8th Grade Science Unit:
Earthly Waves
Unit Snapshot

Topic: Physical Earth	
Grade Level: 8	**Duration:** **9 days**

Summary:
The following activities allow students to experience the differences of speeds at which S and P seismic waves travel through the earth which demonstrates how scientists have determined the different layers of the Earth.

Clear Learning Targets
"I can"…statements

____ compare and contrast the speed and movement of different seismic waves.
____ evaluate seismic data and relate it to how scientists have determined the layers of Earth's interior.
____model and explain how S and P waves move through the earth.

Activity Highlights and Suggested Timeframe

Day 1	**Engagement**: Teacher prompts students with questions about earth's interior. Students examine and theorize how to determine what is inside a mystery cup which relates to how scientists understand and study Earth's interior.
Days 2-3	**Exploration**: The objective of this activity is to give students the opportunity to investigate the reflection and refraction of seismic waves. Students will observe an online earthquake simulation.
Day 4	**Explanation**: Students will utilize the textbook to research the answers to their questions from the engagement activity. Prentice Hall Earth Science pg124-135.
Day 5-7	**Elaboration**: Students will use seismic wave data to determine the depth range of each layer of Earth and well as provide evidence to support the claims of other seismologists.
Day 8 and on-going	**Evaluation**: The objective of the assessments is to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the lesson, and to become aware of students misconceptions related to the seismic waves and the layers of Earth's interior. A teacher-created short-cycle assessment can be used to assess all learning targets (Day 8)
Day 9	**Extension/Intervention**: Based on the results of the short-cycle assessment, facilitate extension and/or intervention activities.

LESSON PLANS

NEW LEARNING STANDARDS:

8.ESS.1B – The composition and properties of Earth's interior are identified by the behavior of seismic waves.

- The refraction and reflection of seismic waves as they move through one type of material to another is used to differentiate the layers of Earth's interior. Earth has an inner and outer core, an upper and lower mantle, and a crust.

Note: The thicknesses of each layer of Earth can vary and be transitional, rather than uniform and distinct as often depicted in textbooks.

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:

During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering)that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Framework for K-12 Science Education Scientific and Engineering Practices

COMMON CORE STATE STANDARDS for LITERACY in SCIENCE:

CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

CCSS.ELA-Literacy.WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

**For more information:* http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf

STUDENT KNOWLEDGE:

Prior Concepts

K-2: Properties of materials can change. Pushing and pulling can affect the motion of an object.

Grades 3-5: Forces change the motion of an object. Rocks have specific characteristics. Heat is a form of energy. Energy can be conserved. Earth's surface has specific characteristics. Heat results when materials rub against each other. Gravitational force and magnetism also are studied.

Grades 6-7: Rocks have characteristics that are related to the environment in which they form. Thermal energy is a measure of the motion of the atoms and molecules in a substance. Energy can be transformed, transferred and conserved. Thermal energy can be transferred through radiation, convection and conduction.

Future Application of Concepts

High School: Thermal energy, gravitational energy, radioactive decay and energy transfer are studied. In the grades 11/12 Physical Geology course, further studies of plate tectonics, seismology and volcanism are found.

MATERIALS:	VOCABULARY:
Engage • Worksheet "Engage Mystery Cup" • Mystery Cup (A paper or thin plastic cup with wax paper covering the lid). The wax paper lid acts as a translucent viewing if it is held up to a light source. A sphere "cup" would be ideal for students to translate the conversation to earth's interior. **Explore** • Worksheet for online simulation "Explore Seismic Waves Online Simulation" • Projector and internet access for teacher **Explain** • "Mystery Cup Explained" handout • Earth Science Textbook **Elaborate** Mapping Earth's Interior: • Worksheets "Mapping Earth's Interior" • Projector and internet access for teacher What's Your Wave?: • Large space indoors or outdoors preferred • Clipboards • Sidewalk chalk or masking tape to draw/label a model of Earth's layers on the ground. • Large Index cards numbered 1-15 to place around the circle • Student Task Cards 1-20 • Student worksheet "What's Your Wave?"	Primary P wave S wave Seismic Waves Reflection Refraction Secondary Crust Density Inner Core Mantle Outer Core Seismograph Seismologist

SAFETY	• All CSS Safety and Laboratory Procedures/Rules apply.	
ADVANCED PREPARATION	• Gather materials for laboratory investigations • Copy student worksheets and articles • Create one or more mystery boxes with an object inside. • Preview online simulation. • If completing the Earthquake walk outside, plan ahead and check the weather forecast. If completing the activity inside, identify and reserve the space. • Teacher needs to mark the area that students will be using for the activity. See activity page.	
ENGAGE **(1 day)** (What will draw students into the learning? How will you determine what your students already know about the topic? What can be done at this point to identify and address misconceptions? Where can connections be made to the real world?)	**Objective:** The objective of this activity is to engage students and assess student knowledge related to the study of Earth's interior through a mystery box activity.	
	What is the teacher doing? **Mystery Cup (Day 1)** • Preparation prior to activity: Mystery Cup (A paper or thin plastic cup with wax paper covering the lid). The wax paper lid acts as a translucent viewing if it is held up to a light source. A sphere "cup" would be ideal for students to translate the conversation to earth's interior.	*What are the students doing?* **Mystery Cup (Day 1)**

	• Distribute entrance ticket to students. • Read the questions aloud to them. • Prompt students to share and explain their conjectures. • Show students the Mystery Cup. • Have students hypothesis how we can figure out what is inside of it without shaking it, cutting it open, or disturbing it in any way. (Expected answers include using some type of tool (i.e. X-ray.) • Discuss with students how they think scientists know what is inside the earth. • This activity should be used as a formative assessment for the teacher to collect misconceptions and also assess prior knowledge.	1. Students answer questions on the "Engage Mystery Cup" student handout. 2. They share their ideas and are involved in a class discussion. 3. Students examine the mystery cup from afar and determine how they could discover what is inside of it without disturbing it. 4. Students transfer their ideas about the mystery cup to the earth and how scientists know what is inside the earth.
EXPLORE **(2 days)** (How will the concept be developed? How is this relevant to students' lives? What can be done at this point to identify and address misconceptions?)	**Objective:** The objective of this activity is to get students to visualize how S and P waves move and create earthquakes as well as guide scientists into understanding what is inside the earth using an on-line simulation. *What is the teacher doing?* **Refraction and Reflection of Seismic Waves (Days 2-3)** **Day 2** Online Simulation: http://aspire.cosmic-ray.org/Labs/SeismicWaves/ • See Teacher Page • Project the online simulation on a projector or SMARTBoard in the front of your classroom. • Lead students through the simulation, discussing what is going on in the diagram. • The webpage is interactive; if you have a SMARTBoard you may consider having students volunteer to move labels to corresponding areas of diagram during interactive class discussion. • Stop and discuss worksheet questions as you go through simulation. • Pull out the mystery cup and relate it to the simulation.	*What are the students doing?* **Refraction and Reflection of Seismic Waves (Days 2-3)** **Day 2** Online Simulation: 1. Actively engaged in simulation on board and class discussion 2. Asking clarifying questions 3. Filling out corresponding worksheet 4. Relating the simulation to the mystery cup and to what they already know about the layers of the Earth.

