Sound from an Empty Coil and Current from a Metal Pile:

Alexander Bell's Thanksgiving Day Discovery and Joseph Henry's Solar Thermometer

Michael G. Littman
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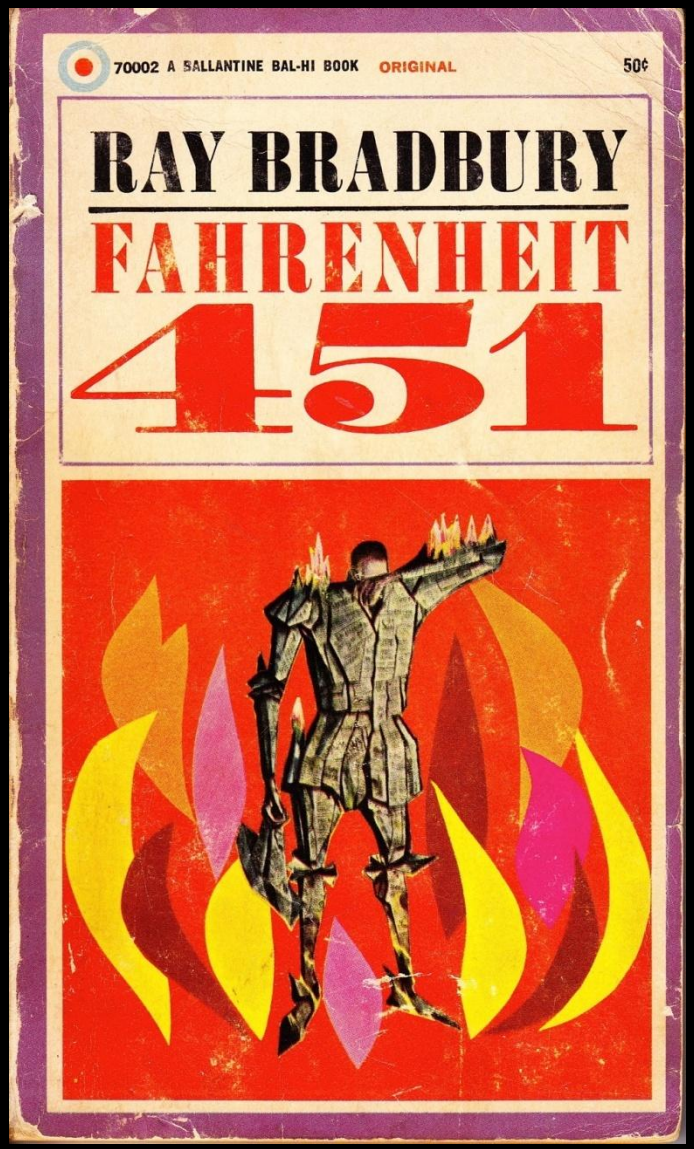
Princeton University

National Museum of American History
November 10, 2015



In Ray Bradbury's *Fahrenheit 451*, Clarisse introduces Montag to an underground society that has kept books and literature alive by memorizing them. (scene from Truffaut's 1966 film)

Vardo (Cal Northridge) and Gary (HKUST)
study letters between Alexander Bell and
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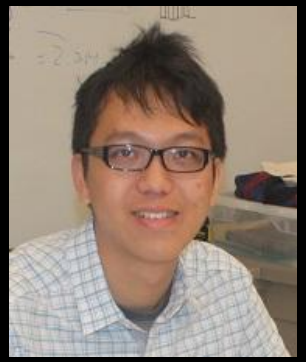

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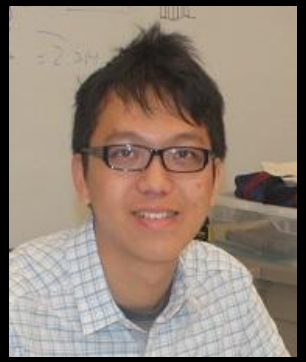

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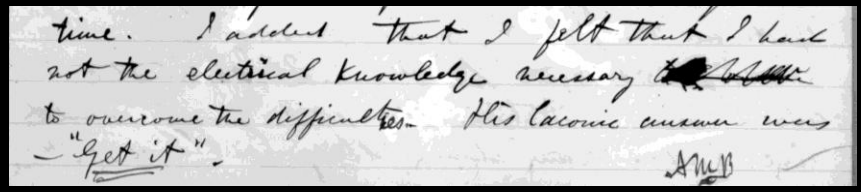
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Alexander Bell's "Get it" letter

How do innovations happen ? Manuscripts

Thermopile [supposedly] used by Henry as a detector in his solar telescope for studying sunspots

How do we know what we know ? Artifacts

Starting points ….

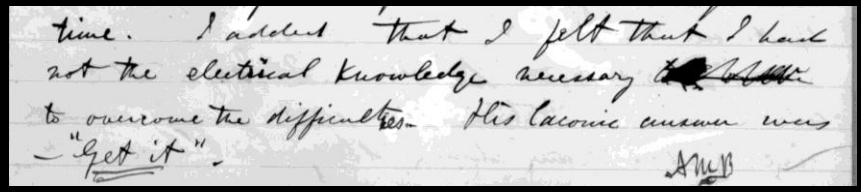
PHOTOGRAPH OF THE PEMBERTON AVENUE SCHOOL FOR THE DEAF, BOSTON. Taken June 21, 1871.

Top row, from left to right,
Rev. Dexter King, the founder of the school.
[illegible], Chairman of the School Committee.
Alexander Graham Bell, Teacher of the teachers.

Fourth row. Teachers.
Annie M. Bond, Sarah Fuller, Ellen L. Barton, Mary H. True.
Thirty-eight pupils in attendance, but four were absent when photograph was taken.

Class Picture – BOSTON 1871

Alexander Graham Bell
Teacher of the teachers



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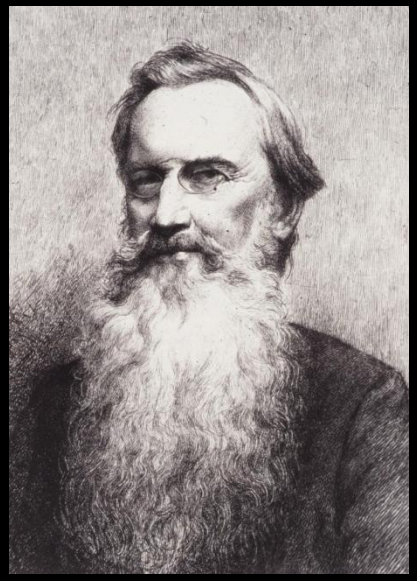
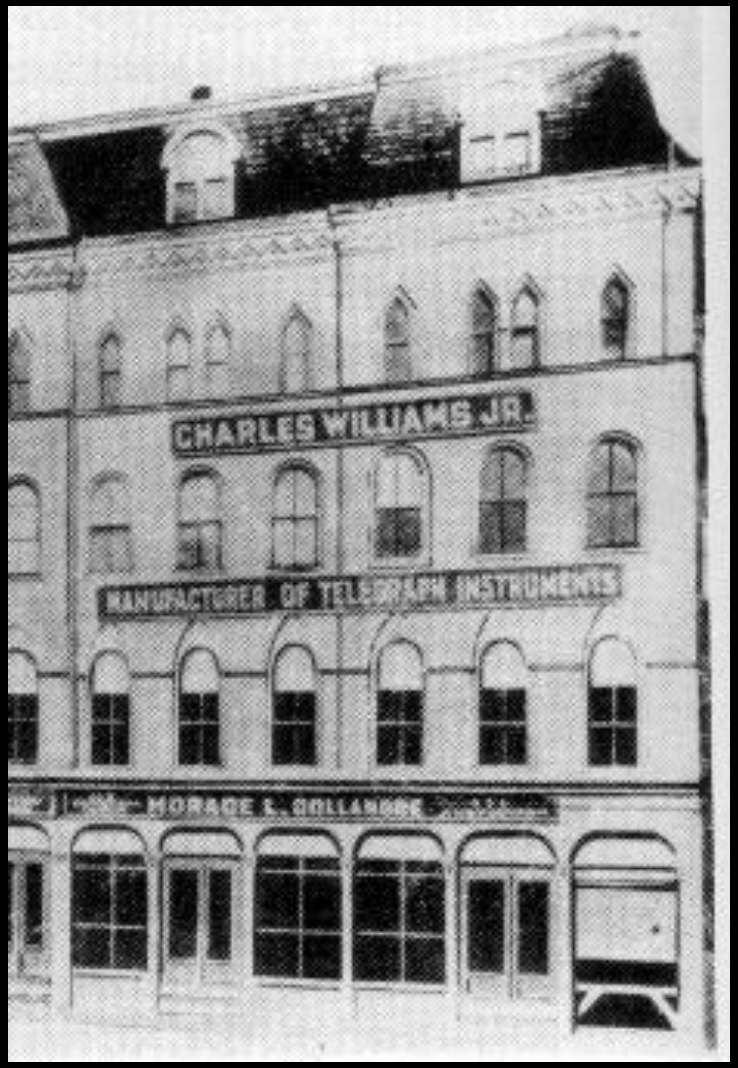
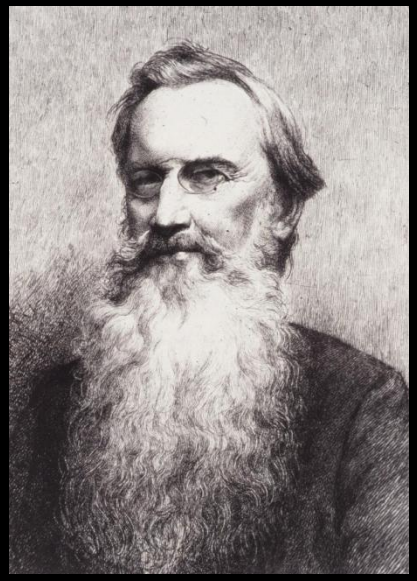


MULTIPLEXING

Bell's idea in early 1874 for sending multiple messages on a single telegraph line.



