

# MAGNETS & THE



NATIONAL

MAGLAB

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NATIONAL HIGH MAGNETIC FIELD LABORATORY

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THIS PRESENTATION IS AVAILABLE TO DOWNLOAD AT:

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[NATIONALMAGLAB.ORG/EDUCATION/](https://nationalmaglab.org/education/)

ABOUT US

# NATIONAL MAGNET LAB

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



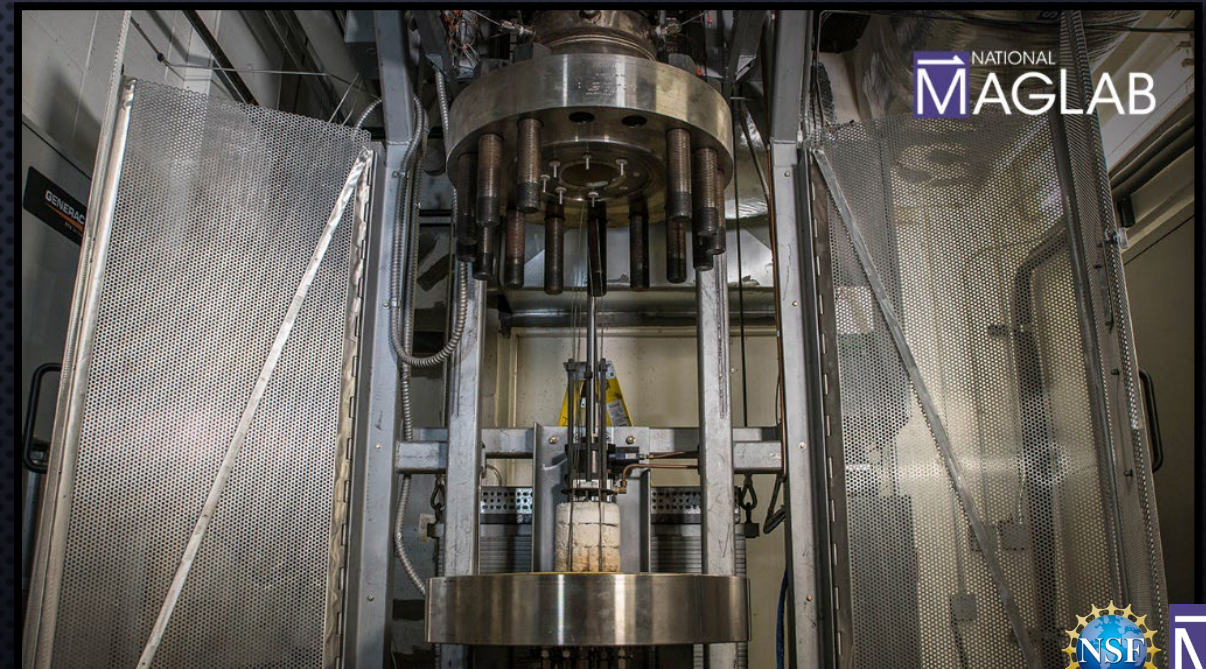
# NATIONAL MAGNET LAB

- 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



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



# NATIONAL HIGH MAGNETIC FIELD LABORATORY

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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.

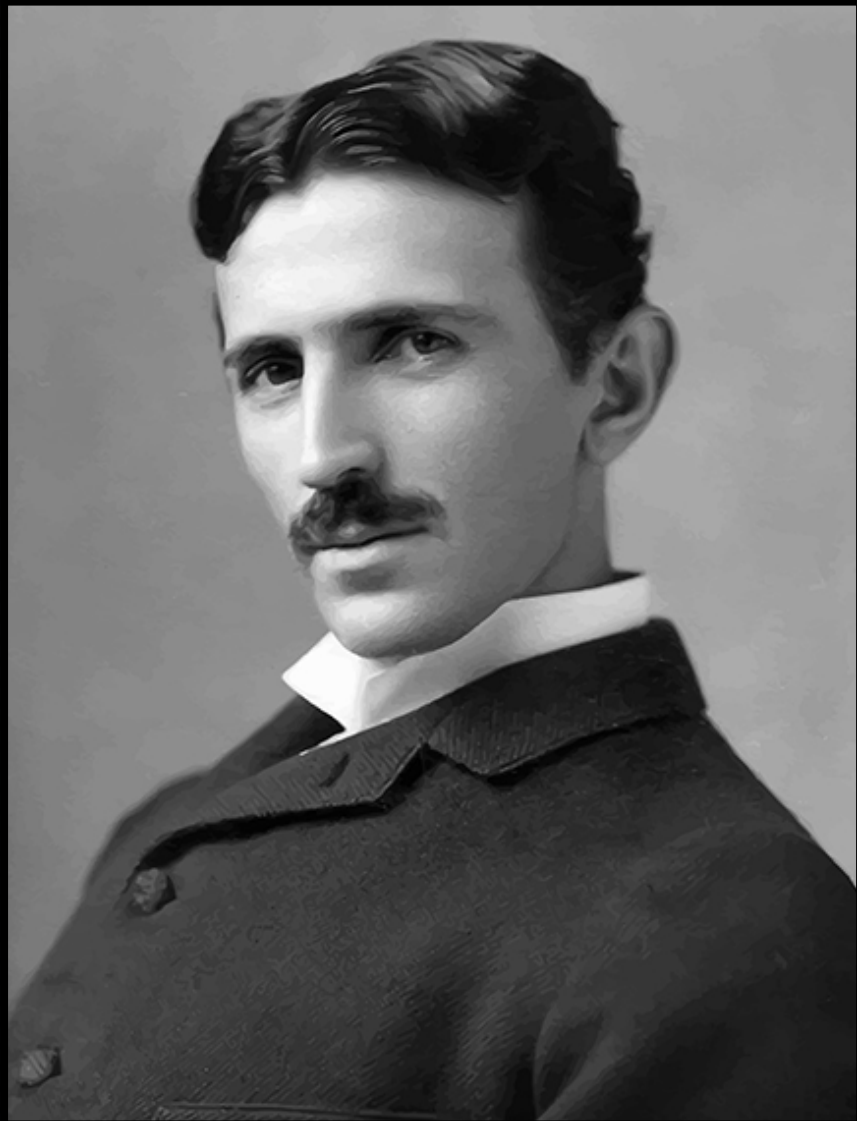




# ABOUT MAGNETS

# TESLA

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

# MAGNETIC FIELDS AROUND US (IN TESLA)

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Refrigerator magnet: .03 T

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Earth's magnetic field: .000045 T

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Person's magnetic field:  $3 \times 10^{-13}$  T

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Junkyard magnet: 1 T

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Magnetic Resonance Imaging (MRI) magnet: 1.5 – 3 T

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# MAGNETIC FIELDS AT THE MAGLAB (IN TESLA)

## WORLD RECORDS IN BLUE

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

# 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

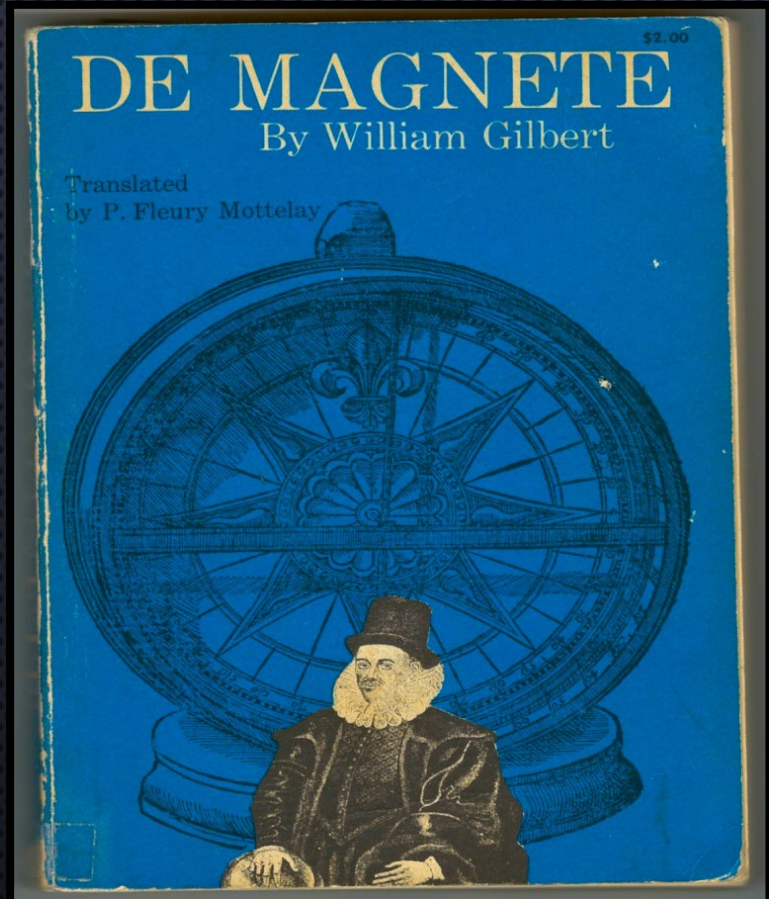
# 1269: PETRUS PEREGRINUS DE MARICOURT

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- Epistola de magnetete
  - 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

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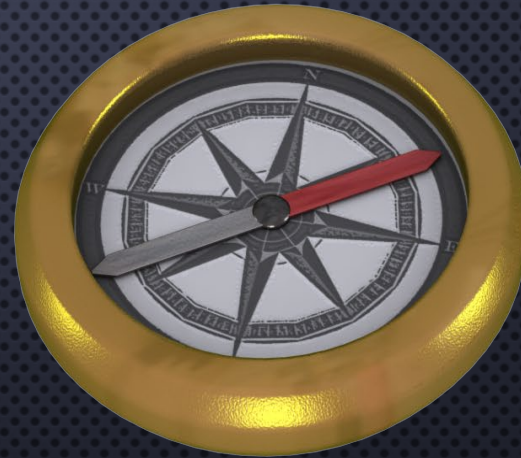
- PUBLISHED DE MAGNETE
  - EARTH IS A MAGNET
- FIRST CRITICAL RESEARCH ON MAGNETS
  - USED LODESTONE
  - DISPELLED SUPERSTITIONS AND MYTHS