	Day 3 Online Simulation: http://aspire.cosmic-ray.org/Labs/SeismicWaves/ • See Teacher Page • This activity can be completed as a class with the teacher as the facilitator, or individual/partner work if laptops, Ipads, or computer lab is available. • Project the same on-line simulation on to the board as day 2 or assist students in finding the website if they are using individual devices. • Reference the Earth Science Textbook pp. 170-171 if needed.	**Day 3** Online Simulation: 1. Actively engaged in the on-line simulation on the board/individual devices. 2. Students complete the corresponding worksheet as a guide and for assessment. 3. Students relate the simulation to the mystery cup and to what they already know about the layers of the Earth.
EXPLAIN **(1 day)** (What products could the students develop and share? How will students share what they have learned? What can be done at this point to identify and address misconceptions?)	**Objective:** The objective of this activity is to cite contextual evidence from the textbook and revisit student answers from the Engage section of the unit, while also reviewing the layers of the earth.	
	What is the teacher doing? **Mystery Cup Explained (Day 4)** • Hand back student Engage worksheets " Engage Mystery Cup" • Have students revisit their engage paper from the activity. • Walk around and clarify questions/ misconceptions as students answer questions. • Handout "Mystery Cup explained" and ensure that students are citing the text (pp.124-127) to support their answers. • Ask students: What ideas did you have correct? What ideas can you now clarify with your new knowledge from today? • Students should be able to relate a seismograph to the study of earth's layers as the tool they were discussing during engage.	*What are the students doing?* **Mystery Cup Explained (Day 4)** • Complete a close read with the "Mystery Cup explained" handout. • Actively reading text from the Earth Science Textbook (pp.124-127) • Answering questions with full-sentences using data and information gained from the book • Thinking back to their answers from yesterday and clarifying/correcting their responses. 1.

ELABORATE **(3 days)** (How will the new knowledge be reinforced, transferred to new and unique situations, or integrated with related concepts?)	**Objective:** Students will use seismic wave data to determine the depth range of each layer of Earth and well as provide evidence to support the claims of other seismologists. As a summative assessment and/or reinforcement, students will model the movement of seismic waves going through the earth.	
	What is the teacher doing? **Mapping Earth's Interior (Days 5-6)** • TEACHER BACKGROUND - Consider watching the following video tutorial from Khan Academy for background information related to S and P waves and the composition of the Earth. http://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-techtonics/v/how-we-know-about-the-earth-s-core • See TEACHER PAGE • Show the Discovery Ed videoclip: Inside our Planet [6:59] • Facilitate a read-aloud of page 1 of the student handout. • Assist students with graphing of S and P wave data and answering questions using their graphs. • Divide students into small groups and assign one of the provided Seismologist Claims. • Assist students with citing evidence from their data and graphs that support the claim. • Have each group share their supporting evidence for each claim. **What's your wave? (Day 7)** TEACHER PREPARATION • Suggested - Reserve a large space outside, the playground is ideal as you can use sidewalk chalk to draw a model of Earth's Layers. If outside space is not available,	*What are the students doing?* **Mapping Earth's Interior (Days 5-6)** 1. Students watch the video clip and write down any questions that they have. 2. Students are engaged in reading Page 1 of the student handout. 3. Students graph P and S wave data using provided graph paper. 4. Students use their graph to respond to questions on their student handout. 5. In assigned groups, students must cite evidence from their graph that supports a claim. 6. Share with the class. **What's your wave? (Day 7)**

	the gym or a large open classroom will also work. • If possible draw a circle or use masking tape on the ground large enough to fit a large class of students around it. • Repeat to show the layers of the Earth inside the large circle. • Place the index cards 1-20 in numerical order around the outside of the circle. • See Teacher Page • Divide students into pairs. • Distribute a Student task/question card to each student pair. It will tell them what action they will be responsible for and the question that they will ask their classmates. • Distribute student worksheets and clip boards(if available). • Discuss the directions before moving to the large open space. • Facilitate the activity by directing each student pair to perform their task on their card one at a time, and then ask their question. • Assist students as they fill out their student sheet. • Follow-up with a class discussion to assess student answers. OPTIONAL Reinforcement: • Earth Science Textbook – Enrich…Differences in Arrival Time (can be found in the Earth Science Textbook All-in-one Teaching Resources Unit 1 book p.310)	1. Student pairs are given a task card with a number on it, a task, and a question. 2. Students stand around the circle by their number. 3. As directed by the teacher, each student performs his/her task that is on the card. The student then asks the question on their card. 4. After each student asks his/her question, the rest of the class writes their answer on their student sheet.

