A Prelude to Pickups: The Solenoid

This activity is designed to lay the foundation for future discussions and learning activities regarding electric guitar pickups, and is appropriate for both middle and high school students. The solenoid is a simple device that is found in technology all around us. In a solenoid, a magnetic field is generated by an electric current flowing through a coil of wire. That magnetic field can be put to work to activate things like switches and valves as components in larger systems. At the core of this learning activity is the Right Hand Rule for Solenoids, which is useful for determining the direction of the magnetic field in a solenoid relative to the direction of the flow of electric current, and vice-versa. Once a student develops an understanding of a magnetic field that fluctuates in both magnitude and direction in keeping with the like fluctuations in electric current, it is only a small leap from there to understand the workings of an electric guitar pickup.

Learning Objectives:

1. Use the Right Hand Rule for Solenoids to determine the orientation of a magnetic field when the direction of electric current is known, and vice-versa.
2. Use the formula for magnetic field force in a Solenoid to make determinations regarding coil windings, electric current, magnetic permeability and solenoid length.
3. Apply a basic understanding of solenoid functions in order to hypothesize about speaker operation.

Standards:

HS-PS2-5 Motion and Stability: Forces and Interactions

Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS4-5 Waves and their Applications in Technologies for Information Transfer

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

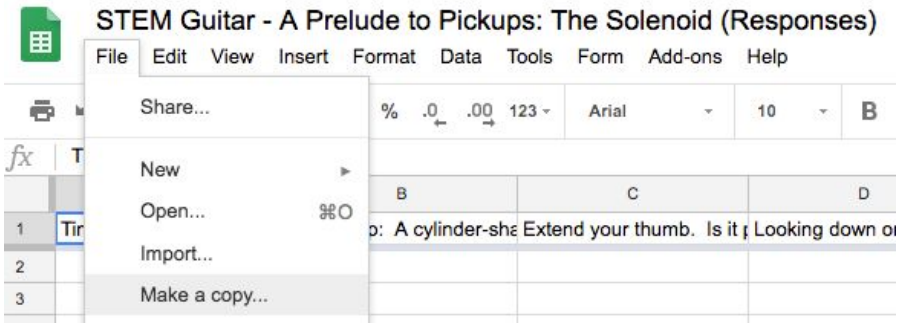
CCSS.Math.Content.HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *For example, rearrange Ohm's law V = IR to highlight resistance, R*

Materials Required:

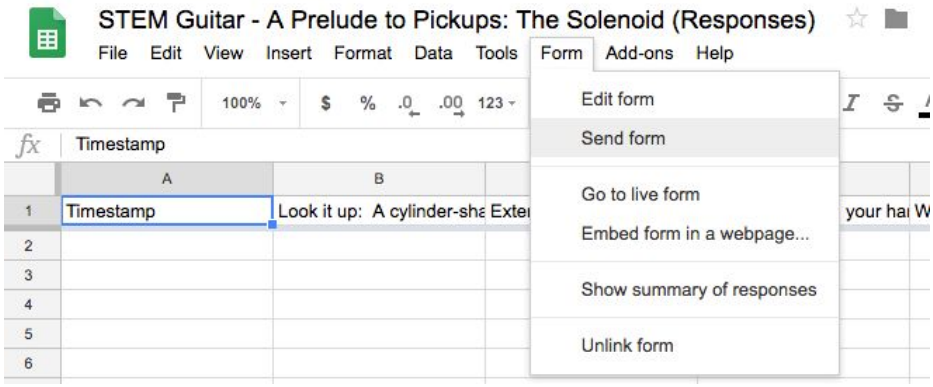
1. A computer with internet access for each student
2. The Google Form, "STEM Guitar - *A Prelude to Pickups: The Solenoid*," found here: https://docs.google.com/spreadsheets/d/1UY-f3ng6YAlpKqYRzCefsYykvyZ6HzvRuXOwwzUo2tQ/edit?usp=sharing

Instructions for accessing, making a copy, and using the form with your students:

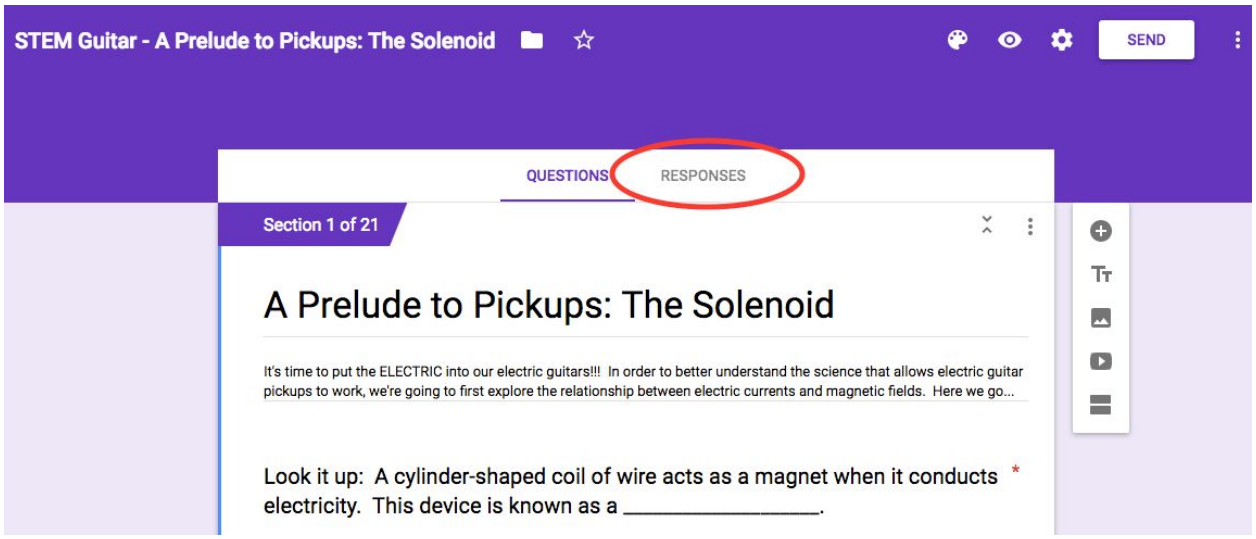
1. Under "File" select "Make a copy", which will allow you to have the form-and-spreadsheet package for your own use:



2. To send the form to your students, choose "Send form" from the "Form" pull-down menu:



3. Your students' responses will automatically populate the spreadsheet. To view your students responses from within the editing view of the form, simply select "Responses" from the top of the form:



Safety:

N/A

References:

Video links within the Google Form (YouTube):
1. Solenoids: https://www.youtube.com/watch?v=X2nro3lfaqw
2. Speaker Demo: https://www.youtube.com/watch?v=lTkzxfIX4EY
3. Intro to Electric Guitar Pickups: https://www.youtube.com/watch?v=uHqqd8OebCU

Supplementary video links (YouTube):
1. Solenoids: https://www.youtube.com/watch?v=i3lGy3MjUhY
2. Electric Guitar Pickups: https://www.youtube.com/watch?v=SfkX-fgmIbc

Activity:

This activity is designed to lay the foundation for our future discussions and learning activities regarding electric guitar pickups. The solenoid is a simple device that is found in technology all around us. In a solenoid, a magnetic field is generated by an electric current flowing through a coil of wire. That magnetic field can be put to work to activate things like switches and valves as components in larger systems. At the core of this learning activity is the Right Hand Rule for Solenoids, which is useful for determining the direction of the magnetic field in a solenoid relative to the direction of the flow of electric current, and vice-versa. Once you have developed an understanding of a magnetic field that fluctuates in both magnitude and direction in keeping with the like fluctuations in electric current, it is only a small leap from there to understand the workings of an electric guitar pickup. Your teacher will share a link to a Google Form, which will take you through the activity.

Name _____

Assessment
A Prelude to Pickups: The Solenoid

1. Match the following description with the appropriate electromechanical device:

A coil of wire that conducts an electric current and produces a magnetic field

A. Solenoid
B. Potentiometer
C. Capacitor
D. Diode

2. Which of the following rules explains the orientation of the magnetic field in a solenoid as it relates to the direction of current flow in the coil, and vice-versa?

A. Tesla's Rule
B. The Right-Hand Rule
C. The Left-Hand Rule
D. None of the Above

3. A constructed solenoid, positioned vertically, has an electric current that flows in a counterclockwise direction when viewed from above. The orientation of the magnetic field in the solenoid is:

A. South UP / North DOWN
B. North UP / South DOWN
C. South CLOCKWISE / North COUNTERCLOCKWISE
D. North CLOCKWISE / South COUNTERCLOCKWISE

4. A constructed solenoid, positioned vertically, has a magnetic field that started as North UP / South DOWN, and then switched to South UP / North DOWN. Which of the following events could explain the switch in magnetic field orientation?

A. The electric current switched from UP to DOWN
B. The electric current switched from DOWN to UP
C. The electric current switched from COUNTERCLOCKWISE to CLOCKWISE
D. The electric current switched from CLOCKWISE to COUNTERCLOCKWISE

For examples 5 - 8, consider our formula for magnetic field force, B, in a solenoid:

$$B = \frac{N\mu_o I}{L}$$

5. According to the above formula, what effect would ***doubling*** the length of a solenoid have on the force due to its magnetic field?

_____

6. According to the above formula, what effect would ***doubling*** the number of coil turns of a solenoid have on the force due to its magnetic field?

_____

7. Solenoid #1 and Solenoid #2 have identical construction. In other words, the length, core material (magnetic permeability), and number of coil turns are the same for each. If the force due to the magnetic field in Solenoid #1 is ***twice*** that of the force due to the magnetic field in Solenoid #2, then which of the following statements must be true?

A. The current in Solenoid #1 is twice the amperage of the current in Solenoid #2
B. The current in Solenoid #2 is twice the amperage of the current in Solenoid #1
C. Trick Question. If the magnetic permeability is the same, then so are the fields!
D. None of the Above.

8. We have learned that the construction of a loudspeaker includes a solenoid (through which the amplified audio signal passes), a stationary magnet, and a cone to vibrate/displace the air. Using the above formula for justification, describe TWO ways that a speaker design can be changed in order to increase volume.

1. _____

_____

2. _____

_____

Assessment Key:

1. A - Solenoid
2. B - The Right-Hand Rule
3. B - North UP / South DOWN
4. C - The electric current switched from COUNTERCLOCKWISE to CLOCKWISE
5. The force due to the magnetic field would be reduced by half
6. The force due to the magnetic field would double
7. A - The current in Solenoid #1 is twice the amperage of the current in Solenoid #2
8. Each of the following changes will increase the force due to the magnetic field in the solenoid, and therefore drive the speaker cone with greater force to produce greater volume: 1. Increasing the number of coil turns (N, numerator) and/or 2. Decreasing the length (depth) of the coil (L, denominator).

Reviewing Faculty Cohort Members:

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