Name: ____ Period: _______ Date: ________

Lesson 1: What did we notice and how would we explain it?

Procedure: Your class will operate a device that will produce an interesting phenomenon. In the space below, record what you observed when the circular disc of this device was spun under the needle.

Observations:

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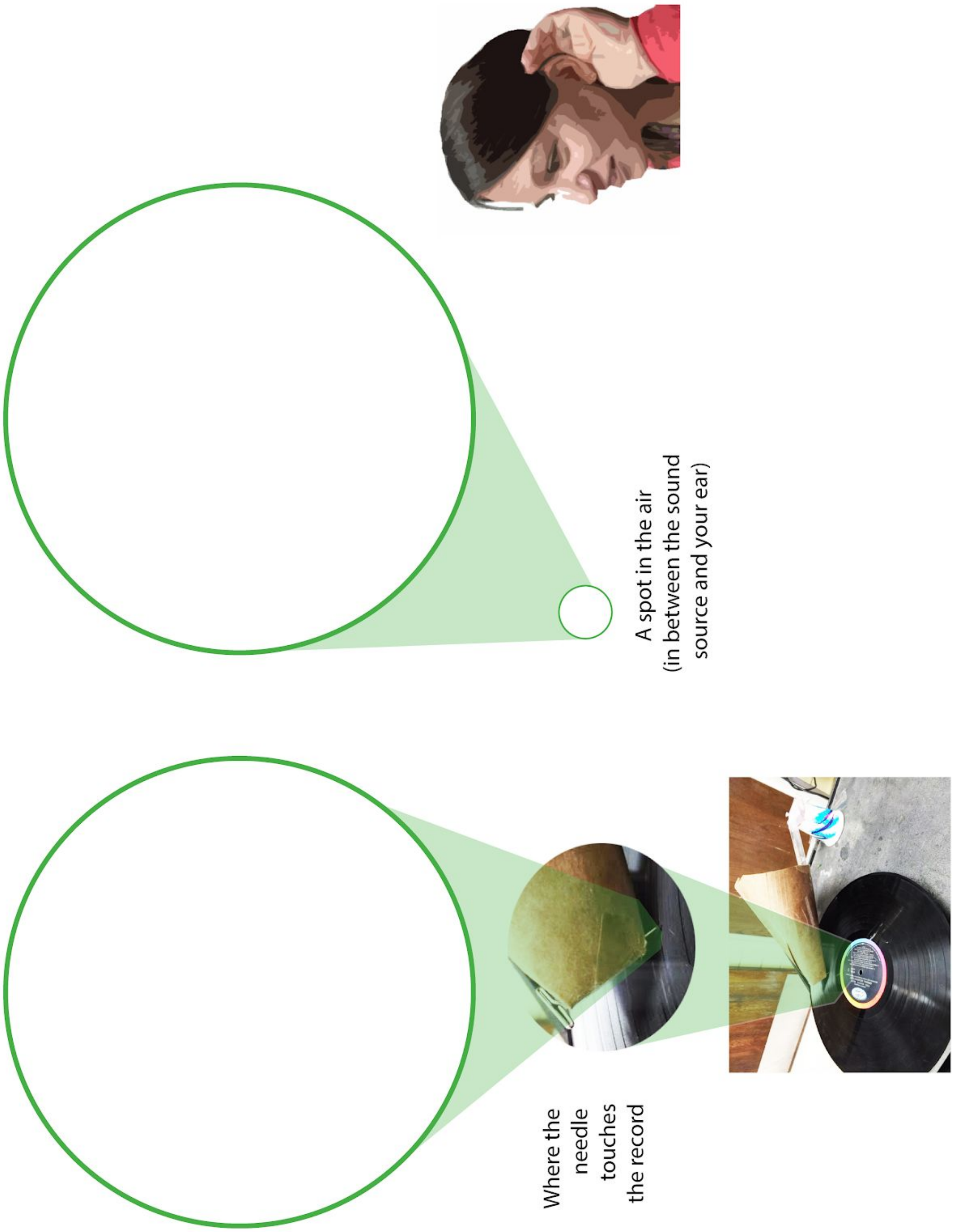
Making Sense: Draw and label a model to help you explain your thoughts on this question: How were you able to hear the different sounds you heard from across the room? Show a zoomed in view of what is happening in each of these locations:

a) where the needle touched the record

b) in a spot in the air between the sound source and your ear



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Q1: What was similar and different between your model and your partner's model?

Similarities between our models	Differences between our models

Consensus Model:

Q2: Take out your student increment model packet, and record the consensus model the class decided on today to explain how we were able hear different sounds from across the room.

Next Steps:

Q3: Let's think more about some other times you have experienced hearing different sounds from a distance. Let's use these experiences to try and generate a list of phenomena involving sound that we also want to try to explain in our unit.

Q4: What questions about sound do these experiences raise for you? List at least two.

Your class formed a Driving Question Board (DQB).

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Q5: List or draw some ideas you have for possible investigations we could conduct in order to help answer some of our questions we posted to the DQB. Keep track of the question that each investigation idea could help answer:

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Name: ______________________________________ Period: _______ Date: ________

Lesson 2: What does the record look like up close?

Part 1

Procedure: Record your observations for each of the data sources in the space below.

Data Source	Observations
A.	
B.	

Making Sense for Part 1:

Q1 Share your ideas with a partner: How might what you observed about the surface of the record be related to the sounds that it makes when spun?

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Part 2

Procedure: Record your observations for each of the phenomena below.

Data Source	Observations
C.	
D.	

Making Sense for Part 2:

Q2: How might the structure of the record surface be related to the sounds that it makes when spun?

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Conclusions:

Q3: What ideas did the class come up with for what might be causing the record and the needle to make different sounds as it is spun?

Next Steps:

Q4: Do you think other objects that produce music also move back and forth when they are making sound?Explain your thoughts.

Q5: How might we go about investigating this question further?

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Name: ____ Period: _______ Date: ________

Lesson 3: Are other objects that produce music also moving back and forth when they make sounds?

Predict:

Q1: What do you think you will feel or see a drum, guitar string, xylophone, or tuning fork doing when you strike or pluck it to make a sound?

____

____

____

Observations:

Data Source	Observations
A.	
B.	

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Making Sense: Discuss the next two questions with a partner.

Q2: What similarities did you notice among how each of these objects moved?

Q3: Why do you think all these objects continued to move the way they did after the thing that initially pushed or pulled on them was no longer touching them?

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Lesson 3: Student Modeling Sheet

Name: ____________________ Period: ________ Date: ________

Lesson 3: How Are These Instruments Moving and What is Causing Them to Move this Way?

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Lesson 3: Student Modeling Sheet

Name: ______________________________ Period: ______ Date: _______

Lesson 3: How Are These Instruments Moving and What is Causing Them to Move this Way?

These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Next Steps:

Q4: Could you use the consensus model your class made that explains how the instruments made sounds to also explain how *any* object produces sound?

Q5: How could we investigate this question further?

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Name: ____ Period: _______ Date: _______

Lesson 4: What do we need to figure out next?

Q1 Our Next Question: What new question is your class investigating?

____

____

____

Q2 Predict: What is your prediction in answer to this question? Why?

____

____

____

____

____

Procedure:

- Observe the setup that your class built with your teacher.
- <u>Discuss with a partner</u>: How will the setup that your class built help you investigate this question?
- Record your observations from the experiment below.

Observations:

Object	What happens when this object is struck softly?	What happens when this object is struck harder?

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Making Sense:
Q3: Make a claim based on the results of this investigation to answer the question that your class wrote above.

Conclusions:
Q4: How can you apply the discoveries you made today to help explain how the interaction between the needle and the record produces sounds?

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Next Steps:

Q5: What new question did your class raise as a result of this investigation?

____

____

____

Q6: How might we go about investigating this question further in future lessons?

____

____

____

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Name: ____ Period: _______ Date: ________

Lesson 5: How do the vibrations of the sound source compare for louder vs. softer sounds?

Planning Our Investigation:

Q1: Describe some of the ways that the behavior of the long wooden stick would be similar to a guitar string or tuning fork when you strike it or pluck it (push or pull on it and release it) to produce a louder vs. a softer sound?

____

____

____

Q2: How could studying the vibrations in a larger scale object like the wooden stick help us understand the vibrations occurring in smaller scale objects like a tuning fork or a record needle?

____

____

____

Procedure:

Q3: The range finder probe can detect and record the distance from an object to the probe many times a second. Describe how the graph changed during the demonstration.

____

____

Q4: When the wooden rod is at rest, how far is it from the detector? ____________________

Q5: What was the shape of the graph when the wooden rod is at rest?

