Wave unit Activities
Many of these use PhET and some use lab equipment

To see how these activities fit into my Archived course, use my school website. Plans fluctuate depending on schedule changes and students' need.
http://jeffcoweb.jeffco.k12.co.us/high/evergreen/science/loeblein/phys_syl/syllabus_p.html

Table of Contents

The PhET activities can also be found in the PhET Teaching Ideas in Microsoft office format. If you would like to edit an activity for your course: All of my activities are posted under the Creative Commons-Attribution license http://creativecommons.org/licenses/by/3.0/, so please acknowledge that they were developed by Trish Loeblein, PhET Team and Evergreen HS, and provide a link back to the main phet website (phet.colorado.edu).

Waves on a String: https://phet.colorado.edu/en/contributions/view/2819

Fourier Making Waves: Activity 1 https://phet.colorado.edu/en/contributions/view/2837

Activity 2 https://phet.colorado.edu/en/contributions/view/2838

PhET Demonstration: https://phet.colorado.edu/en/contributions/view/3043

Sound homework: https://phet.colorado.edu/en/contributions/view/2849

Geometric Optics: https://phet.colorado.edu/en/contributions/view/2852

Fourier Game Tab: https://phet.colorado.edu/en/contributions/view/3042

Resonance: https://phet.colorado.edu/en/contributions/view/3445

Bending Light by Danny Rehn, CU-Bouder: https://phet.colorado.edu/en/contributions/view/3442

Clicker questions for Waves: https://phet.colorado.edu/en/contributions/view/3032

Periodic Motion and Waves: Water, Light and Sound Physics

What is a wave? How do they act? How do waves differ? How do images form?

Class meets 50 and 95 minute blocks. The block days are in bold. Yellow Highlights are PhET.

Day1 Pre-test Waves on a String
Notes: Introduction to Waves
Lab: *Waves on a String Activity* PhET
Do: read text; Concept questions

Day2 Clicker questions: Waves on a String
Notes: **Important Concepts:** oscillation, amplitude, period, frequency **Application**: Damping
Lab: *Fourier-Making Waves* part 1 PhET
Do: read text; Concept questions; worksheet WAVES

Day3 Lab: Sound using LabPro

Day4 Lab: *Sound* PhET
Do: read text; Practice problems

Day5 Notes: clicker questions**:** Sound wave activity (1-8), Demo Doppler
Lab: *Fourier-Making Waves* part 2 PhET
Do: read text; Practice problems

Day6 Notes: Wave descriptors review and demos & Clicker questions: Sound continued (9-18)
Lab: Reflection of light
Do: read text; Practice problems

Day7 Notes: light properties and ray model of light, reflection
Lab: Bending Light PhET
Do: read text; Concept questions; practice problems

Day8 Notes: Refraction and Snell's Law
Lab: Snell's law lab
Full write-up to find the index of refraction for three shapes (one triangle, semicircle incident on curved side, and the double convex lens) at seven incident angles.
Include: 2 summary graphs (Θ_I vs Θ_r and $\sin\Theta_I$ vs $\sin\Theta_r$) with incident information on x-axis with equations and r^2 , calculations for index two ways, raw data sketches, use proper significant digits
Do: read text; Concept questions; practice problems

Day9 Notes: using Excel for multiple curves, lab writing reflection from Specific Heat Labs
Lab: finish Snell's law lab
Do: Snell law worksheet

Day11 Lab: Lens properties

Day12 Notes: Lens problem solving,
Lab: *Geometric optics activity* (PhET)
Do: read text; Concept questions; practice problems

Day14 Clicker questions: Reflection, Lenses and Refraction
Lab: Resonance HS version
Do: read text; Concept questions; practice problems)

Day13 Review Clicker questions: Fourier-Making Waves

Day14 **TEST**

Learning Goals: Waves (Water, Light and Sound)

What is a wave? How do they act? How are do waves differ?

Students will be able to:

<u>Waves on a String</u>

- Discuss waves' properties using common vocabulary and they will be able to predict the behavior of waves through varying medium and at reflective endpoints

<u>Fourier – Making Waves Part 1</u>

- Think about waves as a function of time, space or space-time and explain why waves might be represented in these different ways.

<u>Fourier – Making Waves Part 2</u>

- Define harmonic, determine the relationship between the harmonics,
- Explain the relationship between harmonics and the corresponding wave function.
- Predict what happens when more than one wave is present.

<u>Fourier – Making Waves Game tab</u>

- Apply their understanding about wave characteristics and superposition to match wave functions

<u>Demonstrations for class discussion on reflection, wave interference and Doppler</u>

- Predict the pattern of a reflected wave
- Relate two dimensional representations of waves to three dimensional waves
- Explain wave patterns from interfering waves *(Apply the superposition principle to water, sound and light)*
- Recognize the Doppler effect and predict the change in frequency that occurs.

<u>Sound and Wave Activity</u>

- Explain how different sounds are modeled, described, and produced.
- Design ways to determine the speed, frequency, period and wavelength of a sound wave model.

<u>Geometric Optics Activity</u>

- Explain how an image is formed by a converging lens using ray diagrams
- Explain how changing the lens effects where the image appears and how it looks
- Explain what features a lens would need for real applications

<u>Resonance Activity:</u>

- Describe what resonance means for a simple system of a mass on a spring.
- Identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.
- Give examples of real-world systems to which the understanding of resonance should be applied and explain why.

<u>Bending Light Activity:</u>

- Explain how light bends at the interface between two media and what determines the angle.
- Apply Snell's law to a laser beam incident on the interface between media.
- Describe how the speed and wavelength of light changes in different media.
- Describe the effect of changing wavelength on the angle of refraction.
- Explain how a prism creates a rainbow.

Learning Goals: Waves (Water, Light and Sound)
What is a wave?   How do they act?   How are do waves differ?
Students will be able to:

Properties of Waves
- Distinguish local particle vibrations from overall wave motion
- Differentiate between pulse waves and periodic waves
- Interpret waveforms of transverse and longitudinal waves
- Apply the relationship among wave speed, frequency, and wavelength to solve problems
- Relate energy and amplitude

Wave Interactions
- Apply the superposition principle
- Differentiate between constructive and destructive interference
- Predict when a reflected wave will be inverted
- Predict whether specific traveling waves will produce a standing wave
- Identify nodes and antinodes of a standing wave

Sound waves
- Explain how sound waves are produced
- Relate frequency to pitch
- Compare the speed of sound in various media
- Relate plane waves to spherical waves
- Recognize the Doppler effect, and determine the direction of a frequency shift when there is relative motion between a source and an observer

Characteristics of Light
- Identify the components of the electromagnetic spectrum
- Calculate the frequency of wavelength of electromagnetic radiation
- Recognize that light has a finite speed
- Describe how the brightness of a light source is affected by distance

Flat Mirrors
- Apply the law of reflection for flat mirrors
- Describe the nature of images formed by flat mirrors

Refraction
- Recognize situations in which refraction will occur
- Identify which direction light will bend when it passes from one medium to another
- Solve problems using Snell's law

Thin Lenses
- Find the position of an image produced by a converging or diverging lens, and identify the image as real or virtual
- Calculate the magnification of lenses

Lesson plan for Waves on a String
90 minutes

Learning Goals: Students will be able to discuss wave properties using common vocabulary and they will be able to predict the behavior of waves through varying medium and at reflective endpoints.

Background: This activity is inquiry based. The simulation will be used as the introduction to wave properties and behavior for mechanical waves.

***Waves on a String* Introduction:**
Define a wave for the students. Our book calls the disturbances in the space-time continuum. Demonstrate that the simulation is like a rope on the ground with transverse waves being propagated.

Lesson: Have some long ropes or Tygon tubing and perhaps long springs available for student investigations. Also have thin paper for tracing the waves off the screens. I used a pretest before we started. The student directed portion of the activity took about 40 minutes.
Standing waves: I made a fair one with the following settings: 20 amplitude 30 frequency 0 damping and tension on one tick from right

Post-lesson: I opened Energy Skate Park and showed the Energy-Position and Energy-time graphs to help them relate to prior learning. I asked if the graphs represent waves. We discussed why it might be helpful to use the energy-space vs the energy time graphs. We discussed the vocabulary used in the Waves on a String sim throughout this part and during the clicker questions.

There is a nice demonstration sim of Transverse, Longitudinal, and Periodic Waves at NYU. http://www.physics.nyu.edu/%7Ets2/Animation/waves.htm The sims are not interactive, just movies. I did not think that the other movies were worth using because the sims demonstrate the ideas better. For superposition and standing waves, use Waves on a String. For Doppler, use Wave Interference and drag the water faucet. For longitudinal, use Sound.

Then we did the clicker questions.
Next we did the Fourier 1 activity.

Waves on a String

Learning Goals: Students will be able to discuss waves' properties using common vocabulary and they will be able to predict the behavior of waves through varying medium and at reflective endpoints.

Directions:

1. Open *Waves on a String*, **investigate** wave behavior using the simulation for a few minutes. As you look at the waves' behavior, **talk** about some reasons the waves might act the way they do.

2. **Write** a list of characteristics that you will use in this activity to describe the waves. **Describe** each characteristic in words that any person could understand. Leave some writing space for characteristics that you might think of later during the activity.

3. With the *Oscillate* button on and with *No End* checked, **investigate** waves more carefully using the *Amplitude* slider. **Write** answers to the following after your group has talked about each and agreed.
   a) Define *Amplitude* in everyday language.
   b) Explain how the wave behaves as the *Amplitude* changes using the characteristics you described in #2
   c) Use a rope on the floor for some investigations and explain how you could change the *Amplitude* of a wave.

4. Repeat step number 3, for *Frequency, Tension* and *Damping*.

5. Set *Amplitude* on high, *Frequency, Damping* and *Tension* on low. Also, have on *Oscillate, Timer* and *No End*. Use the *Pause* button to freeze the wave.
   a) **Place** a blank piece of paper on your monitor and **trace** the wave and the wave generator. **Mark** the green balls. This is a vertical position- horizontal position graph, label your axes.
   b) Quickly press *Play,* and then *Pause* again. Use the same piece of paper, put it on the monitor and make sure to get the generator in the same spot. **Trace** the new wave.
   c) **Write** about the differences and similarities in the characteristics. You may have to do some more tests by pressing *Play,* then *Pause* and tracing to test your ideas.
   d) Try some other settings and **talk** about why I recommended the settings that I did.

6. Set *Amplitude* on high, *Frequency, Damping* and *Tension* on low. Also, have on *Oscillate, Timer* and *No End*. Use the *Pause* button to freeze the wave.
   a) **Measure** the vertical location of a green ball with a ruler.
   B) **Record** the vertical position and time.
   b) Quickly press *Play,* then *Pause* repeatedly to **make** a data table the vertical position of the green ball versus time.
   c) **Make** a graph of vertical position versus time.
   d) **Write** about the differences and similarities between vertical position- horizontal position graphs and vertical position-time graphs.

7. **Investigate** how waves behave when the string end is *Fixed* and *Loose* with *Manual* settings. **Discuss** the behavior with your partners. **Test** your ideas and the **write** a summary.

8. **Read** in your book to find out what a standing wave is, **investigate** how to produce one with the simulation and **write** a procedure that another student could follow to produce a standing wave.

Lesson plan: *Fourier-Making Waves*
http://www.phet.colorado.edu 30 minutes and 50 minutes

I have divided the learning goals into two activities. There is a game that could be done without these activities.

1 Wave Representation Learning Goals:
Students will be able to think about waves as a function of time, space or space-time and explain why waves might be represented in these different ways.

2 Superposition of Waves Learning Goals:
Students will be able to:

- Define harmonic, determine the relationship between the harmonics,
- Explain the relationship between harmonics and the corresponding wave function.
- Predict what happens when more than one wave is present. *I want the students to be able to superpose waves to find the sum.*

Background:
We will have added several types of vectors. They do the *Waves on a String* activity before these activities. We did the three activities on two 50 minute days and one 90 minute day, along with some lecture and homework review.

Fourier-Making Waves Introduction:
I didn't need to show my students anything, but I made a list of some hints to remember. You can change the amplitude by grabbing the bar or typing in a number in the box. As soon as you do, the function changes to custom. Also, show how to set the *SUM* window on *Auto scale*. It only auto scales the y axis and reflect axes scales. When you reset, the scale returns to default. The *Sum Graph* is the observable disturbance.

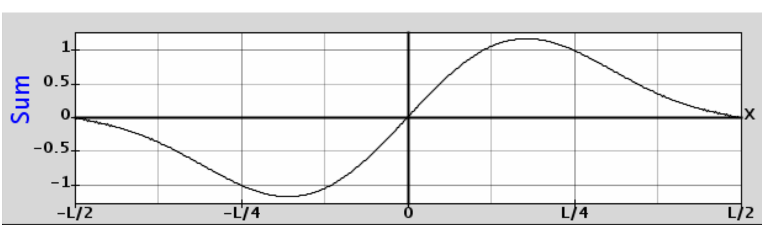
Lesson:
The students will need their papers from the *Waves on a String* activity. Have the students use the lab sheet for guidance.

Things I want to remember when I designed the activities:
Activity 1:

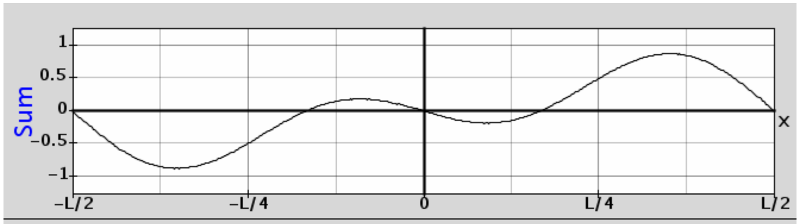
1. When you change function from space to time. There are no changes other than the axis label and period tool now available rather than wavelength.

Activity 2:

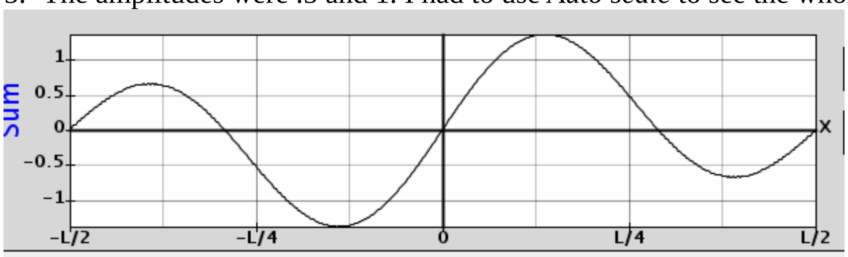
1. Harmonics have same amplitude but wave lengths that get smaller. To calculate the wavelength of n harmonic divide the wavelength of the fundamental wave (n=1), by the n of the harmonic. In our physics books, the fundamental frequency is given value of n=0 so the equation is not in this form, but I expect this is the form that students will derive. We will have to reconcile with the books convention, but I'll do this later.
2. I would want them to see that the SUM window looks like the name and that the individual waves add to give that shape, more harmonics make the sum curve smoother. I am not concerned that they discover the sum part yet.
3. The amplitudes were 1 and .35. The sum looks like this. The x axis labels have changed.



4. The amplitudes were .5 and -.5 for amplitudes. The sum looks like this.



5. The amplitudes were .5 and 1. I had to use *Auto scale* to see the whole graph.



Student directions *Fourier-Making Waves* activity 1: Wave Representation

You will need your Waves on a String answers to do this activity.

Learning Goals:
Students will be able to think about waves as a function of time, space or space-time and explain why waves might be represented in these different ways.

1. Discuss with your partner how you usually think about waves. Make drawings to help you explain the images in your mind as you try to explain waves.

2. Open *Fourier-Making Waves.* Investigate how changing amplitude affects the wave. How do your findings compare to your findings from number 3 in the *Waves on a String* activity? Describe in your own words what the y-axis for wave graphs represents.

3. Change the *function of* to *time(x).* Record how the waves compare, the axes labels and which tools change. Then, repeat using *function of time and space*.

4. Which representation does *Waves on a String* use? (you may need to open *Waves on a String* again)

5. In number 5 in the *Waves on a String* activity, the graph you made was called <u>vertical position-horizontal position</u> graph. Summarize how you made the graph. What would you have to do in *Fourier-Making Waves* to make a similar graph?

6. In number 6 in the *Waves on a String* activity, the graph you made was called <u>vertical position-time</u> graph. Summarize how you made the graph. What would you have to do in *Fourier-Making Waves* to make a similar graph?

7. Use Chapter 12 of your text to see how the author uses different representations of waves to help you understand the definition of a wave.

   a. Find a figure that is the function of time. Sketch the figure and record the figure number.

   b. Find a figure that is the function of space. Sketch the figure and record the figure number.

   c. Read the pages that correspond to these figures. How does the author use each figure to help you understand waves?

   d. Why can't the book represent a wave as a function of space and time? If you were a publisher and wanted to add space-time representations, what could you do? Describe an event where this format could be used to help the reader.

Student directions *Fourier-Making Waves* activity 2: Superposition of Waves
http://www.phet.colorado.edu 40 minutes

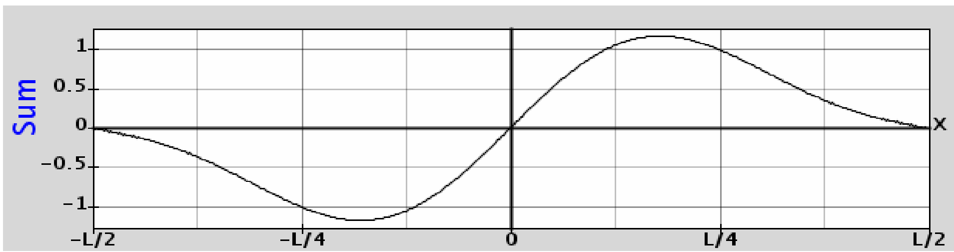
Learning Goals:
Students will be able to:

- Define harmonic, determine the relationship between the harmonics,
- Explain the relationship between harmonics and the corresponding wave function.
- Predict what happens when more than one wave is present.

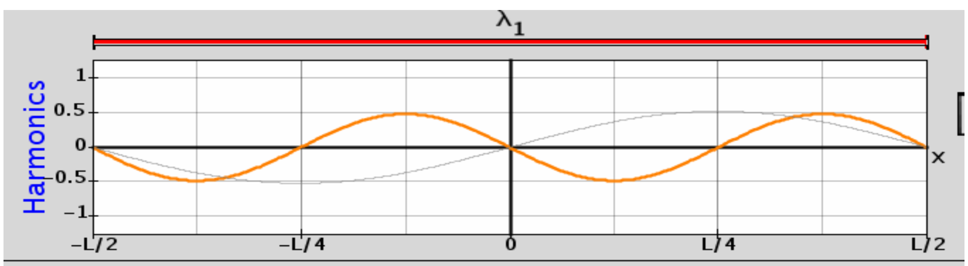
1. Investigate what harmonics are and describe in your own words what harmonic means to you. (You can use the *Wavelength* tool to determine a mathematical relationship between harmonics)

2. Investigate Functions using the *Select Function* tool and *Harmonics* slider. Describe the findings of your investigation.

3. Use the simulation to make a *Sum Graph* that looks like the graph below using only 2 harmonics. It's important to match both the x and y axes. Draw your *Harmonics Graph*, record the Amplitudes that you used, and describe what you thought about as you tried to match the graph.

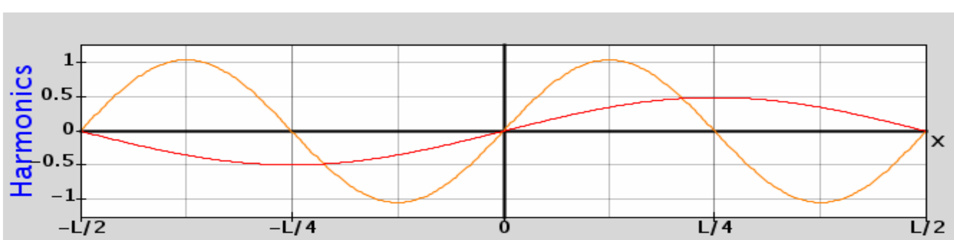


4. Use your thoughts from the previous questions to draw what you think the Sum Graph will look like for the harmonics displayed below.



Use the simulation to test your prediction and make corrections with a different color pen. Record the amplitudes that you used and write a plan for how you could predict the sum of waves.

5. Use your predictions ideas to draw the sum of these waves.



Test your ideas using the simulation. Make corrections on the predicted graph with a different color pen. Correct your plans for prediction also.

6. Design a test for your ideas on wave addition. Explain in detail your experiment and the results. Include evidence that your prediction method is repeatable.

Sound Lab using LabPro

Get a LabPro and microphone, and then connect to a computer. **Setup the Sensor** through the **Experiment** tab if necessary.

1. Say “AAAAAAAA” smoothly into the microphone and hit **Collect**. Once you get a graph that you think is quality, copy it to a Word document and label it #1. Answer the following questions in your document.

a) Would you say this is a periodic wave? Support your answer with characteristics.

b) How many waves are shown in this sample? Explain how you determined this number.

c) Relate how long the probe collected data to something in your everyday experience. For example: “Lunch passes by at a snails pace.” Or “Physics class flies by as fast as a jet by the window.”

d) What is the period of these waves? Explain how you determined the period.

e) What is the frequency of these waves? Explain how you determined the frequency.

f) Calculate the wavelength assuming the speed of sound to be 340 m/s. Relate the length of the sound wave to something in the class room.

g) What is the amplitude of these waves? Explain how you determined amplitude.

h) What would be different about the graph if the sample were 10 times as long? How would your answers for the questions a-g change? Explain your thinking. Change the sample rate and test your ideas. Copy the graph and label it #1h.

2. Now have someone else in your group say “AAAAAA” into the microphone. Copy the graph and label it #2. Compare and contrast the two people’s wave patterns. Be specific in your answer. For example: determine the characteristics that you did for the first person (# of waves, frequency, period, amplitude, and wavelength) and include any qualitative observations.

3. Collect data for a tuning fork by striking it on a soft object. Copy the graph and label it #3. Compare and contrast the waves made by human voice.

4. If you use the same tuning fork to collect data for a sound that is not as loud, what changes would you expect on the display from the sample in #3? Test your ideas. Copy the graph and label it #4. What did you do to make the sound softer? Compare and contrast the waves collected for the louder sound.

***Waves on a String, Wave Interference, and Sound*:**
Demonstrations for class discussion on reflection, wave interference and Doppler

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Learning Goals: Students will be able to
1. Predict the pattern of a reflected wave
2. Relate two dimensional representations of waves to three dimensional waves
3. Explain wave patterns from interfering waves *(Apply the superposition principle to water, sound and light)*
4. Recognize the Doppler effect and predict the change in frequency that occurs.

Background:

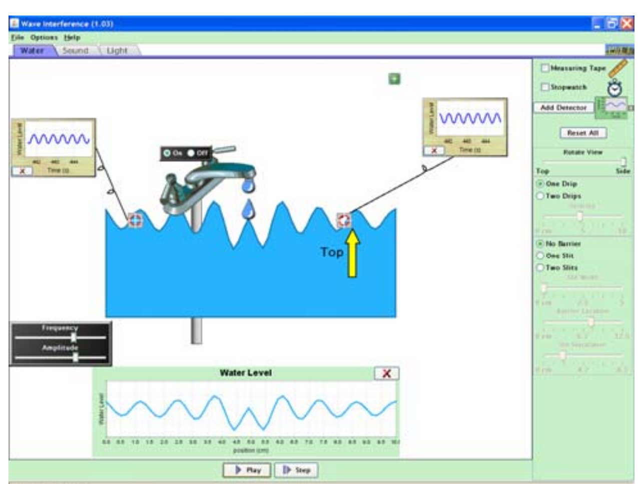
This lesson uses three simulations: ***Waves on a String, Wave Interference, and Sound***. The students will have done the activitites that I wrote: *Waves on a String Activity* (PhET), *Fourier-Making Waves* part 1 & 2 (PhET) and a Sound lab with Labpro as well as some homework on superposition and standing waves. I use Physics by Serway and Faughn 1999 Holt.

Lesson: Have all three sims open before the lesson starts and the Power Point presentation that goes with this lesson. I will also have a long piece of Tygon (rubber) tubing and a wave tank that fits on my overhead. We had discussions in several places that I did not specifically denote.

1. **Predict the pattern of a reflected wave**
   a. Use the slides 2-3 (clicker questions 1-2) and show how ***Waves on a String*** demonstrates the different ends.
   b. Then use slides 4 and 5 (clicker question 3) to have students relate string waves to sound waves. Use the pulse mode in ***Sound*** to show the answer to the slide.
   c. Move the barrier to different locations and angles to see how the 2D wave reflects.
   d. Talk about how wave front direction is represented by vectors. p483
   e. Use a water wave demonstration on the overhead to see this phenomenon with water as seen in 2D.

2. **Relate two dimensional representations of waves to three dimensional waves**
   a. Use Slide 6 for small group discussion
   b. Discuss the 3D nature of most waves. It would be good to have the Tygon tubing and show a standing wave by twirling the rope. Note that the text has no illustrations for 3D except p521 for EM waves and 525 to illustrate brightness inverse square law.
   c. Use a water wave demonstration on the overhead to see these phenomena with water.
   d. Use ***Wave Interference***:

Water tab with faucet moved to middle. Use Rotate view, Show Graph and add detectors. .Sound tab in the particle mode to show one wave to represent 3d.