Bell rents a workbench to experiment



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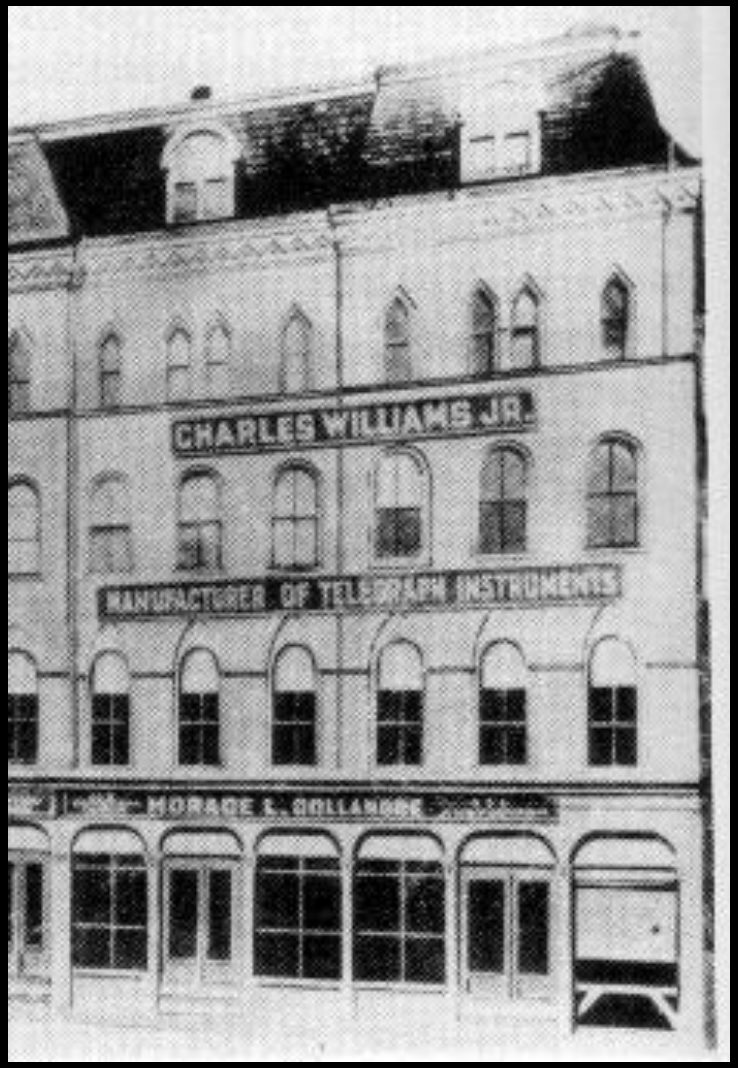

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Bell is helped by Thomas Watson, an assistant in the shop

Eventually Bell, Hubbard, and Watson will form company in that building

Bell to Watson

“Watson, if I can get a mechanism which will make a current of electricity vary in intensity, as the air varies in density when a sound is passing through it, I can telegraph any sound, even the sound of speech.”

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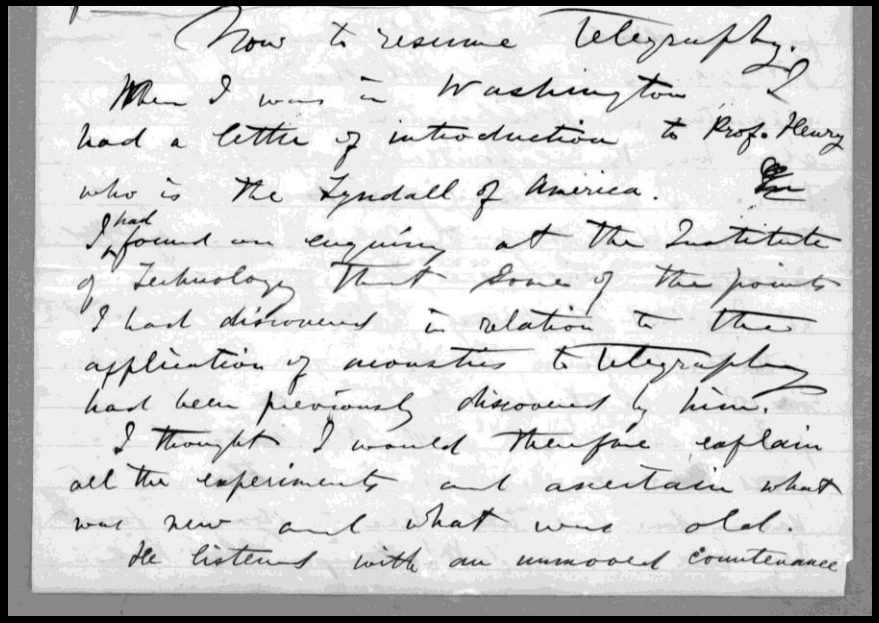

How to resume telegraphy.

When I was in Washington I had a letter of introduction to Prof. Henry who is the Tyndall of America. I had found on enquiry at the Institute of Technology that some of the points I had discovered in relation to the application of acoustics to telegraphy had been previously discovered by him. I thought I would therefore explain all the experiments and ascertain what was new and what was old. He listened with an unmoved countenance

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I told him that on passing an intermittent current of electricity — through an empty helix of insulated copper wire a noise could be heard proceeding from the coil — similar to that heard from the telephone. He started up — said "Is that so" — Will you allow me Mr Bell to repeat your experiments and publish them to the world through the Smithsonian Institute — I course giving you the credit of the discoveries."

I said it would give me extreme pleasure — and added that I had apparatus in Washington — and could show him the experiments myself at any time. He asked if I could do it then if he went with me — and I told him that I had everything in readiness at Mr Hubbard's house. He said "I will go with you now. Have you a carriage here?" I had not — and so he put on his coat and was about to order a carriage — when I offered to save him the trouble of going out on such a raw damp day by bringing

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the apparatus to the Smithsonian Institute. (He was suffering from a cold — and besides is very aged — I believe about 80 years old.)

We appointed noon next day for the experiment.

I set the instrument working and he sat at a table for a long time with the empty coil of wire against his ear listening to the sound.

I felt so much encouraged by his interest — that I determined to ask his advice about the apparatus I have designed for the transmission of the human voice by telegraph. I explained the idea and said "What would you advise me to do — Publish it and let others work it out — or attempt to solve the problem myself."

He said he thought it was "the germ of a great invention" — and advised me to work at it myself instead of publishing.

I said that I recognized the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was — "Get it".

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I cannot tell you how much these two words have encouraged me. I live too much in an atmosphere of discouragement for scientific pursuits. Good Mr Sanders is unfortunately one of the qui bono people — and is too much in the habit of looking at the dark side of things. Such a chimerical

My visit to the Smithsonian Institute seems to me to be the brightest spot in my whole life. I feel now that I am accepted by scientific men as one of them.

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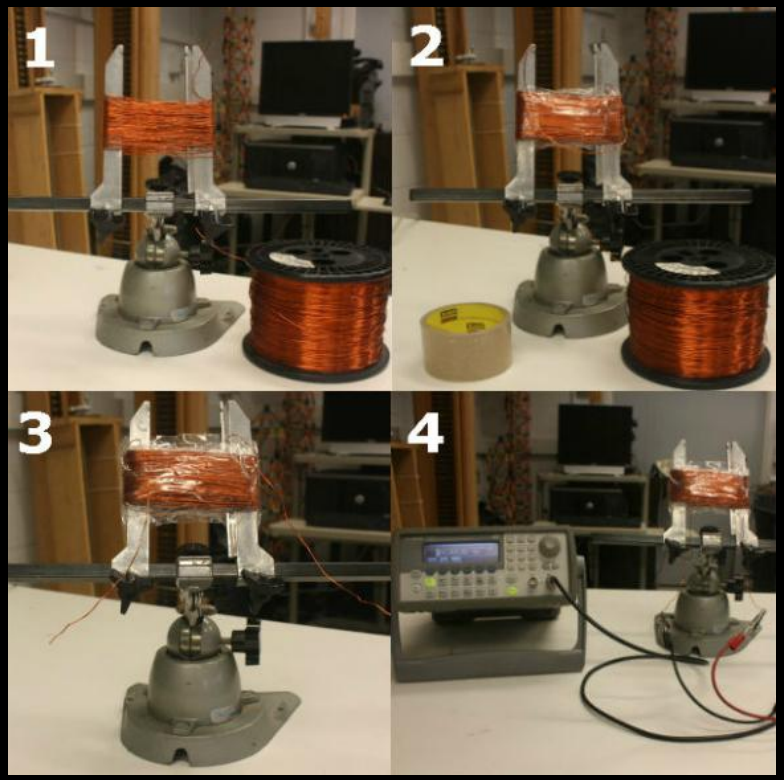
My question to Vardo and Gary ….

Does this empty coil experiment really work ? And if so, why ?

Indeed, it works really well – and even better if the coil is flat



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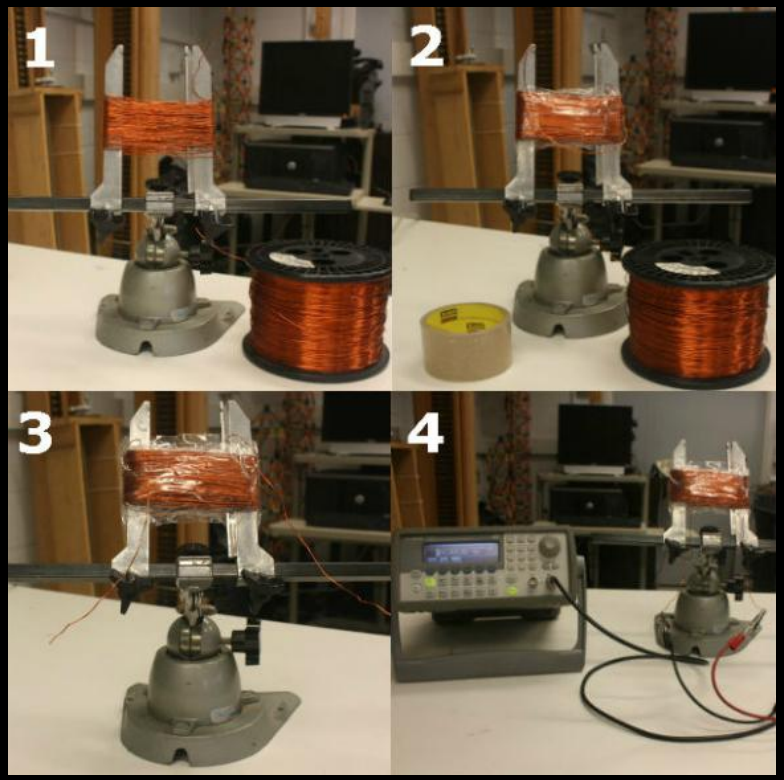

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What is the big deal about an empty coil producing sound ?