____

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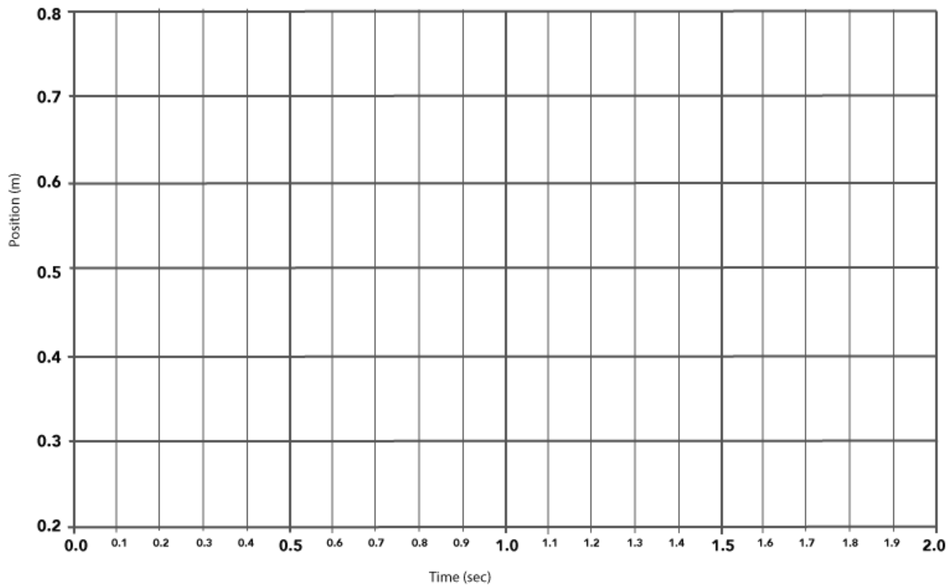
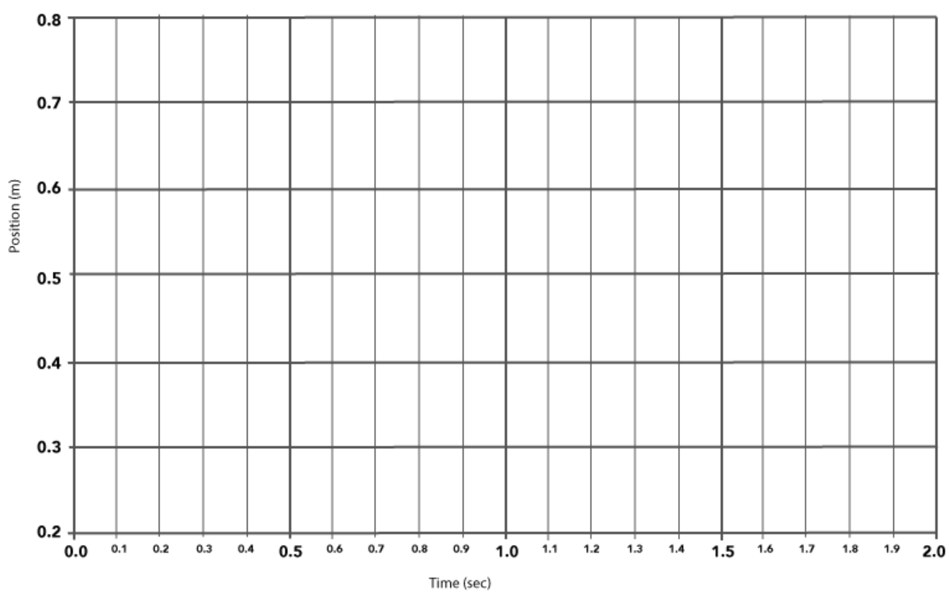
Predict: First draw in the straight line showing the position of the wooden rod when it is at rest, in *both* graphs. Then use a different color pen or pencil to sketch your prediction of what the shape of the *first* graph would look like after the rod is struck lightly with a mallet.

Condition 1: ______________________________________



Using a different color pen or pencil, sketch your prediction of what the shape of this *second* graph would look like after the wooden rod is struck harder with the mallet.

Condition 2: ______________________________________



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Procedure: As a class collect data and generate graphs on Logger Lite to observe and analyze for the two conditions.

Observations

Graph 1	Graph 2

Conclusion:

Q7: How does what we see in the graphs help us answer our original question, “How do the vibrations of the sound source compare for louder vs. softer sounds?”

Next Steps:

Q8: What new questions did these discoveries raise for your class? What new ideas do you have regarding what we should investigate next time?

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Name: ______________________________________ Period: _______ Date: ________

Lesson 6: How do the vibrations from different sound sources compare for higher vs. lower pitch notes?

Q1 Brainstorm: What are some types of musical instruments that we could look at more closely to see how they make different pitch sounds?

____

____

Procedure: Record your observations of the devices as they make different pitch sounds.

Observations

Device A	Device B	Device C

Making Sense:
Q2: What patterns did you notice between how the instruments and the music box made different pitched sounds?

____

____

____

Next Steps:
Q3: What would we need to change about the wooden stick we used in the last investigation, if we wanted to (re)use it to represent the different structures that were producing different notes in the music box?

____

____

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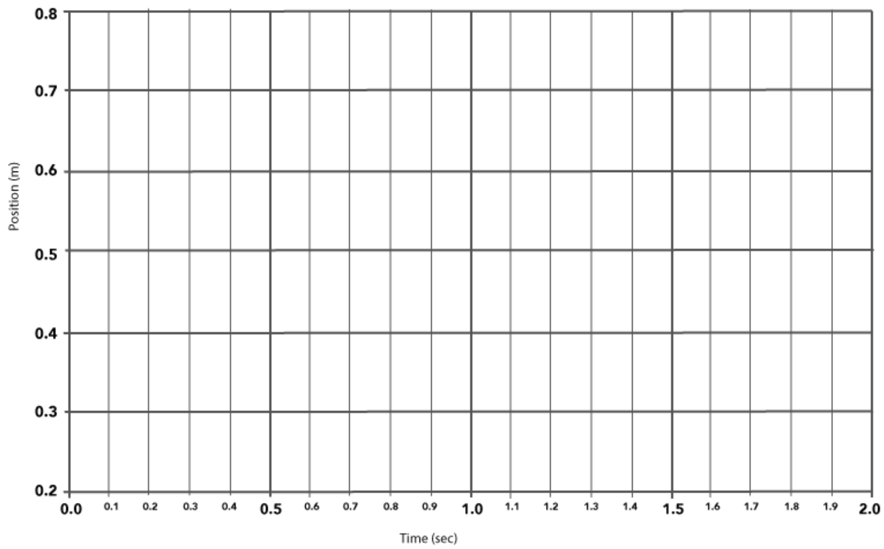
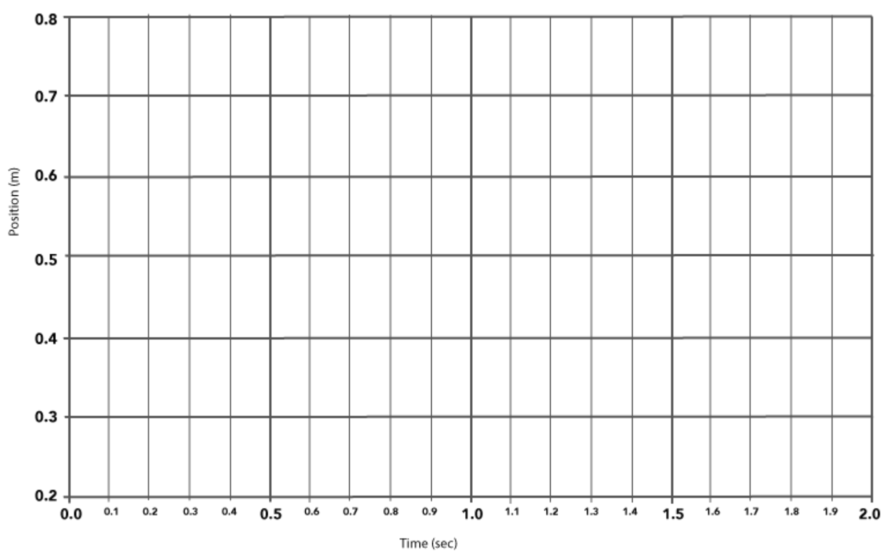
Predict: What do you predict the graphs of the vibrations of the ends of the wooden sticks will look like for these two different conditions your class will test?

Condition 3: ____



Condition 4: ____



These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Procedure: As a class collect data and generate graphs on Logger Lite to observe and analyze for the two conditions.

Observations

Graph 3:	Graph 4:

Making Sense of the results from this lesson and the previous lesson:

Q4: How were the vibrations changing between these two conditions (graphs 3 and 4)?

Q5: What about the vibrations of the sound source will change when a higher pitch note is produced compared to when a lower pitch note is produced?

Conclusions:

Q6: What discoveries did your class make? Record these in your Incremental Model Tracker sheets.

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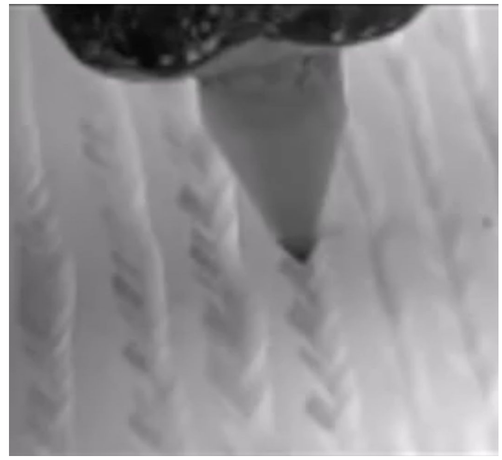
Next Steps:

Q7: Think back to what you know about how the needle and the record surface interact. What about that interaction might help explain how it could be producing so many different sounds (with different pitches and different volumes) at different points on the record?



Q8: How might we go about investigating this question?

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Name: ______________________________________ Period: _______ Date: ________

Lesson 7: How can we explain all the different sounds coming from the needle and the record as you spin it?

Looking Back

Talk with a Partner: What have we figured out that helps answer these questions:

- How do the vibrations from sound sources compare when they produce louder vs. softer sounds?
- How do the vibrations from sound sources compare when they produce higher vs. lower pitch notes?
- What makes the needle on the record vibrate as the record is spun?

Looking Forward - Brainstorm:

Q1: If differences in the volume of a sound and differences in the pitch of a sound are due to the differences in vibrations you described above, then wouldn't something have to be making the needle deform with different amplitudes or vibrate at different frequencies so that it produces different sounds? What might be forcing it to change its pattern of vibration?

