# Make to Learn: Invention Through Emulation

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# Make to learn: invention through emulation

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**Abstract**

The *Make to Learn* coalition was established to identify effective pedagogical approaches for employing makerspaces for educational innovation in schools. The *Make to Learn* coalition is anchored by the *Make to Learn Laboratory* in the Curry School of Education at the University of Virginia and the Laboratory School for Advanced Manufacturing in the Charlottesville City Schools, working in collaboration with the Joseph Henry project at Princeton University, advanced manufacturing programs at Midlands Technical College, and the Smithsonian Institution. This paper describes a key consortium initiative, *American Innovations in an Age of Discovery*. Participating students use school makerspaces to reconstruct working models of transformational inventions. The reconstruction process is grounded in a method employed by historic inventors, *invention through emulation*. The benefits of this approach, updated to take advantage of modern technologies, are discussed in the context of maker education.

Collaboration: Schools of Education and Engineering, Smithsonian, Public Schools
Employing Makerspaces for Educational Innovation
Re-creation of Historic Inventions using 3D Printers, Laser and Die Cutters, CNC Mills

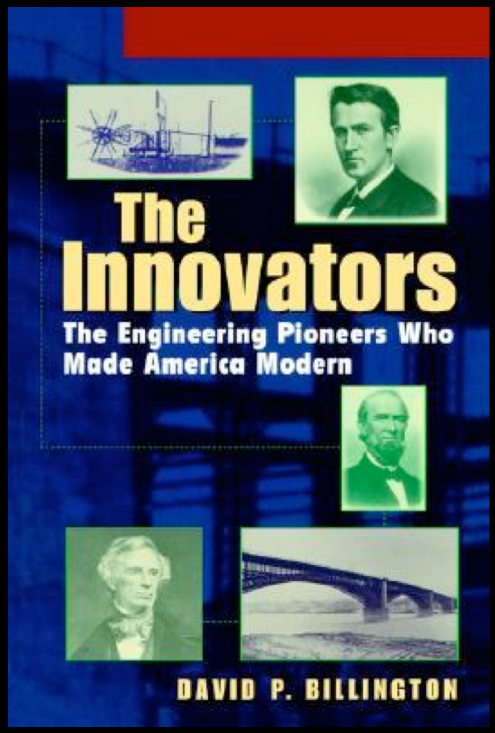
# CEE 102 “Engineering in the Modern World”

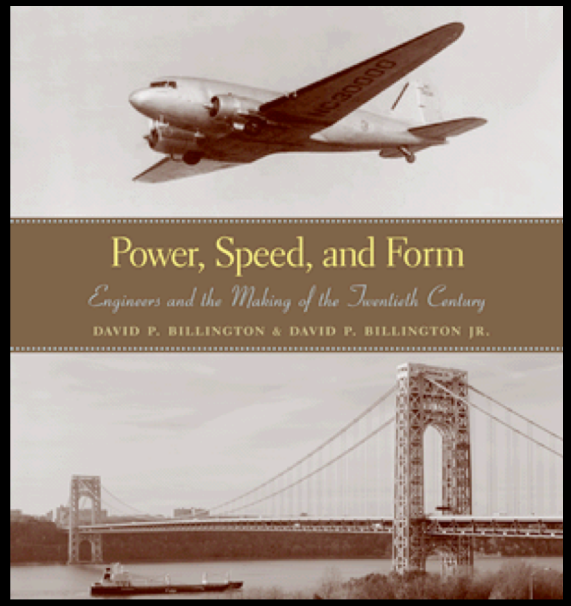
## PERSPECTIVES

| | |
|---|---|
| Scientific | Formulas |
| Social | Context |
| Symbolic | Meaning |

