IB Physics Extended Essay

<u>Research Question:</u> How does the variation of the pickups (the number of turns of the magnetic effect coil affect the frequency of the sound in an electric guitar?

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Introduction:

The term "pickup" refers to a transducer that detects or captures mechanical vibrations made by musical instruments, especially stringed instruments like the electric guitar, and converts these vibrations into an electrical signal that is amplified by an instrument amplifier to produce musical sounds through a loudspeaker in a speaker enclosure. Also possible is direct recording of a pickup's signal.[1]

When I did literature review research, I could not find any study or article that measured the frequency of electric guitars depending on the number of windings. In my research on the internet, I came across a study conducted by the University of Delaware. The study asks us to explain the magnetic field using Faraday's law through magnetism, but it does not say how the result is. As a result, I could not find any research as a literature review. I sent an e-mail to Ola Englund, a musician who makes electric guitars, but he said he had no knowledge about this subject. Likewise, I sent an e-mail to John Petrucci, a very famous musician and the guitarist of Dream Theatre, but I did not receive any useful feedback. Finally, I consulted my guitar teacher, who had made guitars before, and she said that the number of windings would increase the frequency.

I got my extended essay on how the number of coils and coil windings of electric guitars' pickups affect the frequency of the sound because I have been playing electric guitar for 3 years. After starting the guitar, I started to develop an incredible interest in metal music. After I started listening to the music, the tone of the guitar I used started to not satisfy me because the guitar tones used in the songs, I listened to were very harsh. Likewise, since I want to capture this harsh tone, I want to harden the tone I get from the guitar by increasing the number of coils in the pickups.

[1] https://en.wikipedia.org/wiki/Pickup_(music_technology)

A conductor (often copper wire) is wound on a core to create an inductance or electromagnet in an electromagnetic coil. The coils' primary purpose is to generate structural energy by controlling the flow of current via a conductor in a magnetic field. Magnetic fields, which are created by electrical energy, are stored in coils. It employs the electric current flowing through each wire to generate a magnetic field because of the inductor in the coil.

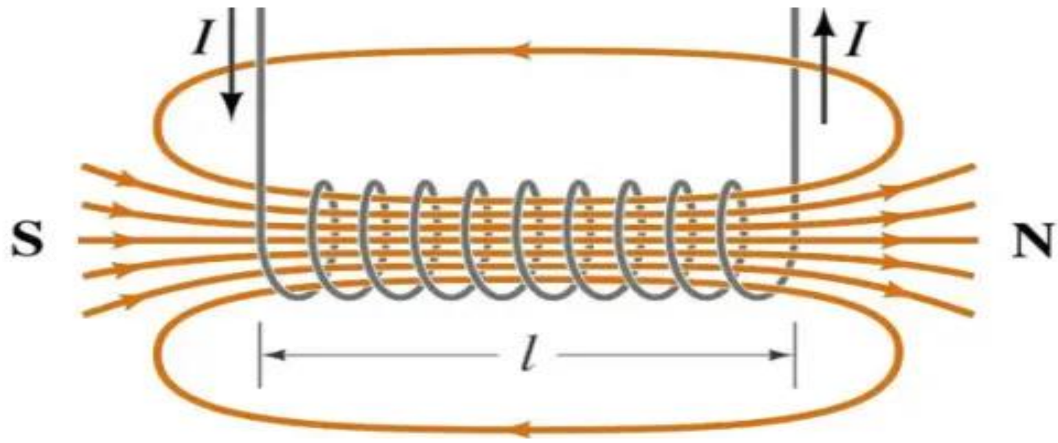

Figure 1[2]: Inductance In the Coil

$$B = \frac{4K\pi IN}{L}$$

B: magnetic field

K: constant

I: current intensity

N: number of windings

L: length of winding

Formula 1[3]: Formula required to calculate magnetic field

Inductance is the energy storage capacity of an inductor in a magnetic field in electromagnetism and electronics. The inductance of a coil can be calculated by the following simplified formula.

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[2] https://www.google.com/url?sa=i&url=https%3A%2F%2Fakademi.robolinkmarket.com%2Fbobin-nedir%2F&psig=AOvVaw2A2msUpD3BVbDncHMnW53f&ust=1686350059456000&source=images&cd=vfe&ved=0CBEQjRxqFwoTCNCw5dPdtP8CFQAAAAAdAAAAABAE

[3] K.Andreas Tsokos,Physics for the IB Diploma, Sixth edition

$$\mu\text{H} = \frac{R^2 N^2}{9R + 10L}$$

Figure 2[4]: Formula of Inductance

In this formula, Henri [µH] (microhenri) is the unit of inductance, R is the coil diameter (measured in inches from the centre of the conductor), N is the number of turns, and L is the coil length in inches.

A transducer that houses one or more permanent magnets (often alnico or ferrite) and a coil of fine enamelled copper wire with thousands of turns is referred to as a magnetic pickup. The pole piece of the pickup focusses the magnetic field produced by the magnet. The pickup's permanent magnet causes the string above it to become magnetized. As a result, a magnetic field aligned with the permanent magnet is produced by the string. The magnetic field that surrounds the string goes up and down with it as it is pulled. According to Faraday's law of induction, this shifting magnetic field causes a current to flow through the pickup's coil. An average output could range from 100 to 300 millivolts. Generally, single coil pickups are wound 7,000-8,000 times, while humbuckers are wound 4,500-5,000 times.[5]