____

____

____

Q2: What sort of data or materials would it be useful to look at again or explore in more detail to help us investigate this question further?

____

____

____

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Investigation 1:

Q3: What differences in loudness or pitch do you hear?

____

____

____

Q4: How must the motion of the needle be changing if it is producing some sounds that are quiet and some that are loud?

____

____

____

Q5: How must the motion of the needle be changing when it producing sounds that are at higher pitches than others?

____

____

How must the motion of the needle be changing when it producing sounds that are at lower pitches than others?

____

____

Q6: Talk with a Partner: How could we use a coffee stirrer to visualize this predicted motion of the needle?

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Procedure for Investigation 2:

1. Take a coffee stirrer and hold one end of it tightly against the side of a table. With your other hand take the end of the coffee stirrer and force it to move it back and forth to show a slow vibration (low frequency), keeping your hand on it the entire time.
2. Then without changing the length of the stirrer, force it back and forth to show a fast vibration (high frequency).
3. Next, move it back and forth to show a vibration of small amplitude.
4. Now move it back and forth to show a vibration of greater amplitude, but at about the same frequency of vibration as you did in step 2.
5. **Talk with a partner about this question:**
    - *In this phenomenon, you forced the same stick to vibrate at different frequencies. What is different about that sort of vibration compared to simply striking or plucking the stick?*

Procedure for Investigation 3:

You and your partner will use two manipulatives together: 1) a paper copy of the photo of the surface of the record from under the microscope and 2) the coffee stirrer (to represent and simulate the bending and movement of the needle) to develop an answer to these two questions:

- How might the structures on the surface be forcing the needle to move back and forth at different frequencies as you spin the record?
- How might the structures on the surface be forcing the needle to deform different distances, and therefore move back and forth at different amplitudes as you spin the record?

Feel free to draw, annotate, or mark up the paper copy of the photo of the surface of the record to try to identify parts of it that might be causing these changes in the pattern of vibration of the needle.

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Making Sense:

Be prepared to share with the class, locations on two parts of the record that support this first claim: *Different sections of grooves could force the needle to deform different distances, and therefore move back and forth at different amplitudes as the record is spun.*

Be prepared to share with the class, locations on two parts of the record that support this second claim: *Different sections of grooves could force the needle to move or bend back and forth at different frequencies as the record is spun.*

Conclusions:

Together with your class summarize your discoveries in your Incremental Model Tracker sheets.

Lesson 7 (part 4): What other phenomenon can we explain with the ideas we have put together so far?

Part 4:

This portion of the lesson is an individual assessment that your teacher will hand out to you separately.

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Name: ____ Period: _______ Date: ________

Lesson 8: How does a sound source make something like this happen?

Q1: What question(s) and phenomenon are your class trying to explain?

____

____

Gallery Walk:

What new ideas did this raise?	What new questions did this lead you to wonder about?

Next Steps:
Q2: What new question(s) did this raise for your class to investigate next?

Q3: How might we go about investigating this?

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Name: ____ Period: _______ Date: ________

Lessons 9 and 10: What are our questions and how will we investigate them?

Investigation 1: A - What question are we going to investigate?	
B - How will we investigate this?	**C - How will this investigation help answer our question?**
D - What claim can we now make about our original question based on the results of this investigation?	

Investigation 2: A - What question are we going to investigate?	
B - How will we investigate this?	**C - How will this investigation help answer our question?**
D - What claim can we now make about our original question based on the results of this investigation?	

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Investigation 3: A - What question are we going to investigate?	
B - How will we investigate this?	**C - How will this investigation help answer our question?**
D - What claim can we now make about our original question based on the results of this investigation?	

Investigation 4: A - What question are we going to investigate?	
B - How will we investigate this?	**C - How will this investigation help answer our question?**
D - What claim can we now make about our original question based on the results of this investigation?	

Conclusions: Update your Incremental Model Tracker sheets to summarize what you figured out.

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Name: ____ Period: _______ Date: __________

Lesson 11 - Part 1: How can we model the medium that sound travels through?

Q1: Brainstorm: What did you hear your classmates say is similar about the three states of matter: gases, liquids, and solids?

____

____

Q2: Model: In the space below, work with your partner to develop a model of the states of matter that your teacher has assigned you.

State of Matter:	State of Matter:
Our Model and Key:	Our Model and Key:

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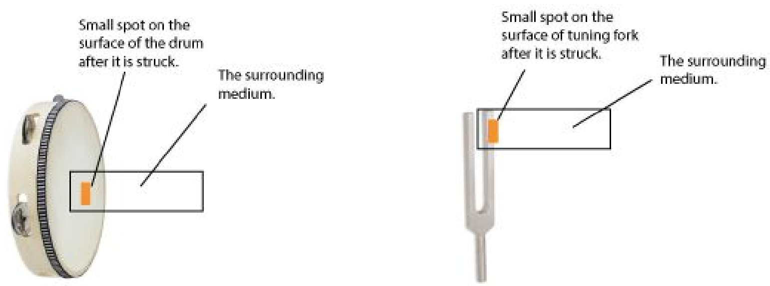
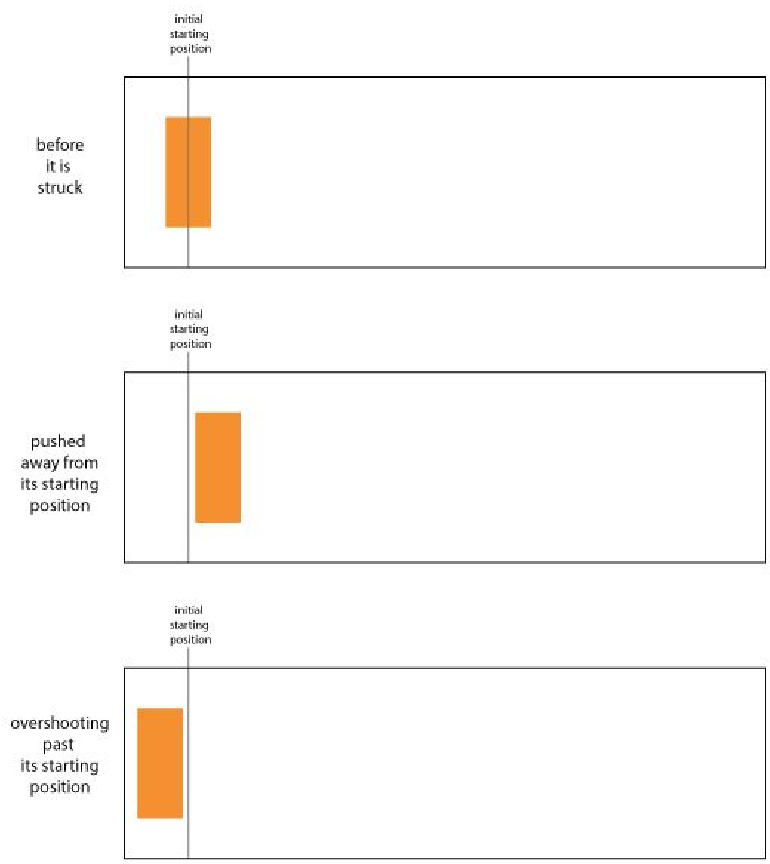
Q3: Home-learning:

- We know that somehow the sound is moving across the matter.
- We know that matter is made of particles too small to see.
- What we still don't know is how the sound is actually moving across the matter.

Re-draw one of your team's models (liquid or gas) that would be next to a small spot on the surface of either one of the objects producing sound (shown as a rectangle in the diagrams below). Then **show what you predict would happen to the matter in the medium if that spot on the sound source started vibrating.** We will share our models at the start of the next lesson.





Lesson 11 - Part 2: How can we model the medium that sound travels through?

Conclusions: Discuss these questions with a partner.

Q4: Today we modeled what the system looks like with liquid particles in it. Would we see similar interactions between particles if we simulated sound traveling through a solid? Or a gas? How would those compare?

Q5: How does this model help us understand why we couldn’t hear any sound when we sucked the air out of the system?

Next Steps: Scientists often build computer simulations to help investigate and visualize outcomes in systems that have parts (or particles) in them that are too small to see. Computer simulations are programmed to have the objects and interactions that the user wants or needs. Think about what you would want to see included in such a computer simulation that would help you understand more how sound travels across a medium.

Q6: What sort of things would you want to be able to adjust about the motion of the sound source in that simulation?

Q7: What sort of particle interactions in the medium would need to be included in the simulation?

Q8: How might running a computer simulation that includes all the things you listed above help us better visualize and understand what exactly is traveling across the medium when a sound is produced from a sound source?

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Name: ____ Period: _______ Date: ________

Lesson 12: What exactly is traveling across the medium?

Investigation 1: What is happening at a spot in space in the medium?

Predict:
Q1: What, if anything, do you expect to see moving across the medium as sound travels away from a sound source?

____

____

Q2: If you could watch the motion of a single particle in the medium, what would you expect to see it doing as sound travels across the medium?