# 1820: HANS CHRISTIAN ØRSTED

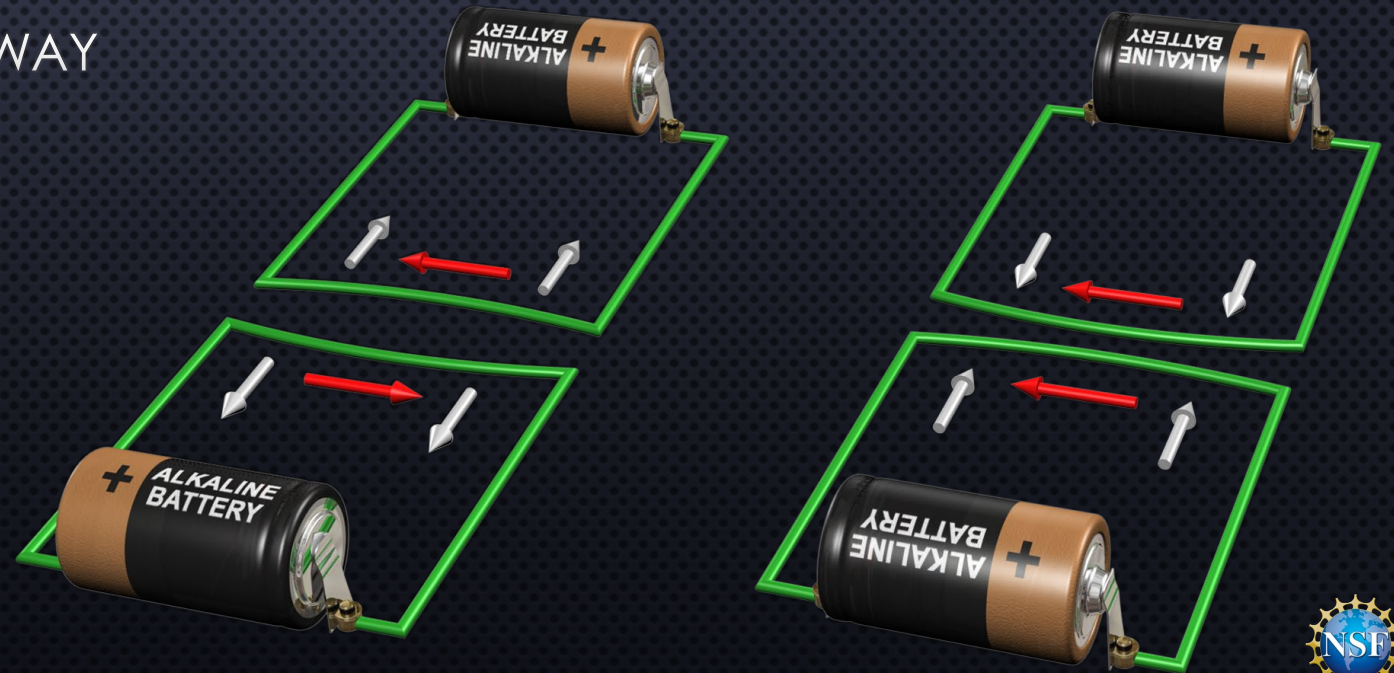
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- AN ELECTRICAL CURRENT CAN CREATE A MAGNETIC FIELD
- ØRSTED SET UP LECTURE DEMONSTRATION
  - USED BATTERY TO SUPPLY CURRENT
  - SHOWED COMPASS NEEDLE DEFLECTING NEAR THE WIRE



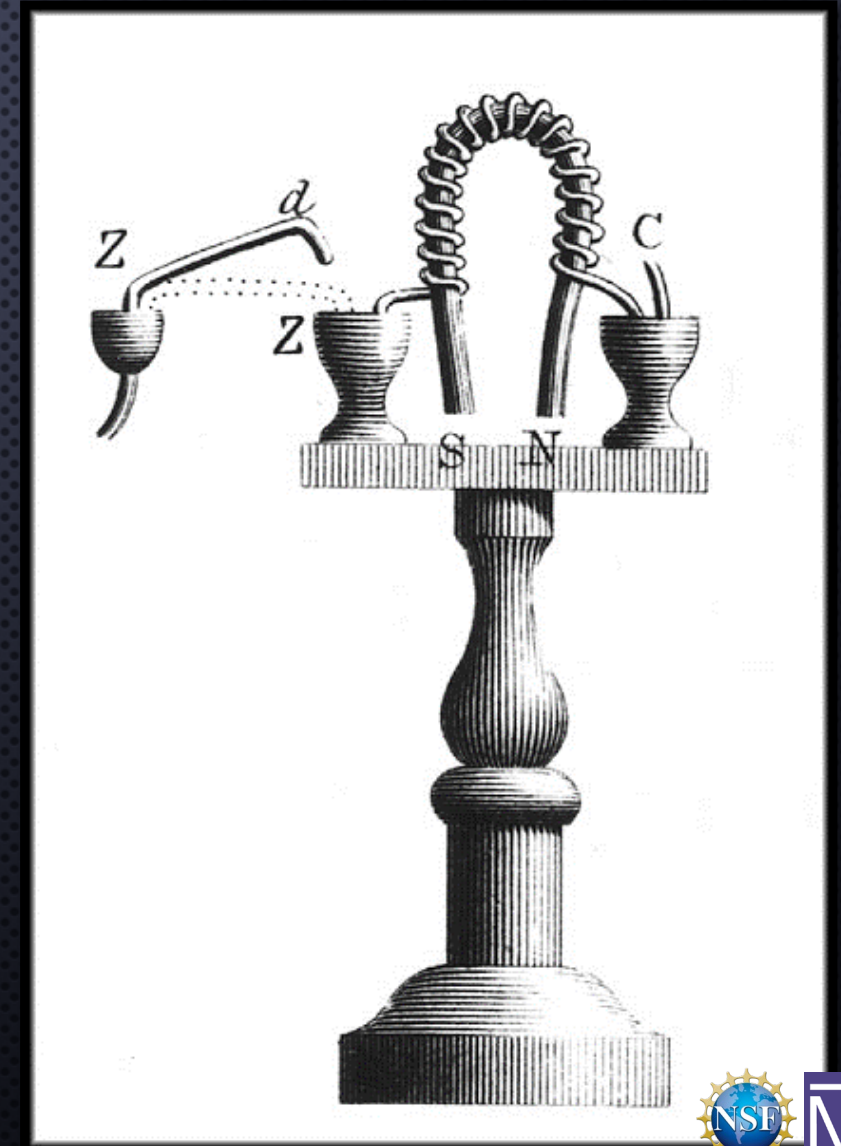
# 1820: ANDRÉ-MARIE AMPÈRE

- 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

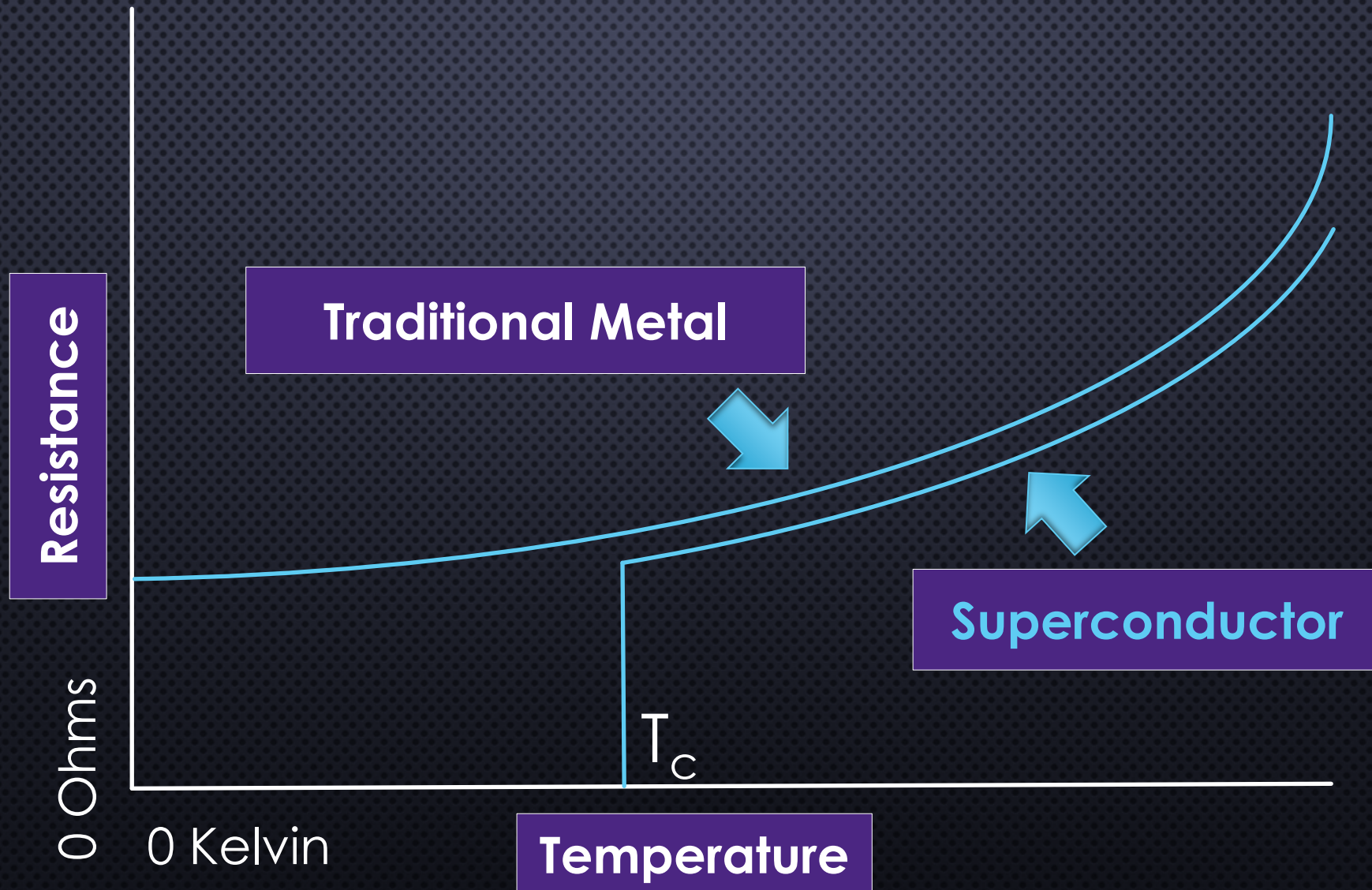


# 1827: JOSEPH HENRY

- IMPROVED THE ELECTROMAGNET
  - LARGER IRON ROD
  - COPPER WIRE
    - INSULATED WITH SILK
  - 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