## CATEGORIES

| | |
|---|---|
| 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?** |

- Inspirational people
- Inspirational objects and systems

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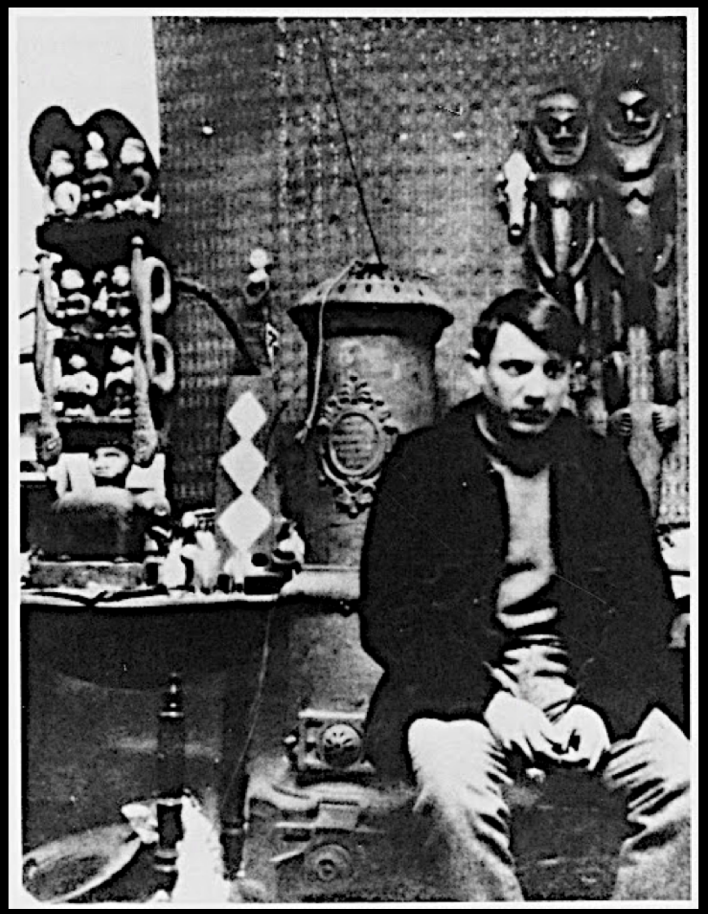
# 19th Century American Innovators

# 20th Century American Innovators

# Imitation – Emulation - Invention

## Pablo Picasso (1881 – 1973)



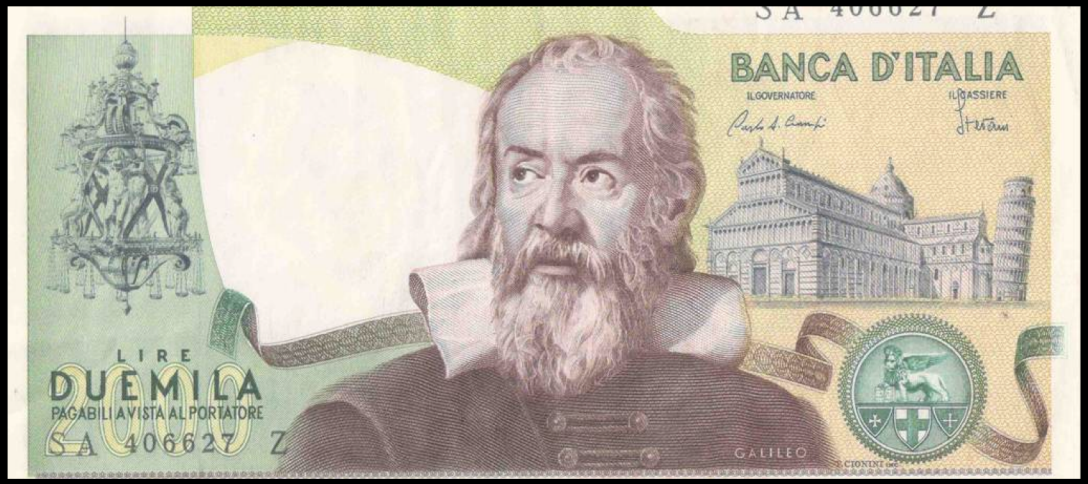
"Good artists copy, great artists steal"

"Les Damoiselles d'Avignon" - 1907

Galileo Galilei (1564 – 1642)

Medical Doctor
Mathematics Professor
Instrument maker
Physicist – theory and experiment
Astronomer

Known for:
Pendulum analysis
Pendulum clock (about 1640)
Parabolic trajectories – free fall
Galilean Telescope
Moons of Jupiter; discovery
Advocate for Copernicus's Ideas