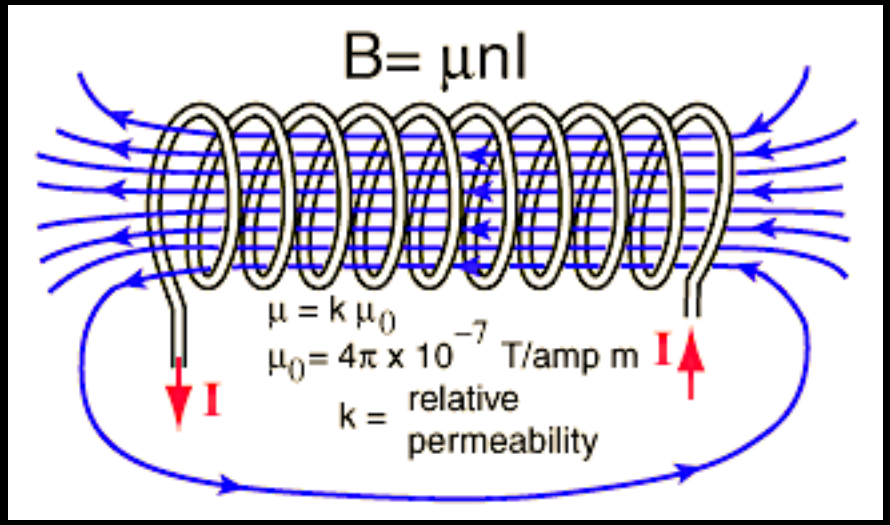
Charles Page in 1838 had published an observation entitled “Galvanic Music” in which a horseshoe magnet was made to ‘ring’ briefly when a nearby coil of many turns was connected to or disconnected from a battery.

The understanding then [not correct] was that magnetism from the coil caused ‘disturbances of molecular forces’ in the nearby horseshoe magnet and these disturbances produced vibration and sound.

Bell’s experiment showed that the magnet was not necessary – there is another explanation.

We understand this effect by considering Ampere’s observation that two wires carrying current in same direction attract one another.

A empty coil is made of many loops of wire – **the current in each loop is going in the same direction** – therefore each loop will attract its immediate neighbors – so when current is flowing, the coil will contract axially – and when the current stops flowing, it will relax to its original form. If you pulse it at audio frequencies, it will vibrate at audio frequencies – thereby producing sound at that frequency.



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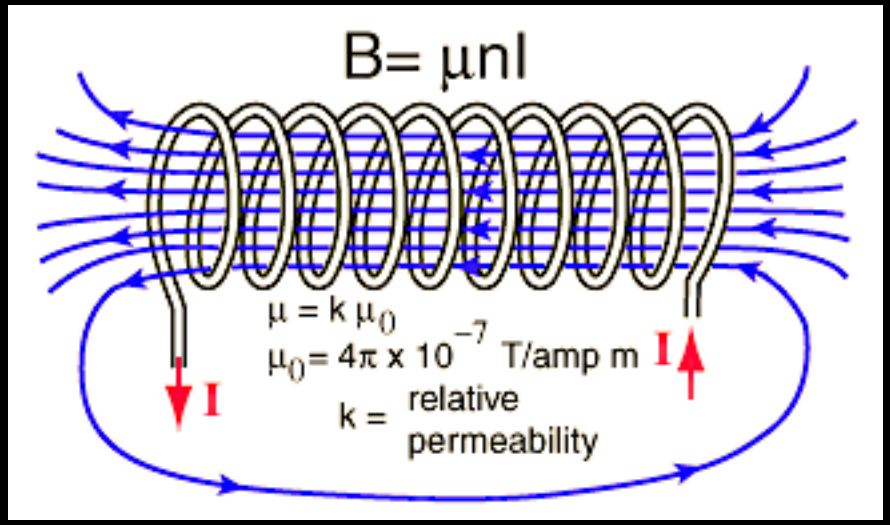
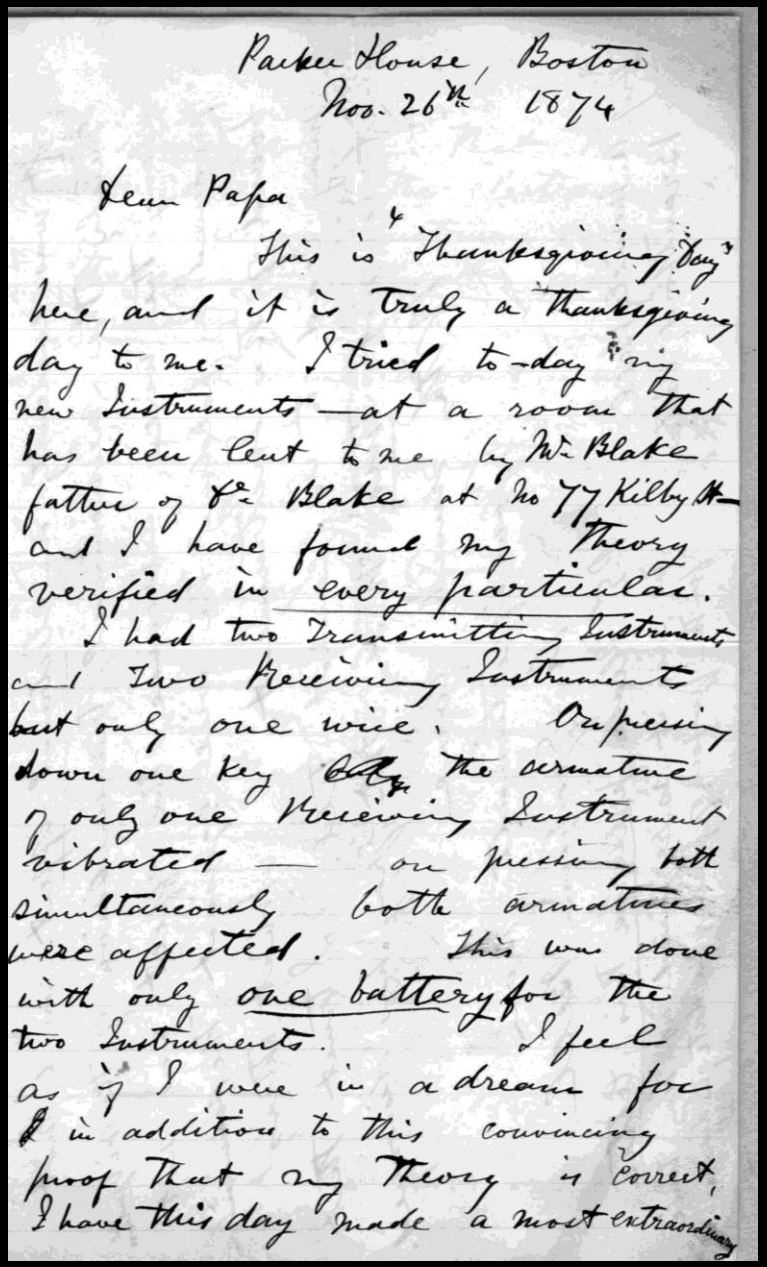


This observation was the first time that Bell was able to achieve what he told Watson he wanted – to convert an arbitrary pulsing current into a sound of the same frequency.

If our explanation for pulsing in a solenoid is right, then one might expect a steady current flowing in a coil should cause it to contract – lets try it.

DEMONSTRATION



Parker House, Boston
Nov. 26th 1874

Dear Papa

This is "Thanksgiving Day" here, and it is truly a Thanksgiving day to me. I tried to-day my new Instruments — at a room that has been lent to me by Mr Blake father of Dr Blake at No 77 Kilby St — and I have found my Theory verified in every particular.

I had two Transmitting Instruments and Two Receiving Instruments but only one wire. On pressing down one key the armature of only one Receiving Instrument vibrated — on pressing both simultaneously both armatures were affected. This was done with only one battery for the two Instruments. I feel as if I were in a dream for I in addition to this convincing proof that my Theory is correct, I have this day made a most extraordinary

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It came about in this way. I was trying to damp the vibrating armature, and was surprised that the note did not stop even when I had grasped the armature firmly in my hand so as to stop its vibrations. I then detached it from the Instrument — and found that the noise proceeded from the magnet itself.

On making & breaking contact the sound was heard or stopped as the case might be. I took the instrument into the hall about fifty feet away from the Transmitting Instrument and closed the door. The same effect was produced.