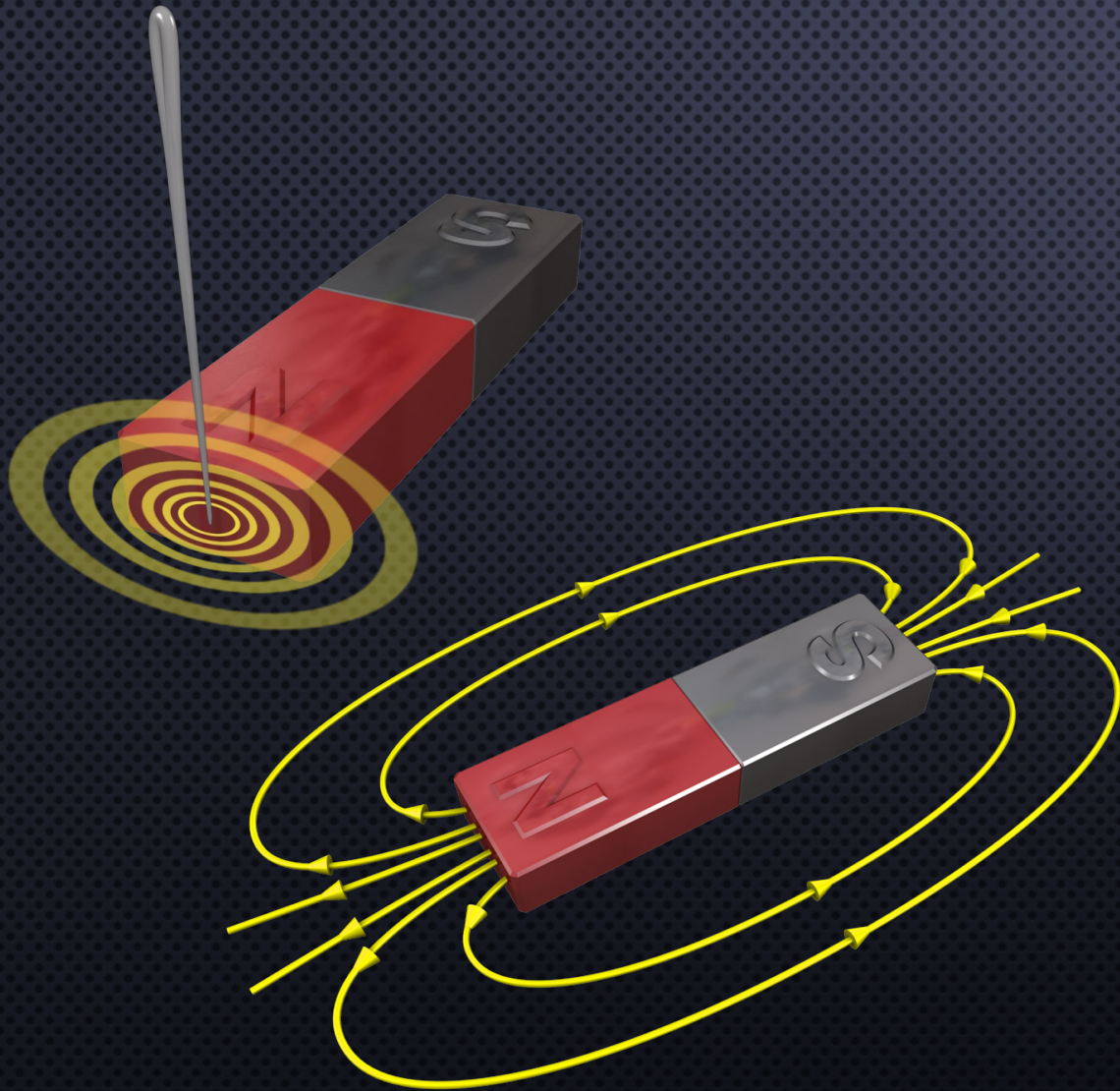
# 1900: SUPERCONDUCTIVITY



# THE SCIENCE OF MAGNETISM

# MAGNETS & MAGNETIC FIELDS

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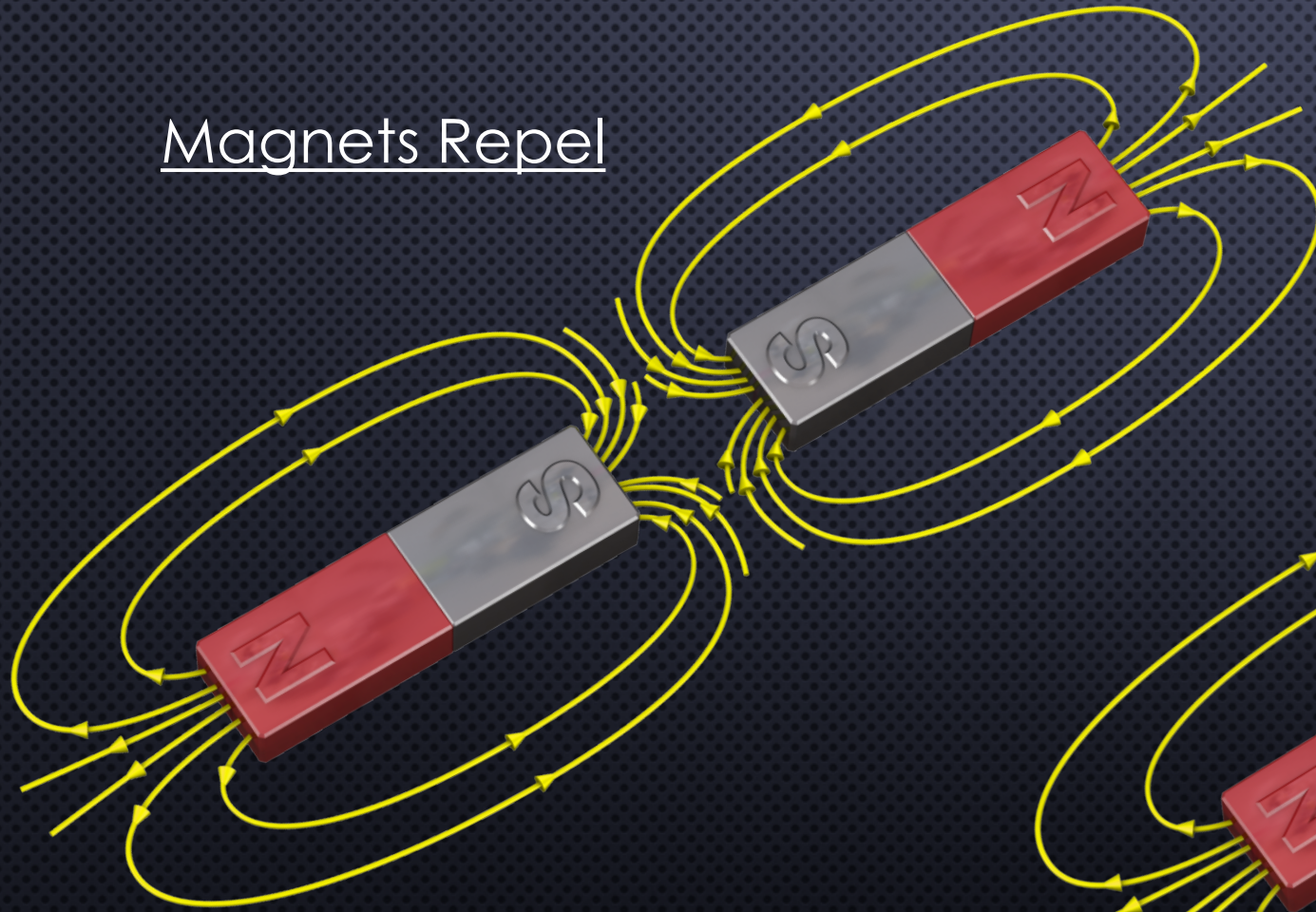


- All magnets have poles
  - North & South
  - Opposites attract; Like repels
- But not really: Magnetic monopole
  - Ongoing research
- All magnets have magnetic fields
- Magnetic field is a vector field
  - Has direction and magnitude

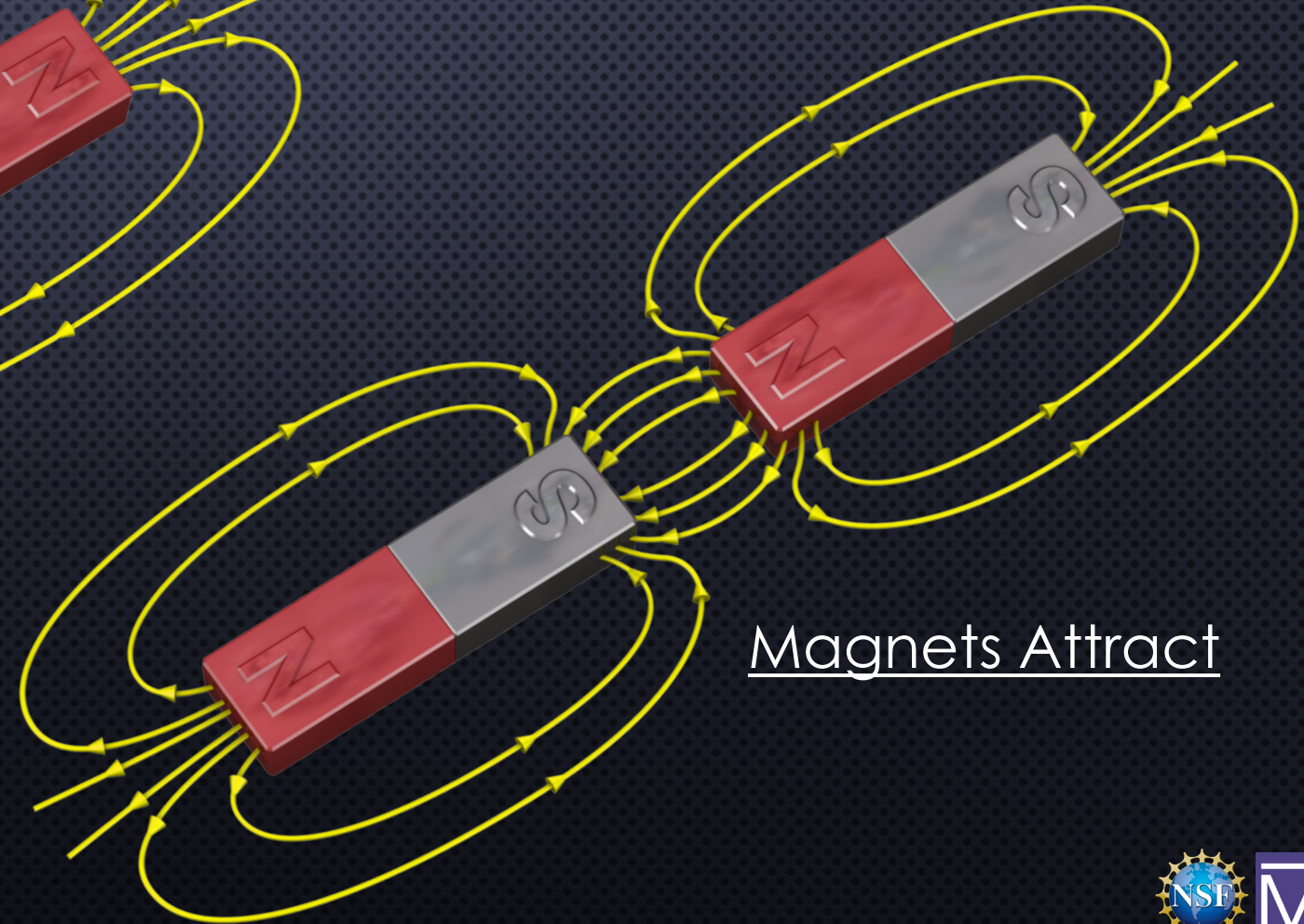
# MAGNETS & MAGNETIC FIELDS

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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