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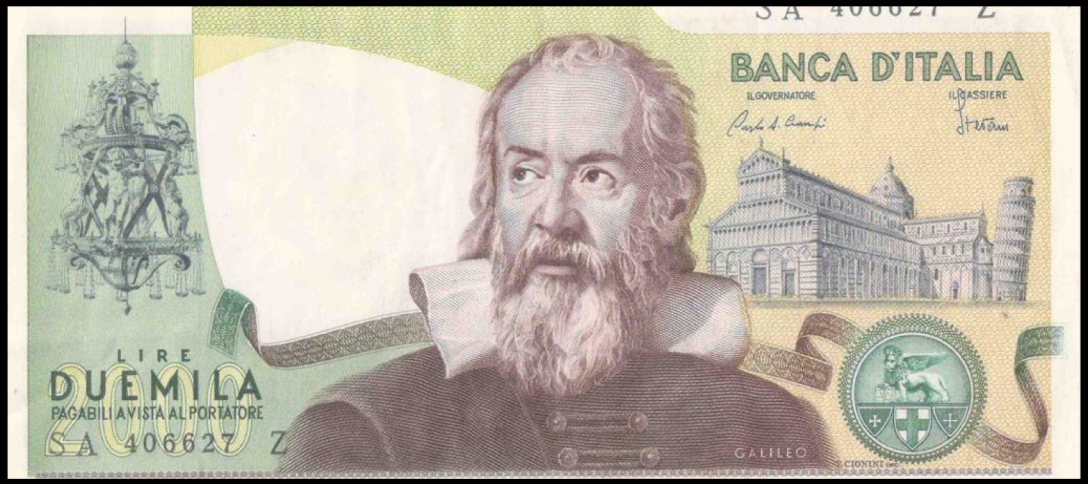
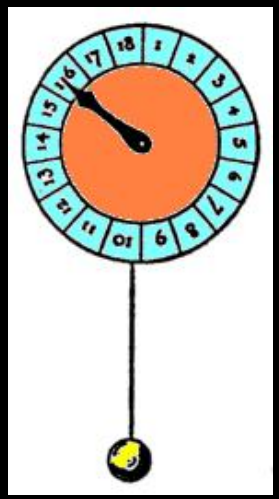
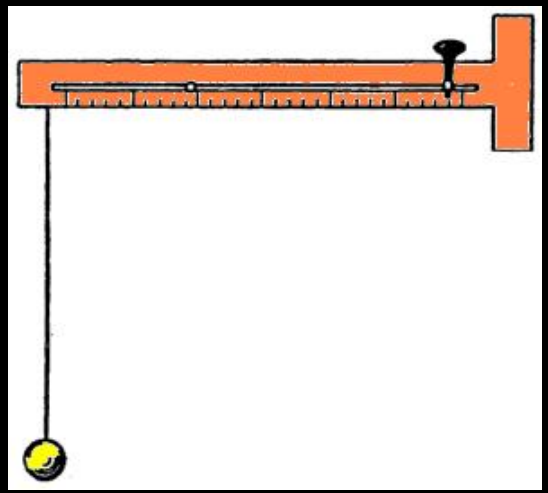



Pulsilogium of Santorius – first precise measuring device in medical history – uses length to quantify pulse rate





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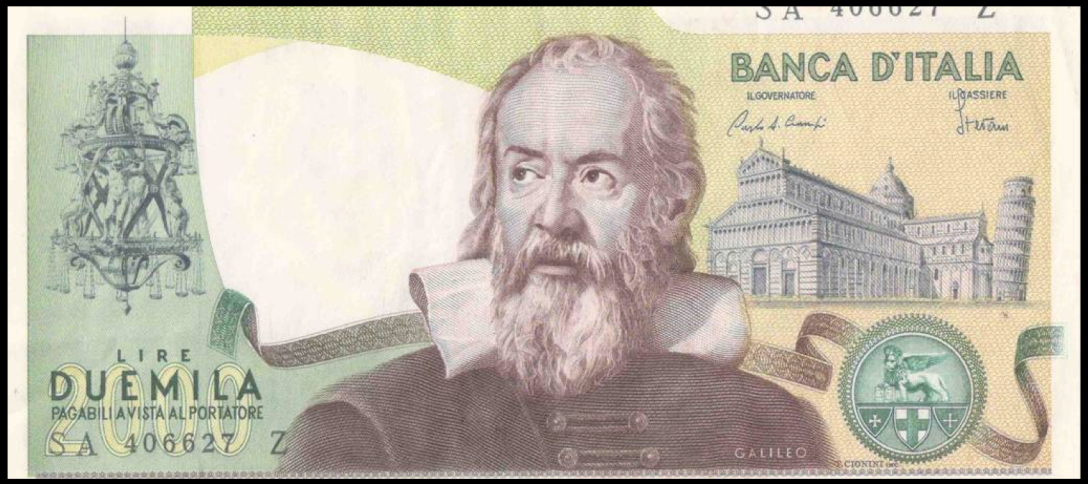
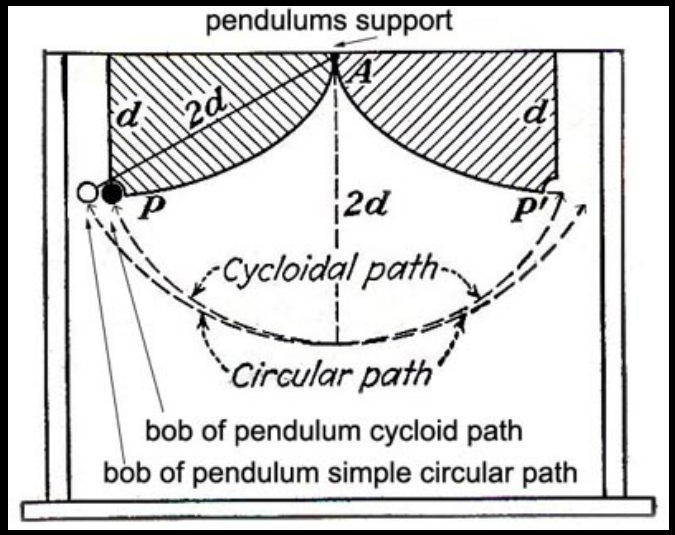