<table>
<tr><td rowspan="2">EVALUATE
(on-going)
(What opportunities will students have to express their thinking? When will students reflect on what they have learned? How will you measure learning as it occurs? What evidence of student learning will you be looking for and/or collecting?)</td><td colspan="2">Objective: The objective of the assessments is to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the lesson, and to become aware of students misconceptions related to the seismic waves and the layers of Earth's interior. A teacher-created short-cycle assessment can be used to assess all learning targets (Day 8)</td></tr>
<tr><td>Formative
How will you measure learning as it occurs?
• Consider developing a teacher-created formative assessment
1. The Mystery Cup activity can used to formatively assess student's prior knowledge related to how scientists study Earth's interior.
2. The Mystery Cup Explained and Mapping Earth's Interior activities can be used to assess student knowledge related to how scientists use seismographs and seismic data to understand the composition of the Earth.</td><td>Summative
What evidence of learning will demonstrate to you that a student has met the learning objectives?
1. What's your Wave? Activity can be used to assess knowledge of seismic waves, the layers of the earth, and how seismic waves are used to study Earth's interior.
2. Teacher-created short cycle assessment will assess all clear learning targets.</td></tr>
<tr><td>EXTENSION/
INTERVENTION
(1 day or as needed)</td><td>EXTENSION
1. Earth Science Textbook Technology Lab: Design a Seismograph (Can be found in All-In-One Teaching Resources Unit 1 Book pp.402-403 or Laboratory Manual pp.50-51.
2. Earth Science Textbook Laboratory Investigation: Investigating the Speed of Earthquake Waves (Can be found in All-In-One Teaching Resources Unit 1 Book pp.414-417 or Laboratory Manual pp.52-55.
3. Write a narrative from the perspective of a P wave or S wave going through the various layers of the earth.</td><td>INTERVENTION
1. www.unitedstreaming.com related videos
2. Earth Science Textbook Earth's Interior Guided Reading and Study (can found in the All-in-one Teaching Resources pp.304-308.)
3. Earth Science Textbook Earth's Interior Review and Reinforce (can found in the All-in-one Teaching Resources p.309)
3. How do Seismic Waves Travel Through Earth? Discovery Activity. Earth Science Textbook p. 169.</td></tr>
<tr><td>COMMON MISCONCEPTIONS</td><td colspan="2">Strategies to address misconceptions:
• Earth's interior is hollow
• Earth's interior is one solid mass
• All earth's layers are solid materials.
• All seismic waves travel through all materials
• All seismic waves travel in straight lines
• Scientists have been able to study the layers of the Earth, by digging deep into the Earth and taking samples of materials.</td></tr>
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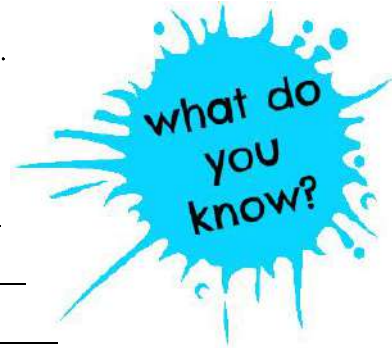
	Misconceptions can be addressed through the use of www.unitedstreaming.com video clips, pictures/diagrams of seismic waves and Earth's layers, as well as through the use of models.
DIFFERENTIATION	Lower-level: Provide additional text resources (tradebooks, articles) that are appropriate for the reading level of the student. For the Investigation Labs consider mixed grouping strategies. Integrate www.unitedstreaming.com videos into instruction. Higher-Level: Consider having students create their own tasks and questions for the What's Your Wave? Activity. Consider assigning extension activities. Strategies for meeting the needs of all learners including gifted students, English Language Learners (ELL) and students with disabilities can be found at the following sites: ELL Learners: http://www.ode.state.oh.us/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=105521 Gifted Learners: http://www.ode.state.oh.us/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=105522 Students with Disabilities: http://www.education.ohio.gov/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=105523
ADDITIONAL RESOURCES	**Textbook Resources:** *Pearson/Prentice Hall Earth Science* Textbook • Chapter 6.1 Earth's Interior pp.124-131 • Chapter 6.2 Earthquakes and Seismic Waves pp. 169-175 • Chapter 6.3: Monitoring Earthquakes pp.178-185 **Websites:** • The USGS provides seismic data for all 50 states, including real-time data, at: http://earthquake.usgs.gov/earthquakes/states/?old=top_states.html • http://geophysics.ou.edu/solid_earth/notes/seismology/seismo_interior/seismo_interior.html • http://www.visionlearning.com/library/module_viewer.php?mid=69 • Annenberg Learner – Earth and Space Science Session 3: http://www.learner.org/courses/essential/earthspace/session3/closer2.html • P and S Wave Animation: http://www.classzone.com/books/earth_science/terc/content/visualizations/es1009/es1009page01.cfm?chapter_no=visualization **Discovery Ed/Other Video Links:** • Inside our Planet [6:59] • Types of Waves [1:15] • Seismology [3:38] • The Earth's Interior [3:33] • Teacher Background: http://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-techtonics/v/how-we-know-about-the-earth-s-core

	Literature: • Gallant, Roy. (2003). Exploring Earth's Interior. New York: Benchmark Books. • West, Krista, (2009). Layers of the Earth. New York: Chelsea House. • Mathez, Edmond A. (2001). Earth: Inside and Out. New York: New Press.

Name:________________________________ Date:__________ Period:_________

Engage Mystery Cup



Expectations: Try to answer all questions. Getting the correct answer is not necessary. I want to know what you know. ***Write in Full-Sentences.***

1. What methods do you think scientists could use to discovery what is inside the Earth? ______________________________

2. What do you think is inside the Earth? Why do you think that?

3. Observe Mystery Cup – The mystery cup is a lot like the Earth. We cannot shake it, we cannot cut it open, and we cannot disturb it. How could we find out what is inside of it? Brainstorm ideas.

- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________

4. Why haven't scientists been able to journey to the center of the Earth? Be detailed.

Reflection and Refraction of Seismic Waves - TEACHER PAGE

(Day 1 of 2)

Use the on-line simulations on the following website:
http://aspire.cosmic-ray.org/Labs/SeismicWaves/

1. Read the information to the class about Seismic Waves, or allow students to read to themselves.
2. See simulation directions below….Using the Mighty Wave Maker simulator, show the movement of both S waves (transverse waves – up and down) and P Waves (longitudinal waves – forward and back). *Students may be familiar with this topic, as waves are included in the 7th grade physical science standards.
3. Students answer the following questions during the simulation manipulation.

P Waves

1) P waves (pressure or primary waves) travel as a region of compression. How would this appear? Using the simulation make the green dots move left and right. Observe what happens to the distance between the dots. During compression, the dots move:
A) closer together or B) further apart.

2) This wave is similar to the way _______________________ travel through air.
A) sound or B) light waves

3) As a P wave travels, the green dots vibrate back and forth __________ to the direction of wave travel.
A) parallel or B) perpendicular

P waves are the fastest kind of seismic wave. A longitudinal P wave has the ability to move through solid rock and fluid rock, like water or the semi-liquid layers of the earth. It pushes and pulls the rock it moves through in the same way sound waves push and pull the air. Have you ever heard a big clap of thunder and heard the windows rattle at the same time? The windows rattle because sound waves push and pull on the glass much like P waves push and pull on rock. Sometimes animals can hear the P waves of an earthquake, but usually humans only feel the "bump" of these waves.

S Waves

4) S waves (shear waves) travel like vibrations in a bowl of Jello. How would this appear? Using the diagram above, make the green dots move up and down.
A) Does the distance between the green dots change, or
B) Is the rectangular shape between the dots distorted?

5) The movement of the green dots is _____________ to the direction of the wave travel. As an S wave travels, the material is distorted but the green dots do not compress (the space between them pretty much stays the same.)

A) parallel or **B) perpendicular**

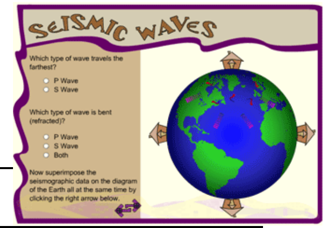
S waves are the second wave you feel in an earthquake. An S wave is slower than a P wave and only moves through solid rock. This wave moves rock up and down, or side-to-side.

Because P waves are compression waves, they can move through a liquid. However, S waves cannot move through a liquid. This is because a liquid is not rigid enough to transmit an S wave. S waves travel more slowly than P waves and, again, S waves cannot travel through a liquid.

So how can scientists use this information about wave travel to determine the internal structure of planet Earth? P and S waves, which are usually generated by earthquakes, volcanoes, or large objects like meteors hitting the earth, can also be produced by man using explosives or other large machinery. Scientists have used this method to gather evidence about the Earth's internal structure. You need just a tiny bit more information regarding this, and then you can try it out for yourself!

Name:____ Date:___________ Period:__________

Explore Seismic Waves - Online Simulation



http://aspire.cosmic-ray.org/Labs/SeismicWaves/

Define P waves: ____

Define S waves: ____

Color of P wave in simulation :__________ Color of S waves in simulation:__________

As a class, experiment with the four seismograph locations to answer the following questions.

