Motors: Copper v. Steel v. Aluminium

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Research Question & Answer/ Hypothesis

How does the material and shape of a wire affect the efficiency of a motor?

If one uses a wire made out of copper and is in the shape of a coil, then it will conduct more energy.

This is based off of copper's ability to have electrons freely move and transmit throughout the metal, and that coils increase the conductivity of heat and electricity through magnetic fields.

Background Information

- **Coils are used very prominently in electrical circuits**
- **Coils increase the strength of a given magnetic field, heightening the conductivity of heat and electricity**
- **Aluminium is less conductive than other materials and takes a larger amount of it to carry the same charge**
- **Wires and electrical currents create a magnetic field that can be read as an electromagnetic charge**
- **Steel oxidizes more easily and quickly than copper or aluminium, so long-term use is ineffective**

Variables

Independent Variable

The shape and material of each wire.

Dependent Variable

The efficiency of each wire based on the shape and material of the wire.

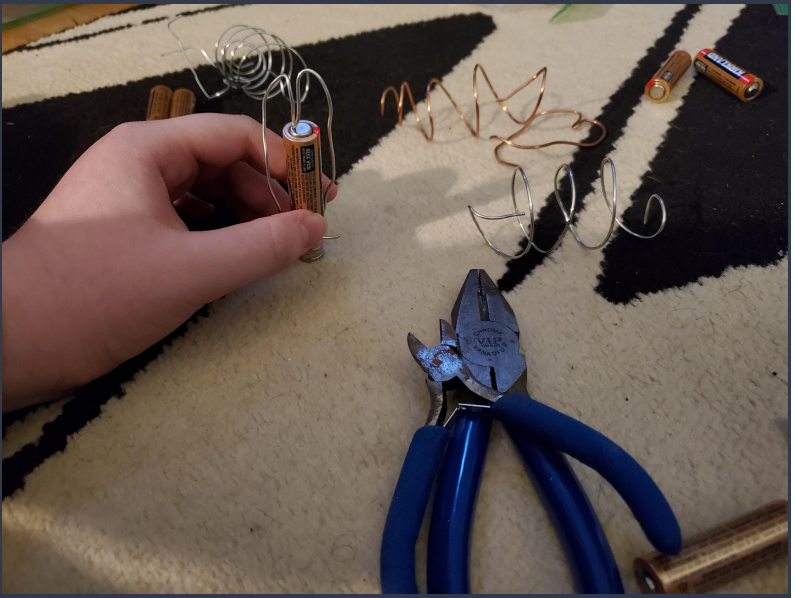
Controls

The battery type, phone, hammer, nail, measurement tools, magnets, and quality of the batteries.

Materials

- 3-5 Rare Earth Magnets
- AA Batteries
- Copper, Aluminium, and Steel Wire (18 Gauge)
- Metrek EMF Meter
- Pliers
- Hammer
- 1 Nail
- Galaxy S10 (any phone with a slow-motion video feature)

Procedure



1. Gain all materials
2. [Optional] - Take the hammer and nail and dent the AA battery without puncturing it
3. Shape (heart or coil) and cut 1 foot of the wire to the size of the battery
4. Place magnets under the battery (each side would work)
5. Place the tip of the wire on top of the battery, and have the lower side of the shape around the battery and magnets
6. Wait for the wire pick up an electrical current and start to spin
7. Record V/m and μT with EMF meter
8. Record slow-motion video with phone
9. Count how many full revolutions are made, and record how many seconds it took
10. Calculate and record how much time it takes to make one full revolution, and how many revolutions it takes each second
11. Repeat steps 2-9 (4-9 would also suffice)

Raw Data: Trial 1

Wire Type	V/m	μT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/Revolution	Revolution/Second
Copper (heart)	2	4.39	65	7.5	0.12	8.67
Copper (coil)	3	4.89	101	14.5	0.14	6.97
Steel (heart)	3	3.27	61	8	0.13	7.63
Steel (coil)	3	4.79	23	2.5	0.11	9.2
Aluminium (heart)	1	3.36	128	18.5	0.14	6.92
Aluminium (coil)	1	4.58	59	10	0.17	5.9