____

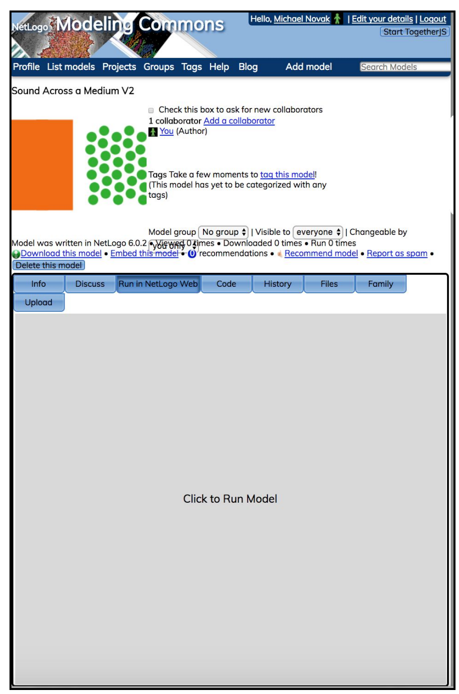
____

____

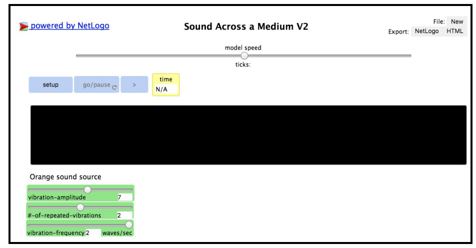
Procedure for loading the model:

1. Open a web browser and go to this web address: http://tinyurl.com/SoundAcrossMedium

2. A screen full of text like the one shown to the right should appear. Scroll to the bottom of the page and use your mouse to click on **Click to Run Model**



3. You should see this interface open now: ----------------->



4. You have now loaded the model and it is ready to run.

Procedure for running the model:

1. Press the SETUP button to initialize the model. -------------------->

2. Press GO/PAUSE to run the model. ------------------->

3. Use your mouse to click on a single green particle to make it red so it easier to track. Pay attention to the motion of this single particle in the medium.
4. Pause the model by pressing the GO/PAUSE button again.
5. Repeat steps 1 through 4.
6. Record your observations below.

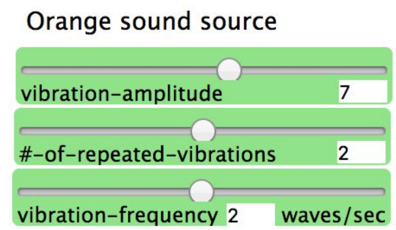
Observations: **(from Investigation 1)**

What patterns do you notice in the motion of a single particle in the medium?	What patterns do you notice in what appears to be happening across the entire medium?

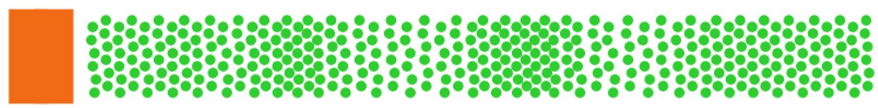
Investigation 2: How will the patterns you see moving across the medium change?

Design an experiment: Decide with a partner which of these three variables you want to change and how you will change it.

Circle the variable you plan to change in the image to the right.



Predict: How do you think the patterns you see moving across the medium will be affected by these changes? Sketch the pattern you think you will see in the box below.

Previous simulation run: An image of the pattern moving across the medium from the previous simulation run, using the values for the variables shown in the sliders above.	
Q3: My prediction of what the pattern moving across the matter (medium) will look like when we change the variable we want to investigate.	

Q4: Why do you think the pattern would look this way?

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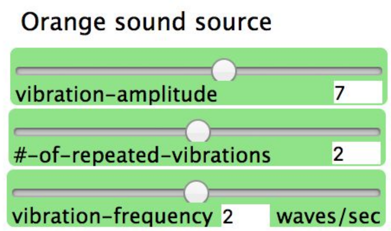
Procedure:

1. You will test your predictions using 2 computers—your computer and your partner's computer.

2. Adjust the sliders on one of the computers to have these values:



3. On the second computer, adjust the values of these sliders so that the one variable you wanted to explore has been changed, but the rest remain the same.

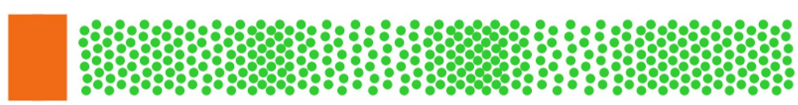
4. Press the SETUP button to initialize the model. ----------->

5. Press GO/PAUSE to run the model. ------------>

6. In the space below, draw a sketch showing how (or describe how) the patterns across the matter (medium) compared.

7. Repeat the steps above if you wish. Go ahead and change the variable again to a new value if you wish.

Observations **(from Investigation 2)**

Previous simulation run: An image of the pattern moving across the medium from the previous simulation run, using the values for the variables shown in the sliders above.	
Our results of what the pattern moving across the matter (medium) looked like when we changed the variable(s).	

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Making Sense:

Q5: What is happening to the particles in the medium that led to the results you observed?

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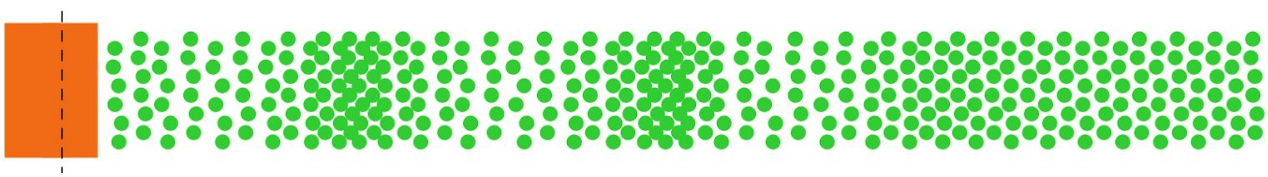
Conclusions:
As a class, construct a simplified model showing how particle density changes across the medium as a sound travels through it.

Frame 1

Frame 2



Frame 3

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Next Steps: Use the ideas developed in this lesson to explain how music produced from the speaker in the truck caused the window in a building across the parking lot to move. Be sure to include the following in your model: vibrations of the sound source, collisions between particles, energy transfer, and changes that happen in particle density across the medium.

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Name: ____ Period: _______ Date: _______

Lesson 13: What are we trying to figure out?

Our Questions:
What questions is your class is trying to answer?

A. ____

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B. ____

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C. ____

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Taking Stock: In small groups using your Incremental Model Tracker sheets and the annotated images from the activity sheets in the last lesson, think about these questions: What pieces do you think are general enough to apply to what we saw in the video with the truck and the window? Highlight or put a mark next to each item on your Incremental Model Tracker.

"Gotta Have It" Checklist: In your small group, use your Incremental Model Tracker and your notes to create a Gotta-Have-It checklist for modeling how sound works.

What does our model need to have?	Apply the checklist to a model by putting a checkmark in the box if the model has that piece (Checklist can be used 4 times).			

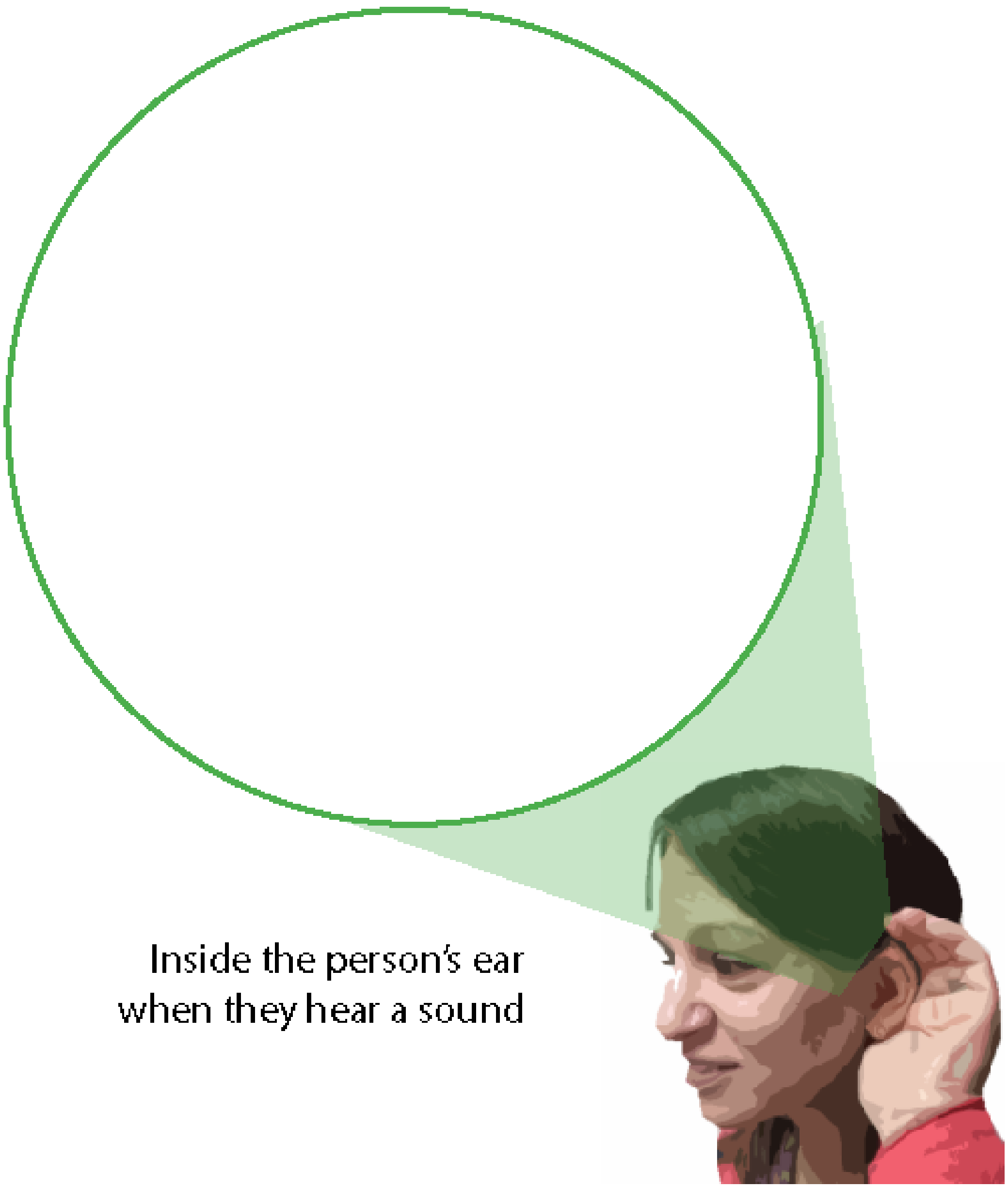
These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

What does our model need to have?	Apply the checklist to a model by putting a checkmark in the box if the model has that piece (Checklist can be used 4 times).			

