# PHY 410 Final Project Video Script

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## Title Slide:

Hey guys, today we are going to be looking at the line frequency and why fans are cooler than you thought they were.

## Introduction:

So what is the line frequency, and why does it matter?

## What is the Line Frequency?:

We all know that when we plug something into a wall outlet, it gets powered, but how does this happen exactly? Well the outlet is connected to the power grid with the power lines that we see lining the street and across the country. These lines carry Alternating Current, or AC, power to our homes. This AC current has an associated frequency with which it operates which we call the line frequency. In America it is 60 Hz, and in other countries it is 50 Hz.

## Where does it come from?:

This frequency comes from the way that power is generated. In the power plants that supply electricity to the grid, power is typically generated with large steam turbines. These turbines consist of a coil that rotates past large copper bars called stator bars. The coil creates a magnetic field that induces a current in the stator bars. Every rotation of the coil corresponds to one AC cycle. This rotational frequency therefore dictates the line frequency.

## Why does it matter?:

Now that we know how the line frequency is determined, we can talk about the importance of it. The most important aspect of the line frequency is that it is incredibly stable. As more load is put on the grid, the frequency starts to decline. As it drops too far, the power companies will start to deny certain areas supply in order to alleviate this load, which is called load shedding. If this fails to let the generators catch up, then the entire grid can blackout. This decline in frequency can be as small as 1 Hert, so a lot of effort is made to keep the frequency very stable. This leads to a number of consequences. One of which is that oven clocks, which are connected to the line frequency, are actually very accurate compared to clocks that are battery powered for instance. Additionally, this stability will mean that the frequency will hopefully be fairly easy to detect in our experiment.

## The Experiment:

Now that we know more about the background behind the line frequency, we can talk about the experiment that we conducted.

## Setup:

Using the PhyPhox phone app, we measured the magnetic field of a normal household box fan. We then exported the data into a csv file and analyzed it in a Jupyter Notebook. We know from Ampere's law that the magnetic field varies linearly with the current, so the frequency of the field and current should be the same. For our purposes, it then suffices to only look at the magnetic field.

## Data:

We started by taking data for 20 seconds, which can be found in the top left plot. We then used numpy's fast fourier transform function to plot the fourier transform of our data in order to find the frequency that we are interested in. This can be seen in the bottom left plot. We see three main peaks in this plot, so we then took a second measurement from the top of the fan in order to find the background signals. This time series and FFT are the middle two plots here. We see that the 40 Hz and 35 Hz signals are much stronger than the 20 Hz signal in the background, so we can safely ignore these two signals. The third measurement that we did was to increase the resolution of the FFT. We do this by measuring for a longer time; one minute in this case. When we take the FFT we see that there is still only one point in the peak that we are interested in, so we need to take an even longer measurement.

## Final Data:

Now, by measuring the magnetic field for a total of 20 minutes, we obtain the following plots. To the right, you can see that much of the current lies around 22.0Hz, plus or minus approximately 0.1Hz. This is what we have been looking for! The current coming from the grid is only of a very small frequency range! This demonstrates that the frequency modulation that power companies do can be seen by performing an experiment at home with a simple college box fan. Due to the mechanics of the induction motor in our fan, the frequency of the current is not necessarily 60Hz, but the acceptable range of frequencies, or the stability, still holds.

## Results and Conclusions: Let's recap what we learned here.

## Final Slide:

First, we introduced the concept of line frequency, or the standard frequency of AC current that comes into our homes. We then discussed why studying the line frequency has implications to the structure of our power grid that can be measured from our household appliances.
We also talked briefly about the physics of the measured magnetic field and how it directly relates to the current within our fan.
We showed the initial data and the fourier transform of said data to find the frequency of the AC current that is running through our fan.
Lastly, by taking enough data, we showed how narrow the band of acceptable frequencies for current is in our outlets, bringing the study of the electrical grid full circle.
All of this information is found in the Github repository found on screen. A complete Jupyter Notebook with step-by-step instructions, along with much more, can be found in the repository. We encourage you to try your own experiment out at home.
If you have any questions, let us know in the comments. Be sure to like, comment, and subscribe.