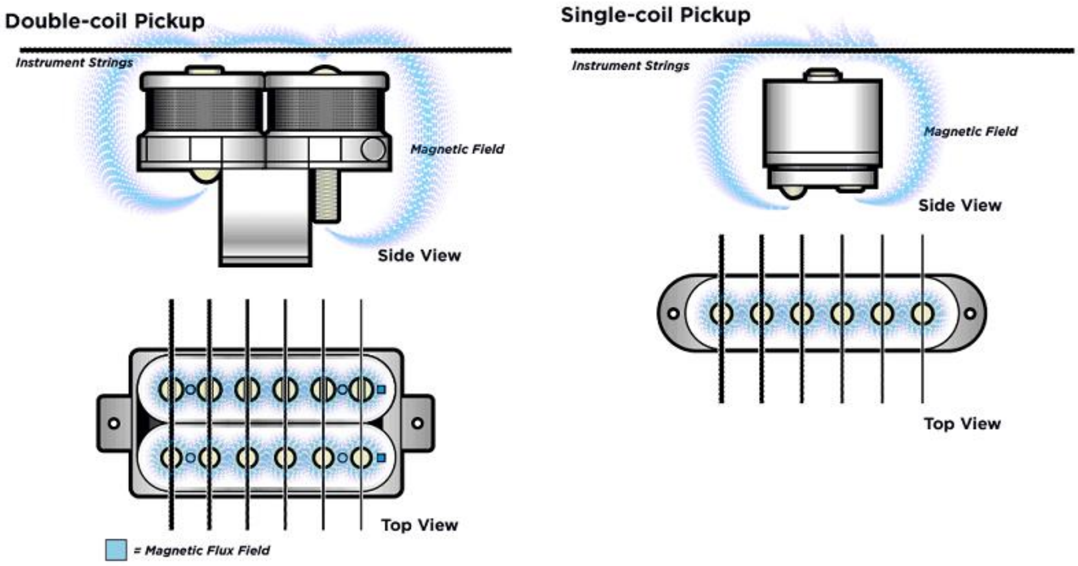

Figure 3[6]: How Pickups Work

Single coil pickups are the first style of electric guitar pickup. Single coil pickups are renowned for creating treble-focused, bright tones that effortlessly cut through background noise. Many amplifiers are made to highlight these single-coil intricacies since they are particularly sensitive to a player's technique's peculiarities.

[4] https://tr.wikipedia.org/wiki/Bobin
[5] https://www.stringskings.com/how-guitar-pickups-sound-tone-depends-factors/
[6] https://www.stringskings.com/how-guitar-pickups-sound-tone-depends-factors/

Figure 4[7]: Image of Single Pickup

A pair of single coil pickups wrapped in the opposite direction make up humbucker pickups. Dual-coil pickups get their "humbucker" moniker from the fact that this eliminates the natural 60 Hz hum that many single-coil pickups create. Humbuckers sound fantastic in practically any genre, just like single-coil pickups do, although jazz and heavy pickups benefit most from their superior performance. rock due to their capacity to generate more powerful bottom frequencies than single coils. Unassuming pickups are frequently more durable than single coils due to the mechanics of their construction, and their high output levels can assist in driving an amplifier into overdrive.[8]

Figure 5[9]: Inside of Single Pickup

Musical notes are distinct and isolable sounds that serve as the most basic structure of western music. Pitch, or more widely, pitch, is the quality that enables the judgement of sounds as "higher" and "lower" in the sense associated with musical melodies. Pitch is a perceptual attribute of sounds that allows their ordering on a frequency-related scale. The frequency required for notes to change varies depending on the note interval. The table showing which note has which frequency is as follows.

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7 https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FSingle_coil_guitar_pickup&psig=AOvVaw2Gz2RiJtt407zpU8jDMDh7&ust=1686351205264000&source=images&cd=vfe&ved=0CBEQjRxqFwoTCNDenPbhtP8CFQAAAAAdAAAAABAE

8 https://www.masterclass.com/articles/guitar-101-what-is-a-guitar-pickup-learn-about-the-different-types-of-electric-guitar-pickups

9 https://www.warmanguitars.co.uk/wp-content/uploads/2021/08/IMG_7768.jpeg

NOTE FREQUENCY CHART | HEROIC AUDIO

	Octave 0	Octave 1	Octave 2	Octave 3	Octave 4	Octave 5	Octave 6	Octave 7	Octave 8	Octave 9	Octave 10
C	16.35	32.70	65.41	130.81	261.63	523.25	1046.50	2093.00	4186.01	8372.02	16744.04
C#	17.32	34.65	69.30	138.59	277.18	554.37	1108.73	2217.46	4434.92	8869.84	17739.69
D	18.35	36.71	73.42	146.83	293.66	587.33	1174.66	2349.32	4698.64	9397.27	18794.55
D#	19.45	38.89	77.78	155.56	311.13	622.25	1244.51	2489.02	4978.03	9956.06	19912.13
E	20.60	41.20	82.41	164.81	329.63	659.26	1318.51	2637.02	5274.04	10548.08	
F	21.83	43.65	87.31	174.61	349.23	698.46	1396.91	2793.83	5587.65	11175.30	
F#	23.12	46.25	92.50	185.00	369.99	739.99	1479.98	2959.96	5919.91	11839.82	
G	24.50	49.00	98.00	196.00	392.00	783.99	1567.98	3135.96	6271.93	12543.86	
G#	25.96	51.91	103.83	207.65	415.30	830.61	1661.22	3322.44	6644.88	13289.75	
A	27.50	55.00	110.00	220.00	440.00	880.00	1760.00	3520.00	7040.00	14080.00	
A#	29.14	58.27	116.54	233.08	466.16	932.33	1864.66	3729.31	7458.62	14917.24	
B	30.87	61.74	123.47	246.94	493.88	987.77	1975.53	3951.07	7902.13	15804.26	

Figure 6[10]: Table showing which note is which frequency

[10] https://www.google.com/url?sa=i&url=https%3A%2F%2Fproducelikeapro.com%2Fblog%2Fnote-frequency-chart%2F&psig=AOvVaw0cx9HUSoGwTsTafr5fKrZn&ust=1708407608073000&source=images&cd=vfe&opi=89978449&ved=0CBIQjRxqFwoTCLCfvbbYtoQDFQAAAAAdAAAAABAQ

Musical Notation	
C	Do
D	Re
E	Mi
F	Fa
G	So
A	La
B	Ti
#	Sharp

Pitch: Pitch is the degree of thickness or thinness of each of the sounds that make up a piece of music.

Seminote: The smallest musical interval frequently employed in Western music is termed a semitone, sometimes known as a half step or semitone.