Explanation

Wire Type	V/m	μT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/ Revolution	Revolution/Second
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This chart shows the raw data in every form for the first trial. It includes, V/m, microteslas, seconds/revolution, etc. This data proves that copper is the most efficient material, and that the heart shape works best for it. Also, aluminium in the heart shape is the least efficient. This can be explained through copper's great electrical conductivity and lack of magnetic field, so the electricity isn't blocked by the magnets.

Raw Data: Trial 2

Wire Type	V/m	µT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/Revolution	Revolution/Second
Copper (heart)	5	5.59	12	2 sec.	0.17	6 rev.
Copper (coil)	4	4.23	66	11 sec.	0.17	6 rev.
Steel (heart)	4	4.14	86	8.5 sec.	0.1	10.12 rev.
Steel (coil)	2	6.22	35	5 sec.	0.14	7 rev.
Aluminium (heart)	3	1.4	11	6 sec.	0.5	1.83 rev.
Aluminium (coil)	0	1.58	6	4.5 sec.	0.75	1.33 rev.

Explanation

Wire Type	V/m	μT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/Revolution	Revolution/Second
Copper (heart)	5	5.59	12	2 sec.	0.17	6 rev.
Copper (coil)	4	4.23	66	11 sec.	0.17	6 rev.
Steel (heart)	4	4.14	86	8.5 sec.	0.1	10.12 rev.
Steel (coil)	2	6.22	35	5 sec.	0.14	7 rev.
Aluminium (heart)	3	1.4	11	6 sec.	0.5	1.83 rev.
Aluminium (coil)	0	1.58	6	4.5 sec.	0.75	1.33 rev.

This chart shows the raw data for the second trial. Unlike the first trial, it seems that steel and copper have a tie for most efficient. Copper still conducts the most electricity, yet steel clearly has a stronger magnetic field and is faster. Steel has both the strongest magnetic field and fastest revolutions in the entire experiment, though is greatly unstable. Still, if steel was able to control its stability, it would be most effective in a motor.

Averaged Data:

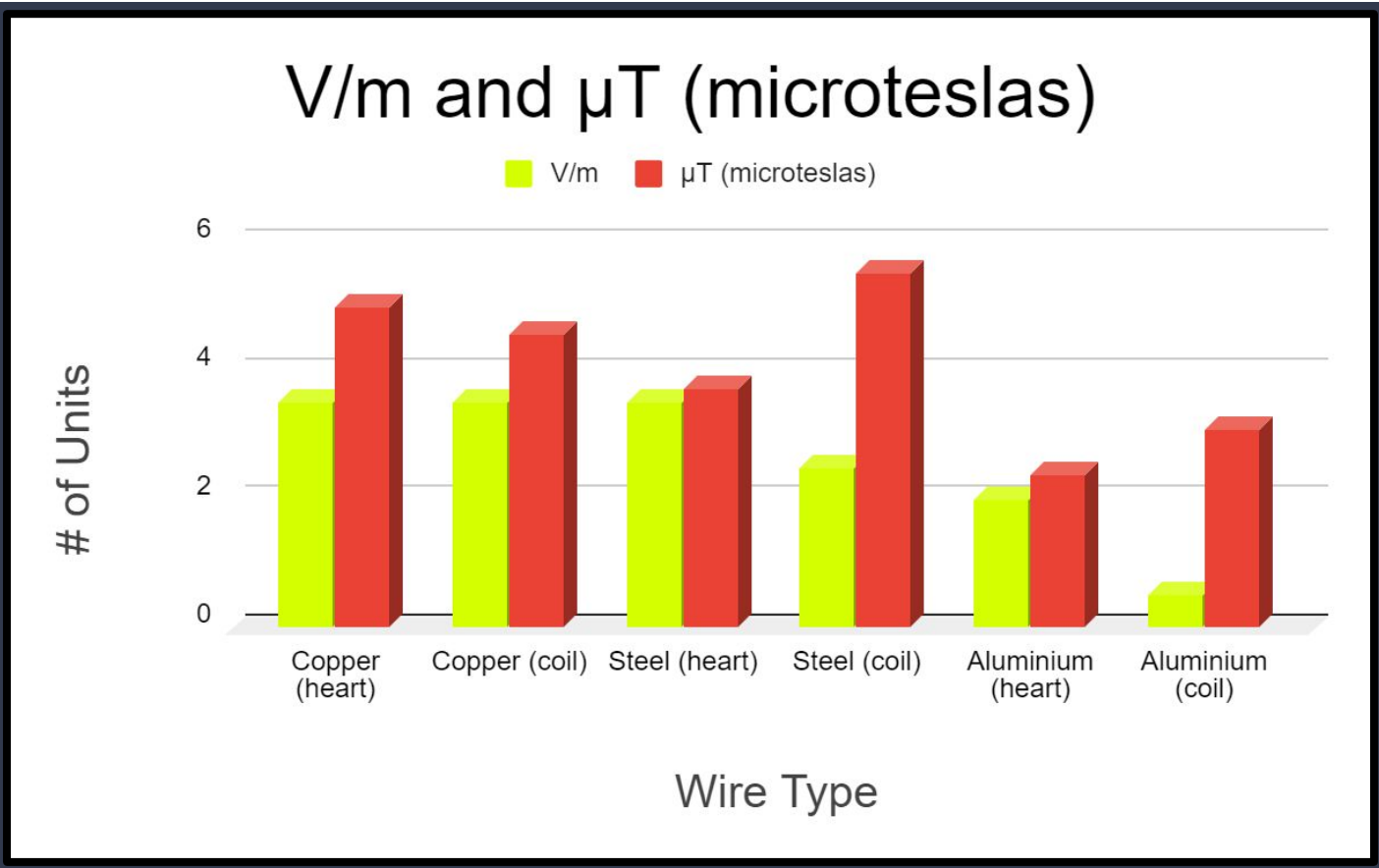
Wire Type	V/m	µT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/Revolution	Revolution/Second
Copper (heart)	3.5	4.99	38.5 rev.	4.75 sec.	0.12	8.1
Copper (coil)	3.5	4.56	83.5 rev.	12.75 sec.	0.15	6.54
Steel (heart)	3.5	3.705	73.5 rev.	8.25 sec.	0.11	8.9
Steel (coil)	2.5	5.505	29 rev.	3.75 sec.	0.13	7.73
Aluminium (heart)	2	2.38	69.5	12.25 sec.	0.18	5.67
Aluminium (coil)	0.5	3.08	32.5	7.25 sec.	0.22	4.48