Galileo estimated correctly that for small amplitudes that the period scaled with √L, but he was not correct in believing that the semi-circular path was a brachistochrone.



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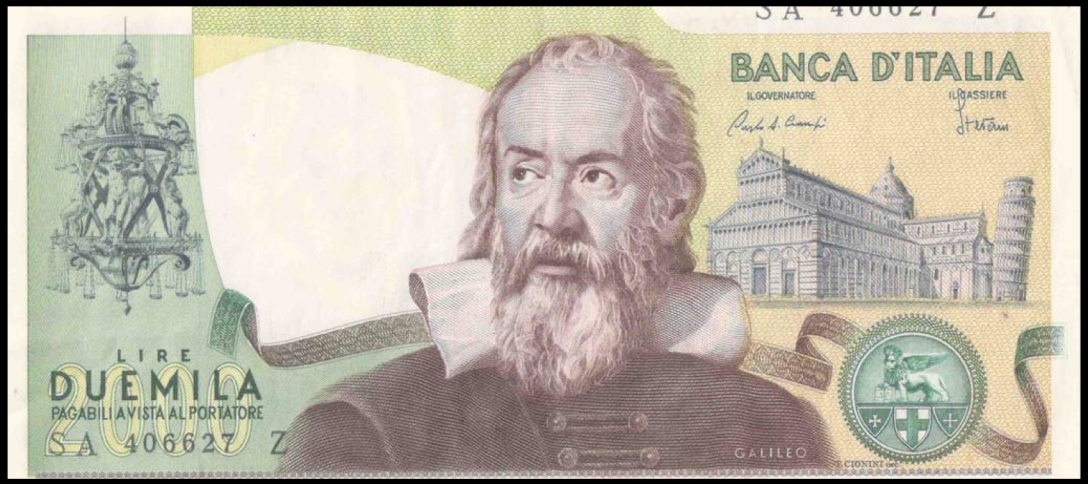
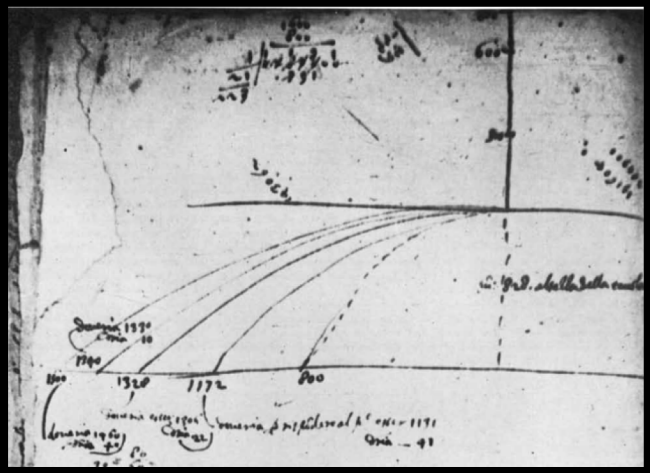



Galileo's parabolic studies are known to be motivated by experiment and the "law of the fall" – used inclined plane