Sharp: Raises the pitch of a note by one seminote

Variables:

Independent Variable	Number of turns of coil: Observing the effect on frequency by changing the magnetic field by changing the number of windings.
Dependent Variable	Number of turns of coil: Observing the effect on frequency by changing the magnetic field by changing the number of windings.
Controlled Variable	
Magnets used in pickup	Since different pickups will change the magnetic fields, the change in frequency according to the number of windings cannot be measured.
The material used to make the pickup	If the outer frame of the pickup is made with a different material, it may affect the frequency, which reduces our ability to make a measurement based on the number of windings
Metal wire used in the coil (copper)	If it is wrapped with different metals, it is not possible to obtain data depending on the number of windings, since different magnetic fields are produced.
Pickup location	If the magnet is placed in a different place, it may cause the oscillation of the wire to be different, thus changing its frequency, and thus a measurement cannot be made depending on the number of windings.
Pickup height	Placing the pickup at a different height may affect the frequency.
Amplifier	If a different amplifier is used, a different tone will be obtained, and this may result in a different frequency.
Metal of the string	If a different metal wire is used, the frequency emitted by the wire will be different and the magnetic will measure it differently, and in this case, no measurement will be made depending on the number of windings.
Thickness of the string	If a wire of different thickness is used, the frequency emitted by the wire will be different and the magnetic will measure it differently, and in this case, a measurement will not be made depending on the number of windings
Technological tools in the environment	Since the technological devices around emit a magnetic field, they may disrupt the magnetic settings and prevent an accurate measurement.

Materials:

- 2 basic pickup frame is about 8.9 cm long and 3.8 wide which is printed from 3d printer
- 43-gauge copper wire (Donau elektronik)
- 6 screws
- 6 neodymium magnets (diameter 5cm thickness 5mm)
- Sandpaper between 400 and 600 grit
- Electric screwdriver (Bosch)
- Ruler (30 cm)
- Rope (2m)
- Coin (1 Turkish Lira)
- Glue (Peligom)
- Rotary grinder (Nordic 135w Mini rotary grinder)
- Polycarbonate goggles (Deltaplus)
- Hot glue (Anadolu strong 60watt)
- Pickup winder
- 4 crocodile clips
- 11-gauge guitar string (Ernie ball 11-48 gauge electric guitar string)
- Tuner (Tuner T1 app)
- Electric Guitar (Ibanez GRG121DX)
- Soldering Machine (SRMTCH 80Watt)
- Gloves (Prosmt electronik)
- Electrical tape (Globe 19mm x 9.15)
- Brass eyelets
- Hacksaw (Bosch easycut)
- Clamp (Wire Clamp)
- Wire stripper (Dowell)

Method:

1. Leave 6 marks on the frame which is printed by 3D printed leaving 1.3 cm between them. Leave a gap of 1.3 cm between the edges of the wood and the first mark.
2. Drill the holes you marked with an electric screwdriver with a tip of 0.24 cm. When the drilling process is completed, clean the plastic parts and dust with a brush.
3. Make another frame using the same materials. Create the base of the pickup by repeating the previous steps. Make the piece the original size and drill holes of the same size. Make sure the two parts are identical.
4. The frames are not smooth because they come from a 3D printer. To make the frames smooth, take a sandpaper between 400 and 600 grit and sand the frames until they are smooth.

5. Drill 2 eyelet holes, 0.19 cm in diameter, in the bottom frame. Make a single hole in each corner. Drill a hole between the 3rd and 4th hole of the frame by using wood file that will be at the bottom, that is, in the middle of the frame. Use any small drill bit you have available. The hole you drilled will be the connection point of the copper wire you will wrap, so the hole should be as small as possible.
6. The brass rings should be glued into the openings. The holes are symmetrical, opening from both ends like tiny screws. Place the bigger, rimmed ends of the holes facing up. Next, fill in the spaces between the metal and plastic by covering the edges of the hole with plastic-safe superglue.
7. Put the holes in alignment with a rotary grinder. Put on some quality polycarbonate goggle and earplugs for protection. Next, flip the flat piece over and start the rotary grinder. Until each hole is flush with the workpiece, grind it.
8. Insert screws into holes. Since there are six strings in the guitar, 6 screws are needed. Position the top flatwork over the bottom one. Slide the lower screw up onto the shafts after threading it through the top flatwork. Ensure that screws between the flatwork pieces are straight as possible. There should be 2.5 cm between frames.
9. Cut the screws placed in the holes with the help of a hacksaw. Fix the flat piece to the workbench with the help of clamps, so that the screws facing the bottom remain on top. While doing this, use protective glasses to prevent metal parts from getting into your eyes. Then cut the screws until they are flush with the surface.
10. Get one neodymium magnet for each screw. Since there are 6 screws, 6 neodymium magnets will be required. Place circular neodymium magnets on the heads of the screws on the upper flat part. Apply some glue, hot silicone and super glue around the screw heads and magnets to seal and secure them and hold them in place. The adhesive will need 24 hours to dry properly. Wait 24 hours and make sure the magnets stick in place completely.
11. Knot the 42-gauge copper wire in the small wire hole we opened between the 3rd and 4th screws. Since we will be making 5 pickups, at least 55 cm long 42-gauge copper wire is required. Unroll some of the wire and then slide it into the small hole where the groove you cut is located. Knot the wire tightly in the hole, but do not cut the wire from the spool as the winding process is not finished yet. Using silver wire is an option, but since silver wire is thin, it will stretch too much and cost too much. Since the purpose of the experiment is to check the number of turns, there will be no purpose in using silver wire.
12. Wrap the 42-gauge copper wire around the screws leaving no gaps. Since doing this winding by hand would take days, the easiest way to do this is to use a pickup winder. The pickup winder is easily available in winding shops. If you cannot find a pickup winder, you can do this winding process with the help of a drill. If you are doing it with a drill, drill a small hole under the middle of the pickup and perform the winding process by rotating the drill. Attach the pickup to the winder and wrap the wire a single turn around its centre. Then start the machine and wind your pickup by repeating this process 5 times, 2 thousand, 4 thousand, 6 thousand, 8 thousand and 10 thousand windings. If the pickup is wrapped correctly, there will be an even and thick wire wrap around the pickup. Therefore, when wrapping the pickup, make sure there is a thick and even wire wrap around the pickup.
13. Use two different colour wires for your pickup. The standard single coil pickup has 2 wires. These cables are available in black and white colours. While the white wire is

the neutral wire, the black wire is the hot wire. You will need to connect the wires to the brass rings to power the pickup. For a double-pickup humbucker, you will need a 4-colour electrical wire. 2- colour wire isn't enough to power both pickups.

