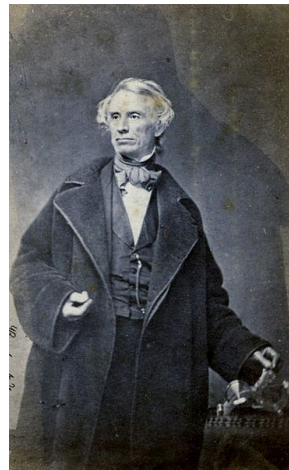


The Advent of Instant Messaging

Joseph Henry, Samuel Morse and the Telegraph



An excerpt from The Rise in Electrical Industry during the Nineteenth Century, MacLaren(1943):

“The desire for speed and more speed, which is prevalent nowadays, does not represent a new characteristic of human nature – at least as far as the transmission of messages is concerned. A classical illustration of this is found in the honors given to the Marathon runner who brought to Athens the news of the overthrow of the Persians hosts in 490 B.C.

Transmission of messages by courier was probably more frequently used than any other method through the ages, although, under favorable conditions, warnings were often sent with remarkable speed by means of beacons lighted from a succession of hilltops. Flags, semaphores or flashes from mirrors were also used to spell out messages. And yet all these methods seem very limited and crude to the **modern man who has the telegraph, telephone, and the wireless set (radio)** at his command for instant communication to the ends of the earth...

The eagerness with which new discoveries were seized upon as possible means of producing new methods of communication is indicative of the great interest attached to this problem” (MacLaren); **the mysterious phenomenon of magnetism.**

“From the sixteenth to the eighteenth century a curious superstition developed in connection to what was called sympathetic magnetism, by means of which many believe that communication would be maintained over unlimited distances...

During the eighteenth century there were literally hundreds of suggestions for utilizing static electricity for telegraphic purposes. Many of these were supported by experiments, and demonstrations were made of communication over short distances by the use of a separate wire for each letter of the alphabet... But nothing of a practical nature developed from these experiments” (MacLaren.)

Joseph Henry followed an independent line of reasoning to other researchers of his time. Accordingly he is “generally conceded to have discovered the fundamental conditions that have made the telegraph a practical success” (MacLaren.)

He greatly improved electromagnets by:

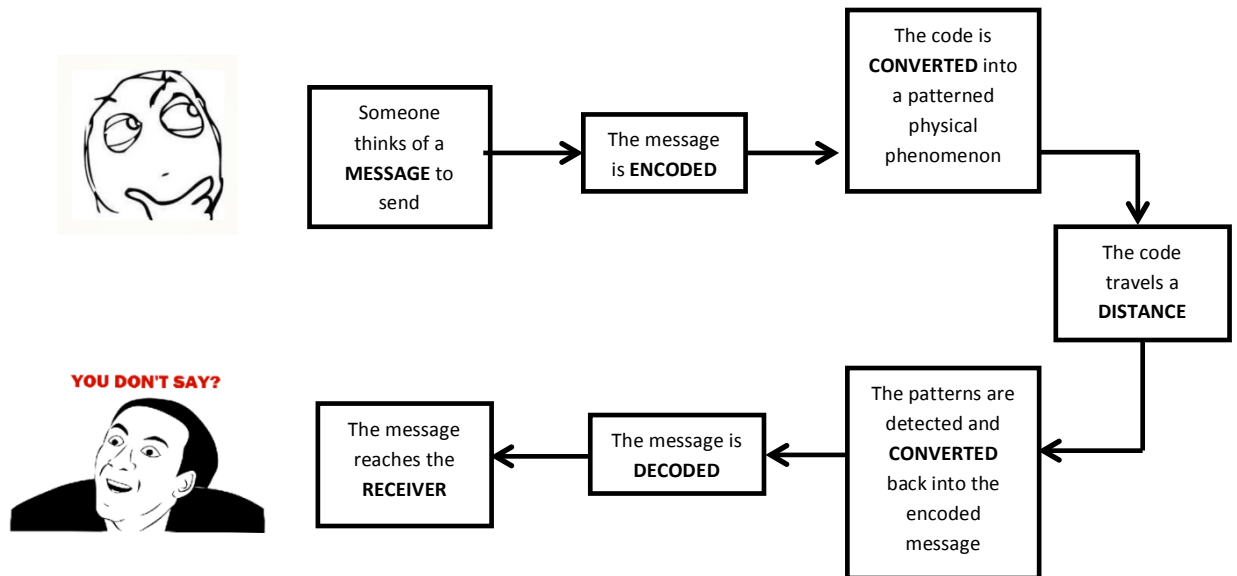
- winding the electromagnet with many turns of fine wire
- Using an intensity battery(that is, a battery with a high voltage)

Using a stronger electromagnet, he made signals with a sounding bell at the end of a line which he developed while he was at the Albany Academy(MacLaren.)

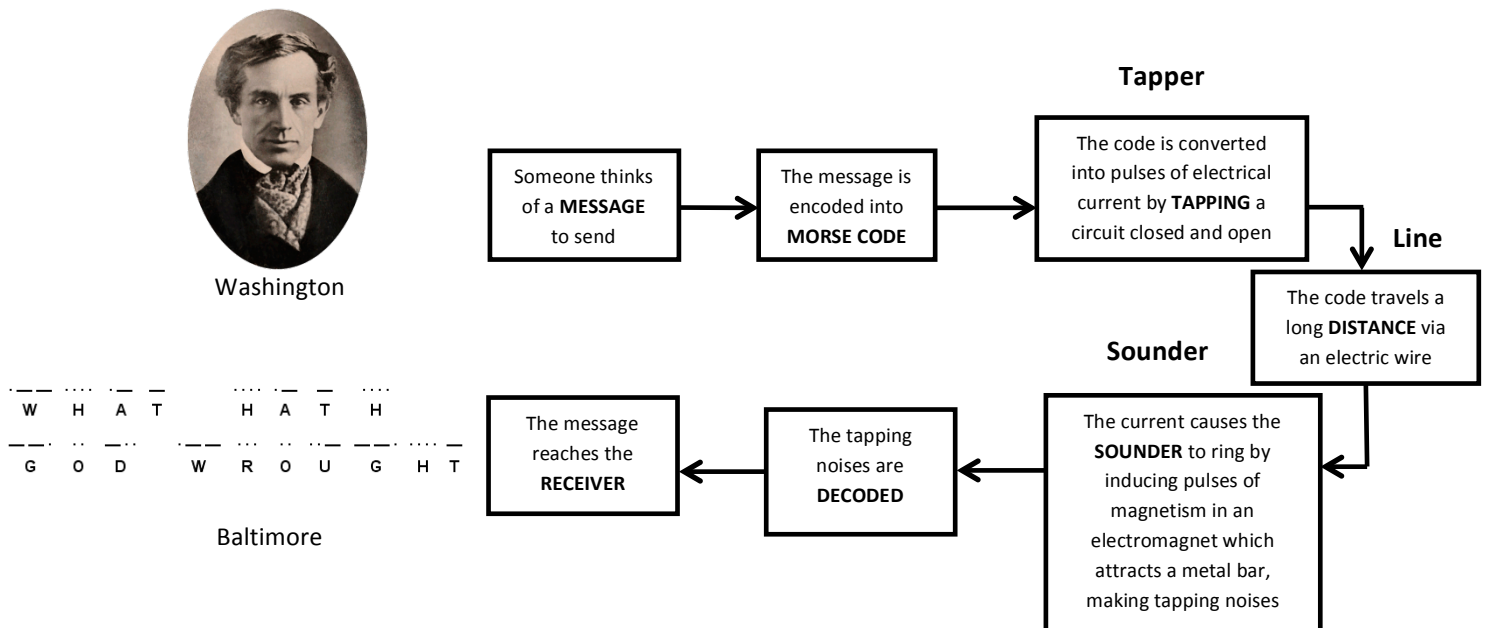
Joseph Henry’s 1831 telegraph consists of a horseshoe electromagnet, a permanent bar magnet that rotates on a pivot, and a bell. The coil used in the horseshoe electromagnet is energized when it is connected to a battery. With the coil energized, one tip of the horseshoe becomes a magnetic NORTH pole and the other tip becomes a magnetic SOUTH pole. A separate PERMANENT magnet is placed nearby. It rotates freely on a pivot and will be attracted to or repelled by the poles of the electromagnet depending on the direction of the current running through the wires. The NORTH-SOUTH polarity of the pole tips of the horseshoe electromagnet are changed by reversing the direction of the current in the wires (which is reversed by swapping the wire connections to the battery.)