His measuring device was a ruler

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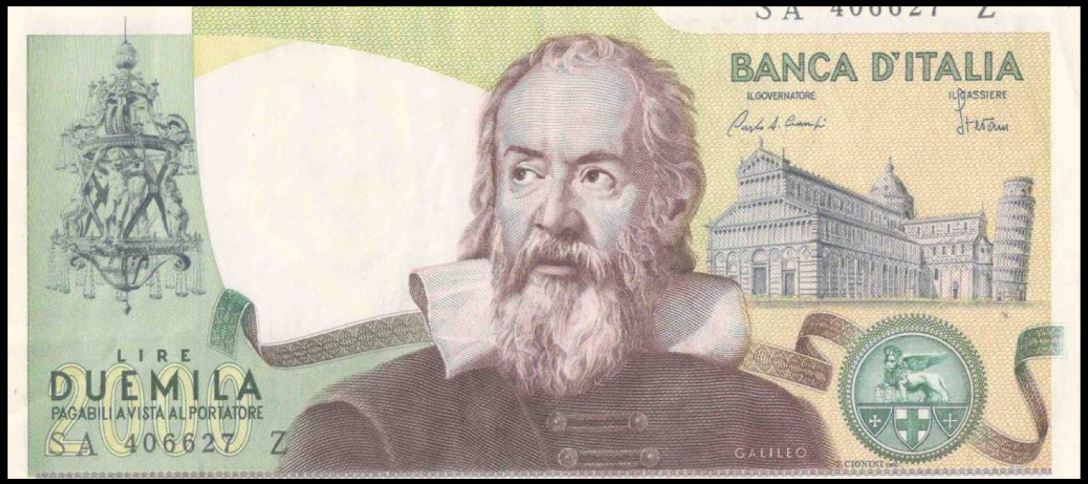


1. Independence of horizontal and vertical motion
2. Conservation of horizontal inertia
3. Independent acceleration in the vertical ("law of the fall")

1. Period varies with the square root of length; the Law of Length
2. Period is independent of amplitude; the Law of Amplitude Independence
3. Period is independent of weight; the Law of Weight Independence

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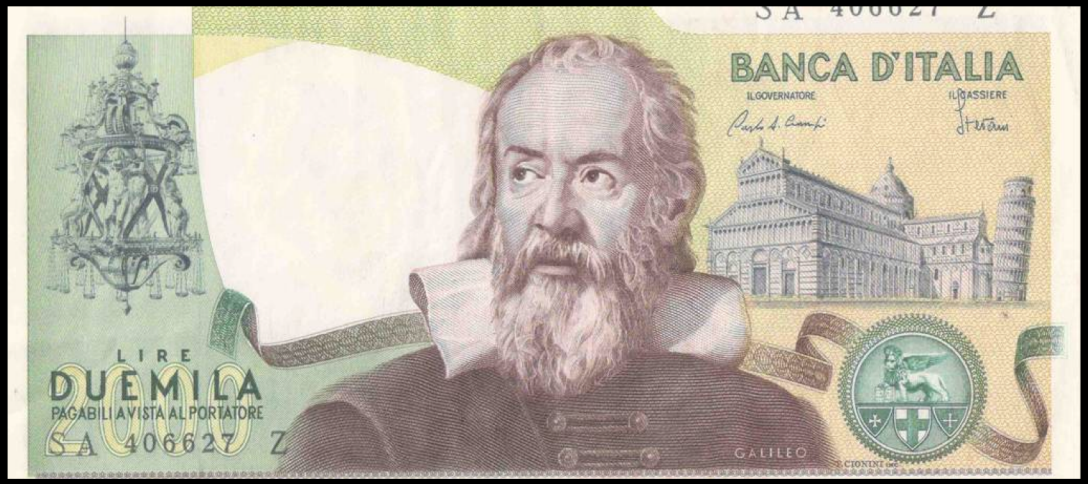
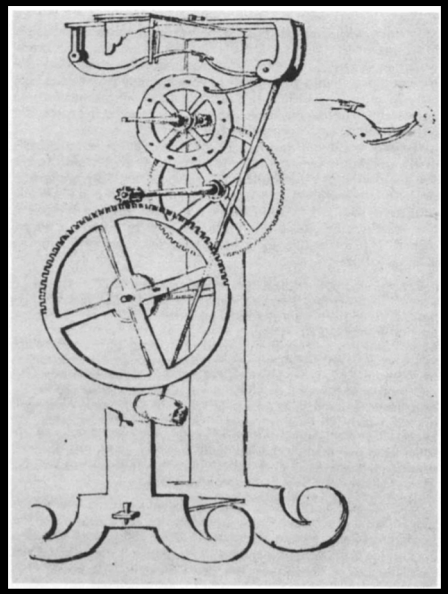
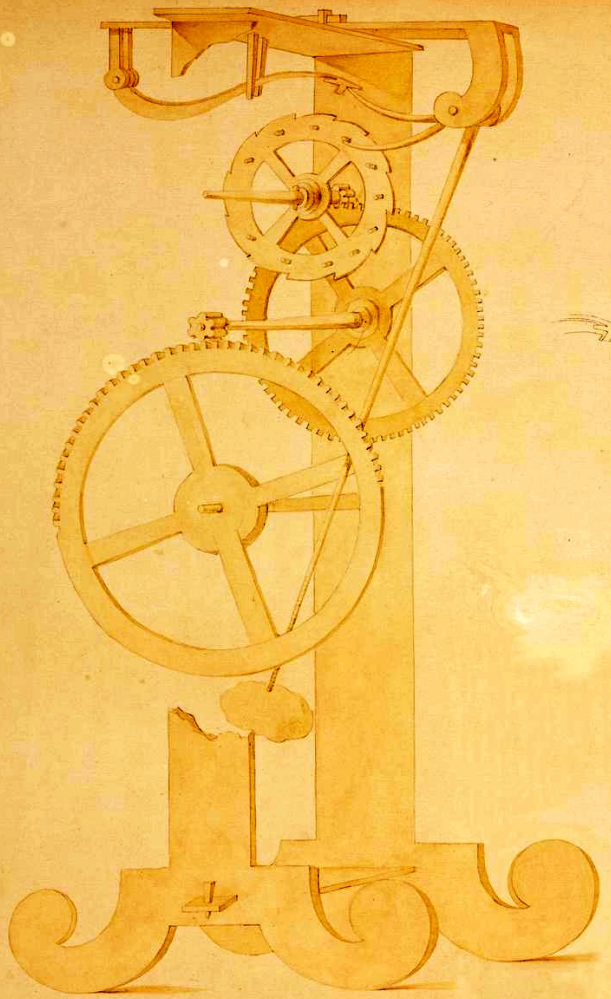