Explanation

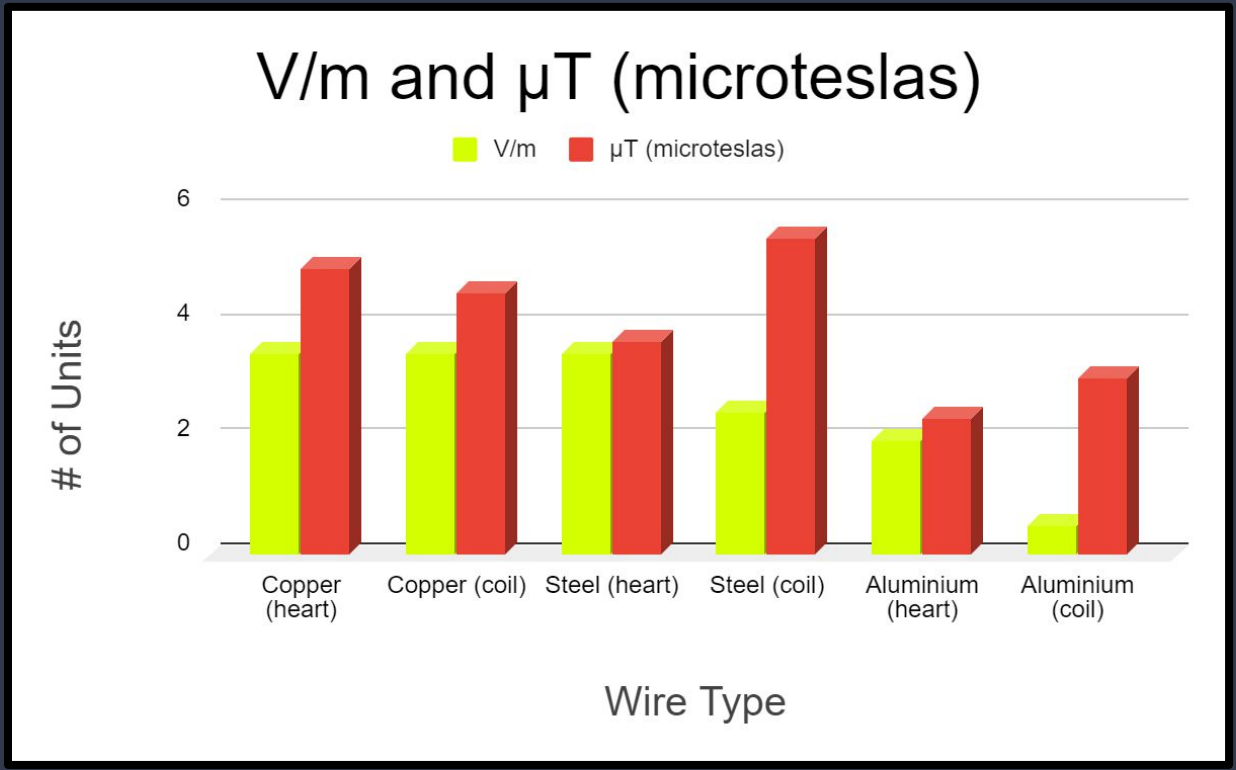
Wire Type	V/m	μT (microteslas)	# of Revolutions	Time (in seconds)	Seconds/Revolution	Revolution/Second
Copper (heart)	3.5	4.99	38.5 rev.	4.75 sec.	0.12	8.1
Copper (coil)	3.5	4.56	83.5 rev.	12.75 sec.	0.15	6.54
Steel (heart)	3.5	3.705	73.5 rev.	8.25 sec.	0.11	8.9
Steel (coil)	2.5	5.505	29 rev.	3.75 sec.	0.13	7.73
Aluminium (heart)	2	2.38	69.5	12.25 sec.	0.18	5.67
Aluminium (coil)	0.5	3.08	32.5	7.25 sec.	0.22	4.48

This final chart shows the averages between both experimental trials. This reiterates the conclusion that copper conducts electricity the best, and aluminium the worst. Even though steel is generally faster, copper in the heart shape is clearly the best. It has one of the strongest magnetic field, fastest revolution speeds, and highest electrical current. While steel has the best magnetic field and the fastest revolution speed, it still falls behind copper on other data points.

