Re-creation of Historical Inventions with 3D Printing for use in STEM Education

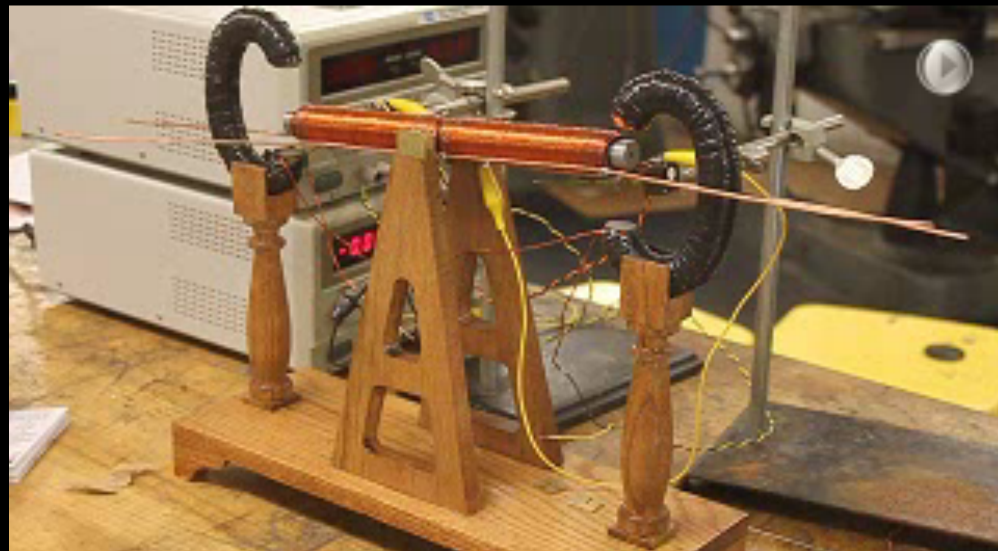
Engineering Objects and Systems

Foundational, Simple and Understandable, Inspirational, and Applicable Today

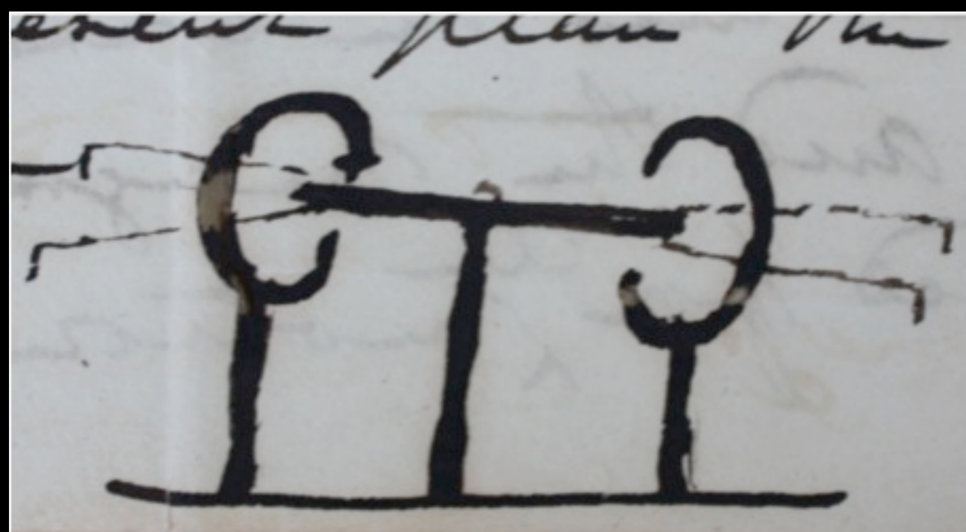
Galileo, Henry, Morse, Edison, Bell, Ford