Samuel Morse’s 1832 telegraph uses a horseshoe magnet to make marks on a moving tape. This is a printing telegraph. He also conceives of a code to send messages with pulses of current. Later he eliminates the tape, replacing it with tapping from a telegraph sounder.

A communication system, like the telegraph, can be broken down into a series of functions:



In the case of the telegraph:



Part A:

The Electromagnet - The essential component of the Sounder

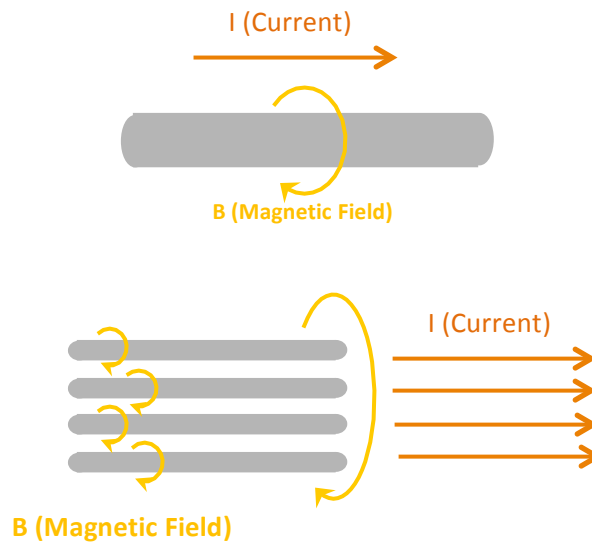
Electromagnets are different from permanent magnets in that they can be turned off and on at will, by connecting them in a circuit with a battery and opening and closing the circuit. The electromagnet is the vital component of the sounder of the telegraph. When it is magnetized it attracts a metal bar causing a tapping noise when the two collide.

Without the sounder it would be impossible to convert the pulses of current (conventional current moves from positive to negative terminals) in the circuit into something audible and intelligible.

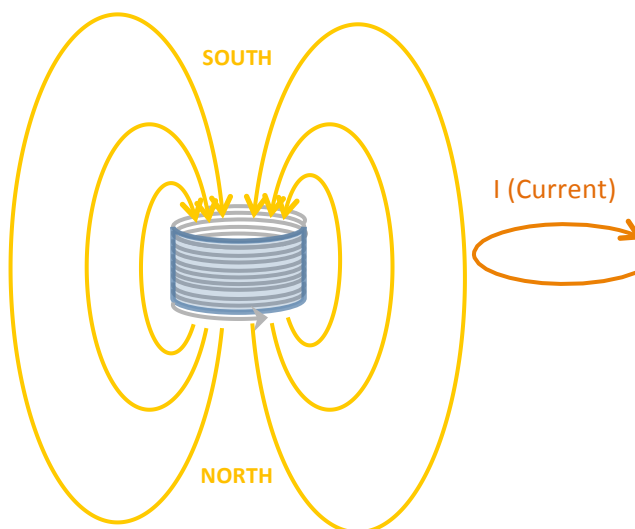
The electromagnet works as such:

When an electrical current flows through a conducting material (commonly a metal wire) a magnetic field is produced around the wire.

If one were to put many wires next to each other all carrying current in the same direction, the magnetic fields between the wires cancel and there is a net magnetic field over all of the wires.



When we wind a single current carrying wire in a series of loops, the same effect produces a larger magnetic field. As long as the wire has current flowing through it, the coil will act as a magnet.



The Sounder is simply an assembly of the electromagnet and a metal bar which makes a noise when the two strike each other.

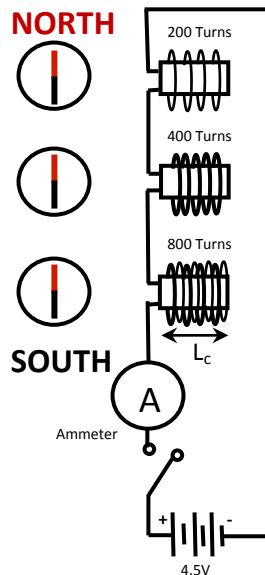
The Strength of the magnetic field (B) depends on three things:

- The **number of loops** in the coil per meter (n)
- The **current** passing through the wire (I)
- The **permeability** of the medium inside the coil (μ)

In order to produce a loud tap from the sounder the force between the magnet and bar needs to be large. Increasing the strength of the magnetic field(B) around the magnet will increase this force. This can be done by increasing the current running through the wires(I), or by increasing the number of loops(N) in the coil or by using an iron core(increasing μ).

The factors which change the strength of the electromagnet:

1) Number of loops in a coil and the induced Magnetic Field strength (± 15 mins)



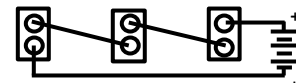
$$B = \mu I n$$

Magnetic Field Strength (G) = constant \times
Current (A) \times Number of turns per unit
length (m^{-1})

$$I = V/R$$

Current (A) = Voltage (V) / Resistance (Ω)

NB the current must pass through the coils in the same direction. Make the wire connections according to the diagram below:



Align the North (red) end of the needles of the compasses with the North lines of the compass mounts. If necessary take the mounting board off of the table and onto the floor (there may be stray magnetic fields produced by the metal in the table!)

Once the north lines are aligned, connect the three coils given at the station ($N = 200, 400$ and 800 turns) in series with the $4.5V$ battery pack. Follow the diagram above.

*When you connect the batteries, measure the angles of deflection of the compass needles for each of the three coils.

*Which compass needle is deflected most, and which the least?

*Which pole of the coils is closest to the compasses? Note that the north end of a bar magnet points north. Thus the red side of the compass needle is a north pole.

*Which pole is attracted to the coils if you reverse the connections to the battery pack?

Use the Hall Probe (Magnetic field probe) to measure the magnetic field strength in the coils. The magnetic sensor is in the tip of the probe – find the white dot at the end of the tip – this white dot should be in the center of the coil. (Note that all three coils have the same

length from end to end (L_c) and that since the coils are in series, the current throughout the circuit is the same everywhere.) You will need to use the Pasco Capstone data acquisition program to take measurements with the Hall Probe. Open Capstone worksheet “Telegraph.cap” from the “cee102_262” folder on the desktop. Ensure that the Hall Probe is set to “Axial” and “x10”. In the worksheet, use “Fast Monitor Mode” and press “Monitor” to see the values of magnetic field strength. Remember to **tare** the Hall Probe, before you take readings.

*Tabulate and graph the three values of N (x-axis) against those of B (y-axis.)

*Does your graph show the anticipated relationship?