1. What type of wave travels the farthest? A. P wave B. S wave

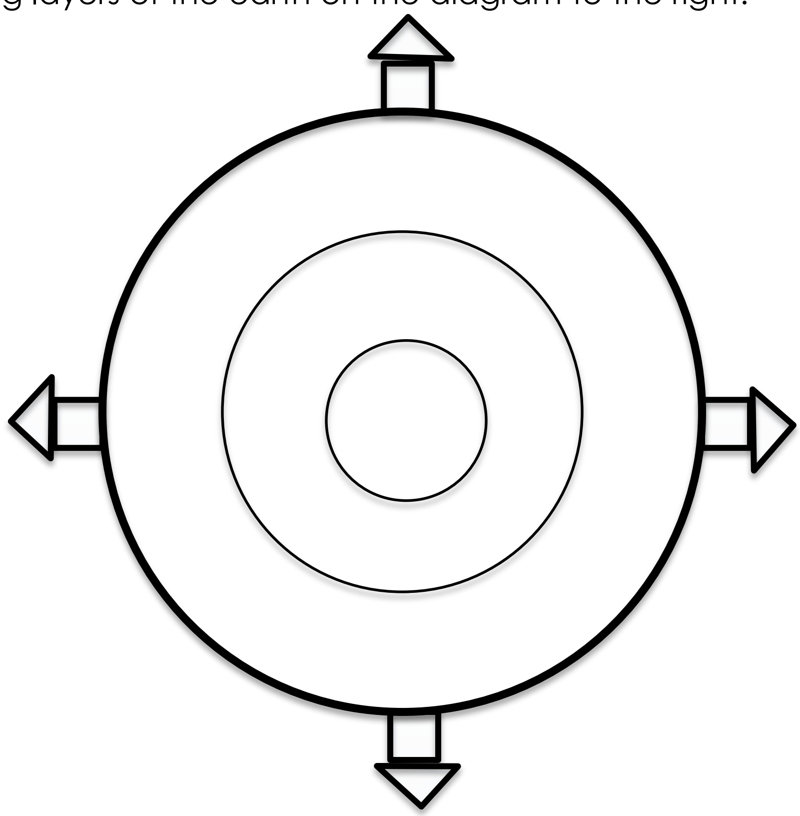
2. What type of wave is bent (refracted)? ____________________

3. Guessing from the behavior of the waves shown here, how many layers of the Earth's interior are there? What observations lead you to your choice?

A. 1 ____
B. 2
C. 3 ____
D. 4 or more ____

4. Label the following layers of the earth on the diagram to the right:

Inner Core
Liquid Core
Mantle
Crust



5. Observe the simulation. What type of wave goes through the earth's center (core)?

____

6. P waves do not go through solids. P waves do not go through the earth's core. This indicated the earth's core is a _______________.

7. Do you think that density would increase or decrease the closer a molecule or particle gets to the center of the earth?

A. Increase B. Decrease

8. Do you think that pressure would increase or decrease the closer a molecule or particle gets to the center of earth?

A. Increase B. Decrease

9. Do you think the temperature would increase or decrease the closer a molecule or particle gets to the center of the earth?

A. Increase B. Decrease

10. Mantle: Would you expect the density of the mantle to be greater or less than the density of the core? Explain your answer using S and P waves.

____

____

11. Would you suspect the density of the mantle to be greater or less than the crust? Why?

____

____

12. Do P waves travel through the mantle? ____ Do S waves travel through the mantle? ____

13. Do you think the mantle is a solid or a liquid? ____

14. Would you expect the crust to be less dense or have a greater density than the mantle?

A. Crust is less dense than mantle B. Crust has a greater density than mantle

15. What is the crust's average density? ___________ units ________

What is the mantle's average density? _________ units ________

Name: **ANSWER KEY**______________________________ Date:__________ Period:__________

Explore Seismic Waves Online Simulation

http://aspire.cosmic-ray.org/Labs/SeismicWaves/

Define P waves: ***P waves* are the fastest seismic waves. A longitudinal earthquake wave that travels through the interior of the earth.**

Define S waves: **S waves are *transverse shear waves*. They cause side-to-side motion perpendicular to their direction of travel.**

Color of P wave in simulation : **Pink**
Color of S waves in simulation: **Red**

As a class experiment with the four seismograph locations to answer the following questions.

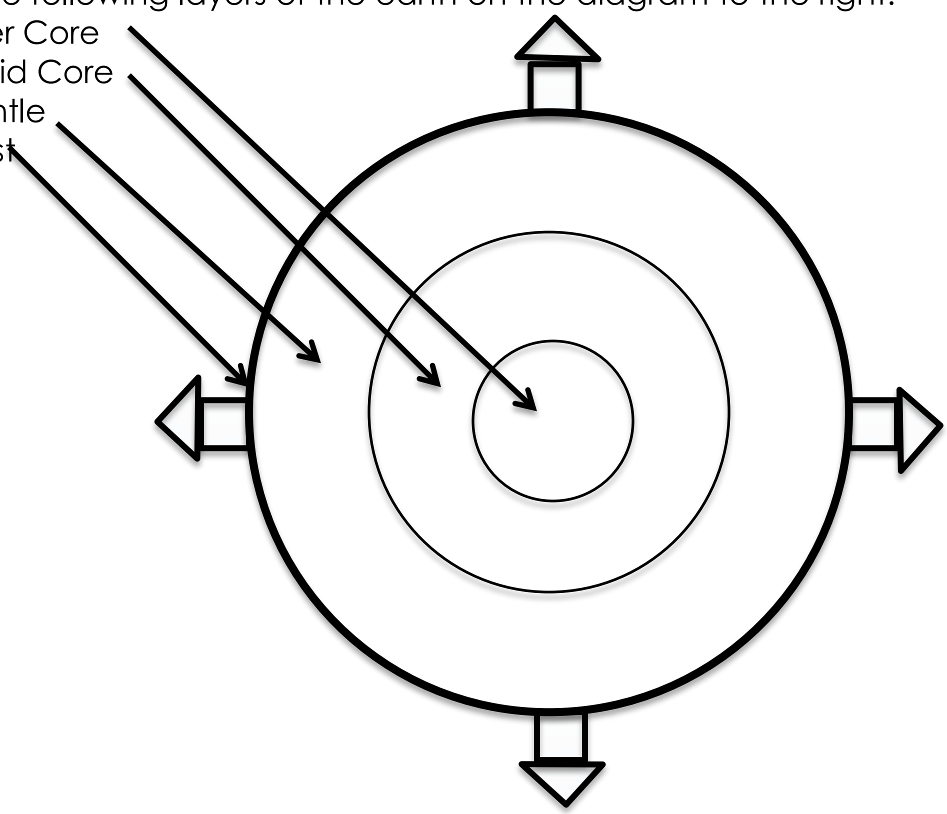
1. What type of wave travels the farthest? **A. P wave** B. S wave

2. What type of wave is bent (refracted)? _____**Both**______________

3. Guessing from the behavior of the waves shown here, how many layers of the Earth's interior are there? What observations lead you to your choice?
   A. 1
   B. 2
   C. 3
   D. 4 or more

   Can see a pattern of 3 types of wave behavior making 3 concentric circles. These are the inner core, outer core and mantle.

4. Label the following layers of the earth on the diagram to the right:
   Inner Core
   Liquid Core
   Mantle
   Crust



5. Observe the simulation. What type of wave goes through the earth's center (core)? **NONE**

6. P waves do not go through solids. P waves do not go through the earth's core. This indicated the earth's core is a **Solid.**

7. Do you think that density would increase or decrease the closer a molecule or particle gets to the center of the earth?