## PERIODIC TABLE OF ELEMENTS

**TABLE KEY**

**1**  
**H**  
Hydrogen  
1.00794

Atomic Number  
Symbol  
Name  
Atomic Mass  
Chemical Group

**CHEMICAL GROUP**

Reactive Nonmetals  
Alkali Metals  
Transition Metals  
Post-Transition Metals

Metalloids  
Noble Gases  
Lanthanoids  
Actinoids

**STATE OF MATTER**

**H** Gas **L** Liquid **S** Solid **U** Unknown

IA	IIA	PERIODIC TABLE OF ELEMENTS										IIIA	IVA	VA	VIA	VIIA	VIIIA
1 <b>H</b> Hydrogen 1.00794																	2 <b>He</b> Helium 4.0026
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012182																10 <b>Ne</b> Neon 20.1797
11 <b>Na</b> Sodium 22.989767	12 <b>Mg</b> Magnesium 24.305																18 <b>Ar</b> Argon 39.948
19 <b>K</b> Potassium 39.0983	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.95591	22 <b>Ti</b> Titanium 47.87	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.93805	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.9332	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.61	33 <b>As</b> Arsenic 74.9216	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.8
37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.9059	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.9055	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Caesium 132.90545	56 <b>Ba</b> Barium 137.327	*	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.96655	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98038	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	**	104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (268)	106 <b>Sg</b> Seaborgium (269)	107 <b>Bh</b> Bohrium (270)	108 <b>Hs</b> Hassium (277)	109 <b>Mt</b> Meitnerium (278)	110 <b>Ds</b> Darmstadtium (281)	111 <b>Rg</b> Roentgenium (282)	112 <b>Cn</b> Copernicium (285)	113 <b>Nh</b> Nihonium (286)	114 <b>Fl</b> Flerovium (289)	115 <b>Mc</b> Moscovium (290)	116 <b>Lv</b> Livermorium (293)	117 <b>Ts</b> Tennessine (294)	118 <b>Og</b> Oganesson (294)
		*	57 <b>La</b> Lanthanum 138.91	58 <b>Ce</b> Cerium 140.12	59 <b>Pr</b> Praseodymium 140.91	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.96	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.93	66 <b>Dy</b> Dysprosium 162.5	67 <b>Ho</b> Holmium 164.93	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93	70 <b>Yb</b> Ytterbium 173.05	71 <b>Lu</b> Lutetium 174.97
		**	89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.04	91 <b>Pa</b> Protactinium 231.04	92 <b>U</b> Uranium 238.03	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendelevium (288)	102 <b>No</b> Nobelium (259)	103 <b>Lr</b> Lawrencium (260)

NATIONAL HIGH  
**MAGNETIC**  
FIELD LABORATORY

DO YOU LIKE MOVIES?



# MAGNETS & MAGNETIC FIELDS

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~~**M**ONSTERS, INC.~~

**M**AGNETS, INC.

INC. = IRON, NICKEL, COBALT

# MAGNETS & MAGNETIC FIELDS

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- MAGNETITE
  - IRON RICH MINERAL
  - LODESTONE IS MAGNETIZED PIECE OF MAGNETITE
  - LED TO FIRST COMPASS



# MAGNETS & MAGNETIC FIELDS

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## PERMANENT MAGNETS

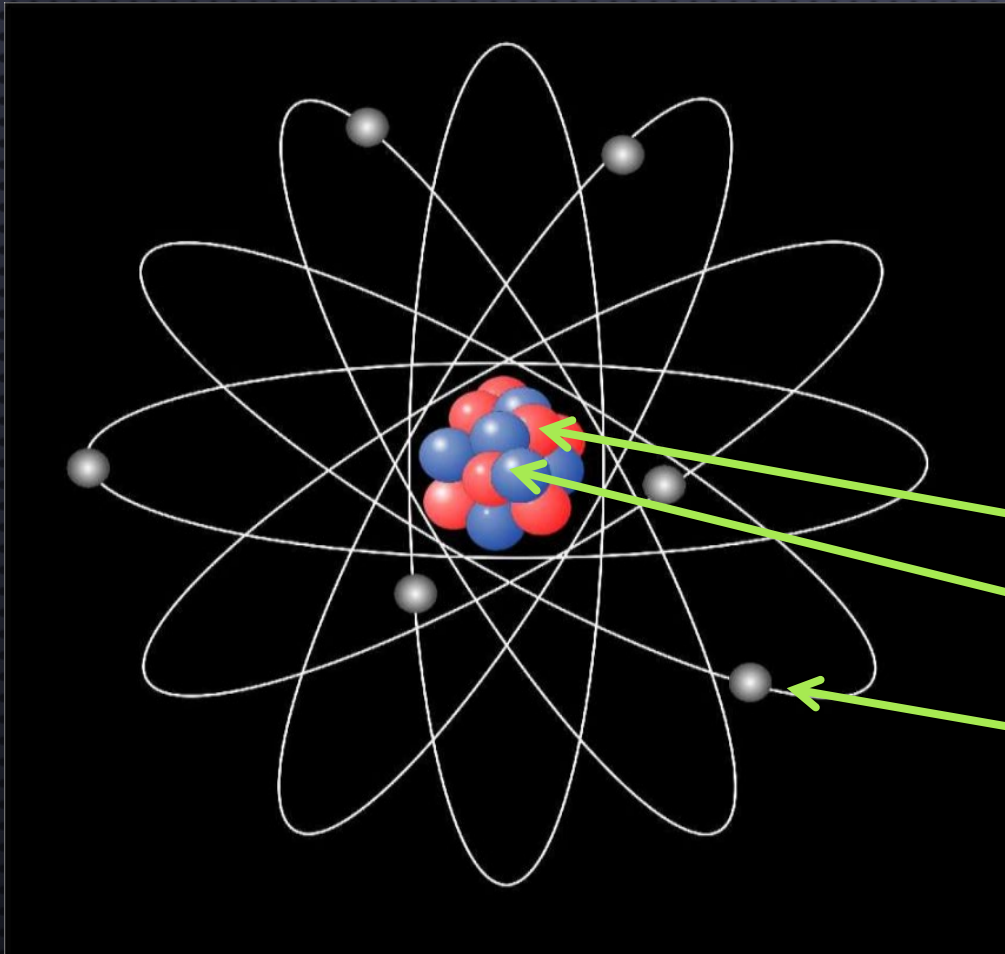
- ALMOST ALWAYS KEEP THEIR FIELD
- FIELDS CAN BE LOST
  - CURIE POINT (HEAT)
  - ELECTRIC CURRENT (DEGAUSS)
  - HITTING IT (BLUNT FORCE)

## 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

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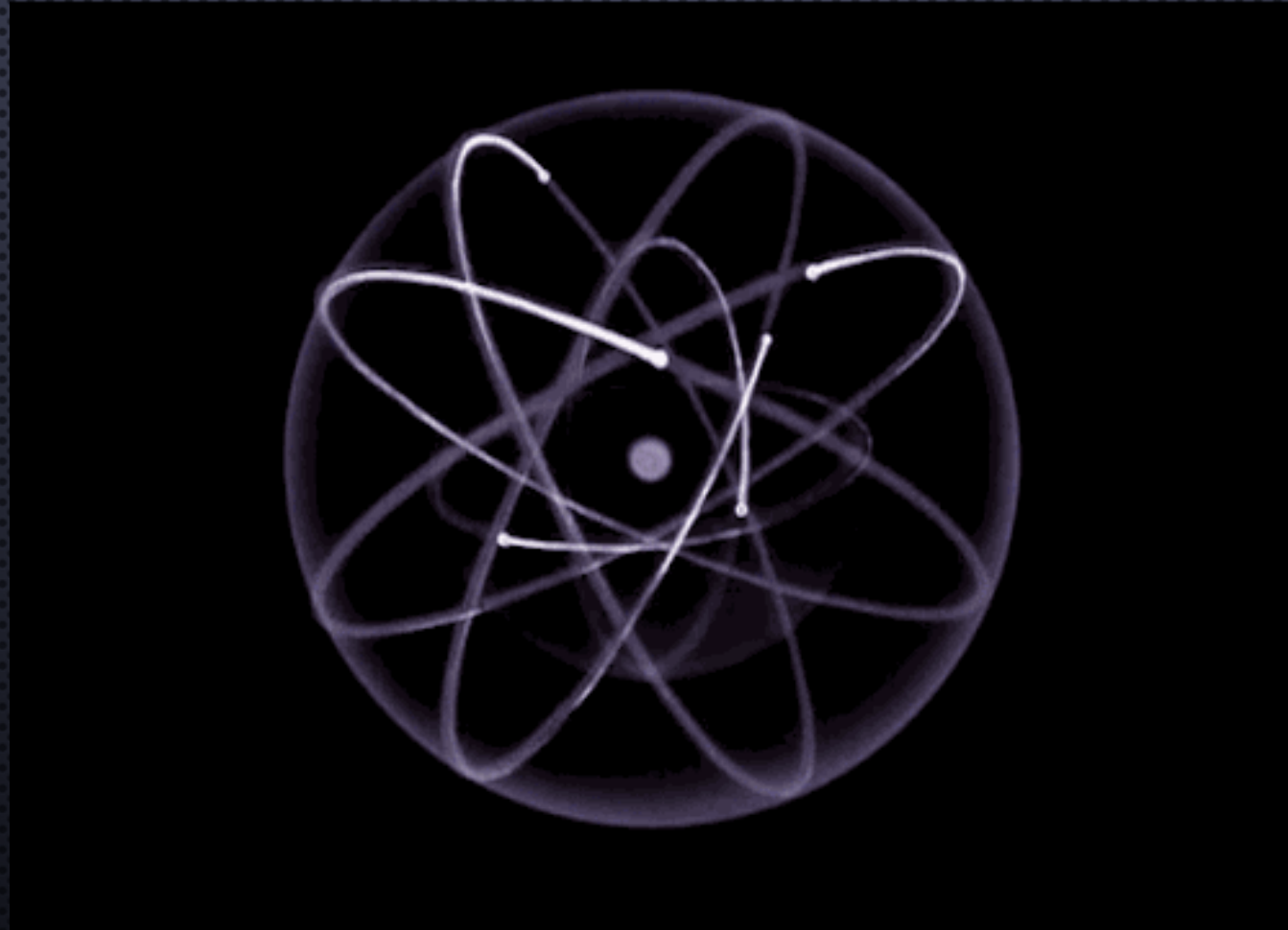


- Name atom comes from *Atomos*, Greek for Indestructible
  - But not really
- The atom is divisible
  - Proton
  - Neutron
  - Electron