Pendulum clock - sketch by Viviani, a young student of Galileo – clock model constructed by son, Vincenzo Galilei





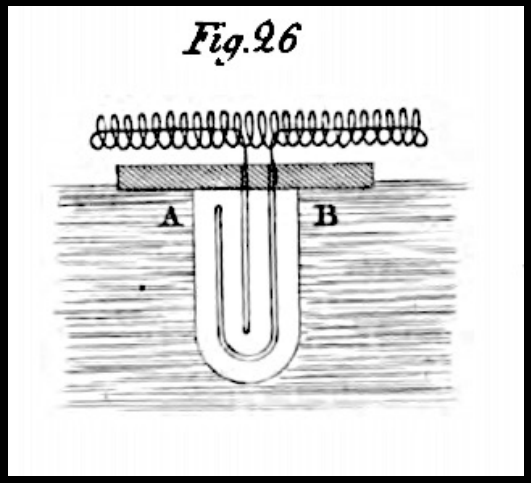
*Copia esatta del disegno che rappresenta il primo concetto dell' applicazione del pendolo all' orivolo, dettato da Galileo già cieco, al figlio Vincenzo e al discepolo Viviani; lucidata dall' originale esistente nei manoscritti Galileiani della Biblioteca Palatina* **P. VI. T. IV.**

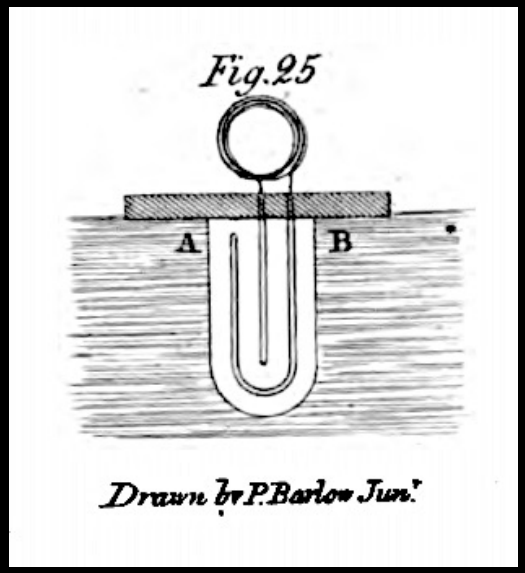
3D Printed Model of Galileo’s Pendulum Clock