A. Increase B. Decrease

8. Do you think that pressure would increase or decrease the closer a molecule or particle gets to the center of earth?

A. Increase B. Decrease

9. Do you think the temperature would increase or decrease the closer a molecule or particle gets to the center of the earth?

A. Increase B. Decrease

10. Mantle: Would you expect the density of the mantle to be greater or less than the density of the core? Explain your answer using S and P waves. **I would expect the mantle to be less dense than the inner core because P waves do go through it so it is a liquid. Liquids are less dense than solids. The mantle is *floating* on the inner core because it is less dense.**

11. Would you suspect the density of the mantle to be greater or less than the crust? Why? **The mantle is denser than the crust because as you get closer to the inner core gravity increases.**

12. Do P waves travel through the mantle? **yes** Do S waves travel through the mantle? **yes**

13. Do you think the mantle is a solid or a liquid? **Liquid (Plastic)**

14. Would you expect the crust to be less dense or have a greater density than the mantle?

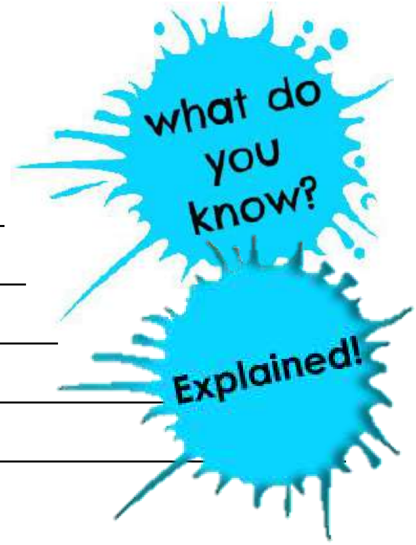
A. crust is less dense than mantle B. Crust has a greater density than mantle

15. What is the crust's average density? **2.5-3.5** units **g/cm3**

What is the mantle's average density? **2.5-5.8** units **g/cm3**

Name:____ Date:__________ Period:_________

"Mystery Cup" **Explained**



Close Reading Expectations: Use the Earth Science textbook to answer the following questions. Cite specific text to support your answer. ***Write in Full-Sentences.***

1. What methods do scientists use to discover what is inside the Earth?(pp. 124-26)

2. What is inside the Earth? Why do scientists think that? (pp.128-130)

3. Hold the mystery cup up to a strong light source. Can you see more of what's inside? If a heat source was inside the cup, how do you think your observations would change?

4. Why haven't scientists been able to journey to the center of the Earth? Cite the textbook examples or an analogy (p.127)

- Consider watching the following video tutorial from Khan Academy for background information related to using S and P waves to understand the composition of the Earth. http://www.khanacademy.org/science/cosmology-and-astronomy/earth-history-topic/plate-techtonics/v/how-we-know-about-the-earth-s-core

Background Information:

Seismic reflection: Seismic waves bounce (reflect) off rock boundaries of different rock type, and their travel times are recorded on a **seismogram**. The seismogram records the time it took for the waves to travel to the boundary, reflect off of it and return to the surface. Seismologists can measure the time this takes and calculate the depth to the boundary.

Seismic waves reflect off of a rock boundary in the earth and return to a seismograph station on the surface.

Seismic refraction: Waves change velocity and direction (refract) when they enter a medium of different density than the one they just passed through.

Seismic Waves will travel at different speeds depending on the **medium** or materials through which the wave is traveling. Examples:

Low-velocity layer: Seismic wave travels slow. *Example: Granite*
High-velocity layer: Seismic wave travels fast. *Example: Gabbro*

Research from seismic reflection and refraction has led to important discoveries such as:

1. There are four main layers of the Earth: The crust, mantle, outer core, and inner core.

2. The continental crust is thicker than oceanic crust and seismic waves travel slower in the continental crust meaning that they are made up of different kinds of rock (granite/basalt).

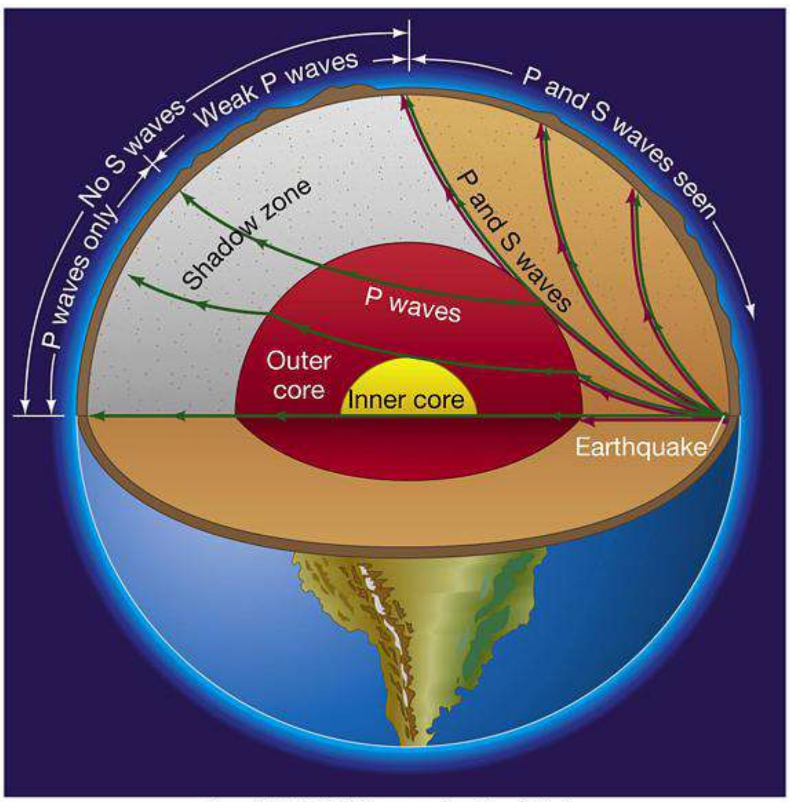
3. There is a distinct boundary between the crust and the mantle called the Mohorovicic discontinuity, or, simply, the Moho. At this boundary, seismic waves are refracted. This is supported through seismic data in which wave speed changes at the boundaries between layers.

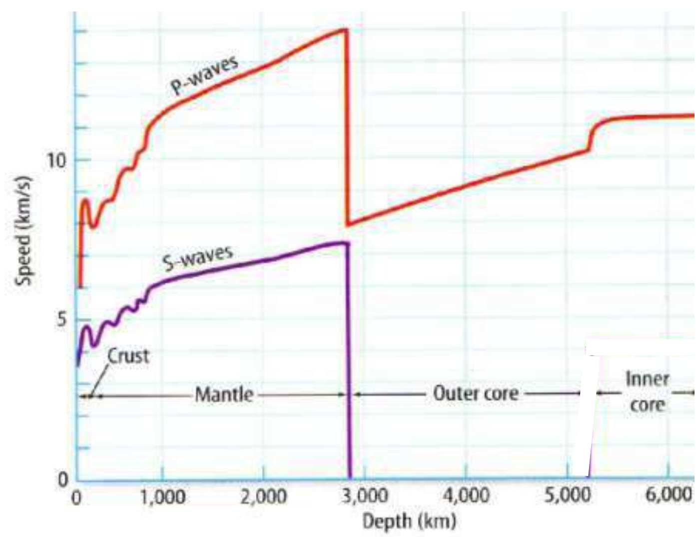
4. There is a layer within the mantle up to 70 km thick beneath the ocean and up to 250 km thick beneath the continents where waves travel slower than in more shallow layers. This layer is called the low-velocity zone, and scientists have concluded that this zone is at least partially liquid. In plate-tectonic theory, it is called the asthenosphere, which is the semi-molten region of the earths' interior just below the earth's rigid crust that allows for tectonic plate movement.

