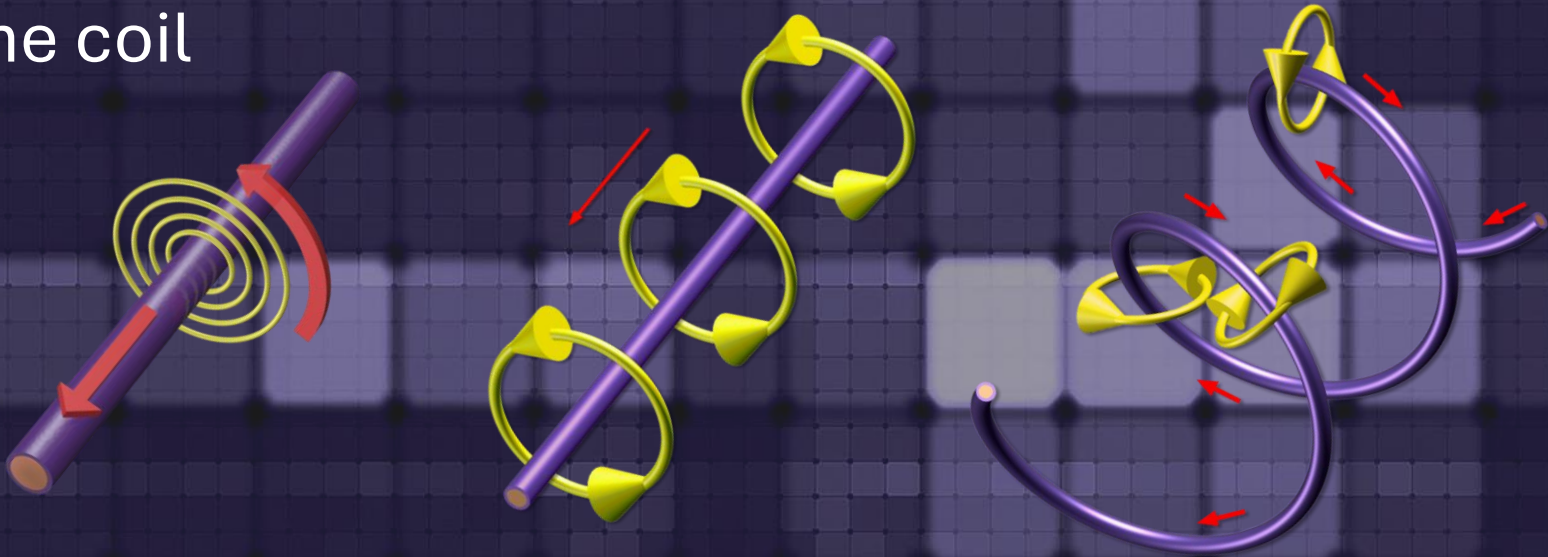
Electromagnetism

- 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
 - Every wire carrying electricity has a weak magnetic field around it

