

# **Topic X**

## **Part 2**

# **Earthquakes**

Topic:	Earthquakes
Aim:	

1. What are earthquake and what causes them?	<b>Earthquakes</b> are the shaking, or rapid motion of the <b>Earth's crust</b> . Caused mainly by <b>faulting</b> (a fracture/ break in the Earth's crust along which there is motion).
2. What is the difference between an earthquake focus and epicenter?	<b>FOCUS</b> -  <b>EPICENTER</b> -
3. What is a tsunami?	a large ocean wave created by an undersea earthquake

4. What two scales are used to measure an earthquake?
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**A.**  
**Modified Mercalli Scale**  
Measures intensity of earthquake based on observations and resulting damage.  
I-XII  
  
**Note:**  
An earthquake might rate higher on the Mercalli Scale than on the Richter scale because damage can be greater in areas where cities are built on weak bedrock even when the earthquake isn't that strong.

**B.**  
**Richter Scale**  
Measures magnitude of earthquake (energy released) using a seismograph.  
  
1-10  
(each successive number on scale is 10x stronger than the previous)

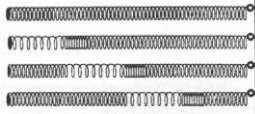
Topic:

# Earthquakes

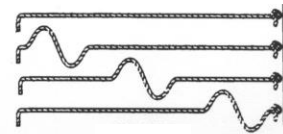
Aim:

**seismic waves** - energy waves produced by an earthquake that travel through the Earth

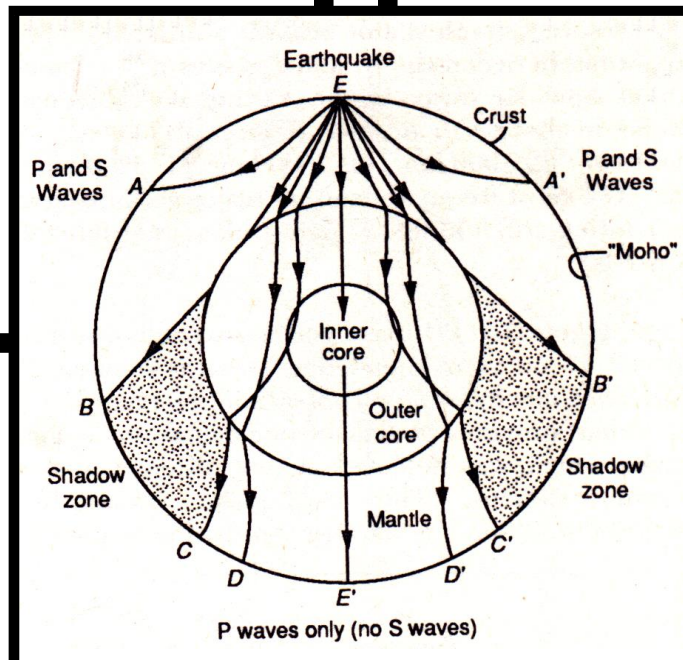
1.



2.



If an earthquake occurs at point E, the waves of energy travel through the Earth. Notice that on the other side of the Earth only P-waves are detected because S-waves cannot travel through the liquid outer core



The waves of energy are bent (refracted) as they travel through substances of different densities. Shadow zones are areas that no earthquake waves can be detected by seismographs because the P-waves are bent away from those areas and S-waves have already been absorbed by the liquid outer core.

## Finding the Distance to the Earthquake Epicenter Key Terms and Dealing with Time Calculations

Important Terminology:

**P and S Wave Arrival Times** – This is the clock time that the P and S waves are recorded at a seismograph that is some distance away from the earthquake epicenter.

**Arrival Time Difference** – the number of minutes and seconds between P and S wave arrival time

**P and S Wave Travel Times** – The P and S wave take some time to travel through the Earth and reach a seismograph at recording station. Travel time is measured in minutes and seconds.