***Waves on a String, Wave Interference, and Sound*:**
Demonstrations for class discussion on reflection, wave interference and Doppler

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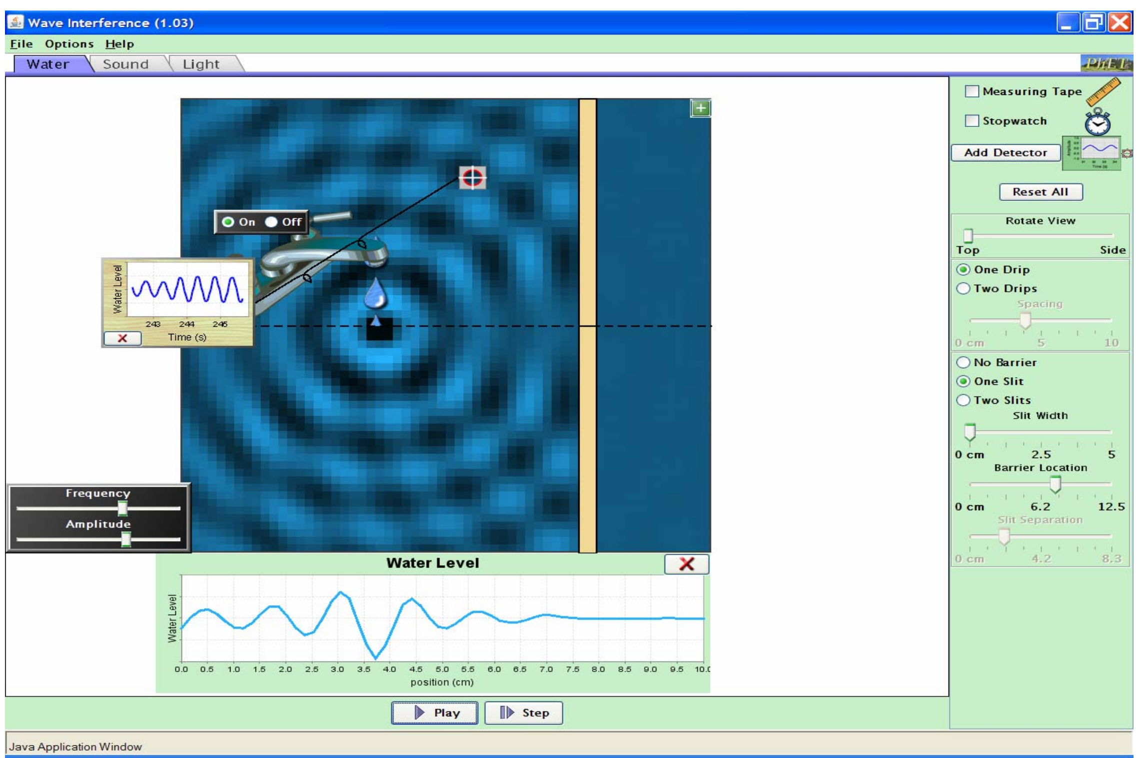
3. **Explain wave patterns from interfering waves *(Apply the superposition principle to water, sound and light)***
   a. Use slide 7 for small group discussion. Then open ***Waves on a String.*** To demonstrate interference with, I used the Pulse feature with Zero damping. First I set the wave characteristics, then pulsed and paused quickly. Then I reset the characteristics and sent another pulse. Quickly, I paused again and used the Step feature for slow motion. You can cycle through the waves interactions many times because the waves will reflect as if from a fixed end from the generator. (You can use slides 8 & 9 if you want the students to practice as a group. I didn't because my text has good sample problems and I have included practice on a worksheet)

   b. To show how interference works with 3D I used ***Wave Interference,*** Water tab. Show Graph and add a detector. Then add a barrier with zero slit width. You can tab between the barrier and no barrier easily and see how the water graphs change. You can Rotate views to see the other view, but I don't think it is as demonstrative.



   c. Switch to the Sound tab and Light tab to show similar patterns

***Waves on a String, Wave Interference, and Sound*:**
Demonstrations for class discussion on reflection, wave interference and Doppler

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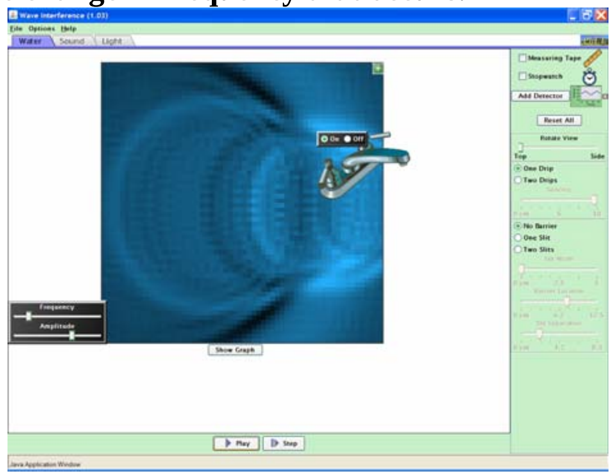
4. **Recognize the Doppler effect & predict the change in frequency that occurs.**



Use ***Wave Interference,*** Water tab. Low frequency, high amplitude and move the faucet slowly. It is difficult to pause to freeze the pattern.

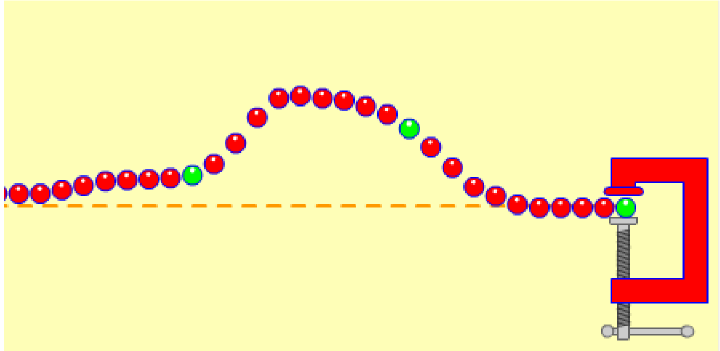
Use **Sound,** set the Listener sound on and have your speakers loud. Move the person around and you'll hear the Doppler Effect.

Also, there is an effective applet at

http://library.thinkquest.org/19537/java/Doppler.html
We discussed how the frequency would be different depending on whether the source was moving away or towards you. We talked about Doppler Radar is used to identify the direction and speed of a storm.

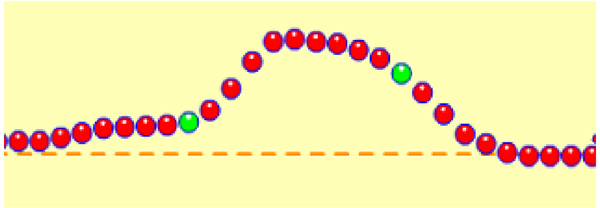
Wave Interference

1. What will this wave look like after it reflects?

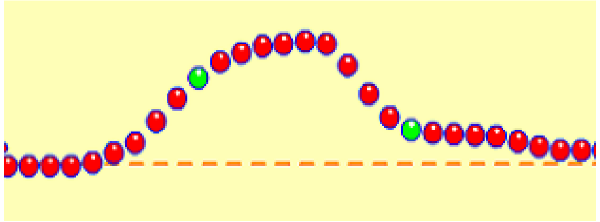


Fixed end

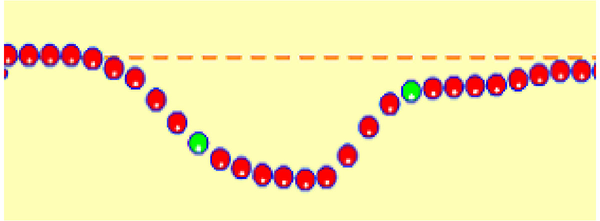
A.



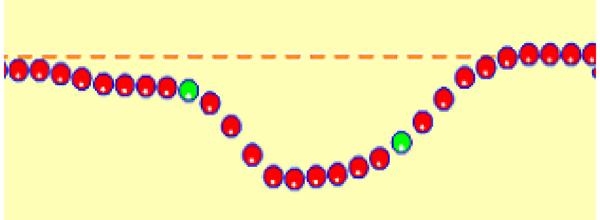
B.



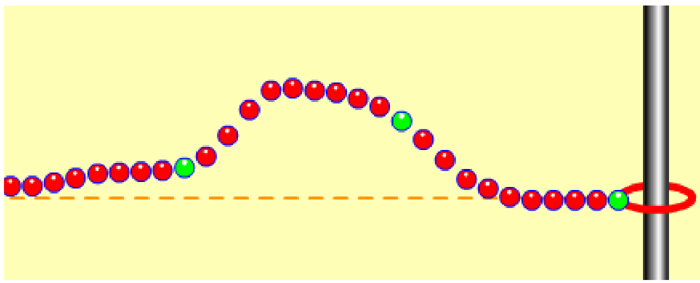
C.



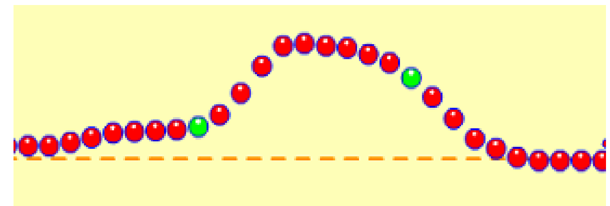
D.

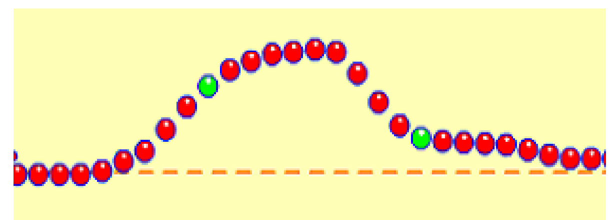


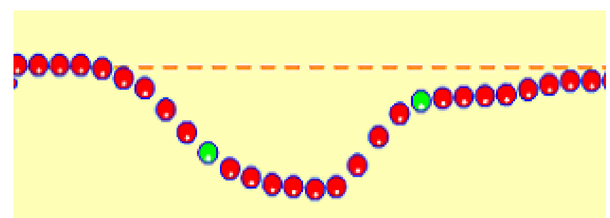
2. What will this wave look like after it reflects?

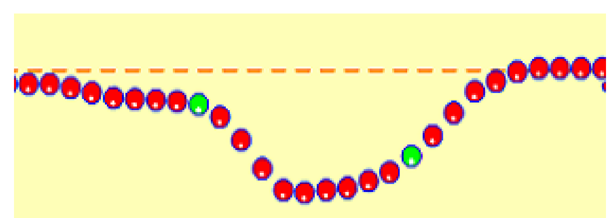


Loose end

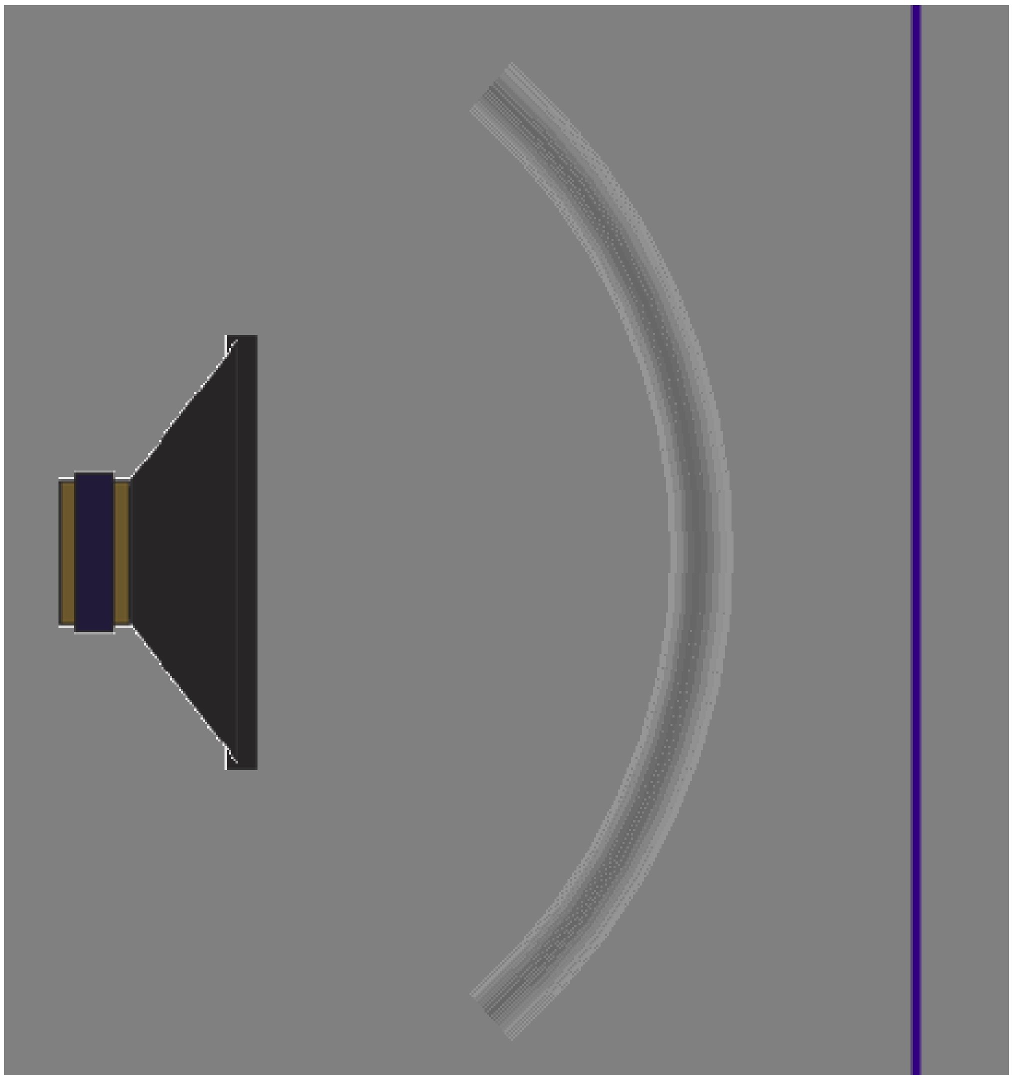
A. 

B. 

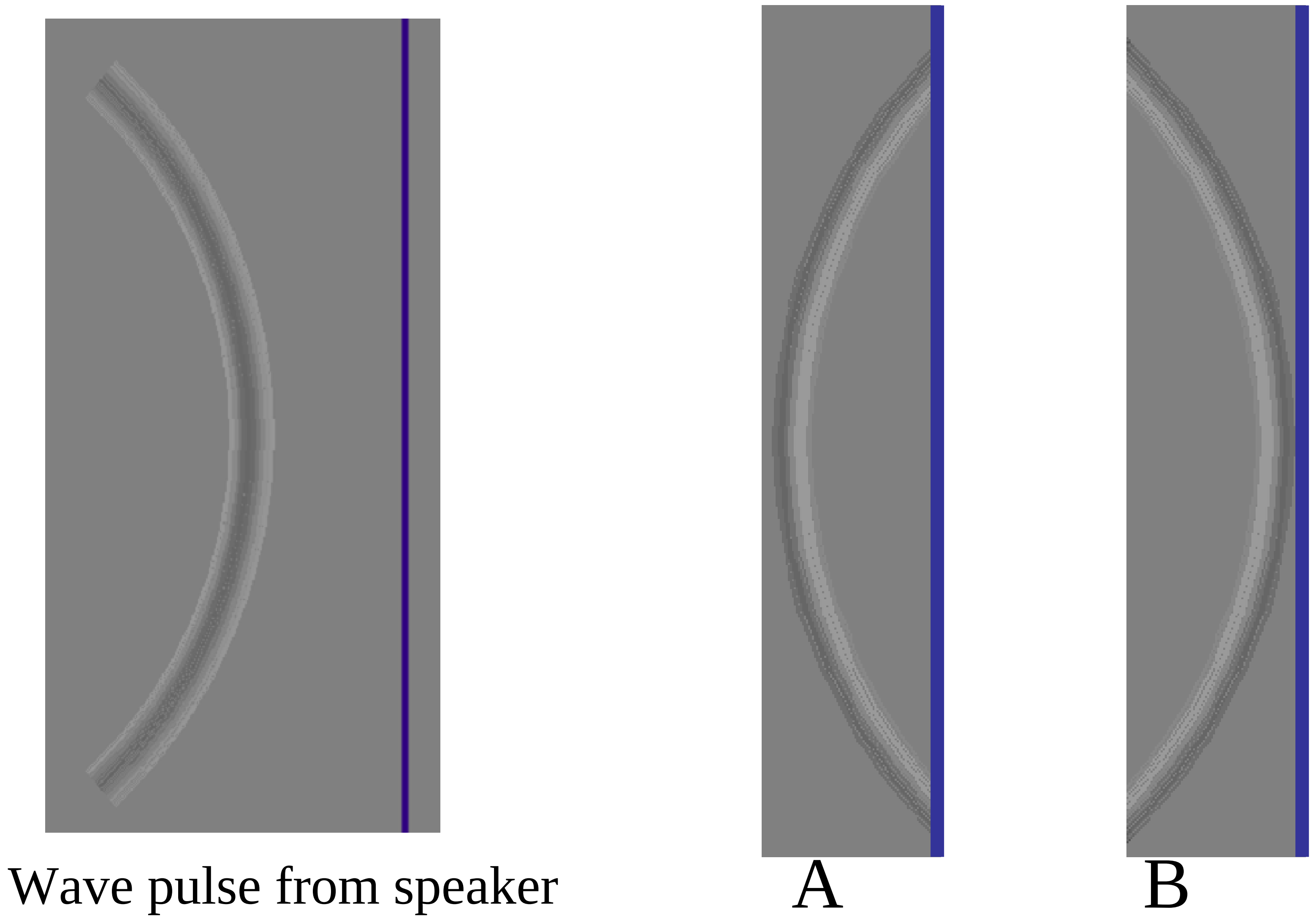
C. 

D. 

Draw what you think this wave will look like after reflecting off the barrier.



3. Which one is the reflection pattern?

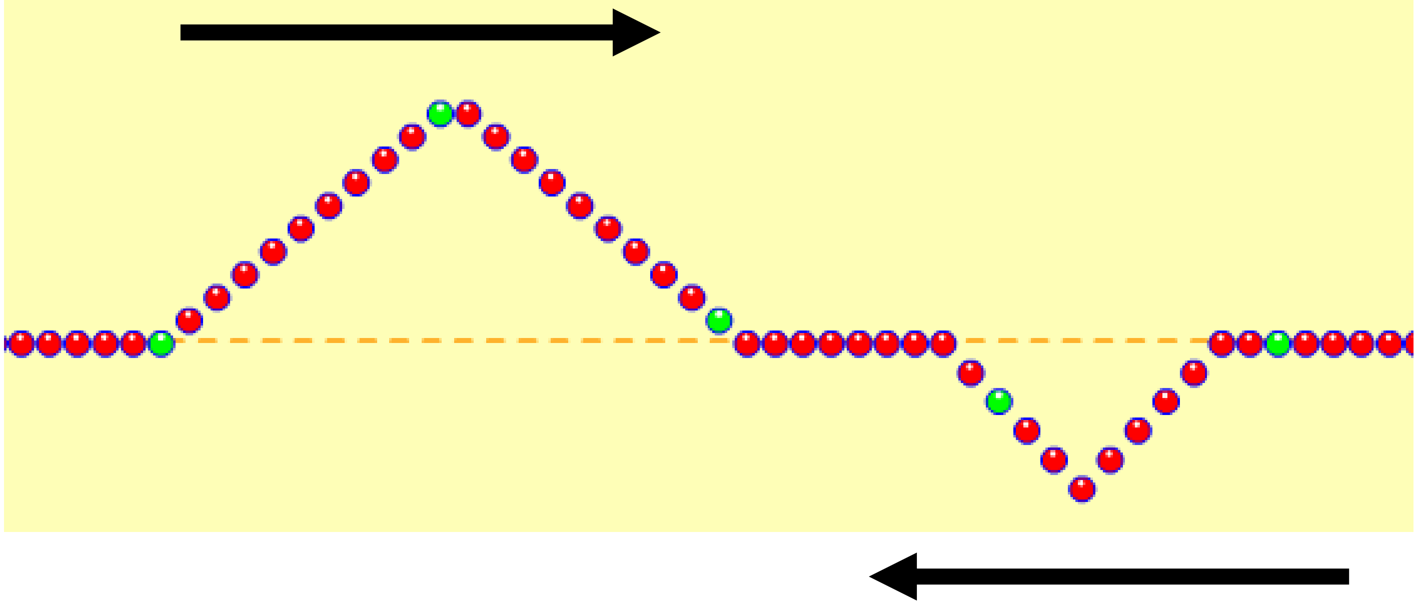


“Sound waves are three dimensional.”

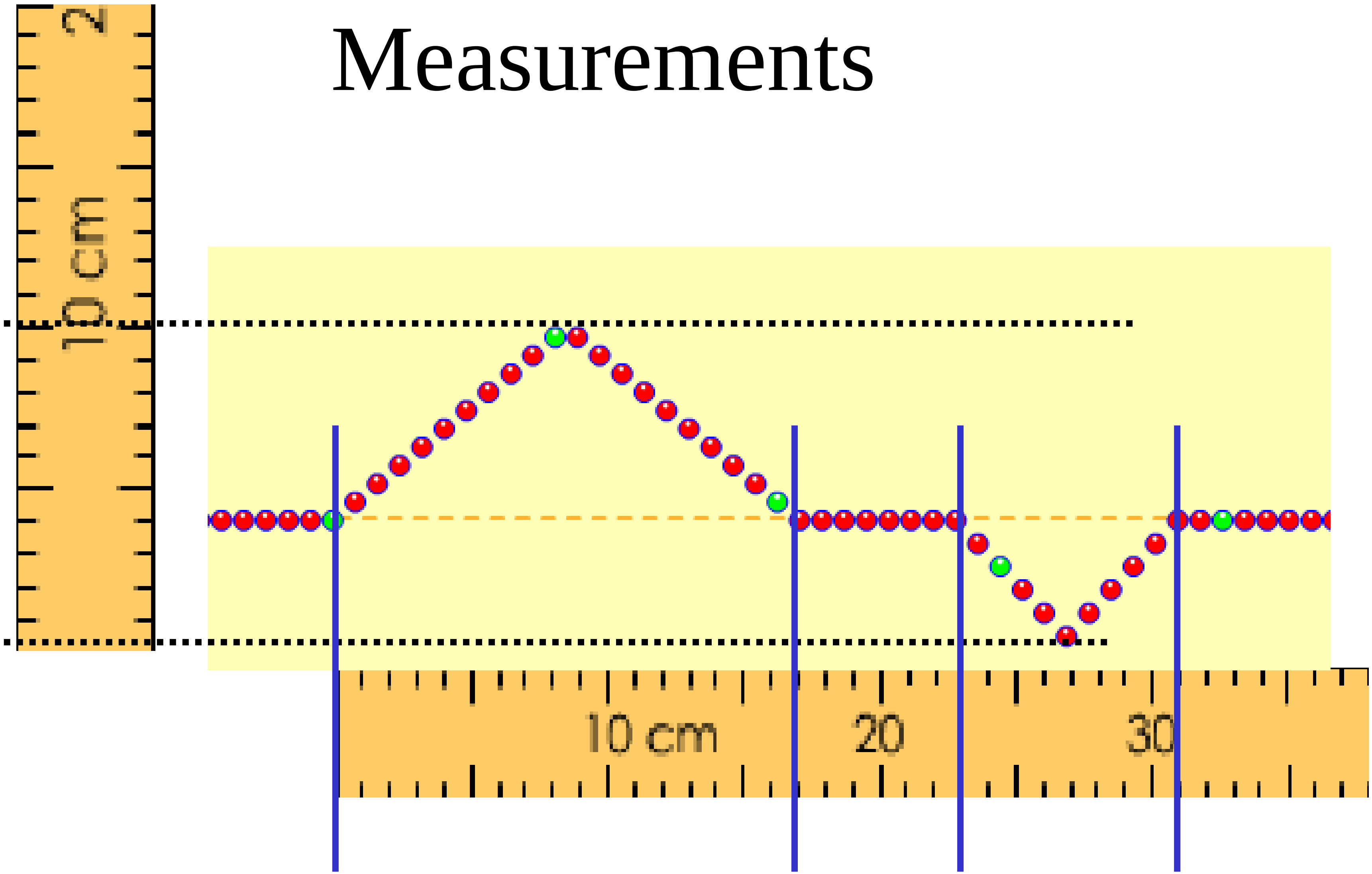
Talk to your partner:

- What evidence you have that supports this.
- How the wave could be represented
- How would reflection change?

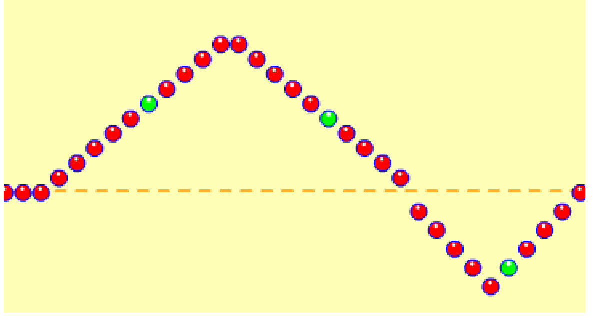
Sketch what you think the pattern will look like

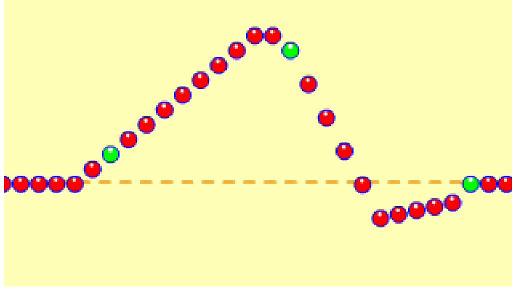


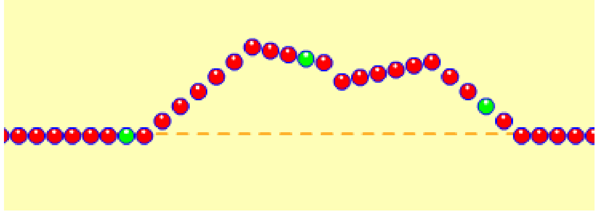
Measurements



Paused clips







Lesson plan for *Sound Waves* activity: **Sound Homework**
http://phet.colorado.edu/ Time for activity 30 minutes.
Learning Goals: Students will be able to

- **Explain how different sounds are modeled, described, and produced.**
- **Design ways to determine the speed, frequency, period and wavelength of a sound wave model.**

Background:
We will have been studying waves and have done the *Waves on a String* activity. I am going to do this after a lab that uses a microphone probe. I'll include the lab I do in the database. The Wave Interference simulation has been added since I wrote this lesson; it has many interesting features that would help tie sound to water and light waves.

Sound Waves Introduction:
I'll use a slinky and a rope to review longitudinal versus transverse waves. Then show how the sim is modeling the compression and rarefaction with dark and light colors. I'll use my overhead wave tank to demonstrate further that the simulation is only showing two dimensions like the wave tank shadow does. We'll have a class discussion to review how waves on a string are generated and how the energy moves through the string. Then we'll compare sound waves are generated and travel. We won't have covered an electricity or magnetism, so we can't really discuss how the speaker is made to vibrate yet.

Lesson: I assigned this to be done at home and several students could not get the sim to open at home. The most common problem was that their security software would not allow them to open the applet. A few had Mac's and this sim isn't designed for Mac OS. Several students came in during open lab time to do the activity or ask questions. I have added clicker questions to go with this simulation. Many are adaptations from CU 1240 class about Sound and Music for non-science majors.

Hints about the sim: The sim could be used to demonstrate a variety of things. I have listed them below sorted by tab. For this activity, I decided to focus on just a few things; see the goals. In our research, it seems that about 1/2 people think that black represents emptiness and light more intensity, and the other 1/2 the inverse. Our group decided that any lesson should require that the students determine what is being represented and then chose black for low density. If you investigate using the first tab, you'll see that when the speaker is going out, the sound wave looks light. I found this a little tricky to observe, but using low frequency helps. So when you go to the last tab and evacuate the chamber, it will make sense that the color goes black like space.

Listen to a Single source:

- Waves modeling: How frequency and amplitude effects the wave model qualitatively
- Wave generation: How the vibration of the speaker changes to make the amplitude and frequency vary. The higher the amplitude, the greater the distance that the speaker vibrates. The frequency changes are apparent by the rate at which the speaker moves.
- Frequency and amplitude relationship to what a listen perceives (pitch and volume). *The students without music background had a difficult time hearing the change in volume; many thought that the pitch was different.*
- Doppler effect (The quality of the computer effects whether or not this can really be used. In my classroom, the computers are not good enough)

Measure

- Waves modeling: How frequency effects the wave model quantitatively (f=#waves/sec)
- Calculate period (T=time/#waves) Or Frequency (# waves/time) Tip: hit reset, start then stop, count the waves. Relate frequency to period mathematically by using T=1/f
- Speed of sound = wavelength * frequency (I got about 340m/s easily. Smaller frequencies gave the best results because the wave front was more clear. Put the ruler on the speaker center, hit reset, start then stop, measure how far a wave front has gone/ time elapsed. The ruler will not be movable when pause is on.)

Lesson plan for *Sound Waves* activity: **Sound Homework**
http://phet.colorado.edu/ Time for activity 30 minutes.
Two Source Interference

- Waves modeling: Two wave interference.

Interference by a barrier

- Waves modeling: Reflection is best seen using the pulse feature. I think the interference is best seen in continuous mode.

Listening with Varying Air pressure

- Waves modeling: Shows how a mechanical wave is affected by the medium.

Student directions *Sound Waves* activity: **Sound homework**
http://phet.colorado.edu 30 minutes

Learning Goals: Students will be able to

- **Explain how different sounds are modeled, described, and produced.**
- **Design ways to determine the speed, frequency, period and wavelength of a sound wave model.**

1. Use the **Listen to a Single Source** tab in *Sound Waves* to start your investigation of sound. Turn on the **Audio Enabled** so you can hear the sound.
    - When you change the frequency, how does the sound change? How does the visual model change?
    - How does changing the amplitude affect the sound and its model?