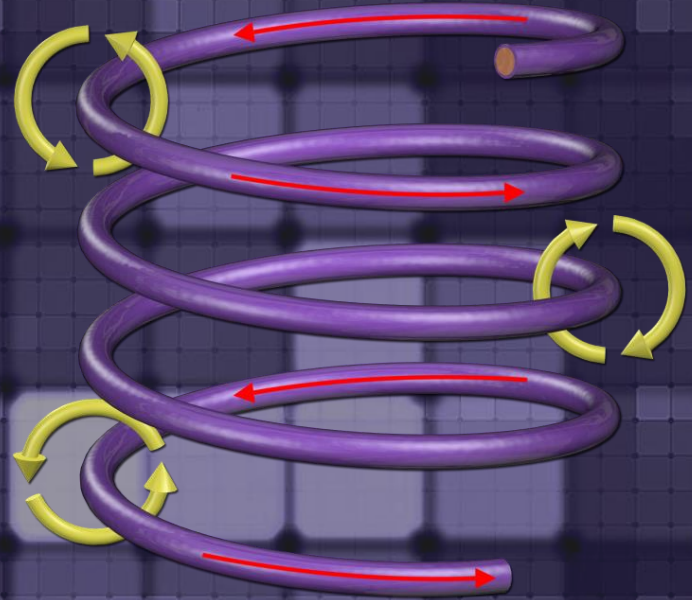
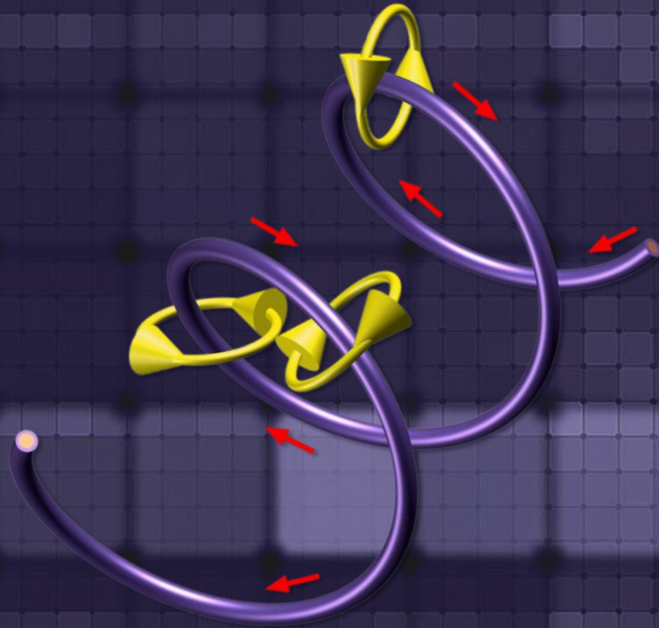


Electromagnetism

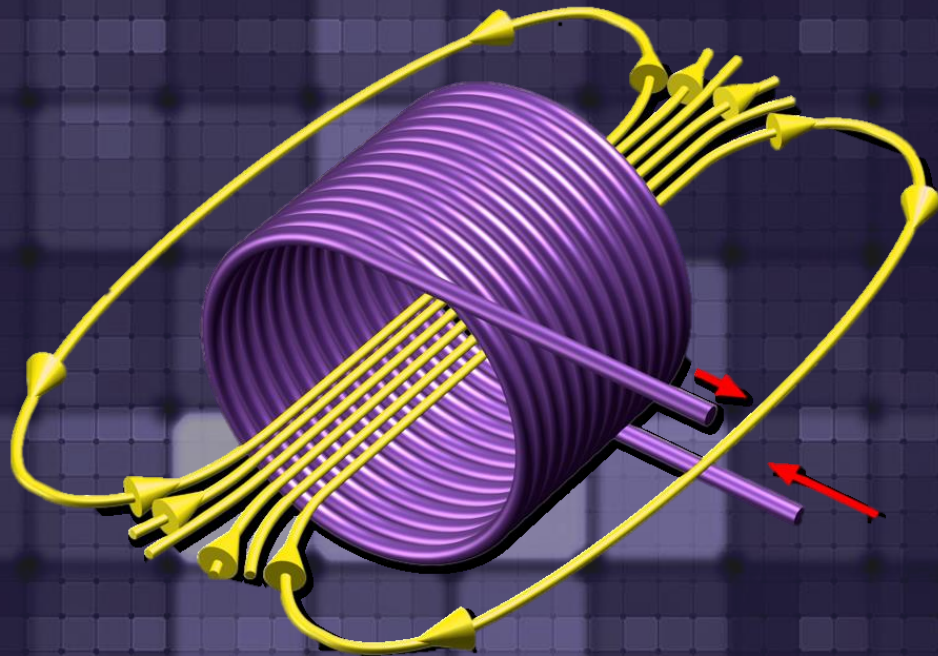
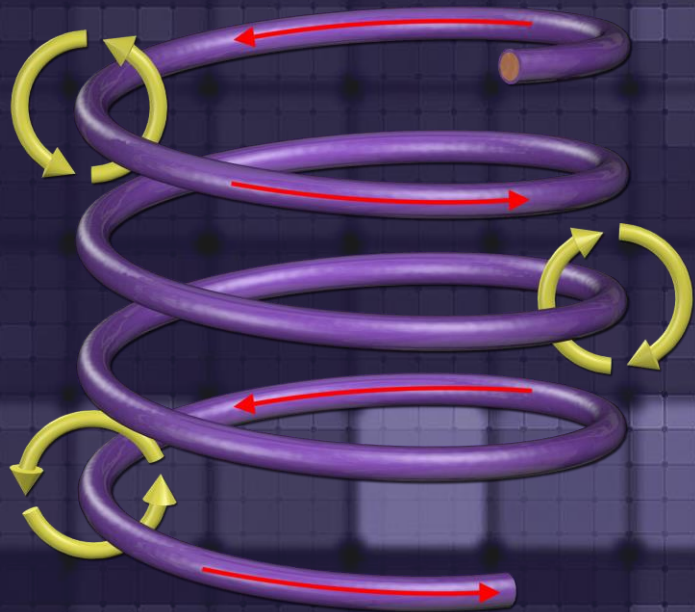
- The field exists at all points along the wire
- Coiling the wire concentrates the magnetic field inside the coil