Prof. Michael Littman
Mechanical and Aerospace Engineering
Princeton University

Charlottesville Va – 16 April 2015

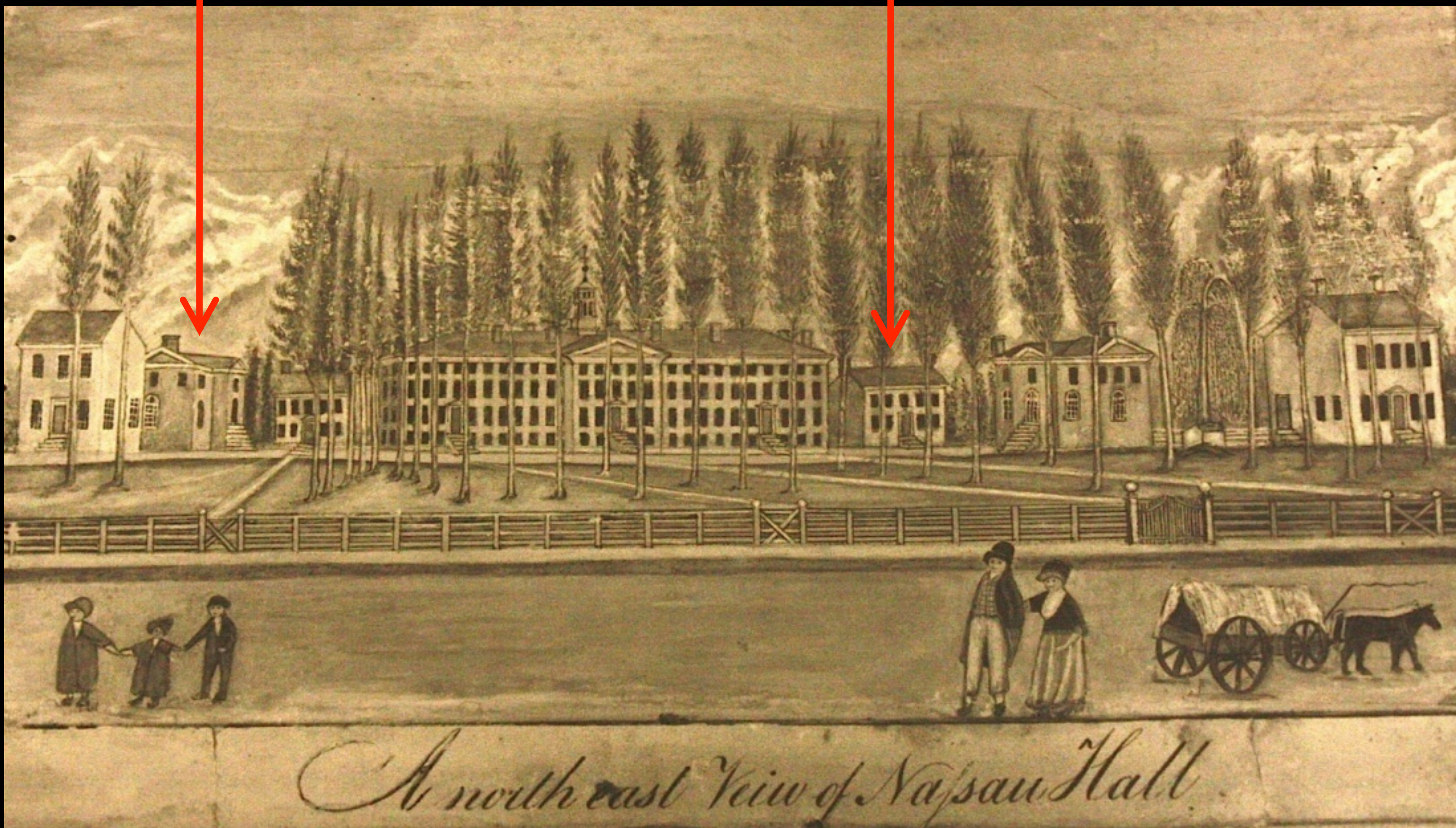


Joseph Henry's Electromagnetic Motor of 1835

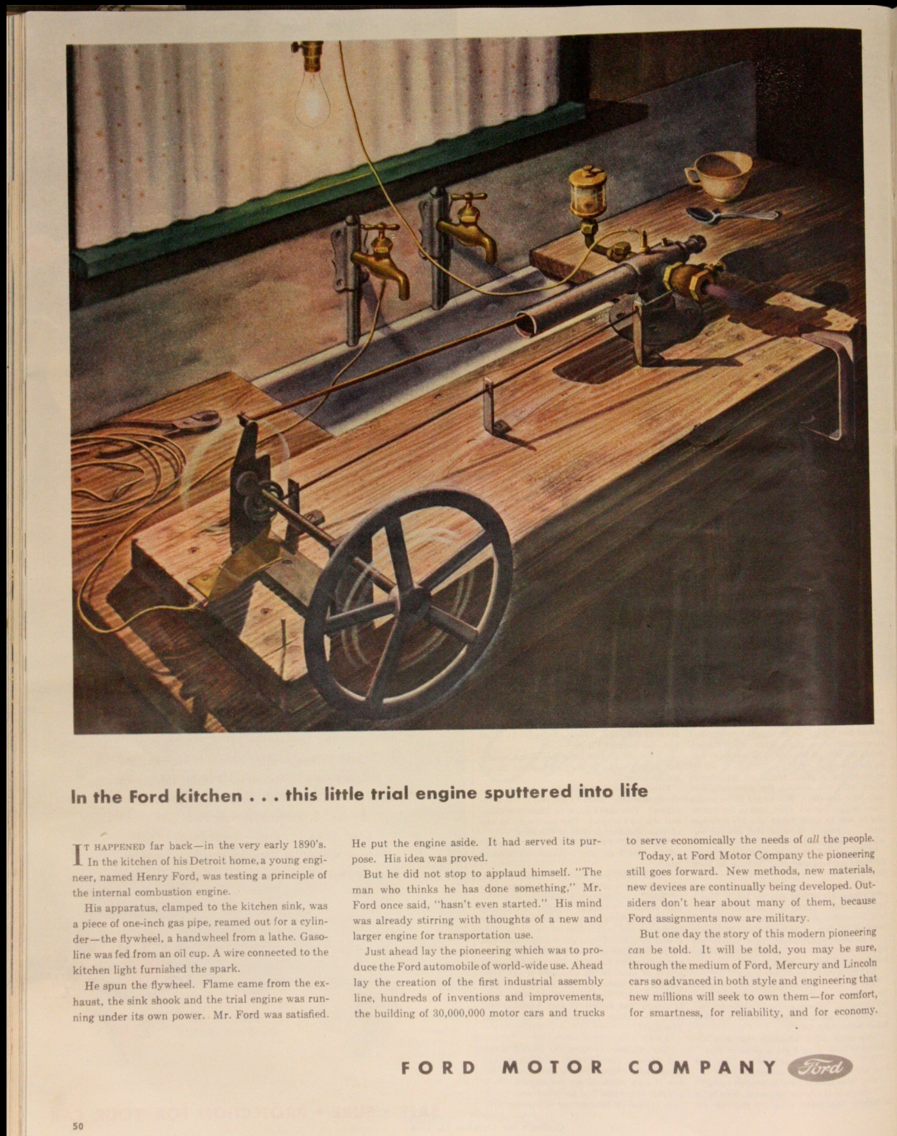


Joseph Henry's Lab
1832 - 1846

Joseph Henry's First House
1832 - 1837



Princeton Front Campus (1825)



In the Ford kitchen . . . this little trial engine sputtered into life

IT HAPPENED far back—in the very early 1890's. In the kitchen of his Detroit home, a young engineer, named Henry Ford, was testing a principle of the internal combustion engine.

His apparatus, clamped to the kitchen sink, was a piece of one-inch gas pipe, reamed out for a cylinder—the flywheel, a handwheel from a lathe. Gasoline was fed from an oil cup. A wire connected to the kitchen light furnished the spark.

He spun the flywheel. Flame came from the exhaust, the sink shook and the trial engine was running under its own power. Mr. Ford was satisfied.

He put the engine aside. It had served its purpose. His idea was proved.

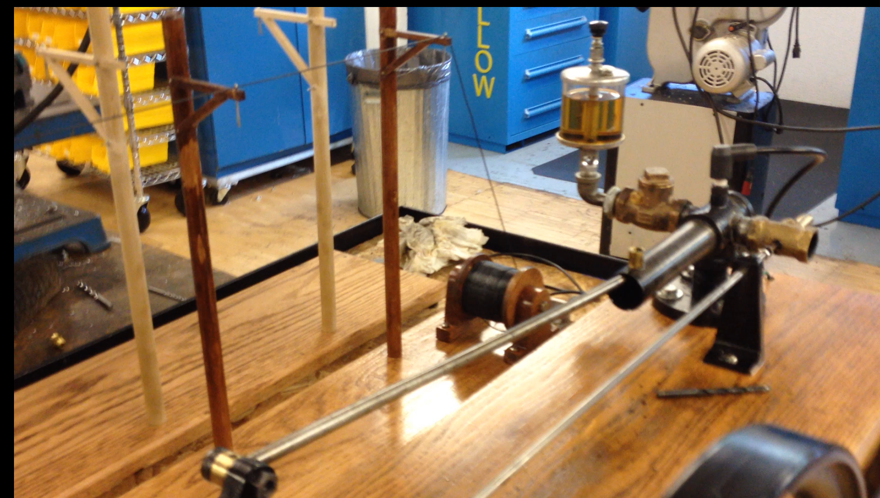
But he did not stop to applaud himself. "The man who thinks he has done something," Mr. Ford once said, "hasn't even started." His mind was already stirring with thoughts of a new and larger engine for transportation use.

Just ahead lay the pioneering which was to produce the Ford automobile of world-wide use. Ahead lay the creation of the first industrial assembly line, hundreds of inventions and improvements, the building of 30,000,000 motor cars and trucks to serve economically the needs of *all* the people.

Today, at Ford Motor Company the pioneering still goes forward. New methods, new materials, new devices are continually being developed. Outsiders don't hear about many of them, because Ford assignments now are military.

But one day the story of this modern pioneering *can* be told. It will be told, you may be sure, through the medium of Ford, Mercury and Lincoln cars so advanced in both style and engineering that new millions will seek to own them—for comfort, for smartness, for reliability, and for economy.

FORD MOTOR COMPANY



Henry Ford's Gasoline Engine
Mack Avenue, Detroit - 1893

Why STEM?

BELIEVES ROCKET CAN REACH MOON

Smithsonian Institution Tells of Prof. Goddard's Invention to Explore Upper Air.

MULTIPLE-CHARGE SYSTEM

Instruments Could Go Up 200 Miles, and Bigger Rocket Might Land on Satellite.

Special to The New York Times.

WASHINGTON, Jan. 11.—Announcement was authorized by the Smithsonian

New York Times - 1920

His Plan Is Not Original.

That Professor GODDARD, with his "chair" in Clark College and the countenancing of the Smithsonian Institution, does not know the relation of action to reaction, and of the need to have something better than a vacuum against which to react—to say that would be absurd. Of course he only seems to lack the knowledge ladled out daily in high schools.