These materials were developed with support from the Gordon and Betty Moore Foundation to Northwestern University and support from the NGSX Project at Clark University, Tidemark Institute, and Northwestern University.

Name: ____ Period: _________ Date: ____________

Lesson 14: What is going on inside my ear that can explain how we can detect certain sounds?



Inside the person's ear
when they hear a sound

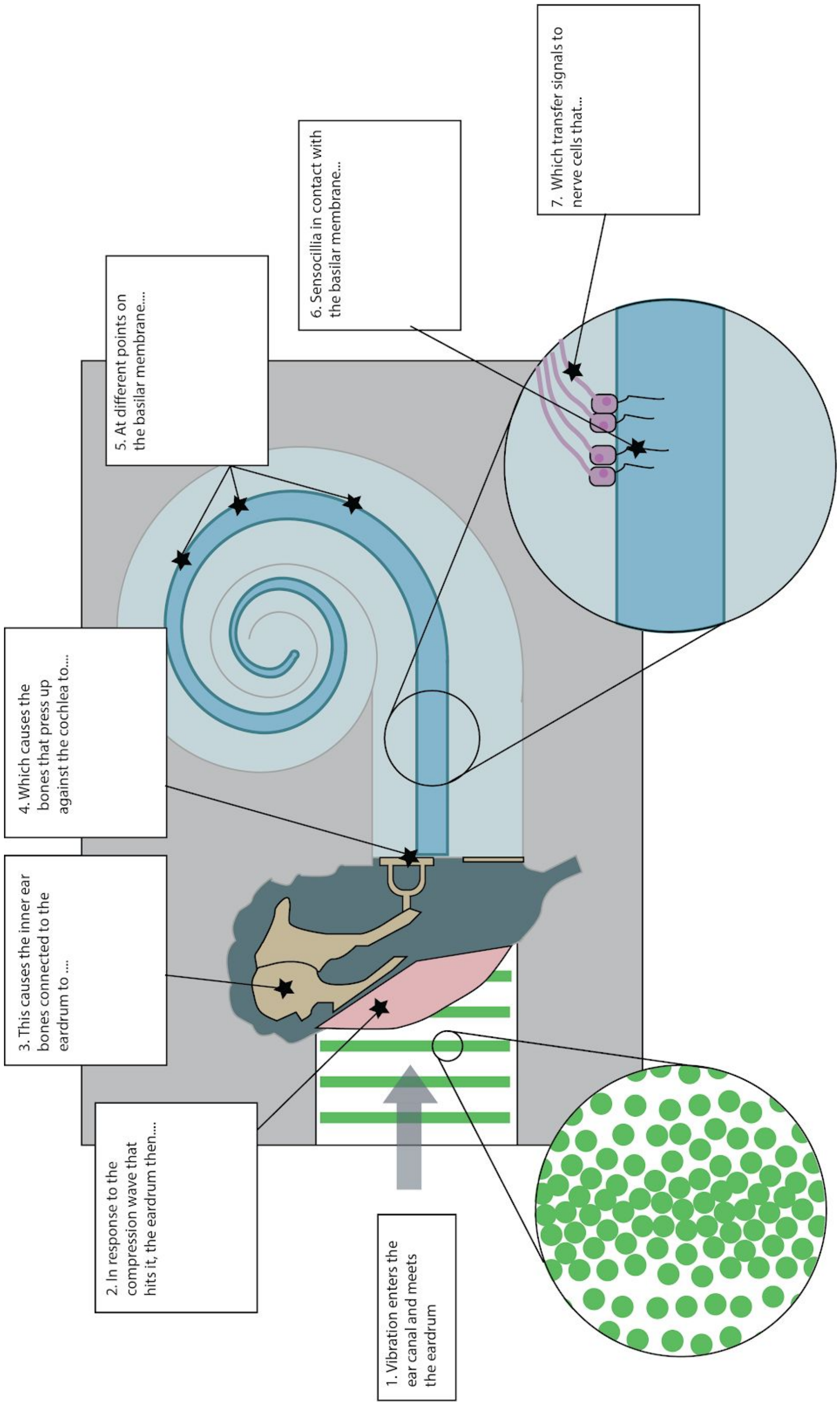
These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Reading and Video links: As you read the provided article, use the space below to take notes on anything you found to help answer our questions about how the structure and function of the ear allow us to detect sound. If you finish early, you may use the reflection questions that follow to continue working.

Questions we're still trying to answer: ● What is happening inside my ear to detect the sound? ● What is going on inside my ear?
Notes from the reading and video links:

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Constructing Explanations: Use what you learned from the article to show how energy from sounds are transmitted through the inner ear and detected by different sensory cells. Track your findings on the diagram below.



These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Name: ____ Period: _________ Date: ____________

Lesson 15: What transfers more energy, waves of bigger amplitude or waves of greater frequency?

In a previous lesson we learned from the ear doctor that stereocilia in a person's inner ear can get damaged by being knocked over. And we found out that louder sounds are more damaging than quieter sounds, and that higher frequency sounds are more damaging that lower frequency sound.

Initial Ideas–Turn and talk: Use ideas related to what is happening to the particles in the medium in each case, and how that would relate to the amount of energy transferred in each case as you discuss each of these questions:

Q1: Why would louder sounds be more damaging to these structures than quieter sounds?
Q2: Why would higher pitch sounds be more damaging than lower pitch sounds?

Predict:
Q3: What would transfer more energy to an object—doubling the amplitude of the wave that hits it or doubling the frequency of the waves that hit it?

____

____

Plan:
Q4: Fill out the table below to keep a record of the materials your class will be using to measure the amount of energy transfer for compression waves.

A vibrating source	A medium	Something to transfer the energy into and measure

Investigation 1: How will you use this setup to change the frequency (number per time period) of a compression wave?	
Investigation 2: How will you use this setup to change the amplitude of a compression wave?	

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Procedure for Investigation 1 <u>Do each of the following five steps within 1 minute:</u>

1. Line up the end of the plastic ruler so that it is right over the 10 cm mark and clamp down the base of the stick. Use clamps to do this or have a partner hold it in place.
2. Place a marker so the left end of it is at 20 cm (10 cm away from the end of the stick).
3. Place four marbles in between the end of the stick and the marker.

4. Pull the end of the ruler back 1 cm. Make sure the first marble is right up against the plastic ruler (you might need help from a partner for this).
5. Release the stick so that the marble is shot down the track and hits the marker.
6. Measure the final distance of the left end of the marker cap and record it in column C in Table 1.
7. <u>Do each of the following within 1 minute:</u> Repeat steps 1 through 6, but change steps 5 and 6 so that they are repeated <u>**two times in row**</u> causing the marker cap to get hit by two collisions before recording its final distance.
8. <u>Do each of the following within 1 minute:</u> Repeat steps 1 through 6, but change steps 5 and 6 so that they are repeated <u>**three times in row**</u> causing the marker cap to get hit by three collisions before recording its final distance.
9. <u>Do each of the following within 1 minute:</u> Repeat steps 1 through 6, but change step 5 and 6 so that they are repeated <u>**four times in row**</u> causing the marker cap to get hit by four collisions before recording its final distance.
10. Calculate how far the cap moved each time and fill in the values for column D in Table 1.

Table 1

A. # of waves in a minute	B. Initial position of target	C. Final position of target after being hit by these waves	D. How far did the target move?
1	20 cm		
2	20 cm		
3	20 cm		
4	20 cm		

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Making Sense of Your Data for Investigation 1: Compare the distances the cap moved in column D of Table 1.

Q6: How many times farther did the cap move in row 2 than it did in row 1? _________

Q7: How many times farther did the cap move in row 3 than it did in row 1? _________

Q8: How many times farther did the cap move in row 4 than it did in row 1? _________

Investigation 2

1. Line up the end of the plastic ruler so that it is right over the 10 cm. Mark and clamp down the base of the stick. Use clamps to do this or have a partner hold it in place.
2. Place a marker so the left end of it is at 20 cm (10 cm away from the end of the stick).
3. Place four marbles in between the end of the stick and the marker.
4. Pull the end of the ruler back 1 cm. Make sure the first marble is right up against the plastic ruler (you might need help from a partner for this).
5. Release the stick so that the marble is shot down the track and hits the marker.
6. Measure the final distance of the left end of the marker and record it in column G in Table 2.
7. Repeat steps 1 through 6, but change step 4 so that you pull the stick back 2 cm.
8. Repeat steps 1 through 6, but change step 4 so that you pull the stick back 3 cm.
9. Repeat steps 1 through 6, but change step 4 so that you pull the stick back 4 cm.
10. Calculate how far the marker moved each time and fill in the values for column H in Table 2.

Table 2

E. How far you pulled back the stick	F. Initial position of target	G. Final position of target after being hit by these waves	H. How far did the target move?
1 cm	20 cm		
2 cm	20 cm		
3 cm	20 cm		
4 cm	20 cm		

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Making Sense of Your Data for Investigation 2: Compare the distances the cap moved in column H of Table 2.