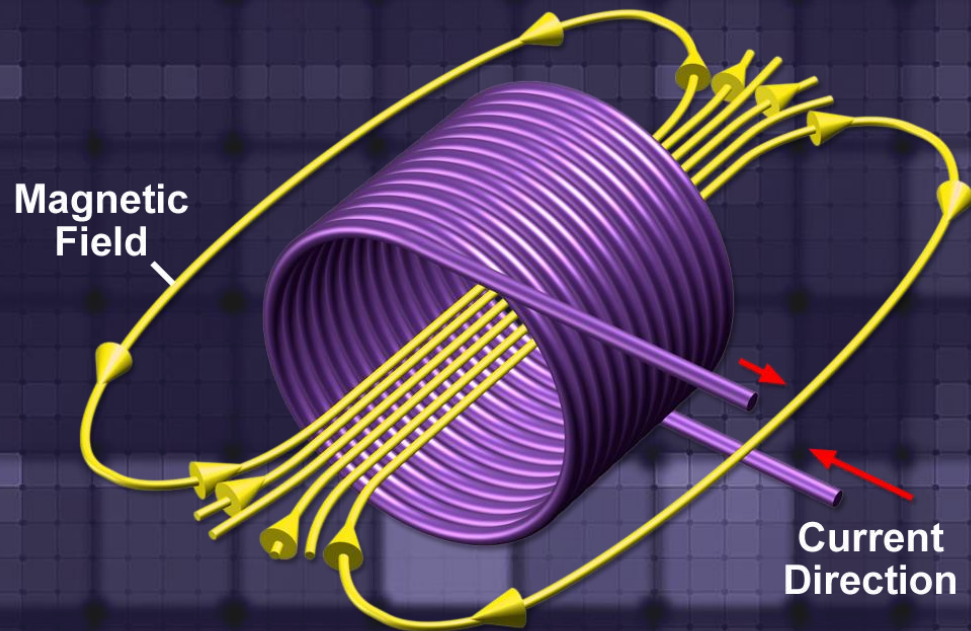
Electromagnetism



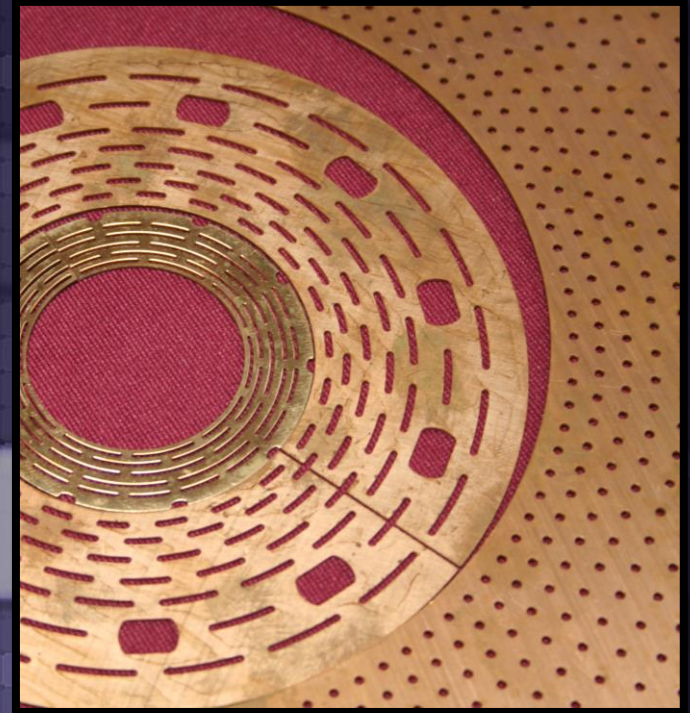