New York Times Editorial on the following day

Einstein Quote

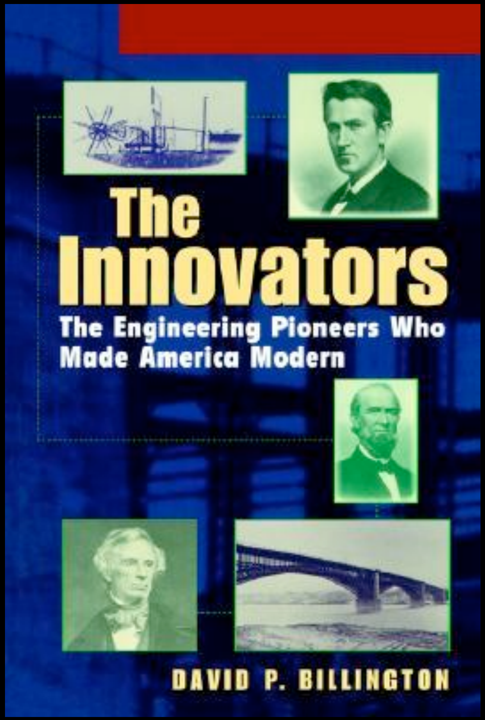
CEE 102 "Engineering in the Modern World"

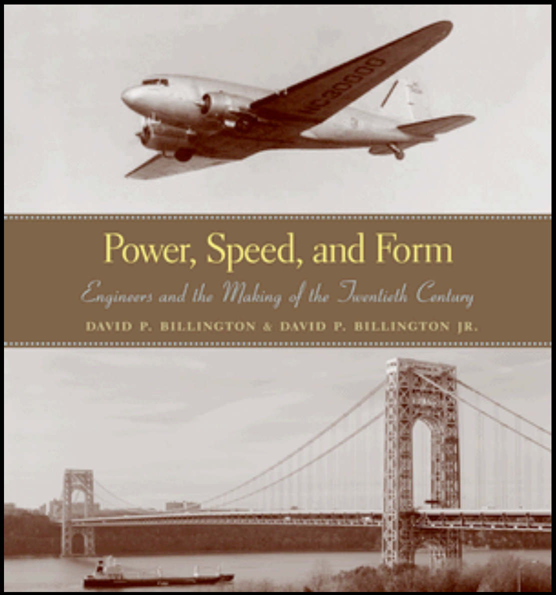
PERSPECTIVES

Scientific	Formulas
Social	Context
Symbolic	Meaning

PLANS

Structures	Civil
Machines	Mechanical
Networks	Electrical
Processes	Chemical





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PERIODS

Iron, Independence, and Industry
1776 - 1855

Connecting the Continent
1830 - 1883

Rise of the Great Industries
1876 - 1939

Regional Restructuring
1921 - 1964

Information and Infrastructure
1946 - present

CEE 102 "Engineering in the Modern World"

How do innovations happen?

Scientific:	**How does it work?**
Social:	**What is it good for?** **What is the context?**
Symbolic:	**Why should I care?**
Person:	**Who did what?**
Motivation:	**Why did they do it?**
History:	**When and Where?** **What is the impact?**

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Men of Progress - 1858

People of Progress - 1999

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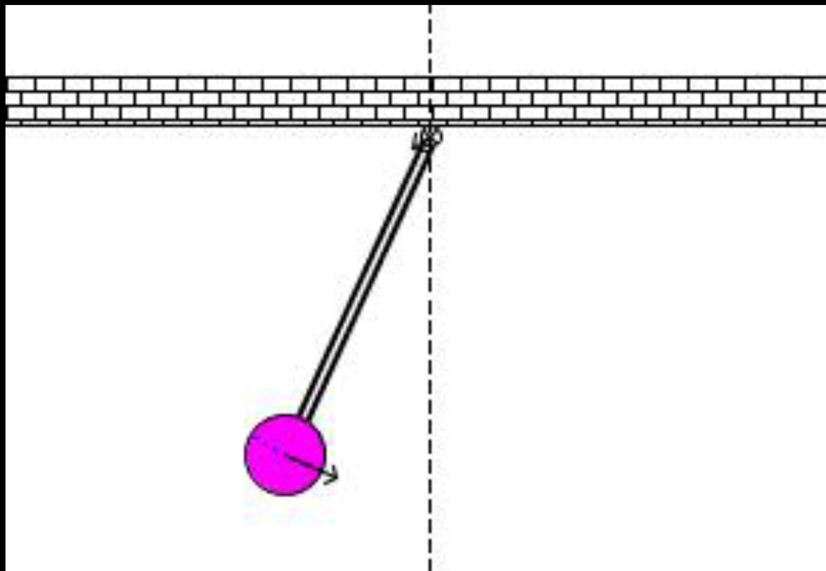
Galileo Galilei (1564 – 1642)



Magic of Gravity and Inertia

Energy Conversion – Potential to Kinetic

Scientist: What is going on here?

Engineer: What can we do with it?

Context: Before Newton and Kelvin

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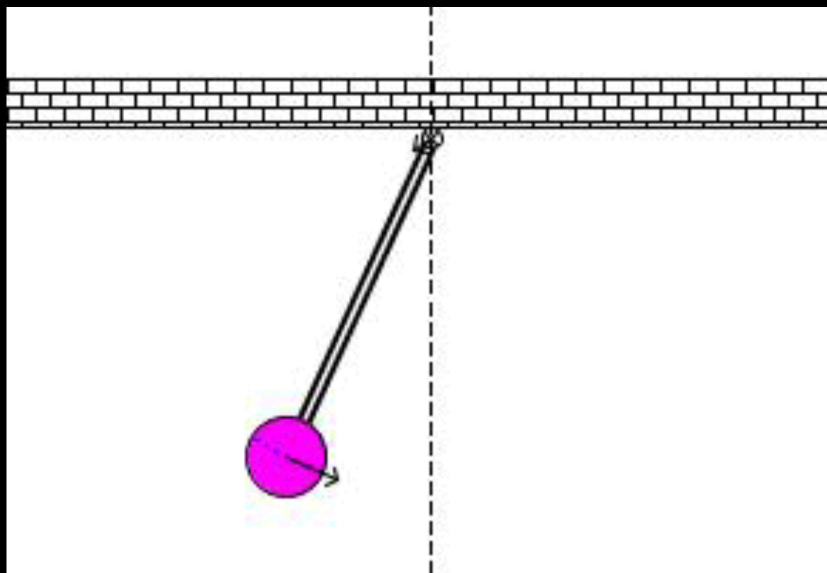

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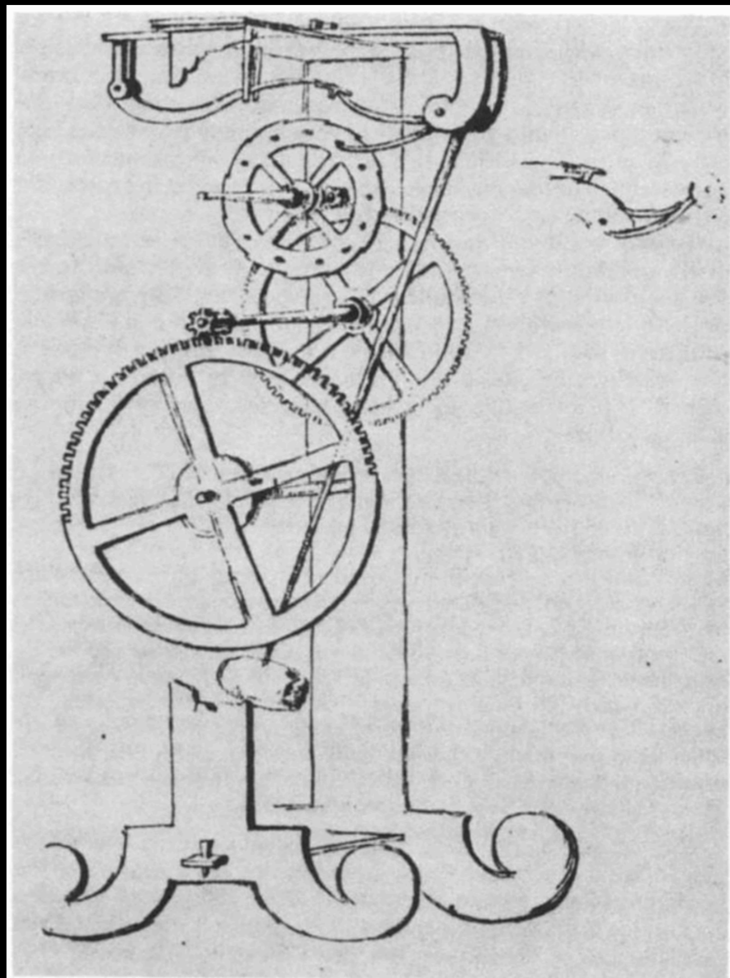
Galileo's Discovery:

- **As long as the swing angle is kept small, the oscillation period is independent of amplitude**
- **Oscillation period is independent of weight of bob**
- **Oscillation period increases as the square-root of the length**

Galileo's Design:

- **Wants to time experiments using pendulum instead of his pulse**
- **Pendulum timer was a good idea, but it had some problems**



Galileo's Pendulum Clock

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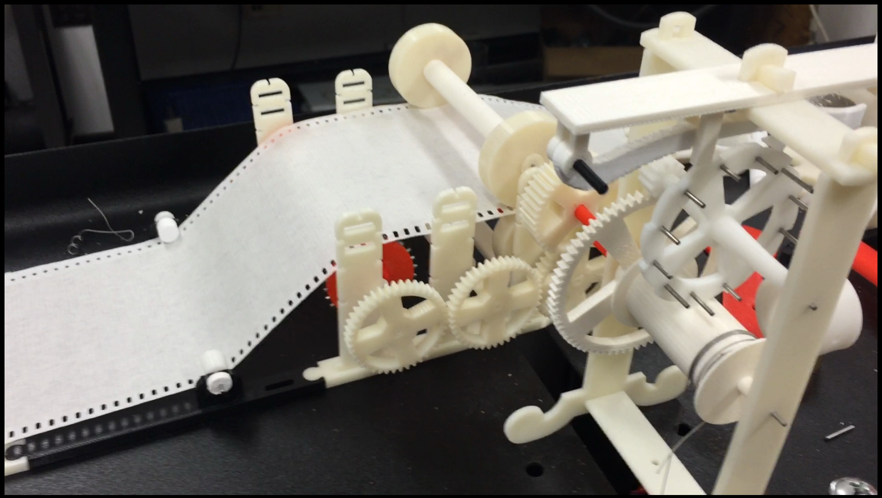
Galileo’s Pendulum Clock

Pendulum will lose amplitude due to friction -Verge and Escape Wheel (pawl and ratchet) and dropping weight compensate for this loss

Another use of a clock – Samuel Morse uses a weight driven clock in 1837 to move a paper strip as part of his printing telegraph



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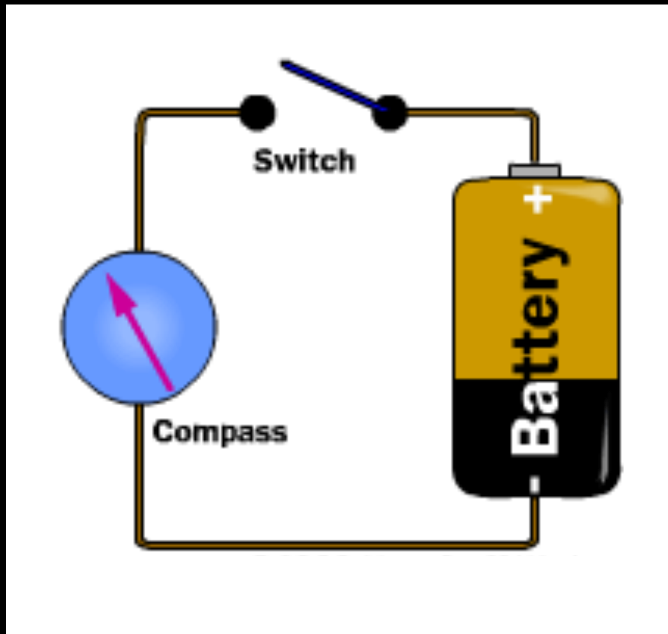

Magic of Electromagnetism

Chemical to Electrical

Electric Current creates Magnetic Field

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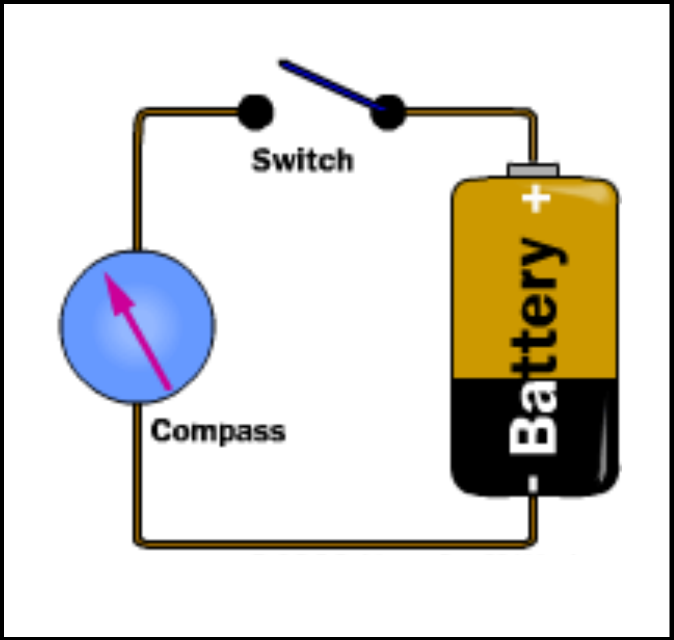

Magic of Electromagnetism
Chemical to Electrical
Electric Current creates Magnetic Field

Many loops
of wire

Scientist: What is going on here?

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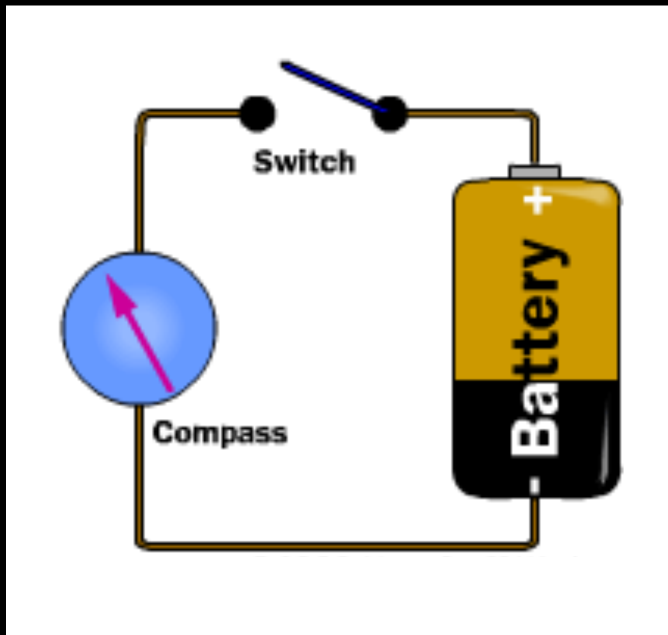
Schweigger’s Galvanic Multiplier
(aka Tangent Galvanometer)
Many turns of wire increases the effect