2. Sound is produced when something vibrates; this movement causes disturbances in the surrounding air pressure. Investigate how the speaker cone moves to produce different sounds. Then, explain the relationships between the movement of the speaker cone and the sound that is made; include drawings to support your explanation.

3. Use the tools on the **Measure** tab to find the speed of sound in air.
    - Make a data table that demonstrates you have a good experiment and show sample calculations.
    - How do your results compare to information that is published? (Include a citation)

4. How could you find the wave length of a sound? Test your idea with several different sounds. Check to see if the results for wavelength make sense. (Include a citation)

5. Describe how you might use the simulation tools to find the period of a wave without using the frequency information.
    - Test your idea with a variety of waves. Check your method by calculating the period using the frequency. Show data and calculations for several trials. Make corrections to the original plan as necessary.

6. Describe how you would find the frequency of a wave if the frequency slider did not have a number display.
    - Test your idea with a variety of waves. Show data and calculations for several trials. Make corrections to the original plan as necessary.

Reflection Lab

Use your own paper to record and sketch what you observe.

1. Flat Surfaces

A.) <u>Single ray.</u> Stand a flat mirror on a piece of paper. Aim a ray at the mirror at an angle. Draw the front of the mirror, the incoming ray and the outgoing ray. Remove the mirror, and then use a protractor to mark a perpendicular to the mirror at the place where the incoming ray hits the mirror (point of interaction). This perpendicular line is called the Normal.

Angles are measured to the normal, not to the surface. Measure and record the incoming angle; it is the angle of incidence. Measure and record the outgoing angle; it is called the angle of reflection.

Repeat this experiment at several different incident angles. Record at least 2 sets of data. How do the incident and reflected angles compare?

B. <u>Multiple rays.</u> Aim several parallel rays (You will have to figure out what to adjust on the ray box) at an angle at a flat mirror and record observations. Then, make the rays divergent and record how they are reflected. Try converging rays too.

C. <u>Inversion.</u> Look at the phrase **CARBON-DI-OXIDE** in the mirror, record what it looks like. Does a mirror cause vertical and/or horizontal inversion?

2. Curved Surfaces

A. <u>Concave mirrors.</u> Aim parallel rays, the converging and then diverging rays at a variety of angles at a concave mirror and record results. Write any conclusions you can draw.

B. <u>Convex mirrors.</u> Aim parallel rays, the converging and then diverging rays at a variety of angles at a concave mirror and record results. Write any conclusions you can draw.

2/22/08

Lens Properties

Part 1: Investigation on light paths

Use a light box and the plastic lens pieces (double convex, double concave, and semicircle) in the wood boxes to determine the effects that lenses have on light paths. Shine the light in the large slices, small slices, and use rays. Make sure to try different incident angles. Sketch many observations, and write a summary of the results. This should take 20 minutes.

Part 2: Lens images with a double convex lens

A. Determine the focal point of a double convex lens using a distant object. If you stand on one side of the room in the dark and put your back to the window or the door opening, an image ca be projected onto an index card. Measure the distance from the lens to the card when the image is clear. This is the focal length.

B. Find the relationships between the object distance and the image distance, the image magnification and the image inversion. There are three relationships to be determined; the object distance is the independent variable. The object will be a lit light bulb; the object distance is measured form the light bulb to the lens. Image distance is the distance from the lens to the clear projection. The magnification is the ratio of the size of the projected image to the object size. The inversion is simply upright or inverted depending on how the image looks compared to the object.

   Choose object placements in a variety of positions (at least seven) that range from larger than twice the focal length to less than the focal length; make sure to use twice the focal length for one point.

   Make a data table, excel graphs and a brief paragraph for summarizing

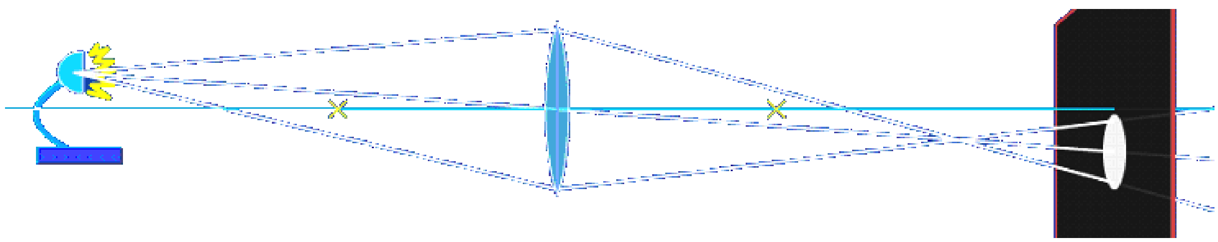
Lesson plan for *Geometric Optics:* Images from Lenses
http://phet.colorado.edu/ Time for activity 50 minutes

Learning Goals: Students will be able to explain *(my notes in italics)*

- How a converging lens makes images. (*real and virtual using ray diagrams)*
- How changing the lens *(radius, index and diameter)* effects where the image appears and how it looks *(magnification and inversion, Brightness and clarity may be easily addressed by demonstration, but I did not include any student directions). What features a lens would need for real applications?*

Things that are well demonstrated by the sim are:

- Effects of curvature and index: the change in focal length, the image position and size
- Diameter effects brightness of image.
- Ray bending.
- Inversion well.
- With the *Rays* off, and the *Screen* on, you can show how the image is visible but not clear except at one point. The screen feature may give students some things that are difficult to understand like this:



- Show guides doesn't seem to have a use for my class

Background: I'll show a real image formed by a convex lens by projecting something outside through the window onto a note card and also use a light bulb to project an image. The class will do a converging lens lab. I'll attach my lab to this activity. They will then use this activity to help explain the results of the lab.

Lesson: The students will need their lens lab results. The activity calls for having magnifying lenses available.

Geometric Optics Introduction: I'll project the sim with ***Screen*** on and **NO Rays**. I'll show how the image is visible but not clear except at one point where the light is small and bright. I will also turn the ***Screen* off** and talk about light is also coming off objects that don't have their own light source. I'll demonstrate again how a magnifying lens makes an image and point out that the light form outside is visible on the card often, but that there is only one position that gives a clear image.

After the activity, good discussion questions would be: Why can't you make projections with a flat piece of glass? I want to project a picture of a small demonstration on the wall for you to see. If I use a magnifying lens, how do I decide where to hold the lens?

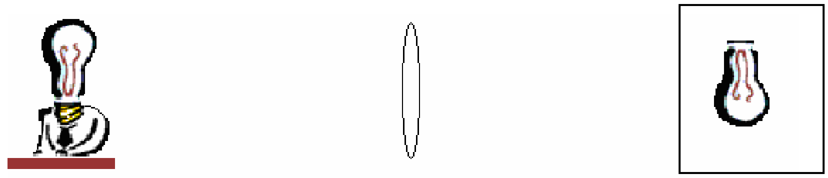
Student directions *Geometric Optics* activity: Images from Lenses

Learning Goals: Students will be able to explain

- How a converging lens makes images.
- How changing the lens effects where the image appears and how it looks.

1. When you did the Lens Lab, you were able to see an image of a light bulb on your note card as in Figure 1.

Figure 1



How do you think the lens changes the light from the bulb to make an image? Why do you think the image was upside down?

- Discuss your ideas with your partner and then make drawings of your ideas.
- Use *Geometric Optics* to test your ideas. Talk about changes in your thinking.

3. Write an <u>illustrated</u> summary for this learning goal: *"Explain how a real image is formed by a converging lens using ray diagrams."* Make sure to include why the image is upside down and varies in size and location.

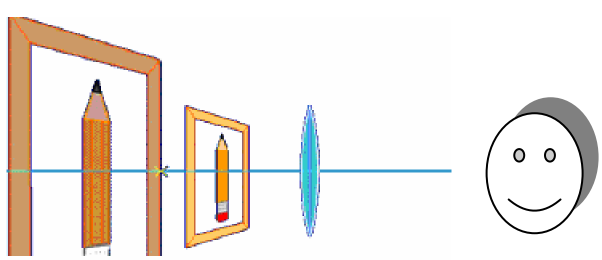
4. If you wanted to make your own lenses for a telescope, what features of a lens do *you think* would affect the images that you can see?

- Use the simulation to test your ideas. Make a table to summarize how each variable affects how an image looks.
- Describe the characteristics that would be best a telescope lens. Explain why your choices would work well.
- What would you choose if you were going to make a microscope? Why?

5. Use your magnifying lens to look at this paper.

- Investigate how to make words appear as large as possible.
- Discuss with your partner how you think the image is formed.

6. Use *Geometric Optics* with ***Virtual Image*** turned on***;*** keep the object on the left side. Imagine that you are on the right looking into the lens like the picture below.



- Type a letter, on a separate sheet, to your parents explaining how a magnifying lens works include how size and location of what you see changes. Illustrate your letter showing how the light rays change to make you see an image

Lesson plan for *Fourier Making Waves*: Game tab

Time for activity

Learning Goals: Students will apply their understanding about wave characteristics and superposition to match wave functions *(and compete for "best score").*

From Fourier Activity 2: Students will be able to:

- Define harmonic, determine the relationship between the harmonics,
- Explain the relationship between harmonics and the corresponding wave function.
- Predict what happens when more than one wave is present.

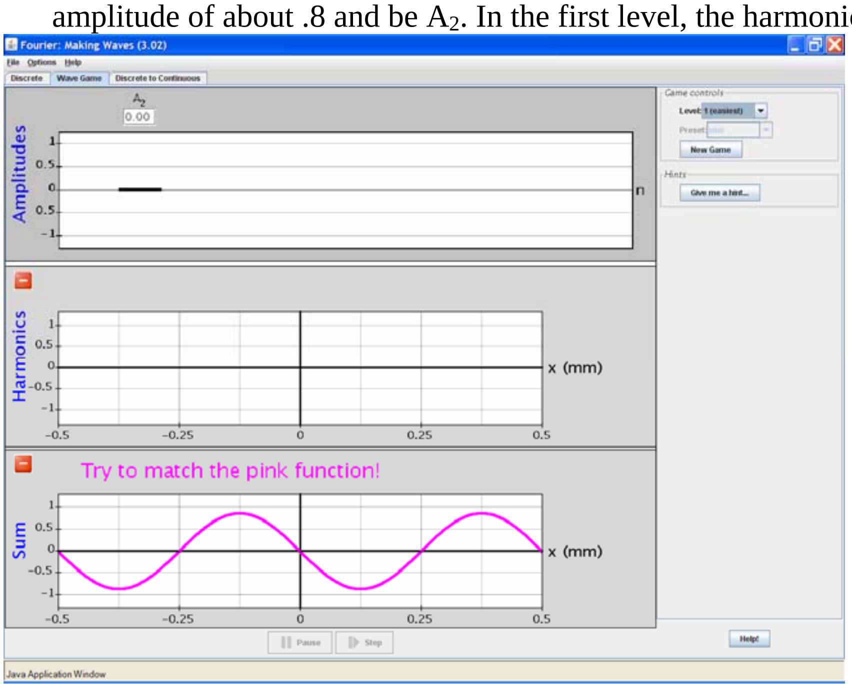
Background: This will be the students' last activity of the wave unit. They will have used this sim for 2 activities 2 weeks before, but this is note required for the game.

***Fourier Making Waves* teaching tips:** The first level is just adjusting amplitude. Level 2 is picking one of two harmonics and adjusting amplitude. Level 3 is picking one of 11 harmonics and adjusting amplitude. Then the wave addition starts.

***Fourier Making Waves* Introduction:** (It is easy to delete a harmonic by typing 0 in to the Amplitude box)

Project ***Fourier Making Waves***. Stay on the **Discrete** tab and minimize the **Sum** window

- Ask "How does changing the amplitude effect the wave?" then demonstrate.
- Ask "How is A_1 different from A_2?" then demonstrate.
- Ask " How many peaks should you see if you give A_8 some amplitude?, then demonstrate.
- Go to the Game tab level 1 and discuss how the knowledge about waves can be used to guess the answer. For example, look at the function to match the number of peaks and amplitude. For example, the curve to match in case below should be negative with amplitude of about .8 and be A_2. In the first level, the harmonic will be provided.



Lesson plan for *Fourier Making Waves*: Game tab

Time for activity

Lesson: Mention that the scores for the first three levels are negative. Here's an example of a possible spreadsheet to keep track of scores.

Level	Joey		Michelle	
	seconds	score	seconds	score
1	na		na	
1	na		na	
1	na		na	
1	na		na	
2	na		na	
2	na		na	
2	na		na	
2	na		na	
3	na		na	
3	na		na	
3	na		na	
3	na		na	
		=B15/A15		

Student directions ***Fourier Making Waves*****: Game tab** activity

Learning Goals: Students will apply their understanding about wave characteristics and superposition to match wave functions.

Do not write on these directions. Use your own paper!! **Lowest score wins!**

1. Use the Level 1 for the beginning of the competition. Take turns:
   Press ***New Game***, think about what should work, and then type in your guess in the Amplitude box.

   Keep score: **-5** points for correct on first try, **-3** for second and **-1** for third.

Name	Game 1	Game 2	Game 3	Game 4	total

2. In Level 2, you have to choose one of two harmonics. Take turns:
   Press ***New Game***, decide which harmonic to use, think about what should work, and then type in their guess in the Amplitude box.

   Keep score: **-7** points for correct on first try, **-4** for second and **-1** for third.

Name	Game 1	Game 2	Game 3	Game 4	total

3. In Level 3, you have to choose one of eleven harmonics. Take turns:
   Press ***New Game***, decide which harmonic to use, think about what should work, and then type in their guess in the Amplitude box.

   Keep score: **-10** points for correct on first try, **-5** for second and **-1** for third.

Name	Game 1	Game 2	Game 3	Game 4	total

4. In the other Levels, you have to choose more than one wave to add to make the SUM. Take turns:
   Start the stopwatch as the player presses the ***New Game*** button. The seconds that it takes to match divided by the level number is the score. Design a spreadsheet to keep track of your scores.

Lesson plan for *Resonance*: High School Version

http://phet.colorado.edu

Learning Goals: Students will be able to:

- Describe what resonance means for a simple system of a mass on a spring.
- Identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.
- Give examples of real-world systems to which the understanding of resonance should be applied and explain why.

Learning Goals: (from the design document)

- What is resonance?
- What affects the resonance frequency of a system? (mass and spring constant for this system, in general "material" and mass.)
- How does the frequency of a driver interact with the natural resonance of a system?
- What is damping? What effect does damping have?
- What effect does gravity have?

Background: Demonstrations might help the student's interest in the spring/mass systems. These systems are used are to be simplified examples to help them understand complex systems. Some simple demos could be

- Rubbing a wet finger around a glass; if you put different heights of liquid in the glass students should be able to hear different tones.
- Plucking a string and varying the length of it. I use a rubber band on a tissue box, but if you have a real string instrument, the real-world context would be more obvious.
- Blowing over a container with a small opening like a soda bottle with varying amount is liquid is nice.
- You can make several "flutes" by cutting straws to different lengths. The mouth piece end should be cut to have a tip 
- Striking pieces of metal of different materials and size.

Resonance **Introduction:**

This sim was designed for college level students so it might be helpful to read the Tips for Teachers for this sim. Three things that might be especially helpful are:

1. Tell students to use the frequency dial slowly
2. Explain that since this sim shows real-life behavior, they may have to make observations over a period of time before they change variables. ie. Changes are transient, so if they expect to see instantaneous results, they will miss key ideas.
3. It may be helpful to have used Waves on a String and Masses and Springs prior to this sim or tell students who feel like they need help to check these more simple sims to help them.

Lesson: Students could do this in pairs or as homework.

Post-Lesson: Clicker questions

Student directions *Resonance* activity
High School Version

Learning Goals: Students will be able to:

1. Describe what resonance means for a simple system of a mass on a spring.
2. Identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.
3. Give examples of real-world systems to which the understanding of resonance should be applied and explain why.

Directions:

1. Find a definition of resonance and cite it.

2. Use the simulation to test ideas you might have about what resonance for a mass on a spring means, the write a description for resonance that is specific including what are the necessary components.

3. Design experiments using the tools provided in the sim to identify what affects the natural resonance for mass-spring systems. Organize your experiments and findings in data tables.

4. Pretend you are helping a student who doesn't have access to this simulation. Write what you would tell them what you learned in your use of the sim including illustrations that could be helpful.

5. Give examples of at least one real-world system to which the understanding of resonance could be applied and explain why understanding resonance would help you (or someone else) use the system more effectively.

Light Reflection and Refraction Pre-Lab using PhET

I) Introduction:

When a light ray strikes a smooth interface separating two transparent materials (like air, glass, or water), the wave is partly reflected and partly refracted (or transmitted) into the second material. For an example of this, imagine you are outside looking at a restaurant window. You can probably see both the inside of the restaurant (from the refracted light) and some of the street behind you (from the reflected light). Similarly, a person in the restaurant can see some of the street scene, as well as a reflection of the other people in the restaurant.

The goal of this pre-lab is to understand *how* light is reflected and refracted, and what the general relationships are between the two. You will be using ***Bending Light*** simulation found at http://phet.colorado.edu/en/simulation/bending-light

II) Initial Observations:

First, let's get acquainted with the PhET sim that we will be using. The red button on the laser turns the light on.

What do you notice about the angles of the reflected and refracted light? Briefly, give a qualitative description of the following features:

> What happens to the reflected and refracted rays as you change the angle of the incident light beam?
>
> What does changing the index of refraction do to the refracted and reflected light?

III) Quantitative Analysis:

Now let's try to find a mathematical expression for what we are seeing. First, notice that there is a protractor and intensity meter that can be found in the lower right of the sim.

For convenience (and by convention), try measuring angles as starting from the vertical axis and going down to the laser beam. (The same goes for the refracted beam – but now you will want to measure from the z-axis *up* to the beam.)

1) Find a relationship relating the angle of the incident light and reflected light. (Remember to use the convention of angles just described!)

2) Find a relationship relating the angle of the incident beam to the angle of the refracted beam:

This one isn't quite as easy to see right away, and you might have to find a way to take data to figure out the relationship. Here is a hint to get you started: the general relationship for this situation is given by:

$$\frac{sin\alpha}{sin\beta} = \frac{n}{m}$$

Here α and β are angles corresponding to either the medium on top or bottom, and n and m are the indices of reflection of either the top or bottom material.

Your job is to come up with a way of figuring out which variable corresponds to which material. The recorder's job will be especially important here. Rather than just writing down your results, you MUST **write down a description (2-3 paragraphs) of the process you went through in trying to figure this out**. In addition, **write down any data you collect**, and **give a description of why it is consistent with your conclusion.**

IV) Trying another approach:

You should have just come up with one method for finding out which media the variables above correspond to. Now come up with a different approach. (There are at least two approaches to solving this problem, and your job is to figure out what the other is.)

You don't actually have to collect all of the data again, but do give a description (2-3 paragraphs) of what how you would go about figuring this out.

V) Prism Break (EXTRA CREDIT)

Now switch to the tab on the top of the PhET sim titled "Prism Break." For this:

Try playing around with the various sorts of prisms and answer the following (a couple of sentences per answer is sufficient):

1) Are the reflection and refraction of light color-dependent? How can you tell?

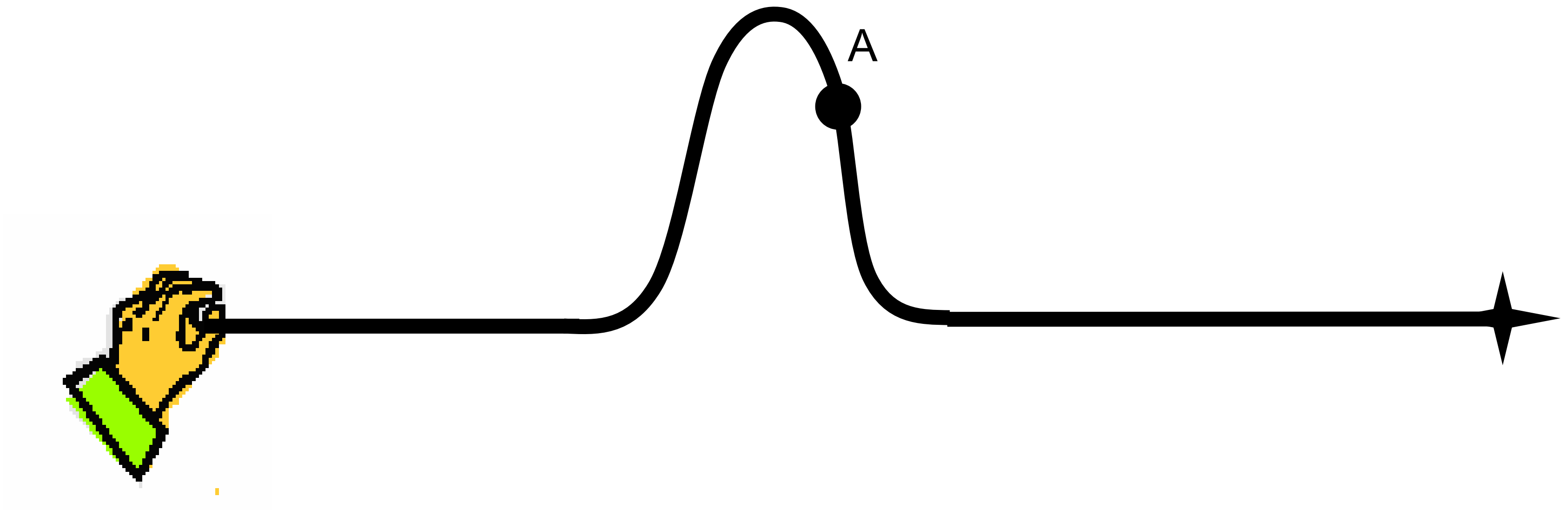
2) Which shapes split the white light into different colors the best? Is there a particular set-up that you found demonstrates this well?

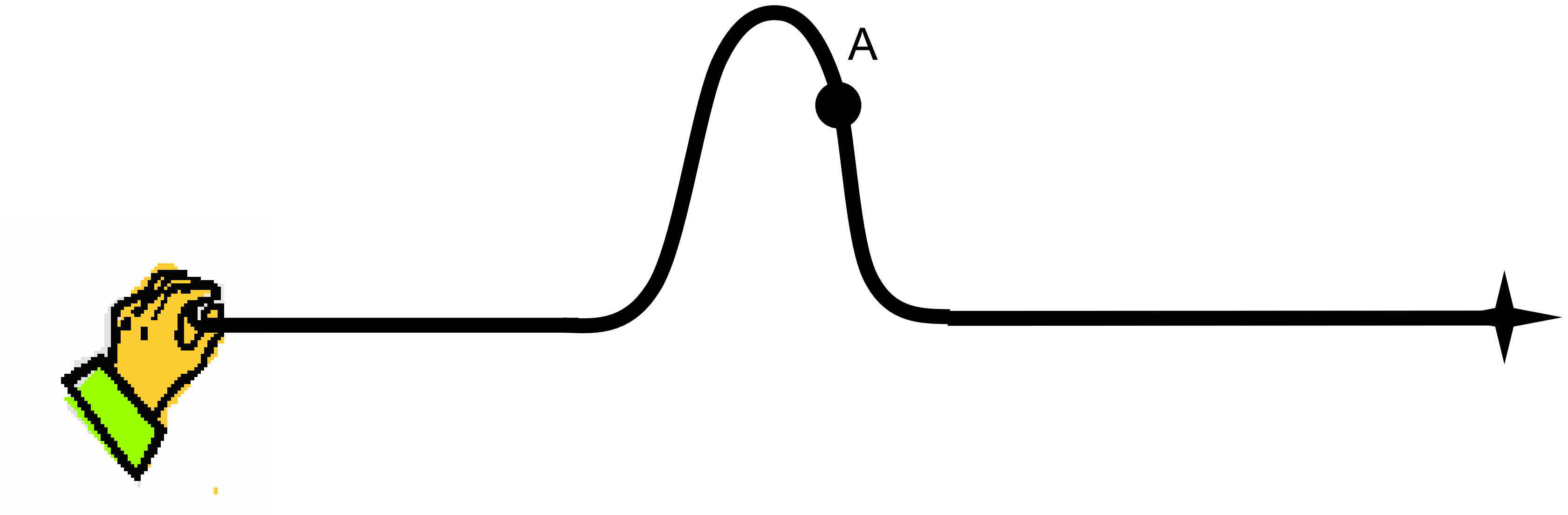
3) Given that white light can be split, try to make a situation where light forms a rainbow. What shape did you use to do this? Can you make a double rainbow in any way?

Clicker Questions for Wave unit

I gave these clicker questions after the activity was completed except for the Wave interference demonstration day.