Eureka moment

ARMATURE

COIL

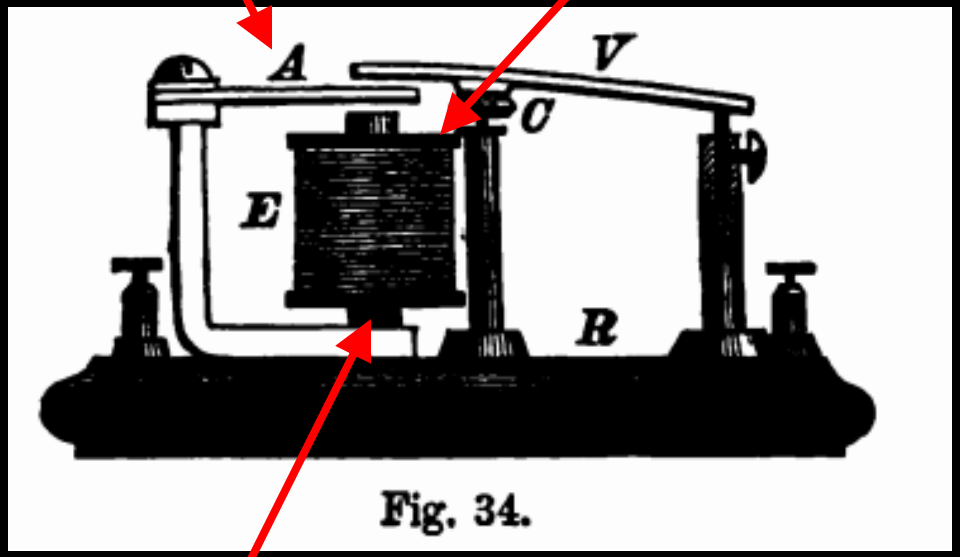

Fig. 34.

IRON CORE

Bell's receiving instrument

Original intent - Armature has a natural ringing frequency. When that frequency is pulsed in the coil, the armature will be forced resonantly into oscillation. If the amplitude is large enough, the armature will make contact to the conductor labeled 'V' in the figure

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Letter No II.

Salem, Mass.
Nov. 27th 1874

Dear Mr Hubbard

The experiments commenced yesterday at No 77 Kilby Street, Boston, were continued to-day with most astonishing results.

I record them here in the order in which they were made.

The armature of one of the transmitting Instruments described in yesterday's letter, was set in vibrations so as to create an intermittent current in an "empty" helix of insulated copper wire.

On applying the helix to my ear a very faint noise was perceived issuing from it. The sound was much more distinct when I stopped up one end of the helix with my finger. It became still more audible when the end was plugged with a piece of wood as suggested by my friend Mr P. D. Richards (who happened to be present). At its best however the sound was so faint as to be inappreciable to Mr Richards. (The machinery in a workshop overhead interfered greatly with all the experiments).

After Mr Richards had gone the machinery stopped for a time and then the sound emanating from the coil was very apparent.

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The next day – Letter to Hubbard

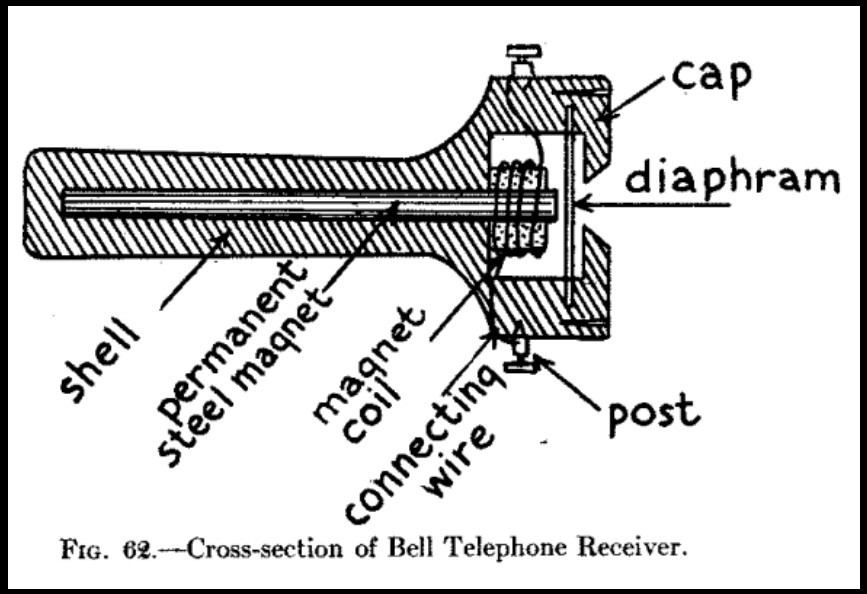
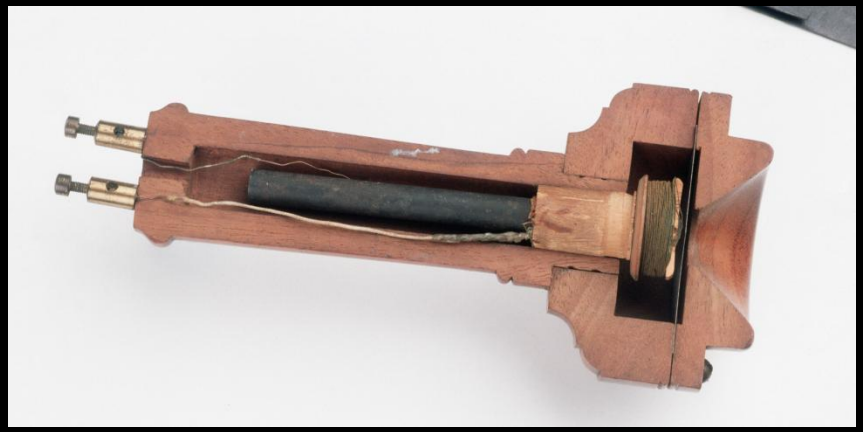


FIG. 62.—Cross-section of Bell Telephone Receiver.



Bell's improved receiver used coil in addition to a permanent magnet and an iron diaphragm - This concept is applied in candlestick telephones, radio headphones, and horn loudspeakers

Precursor to the modern loudspeaker

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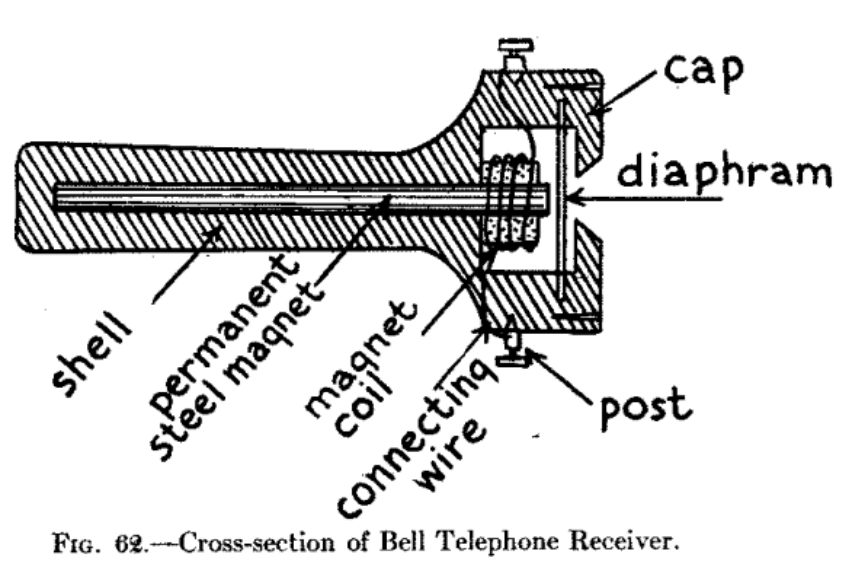

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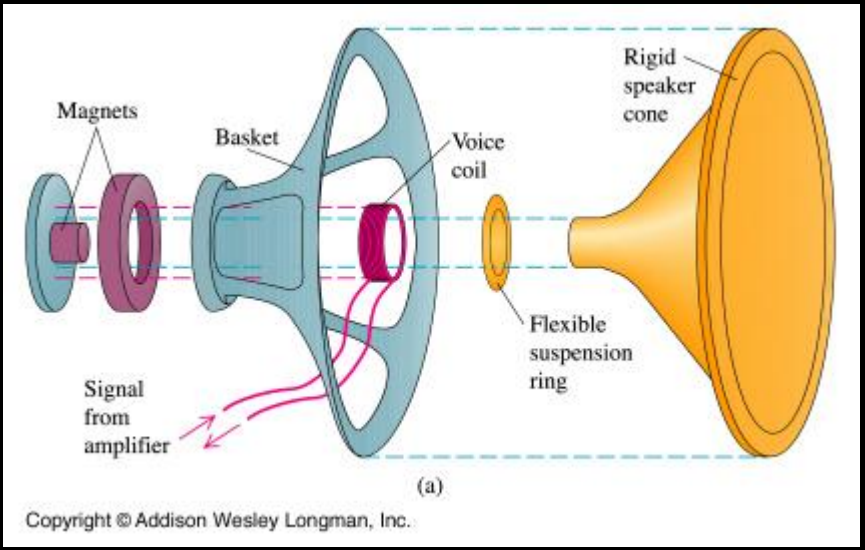