2) Current and the induced Magnetic Field strength (± 10 mins)

Use the circuit as you did above, but only take magnetic field measurements from the 800 turn coil. Vary the current in the circuit by connecting different numbers of batteries in the circuit. (Connect one, two and three batteries in the circuit.) (By Ohm’s law, when we increase the voltage supplied to the circuit and the resistance remains the same, the current must increase.) You may have noted that an ammeter is connected in the circuit assembly; use this to monitor the current strength in the circuit.

*For which Voltages is the compass needle next to your coil deflected the most, and which the least?

*Measure angles of deflection and determine which pole (North or South) is deflecting the compass needle.

For every voltage take readings of I with the ammeter and B with the Hall Probe inserted into the 800 turn coil.

*Tabulate and graph three values of I (x-axis) against B (y-axis.)

*Does your graph show the anticipated relationship above ($B = \mu I n$)?

With a 1.5Volt battery pack, energize the coils and observe the deflection. Now insert the iron core into each of the coils and observe the deflection of the compass needles one by one.

What do you observe?

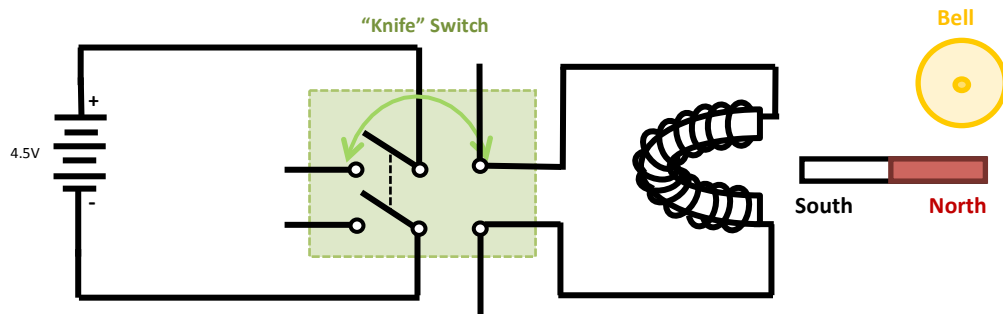
What factor are you changing by inserting the iron core?

Part B:**Joseph Henry's Pole Changing Circuit** (± 10 mins)

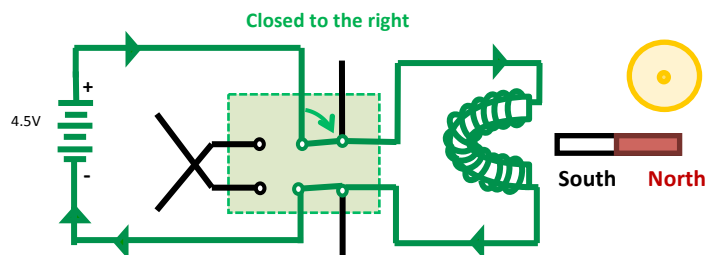
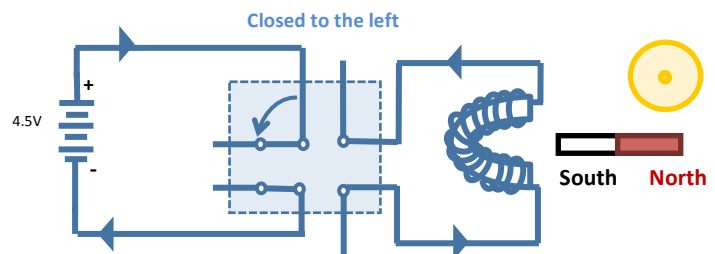
(Making a sounder with the electromagnet)

Joseph Henry realized that by reversing the direction of current within an electromagnet its poles could be reversed and consequently the direction of the force on a nearby bar magnet could be reversed. In his basic telegraph circuit he reversed the direction of the electromagnet and a pivoting bar magnet mounted close to the electromagnet would swing in response to the changing magnetic fields, striking a bell.

You will now reproduce the pole changer circuit devised by Joseph Henry as it is drawn below. (The



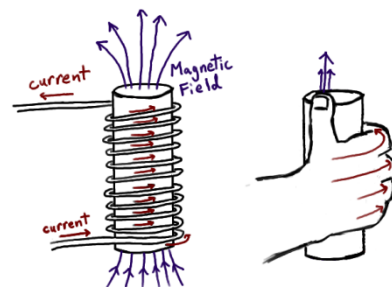
The switch needs to be wired so that it can reverse the direction of current through the magnet without having to reconfigure the circuit. This allows the operator to control the bar magnet's movement toward and away from the bell.



*Figure out how to wire the circuit to achieve this. Hint: You need only two wires and there are only four places where you can make connections. You may consult the appendix should you encounter difficulty.

*Observe the polarity of the electromagnet and attempt to determine the direction of current which must correspond to the induced poles. Swing the Knife Switch back and forth several times to ring the bell.

Does this work?



Show your TA your correct setup

appendix has a key explaining the circuit diagram components.)

Part C:

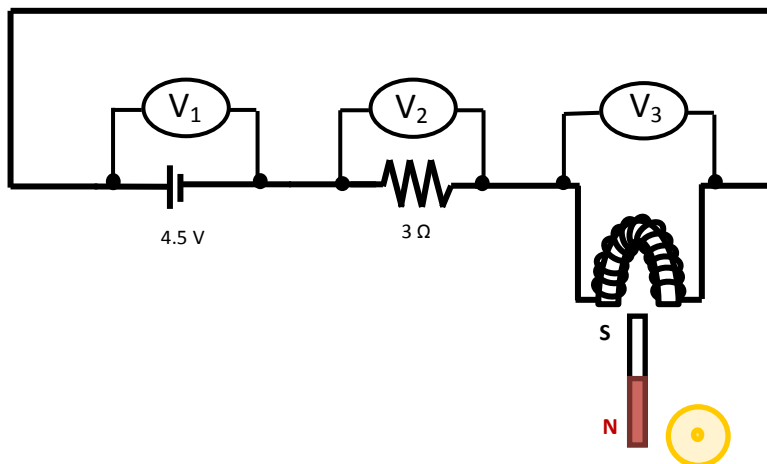
Overcoming Resistance (± 40 mins)

1. Resistance of the Sounder

As you have read, Joseph Henry encountered issues with the strength of the current in his bell sounder circuit when he significantly increased the length of wires between the tapper and sounder. He realized that the long lengths of wires in the electromagnets and the lines introduced significant resistances.

In this section you will investigate the resistances of the components in the pole changer circuit.

Assemble the apparatus as shown below:



The reading on Voltmeter 1 (V_1) indicates the EMF(Voltage) of the battery pack (that is the total voltage “supplied” to the circuit.)

This voltage is divided proportionally across the two resistors in the series circuit; so that $V_1 = V_2 + V_3$. Also note that this is a series circuit so the current is the same everywhere in the circuit. We assume here that no current flows through the Voltmeters (this is a pretty good assumption.) You must push the on/off button to complete the circuit. When the button is pushed the magnet should swing and ring the bell. If it does not, reverse the electromagnet’s leads.