Electromagnetism



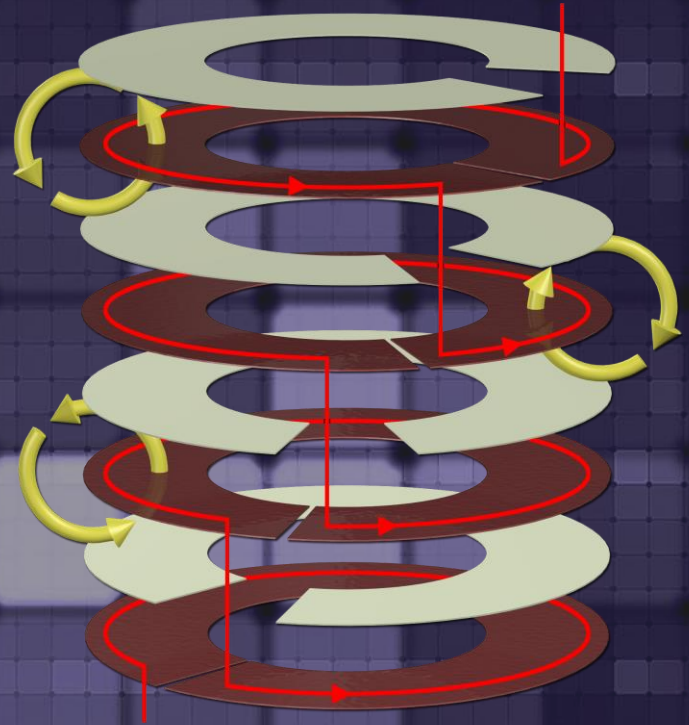
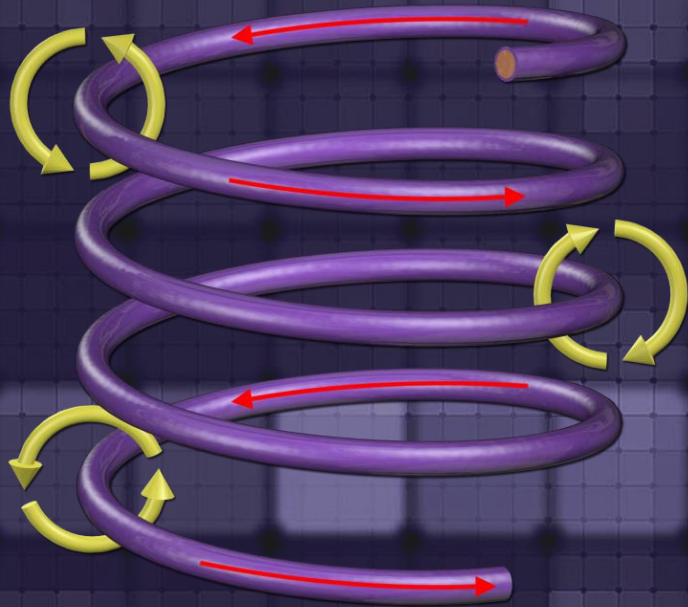
Electromagnetism