14. If you are making a humbucker, insert a 4-wire cable between the pickups. Pickups consisting of 2 coils are called humbuckers. After placing the pickups side by side, pass the 4-wire cable between the pickups. Make sure the cables protrude from between the pickups. Since it protrudes, you can easily connect the cables to the. The wire will have some combination of colours including red, blue, black and green. A second pickup is needed to make a humbucker, so make the second pickup the same as the first by following the previous steps exactly.
15. Use wire strippers to expose the ends of the cables. After fixing the cables somewhere, hold the ends with the cable stripping tool. Squeeze the cable stripper until the coloured plastic layer on the cable is cut away. Push the wire stripper forward to tear off the coloured plastic layer, exposing the copper wire underneath. Exposing approximately 1/2 inch (1.3 cm) of each wire. Make sure you have enough exposed wires available to you. You may also need to cut the guitar strings if they look frayed.
16. Solder the wires to brass rings or similar wires. Find the black wire coming from the guitar. Twist the wires together. After twisting, melt the wires together. Place the remaining wires over the brass rings and solder them in place. For the humbucker, solder the red wire to one eyelet, then solder the green and blue wire to the other eyelet.
17. Loosen the screws on all 4 sides of the guitar pickup and remove the guitar pickup from the frame.
18. Open the cover on the back of the guitar and take a picture of the cables where the pickup is soldered, because we will need to remember which cable is plugged into where when we install the pickup we made. Remove the pickup from the guitar by unsoldering the pickup's wires.
19. Insert the pickup we made through the pickup hole on the front of the guitar, with the cables towards the back. Solder the pickup's wires to the circuit on the back of the guitar, looking at the photo.
20. Fix the pickup to the front of the guitar with the screws coming from the guitar.
21. Reset the effects on the amp and turn it to clean tone. If overdrive or distortion occurs, it may affect the frequency.
22. After adjusting the amplifier, connect the guitar to the amplifier using the jack.
23. Turn on the tuner.
24. Before turning on the amplifier, measure the frequency of the guitar string without pickup to ensure that the effect created by the pickup is.
25. In order to measure the frequency of the strings accurately, it is necessary to apply the same force when pulling. When it is not possible to do this manually, place the guitar upside down and tie a coin to the guitar string with a string. Always cut the string from a distance rather than hitting it.
26. Turn on the amplifier and measure the frequency of the string and the effect of the pickup.
27. This process is repeated 5 times in order to make this experiment more precise and reliable.

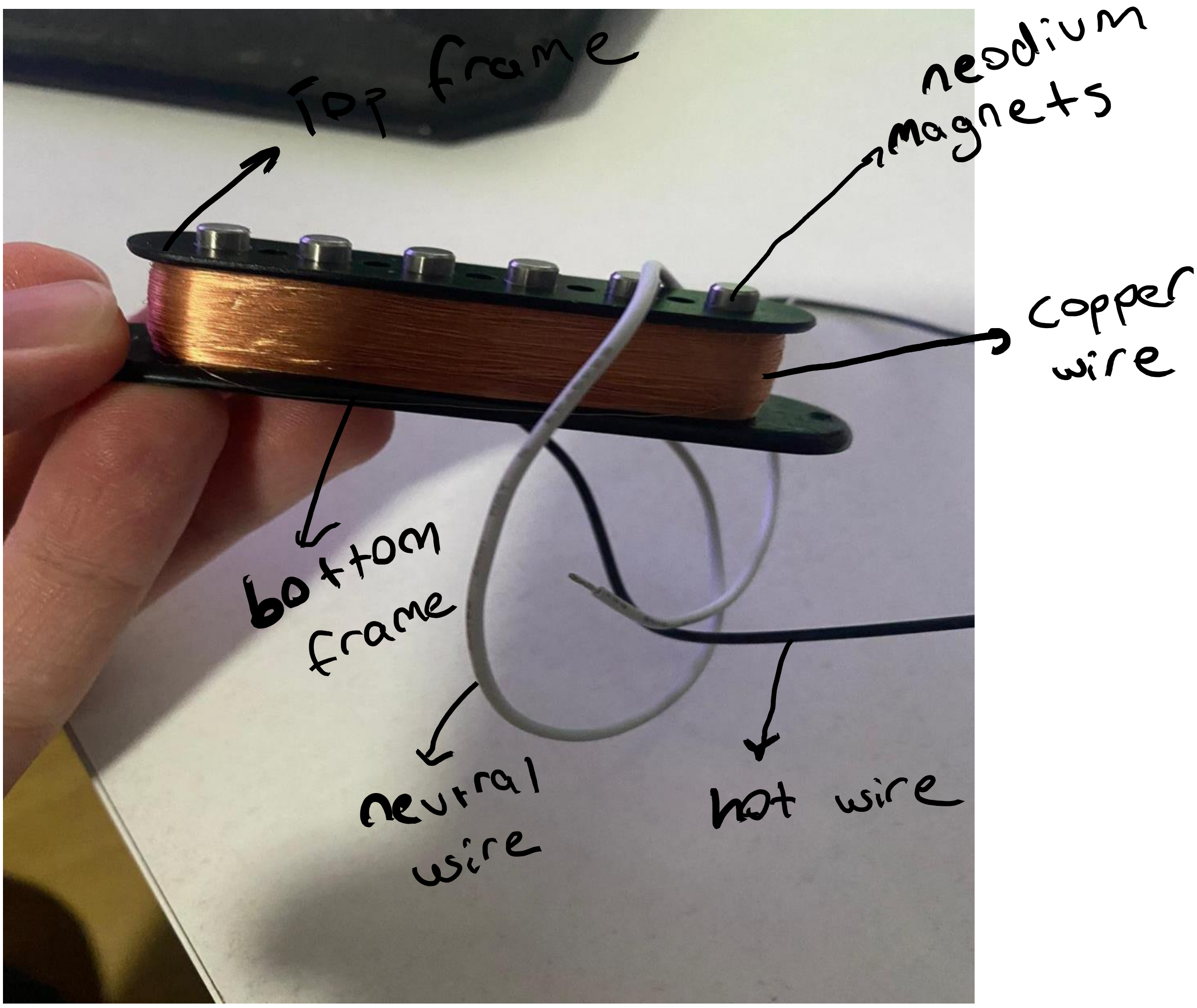


Image 1: 10 thousand winding pickup I made

Data Processing and Presentation:

In this study, we will examine how the magnetic field affects the sound frequency with the help of the pickups in the electric guitar. In order to measure how these coils affect the frequency, the stock pickups of the guitar will be removed, and measurements will be taken with 2, 4, 6, 8 and 10 thousand winding coil pickups. Pickups containing different wound coils were attached to the guitar one by one, the same strings were pulled with the same force, and the frequencies produced were measured through the tuner and noted on paper. While making measurements, since the wires cannot be pulled manually with the same force, a weight (coin) was tied to the wire through a 5 cm rope and cut 3 cm above it each time, and the frequency coming out of the wires pulled with the same force was noted. To see the frequency change in the wire, the frequency of the wire of the same thickness was measured without the magnetics working and it was 140 Hz. To make the data more reliable, this process was performed 5 times, and the data was averaged. Table 1 below contains 5 different data from each experiment and their average. The uncertainty of the tuner I use to get the data is ± 0.1.

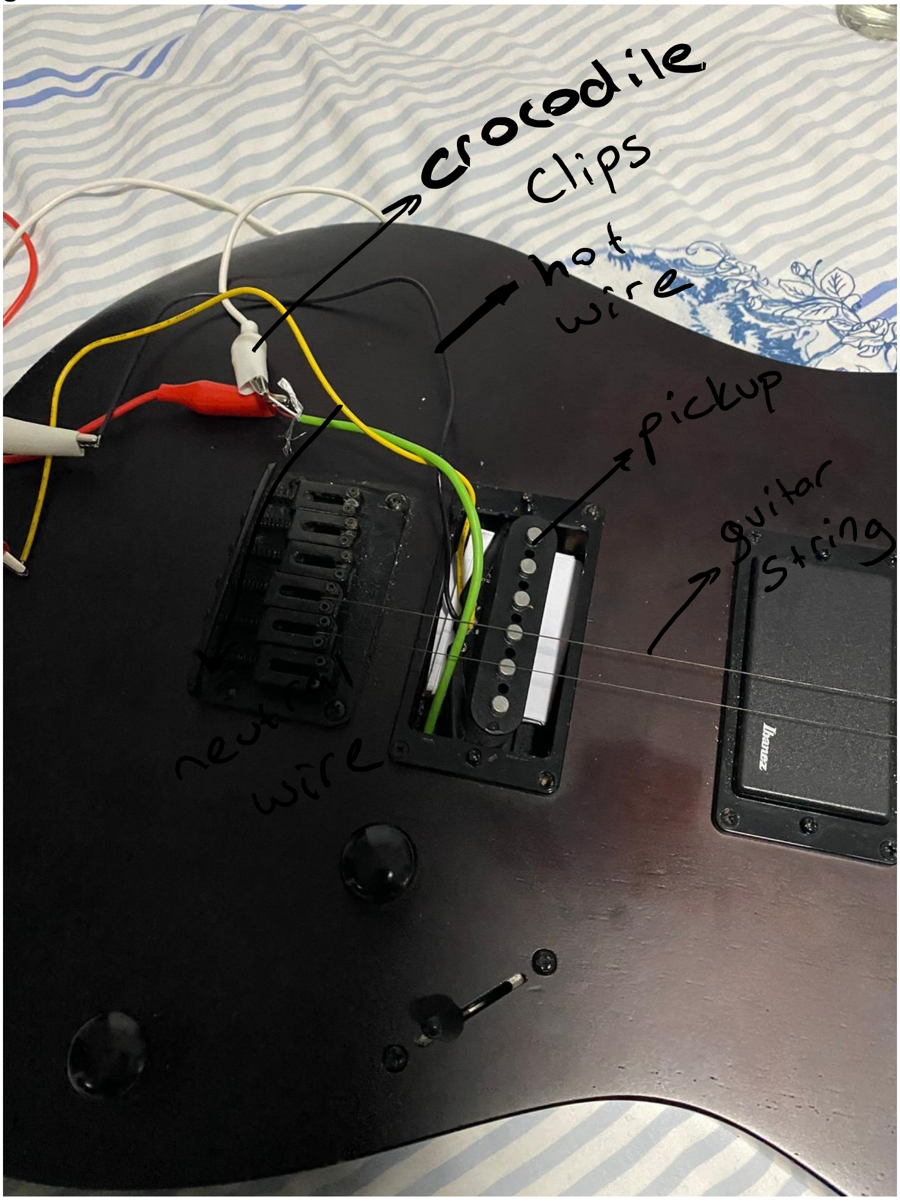


Image 2: Plugging the pickups into the guitar and receiving data

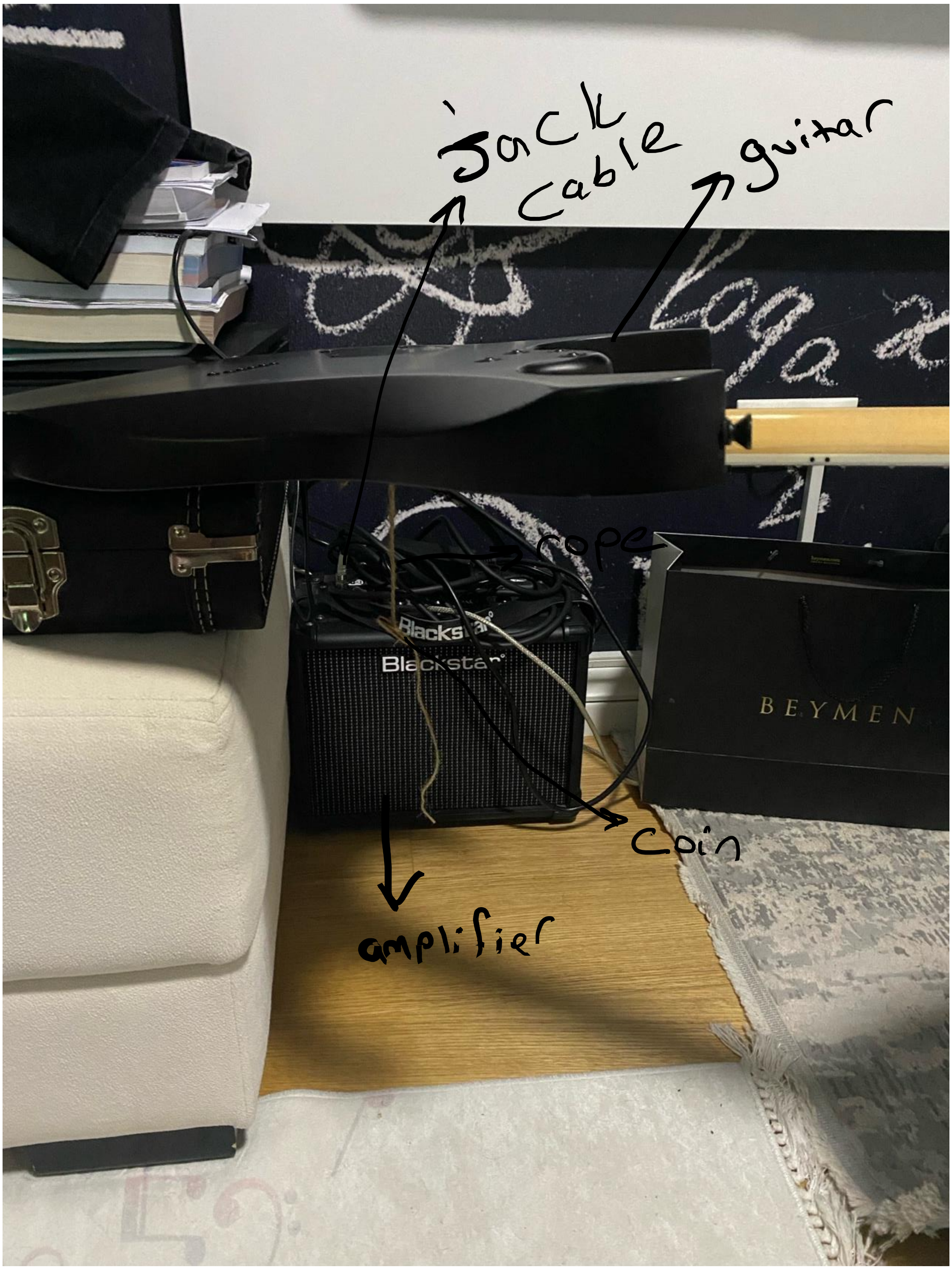
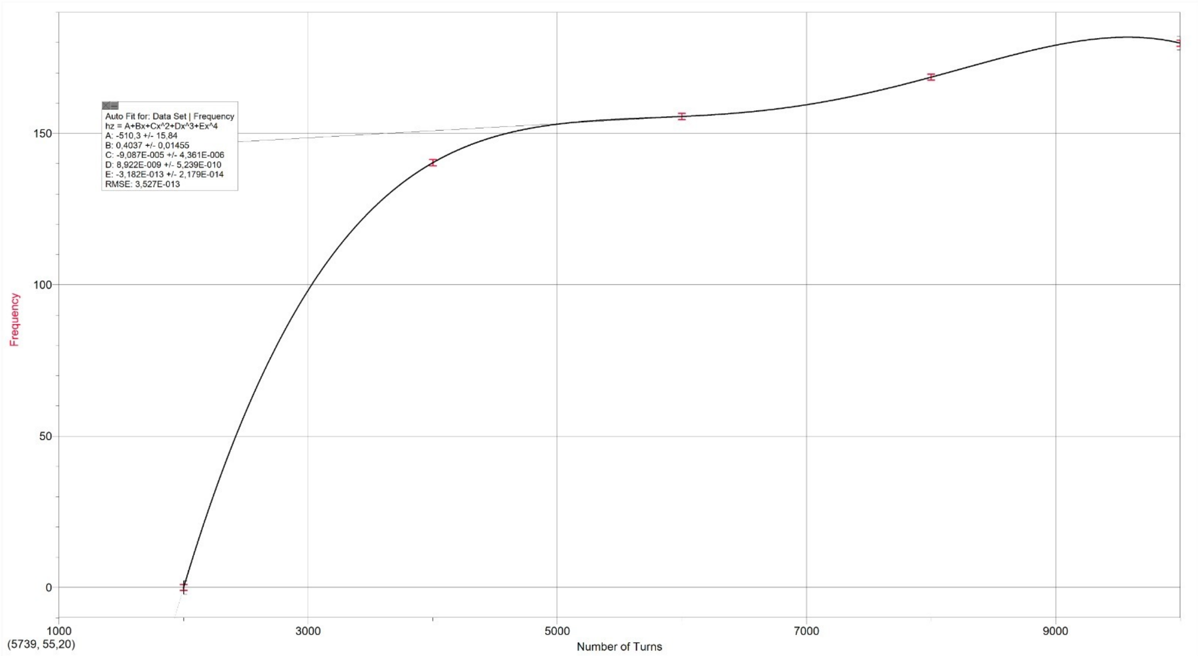