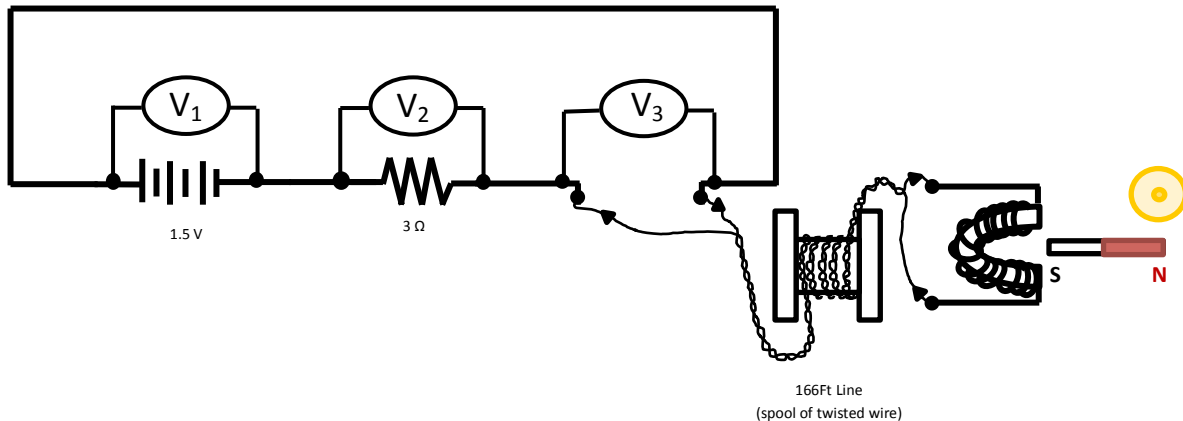
*** Given the above set-up you are to determine**

- **the current flowing in the series circuit**
- **the total resistance of the circuit**
- **the resistance of the electromagnet’s winding**

(Ohm’s law will be useful. Consult the appendix for assistance on calculations)

2. Resistance of the long line

Now assemble the apparatus as shown below, including the long lengths of wire(wrapped around a spool for your convenience) which mimic the long lengths of wire which would feature in a telegraph system.



***Now using the value of resistance of the electromagnet, determine by measurement and calculation:**

- the new current of the circuit
- the new total resistance
- the extra resistance introduced by adding the long lines of wire.

$$R = \rho L / A$$

Ohm's Law of Resistance

Resistance(Ω) = Resistivity(Ωm) x
Length(m) / Cross-sectional Area(m^2)

*What has happened to the value of the current in the circuit?

Using the relationship outlined in Ohm's law of resistance we can understand the factors which affect the magnitude of resistance in a wire (or other conductor.)

*Given that the radius of the wire is 0.5mm($5 \times 10^{-4}\text{m}$) and that the area of a circle is πr^2 calculate the cross sectional area of the wire lines and use this to calculate the resistivity of the wire.

*According to the equation, name two ways one could decrease the resistance introduced by the spool of wire while keeping it exactly the same length.

Assume the radius of the wire is 0.5mm($5 \times 10^{-4}\text{m}$) and that the length of wire introduced is 332feet ($\sim 100\text{m}$).

*Bearing in mind our previous discussion about electromagnets, how do you expect adding the long line will affect the strength of the electromagnet?

*How would you go about correcting this? (What would Joseph Henry have done?)

*What voltage is necessary for the sounder to work as it did before the long line was added to the circuit?

Note: Try it out by connecting several battery packs in series. How many do you need to get the sounder to ring the bell strongly?

Part D:

Coding information for telegraphic transmission:

The telegraph enabled signals to be transmitted great distances.

The next challenge was to establish a system by which these signals could represent messages.

As you know Samuel Morse developed Morse code as a system of representing characters by a stream of dots and dashes.

You may know that SOS is represented as ... --- ... or you may recall one of the first text tones on the Nokia 3310 which was ... -- ... or SMS (Short Message Service).

Below is an explanation of the International (standardized) Morse Code:

LETTERS.		
A ---	L ---	W ---
B ---	M ---	X ---
C ---	N ---	Y ---
D ---	O ---	Z ---
E -	P ---	
F ---	Q ---	Ch ---
G ---	R ---	Ä ---
H ---	S ---	Ö ---
I --	T --	Û ---
J ---	U ---	É ---
K ---	V ---	Ñ ---
NUMERALS.		
1 ---	4 ---	8 ---
2 ---	5 ---	9 ---
3 ---	6 ---	0 ---
	7 ---	
PUNCTUATION, ETC.		
Period (.)	---	
Comma (,)	---	
Query (?)	---	
Exclamation (!)	---	
Apostrophe (')	---	
Hyphen (-)	---	
Fresh paragraph,	---	
Inverted commas,	---	

(Prescott)

Messages are made up of dots, dashes and spaces. The length of time of the dot is the shortest.

It is important to note that:

A dot is 1 unit of time (t_0)

A dash is 3 units ($3t_0$)

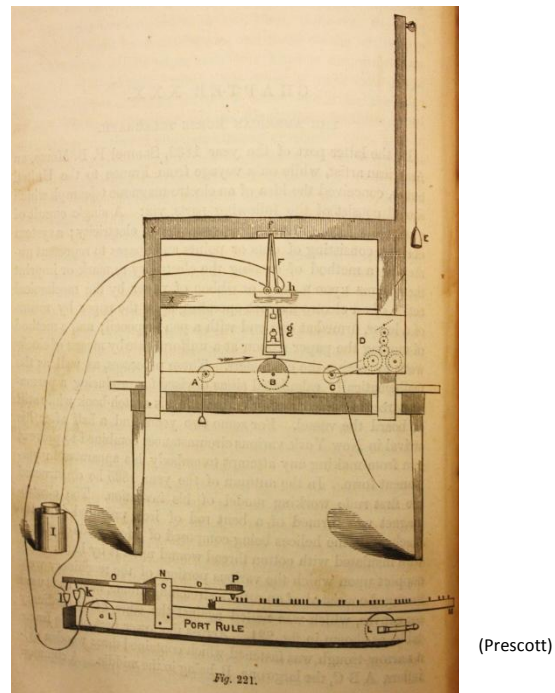
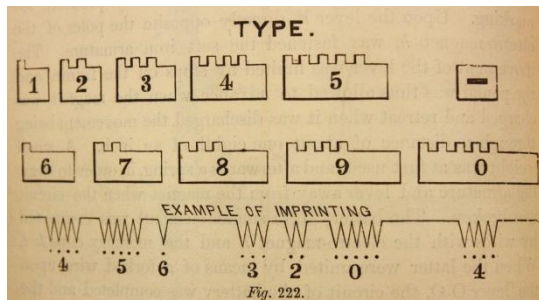
The space between dots and dashes is 1 unit (t_0)

Between characters is 3 units ($3t_0$)

Between words is 7 units ($7t_0$)

Port Rule Experiment: (± 10 mins)

Diagrams of Morse's original Port Rule (right) and the keys which he inserted into the port rule with their corresponding tick marks (below.) Each key represents one letter or number.



The setup you have been given consists of a small electric train running on a train track. The bridge has an electrical circuit mounted to it which has an electronic light gate mounted under the bridge and relay which clicks whenever the light between the photodiode and sensor is interrupted and then uninterrupted. Mounted to the train are keys which have patterned strips of vertical opaque plastic. As the train runs on the tracks keys interrupt the beam of light causing pulses of current to be sent to the computer.

*You are to determine the message encoded on the train line (note the forward and reverse messages) by reading the tick marks off of the computer and comparing them to the international Morse Code shown on the previous page. (Please save a copy of your graph)

The train should be connected to the computer input panel. If you have not done so already, open the Pasco Capstone file titled "Telegraph" and select the tab titled "Part D".

Once the equipment is working correctly run the train back and forth a few times and then capture the train's motion in each direction by clicking "record" and "stop".

Use the mouse scroll to focus in on the different sections of your graph.