Waves on a String


A



1. If you advance the movie one frame, the knot at point A would be

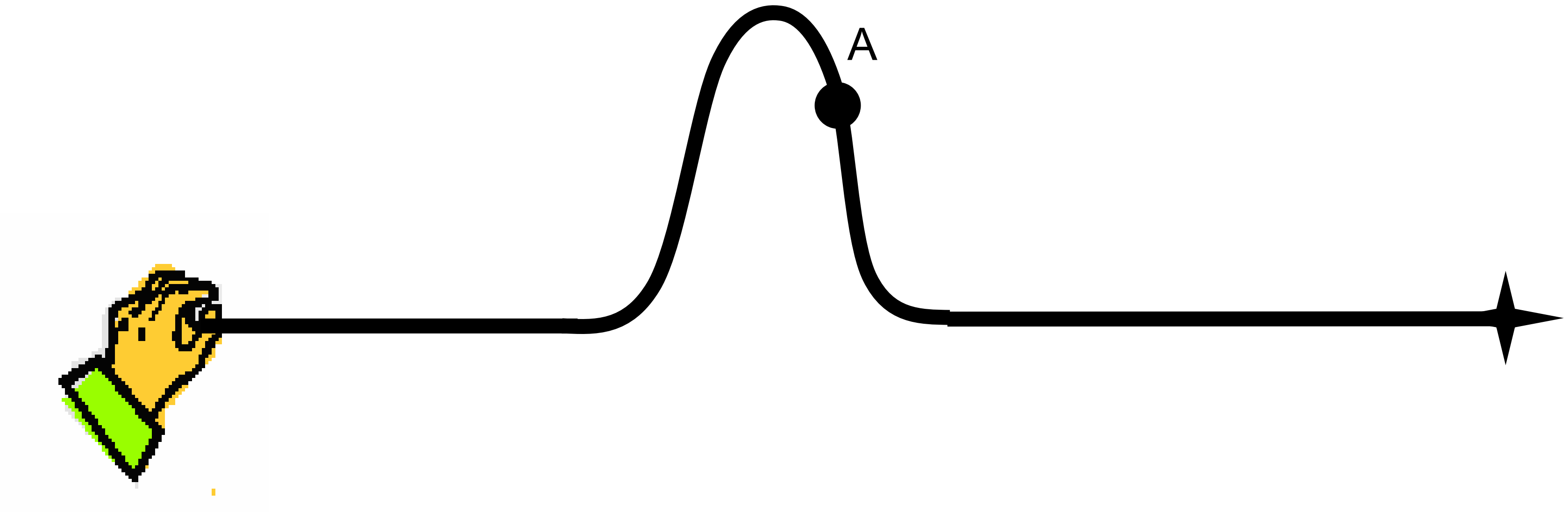
A. in the same place

B. higher

C. lower

D. to the right

E. to the left

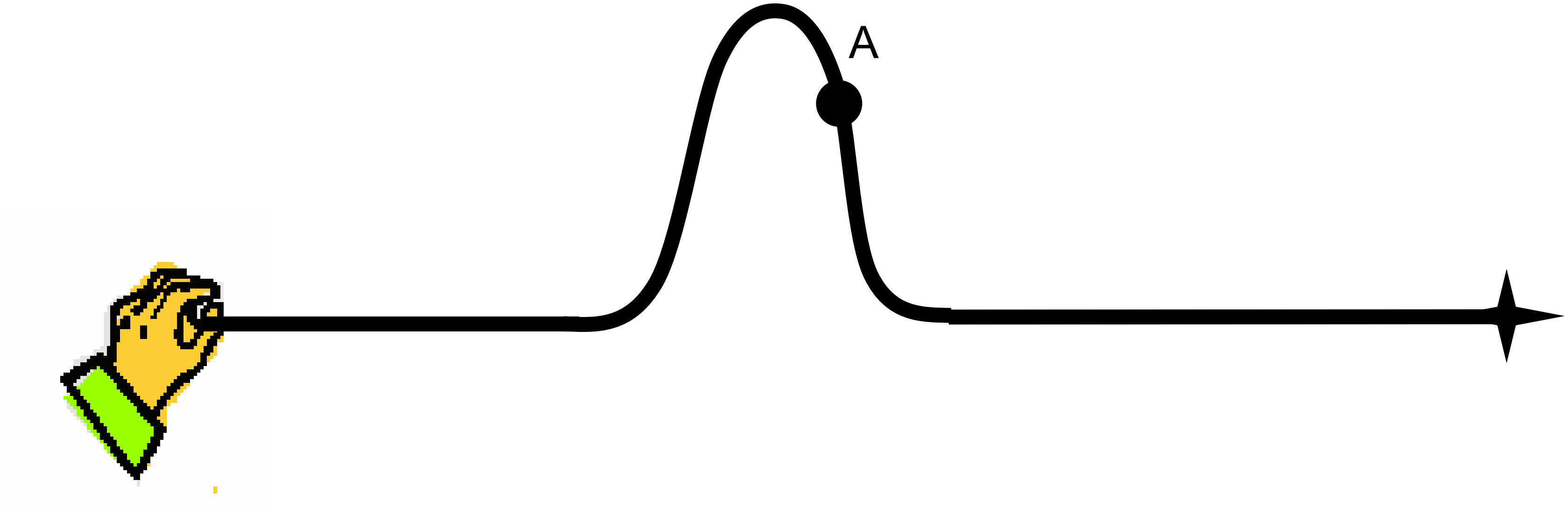


2. If the person generates a new pulse like the first but more quickly, the pulse would be

A. same size

B. wider

C. narrower

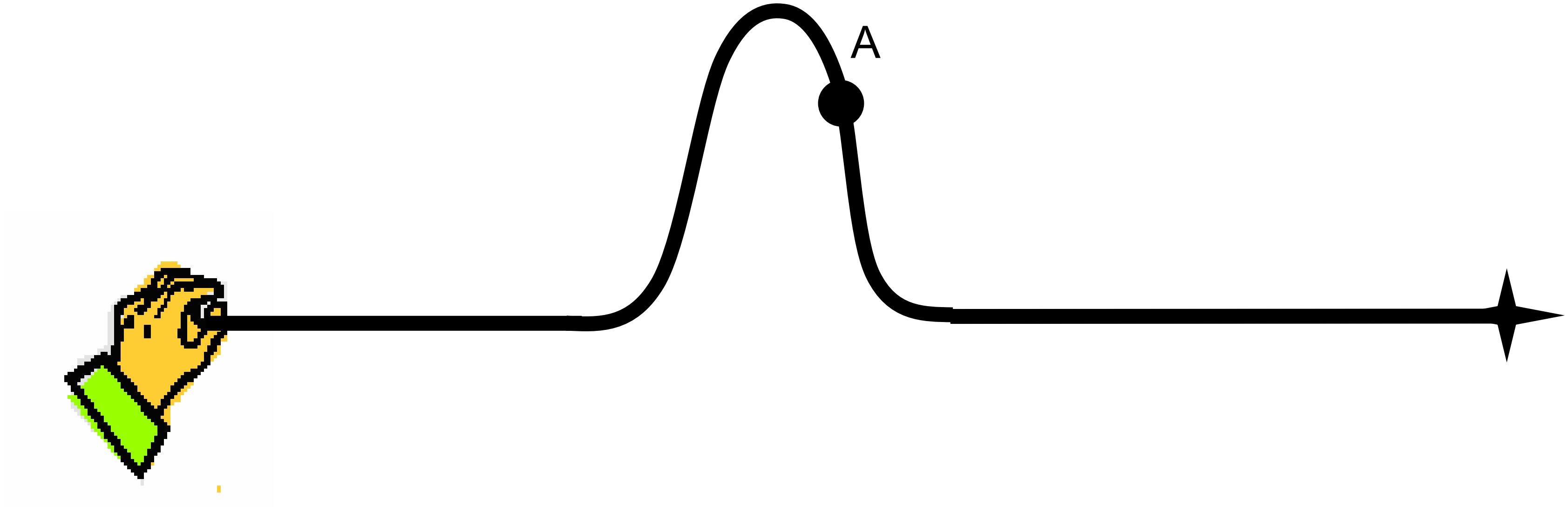


3. If the person generates another pulse like the first but he moves his hand further, the pulse would be

A. same size

B. taller

C. shorter

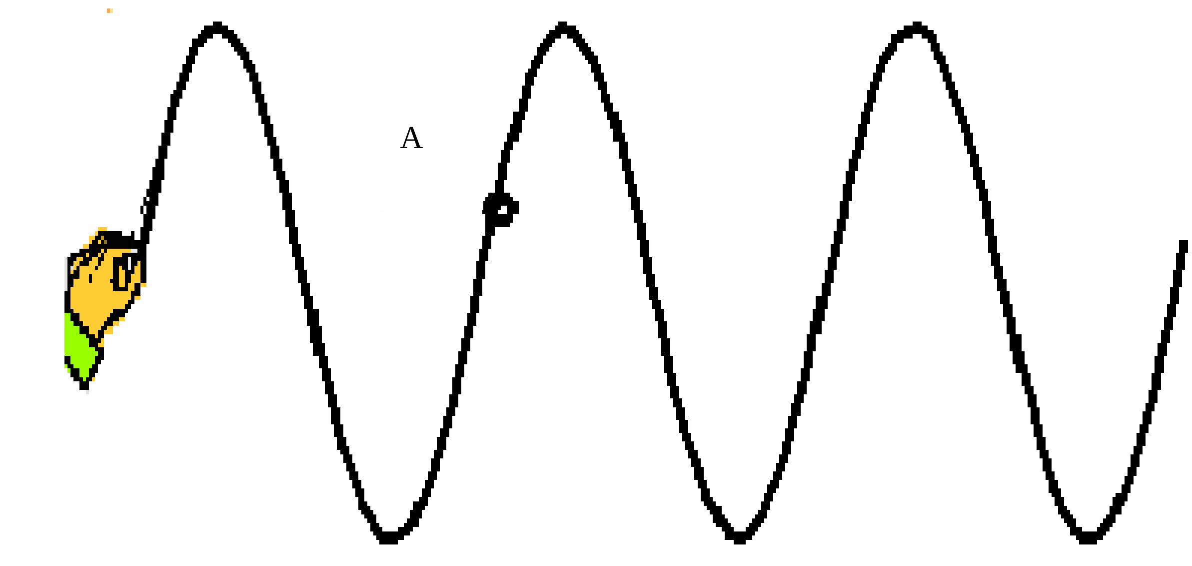


4. If the person generates another pulse like the first but the rope is tightened, the pulse will move

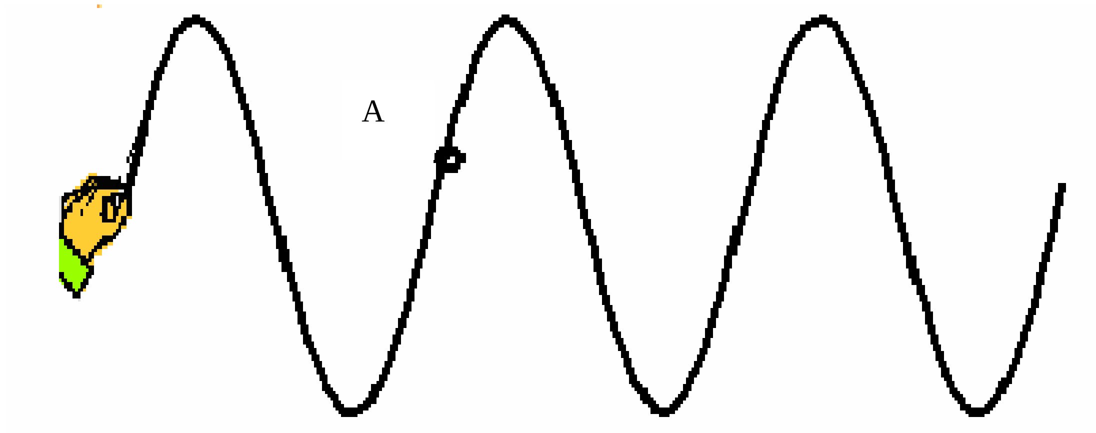
A. at the same rate

B. faster

C. slower

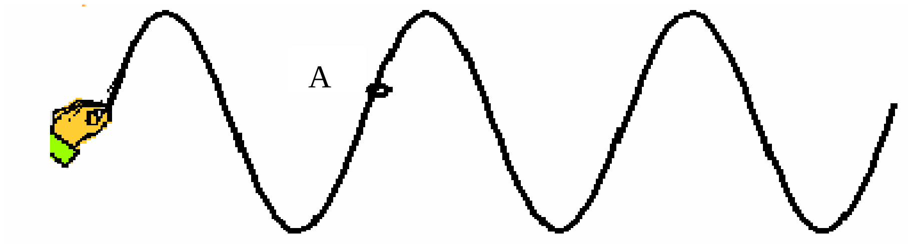


Intro slide for following questions



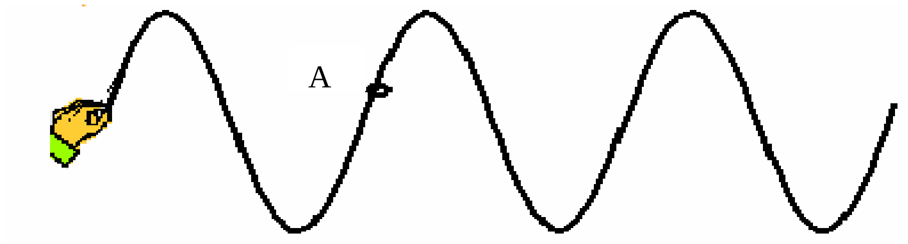
5. If you advance the movie one frame, the knot at point A would be

A. in the same place
B. higher
C. lower
D. to the right
E. to the left



6. If you advance the movie one frame, the pattern of the waves will be __________relative to the hand.

A. in the same place
B. shifted right
C. shifted left
D. shifted up
E. shifted down



7. If the person starts over and moves his hand more quickly, the peaks of the waves will be

A. the same distance apart

B. further apart

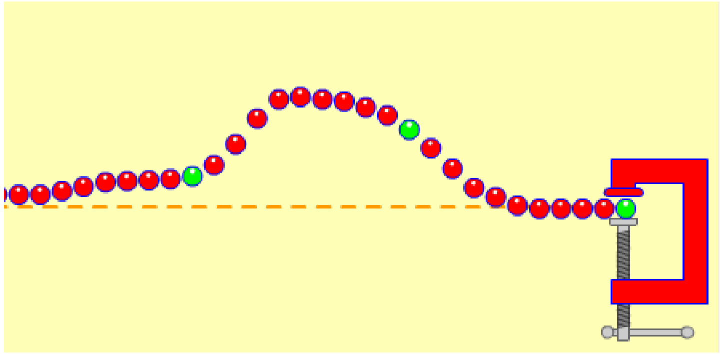
C. closer together

8. If you lower the frequency of a wave on a string you will

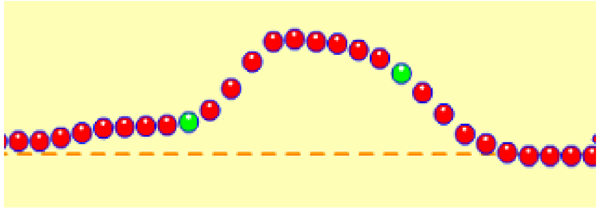
A. lower its speed.
B. increase its wavelength.
C. lower its amplitude.
D. shorten its period.

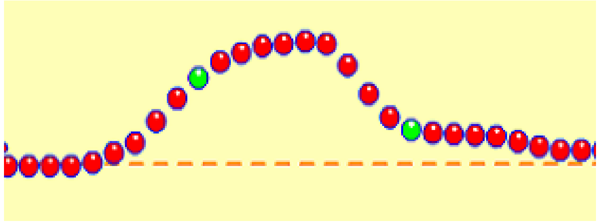
Fourier clicker questions

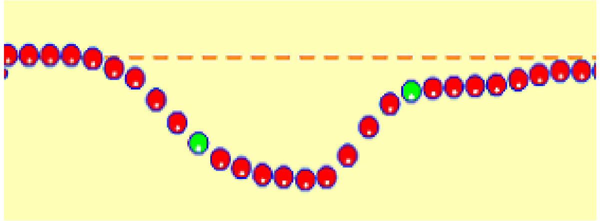
1. What will this wave look like after it reflects?

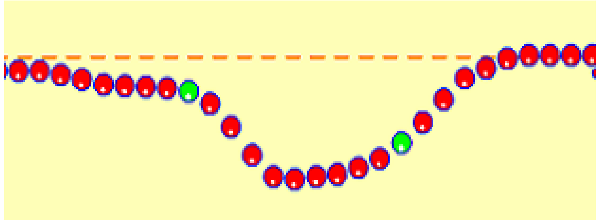


Fixed end

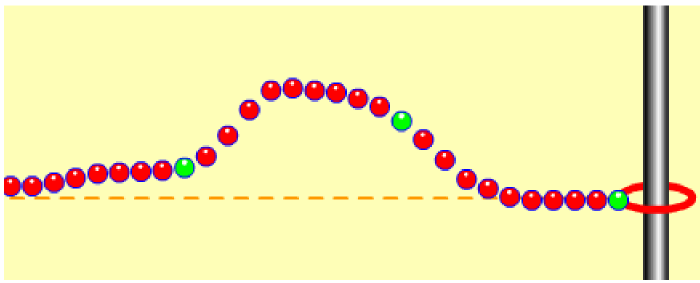
A. 

B. 

C. 

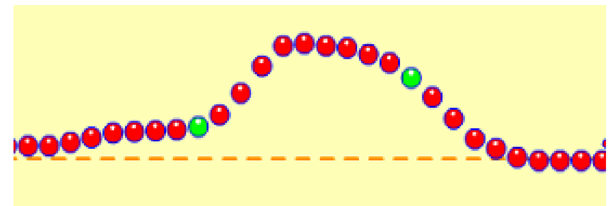
D. 

2. What will this wave look like after it reflects?

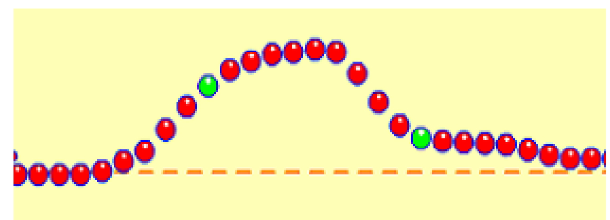


Loose end

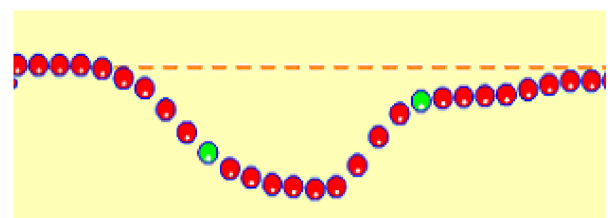
A.



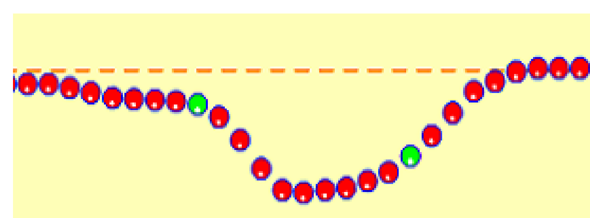
B.



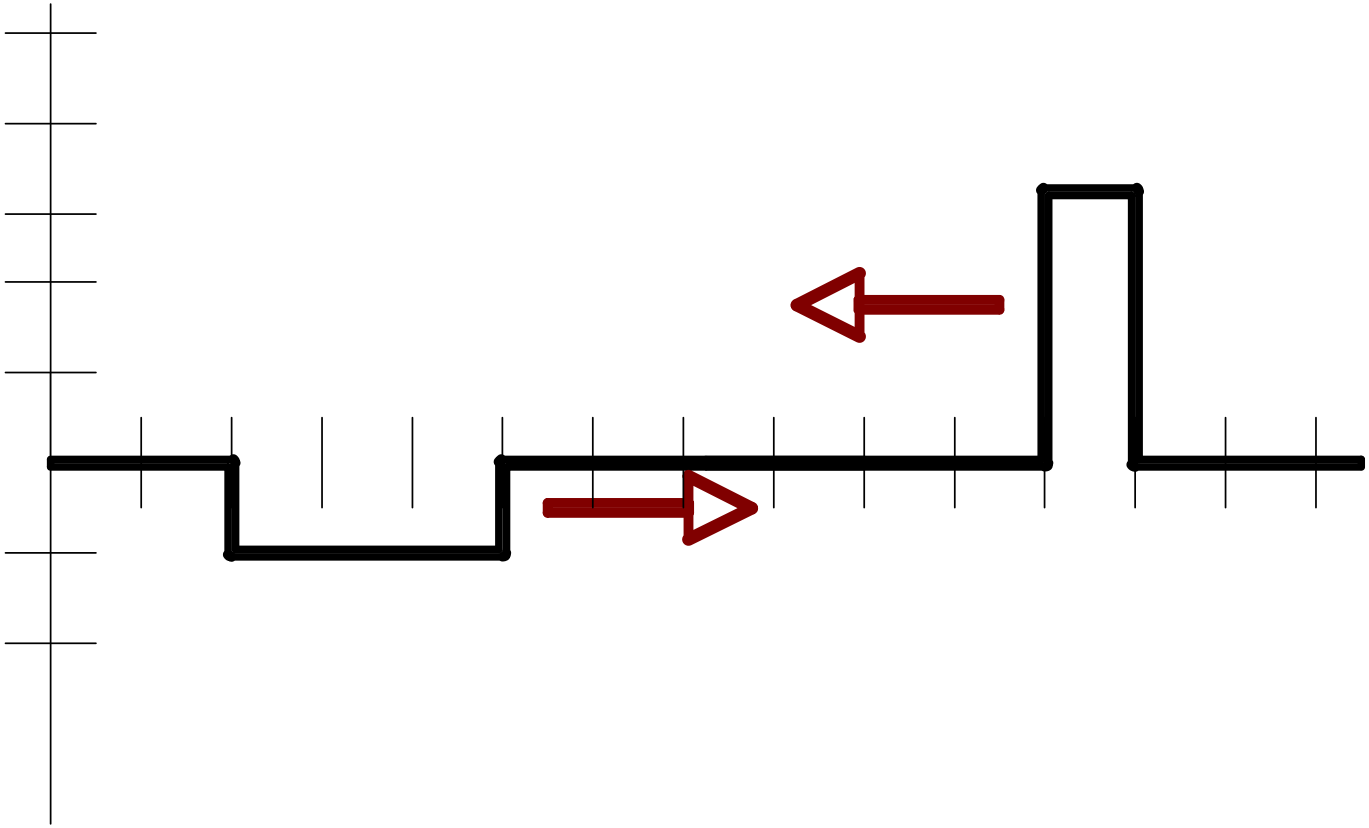
C.

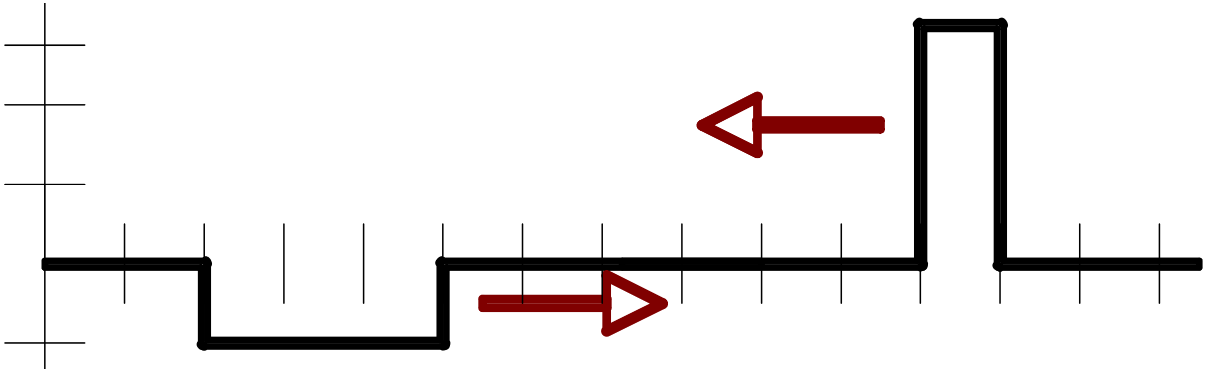


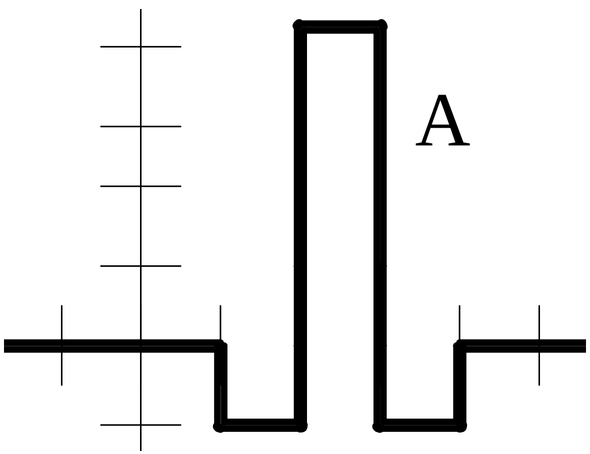
D.



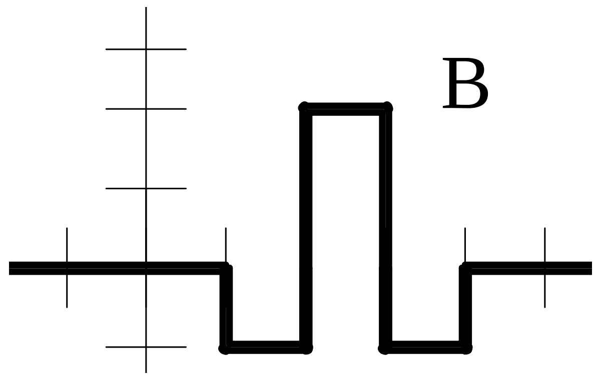
3. The pulse on the left is moving right, the pulse on the right is moving left. What do you see when the pulses overlap?