**Earthquake Origin Time** – the time that the earthquake actually occurred.

*Here would be an example of a seismic event:*

An earthquake's origin time is 5:00:00am. If a seismograph recording station is 4000 km away from the earthquake epicenter, it would take 7 minutes for the P-wave to travel to that station, and its arrival time at the station would be 5:07am. The S-waves from the same earthquake have a travel time of 12 minutes and 40 seconds and would arrive at the recording station at 5:12:40am. The arrival time difference between the P and S waves is 5 minutes and 40 seconds.

Subtracting Times:

Some subtraction will be easy and you can proceed through it as if it were a normal math problem.

For example:

P-Wave Arrival Time – 6:06:00am

S-Wave Arrival Time – 6:10:40am



$\begin{array}{r} 6:10:40 \\ - 6:06:00 \\ \hline 0:04:40 \text{ (4m 40s)} \end{array}$
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You try ...

P-Wave Arrival Time – 10:01:30am

S-Wave Arrival Time – 10:06:40am



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Some subtraction requires a special technique of "borrowing" time ...

**FOR EXAMPLE:**

P-Wave Arrival Time – 11:30:20pm  
S-Wave Arrival Time – 11:33:00pm



11:33:00	← can't be subtracted as is
<u>- 11:30:20</u>	
32 60	
11: <del>33</del> :00	← you have to borrow a minute and add it to the seconds column
<u>- 11:30:20</u>	
00:02:40	
(2m 40s)	

**A SECOND EXAMPLE:**

P-Wave Arrival Time – 1:15:40pm  
S-Wave Arrival Time – 1:21:20pm



1:21:20	← can't be subtracted as is
<u>- 1:15:40</u>	
20 80	
1: <del>21</del> :20	← you have to borrow a minute and add it to the seconds column
<u>- 1:15:40</u>	
00:05:40	
(5m 40s)	

1. P-Wave Arrival Time – 10:47:30pm  
S-Wave Arrival Time – 10:55:15pm

Time Difference \_\_\_\_\_

2. P-Wave Arrival Time – 12:14:40am  
S-Wave Arrival Time – 12:19:10am

Time Difference \_\_\_\_\_

3. P-Wave Arrival Time – 4:33:30pm  
S-Wave Arrival Time – 4:44:40pm

Time Difference \_\_\_\_\_

4. P-Wave Arrival Time – 7:58:20pm  
S-Wave Arrival Time – 8:06:20pm

Time Difference \_\_\_\_\_

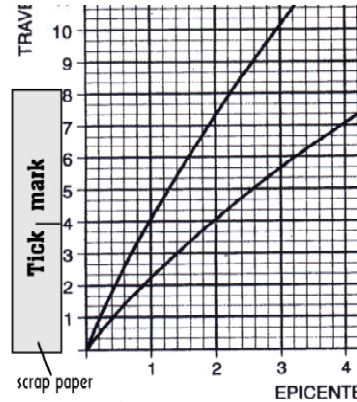
## **Finding the Distance to the Earthquake Epicenter**

1. Find the difference in time between the **P-Wave and S-Wave Arrival Times.**

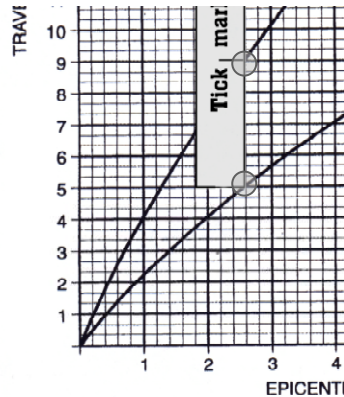
Ex. P-wave arrival time = 5:40pm      S-wave arrival time = 5:44pm

time difference (**lag time**) = 4 minutes

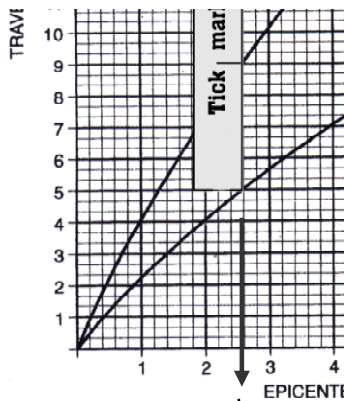
2. Using a scrap of paper, Mark off the **Arrival Time Difference** calculated in step #1 on the Y-Axis of the Grid. (See Set-up to the right)



3. "Ride the P-Wave" - Move the corner of the scrap paper along the P-Wave graph line until the mark you made hits the S-Wave graph line.