5. P-waves can pass through the outer core but S-waves cannot since S-waves only travel through solids. The outer core is a molten liquid.
    - S-waves cannot travel through liquids because they are shear waves, which attempt to change the shape of what they pass through. Simply put, a liquid "doesn"t care" what shape it's in—for example, you can empty a bottle of water into an empty box, and it will change shape with the shape of container. Liquids cannot support shear stresses, so shearing has no effect on them. Therefore, a liquid will not propagate shears waves.

6. Both P- and S-waves slow down when they reach the asthenosphere. Because of this, scientists know that the asthenosphere is partially liquid

7. Changes in velocity (km/s) of P- and S-waves allow seismologists to identify the locations of boundaries within the earth such as the Mohorovicic boundary near the earth's surface and the boundary between the mantle and outer core.





Name________________________________Date___________________________Period____

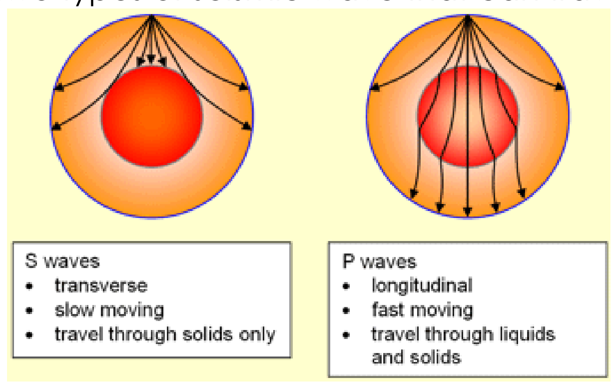
Mapping Earth's Interior

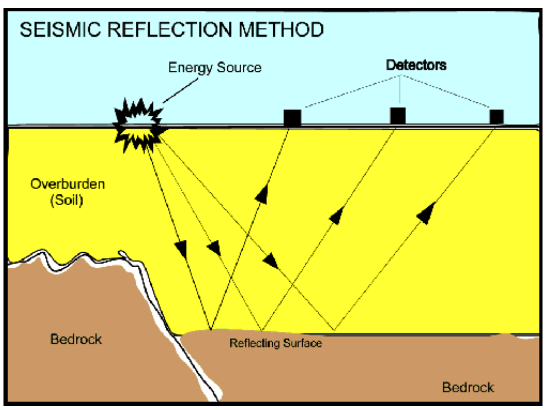
Earthquakes happen when large parts of the Earth's crust and upper mantle move suddenly. It is difficult to predict exactly when and where an earthquake will happen, even when a lot of data is available.

Earthquakes produce shockwaves called **seismic waves**. These waves can be detected using seismographs. Some seismic waves are surface waves, while others can travel through the Earth. The table shows the properties of the two types of seismic wave that can travel through the Earth.

	P waves	S waves
Type of wave	longitudinal	transverse
Relative speed	faster	slower
What can they travel through?	solids and liquids	solids only

http://www.frankswebspace.org.uk/ScienceAndMaths/physics/physicsGCSE/earthquakes.htm





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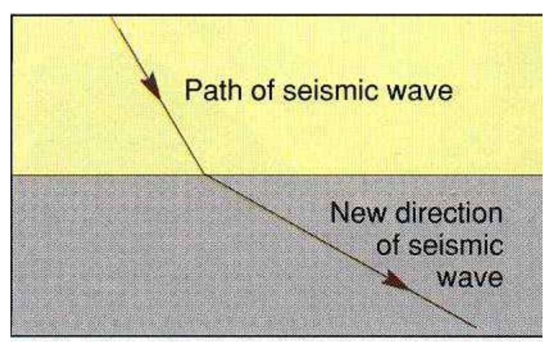
Seismic Waves will travel at different speeds depending on the **medium** or materials through which the wave is traveling. Examples:

Low-speed layer: Seismic wave travels slow.
Example: Granite
High-velocity layer: Seismic wave travels fast.
Example: Gabbro



Fellow Seismologists - We have just received data from the field. It is your job to analyze the data and determine the depth of the layers of the Earth. Also, there have been claims made by other seismologists. We need you to provide evidence that supports these claims. Good Luck!

Directions:

1. Based on the given data, create a double line graph showing the relationship between P-wave speed/S-wave speed and depth within the Earth.

2. Determine the depth range for each layer of earth.

3. Analyze data and provide evidence that supports the claims of other seismologists.

Seismic Wave Data

Wave Type	Depth (km)	Speed (km/s)
P	0	6
P	50	9
P	200	8
P	500	9
P	1000	11
P	2000	13
P	2900	14
P	2900	8
P	4000	9
P	5200	10
P	5200	11
P	5500	11
P	6000	11
P	6400	11

Wave Type	Depth (km)	Speed (km/s)
S	0	3.5
S	50	5
S	200	4
S	500	5
S	1000	6
S	2000	7
S	2900	7.5
S	2900	0
S	4000	
S	5200	
S	5200	
S	5500	
S	6000	
S	6400	

Name____Date_______________________Period_______

Mapping Earth's Interior - Data Analysis

We know that seismic waves move at various speeds depending on the material through which the wave is traveling. Therefore, we can determine where there may be a change in material (layer) based on the data and your graph.

1. Develop a way to label your graph to show the depth boundaries of each of Earth's layers .

2. What is the crust's approximate depth range (km)?
   From _____________km to _____________km

   What is the mantle's approximate depth range (km)?
   From _____________km to _____________km

   What is the Outer Core's approximate depth range (km)?
   From _____________km to _____________km

   What is the Inner Core's approximate depth range (km)?
   From _____________km to _____________km

   OPTIONAL: Use the information above to draw a scale model of the Earth and each of its layers.

Based on your graphs, answer the following questions:

3. As it relates to wave speed, what are the similarities between the S and P waves based on your graph?
   ____
   ____
   ____

4. As it relates to wave speed, what are the differences between the S and P waves based on your graph?
   ____
   ____
   ____

Name________________________________Date_______________________Period________

The following claims have been made by seismologists. In your assigned group, cite evidence from your graph that supports each claim. Present your evidence to the class and explain how the evidence supports the claim.

Claims:

S waves can only travel through solids.

P waves can travel through all materials.