Q9: How many times farther did the cap move in row 2 than it did in row 1? _________

Q10: How many times farther did the cap move in row 3 than it did in row 1? _________

Q11: How many times farther did the cap move in row 4 than it did in row 1? _________

Class Results from All Groups

Group	Investigation 1: Frequency vs. Energy			Investigation 2: Amplitude vs. Energy		
	When the frequency of the waves was 2 times the original value, how many times more energy was transferred? (Q6)	When the frequency of the waves was 3 times the original value, how many times more energy was transferred? (Q7)	When the frequency of the waves was 4 times the original value, how many times more energy was transferred? (Q8)	When the amplitude of the wave was 2 times the original value, how many times more energy was transferred? (Q9)	When the amplitude of the wave was 3 times the original value, how many times more energy was transferred? (Q10)	When the amplitude of the wave was 4 times the original value, how many times more energy was transferred? (Q11)

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Q12: After calculating a typical value for each column of data, what patterns do you notice?

Conclusions:

Q13: What relationship did the class discover between the frequency of a wave and its energy and between the amplitude of a wave and its energy? Record your discoveries in your Incremental Model Tracker.

Q14: How does what we figured out help us provide a deeper explanation to some of our original questions below?

- Why would louder sounds be more damaging to these structures than quieter sounds?
- Why would higher pitch sounds be more damaging than lower pitch sounds?
- What would transfer more energy to our eardrum or the window: doubling the amplitude of the waves that hit it or doubling the frequency of the waves that hit it?

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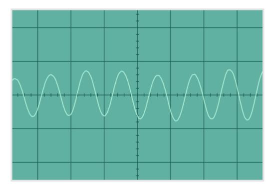
Name: ____ Period: _________ Date: ____________

Lesson 16: Why do sounds get harder to hear the farther away we are from their source?

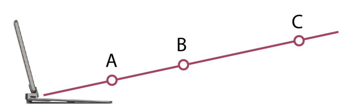
Prior Experiences: Q1: Discuss any experience you've had where the sound from a sound source changed as you got closer or further from the sound source.

Background: You saw how to set up a computer so that it plays a single tone. And you saw how we could use another computer's microphone to detect the sounds that reaches it. The image to the right is a distance vs. time graph of the vibrations detected by the computer with the microphone when it was about 0.6 m away from the sound source.

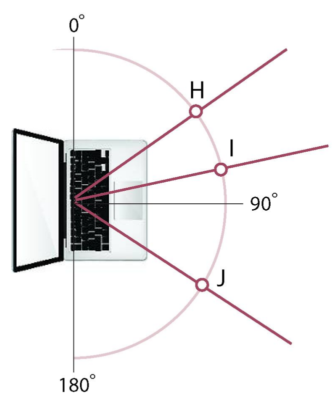


Predict:

Q2: If you moved the microphone from position A to B to C as shown in the diagram to the right do you think the graph would change or stay the same?



Q3: If you moved the microphone from position H to I to J (keeping the distance from the source the same) as shown in the diagram to the right do you think the graph would change or stay the same?



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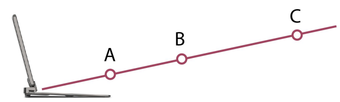
Plan for your first investigation:

As a group, decide on three distances between 0 and 2 meters from the sound source that you want to compare.



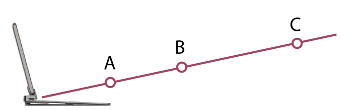
positions	A	B	C
distance			

Procedure for the first investigation:

1. Your group and another group will share a lab setup with a single computer speaker producing a sound. There should be enough room for both groups to tape down one end of their tape measure (or string) to right in front of the computer speaker.
2. When your teacher gives you the signal you will start the program for playing the sound at the sound source computer.
3. Have one member of the group pull the group's tape measure (or string) straight, while another member of the group lines up the microphone of the tablet/iPad/Chromebook along it to that it is pointed straight at the other computer's speaker.
4. Record your observations of the graphs on the oscilloscope at the different positions A, B, and C on the next page.

Observations:

Q4: Describe (or sketch) any changes you observed in the graph produced at position A versus position B versus position C?



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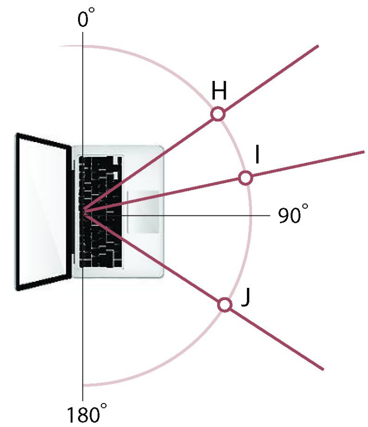
Plan for your second investigation:

For this investigation you will keep the microphone at 0.75 meters from the sound source the entire time. As a group, decide on three different angles (between 0° and 180°) that you want to capture data from.



positions	H	I	J
angle			

Procedure for the second investigation:

5. If you are using string instead of a tape measure, mark the location of A, B, C, and the 0.75 meter location for H, I, and J on the string using labeled pieces of tape.

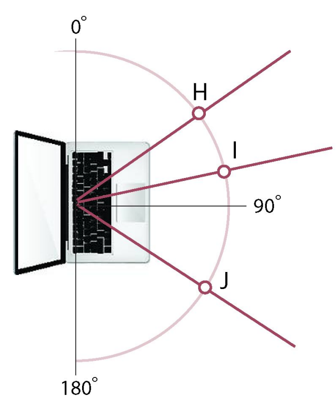
6. Have one member of the group hold a protractor near the speaker while another member pulls the tape measure (or string) tight along the angle you are collecting data for (H, I, or J). This will allow the third member to line up the microphone of the tablet/iPad/Chromebook toward the source along this line.

7. Move the protractor out of the way of the speaker as you record observations of the graphs on the oscilloscope at different positions H, I, and J on the next page in Q5.

8. When your teacher tells you time is up, turn the sounds off on the station computer.

Observations:

Q5: Describe (or sketch) any changes you observed in the graph produced at position H versus position I versus position J?



Making Sense:

Q6: Why **would changing the distance cause the amplitude of the sound waves to change** that are detected by the microphone?

In the space below develop a model (with a labeled key) to explain this phenomenon:

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Intentional blank page

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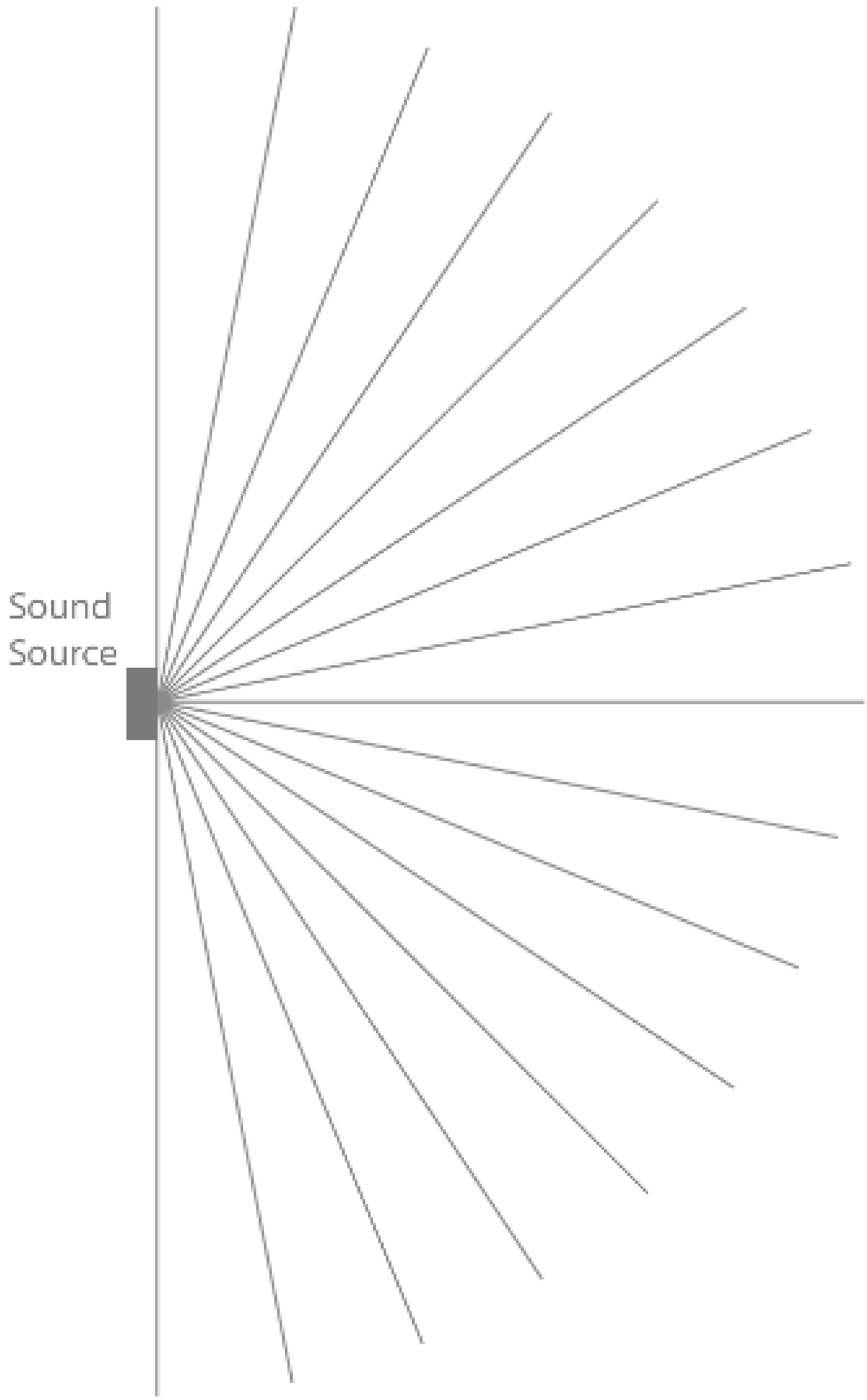
Conclusions:

Q7: As a whole class, annotate the diagram below to develop a model that helps your class explain the results from this investigation:



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Q8: How does this model help explain why sounds get quieter the farther away from a sound source you get?