Image 3: Photo of the model while the data is being taken

	1st trial	2nd trial	3rd trial	4th trial	5th trial	Mean ± Standard Deviation
2000 turns	140 hz to 0 hz	140 hz to 0 hz	140 hz to 0 hz	140 hz to 0 hz	140 hz to 0 hz	140 hz to 0 hz ± 1.0
4000 turns	140 hz to 140.7 hz	140 hz to 141 hz	140 hz to 139.6 hz	140 hz to 140.3 hz	140 hz to 140 hz	140 hz to 140,32 hz ±1.0 (C3# to C3#)
6000 turns	140 hz to 156,7 hz	140 hz to 155,4 hz	140 hz to 155,5 hz	140 hz to 155 hz	140 hz to 155,4 hz	140 hz to 155,6 hz ± 1.0 (C3# to D3#)
8000 turns	140 hz to 168.7 hz	140 hz to 169.9 hz	140 hz to 168 hz	140 hz to 168.2 hz	140 hz to 168.1 hz	140 hz to 168,58 hz ± 1.0 (C3# to E3)
10000 turns	140 hz to 180 hz	140 hz to 180.5 hz	140 hz to 179hz	140 hz to 180 hz	140 hz to 179.5 hz	140 hz to 179.8 hz ± 1 (C3# to F3)

Table 1: The effect of the number of coils turns in the pickup on the sound frequency of the guitar string.



Graph 1: The effect of the number of coils turns in the pickup on the sound frequency of the guitar string.

The frequency used in the graph is the average of 5 valued trials.

$$B = \frac{4K\pi IN}{L}$$

B: magnetic field

K: constant

I: current intensity

N: number of windings

L: length of winding

In the experiment, it was aimed to measure the effect of the magnetic field on frequency. However, as seen in the magnetic field formula above, only n (the number of windings) is different. Since a comparison will be made in this experiment, K, I, L and 4 will be simplified and only n, the number of windings, will remain. For this reason, the number of windings, not the data of the magnetic field, is used in the graphics. Using the formula above, the magnetic field created by the pickups I use can be calculated.

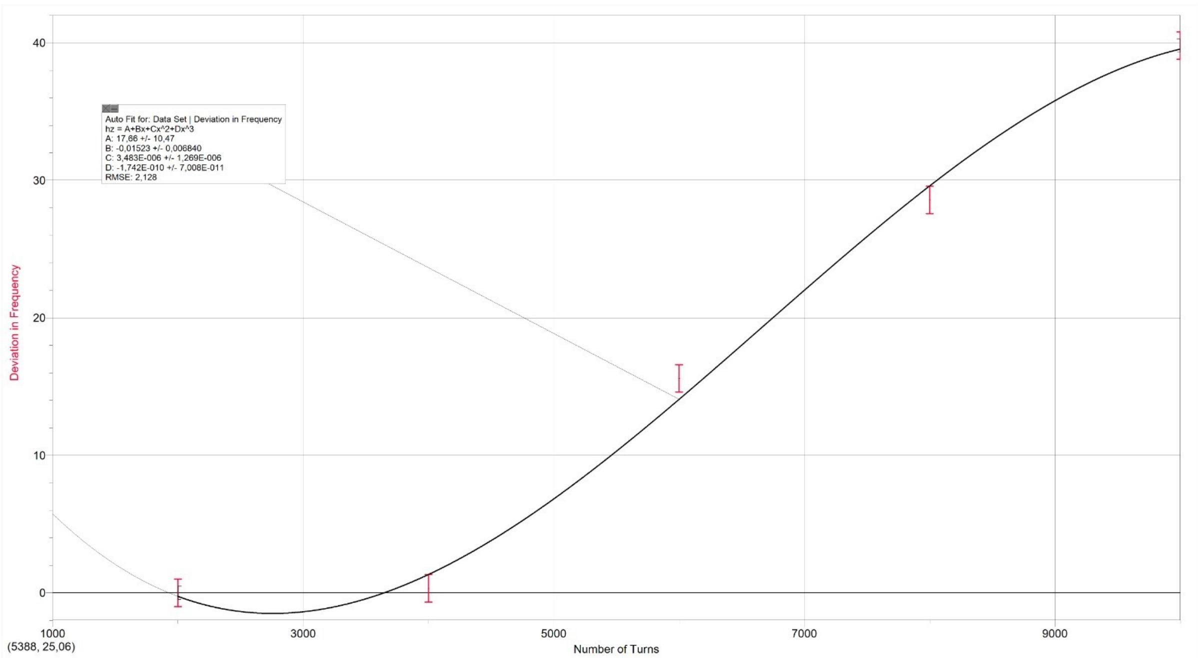
When we look at the graph and the table in general, we see an exponential increase. As the number of windings of the coil inside the magnet increases, the frequency of the wire increases significantly under the influence of the magnetic field. At values from 2 thousand windings to 10 thousand windings, the frequency goes up to 179.8 Hz. In the experiment, I used values from 2 thousand to 10 thousand windings. As you can see, no data was generated in 2 thousand windings, so I used 2 thousand windings as the lower limit. I used 10 thousand windings as the upper limit because there was no room in the magnetic mold I printed that could accommodate more windings. Even if I had printed the mold larger, this time the pickup would not have fit into the guitar in my hand.

As seen in the table and graph above, I could not get data from the magnetic device containing a coil of 2 thousand turns. Since 2 thousand windings could not create a sufficient magnetic field, the pickup could not capture the frequency in the wire and transmit it to the amplifier.

The magnetic coil containing 4 thousand turns converted the 140 Hz frequency into 140.32 Hz frequency. This 140.32 Hz value is the most appropriate value to use for the guitar because the frequency remained almost exactly the same. While the wire not under the influence of the magnetic field created 140 Hz, the one under the influence of the magnet containing 4 thousand windings created a value of 140.32 Hz. This shows that it transmits the sound to the amplifier with a very small deviation.

While there were increases in frequency in the 6 thousand windings, these increases were very large in the 8 and 10 thousand windings. The reason for these large increases is that the data increases linearly. There appears to be a linear increase in frequency starting from 4 thousand windings.

While the 4 thousand winding magnetic kept the C3# note constant at the C3# note, the 6 thousand winding magnetic changed it to D3#. While the 8 thousand magnetic turned the C3# note to E3, the 10 thousand wound pickup turned it into F3.