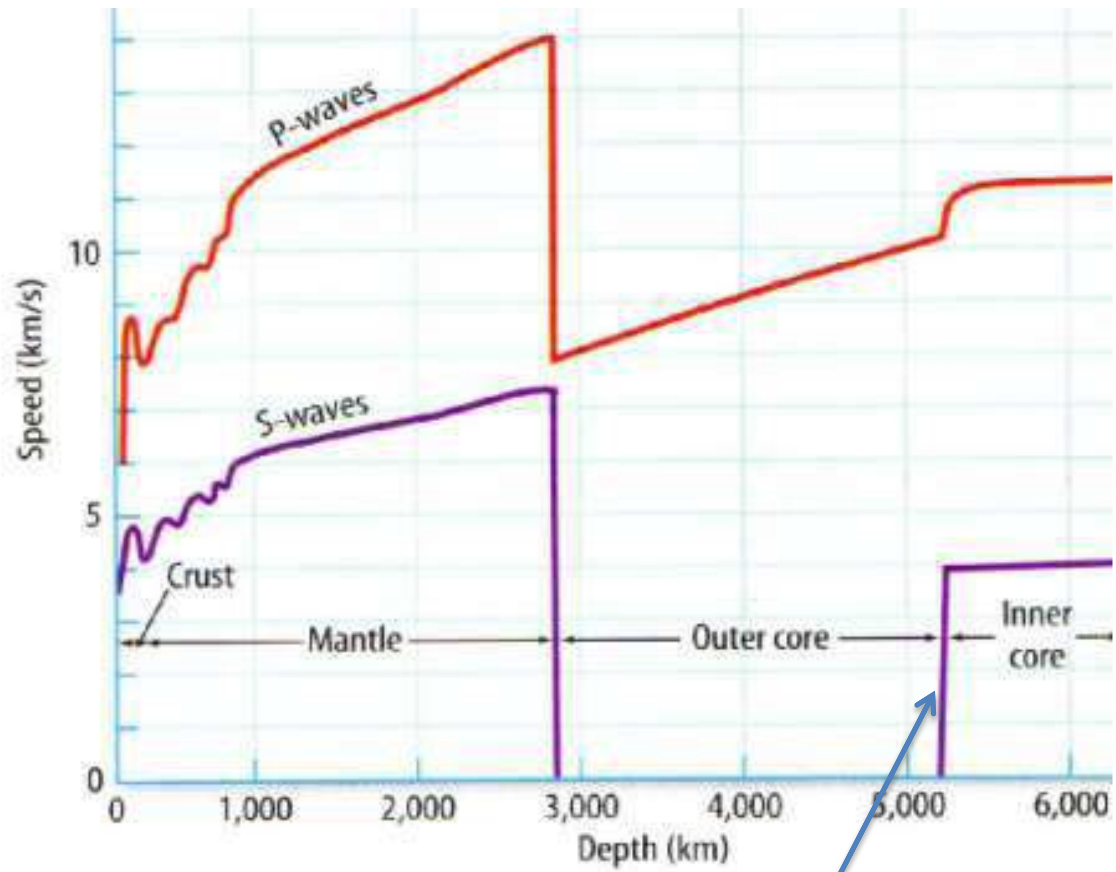
There are 4 main layers that make up earth's interior.

S waves and P waves travel at different speeds.

Seismic waves travel at different speeds depending on the material through which they are traveling.

The outer core is made of a liquid.

Seismic waves travel faster through solids than liquids.



Note: The S-waves portion of the data and graph in relation to the Inner Core has been omitted for this lesson, as details concerning this phenomena are not appropriate at this level.

Name______TEACHER ANSWER KEY________Date________________________Period_______

Mapping Earth's Interior - Data Analysis

We know that seismic waves move at various speeds depending on the material through which the wave is traveling. Therefore, we can determine where there may be a change in material (layer) based on the data and your graph.

1. Develop a way to label your graph to show the depth boundaries of each of Earth's layers . ***(see previous page)***

2. What is the crust's approximate depth range(km)?
   From __**0**___km to ____**50**___km

   What is the mantle's approximate depth range(km)?
   From ____**50**_____km to ____**2900**______km

   What is the Outer Core's approximate depth range(km)?
   From ___**2900**_____km to ____**5200**____km

   What is the Inner Core's approximate depth range(km)?
   From ___**5200**_____km to ___**6400**_____km

   OPTIONAL: Use the information above to draw a scale model of the Earth and each of its layers.

Based on your graphs, answer the following questions:

3. As it relates to wave speed, what are the similarities between the S and P waves based on your graph?
   S and P waves both change speed when coming in contact with a new layer of material.

4. As it relates to wave speed, what are the differences between the S and P waves based on your graph?
   S waves move slower than P waves

Name___**TEACHER ANSWER KEY**_____Date________________________Period________

The following claims have been made by seismologists. In your assigned group, cite evidence from your graph that supports each claim. Present your evidence to the class and explain how the evidence supports the claim.

Claims:

S waves can only travel through solids.

- *The S waves on the graph stop(drop to a speed of 0 km/s) when they reach the outer core, which we know to be solid.*

P waves can travel through both solids and liquids.

- *The P waves on the graph travel through all layers.*

There are 4 main layers that make up earth's interior.

- *Based on the P waves graph, there are 3 distinct points in which the speed suddenly decreases showing a difference in material, and separating the 4 areas.*
- *3 distinct points are: 50-100km; 2900 km; 5200km*

S waves and P waves travel at different speeds.

- *Based on the data and graphs, the S waves travel at a slower rate of speed than the P waves at any depth.*
- *Example: At a depth of 1000km, P waves are traveling at 11 km/s while S waves are traveling at 6 km/s.*

Seismic waves travel at different speeds depending on the material through which they are traveling.

- *Based on the graph, when a wave passes from one layer to another there is a dramatic change in speed.*
- *Example: When P waves travel from the mantle(solid)to the outer core(liquid), the speed decrease from 14 km/s to 8 km/s.*

The outer core is made of a liquid.