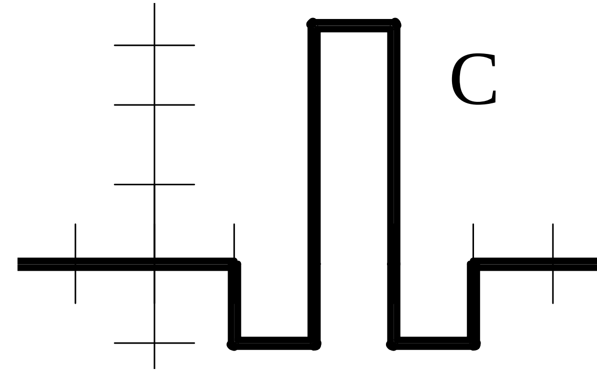




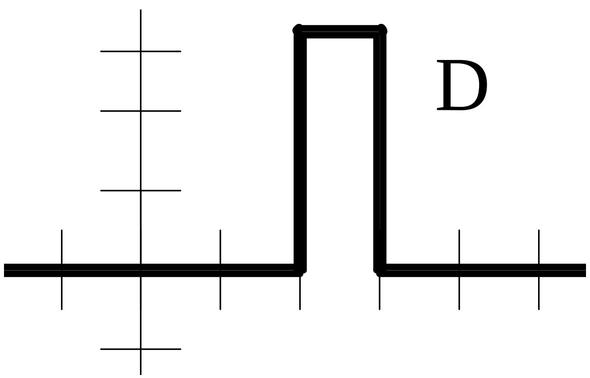
A



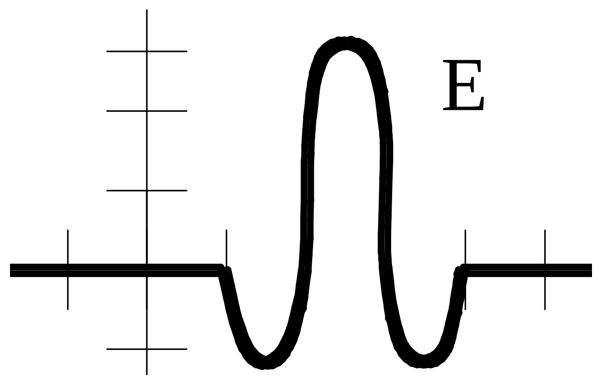
B



C

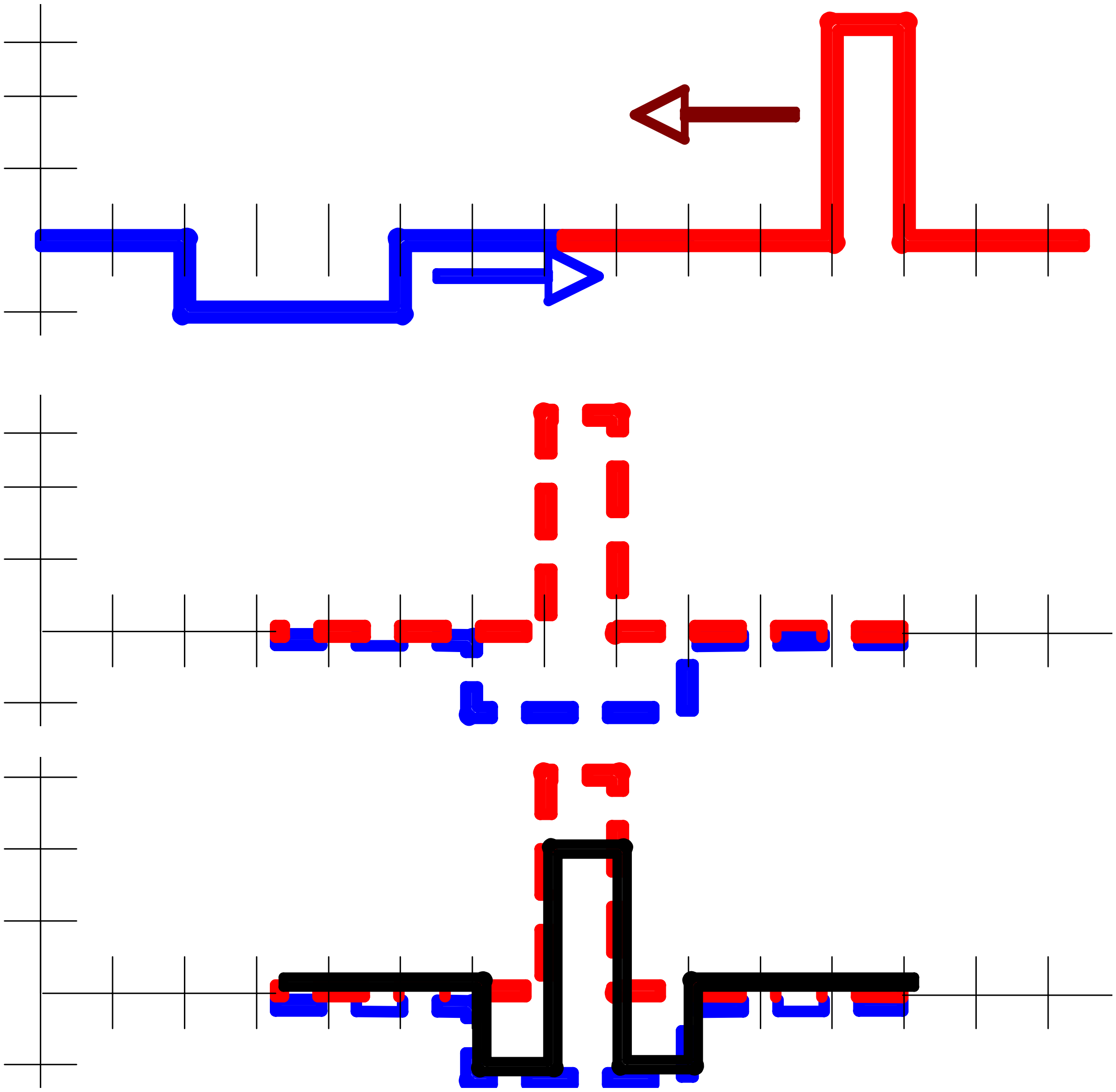


D



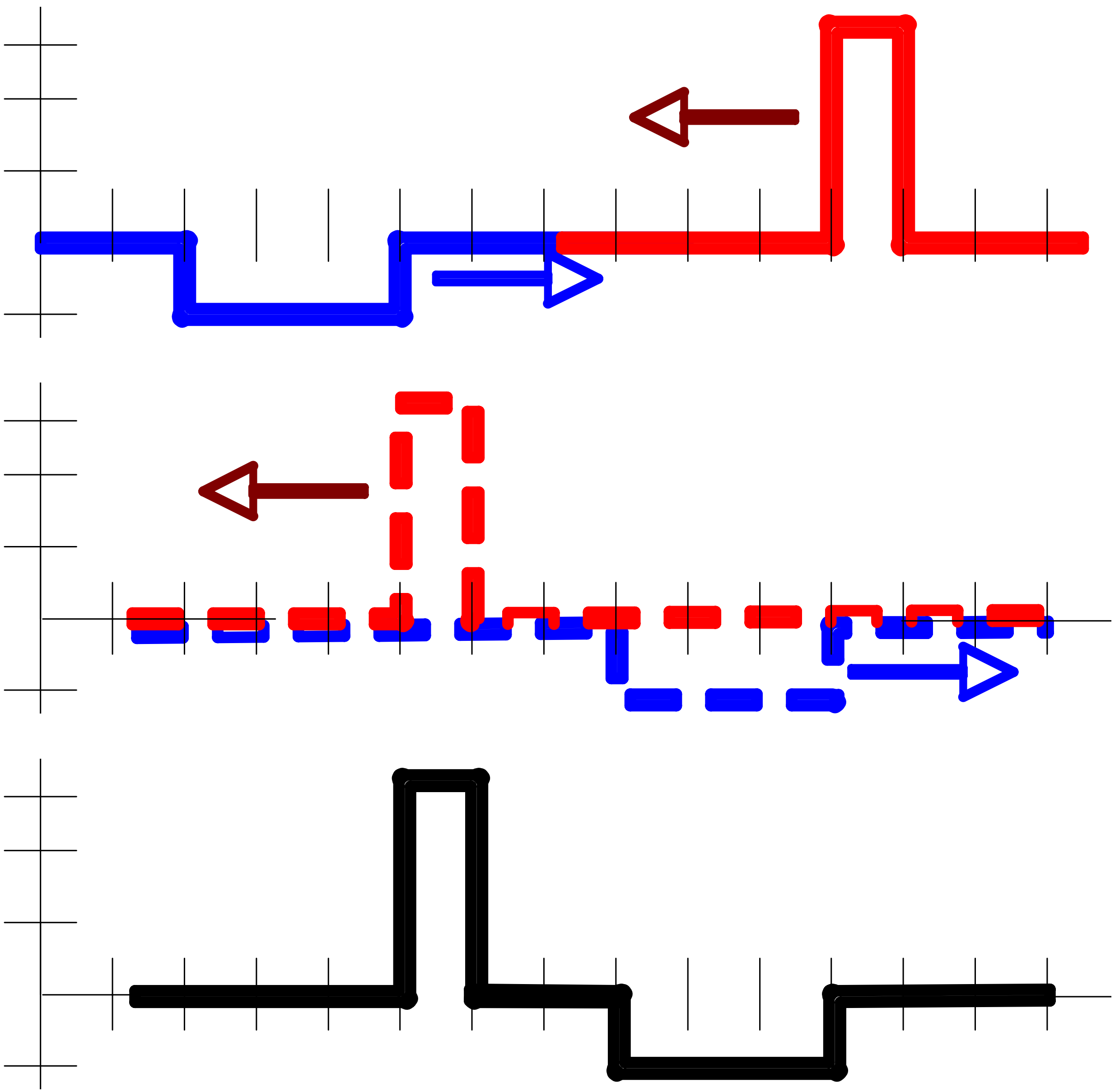
E

Rest of question



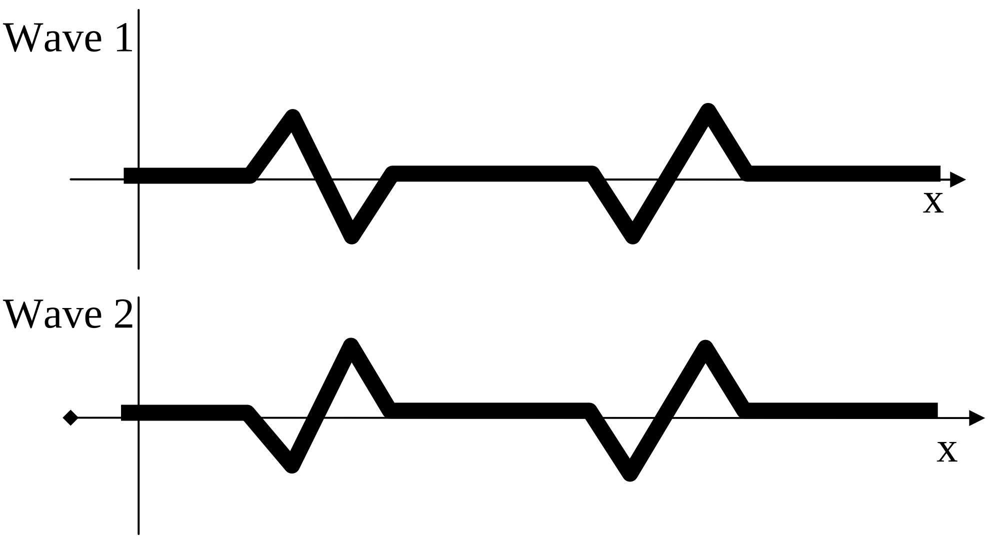
B

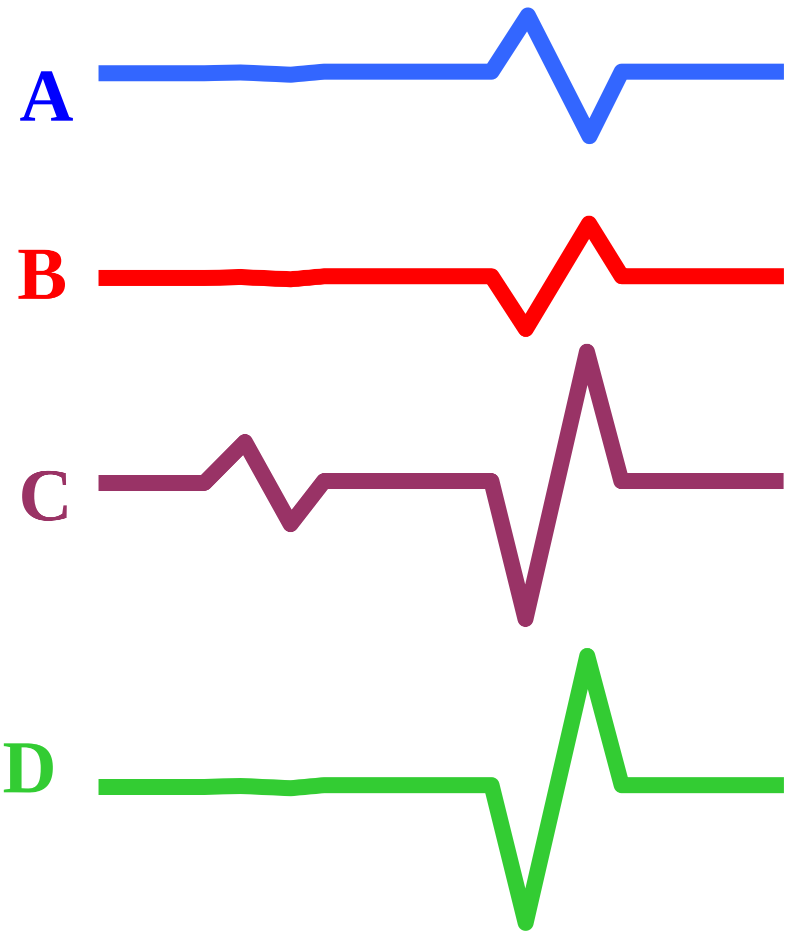
answer



After interacting

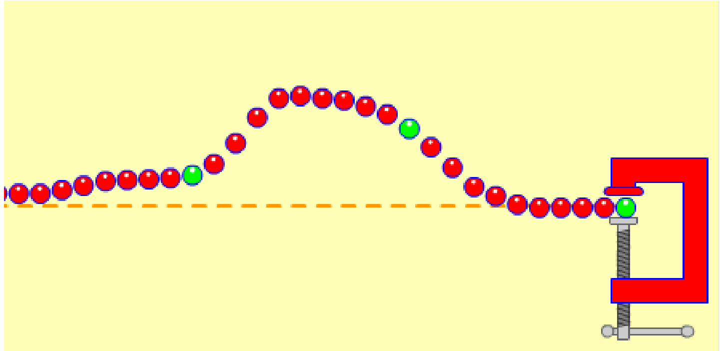
4. If these two waves were moving through water at the same time, what would the water look like?





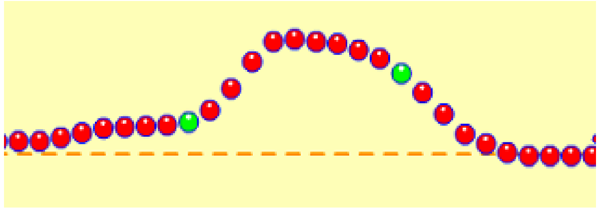
Wave Interference

1. What will this wave look like after it reflects?

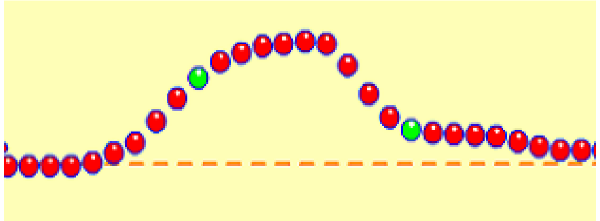


Fixed end

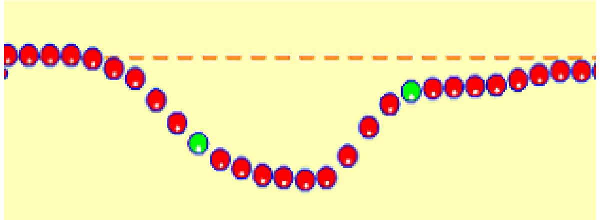
A.



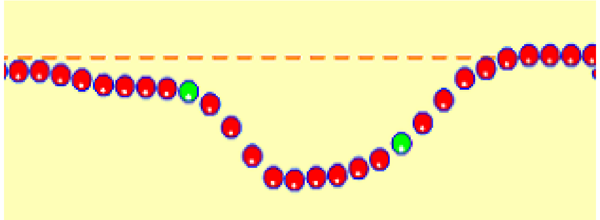
B.



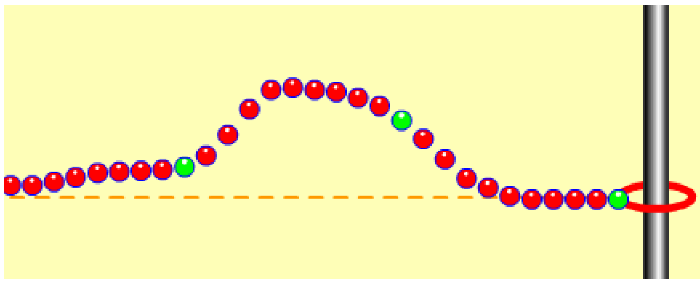
C.



D.

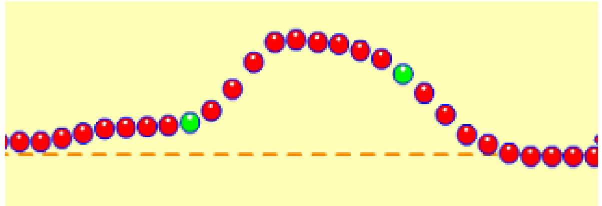


2. What will this wave look like after it reflects?

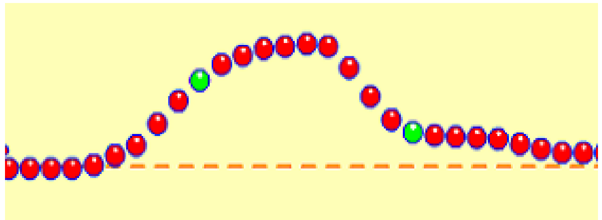


Loose end

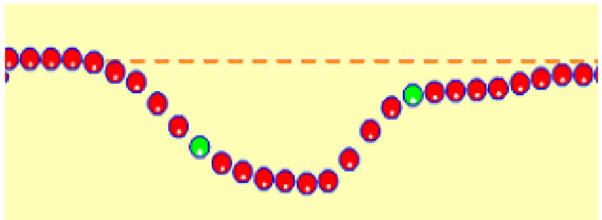
A.



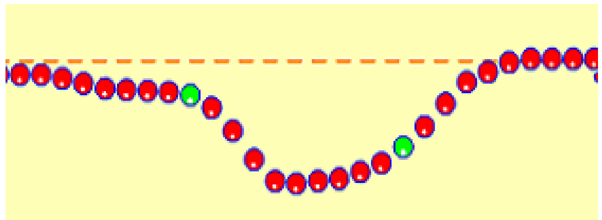
B.



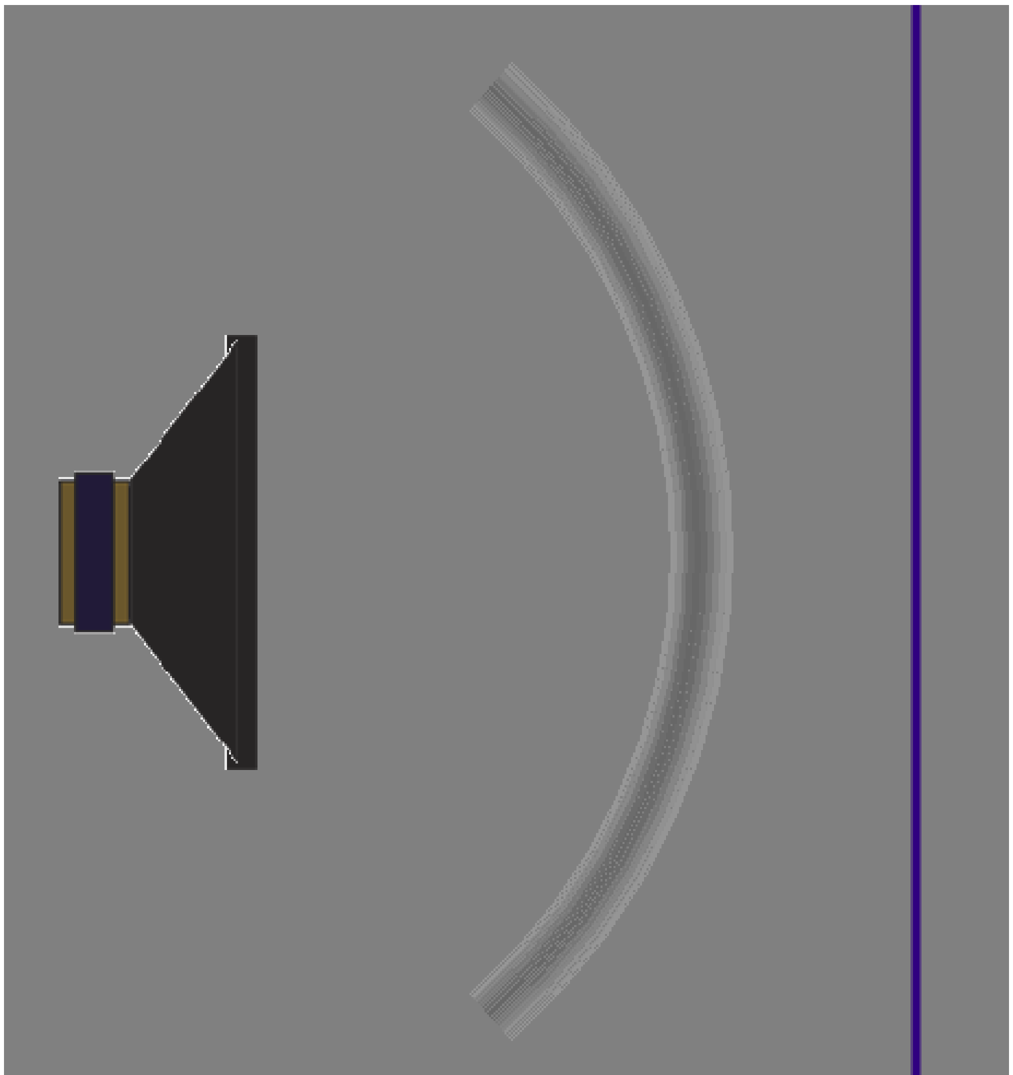
C.



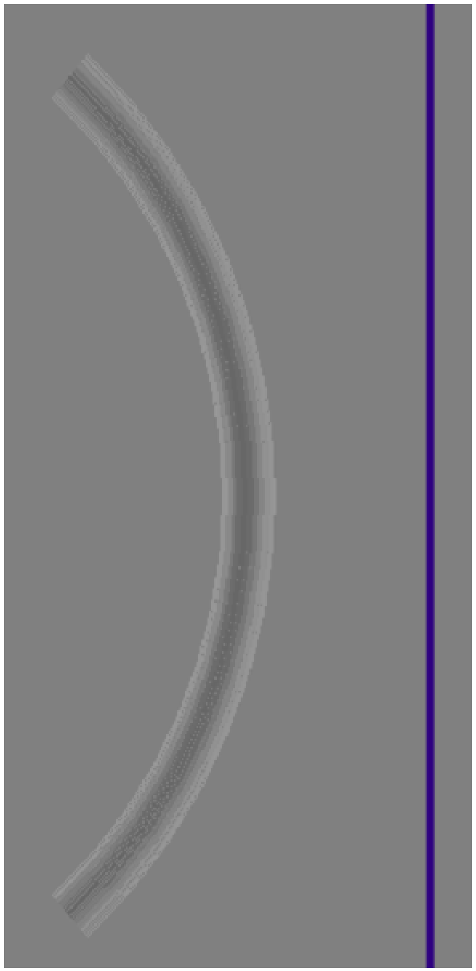
D.



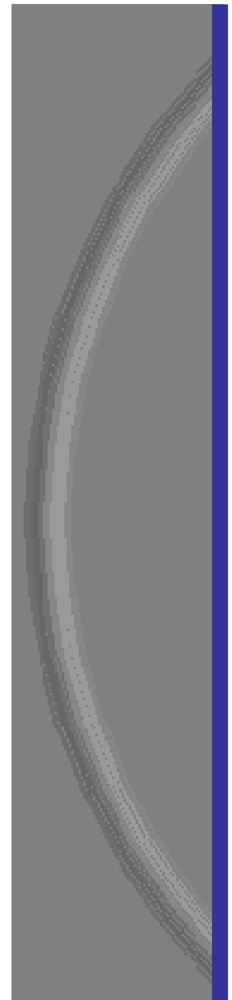
Draw what you think this wave will look like after reflecting off the barrier.



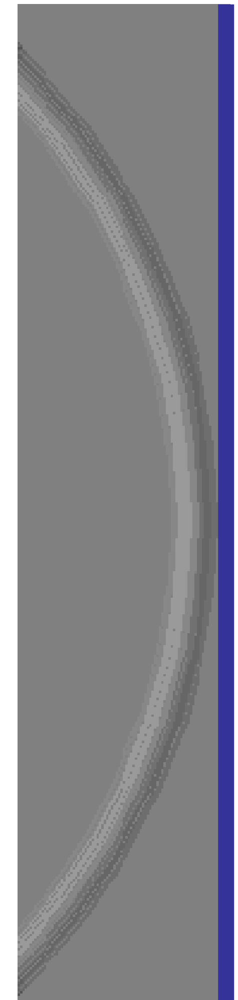
3. Which one is the reflection pattern?



Wave pulse from speaker



A



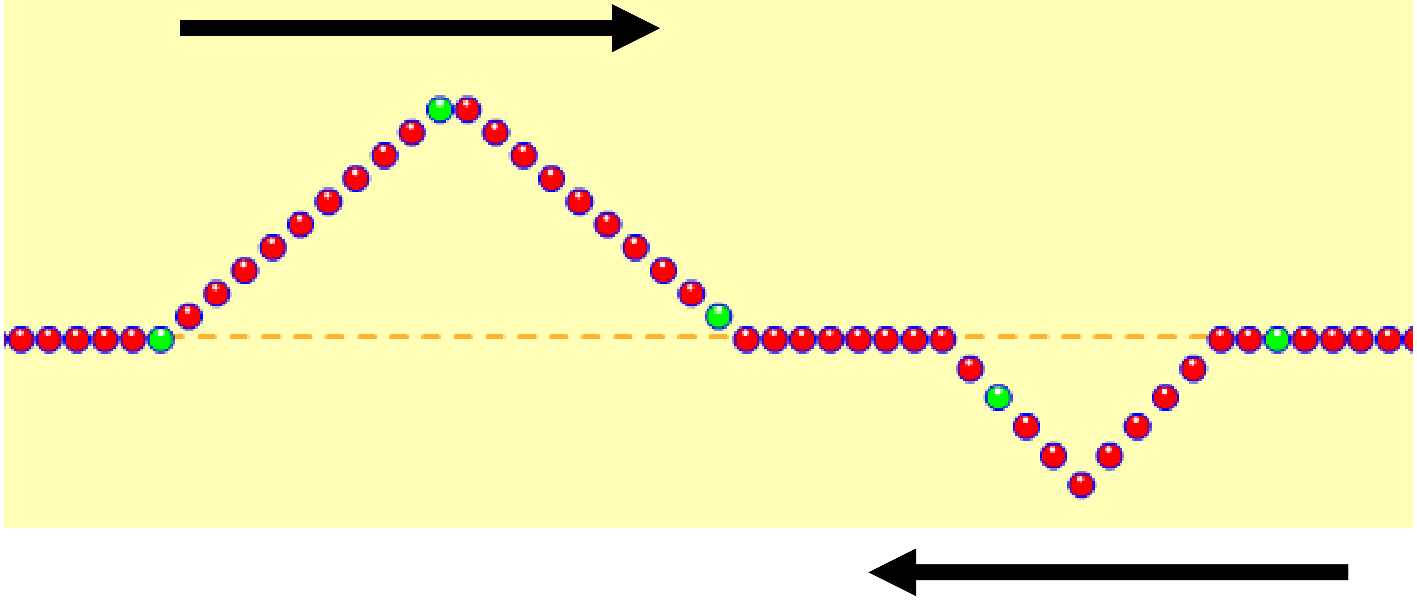
B

“Sound waves are three dimensional.”

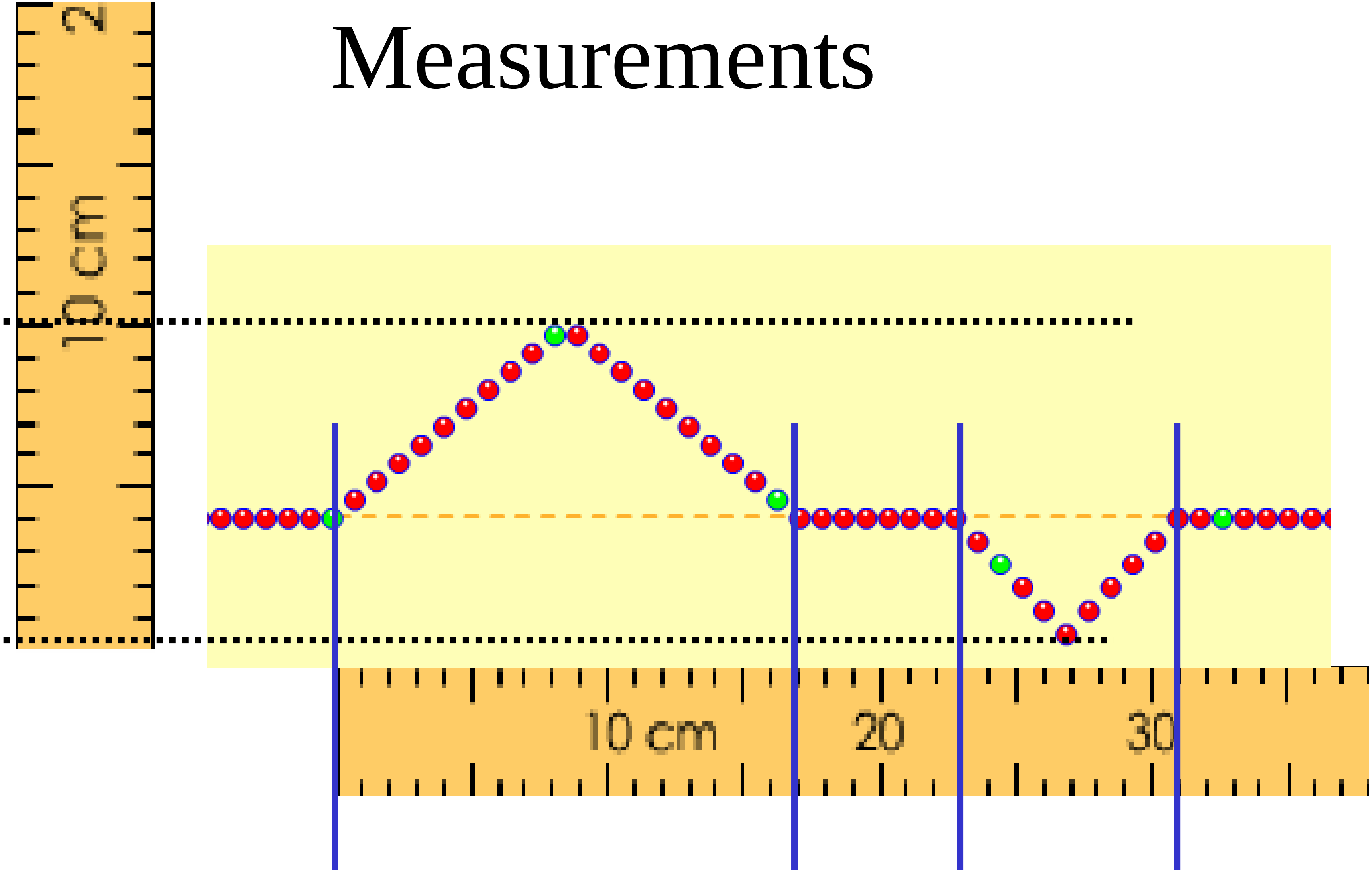
Talk to your partner:

- What evidence you have that supports this.
- How the wave could be represented
- How would reflection change?