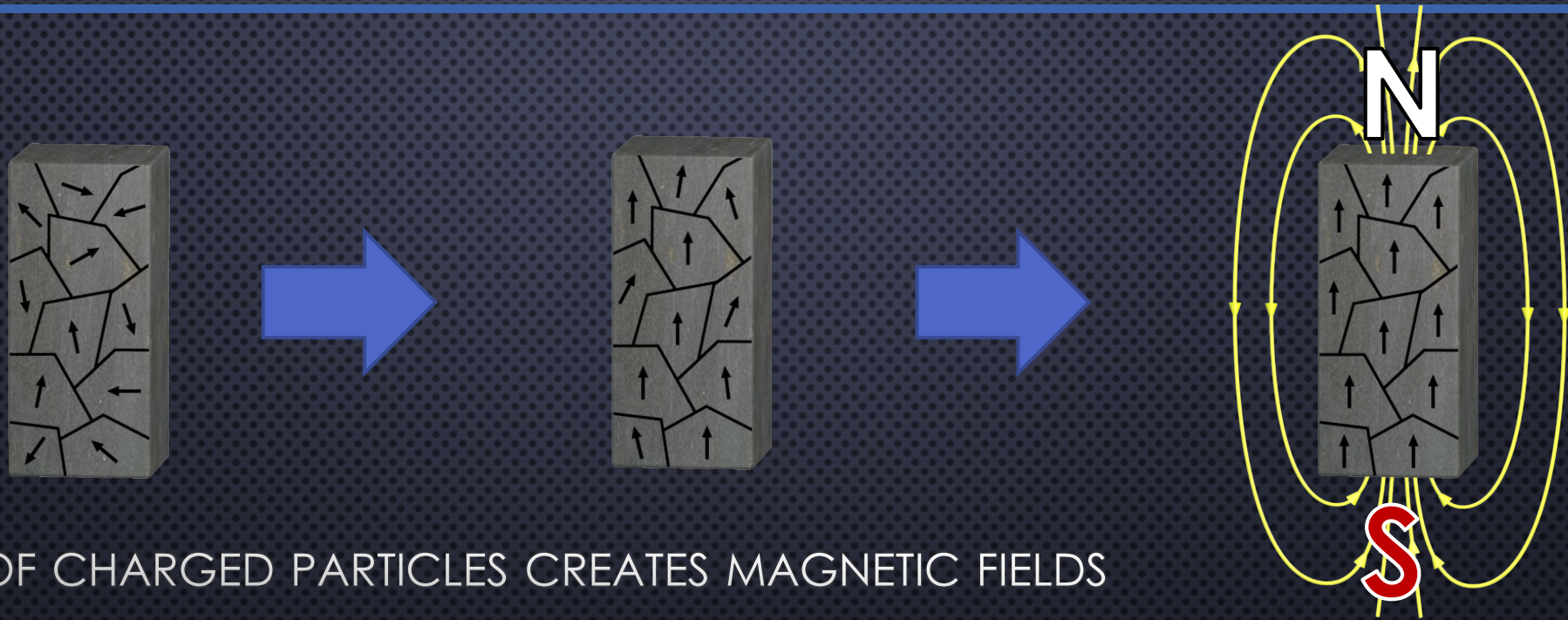


# MAGNETS & MAGNETIC FIELDS

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# WHAT MAKES MAGNETISM?



- 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

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- ELECTRONS MAKE MAGNETISM WORK
  - SPIN OF ELECTRONS
  
- ELECTRONS MAKE ELECTRICITY WORK
  - MOVEMENT OF ELECTRONS

# ELECTROMAGNETISM

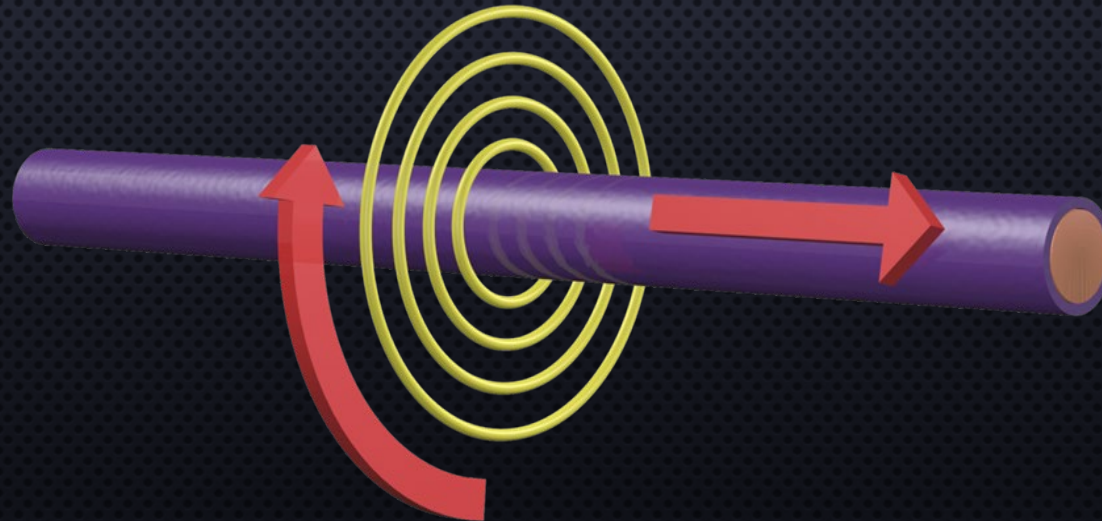
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- THE TWO ARE SO CLOSELY RELATED
- WHERE THERE IS ELECTRICITY, THERE IS A MAGNETIC FIELD
  - WHEN ELECTRONS FLOW, THEY LINE UP (ØRSTED)
- WHERE THERE IS A MAGNETIC FIELD, ELECTRICITY CAN BE CREATED (FARADAY)
  - MAGNETIC FLUX CAN CREATE MOVEMENT OF ELECTRONS

# ELECTROMAGNETISM

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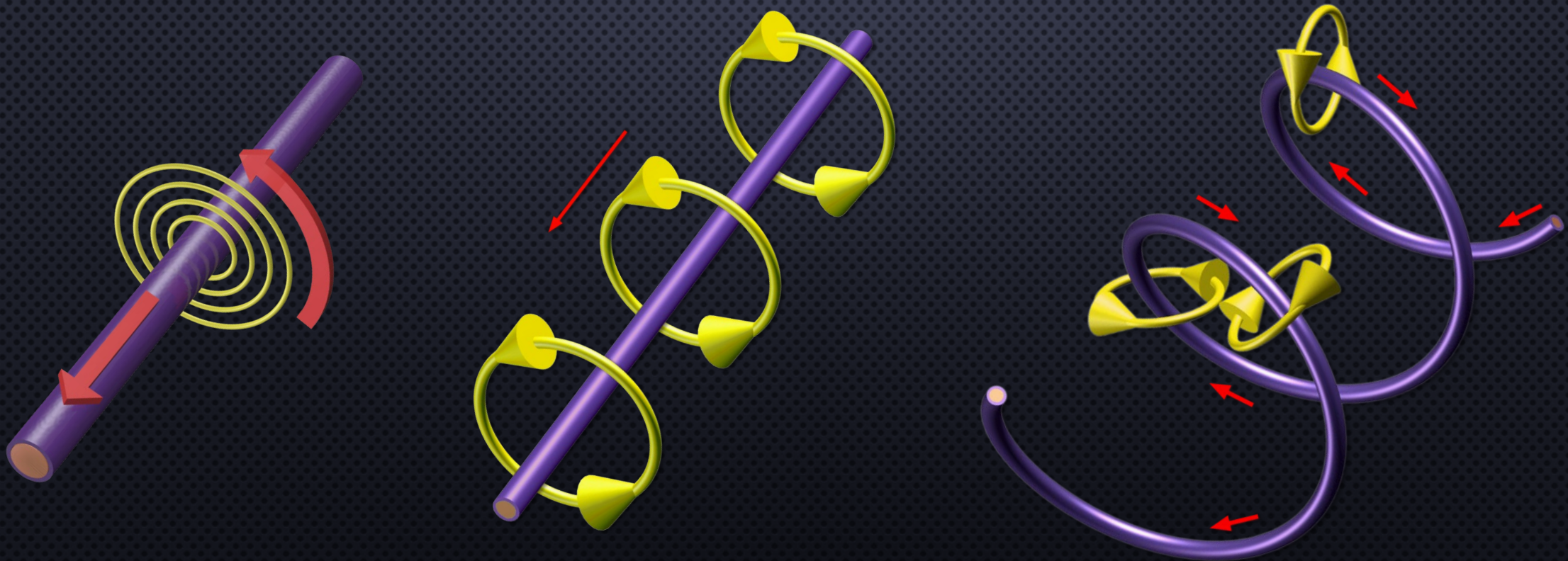
- ELECTRICITY IS THE FLOW OF ELECTRONS
  - ELECTRONS FLOW IN SAME DIRECTION
- THIS ALIGNMENT OF ELECTRONS CREATES A MAGNETIC FIELD AROUND THE CONDUCTOR
  - SIMILAR TO ELECTRONS LINING UP IN A PERMANENT MAGNET
  - SO *EVERY* WIRE CARRYING ELECTRICITY HAS A WEAK MAGNETIC FIELD AROUND IT