Q9: Next Steps:

- Think back to our anchoring phenomenon of the record and needle. Was there anything in that device that might have prevented the sound from spreading out like our model is showing?
- If you can't hear someone talking from far away, and you can't move closer to them, is there anything you could do to help you hear the sound better?
- How we might investigate some of these ideas further?

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Name: ____ Period: _________ Date: ____________

Lesson 17: Can I design a solution to amplify the sounds that reach my ears?

Design a solution:

The diagrams below represent the distance at which a person can no longer hear the watch ticking, because the amplitude of the sound wave has decreased due to its energy spreading out over space (radiating).

Q1: What solutions could you design out of file folders, tape, and scissors that might amplify the sound that reaches your ear? Show these solutions in the space below.

Solution 1

Solution 2

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Investigation 1

Q2: Preparing to test your solutions: Create a data table in the space below to test all the designs that you want to test. What data will you collect? How will you keep track of the structure of each design that you tested and how well it performed?

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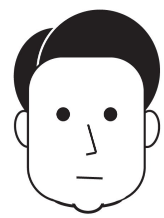
Making Sense of Investigation 1

Q3: Pick one of the solutions that helped amplify the sound that got to your ear from the ticking watch. Draw models to help explain two things:

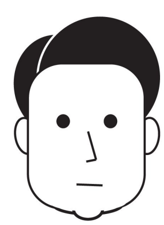
- Part 1–How did this structure end up making the sound loud enough for you to hear?
- Part 2–Why, without this structure, is the sound too quiet for you to hear from a certain distance?

Use the arrow representation your class developed to represent the direction the sound waves travel in your models to show what happens to the sound energy between the sound source and your ear.

Model Part 1: How this structure made the sound loud enough for you to hear



Model Part 2: Why, without this structure, the sound is too quiet for you to hear from a certain distance



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Conclusions:

Q4: What are some ideas you saw represented in the models shared in your class?

Next Steps:

Q5: What question did your class decide you needed to investigate further?

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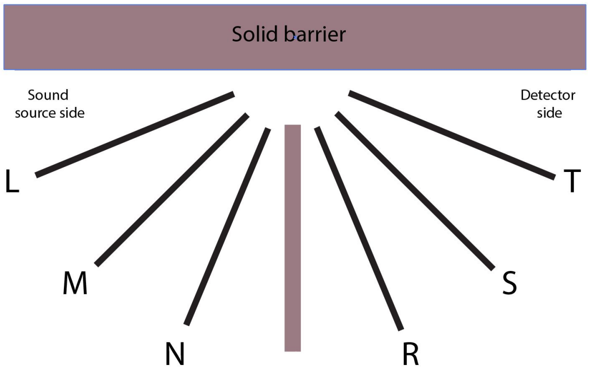
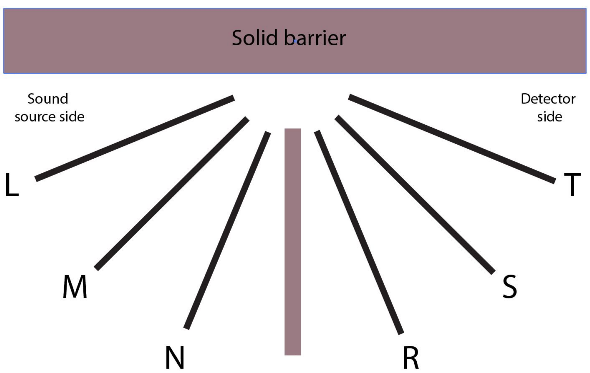
Investigation 2

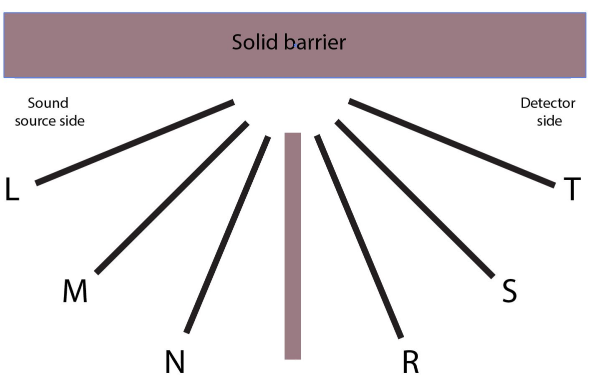
Results for: ____________________________ Notes:



Results for: ____________________________ Notes:



Results for: ____________________________ Notes:



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Making Sense

Q6: How would you describe the patterns you noticed in the data?

Conclusions:

Q7: What discoveries did your class make?

Q8: How can you use this discovery to explain the function of the cone in the anchoring event (the needle and record player that produced all those sounds you heard in Lesson 1)?

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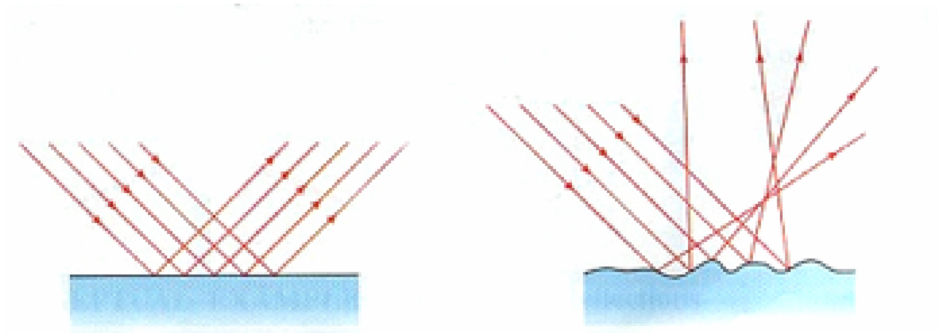
Name: ____ Period: _________ Date: ____________

Lesson 18: What happens to the energy of a sound wave when it reaches a boundary between two different media?

Model Comparison: You used the model below to explain and predict something about how sound waves interact with matter.



Q1: What does this model help explain and predict?

____

____

____

Q2: Model Development: What new phenomenon are you trying to explain and predict?

____

____

____

____

Draw and label a model as a class that helps explain this phenomenon.

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Investigation

Q3: Draw and label the setup that your class made to represent the boundary between two different media that sound could travel through.

Q4: What patterns did you notice in the phenomena you explored with this setup?

Q5: How are these patterns related to the model you drew on the first page?

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Name: ____ Period: __________ Date: ______________

Lesson 19: What else happens to the energy of the sound wave as it interacts with different stuff?

Observations from Phenomenon #1:

Q1: Model development: What new phenomenon are you trying to explain?

____

____

____

____

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Observations from Phenomenon #2:

Making Sense:

Q2: What claim can you now make about what happens to some of the energy that goes into a material as it is bent back and forth over and over again?

Q3: Use this claim to predict what is happening to some of the sound energy that is absorbed by the foam panels in the picture below.

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Lesson 20: How can we explain our anchoring phenomena and which of our questions can we answer now?

Developing a Model:

What are the three components (and related questions) of the model that your class will develop?

What component of the model and related question is your team working on?

Planning: To prepare for developing your model,

- Read through your incremental model tracking tool and “gotta have it” check-list
- Revisit any previous models that your class has developed to explain this component of how sound works
- Use the space provided to sketch and brainstorm ideas with your team before working directly on the poster paper

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Brainstorm: Use the space below to sketch out some notes and thoughts about your team's model.

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Providing Feedback: As you visit each team's model during the gallery walk, leave them specific feedback using sticky notes. Be sure to highlight: what is already clear and accurate, what might be missing, and what might still be tough to understand in their model.

Reflection: After returning to your model, read through your feedback with the team. Use the feedback provided by your peers to make any revisions to your model.

Revisions:

Sharing: Once teams have revised and improved their models, share your model with the class to help develop the class consensus model and answer the Driving Question for the unit.

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Lesson 21: Can a single object, like a speaker or a needle, really be forced to make all these different sounds?

Investigation 1

Q1 Observations - Discuss the following with a partner:

What evidence did you see in the video alone that the speaker is being forced to produce sounds at different volumes?	What evidence did you see in the video alone that the speaker is being forced to produce sounds at different pitches?

Investigation 2

Q2 Predict: What do you think is providing the energy to make the speaker vibrate at different frequencies and with different amplitudes?