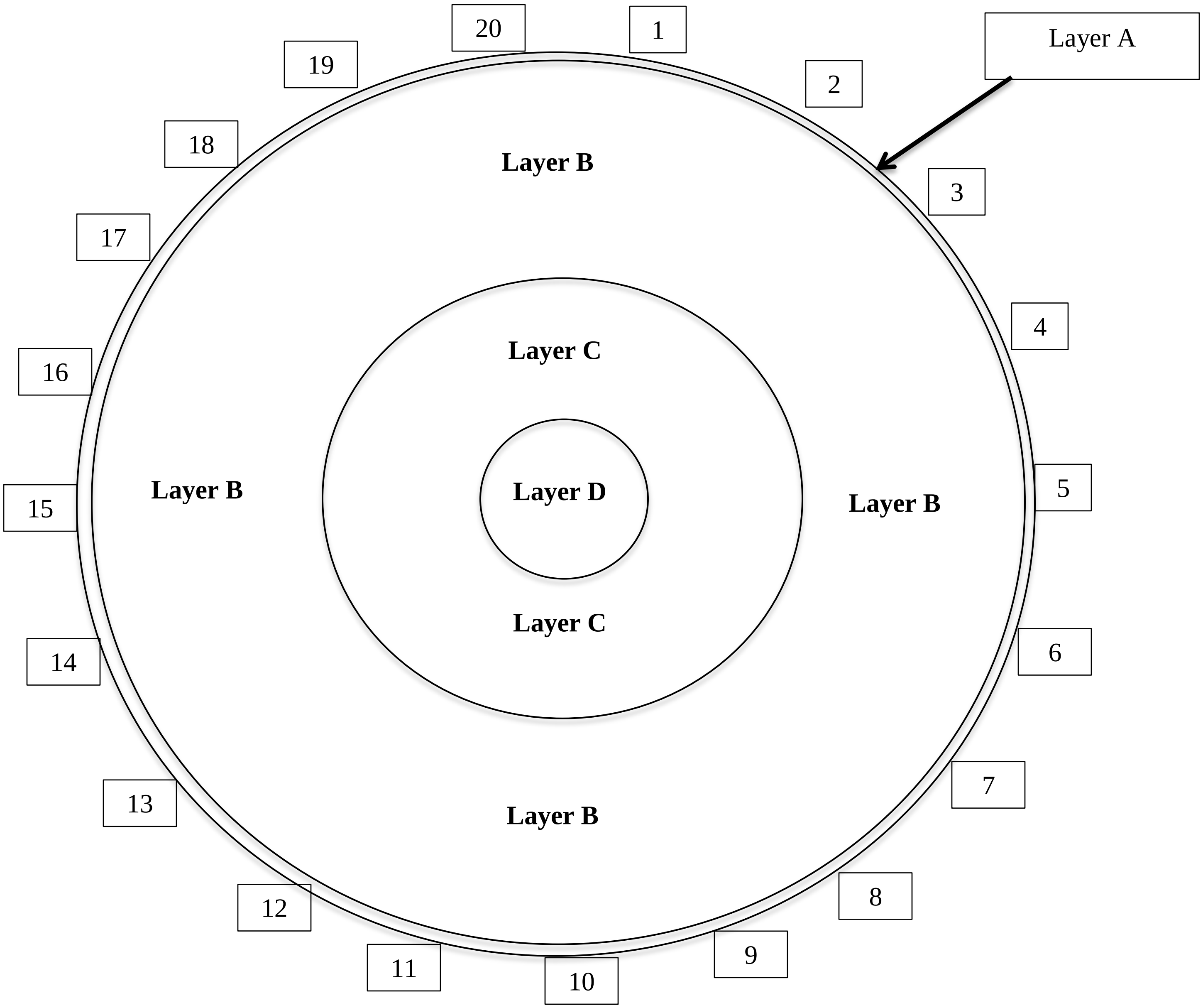
- *Since we know that S waves do not travel through solids, and the graph shows that S waves drop to 0 km/s(stop) when traveling from the mantle into the outer core, we can conclude that the outer core is made of liquid.*

Seismic waves travel faster through solids than liquids.

- *Based on the P waves graph, the P waves travel at a faster speed while moving through the mantle and inner core (both solids), while traveling slower through the outer core (liquid).*

What's Your Wave? – TEACHER PAGE

- Reserve a large space outside, in the gym, or a large open classroom will also work
- Draw with sidewalk chalk or use painters/masking tape on the ground and create a large model of Earth's Layers. Label the layers A, B, C, and D as seen in the diagram below.
- Using large index card tents, number them 1-20, and place evenly spaced along the circumference of the Earth layers model.



- Cut out and distribute student task cards to student pairs. One # to each pair.
- Students should line up by their index card number.
- Upon direction by the teacher, one student performs the assigned task from their card and the other asks the corresponding question.
- Other students observe the action by the student and answer the related question. Answers are recorded on the student sheet.

Student Task Cards/Questions: Cut out and distribute one to each student pair

#1 **Task: Stand in Layer D** **Question: What is the name of the Earth layer that I'm standing in?**	**#2** **Task: Stand somewhere in Layer C** **Question: What is the name of the Earth layer that I'm standing in?**
#3 **Task: Walk to the boundary line between Layers B and C, and stop.** **Question: I'm an S wave and I can't seem to go any further. Why not?**	**#4** **Task: Stand in layer D** **Question: Why is my layer underneath all other layers?**
#5 **Task: Jump up and down in place 3 times.** **Question: I have just created an Earthquake. What type of waves am I producing?**	**#6** **Task: Walk to the boundary line between Layers B and C, then walk back to your original position.** **Question: I am an S wave. When I hit the outer core, my movement reversed and I ended back where I started. What is this movement called?**
#7 **Task: Walk to #13 (only through layer B) in a zigzag pattern** **Question: What type of seismic wave am I?**	**#8** **Task: Stand on Layer A** **Question: What is the name of the Earth layer that I'm standing in?**
#9 **Task: Run to #20** **Question: What type of seismic wave am I?**	**#10** **Task: Stand in place** **Question: If I were an S wave, identify a location # that I might travel to.**

#11 **Task: Stand somewhere in Layer B** **Question: What is the name of the Earth layer that I'm standing in?**	**#12** **Task: Jump up and down 3 times** **Question: I am an earthquake that just occurred in the North Pole. Could detectors in the South Pole detect my S waves?**
#13 **Task: Stand in Place** **Question: I am a person that studies earthquakes and the mechanical properties of the earth. What am I called?**	**#14** **Task: Walk to the boundary line between Layers B and C, then walk back to your original position.** **Question: What type of seismic wave am I?**
#15 **Task: Walk to the boundary line between Layers B and C, then walk to #7.** **Question: I am a P wave. But when I hit the outer core, my direction shifted slightly. What is this shift in direction called?**	**#16** **Task: Stand in layer A** **Question: Why is my layer on top of all of the other layers?**
#17 **Task: Jump up and down 3 times.** **Question: I am an earthquake that just occurred in China. Could sensors on the other side of the world in Argentina detect my P waves?**	**#18** **Task: Very slowly, walk to #3.** **Question: What type of seismic wave am I?**
#19 **Task: Stand in place.** **Question: I am a detector that senses and records S and P waves. What device am I?**	**#20** **Task: Run to #10** **Question: What type of seismic wave am I?**

Name________________________________Date___________________Period_________

What's your Wave? Answer Sheet

1.	**2.**
3.	**4.**
5.	**6.**
7.	**8.**
9.	**10.**
11.	**12.**
13.	**14.**
15.	**16.**
17.	**18.**
19.	**20.**

Summarize in your own words, how scientists use seismic data to understand earth's interior.

Name___**TEACHER ANSWER KEY**____Date____________________Period_________

What's your Wave? Answer Sheet

1. Inner Core	**2. Outer Core**
3. The inner core is made up of liquid and S waves only travel through solids	**4. The inner core is made of solid iron and is the most dense.**
5. Seismic Waves	**6. Reflection**
7. S Wave	**8. Crust**
9. P Wave	**10. Any location between #4 and #16**
11. Mantle	**12. No, I cannot travel through the liquid inner core.**
13. Seismologist	**14. S Wave**
15. Refraction	**16. The crust is the least dense.**
17. Yes	**18. S Wave**
19. Seismograph	**20. P wave**

Summarize in your own words, how scientists use Seismic Data to understand Earth's interior.

Answers will vary. An example answer:

Scientists analyze the direction, movement, and speed of S and P Waves as they move through the Earth. They can then determine the depth at which each layer resides, the state of matter, and composition of each layer.