<u>Graph 2:</u> Amount of frequency deflection of pickups

4 thousand windings deflected the magnetic frequency by 0.32 Hz. The 6 thousand winding magnetic deflected 15.6 Hz. While 8 thousand windings of the magnetic deflected 28.58 Hz, 10 thousand windings deflected 39.8 Hz. As seen in the data and the graph, there is an exponential relationship in the deviation in the number of windings and frequency. This relationship can be formulated as A+BX+CX^2+DX^3. A represents 17.66+/- 10.47 while B represents -0.01523+/- 0.006840. C shows 3,483E-006+/- 1,269E006 while D shows -1,742E-010+/- 7,008E011.

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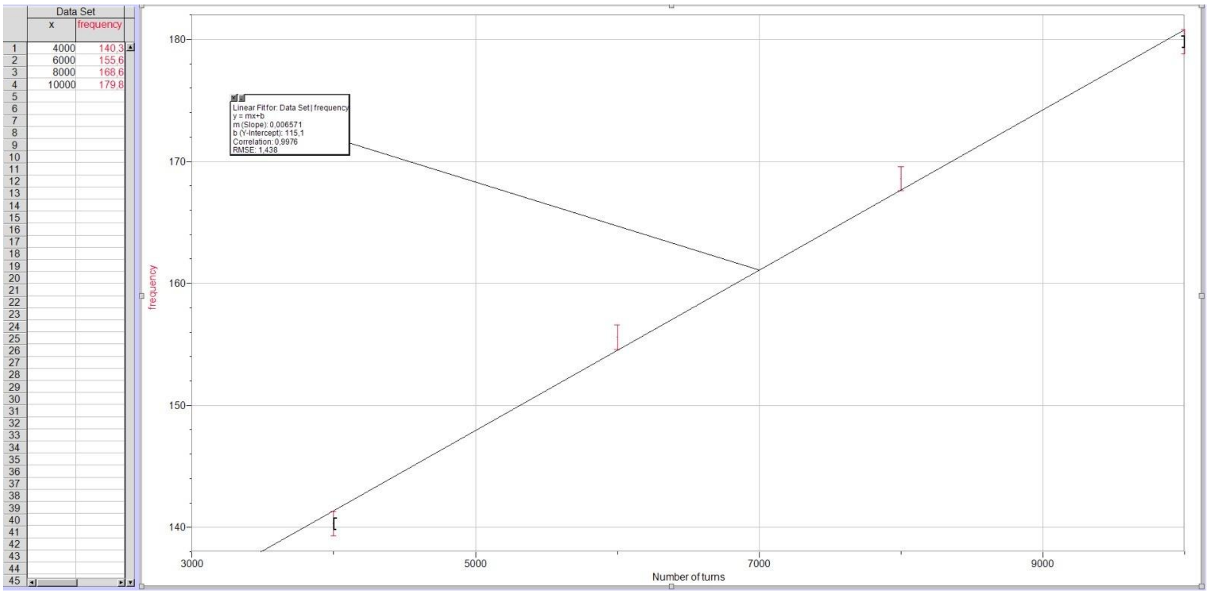

Graph 2: Linearity from the 4 thousandth winding

As seen in the graph above, this linear graph can be written as mx+b. Here m represents the slope, while b represents the point where it intersects the y-axis. While m, that is, the slope is 0.006571, b, that is, the place where it intersects the y axis, is 115.1. From here we can say that as each x value, that is, the number of windings increases by 1, there is an increase of 0.006571 in frequency. Since I observed an increase in every 2000 windings in my experience, there was an increase of 13,142 Hz with each data reception. This 13,142 increase was obtained by multiplying 2000 by the number 0.006571.

Conclusion:

According to my experiment, I observed that increasing the magnetic field increases the sound frequency. In the experiment, I increased the magnetic field with the number of windings. This increase was exponential. I have not come across anyone who has done this experiment on the literature review, so we cannot say that increasing the magnetic field definitely increases the sound frequency. This experiment can be tried by different people and reached a certainty.

Since there were some random and systematic errors during this experiment, changes need to be made in future research on this subject to make the experiment more professional.

- Measurements can be made with a more professional tuner. The tuner used in the experiment was a tuner with a phone application that I use to tune my guitar while playing.
- The increase in frequency can be observed by using different wires while winding the coils. Since I could not find the thickness of the wire mentioned by the sources I researched and the people I talked to in any winding shop in the city I live in, I used a wire of a different thickness, which may have caused errors.
- The strings of the guitar can be tested by constantly renewing them. I always used the same wire when measuring frequency. The string may have fallen out of tune as it was used.
- Measurements can be taken with a studio quality amplifier and a guitar. The guitar and amplifier used in the experiment were very simple amplifiers and guitars, so they may have caused errors in the experiment.

My purpose in doing this experiment was to achieve harsher guitar tones by increasing the magnetic field. Based on the data from the experiment, I realized that the harsh guitar tones were not caused by the magnetic field. The frequency increases as the magnetic field increases, but as the number of windings increases, the sound I get from the amplifier becomes more ridiculous. No good sound would come out of a guitar played with those pickups. In addition, this increase in frequency also changed the sounds. While the normal tuning of the string was 140 Hz, that is, c3#, it increased to 179.8 Hz, that is, f3. This may cause problems in the melodies you want to create.

People who will conduct this experiment in the future can measure the changes in frequency resulting from the number of windings by increasing the number of windings by 500 rather than 2 thousand. Thus, the sound frequency of the magnetic field coming from the guitar can be formulated. A formula can be produced by drawing a better and more consistent graph with the data taken with the intermediate values of 2 thousand. Thus, new studies can be carried out based on the linearization I made with the formula consisting of a more consistent graphic.

If I were to do this experiment again, I would want to keep the number of windings constant and do it with a different wire. Thus, I would like to measure the effect of the magnetic wire created by a different wire on the frequency. Or I would like to measure the shift in sound that occurs by increasing the magnetic field in a different way.

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