# ELECTROMAGNETISM

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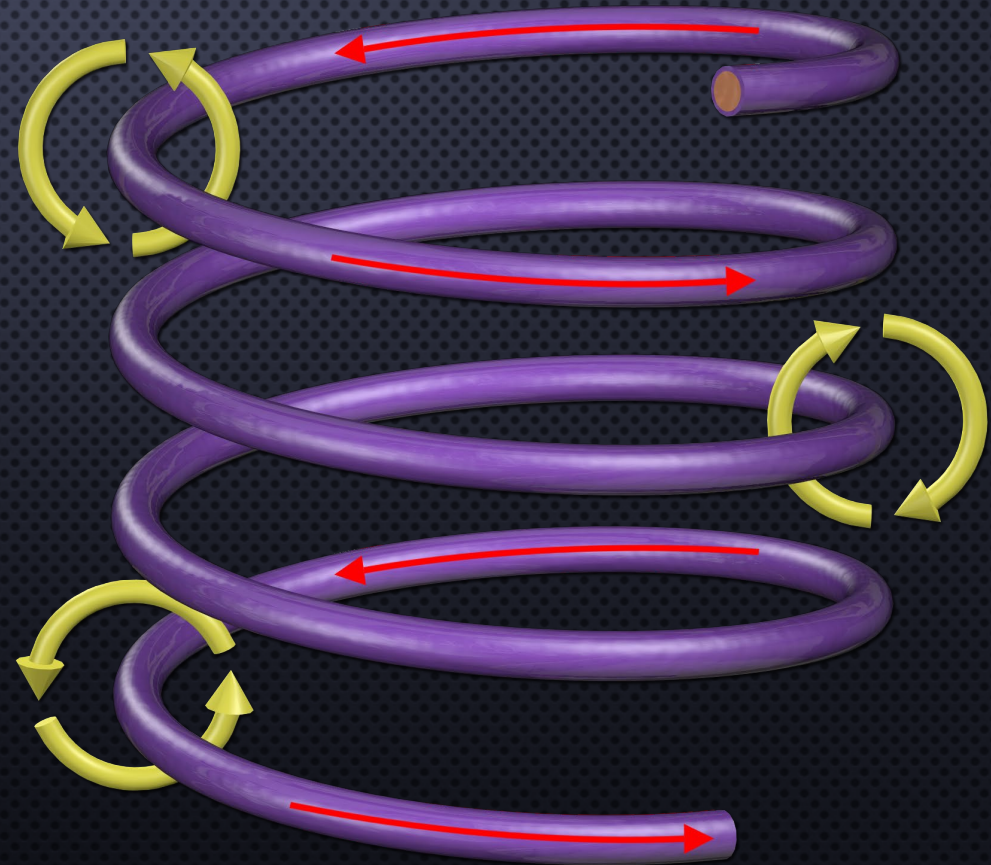
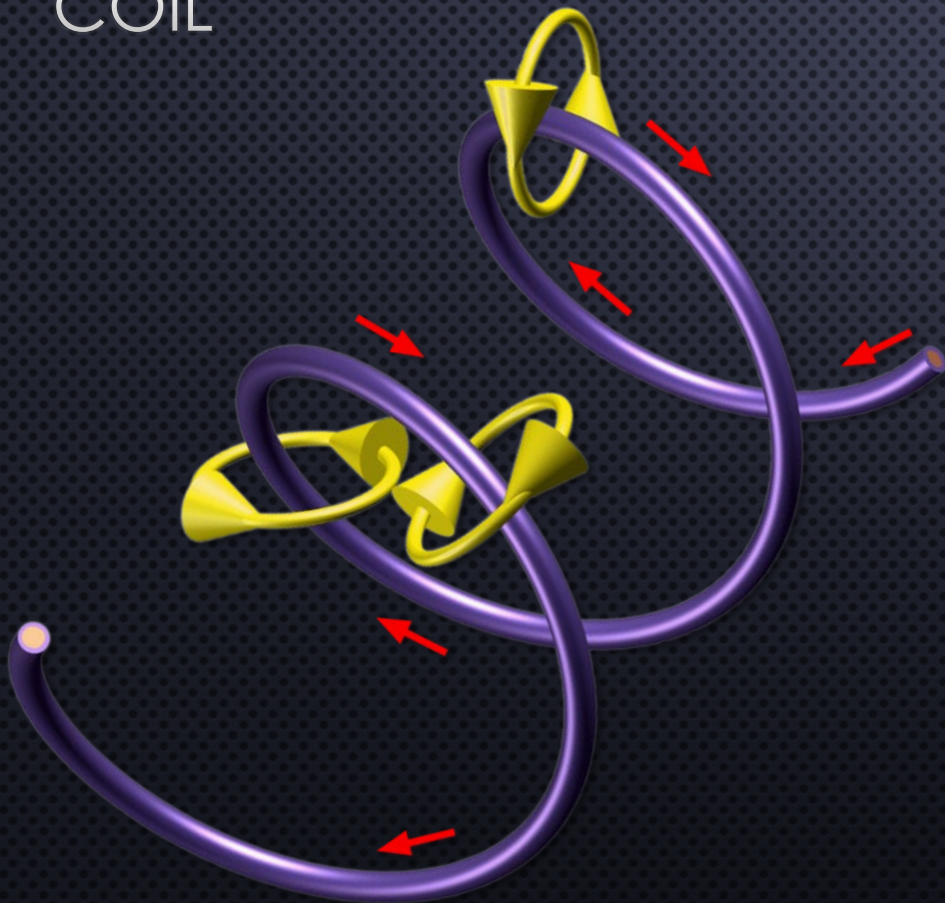
- THE FIELD EXISTS AT ALL POINTS ALONG THE WIRE
- COILING THE WIRE CONCENTRATES THE MAGNETIC FIELD INSIDE THE COIL



# ELECTROMAGNETISM

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- COILING THE WIRE CONCENTRATES THE MAGNETIC FIELD INSIDE THE COIL

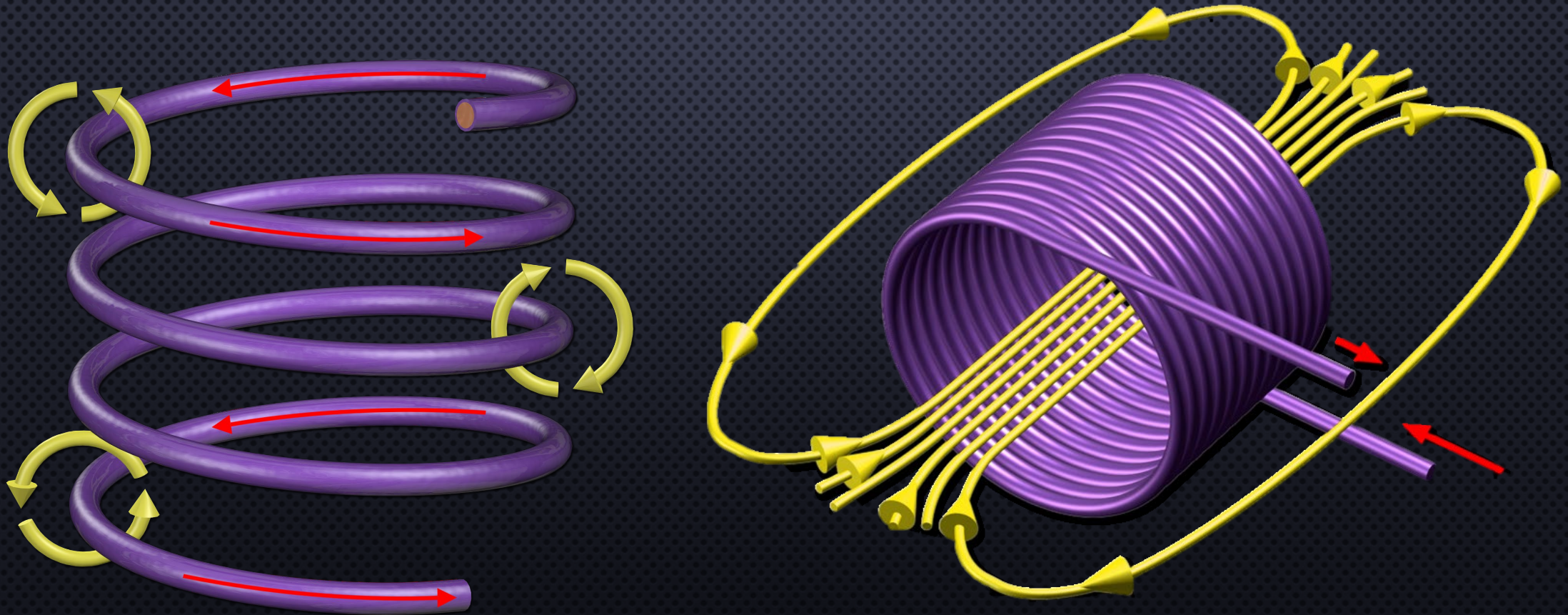




# ELECTROMAGNETISM

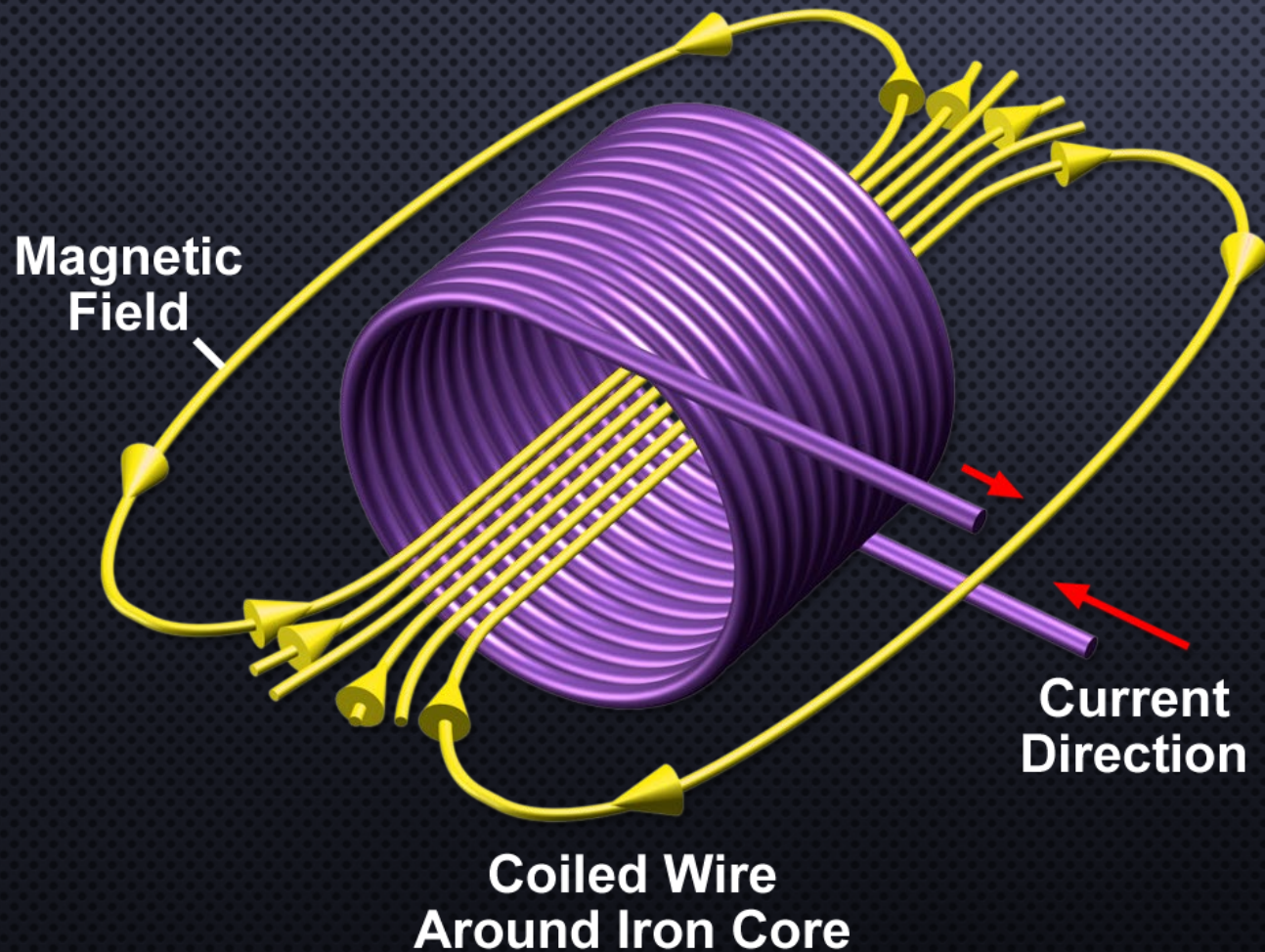
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- COILING THE WIRE CONCENTRATES THE MAGNETIC FIELD INSIDE THE COIL