Volts/Meter & Microteslas

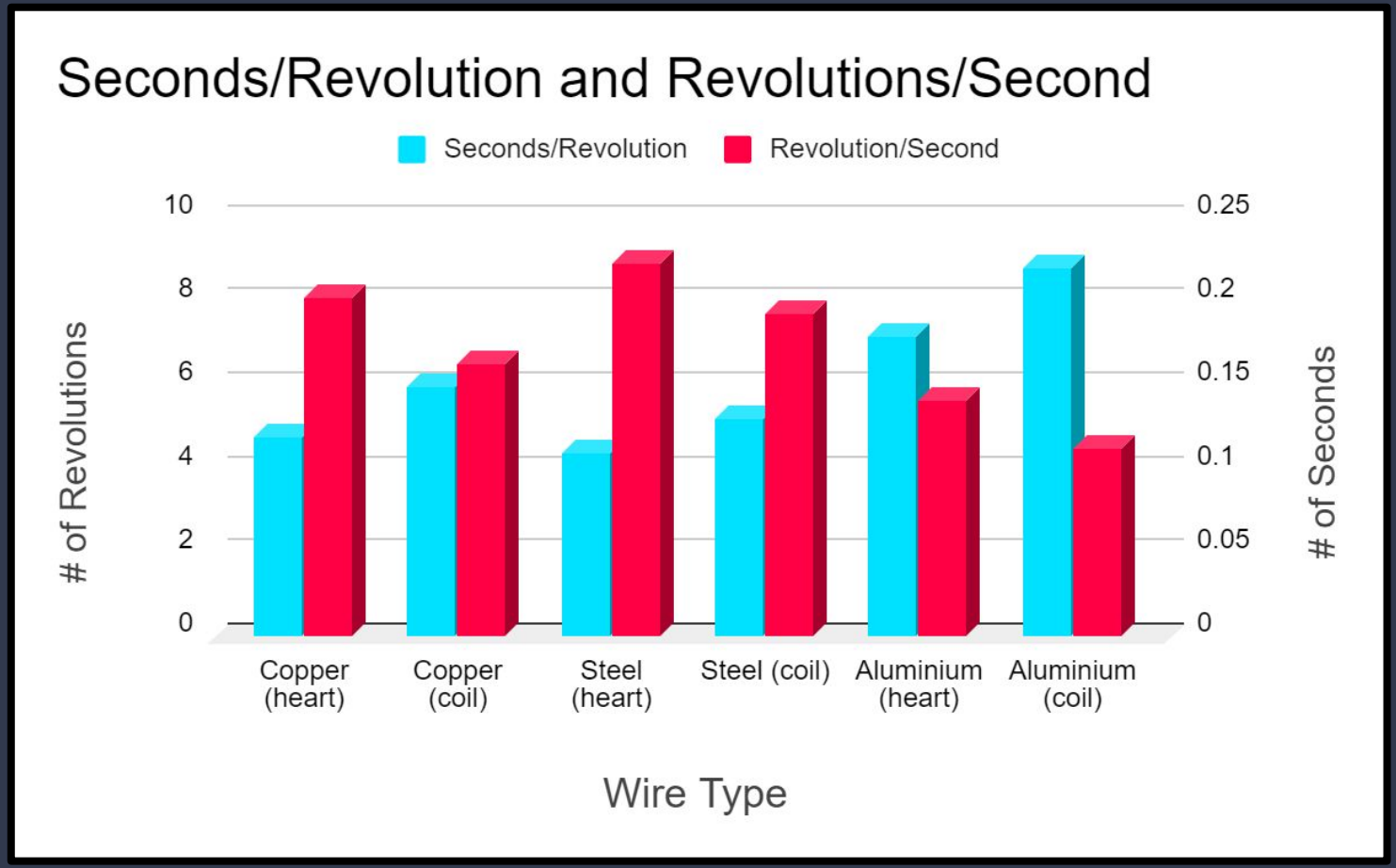


Explanation



This first graph shows the relationship between the data points for V/m and µT for each material and shape of wire. As you can see, steel in the coil shape spikes in microteslas. Also, copper consistently has the most V/m. Aluminium has the worst data across the board and pales in comparison to the other metals.