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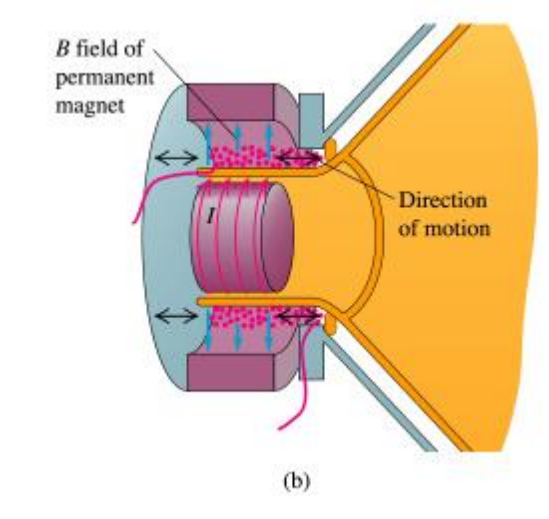
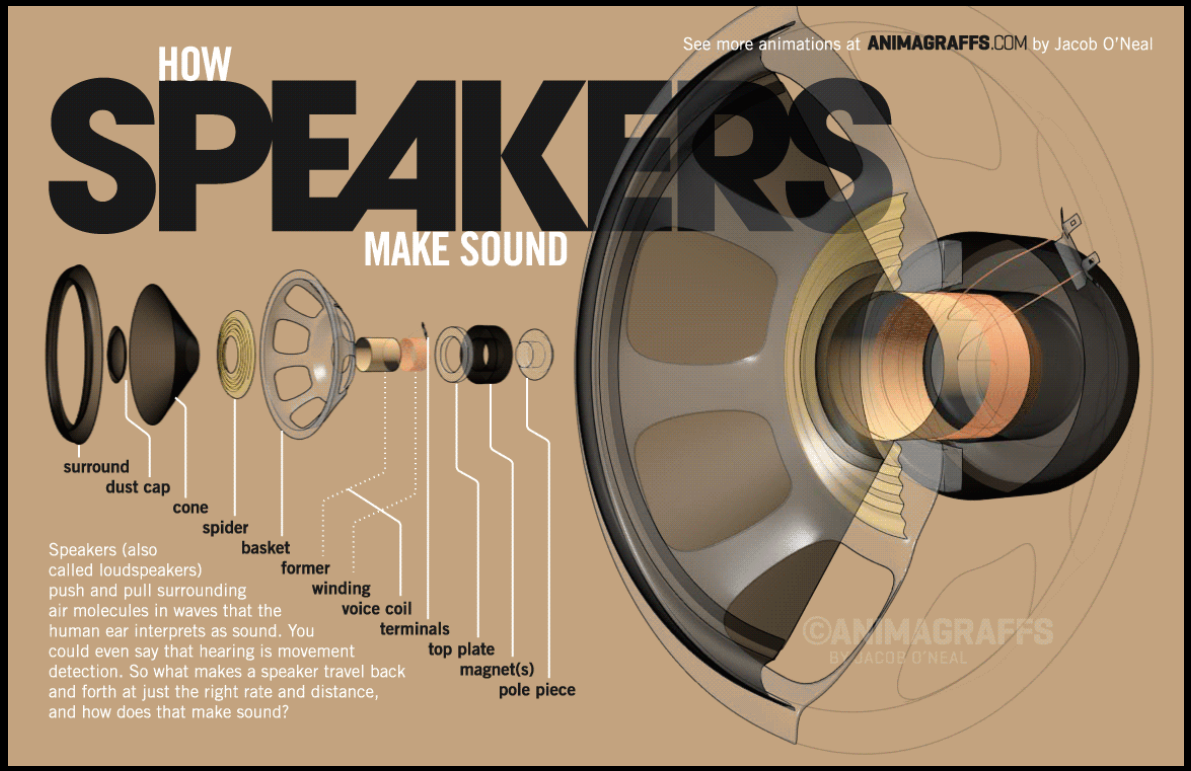
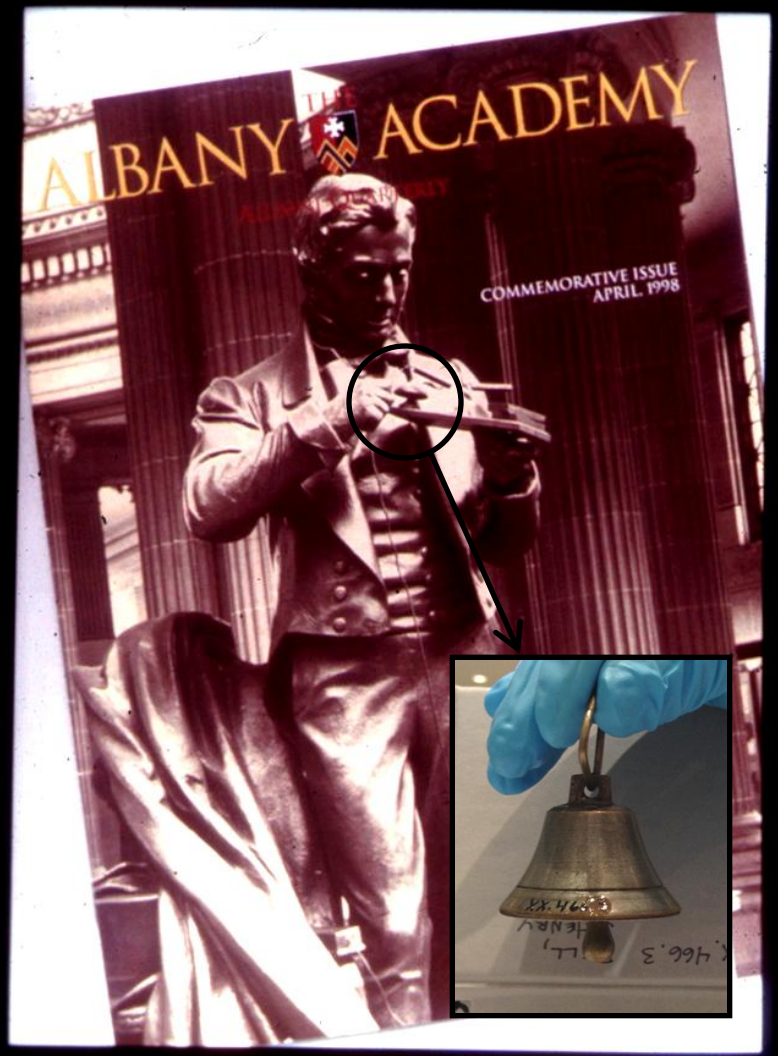


Modern Loudspeaker

Moving coil idea due to Ernst Siemens - 1878

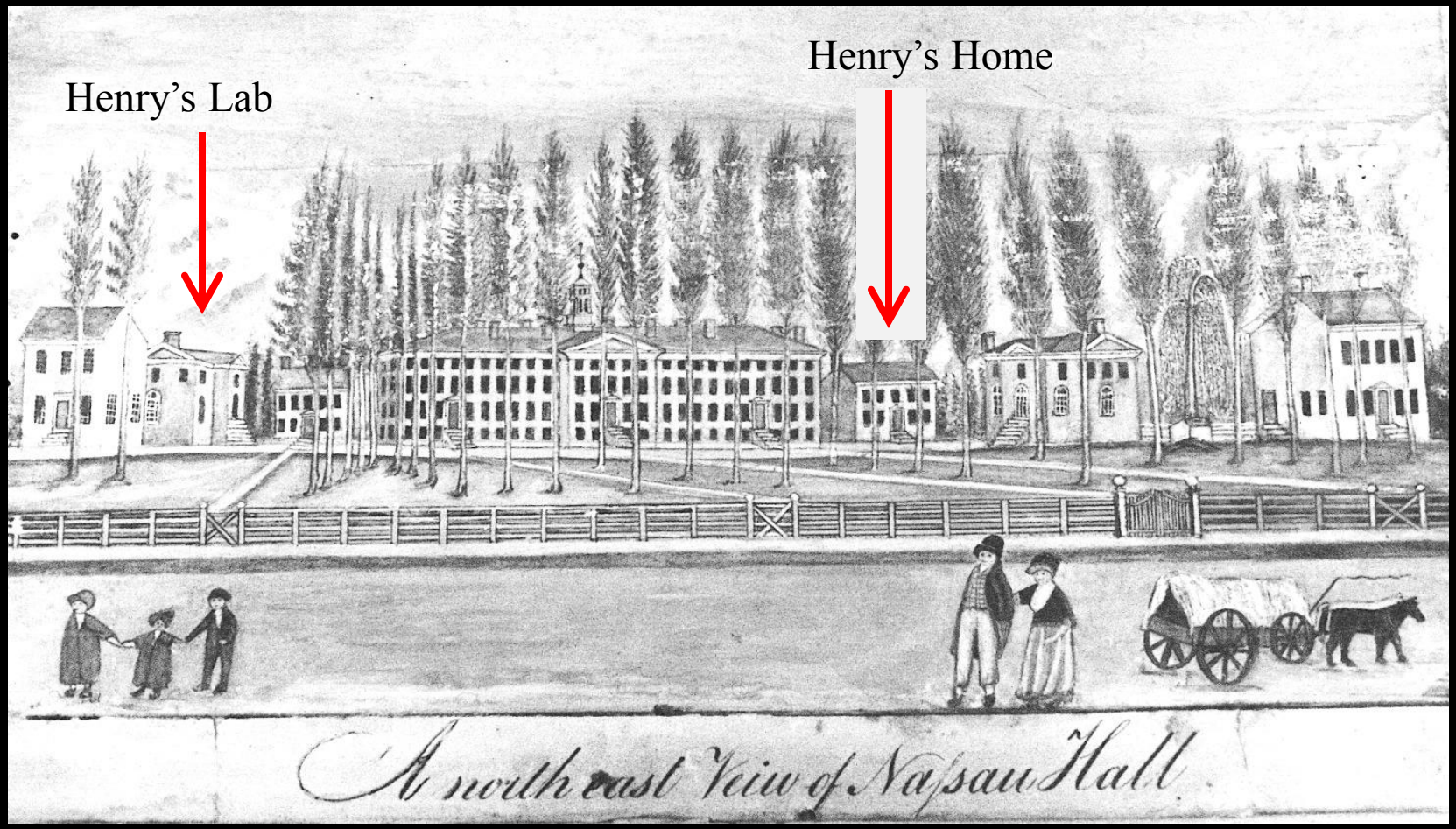


DEMONSTRATION OF 3D PRINTED LOUDSPEAKER

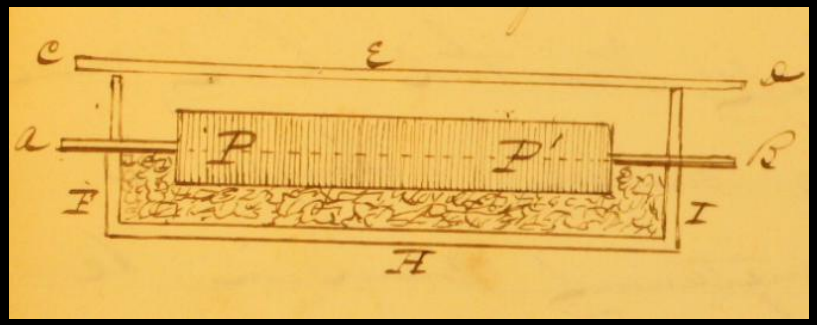


Science and Math Teacher Joseph Henry holding the first telegraph

Joseph Henry joins faculty of Princeton College in 1832



Caption: Thermopile used by Henry as a detector in his solar telescope for studying sunspots [NOT CORRECT]