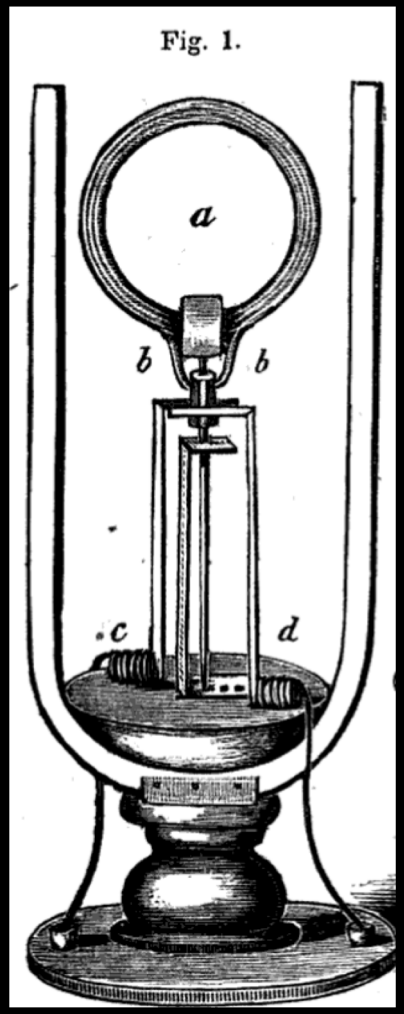
Charles Grafton Page (1812 – 1868)

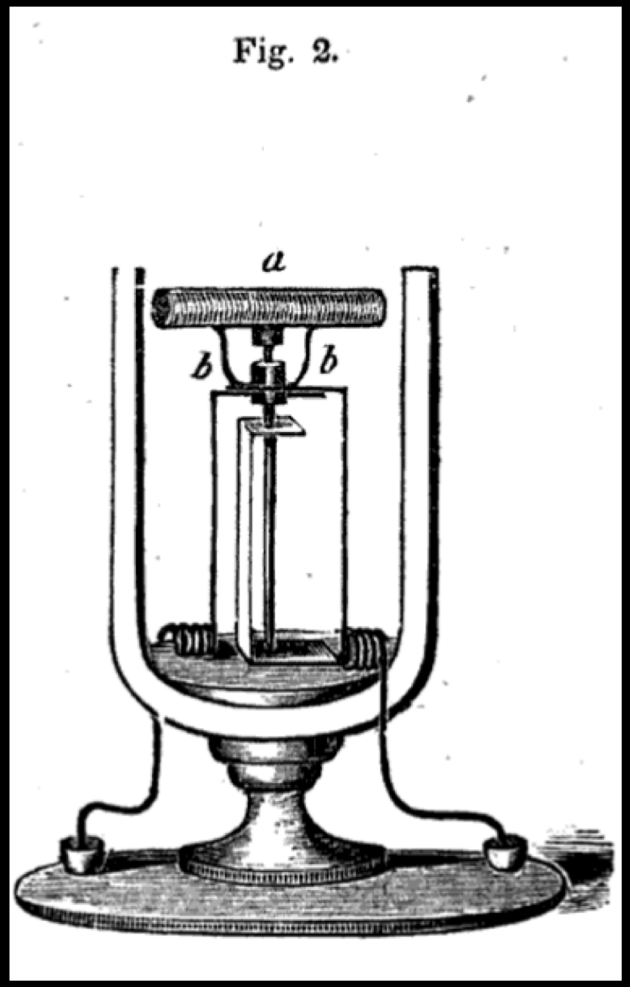
Medical Doctor
Chemistry Professor
Instrument maker
Patent Examiner
Electromagnetic Inventions

Known for:
Shocking Coils (iron wire bundle instead of solid core - 1836)
Commutated electric motor (1837)
Axial engine – solenoid motor (1845)
Electric Locomotive