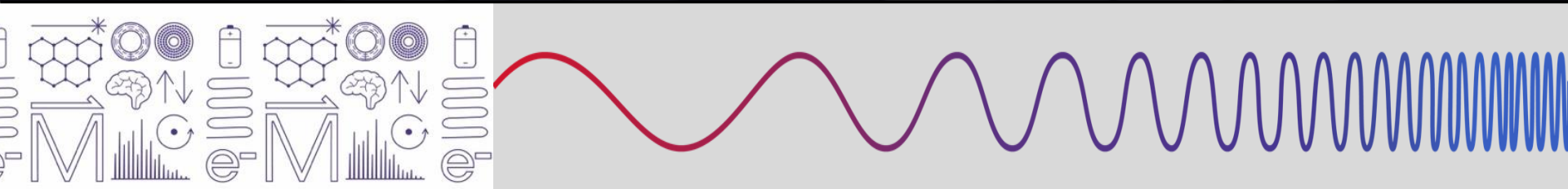
Electromagnetism



Electromagnetism



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



- Meteors are high in iron content
- Burn up in atmosphere
- Waves wash them ashore

- 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

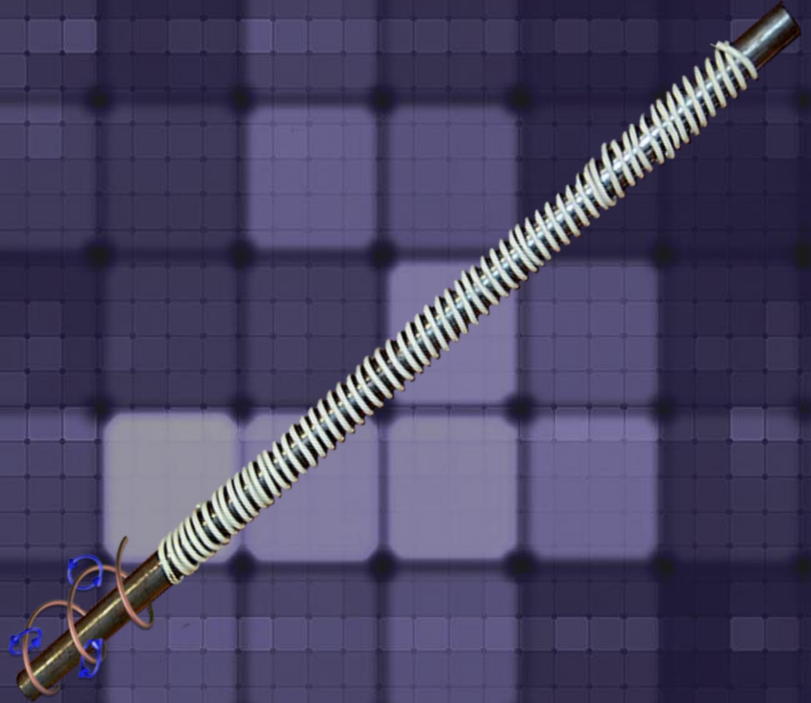
Electromagnetism

- Materials
 - Copper wire
 - Iron rod
 - Battery
- Extensions:
 - 2 batteries
 - In line?
 - Smaller iron core
 - Aluminum or wooden rod
 - Will they work?