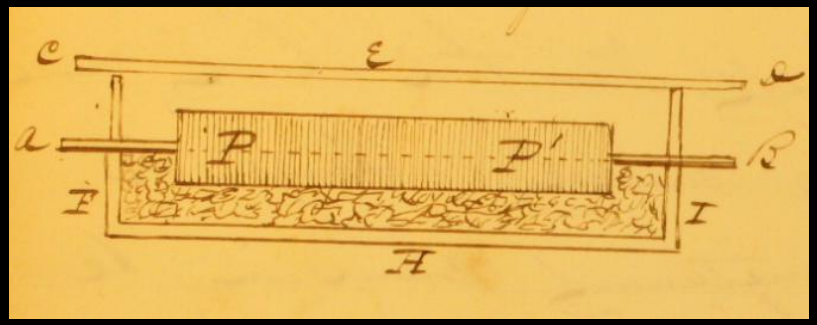


From Henry Daniel Ayers (student) notebook – 1841 – ice water below and hot iron bar above – can generate sparks

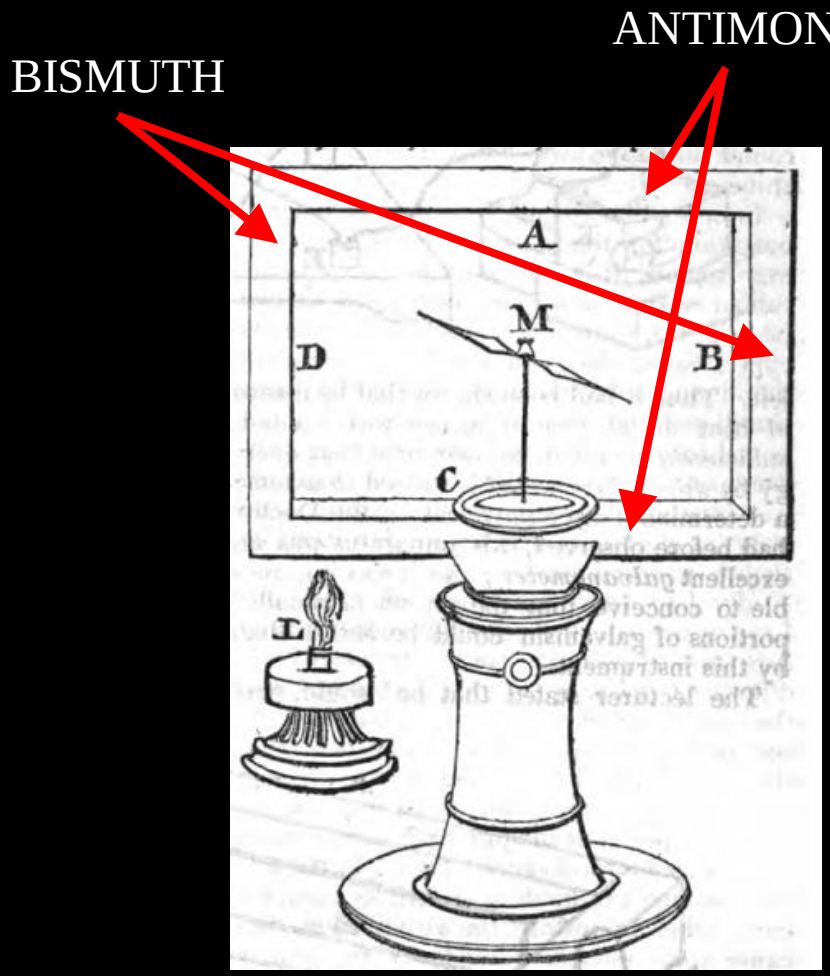
Timeline

1820	Electricity linked to Magnetism
1825	First Horseshoe Electromagnet
1830	Henry's Strong Electromagnet, Sounding Telegraph, Motor
1836	Henry's single wire telegraph
1841	Henry notes – thermoelectricity
1845	Henry's Sunspot Temperature (with Stephen Alexander)

Caption: Thermopile used by Henry as a detector in his solar telescope for studying sunspots [NOT CORRECT]



From Henry Daniel Ayers (student) notebook – 1841 – ice water below and hot iron bar above – can generate sparks

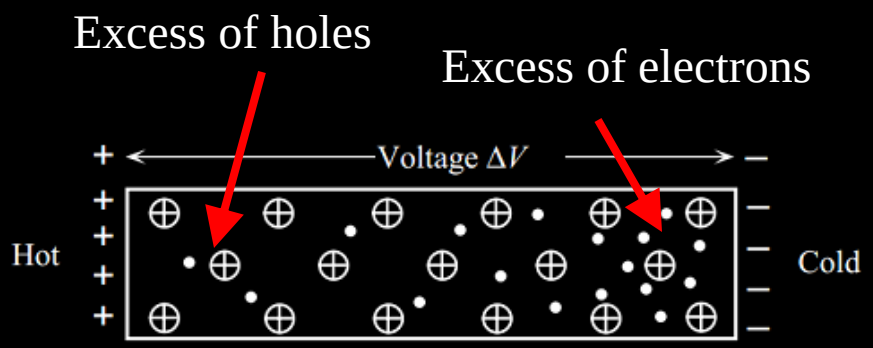


Seebeck Experiment

1821 – discovery of thermoelectricity

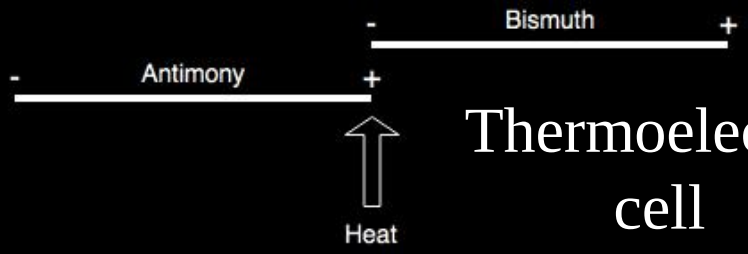
thermal generation of current – converts temperature difference into electric current

current deflects magnetic compass needle

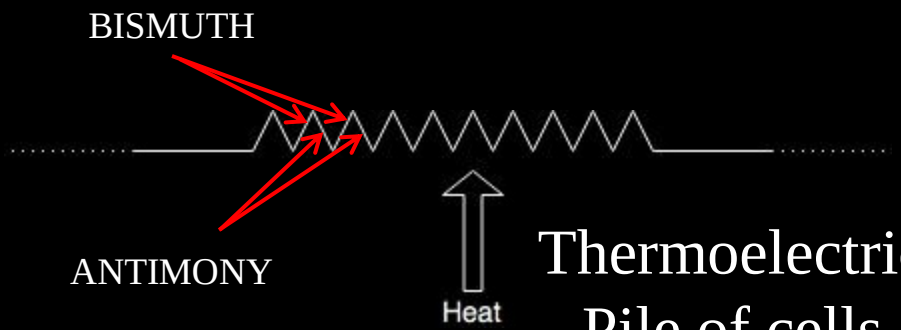


Antimony – an ‘n-type’ material

Bismuth is a ‘p-type’ material



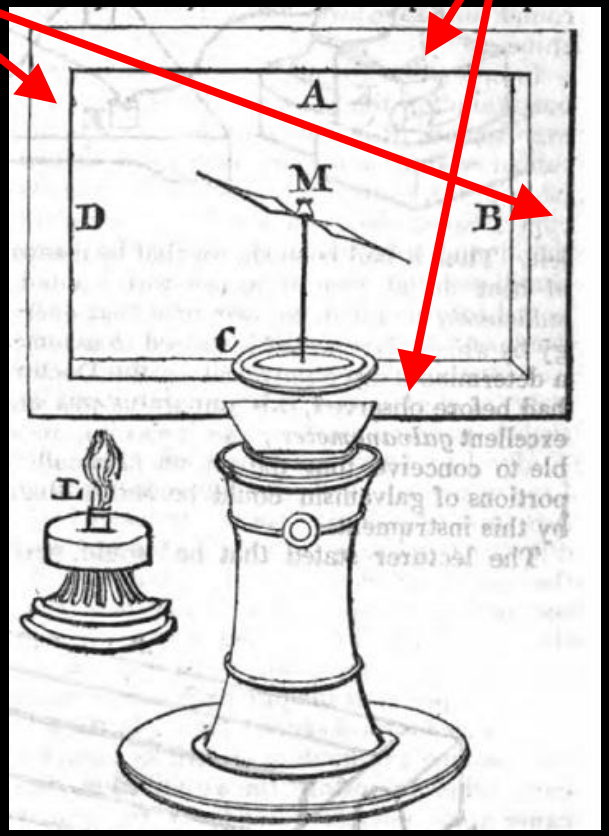
Thermoelectric cell



Thermoelectric Pile of cells

BISMUTH

ANTIMONY



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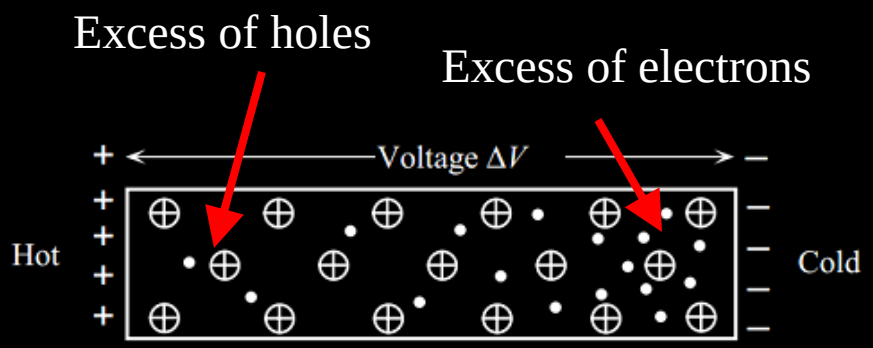