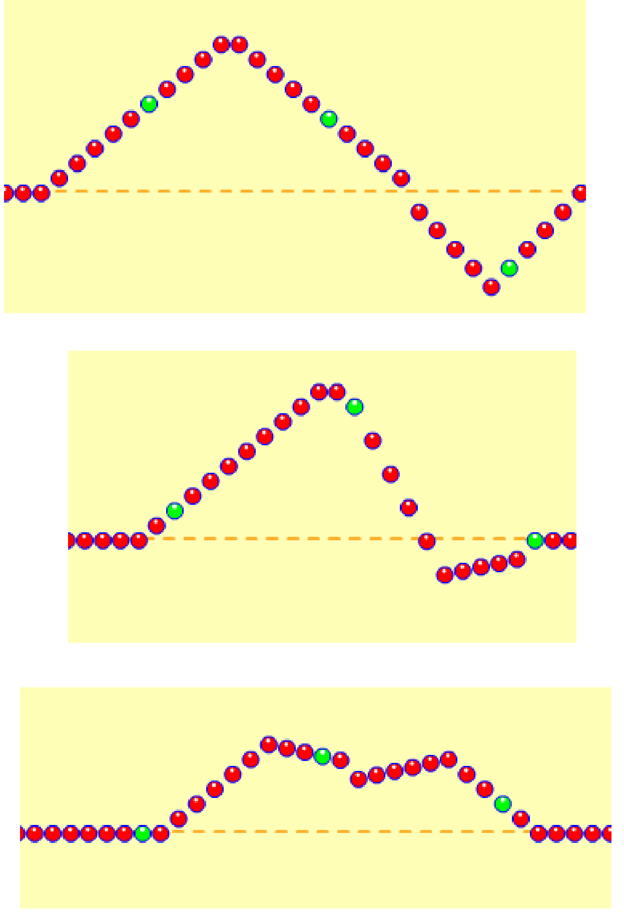
Sketch what you think the pattern will look like



Measurements



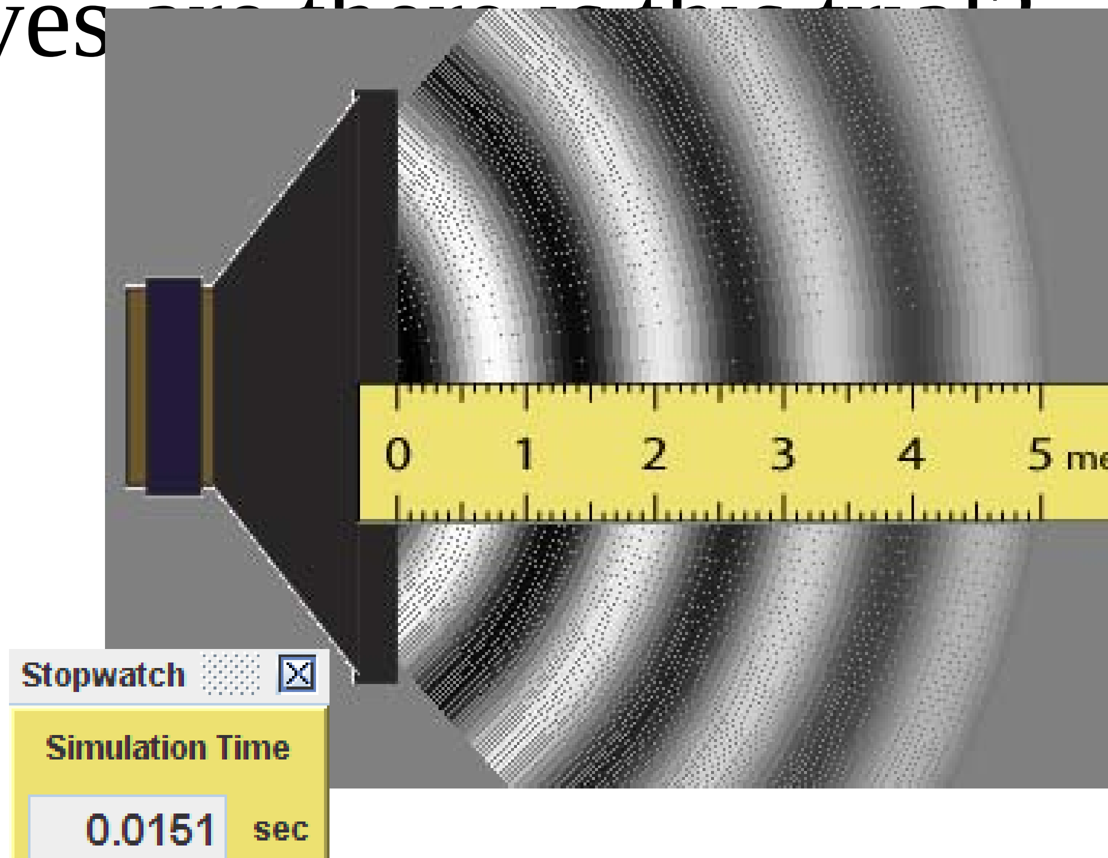
Paused clips



Sound activity

I used questions 1-8 with the sound activity and the rest on the next day.

1. A student started the speaker by clicking on the stopwatch. How many sound waves



A. 3

B. 5

C. 4

D. 8

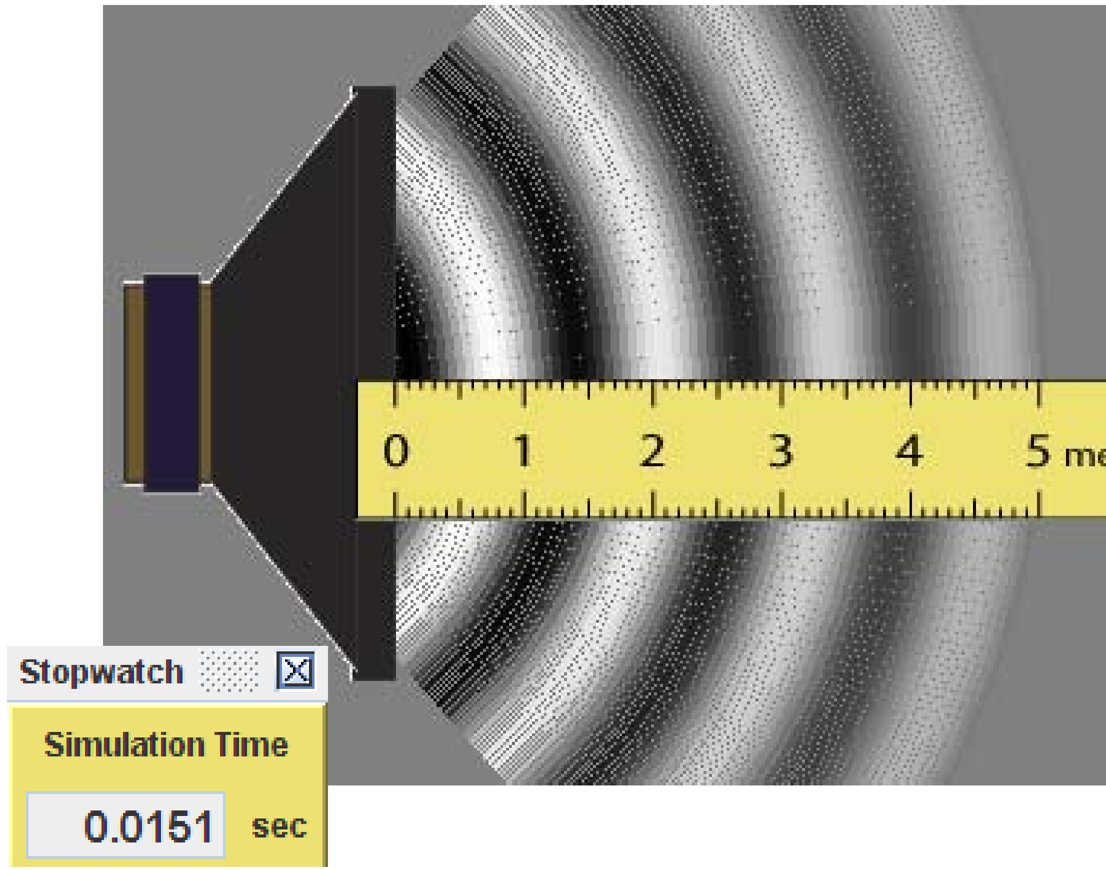
2. What is the speed of the sound waves shown here?

A. 300 m/s

B. 330 m/s

C. 0.0030 m/s

D. 66 m/s



3. What is the frequency of the sound waves shown here?

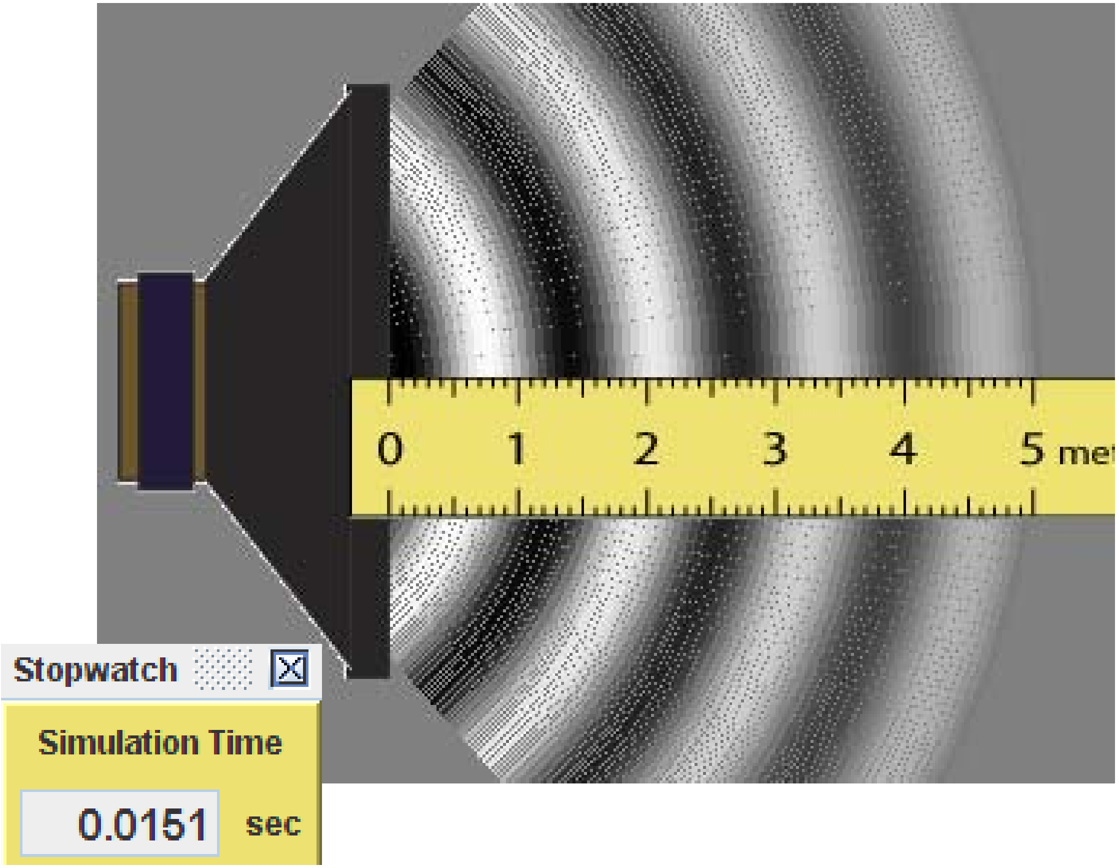
A. 0.0037 hz

B. 66 hz

C. 260 hz

D. 300 hz

E. 330 hz



4. What is the period of the sound waves shown here?

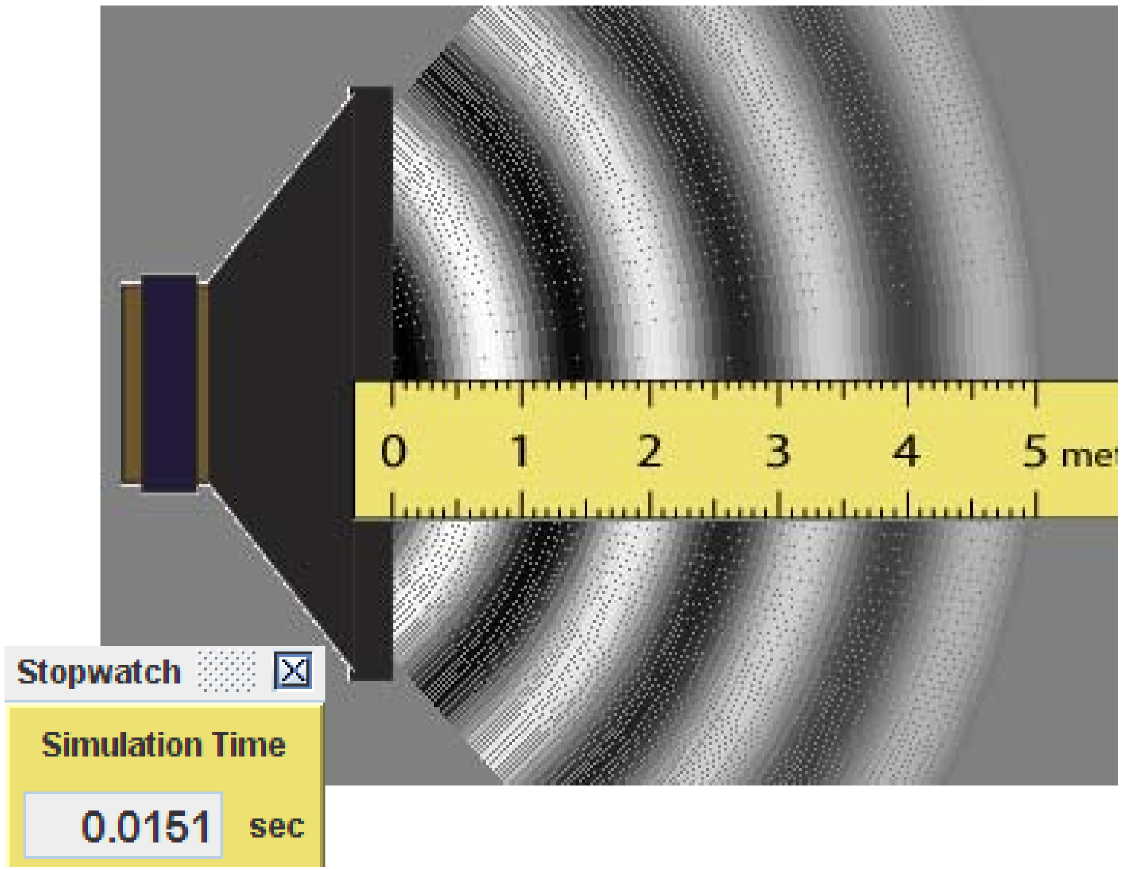
A. 0.0151 s

B. 0.0037 s

C. 260 s

D. 300 s

E. 330 s



5. What is the wavelength of the sound waves shown here?

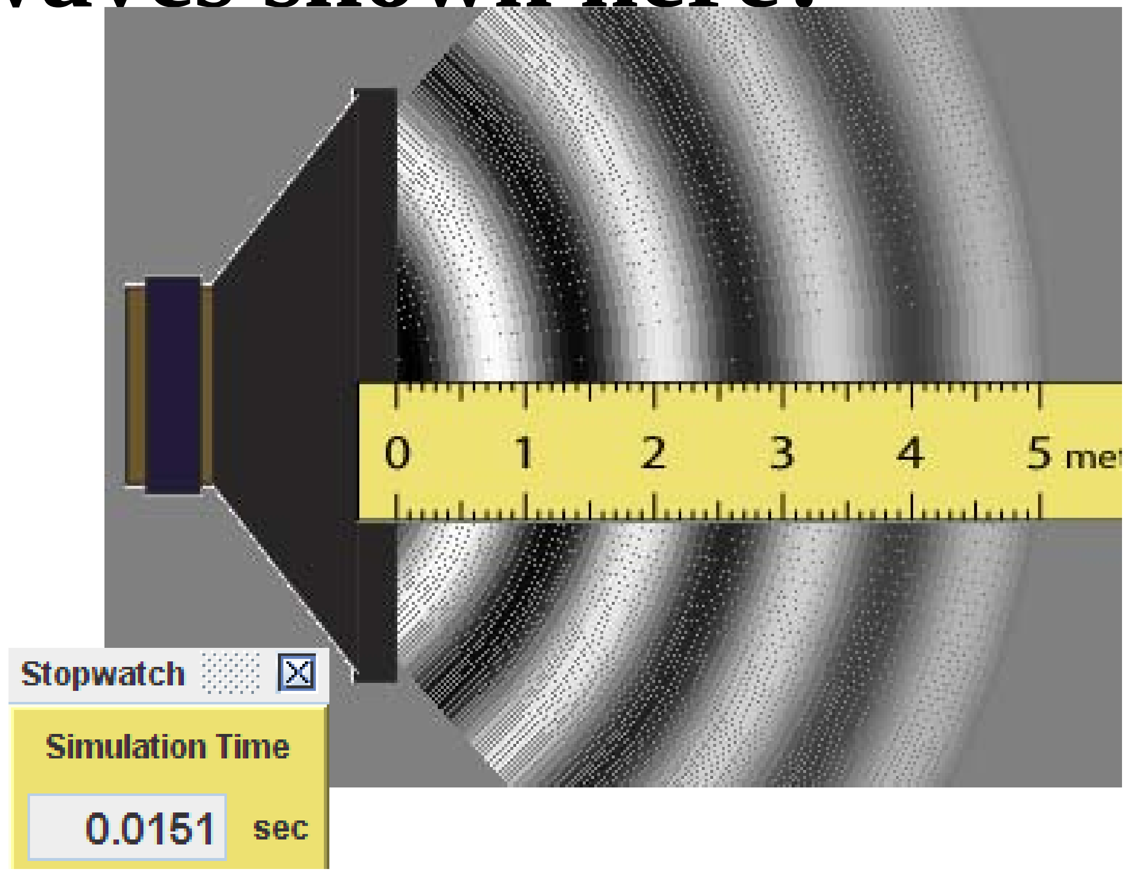
A. 5 m

B. 1.3 m

C. 1 m

D. 0.71 m

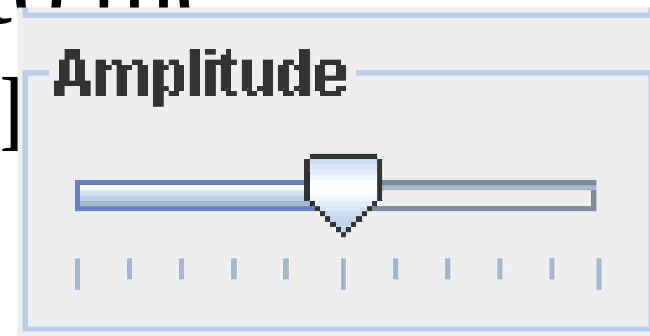
E. 300 m



6. If your lab partner moved the frequency slider to the left so that it changed from 500 to 250 the period would be

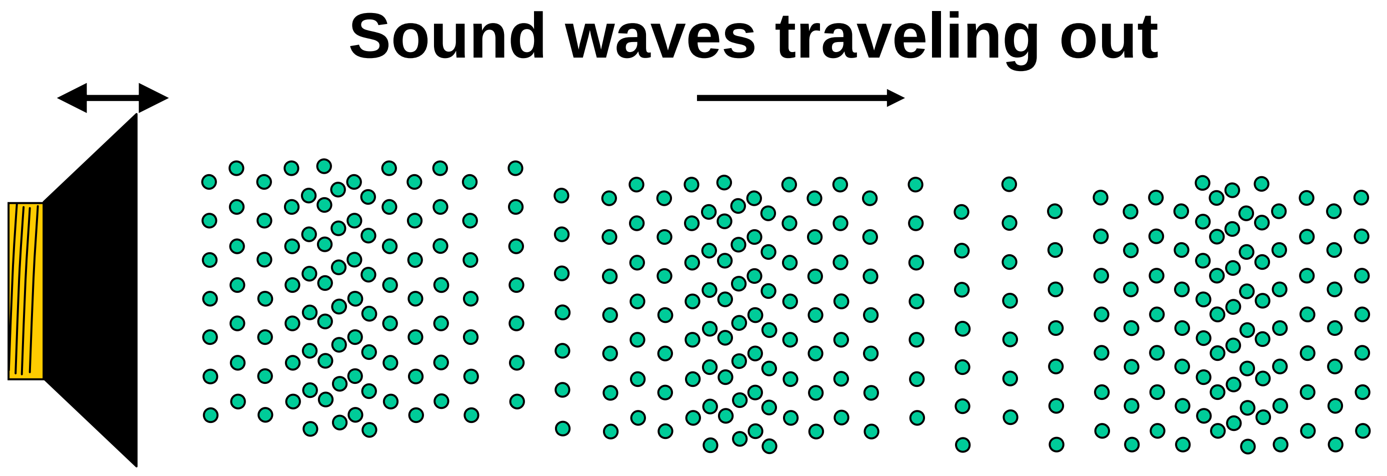
A. twice as big
B. 1/2 as big
C. Stays the same
D. 1/4 times as big
E. Not enough information to decide

7. If you moved the slider to the far right, doubling the ampl



the period would be…

A. twice as big
B. 1/2 as big
C. Stays the same
D. 1/4 times as big
E. Not enough information to decide



8. If the speaker vibrates back and forth at 200 Hz how much time passes between each time it produces a maximum in pressure?

a. 0.2 seconds
b. 0.200 seconds
c. 0.005 seconds
d. 0.02 seconds
e. 0.05 seconds

9.A speaker is playing a constant note. What happens to the sound when you

1) put a solid, thick glass jar over it and
2) pump the air out from the jar.

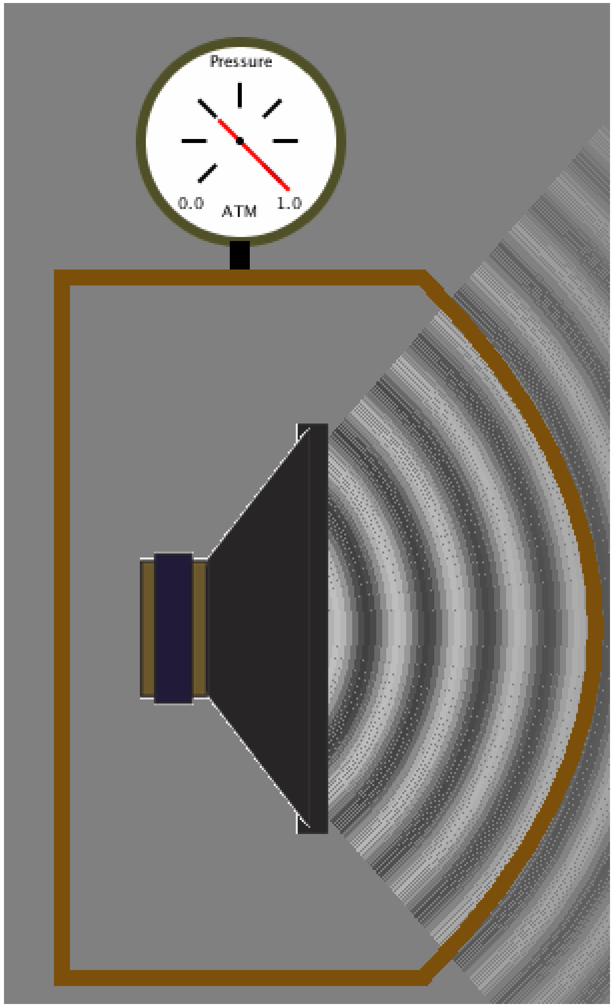
A) 1 => hardly any difference
2 => hardly any difference

B) 1=> hardly any difference
2 => much quieter

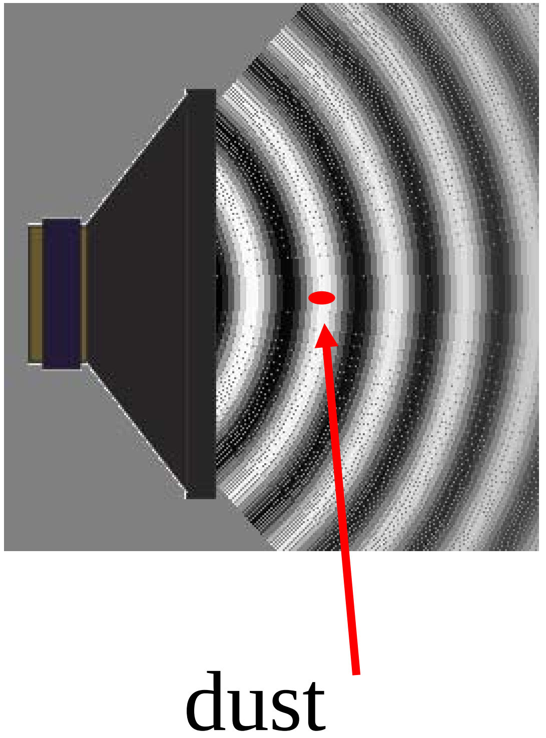
C) 1=> noticeably quieter
2 => hardly any MORE quiet

D) 1=> noticeably quieter
2=> much quieter still (near silence)

E) None of these/something else/??



10. If you could put a dust particle in front of the speaker. Which choice below shows the *motion* of the dust particle?



A) (up and down)

B) (steadily to the right)

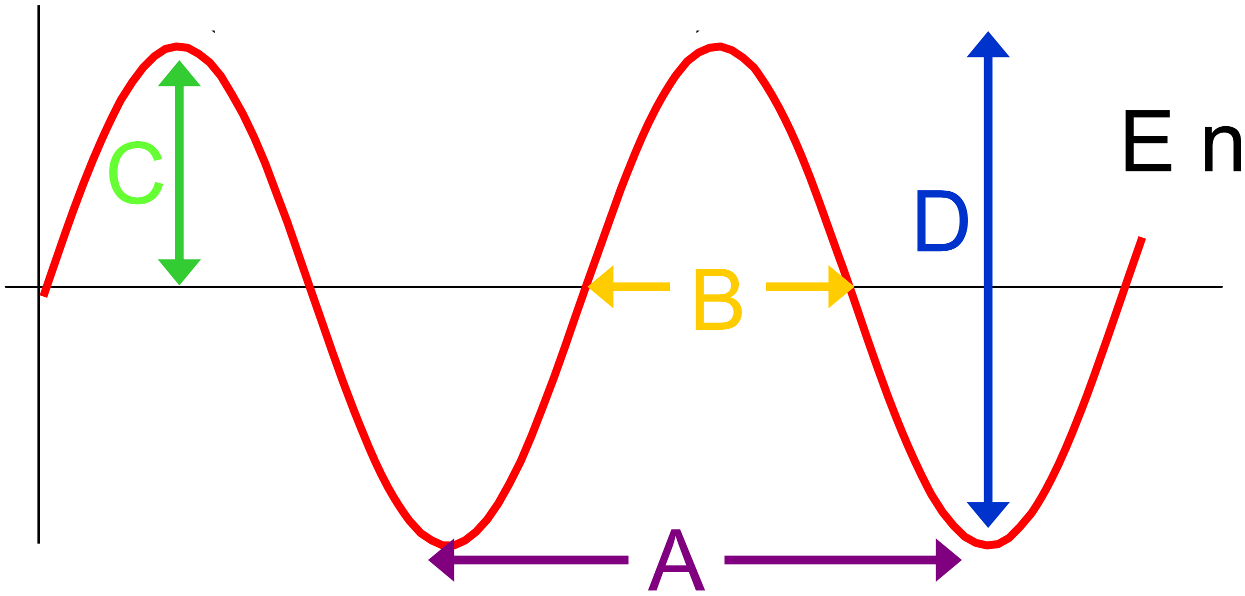
C) (left and right)

D) (no motion)

E) (circular path)

11.The picture shows "displacement as a function of location along a string"

What is the wavelength ("λ")?