Electromagnetism

- Poles (Winding direction)
 - Which is North or South?
 - Right hand rule
- Variables:
 - Neatness
 - Number of winds
 - Wire gauge
 - Battery strength
 - Core size
 - Temperature
 - Precision



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

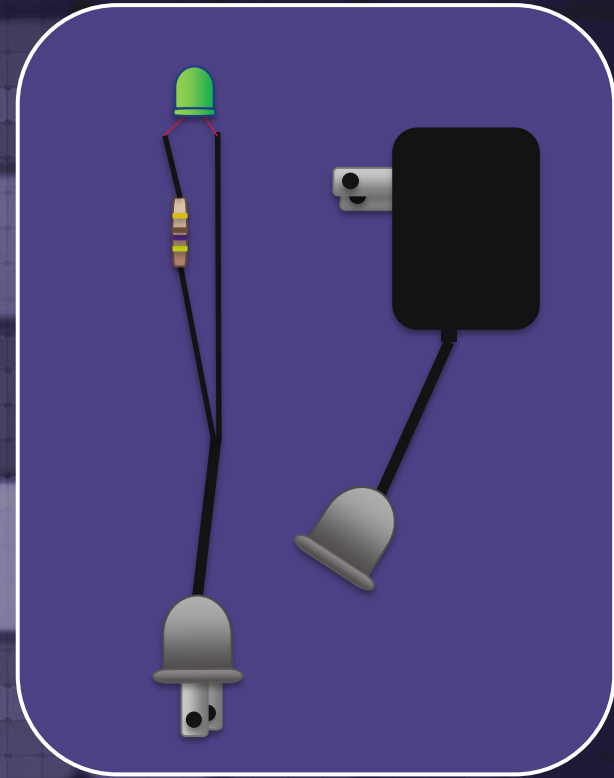


AC/DC Current Detector

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 | EXPLORING THE WIDE WORLD OF ELECTRICITY AND MAGNETISM
FROM THE NATIONAL HIGH MAGNETIC FIELD LABORATORY

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

Plotting Electric Field Lines

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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 $F = mg$ (force = mass of the ball \times gravity) **Figure 1.**

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.

[FIND OUT MORE](#)

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Topic
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-- Select Grade (U.S.) --

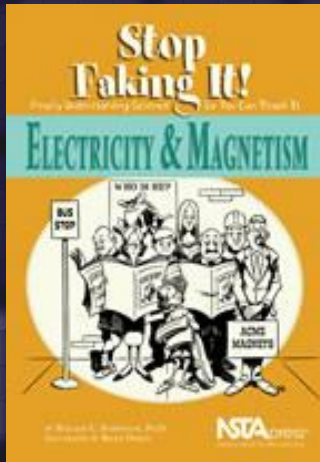
[Find My Science!](#) [Reset](#)

More Lesson Plan Ideas

- Electric Motors
- Ion Motors
- Homopolar Motors
- Permanent Magnets
- Making Microphones