*Decode the message from the graph.

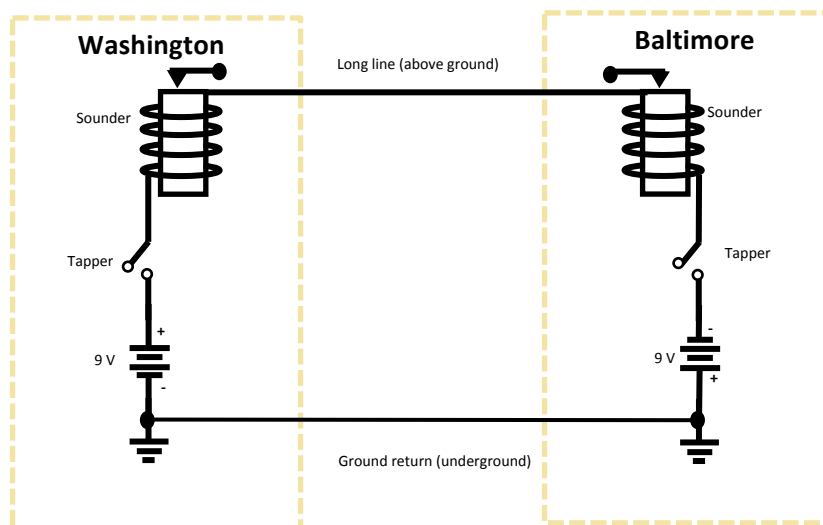
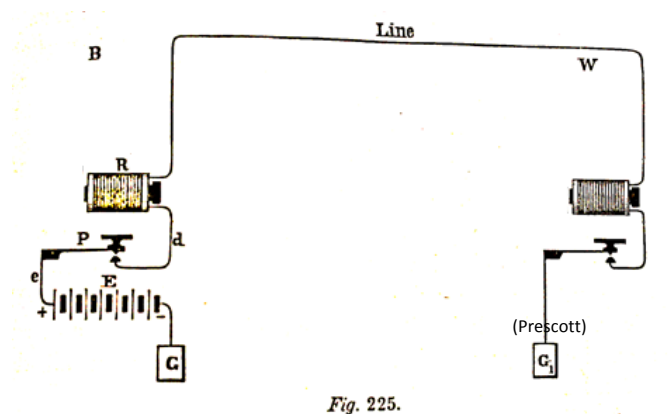
*What do you notice about the reverse and forward messages? Try to write each of these words backwards. Notice that you do not get the same effect as with Morse code. Which Morse Code letters reverse to which other letters?

Part E:**Simplex and Duplex telegraphs:** (± 10 mins)

You now understand the basic elements of a telegraph and the early problems faced by Joseph Henry.

*With the given equipment assemble a **SIMPLEX TELEGRAPH** (a telegraph in which one message may be sent at a time.) Show your TA your setup before you continue.

Below is a (simplified) diagram of the simplex telegraph between Baltimore and Washington. Use the diagram to assist you, to build your own simplex telegraph using two keys, two sounders and a long line(telegraph poles.)



When the telegraph was not in use, a small metal wedge was inserted between the key(P) and its anvil.

* Why was this done?

*If the circuit were left standing with both wedges inserted, what would happen to the battery?

The major short-coming of the above circuit is that only one message may be sent at any given time. Also assembling individual circuits and lines so that multiple messages can be sent simultaneously is expensive.

Thus telegraphers at the time set out to create duplex telegraphs. These were telegraphs which could send messages in both directions simultaneously with one line. The major difficulty in these cases was preventing the sender from ringing his own sounder while still sounding the receiver's sounder. The two early ingenious methods developed were the differential duplex and bridge duplex systems. (A conceptual explanation of the differential Duplex Telegraph is included in the Appendix.)

The Bridge Duplex telegraph: (± 10 mins)

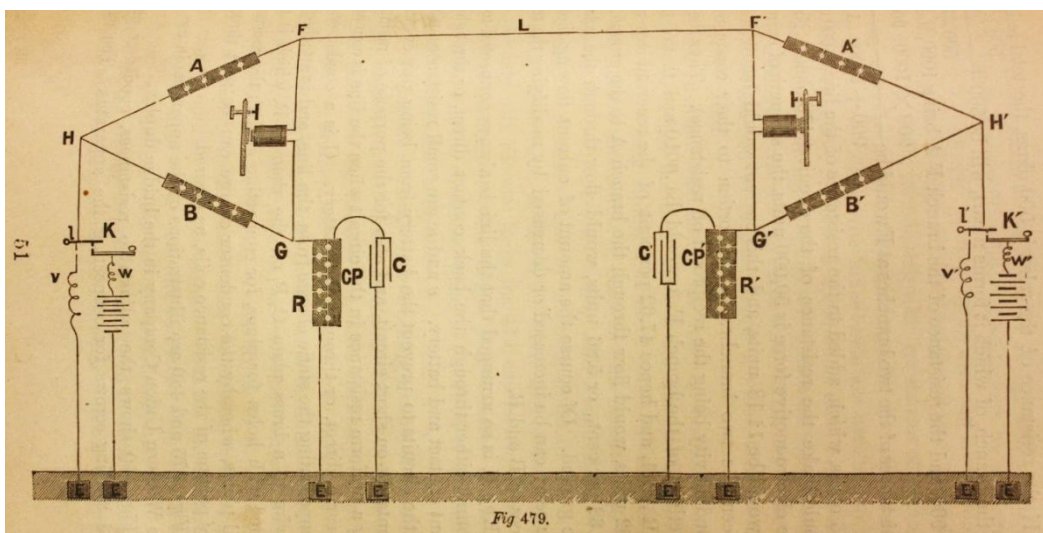
In order for a duplex telegraph to work it must meet one critical criterion: **it must transmit two signals along one line where the tapping on side A is only sounded on side B (and vice versa).**

You may wonder if this is even possible!

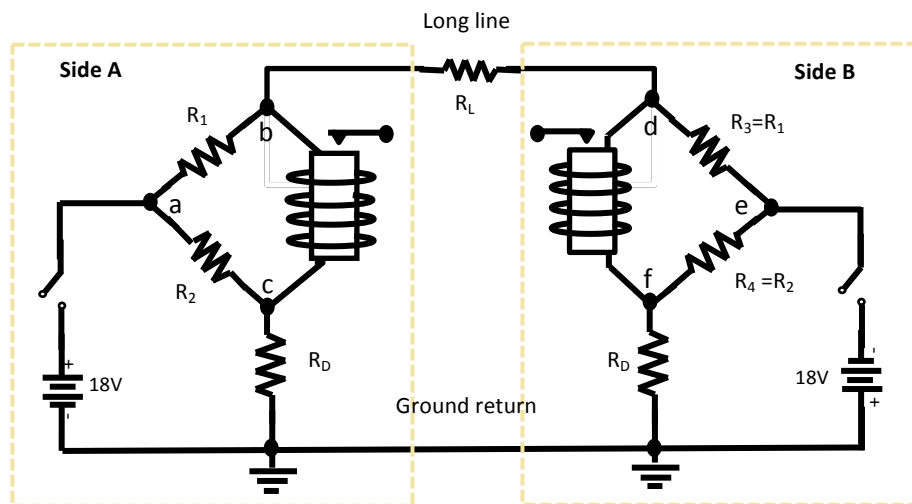
How do you have two signals running in opposite directions over one wire simultaneously without both signals sounding both sounders and jumbling the transmissions?