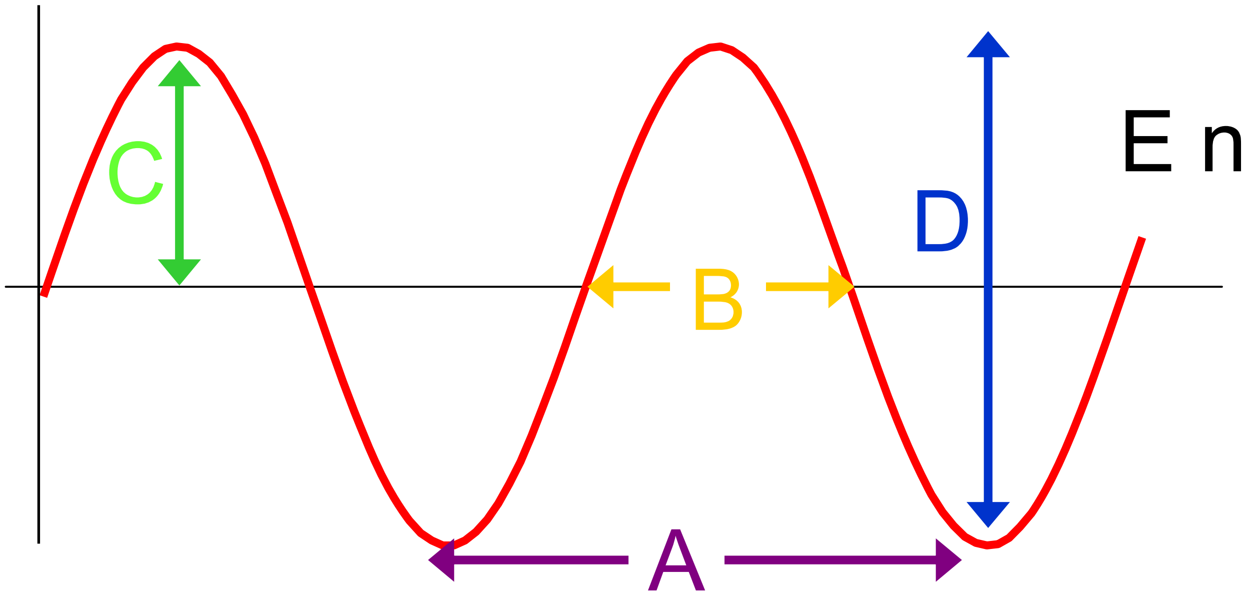


E none of these

Remember X axis is **position** not time

12. The picture shows "displacement as a function of location along a string"

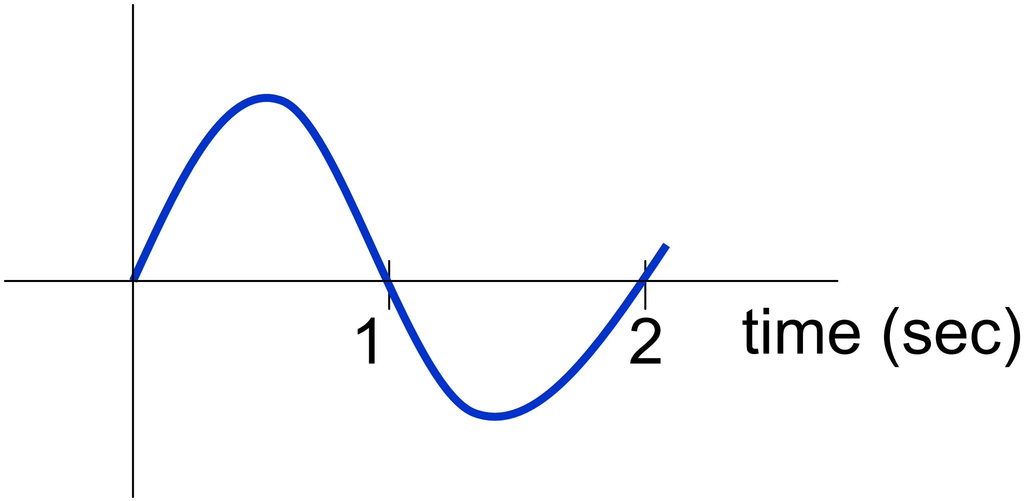
What is the amplitude?



E none of these

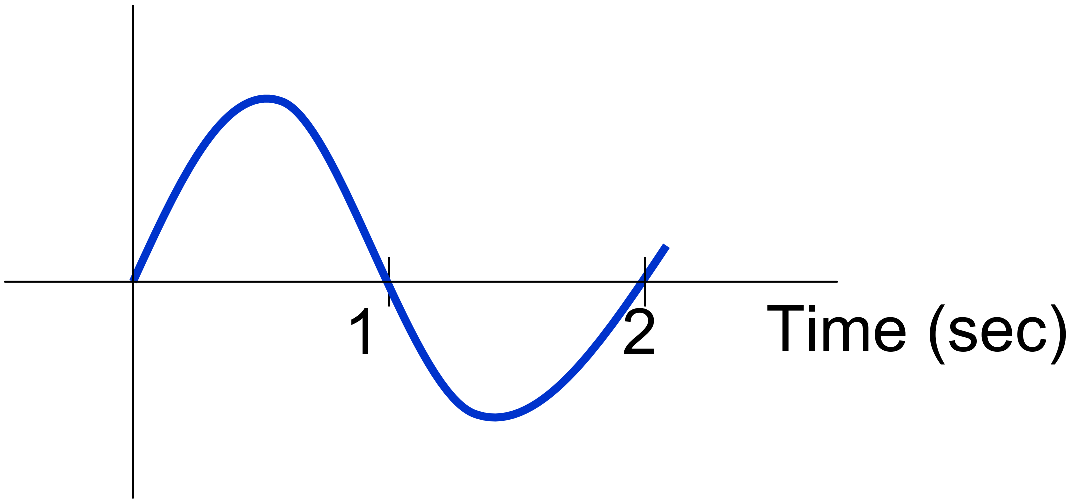
Remember X axis is **position** not time

13. Looking at the following waveform, what is the period? assume it repeats itself over and over



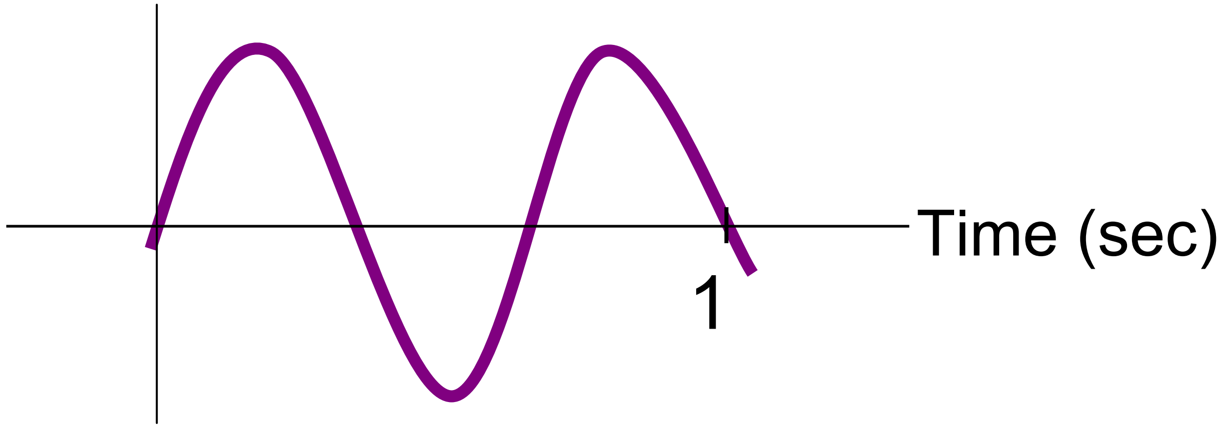
A. 1 sec
B. 2 sec
C. 1 m/s
D. 2 m/s
E. Not enough information

14 Looking at that same wave, what is its speed?



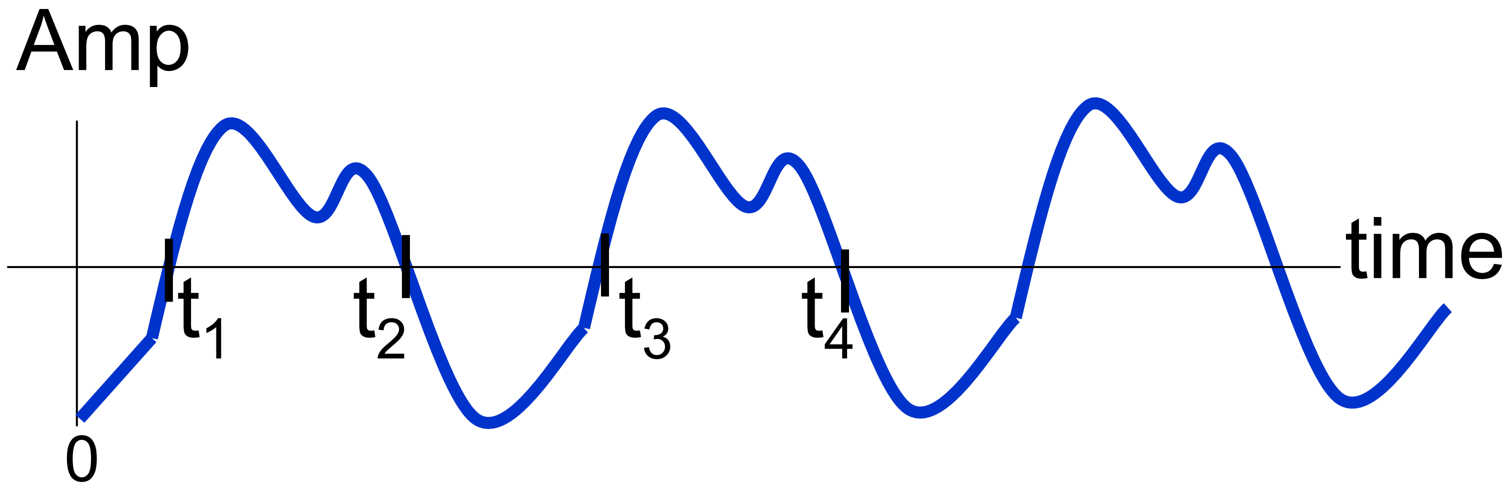
A. 1/2 m/s
B. 2 m/s
C. 5 m/s
D. 20 m/s
E. Not enough information

15 The wavelength, λ, is 10 m. What is the speed of this wave?



A) 1 m/s
B) just under 7 m/s
C) 10 m/s
D) 15 m/s
E) None of the above/not enough info/not sure

17 What is the period of this wave?



a) t_1

b) t_2

c) $t_2 - t_1$

d) $t_3 - t_1$

e) None of the above

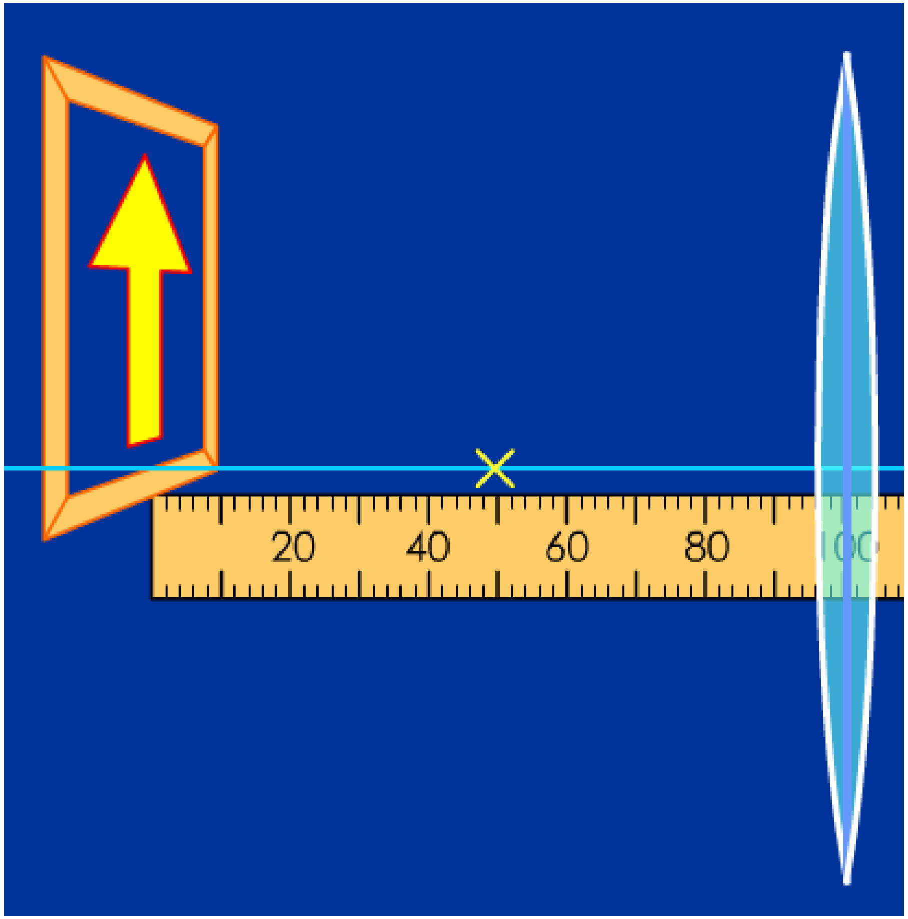
18 Which one of the following is most likely to be *impossible*?

A. Transverse waves in a gas
B. Longitudinal waves in a gas
C. Transverse waves in a solid
D. Longitudinal waves in a solid
E. They all seem perfectly possible

Reflection and Lenses

Plane mirrors only

Where will the image appear?



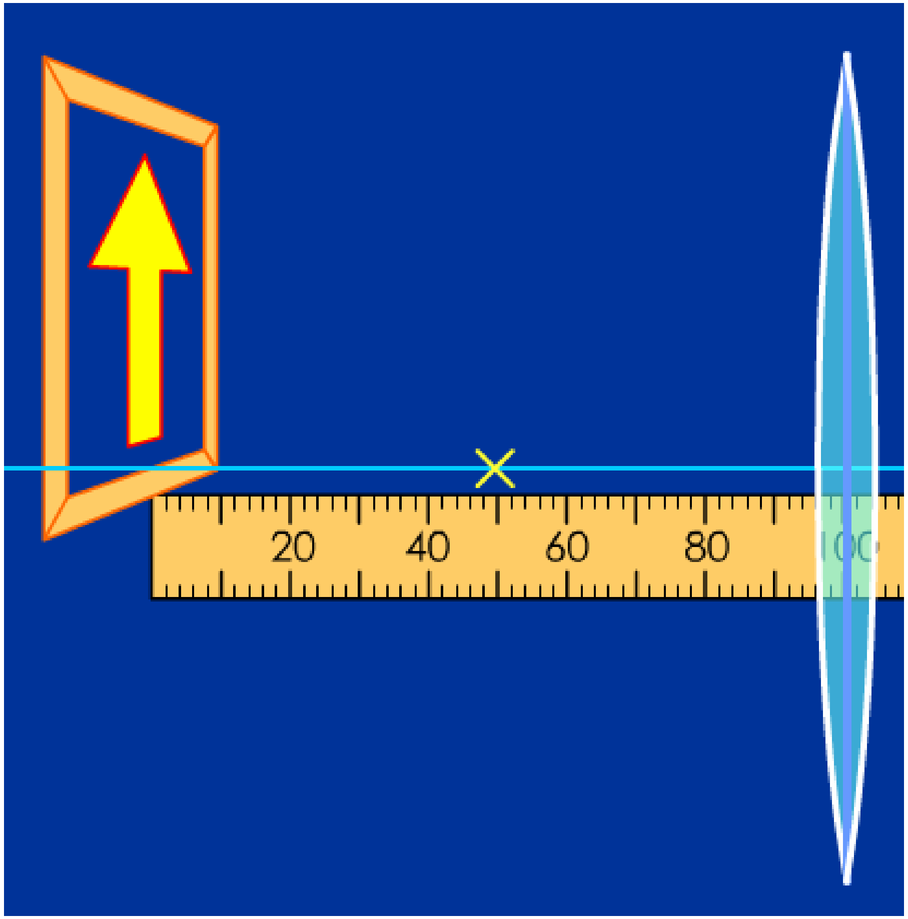
A. On the left, at the zero mark.

B. On the right, at the 150 mark.

C. On the right, at the 200 mark.

D. On the right, at the 300 mark.

How will the image look?



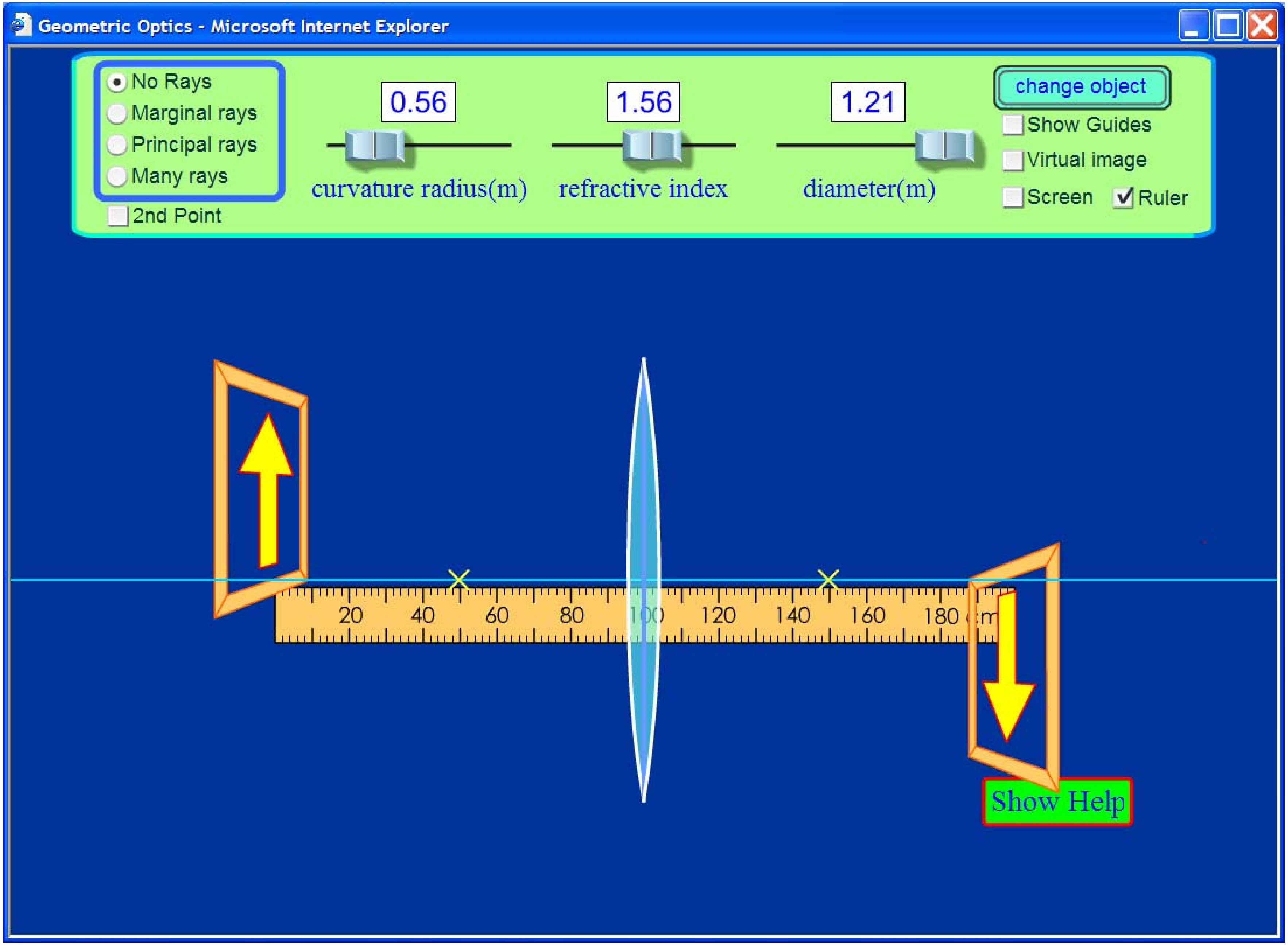
A. Same size ⇧

B. Smaller ⇧

C. Larger ⇧

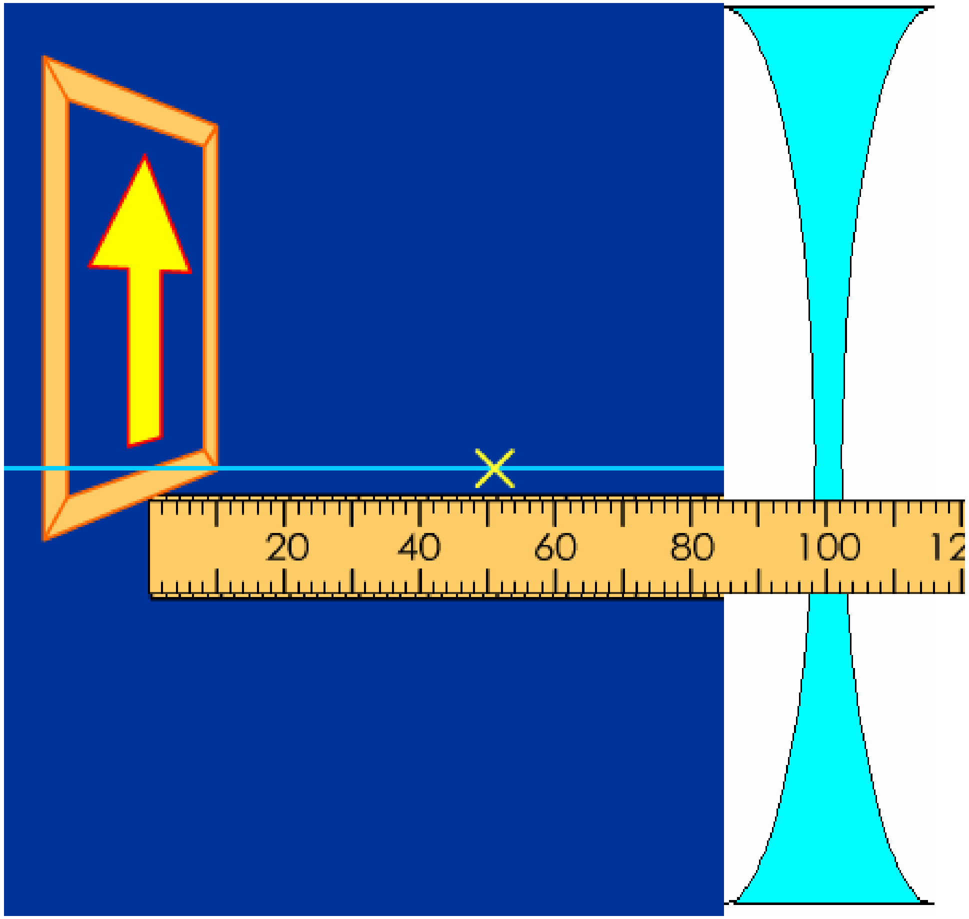
D. Same size ⇩

E. Smaller ⇩



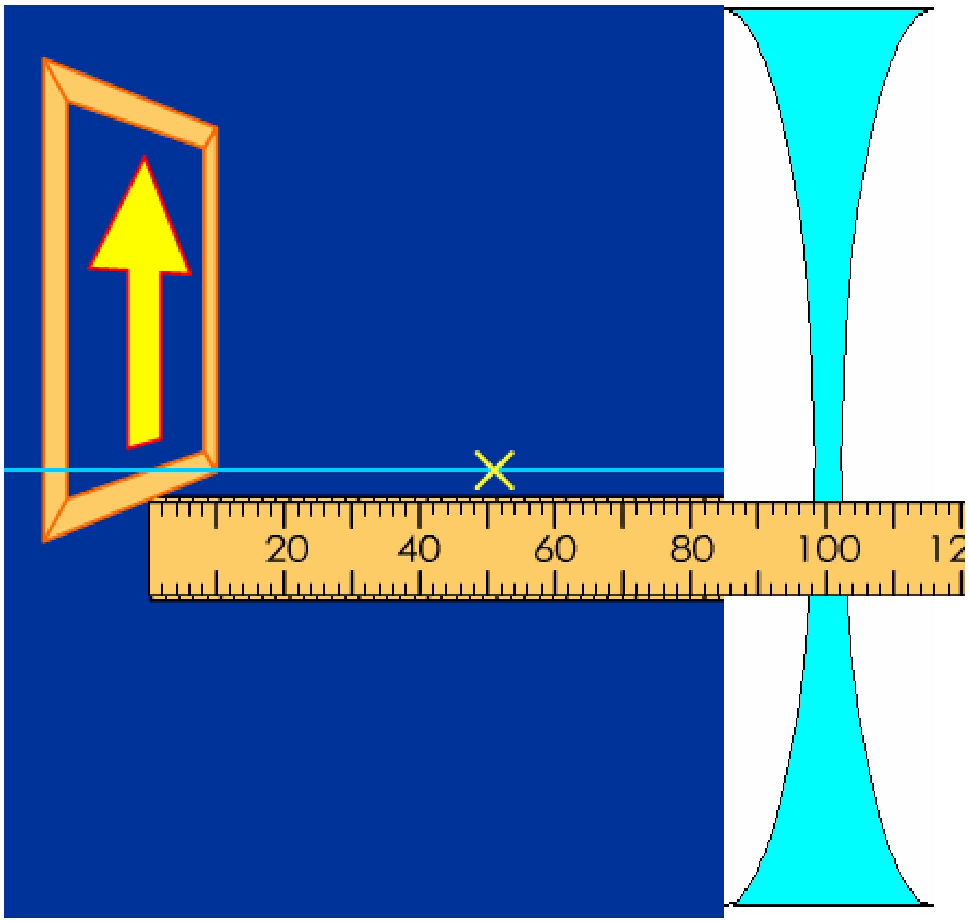
Geometric Optics - Microsoft Internet Explorer
No Rays
Marginal rays
Principal rays
Many rays
2nd Point
0.56
curvature radius(m)
1.56
refractive index
1.21
diameter(m)
change object
Show Guides
Virtual image
Screen
Ruler
20
40
60
80
100
120
140
160
180
cm
Show Help

Where will the image appear if the lens were concave?



A. On the left, at the zero mark.
B. On the left, at the 67 mark.
C. On the left, at the 33 mark.
D. On the right, at the 200 mark.

How will the image look?