Stop Faking It

Bill Robertson



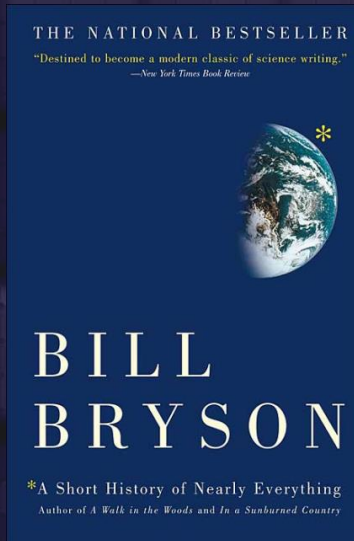
Driving Force

James D. Livingston



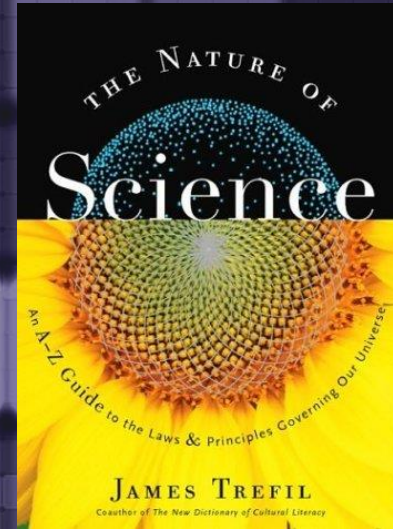
A Short History of Nearly Everything

Bill Bryson



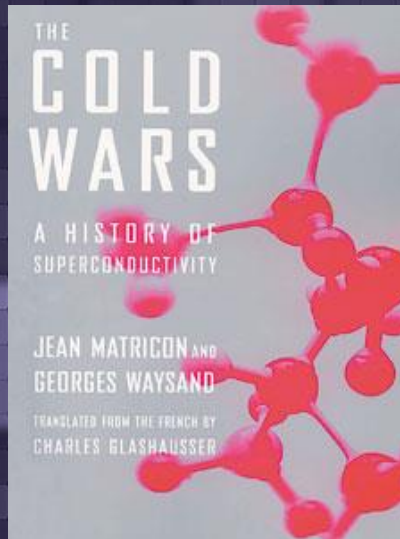
The Nature of Science

James Trefil



The Cold Wars

Jean Matricon &
Georges Waysand



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Education

The MagLab provides educational programming across all academic levels - from kindergarten to postdoctoral.

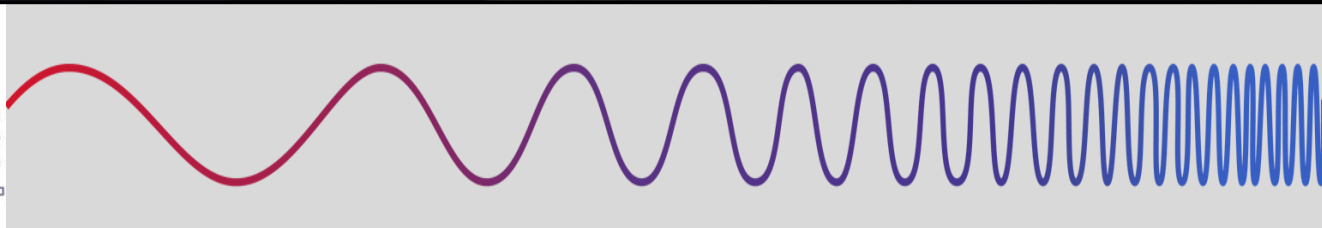
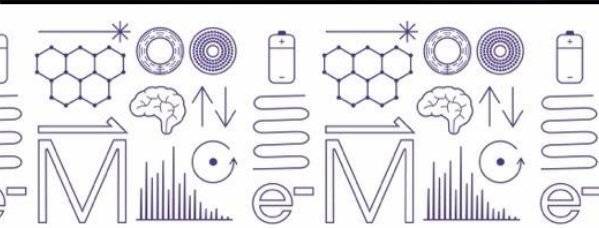
With a strong commitment to education, the lab supports educational programming at all academic levels: K-12, technical, undergraduate, graduate and postdoctoral.

Bulletin Board

2023 Florida

MagLab

Research Experience for Teachers (RET)



MagLab RET

Summer 2025 Program (June 23-27)

- Summer Program
 - 1 Week in Person
 - In the MagLab
 - 4 weeks virtual
 - Wherever Home Is
- \$3600 stipend
- How Do I Get Accepted
 - Complete online application
 - Complete program surveys
 - Submit lesson plan

2025 MagLab RET

- Week in Tallahassee we supply
 - Housing
 - Travel stipend
- Program is open to Elementary, Middle, and High School teachers
- Pre-service teacher positions available



2025 MagLab RET

- 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
 - Condensed Matter
 - Environmental Science
 - Quantum Phenomenon
 - Theoretical Physics

2025 MagLab RET

Applications Open now!

Thank you!

Carlos R. Villa
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