4. Go Straight down and read off the **Distance to the Epicenter.**



**2.6 x 10<sup>3</sup> km = 2600 km**

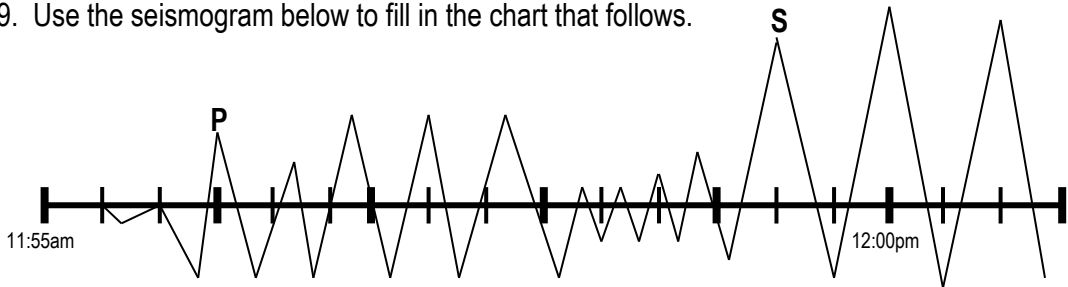
## Earthquake Data Interpretations

1. What is the distance to an earthquake epicenter if the P-wave arrival time is 2:31 p.m. and the S-wave arrival time is 2:37 p.m.? \_\_\_\_\_
2. If the earthquake detection station records the difference in arrival times between P-and S-waves is 10 minutes 20 seconds, what is the distance to the earthquake epicenter from the recording station? \_\_\_\_\_
3. If the earthquake epicenter is 9000 km away from a recording station, how long is the P-wave travel time to that station? \_\_\_\_\_
4. If it takes 19 minutes and 40 seconds for the S-waves of an earthquake to reach a recording station, how far away is the earthquake epicenter from that station? \_\_\_\_\_
5. If a seismograph station is 6600 km from an epicenter, and the P-wave arrived at this station at 7:30 a.m., what was the origin time of the earthquake? \_\_\_\_\_
6. An earthquake struck a location at 1:35 p.m. If a seismograph station is 4000 km from the earthquake epicenter, at what time would the first P-waves arrive at the seismograph station? \_\_\_\_\_

7. A seismic station is recording the seismic waves produced by an earthquake that occurred 3000 kilometers away. How long after the arrival of the first P-wave will the first S-wave arrive? \_\_\_\_\_

8. An earthquake's first P-wave arrives at a seismic station at 12:00:00. This P-wave has traveled 6000 kilometers from the epicenter. At what time will the first S-wave from the same earthquake arrive at the seismic station? \_\_\_\_\_

9. Use the seismogram below to fill in the chart that follows.

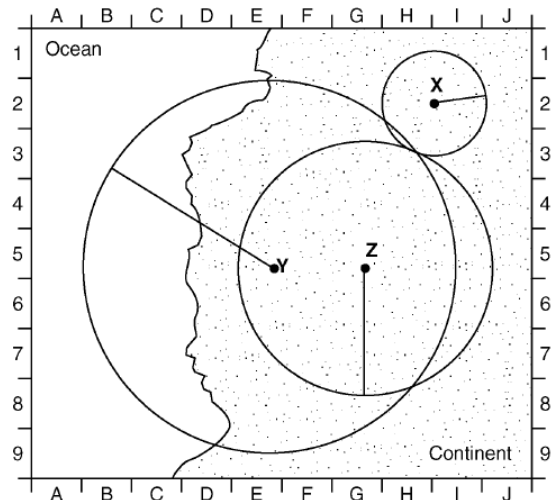


a. P-Wave Arrival Time	
b. S-Wave Arrival Time	
c. Arrival Time Difference (Lag Time)	
d. Distance to Epicenter	
e. P-Wave Travel Time	
f. S-Wave Travel Time	
g. Earthquake Origin Time	

10. Base your answer to the following question on the diagram and map below. The diagram shows three seismograms of the same earthquake recorded at three different seismic stations, X, Y, and Z. The distances from each seismic station to the earthquake epicenter have been drawn on the map. A coordinate system has been placed on the map to describe locations.