Demonstration



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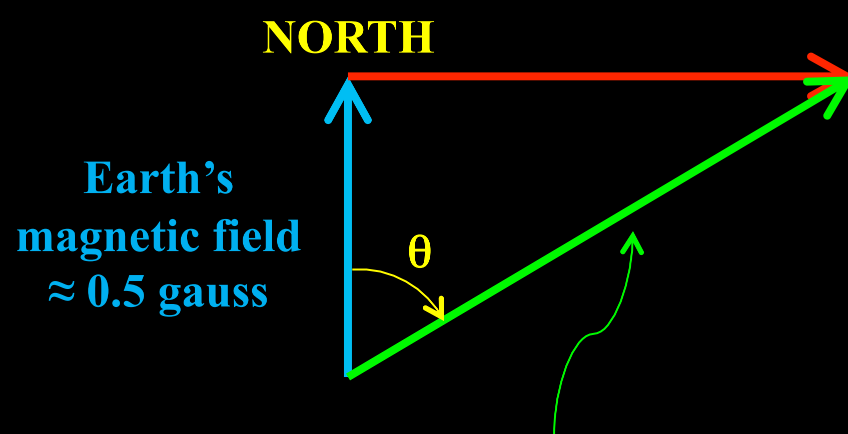
Why is it called a Tangent Galvanometer ?

magnetic field due to current in coil of many turns

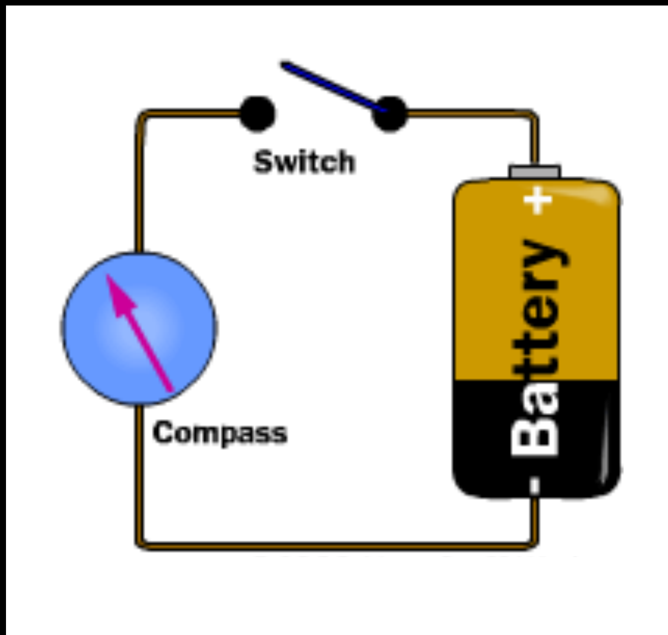
- **strength proportional to current**



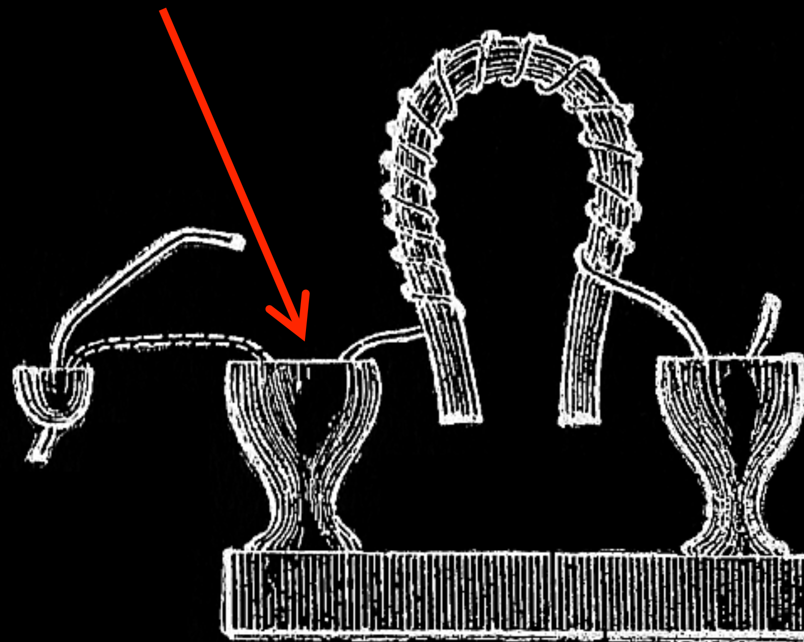
Resultant field is vector sum of two magnetic fields

- **current is proportional to tan θ**
- **measure θ using magnetic compass to determine current**

- Great way to teach vectors
- Ammeter with all parts visible



Galvanic cell
(battery)



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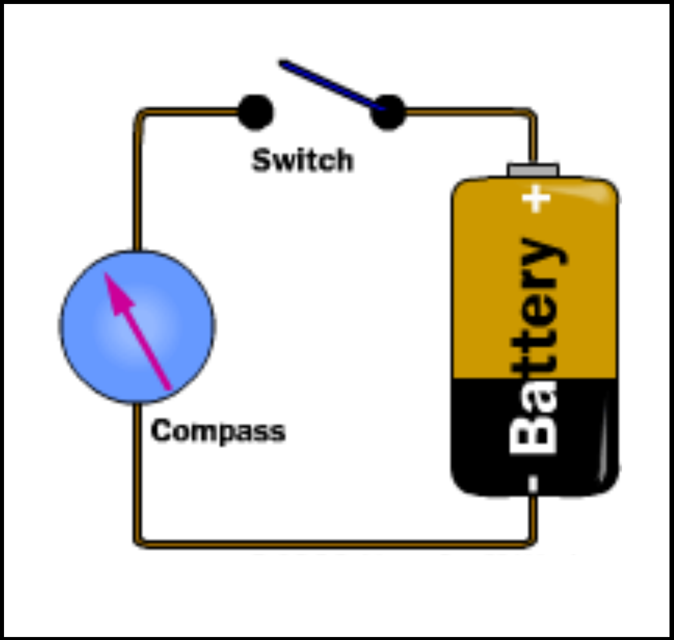
Sturgeon's Horseshoe Electromagnet
Can lift iron bar – but not heavy ones



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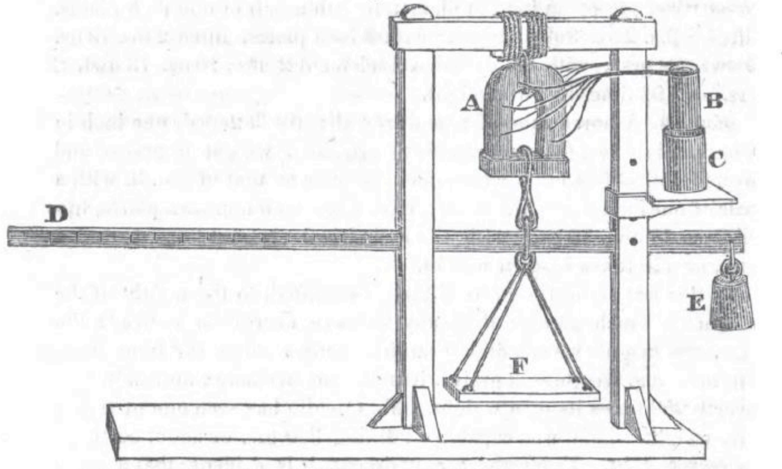
Henry's Discovery:

- Inspired by Schweigger's multiplier, he uses many turns of wire to make a stronger horseshoe electromagnet
- When using a single cell battery, it is better to use many separate coils of wire connected in parallel instead of one long coil
- Compound battery (that is, many cells wired in series) can overcome loss due to resistance of a long wire

Henry's Engineering Designs:

- Move an armature – first electric machine and first electromagnetic relay
- Sound a bell at a distance – first telegraph



A, the magnet covered with linen, the ends of the wires projecting so as to be soldered to the galvanic element B. C, a cup with dilute acid on a moveable shelf. D, a graduated lever. E, a counterpoise. F, a scale for supporting weights; when a small sliding weight on the lever is not used; a second galvanic element is attached to the appparatus so that the poles of the magnet can be instantly reversed, this is emitted in the figure.