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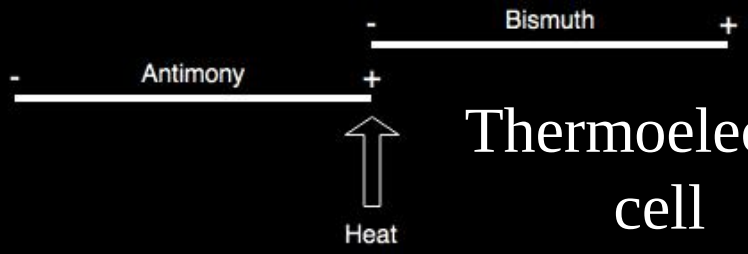

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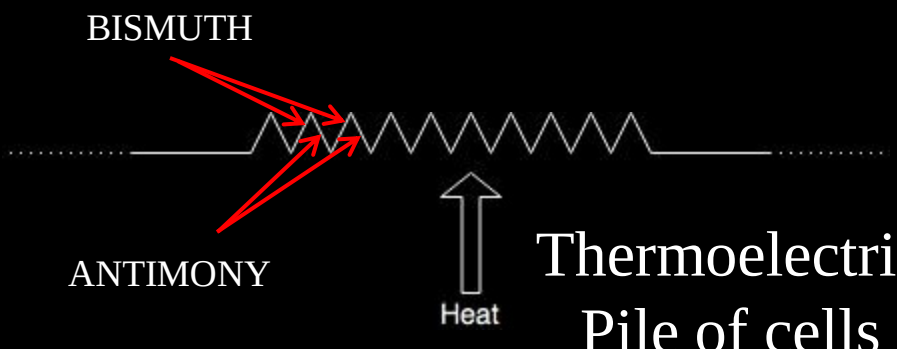
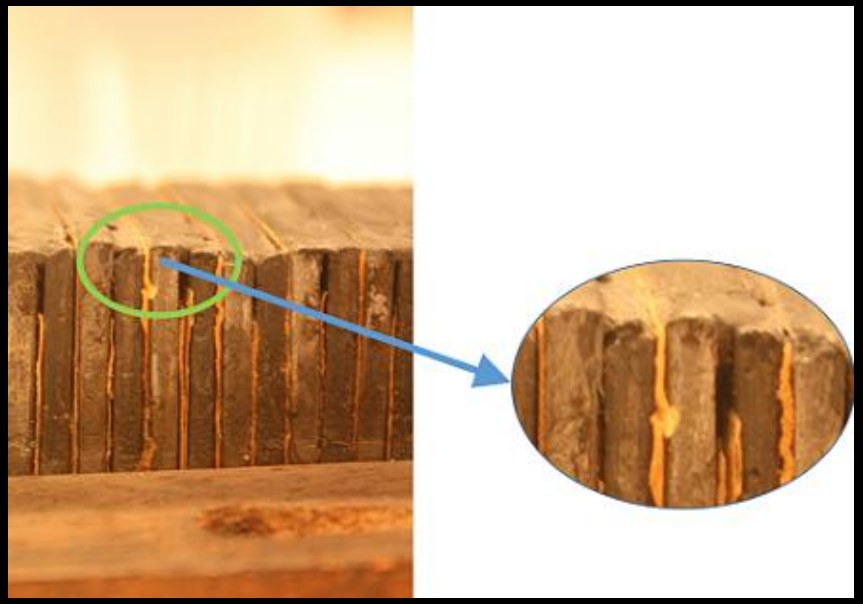
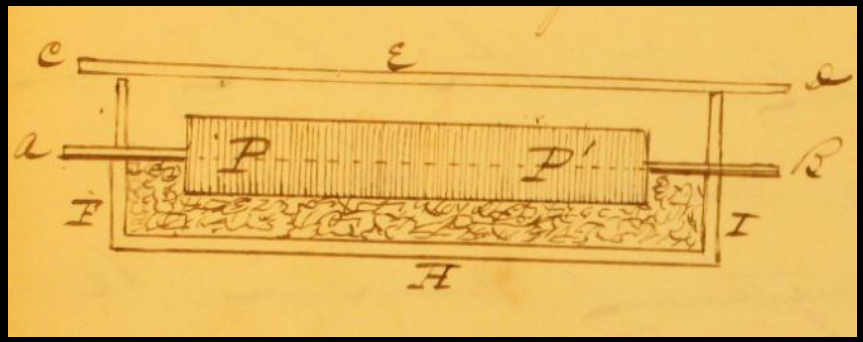
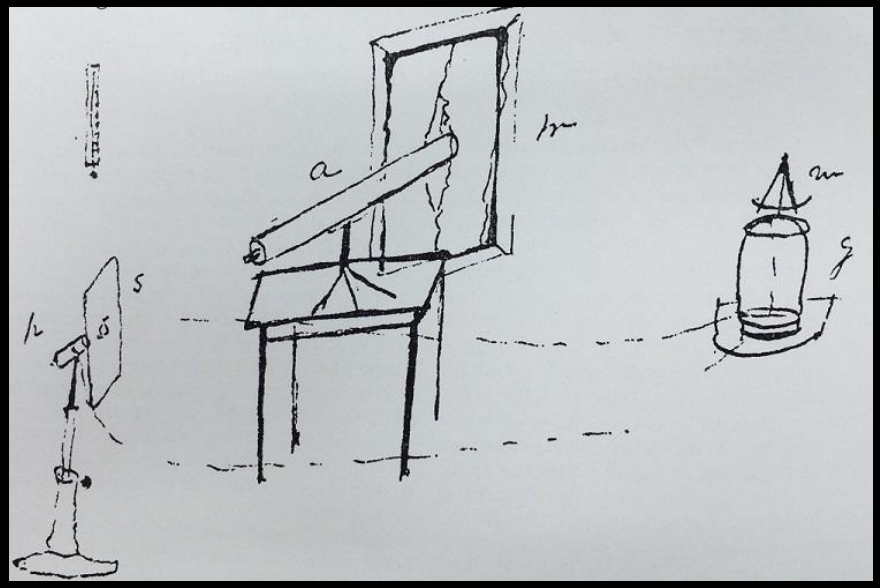


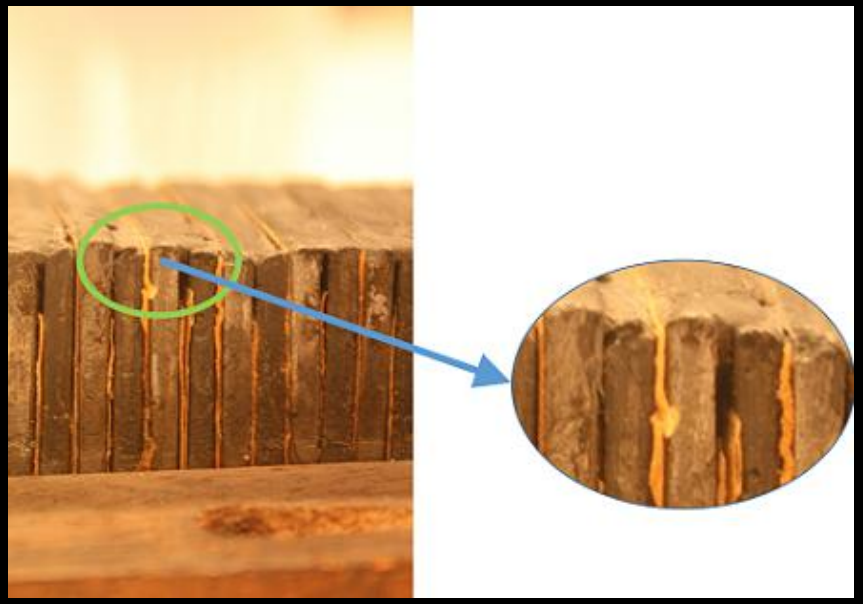
Thermoelectric Pile of cells



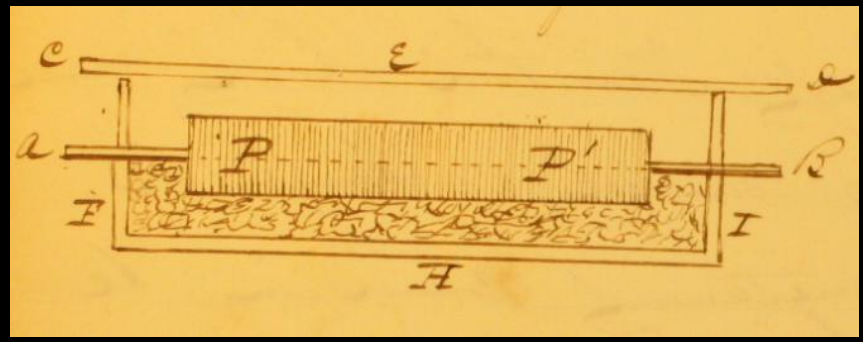


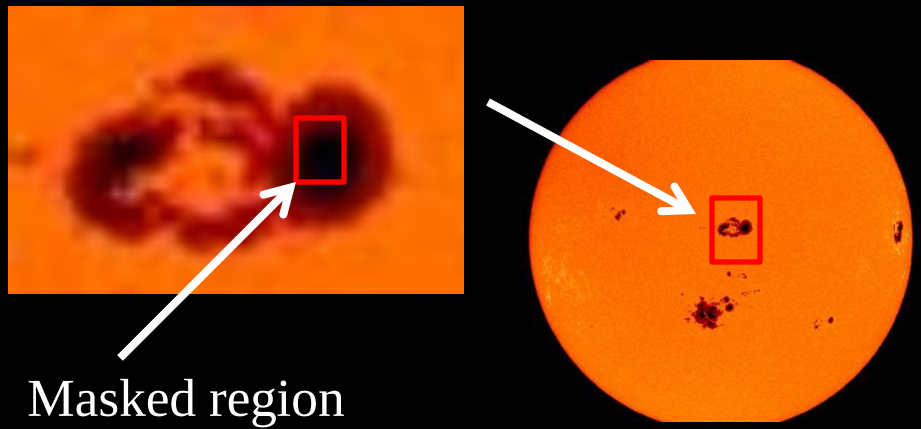
Functions also as a thermometer
Henry notes sensitivity as 1/1500-th of a degree Fahrenheit





Jan 1845 measurement (with Stephen Alexander – his brother-in-law) of sunspot temperature – uses a Rumkorff thermopile (location unknown) to show that sunspots are cooler than luminous surfaces of sun.