At which coordinate would the epicenter of this earthquake be located?

- (1) H-7
- (2) H-3
- (3) E-5
- (4) G-5





## PROBLEMS HANDLING SEISMIC WAVES: TAKE 2

Part of solving seismic wave related questions is figuring out the correct method to approach the problem. BE SYSTEMATIC! Some questions can be done in one step, some require multiple steps.

### THE FIRST THING YOU SHOULD ALWAYS DO:

Always begin a question by asking yourself what type of question you are dealing with ... Is it:

1. RIDE THE WAVE
2. JUST GO
3.  $X \rightarrow \triangle$  : ORIGIN TIME
4. S AFTER P: REVERSE RIDE

### Example 1:

Following an earthquake, a seismograph station recorded the arrival of a *P*-wave at 1:05:00 a.m. and an *S*-wave at 1:14:30 a.m. What is the distance from the seismograph station to the epicenter of the earthquake? \_\_\_\_\_

### Example 2:

How far does an earthquake *P*-wave travel in 3 minutes 40 seconds? \_\_\_\_\_

### Example 3:

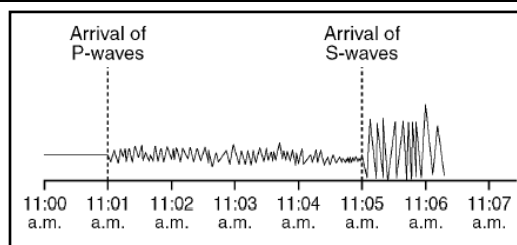
The distance from a seismic recording station to an earthquake epicenter is 1800km. The station recorded the arrival of the first *P*-waves from the earthquake at 5:06pm. What time would the first *S*-waves arrive at the recording station? \_\_\_\_\_

### Example 4:

A seismographic station determines that its distance from the epicenter of an earthquake is 3000 kilometers. If the *P*-wave arrived at the station at 9:10:00 a.m., the time of the earthquake's origin was \_\_\_\_\_

### Example 5:

According to the data in the seismogram, what is the distance to the epicenter? \_\_\_\_\_



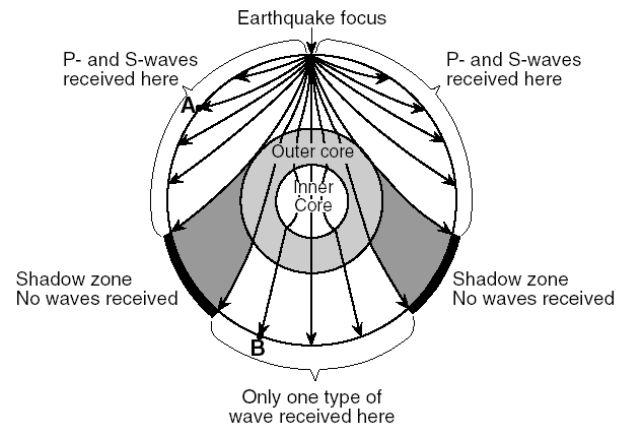
## Some Final Practice Questions on Earthquakes

- How long would it take for the first S-wave to arrive at a seismic station 3,000 kilometers away from the epicenter of an earthquake?
 

(1) 4 min 20 sec	(3) 10 min 10 sec
(2) 5 min 40 sec	(4) 13 min 20 sec

Base your answers to **questions 2 and 3** on the cross-sectional view of Earth below, which shows seismic waves traveling from the focus of an earthquake. Points *A* and *B* are locations on Earth's surface.