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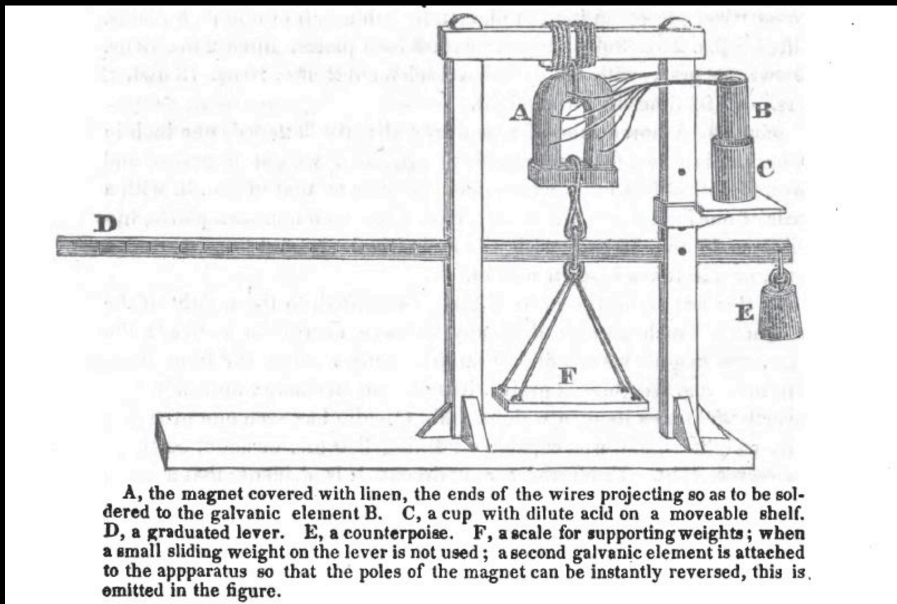

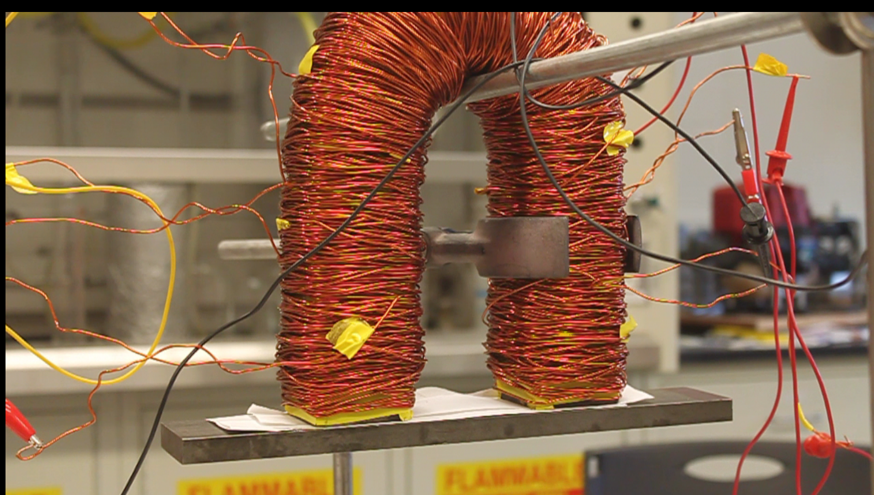

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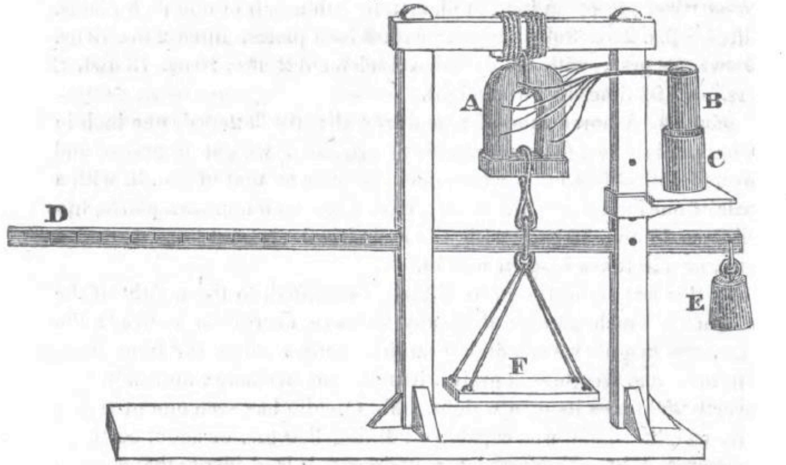

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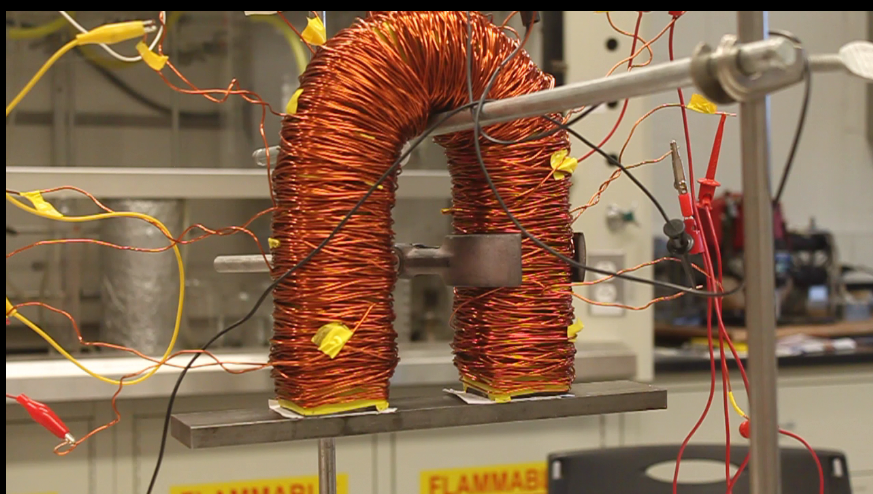

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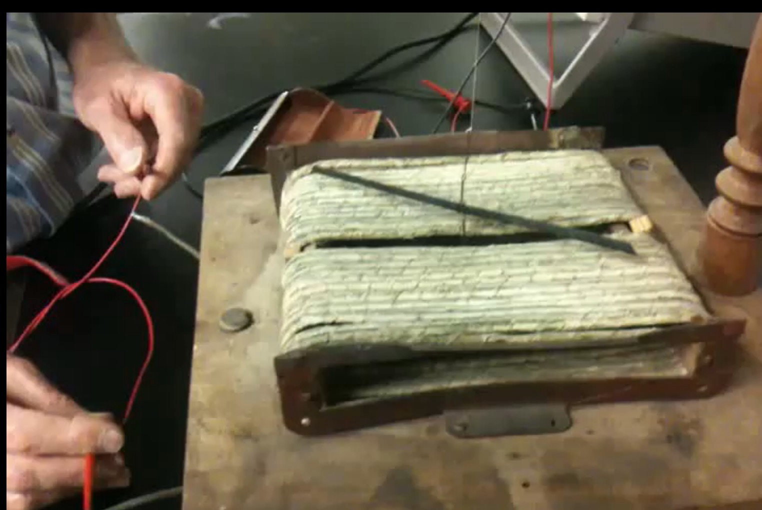