The circuit had to be manipulated so that that side A's sounder was bypassed by side A's signal, but not by side B's signal coming in the other direction. This is achieved with a Wheatstone bridge (the triangular arrangement below.)

Figure 479 is Stearns' Bridge Duplex circuit as assembled by Western Union Telegraph Company.



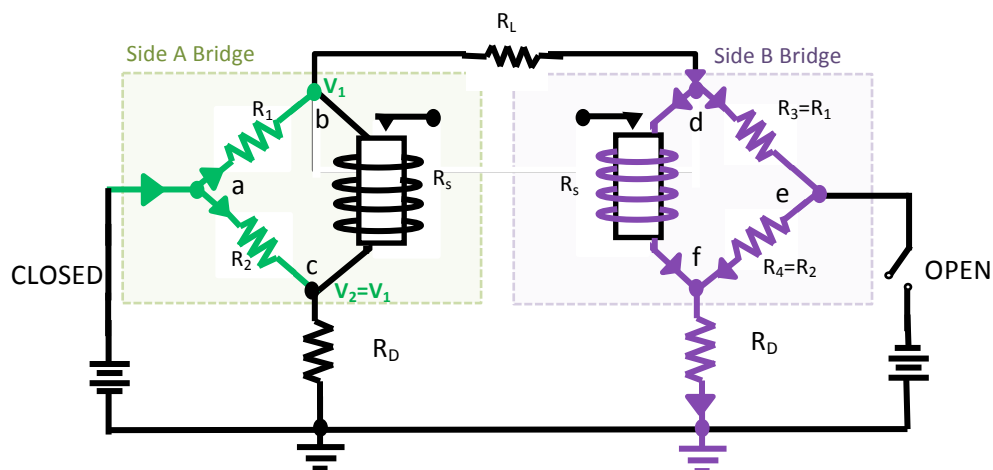
Below is the bridge duplex telegraph circuit we will be working with:
(see the appendix for any symbols you do not understand)



The Wheatstone Bridge performs two different roles depending on the direction of flow of the current:

If the current enters Side A's Wheatstone Bridge at a, it is divided across the two resistor branches. The resistance of each resistor is calculated so that the "voltage drop" across each is the same (and is equal to IR .) Thus the voltage at points b and c are equal (even though the current strength is not the same.) Since there is no difference in voltage between these points, no current flows through the electromagnet and the sounder remains silent.

If the current enters the right bridge at d, the bridge no longer diverts the current around Side B's electromagnet. The Bridge becomes a set of parallel resistors and a portion of the current flows through the electromagnet, ringing the sounder.



Assemble and test the Bridge Duplex Telegraph. Show it to your TA when you are complete.

The remaining calculation is optional – you will receive EXTRA CREDIT (5 points to be added to Lab report grade) for attempting it – Figure out how the Bridge Duplex Telegraph works by calculating the voltages b and c in the diagram below using the resistor values given below. You will find that both voltages (b and c) are the same. Since side A's sounder is connected between points b and c, and since the voltages are the same, when side A's key is depressed, the sounder will not carry any current and therefore it will not sound. The situation on side B is different since the current enters in at the top (point d in the figure on the previous page). The current splits at point d but some current will flow in the side B sounder causing it to click.

The major obstacle in designing a bridge duplex telegraph is calculating the magnitudes of resistors which allow the circuit to divert current around the sounder or channel it through the sounder, however this has been done for you.

$$R_1=R_3=R_D=100\Omega$$

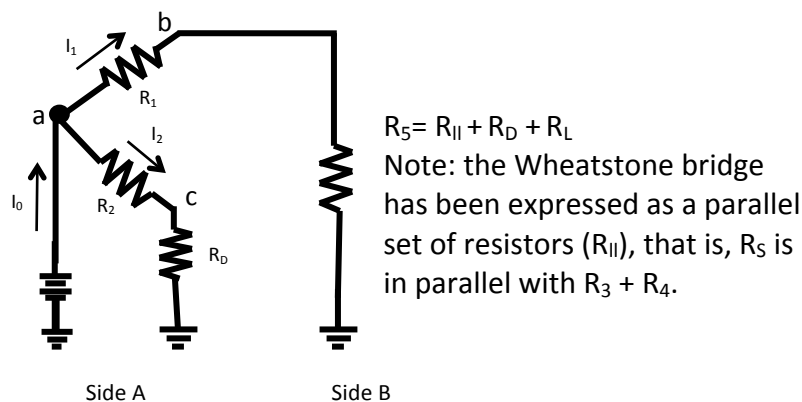
$$R_2 = R_4 = 50 \Omega$$

$$R_S = 150\Omega$$

$$R_L = 25\Omega$$

The voltage of the battery is 18V.

Note if we follow the current flowing from just one of the batteries when the tapper is down (and we set the voltages as exactly equal at points b and c) the circuit diagram may be simplified as such:



*Calculate the value of R_5 , that is $R_{II} + R_D + R_L$.

*What will the Voltage drop over R_2 be? (Note: $R_D=R_2$ and the Voltage at ground is zero) Therefore what will the “voltage drop over R_1 be?









*Calculate the values of I_1 and I_2 .

*What is the value of I_0 ?

*What is the total resistance of the circuit?

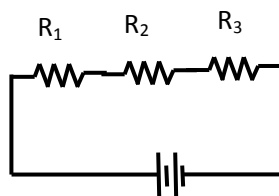
Appendix:

Common Circuit components:

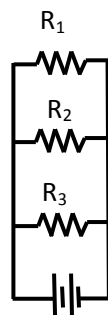
	Switch (Tapper) (Opens and closes the circuit)		Resistor ("Uses" Voltage)
	Power Supply ("Supplies" Current and Voltage)		Variable Resistor
	Earth (Completes the circuit between power supplies)		Coil & Iron core (electromagnet) (Sounder) (Also a resistor)
	Voltmeter Gives readings of Potential Difference(V) across components Ideally has infinite resistance, therefore almost no current passes through it		Ammeter Measures current Should be connected in series with other components

Resistors in series and in parallel:

When finding the total resistance of a series of resistors in parallel we may simply add their magnitudes.