Seconds/Revolution & Revolutions/Second:



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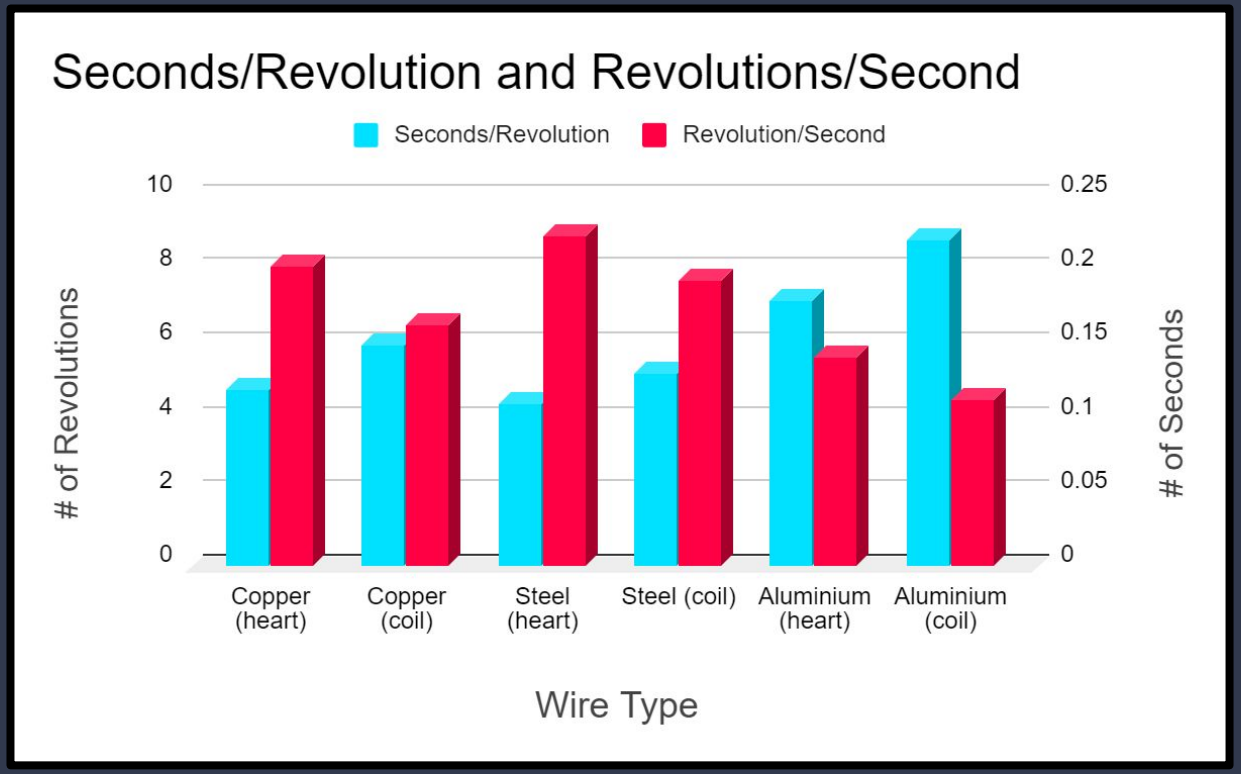
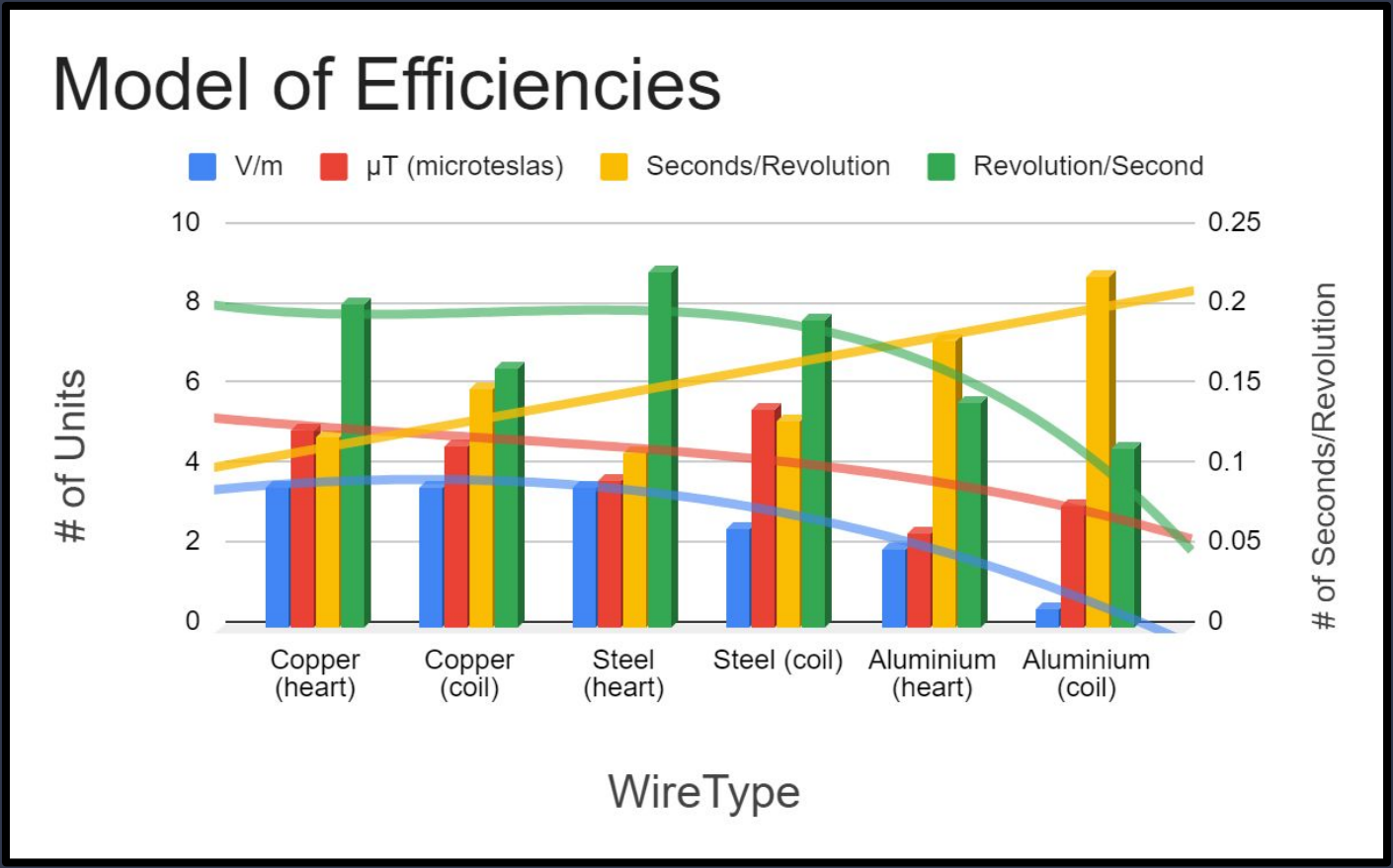
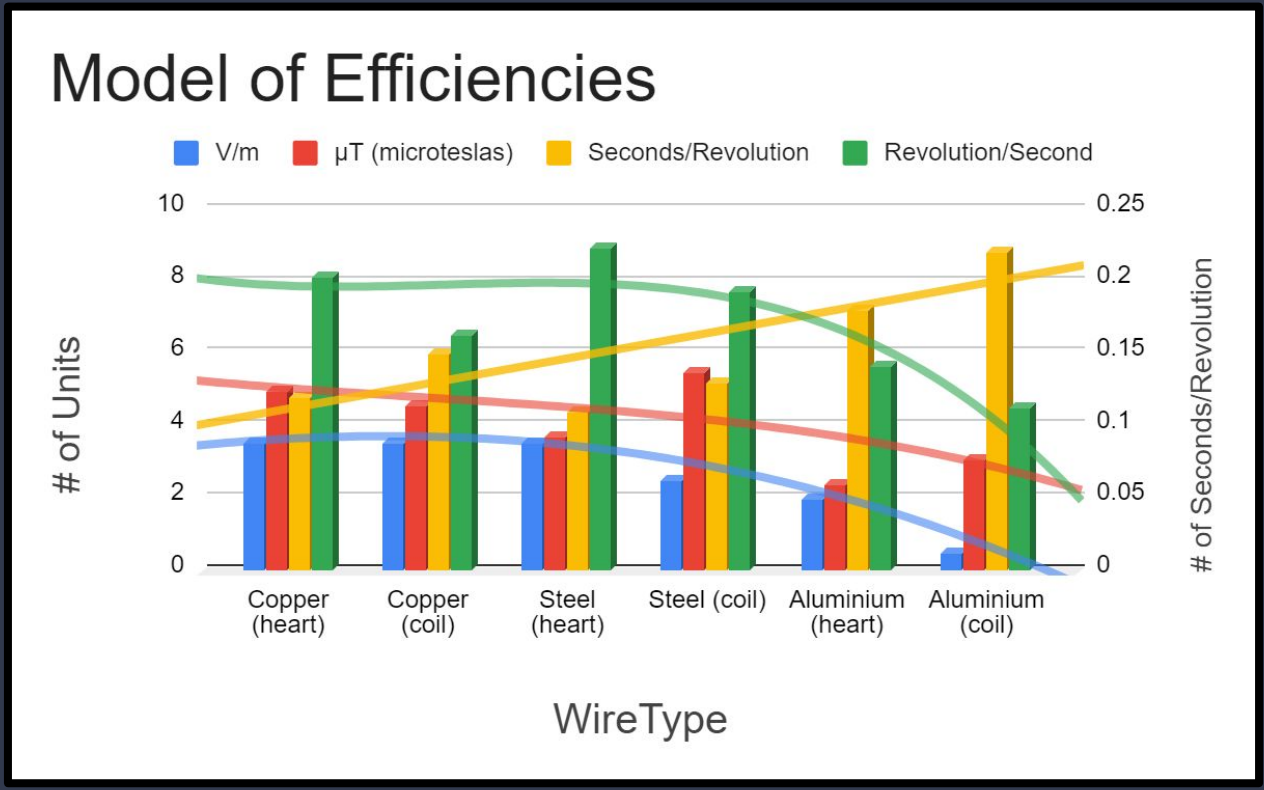