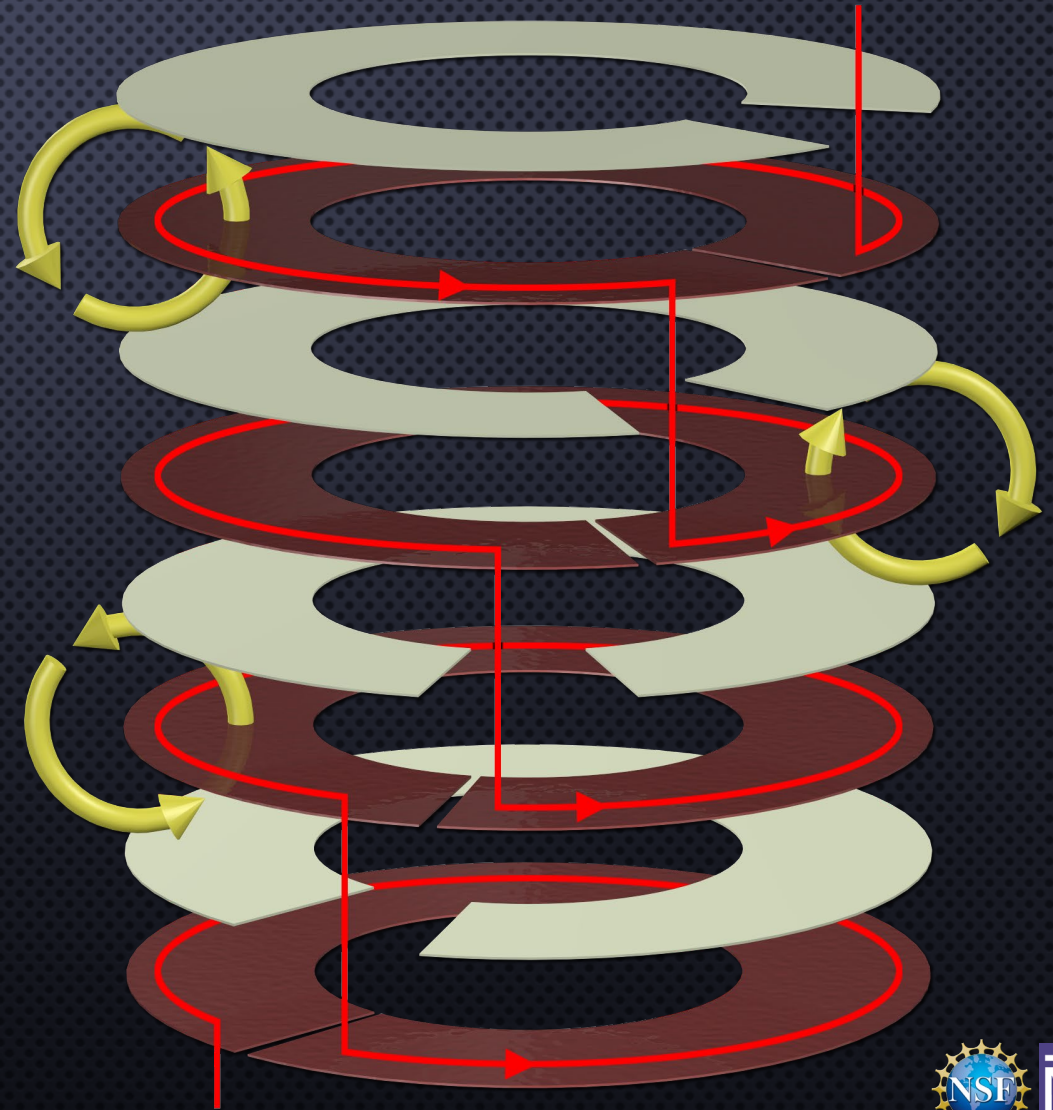
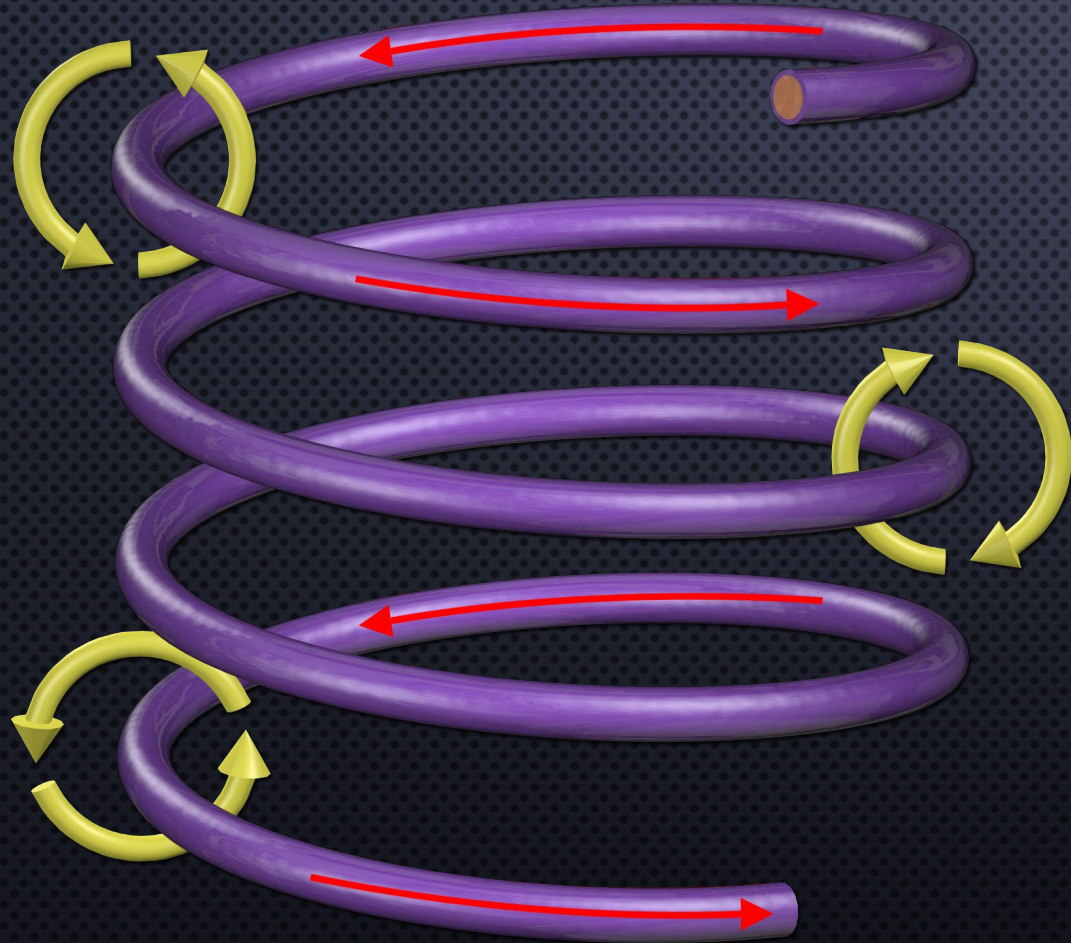
# ELECTROMAGNETISM

- THE MAGNETIC FIELD IS STRONGEST INSIDE THE COIL



# DC RESISTIVE MAGNET BITTER PLATES

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# DC RESISTIVE MAGNET BITTER PLATES

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**MAGNETISM  
ACTIVITIES  
FOR YOUR  
CLASSROOM**

# MAGNETISM



- MAGNET EXPLORATION
- SELF DISCOVERY ACTIVITY
- GROUP EFFORT
- COMMUNICATE YOUR DISCOVERY
- SHARE WITH THE CLASS

# COW MAGNETS

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# 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)...





# MAGNETISM IN OUR FOOD

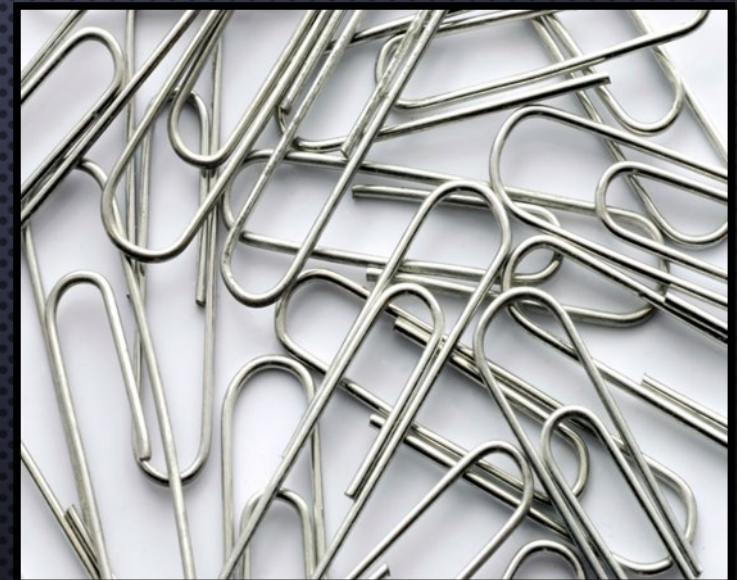
- IRON IN CEREAL
  - NIB MAGNET IS A MUST
  - TOTAL BRAND
  - BABY COOKIES (HIGH IN IRON)
- THE HOOK:
  - BLEND A \$1
  - USE A NIB MAGNET
  - PULL OUT THE IRON



# PERMANENT & TEMPORARY MAGNETS

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- 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

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- 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

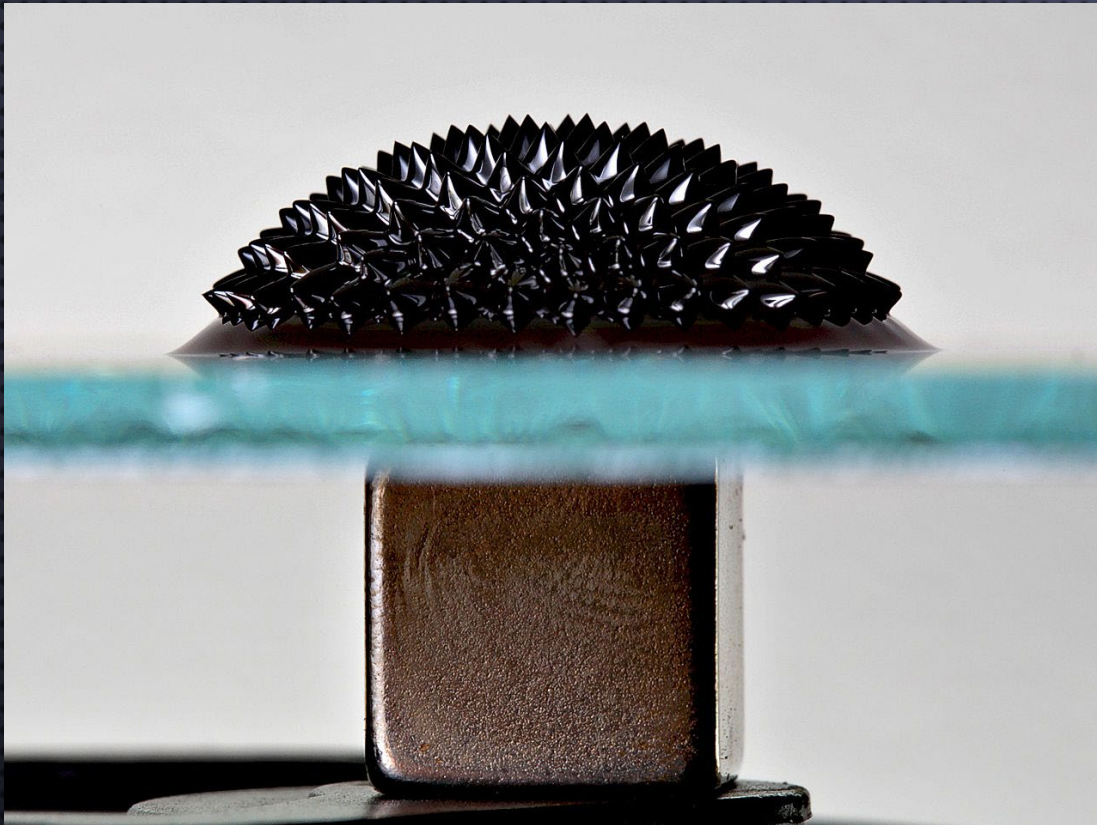
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- MAGNETS ARE MAGNETIZED SHORT LENGTH
- MADE OF STRONG BARIUM FERRITE
- THEY ATTRACT BUT BOUNCE UPON IMPACT AND SEPARATE
- PROCESS REPEATS WITH A LITTLE ENERGY LOST EACH TIME
- PITCH CHANGES
  - FREQUENCY INCREASES
  - AMPLITUDE DECREASES