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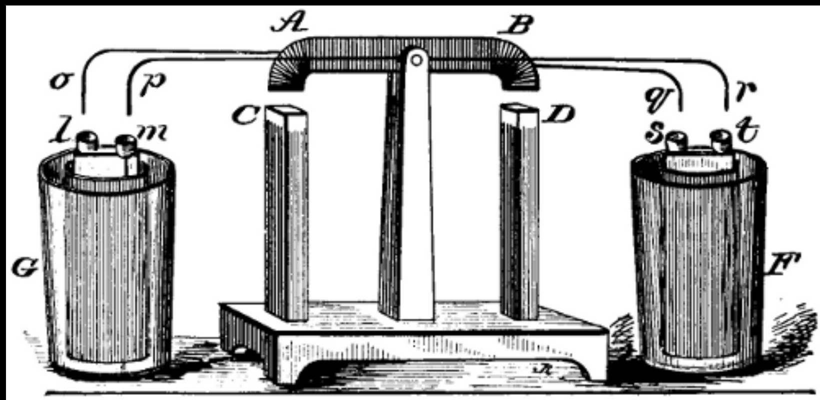
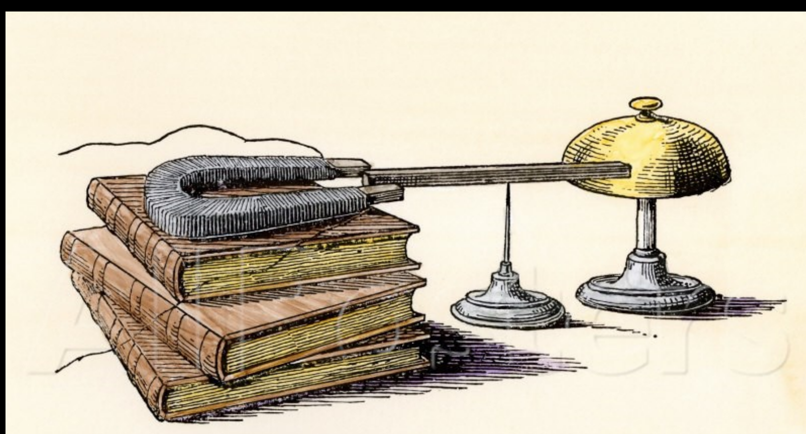


First Motor and Relay
POWER



First Telegraph
INFORMATION

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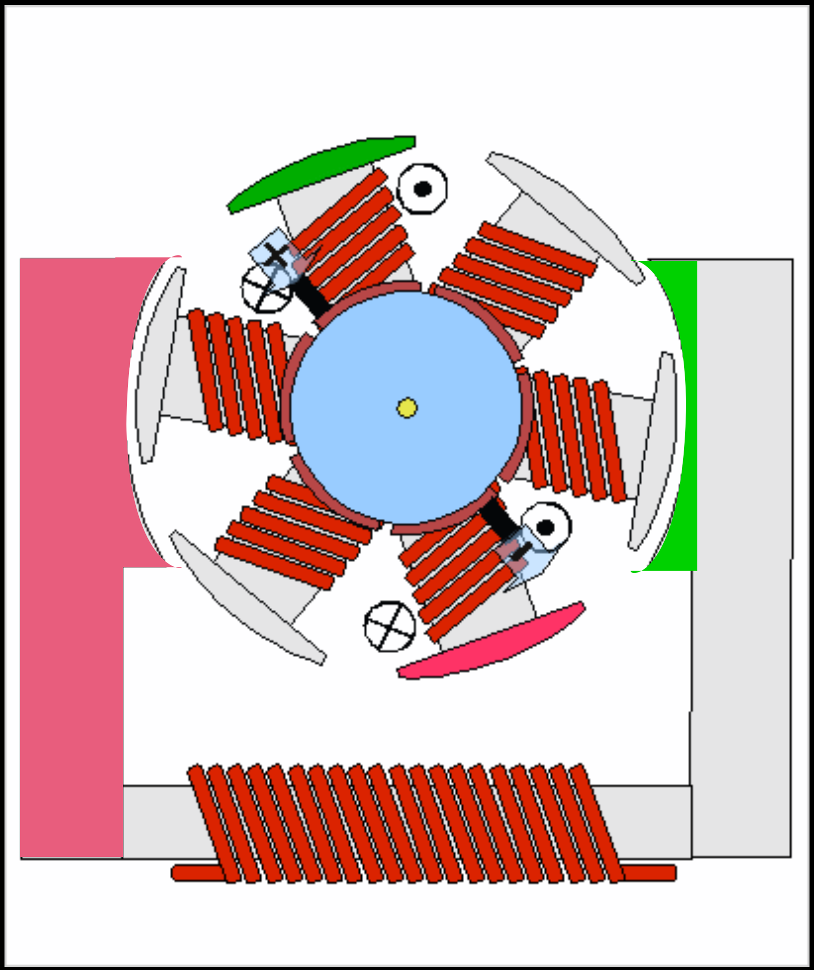

Modern DC Motor

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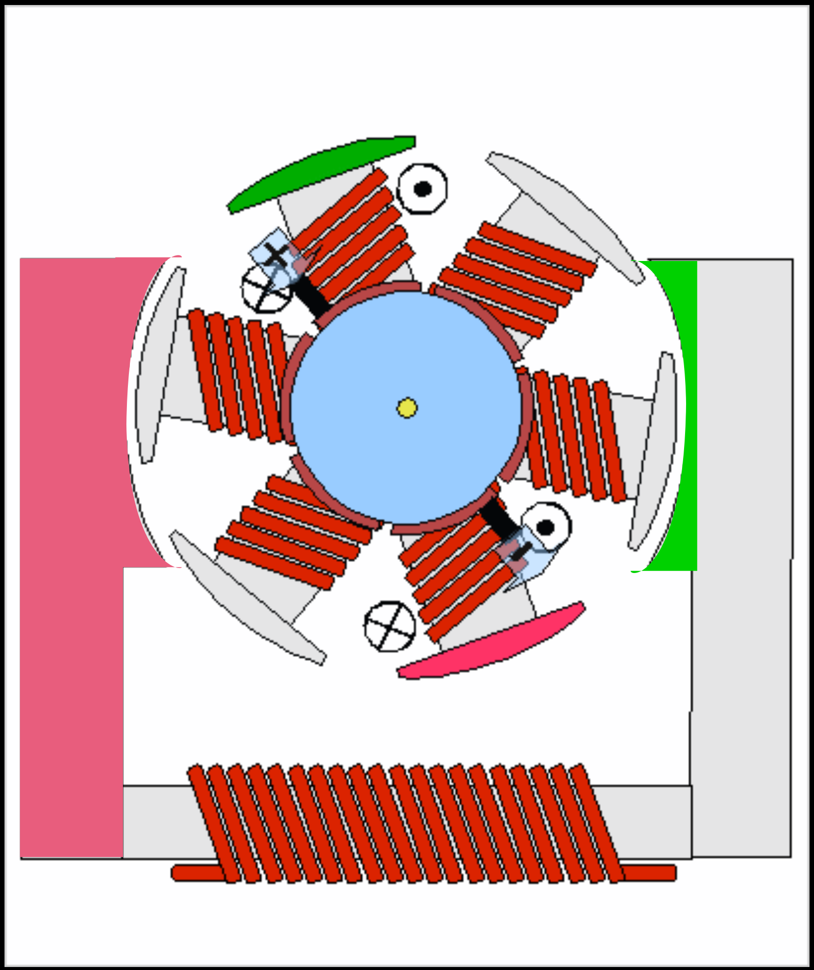
3D Printing of Important Inventions