Commutated DC motor – 1837 – Charles Grafton Page

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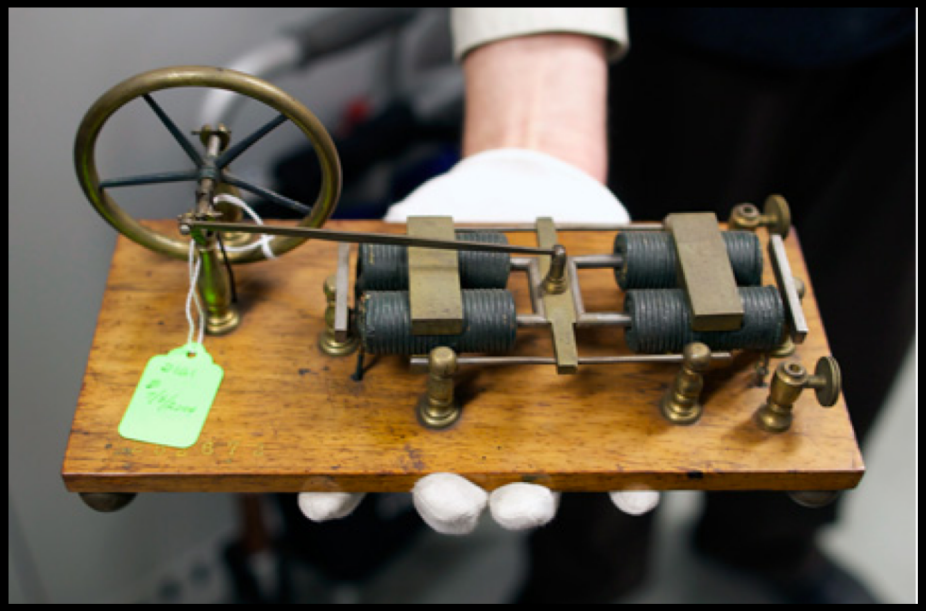
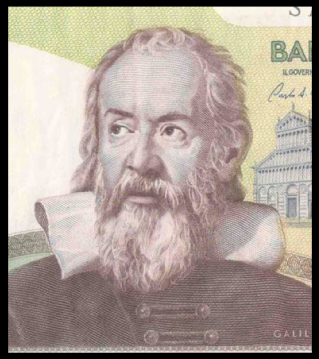


Animation of Page's Axial Engine

Smithsonian Invention Kits – in Collaboration with University of Virginia and Princeton

3D solenoid motor inspired by Page’s Axial Engine



Galileo Galilei

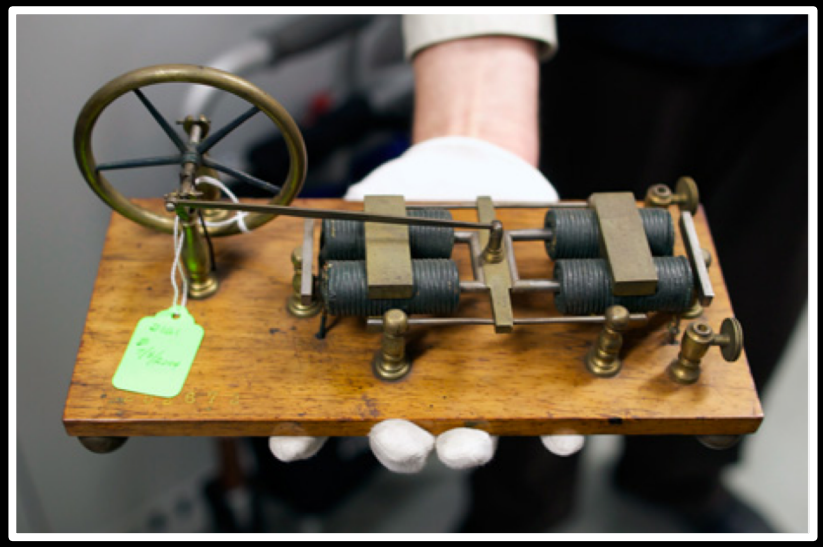
Pendulum Clock

Measure Human Pulse
Determine Longitude

Charles Grafton Page

Electric Motor

Electricity for motive power



DEMO using AutoDesk Fusion 360
FlashForge Inventor
Bantam Tools OtherMill

CAD Design
3D Printer
CNC Mill

# Engineering and Scientific Innovations

Use examples – not all bridges – but the Golden Gate Bridge
Tell a story – show how it works – let them do it (auditory, visual, tactile)
Put a face on it – biography – who did what, and when and where and why
Highlight inspirational innovators and their inventions
Teach the teachers – Learn from teachers
Keep it simple – use original instruments if possible
Explore big picture – technical, social, legacy
… then, challenge kids to build on key ideas – make their own inventions

Not just communicating, but getting response:

I can do that!
I want to do that!

## Replicate – Modify – Apply

END

imitation – emulation - invention

1. STEM education – target middle school and high school
2. CEE 102 – course objectives – put a face on the work
3. Picasso
4. Galileo - clocks
5. Page - motors
6. 3D Printing and CNC Milling
7. Approach

1. Don’t just talk about bridges – use a specific one
2. Who did it?
3. Why did they do it?
4. What was the environment?
5. What is the impact?
6. Replicate – modify – apply
7. tell – show - do

Inspiration …

Not just to communicate ...

Response: I can do that

I want to do that