Masked region

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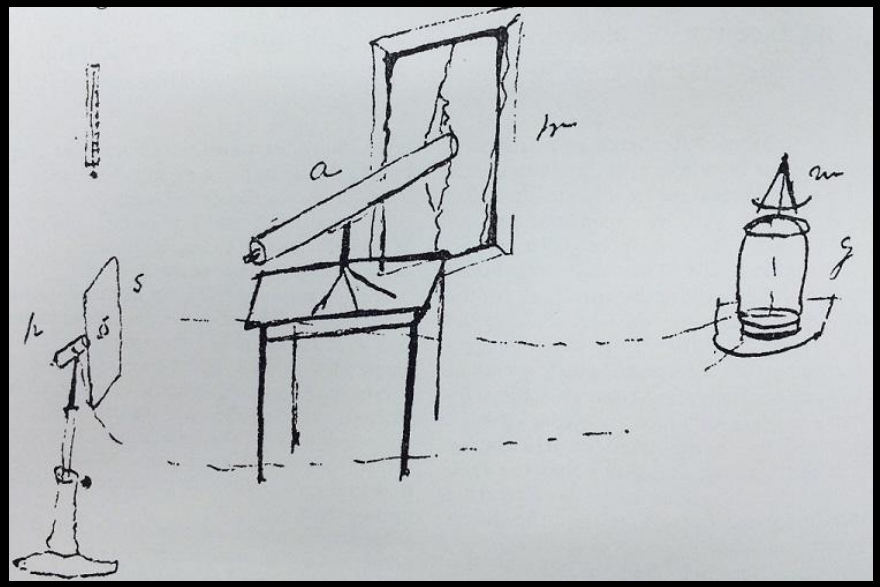
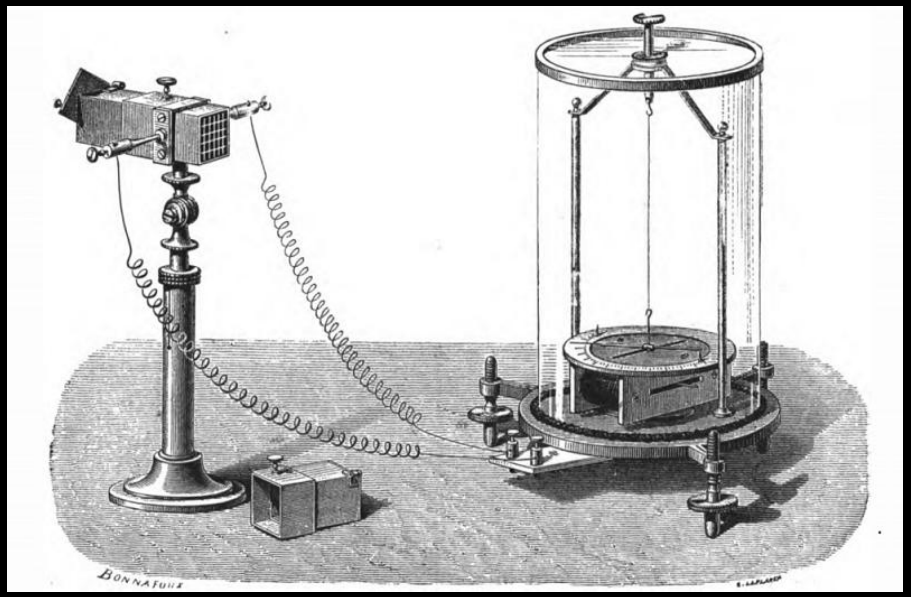


Thermopile

Galvanometer (Measures current)



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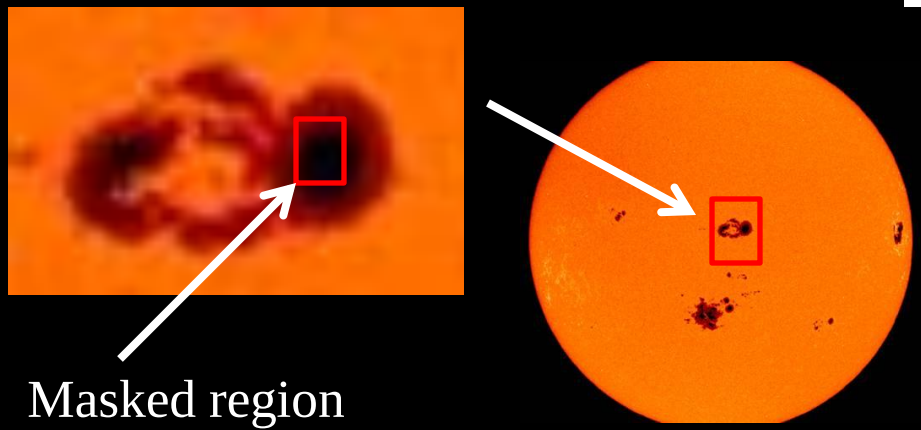

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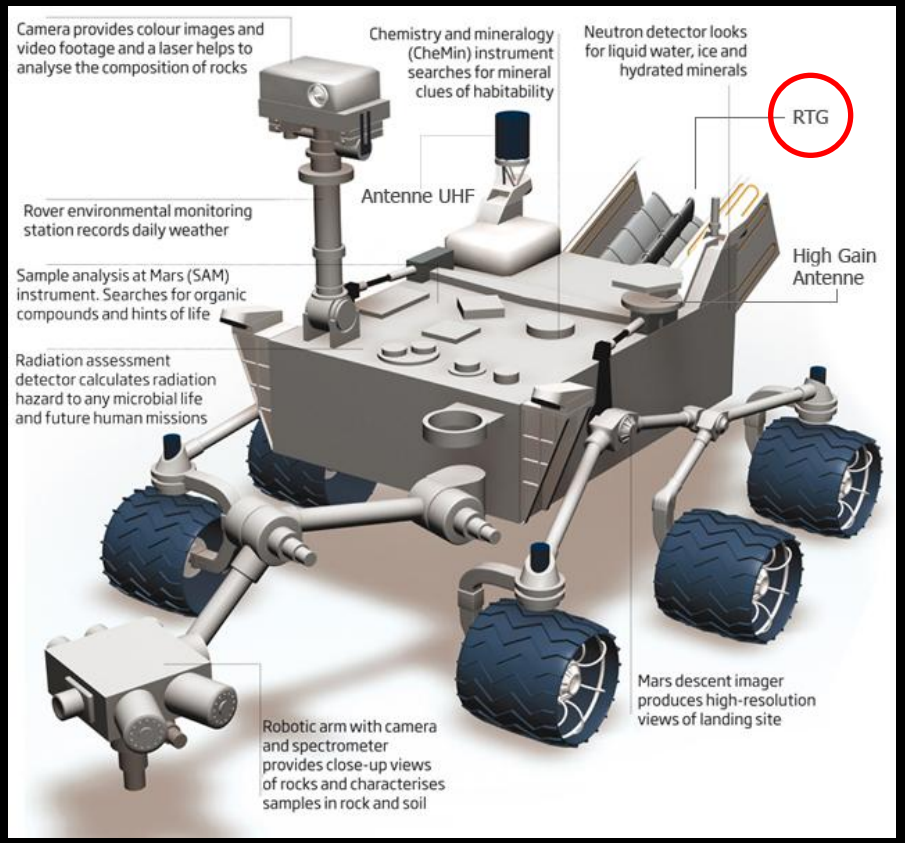
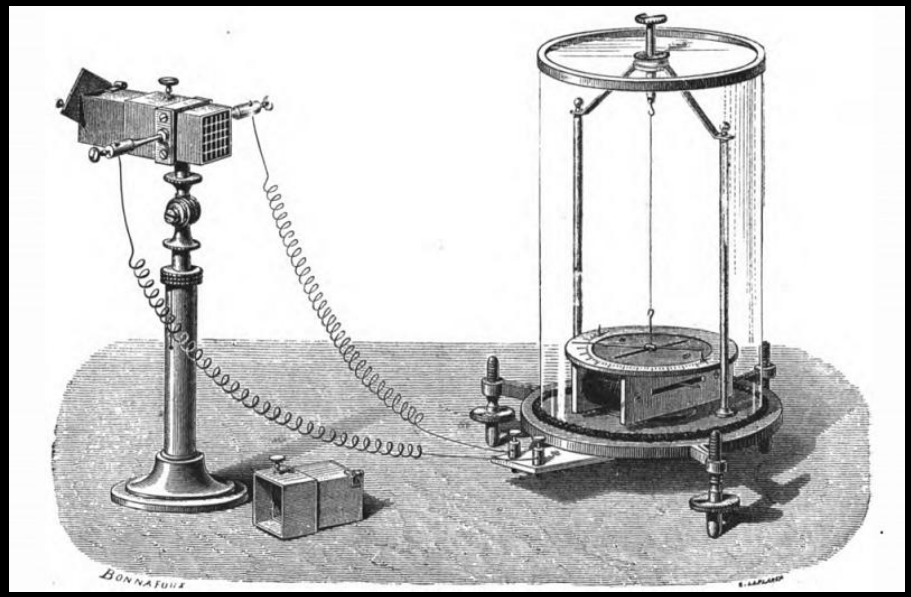


Modern application
Mars Curiosity Rover
RTG – radioisotope thermoelectric generator
main power source

Thermopile

Galvanometer (Measures current)



DEMONSTRATION VIDEOS

A final thought about the importance of preserving and understanding manuscripts and artifacts, and in getting young people interested …