University of Virginia,
Smithsonian, and Princeton



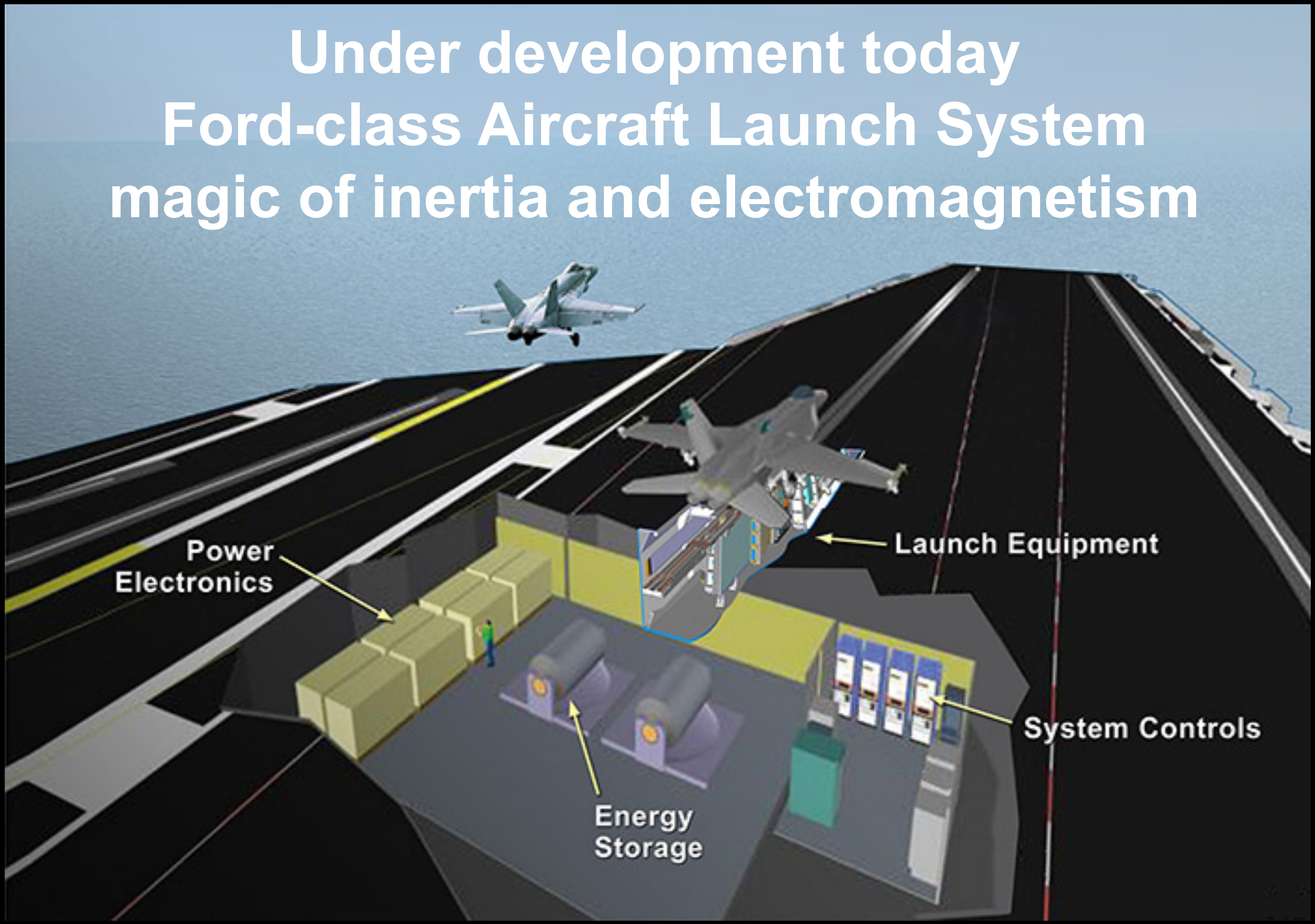
Modern DC Motor

3D Printers in secondary schools
University of Virginia and Virginia Schools

3D Scanning of Historical Artifacts
Smithsonian Institution

Historical Re-creation of Inventions
Princeton University

Modern Day Applications



INERTIA: Energy Stored in Flywheel linked to Electric Generator
ELECTROMAGNETISM: Propelled / Lifted by Electromagnetic Travelling Wave

Modern Day Applications

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An educational approach …

- teach the fundamentals – keep it simple
- historical inventions can be easy to understand and are sometimes inspirational
- if you make a model bridge, make it a model of a real bridge
- less is more – stay out of the weeds
- task students to build upon the fundamentals through their own designs
- tell them, show them, have them do it
- and have them do it just after it is introduced in class
- make connections to the modern day
- have fun

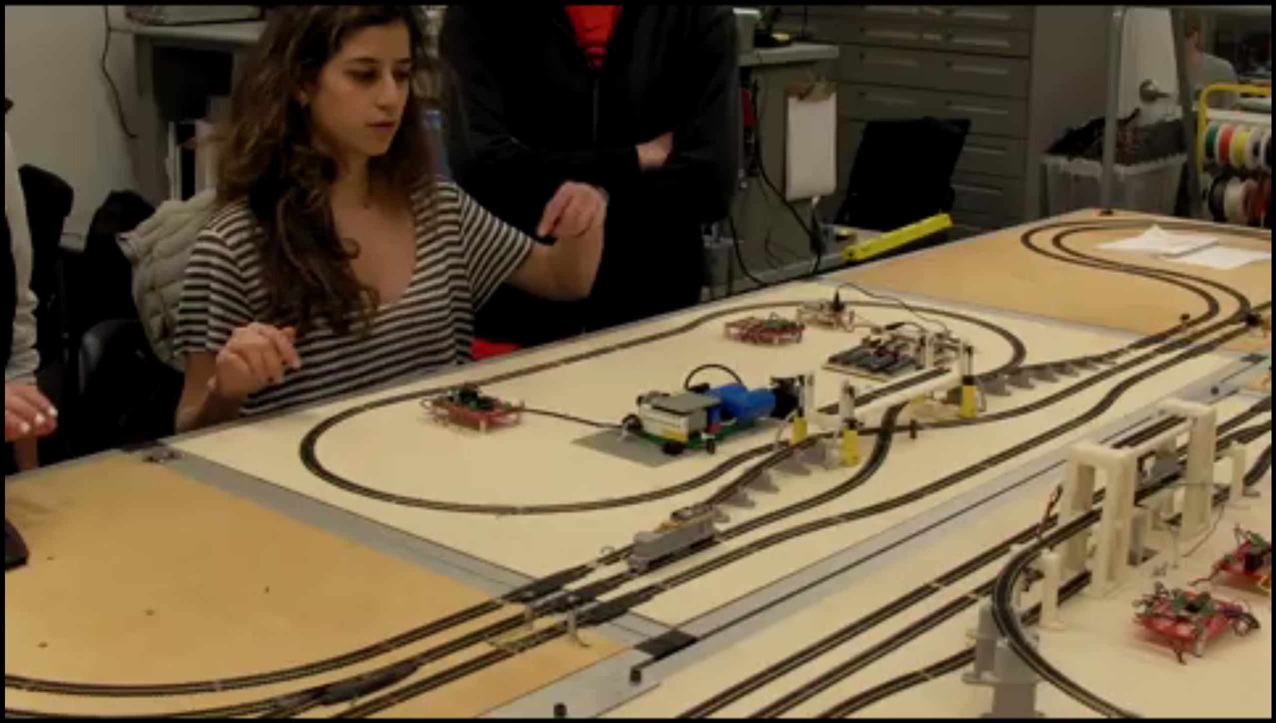
Princeton Colleagues

Emeritus Prof. David Billington

Luke Stern

END

Microcomputer Control of Toy Trains



Art and Science of Motorcycle Design