This chart shows the relationship between seconds per revolution and revolutions per second. Without a doubt, steel was most effective in speed and efficiency. In both its heart and coil shape, steel wire had the most revolutions per second, and the least amount of time for each revolution. Only copper (heart) came close to reaching steel's speed.

Measures of Efficiency:



Explanation



This graph explores the averages of all the data that was recording throughout the experiment. It shows that aluminium was consistently least efficient in every category. This is contrasted with copper and steel combating for most effective. Copper was clearly not as fast, but steel didn't conduct electricity as well.

Conclusion

- **Aluminium was least efficient in every model of effectiveness**
- **Steel was produced a stronger magnetic field and sped the fastest**
- **Copper conducts electricity the best and was most stable**
- **Copper in a heart shape was the most consistently efficient**
- **Steel could be more efficient if it was more stable and produced more electricity**
- **Wire that wasn’t magnetic allowed for the electrons to move freely and not get stuck from the magnets**
- **Coiled wire strengthened its magnetic field, but had difficulty completing the electrical circuit**

In Addition

- **In instances where it can be stable, steel would be most efficient, though would not last as long due to its rapid oxidation**
- **The data was very different from trial-to-trial, and more trials would've made the experiment more accurate**
- **More materials for the wires would have opened up more data, as would have more shapes for said wires**
- **Also, would the thickness of the wires impact the experiment, and would aluminium have conducted more electricity because of it?**
- **Furthermore, how could aluminium's greater magnetic field have helped itself?**
- **Would the motor work better if the magnets moved instead of the wire?**
- **Does the motor even need a magnet, and if so, would it work better or worse?**
- **What are other ways of measuring the wires' efficiencies?**

Bibliography

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ANY QUESTIONS?