$$R_{\text{Total}} = R_1 + R_2 + R_3$$

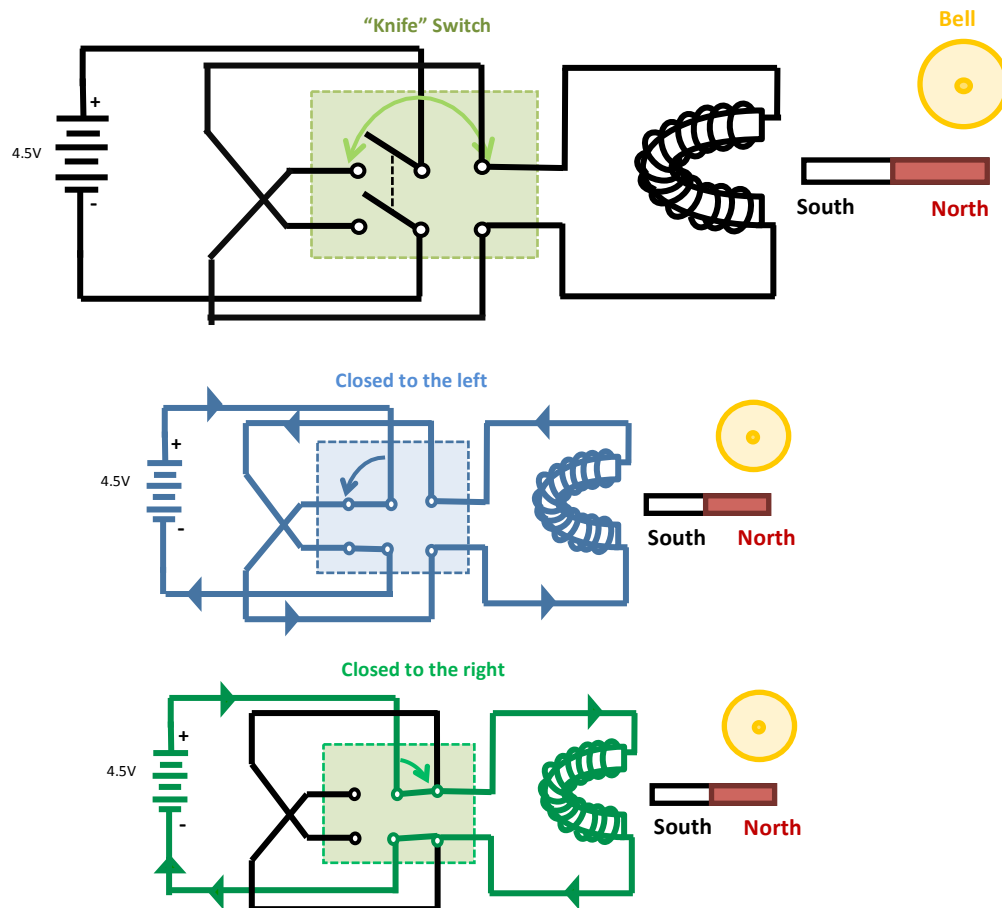


$$1/R_{\text{Total}} = 1/R_1 + 1/R_2 + 1/R_3$$

$$1/R_{\text{Total}} = (R_3 R_2 + R_1 R_3 + R_1 R_2) / (R_1 R_2 R_3)$$

$$R_{\text{Total}} = (R_1 R_2 R_3) / (R_3 R_2 + R_1 R_3 + R_1 R_2)$$

Assembly of the pole changing circuit:

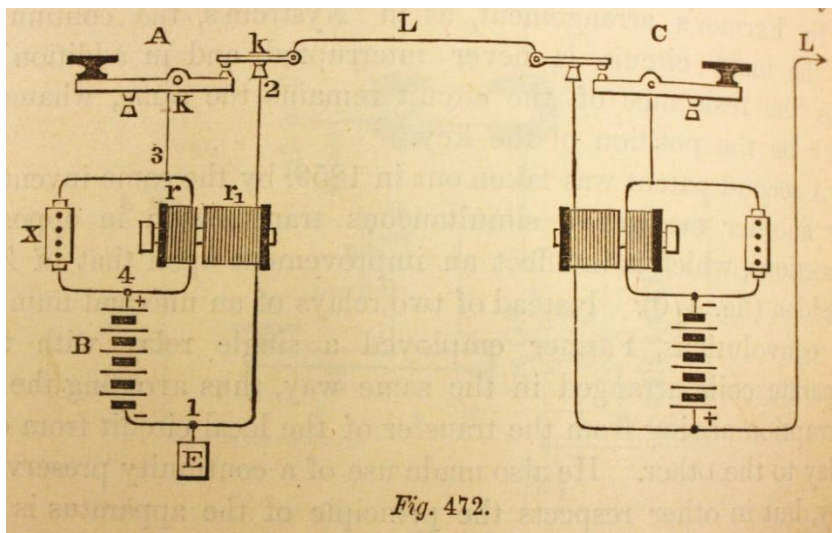


Differential Telegraph circuit:

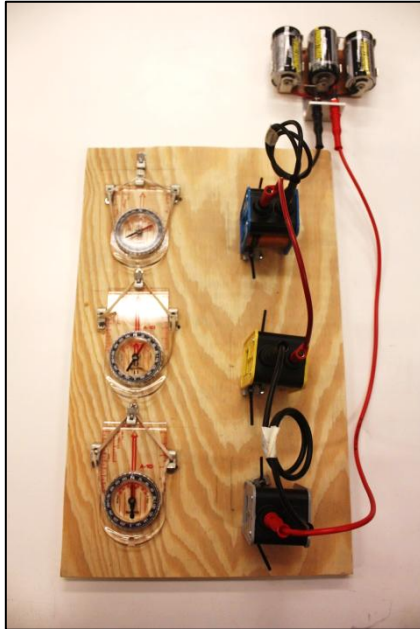
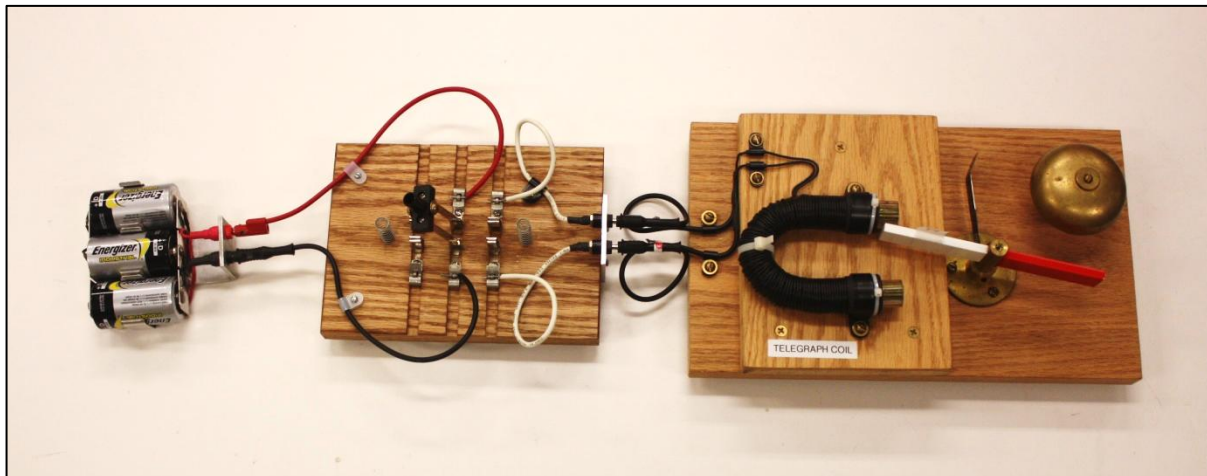
Like in the bridge telegraph the differential telegraph setup activates Side B's sounder when A's tapper is tapped while avoiding activating Side A's sounder.