A. Same size

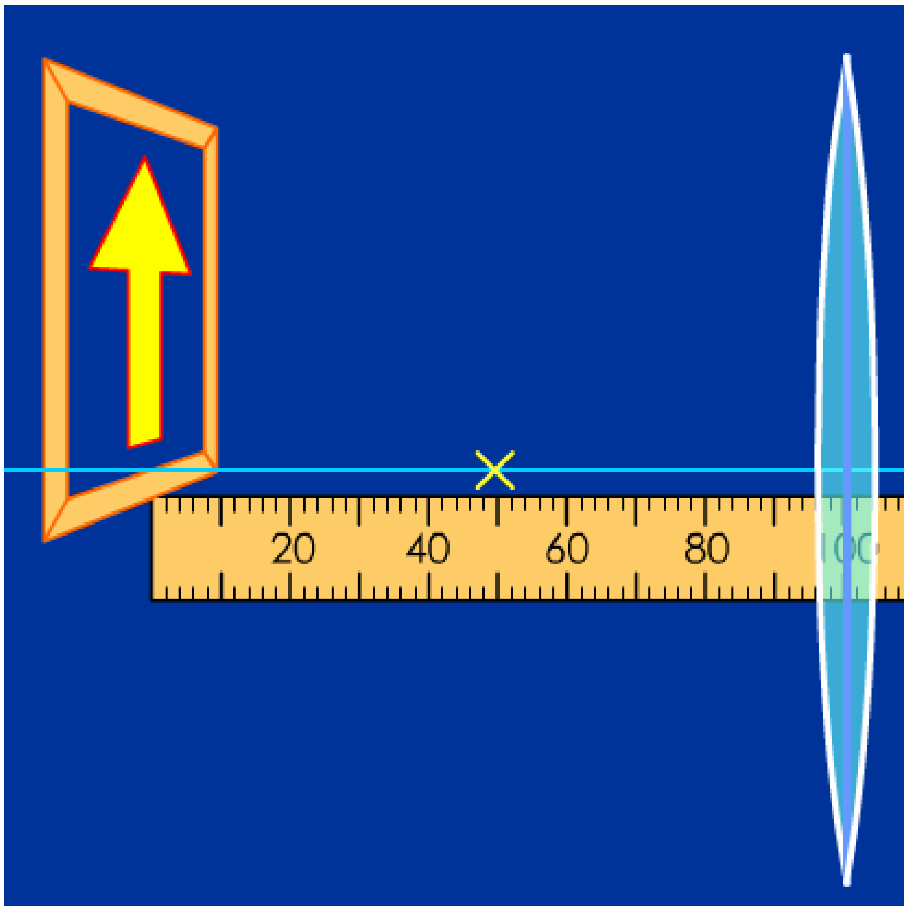
B. Smaller

C. Larger

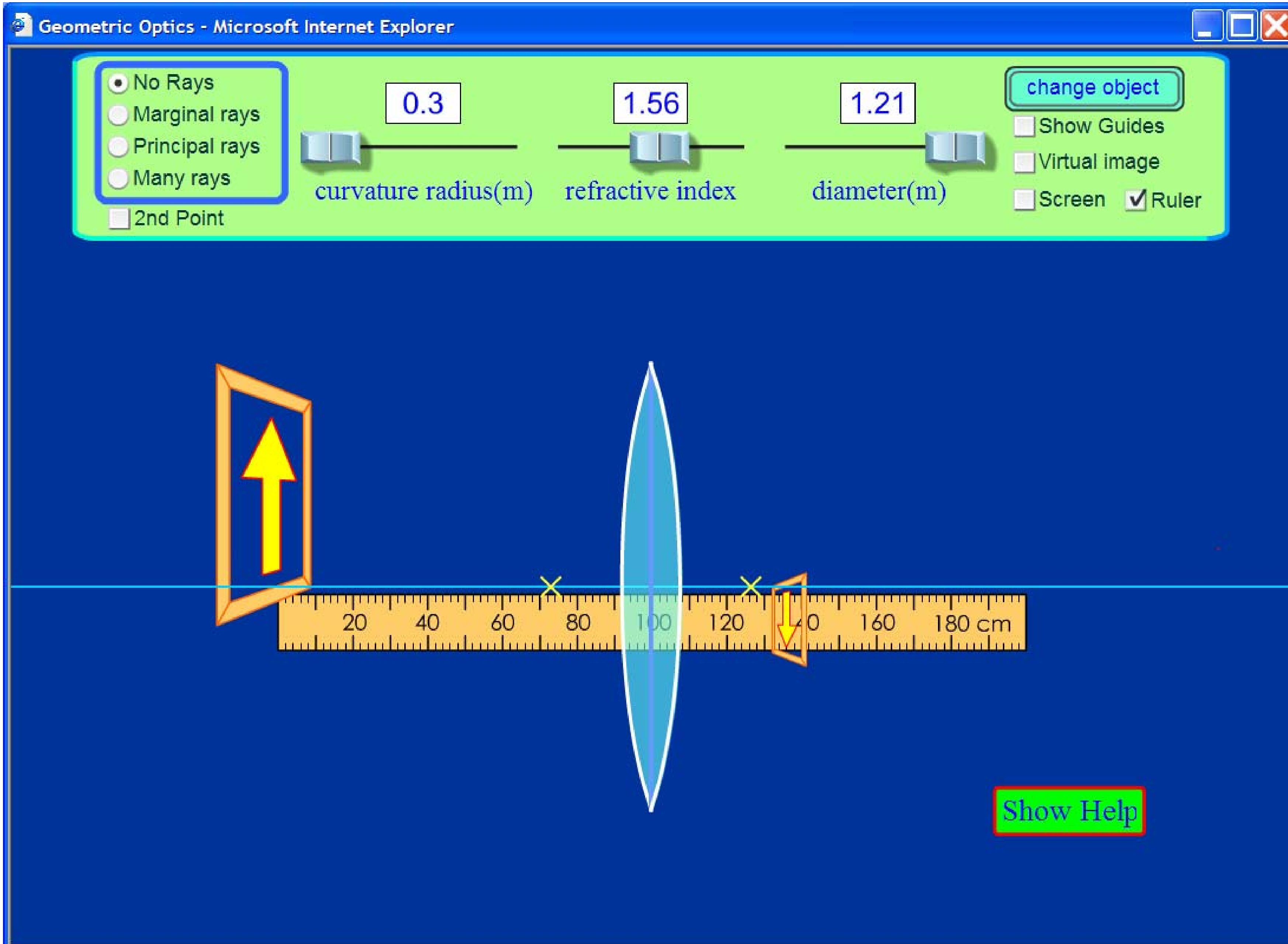
D. Same size

E. Smaller

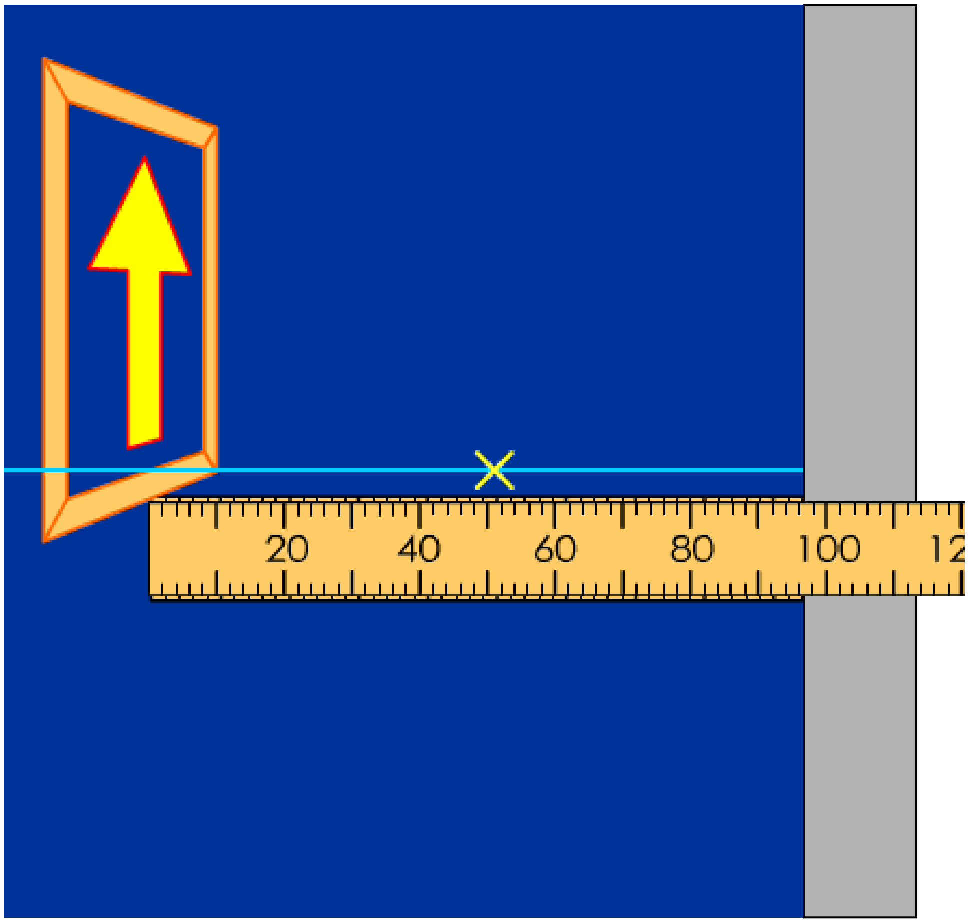
If the lens is made fatter in the middle, how will the image change?



A. Larger, further away
B. Smaller, further away
C. Larger, closer
D. Smaller, closer


Geometric Optics - Microsoft Internet Explorer
No Rays
Marginal rays
Principal rays
Many rays
2nd Point
0.3
curvature radius(m)
1.56
refractive index
1.21
diameter(m)
change object
Show Guides
Virtual image
Screen
Ruler
20
40
60
80
100
120
160
180 cm
Show Help

If you replace the lens with a mirror, the image will be



A. Same size

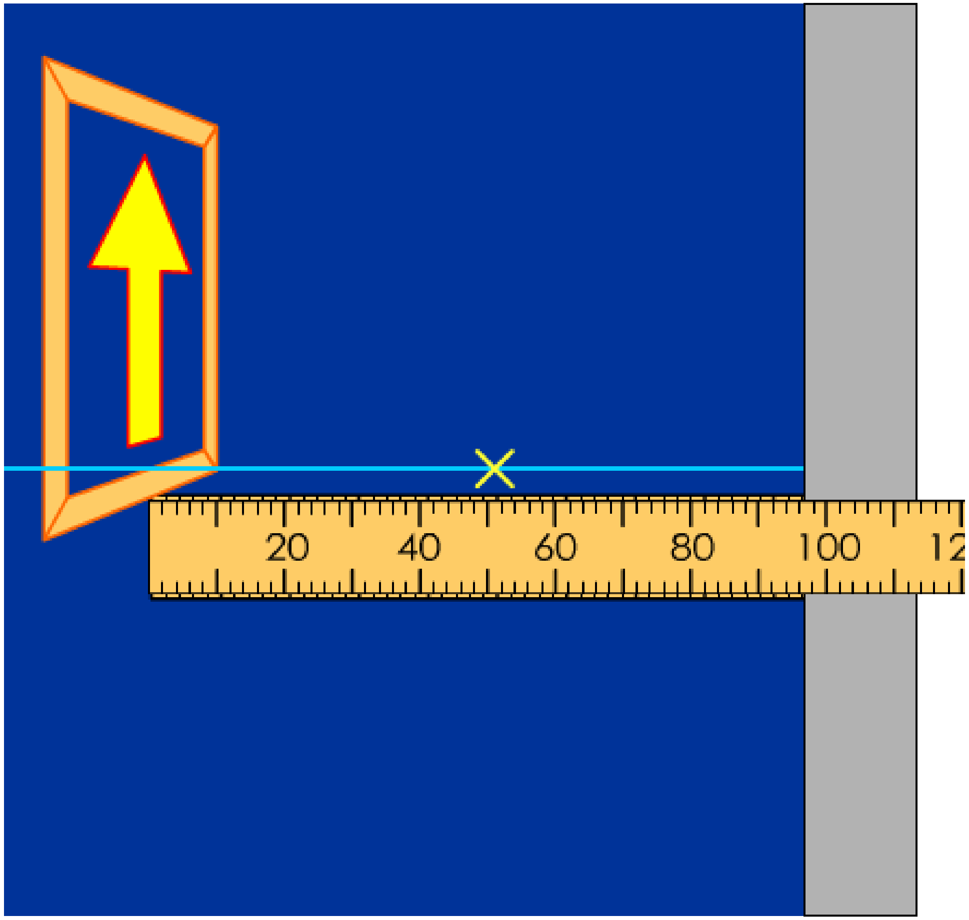
B. Smaller

C. Larger

D. Same size

E. Smaller

If you move the arrow towards the mirror, the image will be



A. Same size

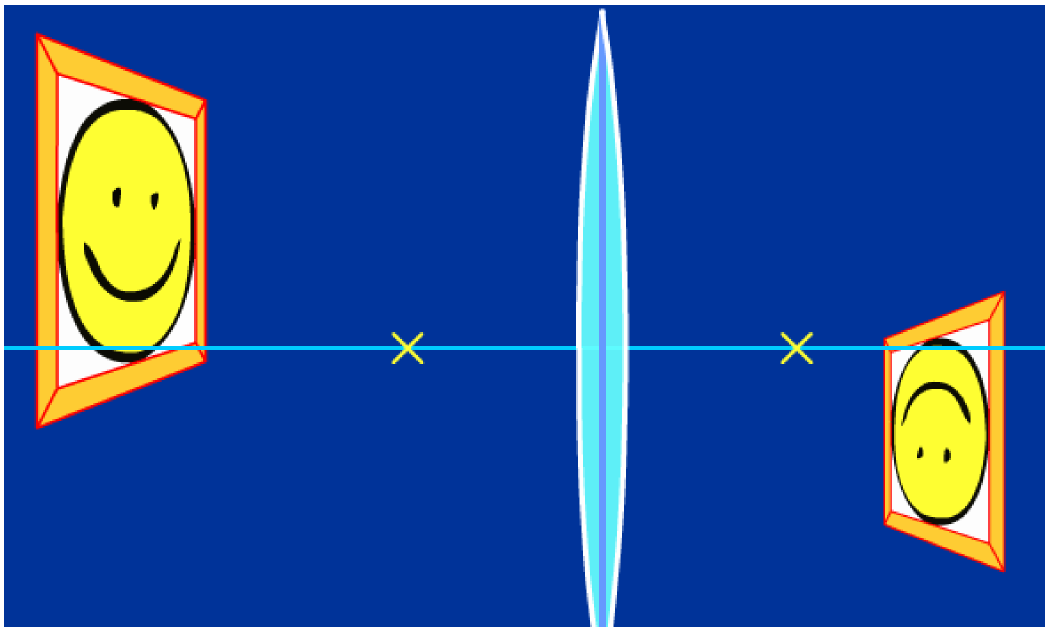
B. Smaller

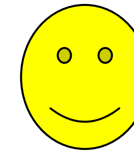
C. Larger

D. Same size

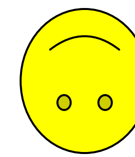
E. Smaller

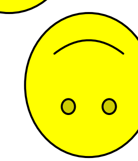
If the lens had a lower index of refraction, the image be

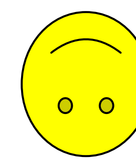


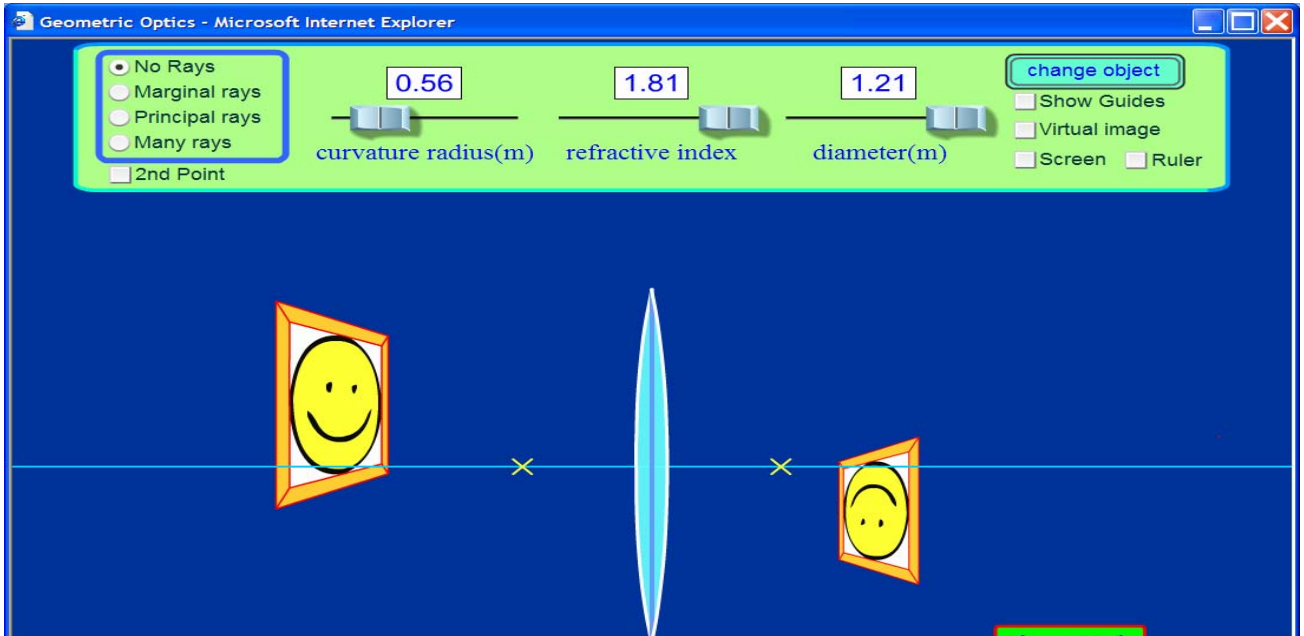
A. Same size 

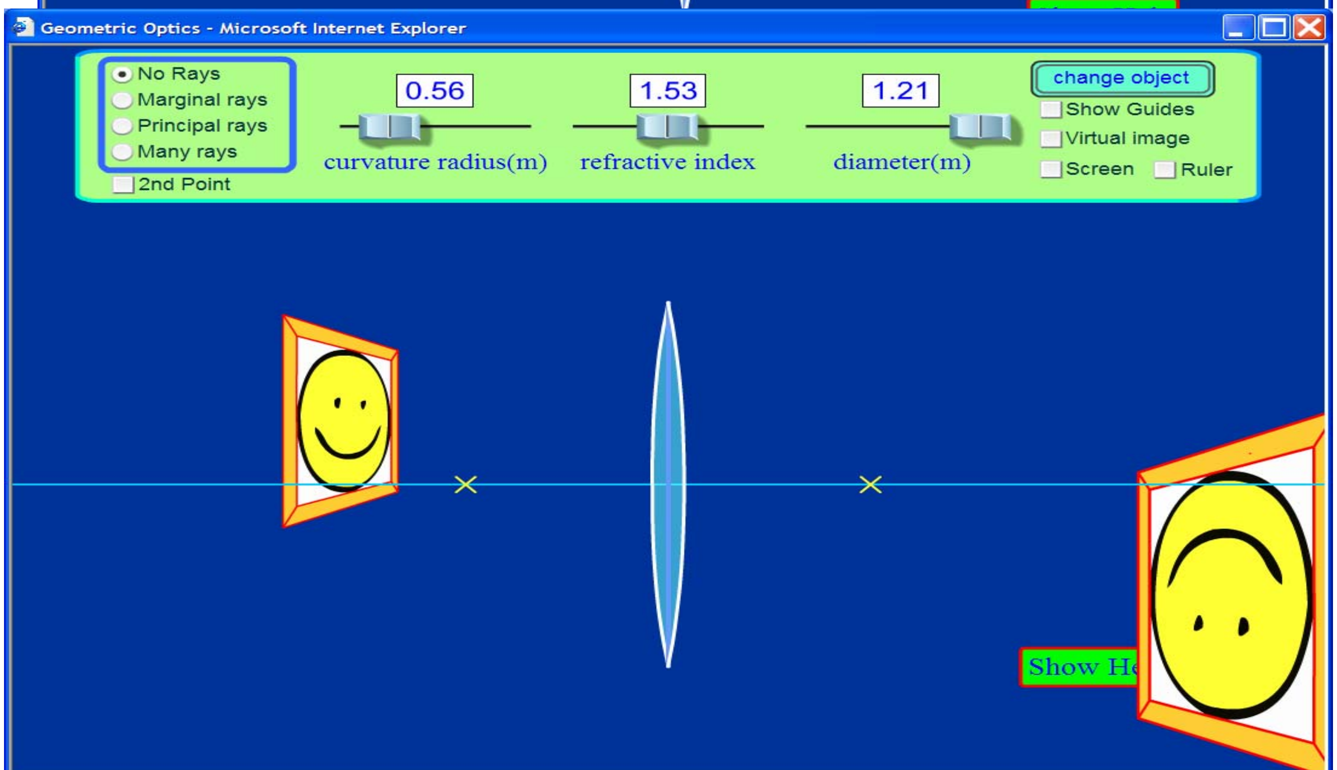
B. Smaller 

C. Larger 

D. Same size 

E. Smaller 


Geometric Optics - Microsoft Internet Explorer
No Rays
Marginal rays
Principal rays
Many rays
2nd Point
0.56
curvature radius(m)
1.81
refractive index
1.21
diameter(m)
change object
Show Guides
Virtual image
Screen
Ruler


Geometric Optics - Microsoft Internet Explorer
No Rays
Marginal rays
Principal rays
Many rays
2nd Point
0.56
curvature radius(m)
1.53
refractive index
1.21
diameter(m)
change object
Show Guides
Virtual image
Screen
Ruler

Resonance

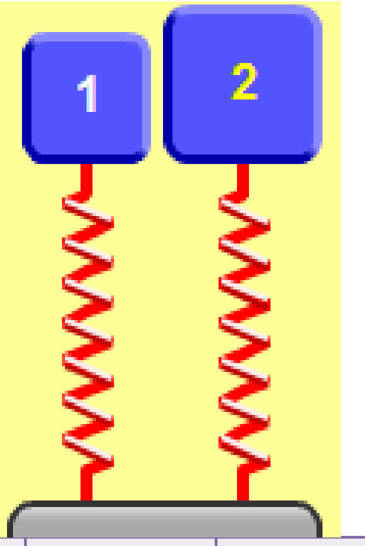
Clicker questions

by Trish Loeblein and Mike Dubson

Learning Goals: Students will be able to:

1. Describe what resonance means for a simple system of a mass on a spring.
2. Identify, through experimentation, cause and effect relationships that affect natural resonance of these systems.
3. Give examples of real-world systems to which the understanding of resonance should be applied and explain why. (not addressed in CQs)

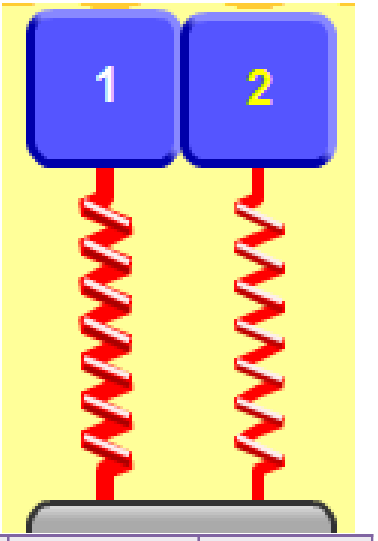
1. **Which system will have the lower resonant frequency?**



Mass (kg)	**2.5**	**5.0**
Spring constant (N/m)	**100**	**100**

A) 1   B) 2 C) Same frequency

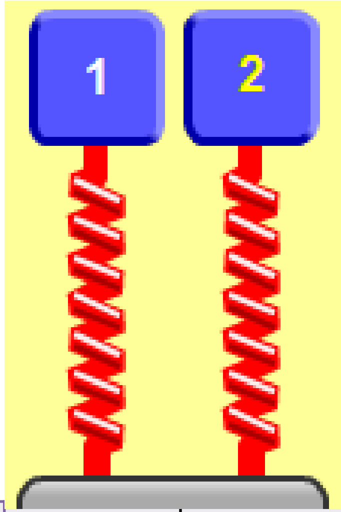
2. **Which system will have the lower resonany frequency?**



Mass (kg)	**5.0**	**5.0**
Spring constant (N/m)	**200**	**100**

A) 1   B) 2 C) Same frequency.

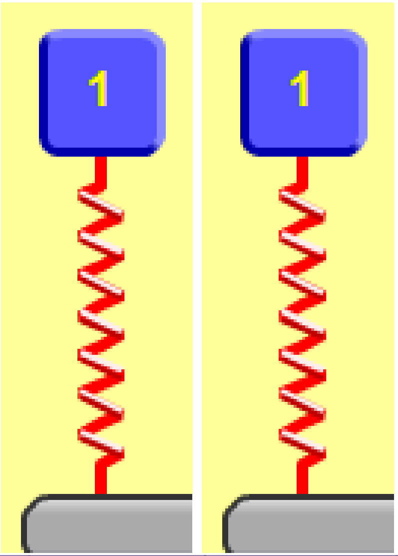
3. **Which system will have the lower resonance frequency?**



Mass (kg)	3.0	3.0
Spring constant (N/m)	400	400
Driver Amplitude (cm)	0.5	1.5

A) 1 B) 2 C) Same frequency.

4. **Which best describes how the motion of the masses vary?**



A. Less driver amplitude results in greater max height & faster oscillation

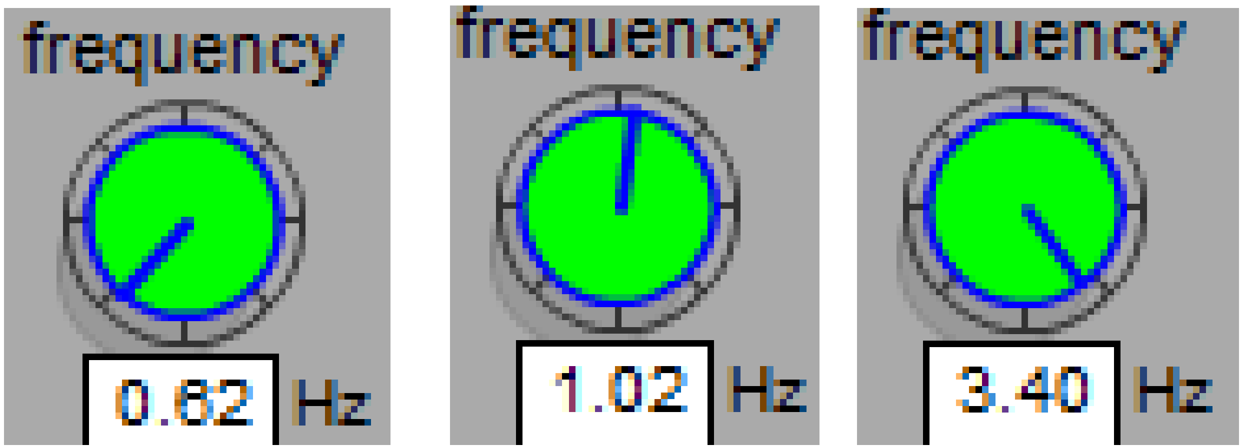
B. More driver amplitude results in greater max height & faster oscillation

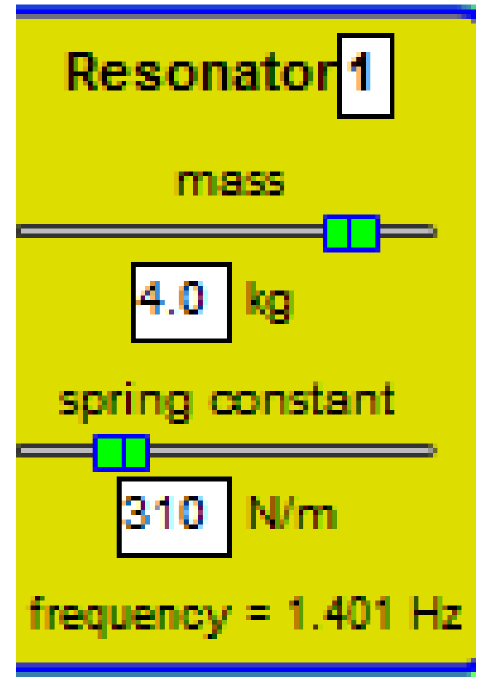
C. Less driver amplitude results in greater max height

D. More driver amplitude results in greater max height

Mass (kg)	3.0	3.0
Spring constant (N/m)	400	400
Driver Amplitude (cm)	0.5	1.5

4. **If the frequency f of the driver is not the same as the resonant frequency, which statement is most accurate?**





The steady-state amplitude is ..

a) **smallest at the highest driver f.**

b) **largest at the highest driver f.**

c) **is largest at driver f nearest the resonant frequency.**

d) **is independent of driver f.**