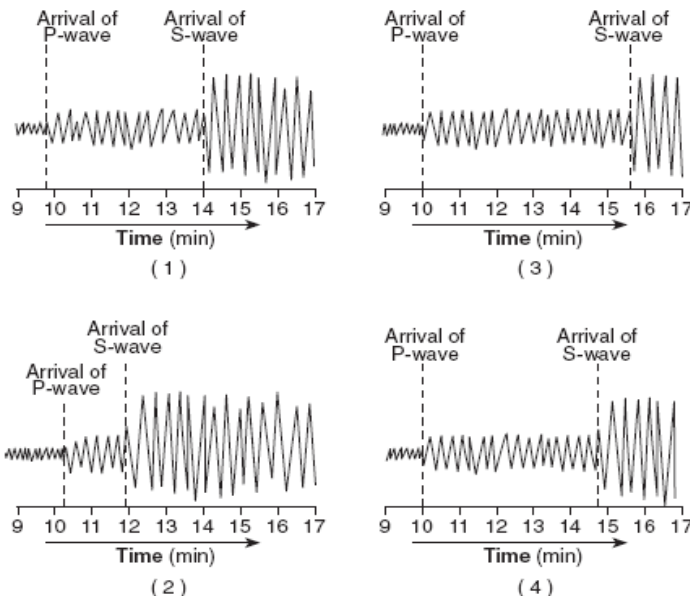
- Which statement best explains why only one type of seismic wave was recorded at location *B*?
  - (1) S-waves cannot travel through the liquid outer core.
  - (2) S-waves cannot travel through the liquid inner core.
  - (3) P-waves cannot travel through the solid outer core.
  - (4) P-waves cannot travel through the solid inner core.



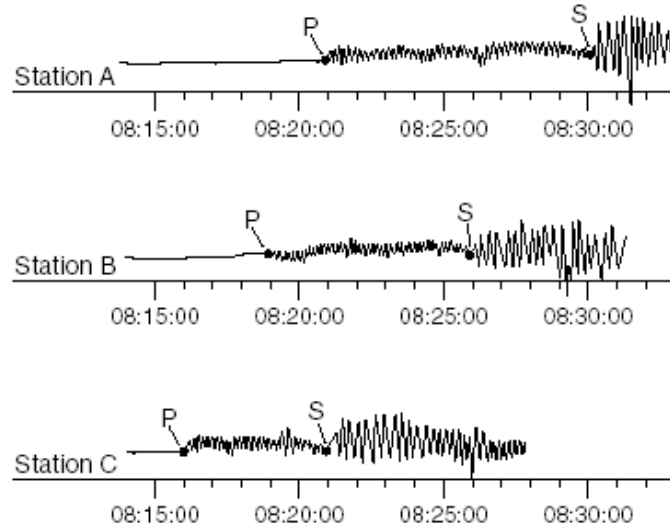
- A seismic station located at point *A* is 5400 kilometers away from the epicenter of the earthquake. If the arrival time for the *P*-wave at point *A* was 2:00 p.m., the arrival time for the *S*-wave at point *A* was approximately
 

(1) 1:53 p.m.	(3) 2:09 p.m.
(2) 2:07 p.m.	(4) 2:16 p.m.

- Which seismogram was recorded approximately 4,000 kilometers from an earthquake epicenter?



**Questions 5-6:** The diagram below represents three seismograms showing the same earthquake as it was recorded at three different seismic stations, A, B, and C.



5. Which statement correctly describes the distance between the earthquake epicenter and these seismic stations?
  - (1) A is closest to the epicenter, and C is farthest from the epicenter.
  - (2) B is closest to the epicenter, and C is farthest from the epicenter.
  - (3) C is closest to the epicenter, and A is farthest from the epicenter.
  - (4) A is closest to the epicenter, and B is farthest from the epicenter.
  
6. What is the distance to the epicenter from station C?
 

(1) 1300 km	(3) 3400 km
(2) 2600 km	(4) 4000 km
  
7. The distance from Albany, New York, to the epicenter of this earthquake is 5600 km. Approximately how much longer did it take for the S-wave to arrive at Albany than the P-wave?
 

(1) 4 minutes and 20 seconds	(3) 9 minutes and 0 seconds
(2) 7 minutes and 10 seconds	(4) 16 minutes and 10 seconds
  
8. If a P-wave takes 8 minutes and 20 seconds to travel from an earthquake epicenter to a seismic recording station, how far away from that station did that earthquake occur?
 

(1) 4000 km	(3) 6000 km
(2) 5000 km	(4) 8000 km