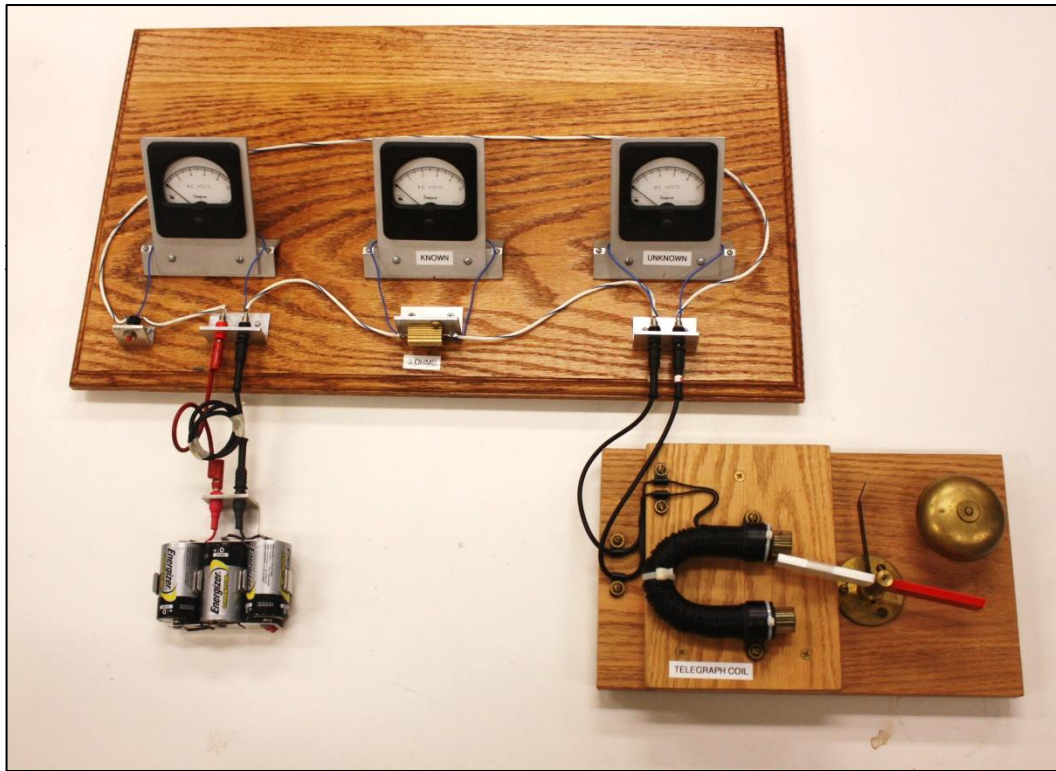
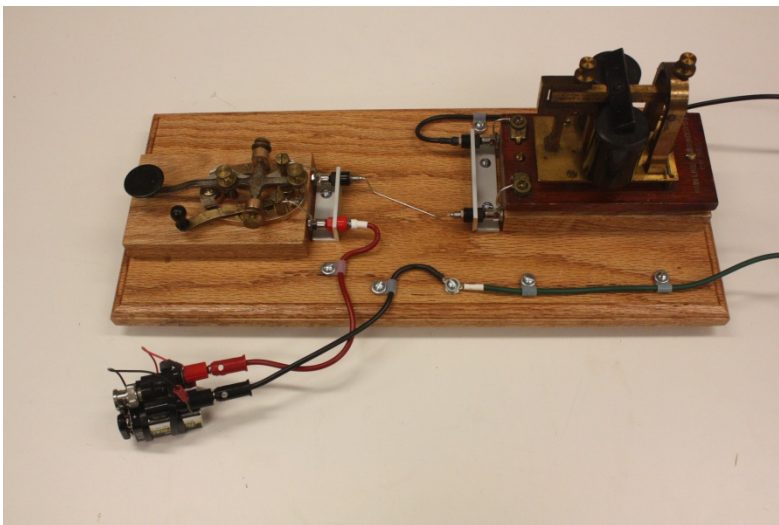
This is achieved by feeding the current of Side A into the middle of the electromagnet. The Current and Number of turns on either side of the inlet are adjusted so that the induced magnetisms are equal in magnitude, but opposite in direction, and therefore cancel. However the current which flows to the other side is fed through the entire length of electromagnet B and the sounder is activated.

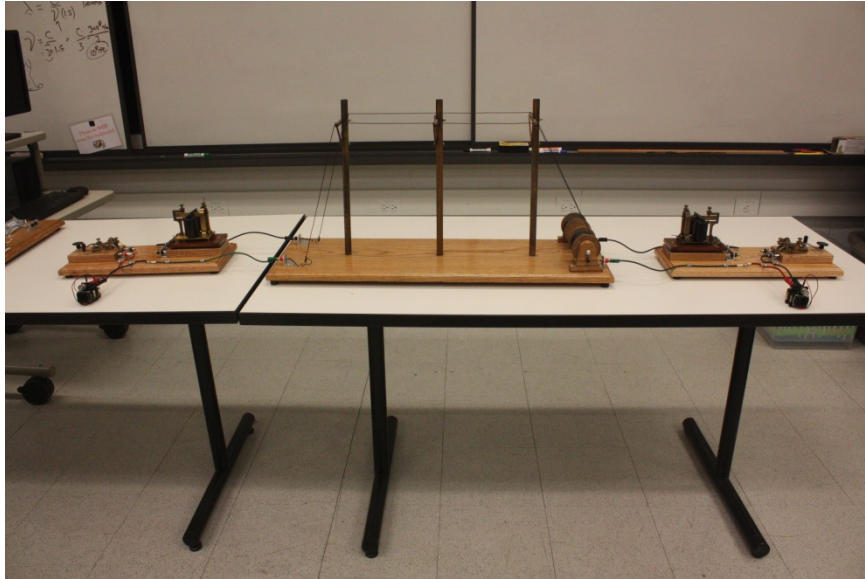
Figure 472 is one of Moses G. Farmer's Differential Duplex assemblies:



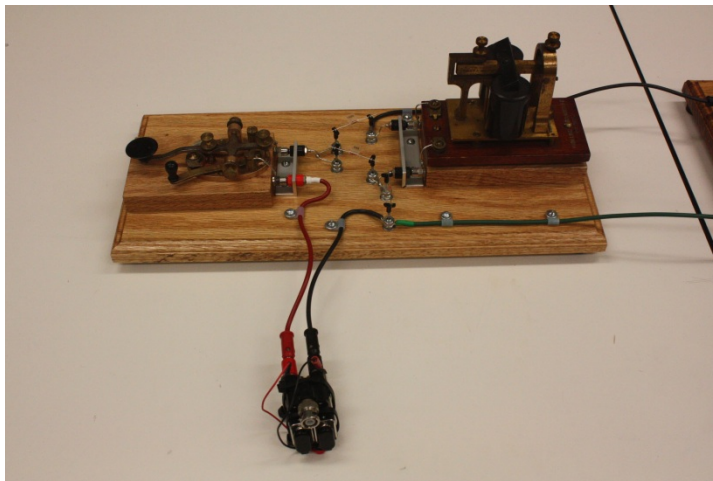
(Prescott)

Assistance with assembly and wiring:**Part A:****Part B:**

Part C:**Part D:
Simplex:**



Duplex:



Works Cited:

- 1 Prescott, George B. *Electricity and the Electric Telegraph*. New York: D. Appleton and Company, 1877. Print.
- 2 MacLaren, Malcolm. *The rise of the Electrical Industry during the Nineteenth Century*. Princeton: Princeton University Press, 1943. Print.
- 3 Fulton, Donald E. "Telegraph." *Twinkle Toes Engineering*. N.p., Jun 2008. Web. 15 Jul. 2013. <http://twinkle_toes_engineering.home.comcast.net/~twinkle_toes_engineering/telegraph.htm>.
- 4 Barry J. Blake, *Secret Language: Codes, Tricks, Spies, Thieves, and Symbols*, Oxford University Press, 2010, [ISBN 0-19-957928-8](#), p. 15.

Images:

Unidentified Photographer, . *Samuel Finley Breese Morse*. 1840. Photograph. Archives of American ArtLink back to Institution infobox template Macbeth Gallery records, New York. Web. 15 Jul 2013. < Smithsonian Photography Search>.

Daguerrotype of Morse in Paris While the inscription on verso reads: "This daguerreotype of Father was taken in Paris in 1840 by Daguerre himself" this is not a daguerreotype and it is not possible to identify with certainty that the photographer was Louis Jacques Mandé Daguerre, see Unidentified Photographer Smithsonian Photography Search

Right hand rule image: <http://deusexdice.wordpress.com/tag/right-hand-rule/>