# THE MAGNETIC HEDGEHOG

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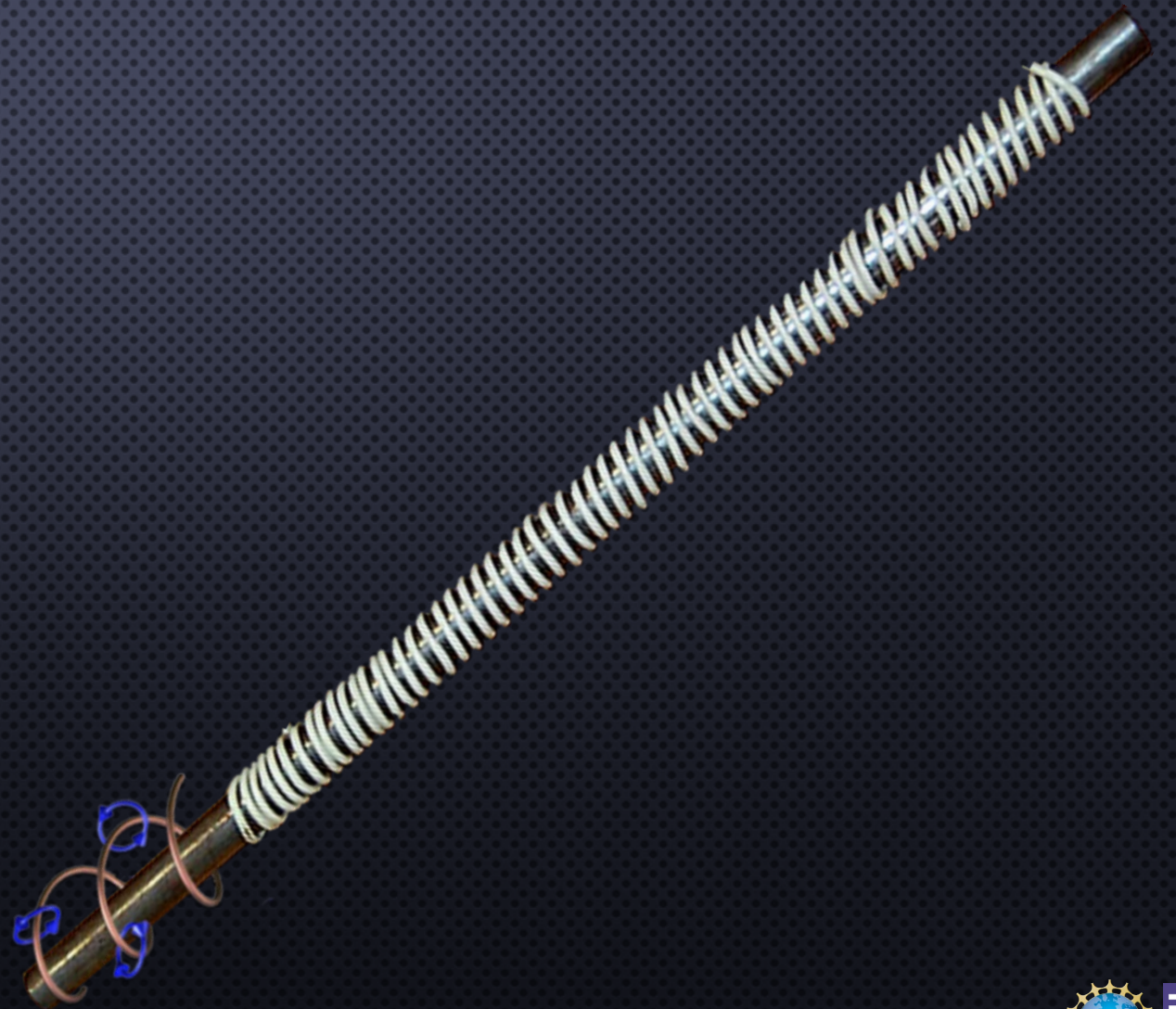


- FERROFLUIDS AKA LIQUID MAGNETS
  - SUSPENSION OF IRON NANOPARTICLES
- FLUID ADHERES TO MAGNETIC FIELD LINES
- INCREDIBLY ATTRACTIVE
  - **BE CAUTIOUS**

# ELECTROMAGNETISM EXTENSIONS

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- RIGHT HAND RULE
  - DIRECTION OF FIELD
- POLES (WINDING DIRECTION)
- VARIABLES:
  - NEATNESS
  - NUMBER OF WINDS
  - WIRE GAUGE
  - BATTERY STRENGTH
  - TEMPERATURE
  - PRECISION



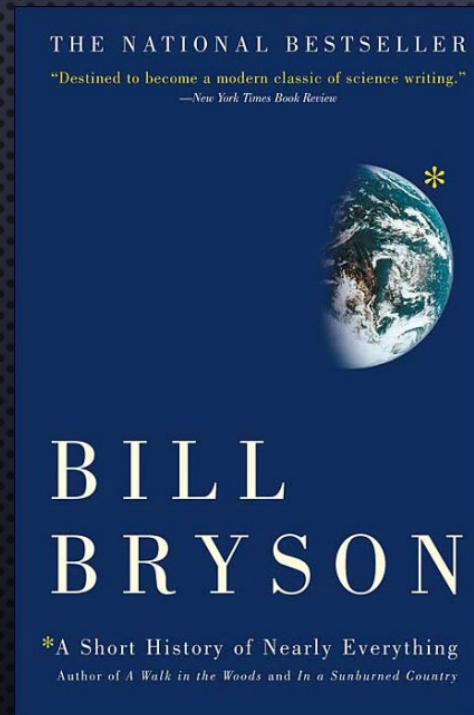
MAGNETISM  
RESOURCES  
FOR FURTHER  
LEARNING





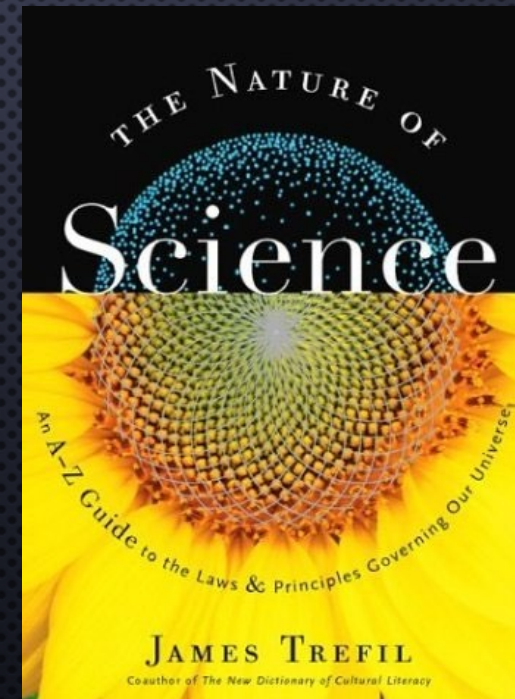
# A SHORT HISTORY OF NEARLY EVERYTHING

BILL BRYSON



# THE NATURE OF SCIENCE

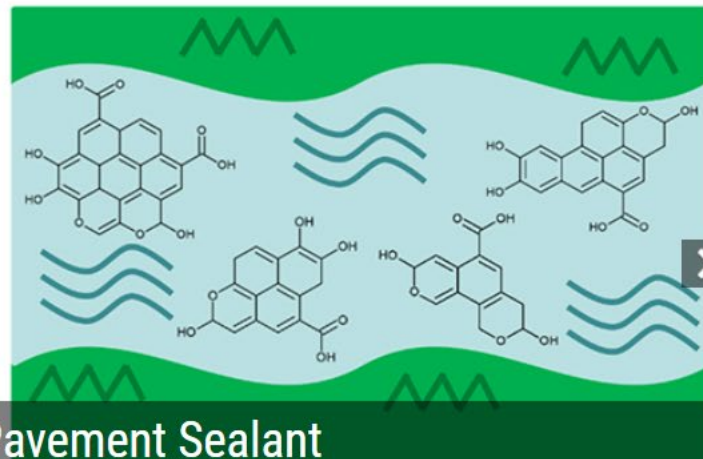
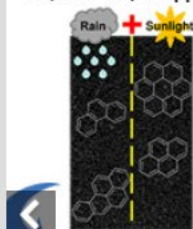
JAMES TREFIL





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

Coal Tar Pavement Sealant:  
50,000 – 75,000 ppm PAHs



### 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.

Laboratory Scale Weathering (1998 and 2007)

Toxic Chemicals in Groundwater Ecosystems



### Research Initiatives

MATERIALS



ENERGY



LIFE



### See-Thru Science



Popular YouTube See-Thru Science Series is now available En Español. [Find out more.](#)

### User Facilities

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

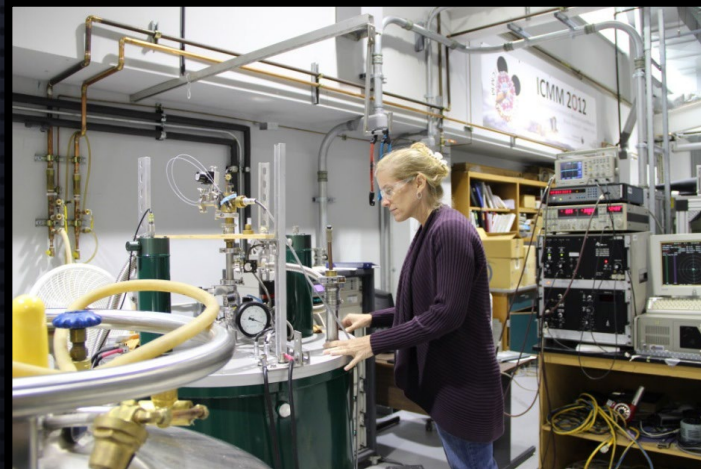


MAGLAB  
RESEARCH  
EXPERIENCE FOR  
TEACHERS  
(RET)

# MAGLAB RET 2023

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- SUMMER PROGRAM
  - 1 WEEK IN PERSON
    - IN THE MAGLAB
  - 5 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

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- 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

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- BUSINESS CARDS
  - PLEASE DO NOT HESITATE TO CONTACT US WITH QUESTIONS, IDEAS, SUGGESTIONS, ETC...
- RET APPLICATIONS:
  - [HTTPS://NATIONALMAGLAB.ORG/EDUCATION/](https://nationalmaglab.org/education/)

# Thank You



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