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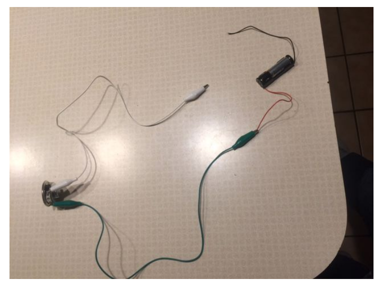
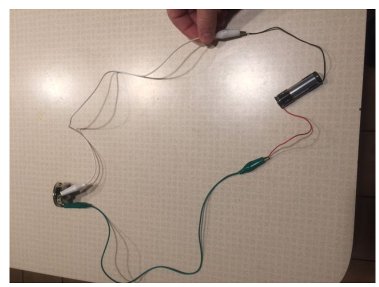
Materials needed:

- 1 Small speaker, 2 alligator clips, 1 AA battery holder and battery

Procedure:

1. Find the two leads on the side of the speaker and hook two alligator clips to them.	
2. Hook one of the alligator clips to the end of the red wire coming from the AA battery holder	
3. Bring the end of the other alligator clip close to the end of the black wire coming from the AA battery holder, but don't touch them together yet.	
4. Now touch that end of the alligator clip to the end of the black wire coming from the AA battery holder. Remove it. Repeat every 2 seconds.	
5. Increase how frequently you touch the alligator clip to the end of the black wire and remove it to once every second.	
6. Increase **how frequently** you touch and remove the alligator clip to the end of the black wire. Try to do this as rapidly as you can.	
7. Record your observations below.	
8. Try flipping which alligator clip is connected to the black wire and which is connected to the red wire on the battery holder and repeat the steps above.	

Observations:

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Q3 Making Sense: How were you able to force the speaker to move back and forth at a higher frequency?

____

____

____

Q4: The battery you used was a 1.5V AA battery. The V stands for voltage, which is related to the amount of electrical energy the battery can supply. If you replaced this battery with a 9V battery, do you think the speaker would deform at the same distance when you connect it to the new battery as it did when it was connected to the old battery? Explain.

____

____

____

Q5 Conclusions:

Q6 Next steps: What questions could we answer by dissecting a speaker further and/or trying to build our own?

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Lesson 22: What else is inside a speaker that makes it move?

Investigation 1: What are some similar structures you saw in both speakers that were dissected?

____

____

____

Investigation 2:

The directions you will follow will show you how to attach the coil of wire to a plastic cup. But you can also try attaching it to other objects, and see if they make sounds too.

In step 1 you can glue the coils of the wire to a different material, or differently shaped object.

Work with a group to plan on trying at least two different objects to try to attach the coil of wires to test if the object vibrates and produces sounds.

1. Hot glue the coils of electromagnet wire to the surface of the object you want to make vibrate

3. Bring a strong magnet close to the center of the wire coils. You should hear the song coming from the surface of the object. You may need to get closer to the object and/or hold it to your ear.

2. Hook each end of the wire coil to the two ends of a stripped aux. audio cord; you may want to use alligator clips to attach it together. Plug the aux. cord into an electronic device that is playing music.

What is the 1st object your group wants to try to attach the coils of wire to?	What is the 2nd object your group wants to try to attach the coils of wire to?

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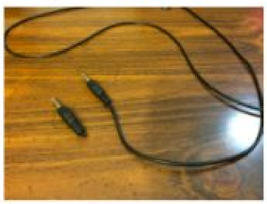
Now that you know what the 3 main parts of a speaker are, you will need to follow a more detailed procedure to build your 1st speaker.

Work in teams of 4-5 people. Have one pair of students try your 1st object (in place of the plastic cup shown above), and have the other pair of students try your 2nd object. Each pair of students should try to build their own speaker, so that the group can compare results from both objects they tested.

Materials needed

For plugging into a headphone jack on a computer or phone



A. Aux. cord with one end cut off and the end of the wires exposed

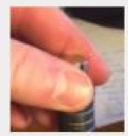
For connecting the aux. cord to the speaker

B. Two alligator clips

For building the speaker

C. A 30 to 40 ft. piece of electromagnet wire coiled in loops, with both ends stripped.

D. A strong magnet that is smaller than the diameter of the loops in the coils of the wire shown above.



E. Any object that you want to try to make vibrate (and turn into a speaker).

F. A glue gun

G.You also will need an electronic music device (computer, tablet, smartphone) to hook this all up to, to test it.

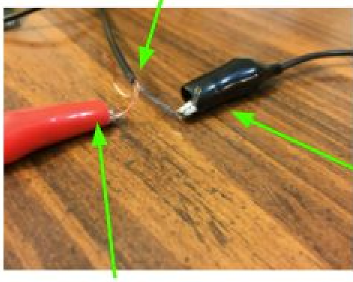
In step 1

Use a hot glue gun to attach the coils of wire to the object you want to try to make vibrate. You can peel the glue off and try a different object with the same coil of wire later.

These materials were developed with funding through a grant from the Gordon and Betty Moore Foundation to Northwestern University and the University of Colorado Boulder.

Keep a gap between these
The 2 different wires to prevent a
short circuit.

In step 2

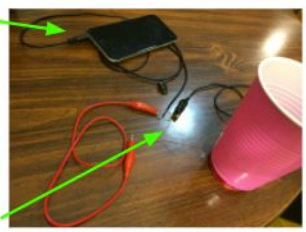


B. Clip the other alligator clip to the copper end of the black wire on the aux. cord.

A. Clip one the alligator clips to the copper end of the red wire on the aux. Cord.

C. Clip the other ends of the alligator clips to the copper ends of your coil of speaker wire (which will be glued onto the object that you want to make vibrate)

D. Start a song playing on your electronic device with the volume turned up. Plug in the aux cord to it. The sound will go away for now.



E. Make sure the black and red wires aren't touching (this would cause a short circuit) and the electricity won't flow through the coil.

Step 3

A. Bring one or more magnets close to the center of the coils of the wire. Listen closely. Bring the object that has the coil on it close to your ear. You should hear music coming from it! You should also be able to feel it vibrating!

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Observations: After you have assembled and tested each object, record observations you notice in the space below about how each object you tested functions.

	1st object tested	2nd object tested
Describe the object you tested. You can include a sketch and labels if you wish.		
Did it vibrate?		
Did it produce sound?		
If both produced sound, how did the sound produced from the two objects compare? Were there any differences in sound quality?		

Next Steps: Dissecting a speaker helped us find 3 key structures that work together to convert electrical energy to motion (vibrations) in order to produce different sounds.

Microphones detect sounds. What structures would you expect to find in a microphone if you dissected it?

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The first phenomenon you explored in this unit was a homemade record player. Brainstorm what type of things you could use to build a homemade recorder that captures, stores, and makes a record- but doesn't use electricity?

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Name: ____

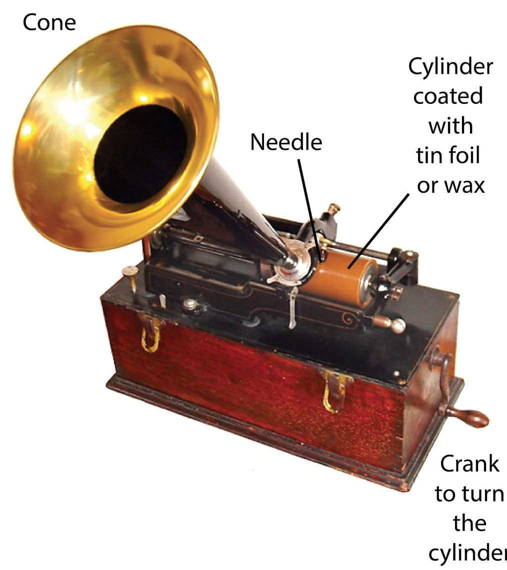
Lesson 23: How were audio recordings made, copied, shared, and played back long ago vs. now?

Text adapted from: https://en.wikipedia.org/wiki/Phonograph_cylinder

The first audio recordings ever made were produced on a device similar to the one shown to the right.

On July 18, 1877, Thomas Edison and his team invented the phonograph. His first successful recording and playback of intelligible sounds were achieved early the following December. The phonograph used a thin sheet of tin foil wrapped around a hand-cranked grooved metal cylinder to record the sounds on. The photograph to the right shows the basic parts of the device.

Q1 Predict: In the space below, explain how these parts worked together to capture and record sounds. Use labeled diagrams if you wish.



Original image from https://en.wikipedia.org/wiki/Phonograph_cylinder

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Background Information: Following seven years of research and experimentation at their Volta Laboratory, Charles Sumner Tainter, Alexander Graham Bell, and Chichester Bell replaced tin foil with wax as the recording surface. In 1887, their "Graphophone" system, which recorded sounds on disposable cardboard tubes with a thin wax coating, was released.

After this system was demonstrated to Edison's representatives, Edison quickly resumed work on the phonograph. He settled on a thicker, all-wax cylinder; the surface of which could be repeatedly shaved down for reuse. Both the Graphophone and Edison's "Perfected Phonograph" were commercialized in 1888. Eventually, a patent-sharing agreement was signed and the wax-coated cardboard tubes were abandoned in favor of Edison's all-wax cylinders as an interchangeable standard format.

Prerecorded wax cylinders went on the market in 1889. These had professionally-made recordings of songs, instrumental music, or humorous monologues in their grooves. They were made of a relatively soft wax formulation and would wear out after they were played a few dozen times. The buyer could then use a mechanism which left their surfaces shaved smooth so new recordings could be made on them.

Turn and Talk: What new information did this reading provide you to help you figure out how this device worked? **Investigation:** Analyze the following video: https://www.youtube.com/watch?v=CJXDtrq4McY **Q2:** Record any new ideas you figured out that can help explain: ● How this device records information about the sounds it detected on a wax cylinder? ● How those sounds can be played back (without a microphone)?	

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Next Steps:

	Analog recordings	Digital recordings
	Such as a vinyl record 	Such as a computer audio files like .wav or .mpg .mp3 
Which seems easier to use to make an audio recording of a sound?		
Once an audio recording is made in this format, which seems easier to store? Explain.		
Which do you think is easier to make a copy of a recording to send to someone far away? Explain.		
Which do you think can be damaged or lost more easily? Explain.		
Which is easier to playback in a variety of settings? Explain.		

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