

Analyzing S- and P-Waves

As you learned in your textbook, scientists use seismic waves to learn about Earth's interior. Seismic waves are the rumbles you feel during an earthquake. Three types of seismic waves are generated during an earthquake. Surface waves, or L-waves, travel along Earth's surface. They are the slowest-moving waves and cause the most damage. Primary waves, or P-waves, and secondary waves, or S-waves, move through the interior of Earth. P-waves are the fastest seismic waves, and they can travel through any material in Earth's interior. S-waves move about half as fast as P-waves, and they can travel only through solids.

Scientists can use information from seismic waves to find clues about Earth's interior. During an earthquake, seismic waves travel through Earth's interior. Scientists can use the differences in the speed that S-waves and P-waves travel to learn about the different materials that make up Earth's interior. They also use the differences in speed to determine information about an earthquake. P-waves are always the first to reach a recording station. Their arrival time and intensity, as well as that of the S-waves that follow, are measured using an instrument called a *seismograph*. Information from a minimum of three recording stations is compiled to locate the epicenter of an earthquake, which is the point on Earth's surface directly above an earthquake's starting point. This information is used to identify the focus—the point inside Earth where an earthquake begins.

In this experiment, you will simulate the movement of P- and S-waves and measure the difference in their arrival times. You will combine this data with data from other stations to locate the epicenter of the earthquake.

OBJECTIVES

Compare the movement of S- and P-waves generated by an earthquake.

Graph data regarding S- and P-wave travel time.

Explain the relationship between distance and seismic wave travel time using graphed data.

Combine data to locate the epicenter of a simulated earthquake by triangulation.

MATERIALS

- calculator
- drawing compass
- flags or other markers (4)
- graph paper
- large, open space (at least 6 m × 6 m)
- meter stick
- pencils, colored
- ruler
- stopwatch (3)
- tape, masking

Analyzing S- and P-Waves *continued***Procedure****PART I—CONSTRUCTING THE TRAVEL-TIME GRAPH**

1. Organize a group of 9 students into 3 groups of 3. Choose 3 students to model S-waves, 3 students to model P-waves, and 3 students to operate stopwatches.
2. Use masking tape to mark a 6-meter line at 0, 2, 4, and 6 meters. Students acting as timers should stand at the 2-, 4-, and 6-meter marks. (If space is limited, mark a 3-meter line at 0, 1, 2 and 3 meters.)
3. Create and practice a “cadence” for the 3 students modeling S-waves. On the word “Go,” S-wave modelers should proceed slowly to the 6-meter mark, with each timer recording the number of seconds required for the slow walkers to pass his or her station. Repeat this practice with the 3 students modeling the faster-moving P-waves, having these students move at a walking pace that is about twice as fast as the slow one. Why is it important for the members of each group to move at the same pace?

4. Once a cadence is established, run two time trials for each group. All three S-wave modelers should begin walking from the 0 mark when the timers start their stopwatches. Record times required to pass the 2-, 4-, and 6-meter marks. If the results from the two trials produce similar times, average and record them in Table 1. Repeat for P-wave modelers, and record data in Table 1.

TABLE 1: TRAVEL TIME DATA FOR S-WAVE AND P-WAVE MODELERS

Distance (m)	Walk Time for S-wave modelers (s)	Walk Time for P-wave modelers (s)	S-wave Time – P-wave Time (s)
0	0	0	0
2			
4			
6			

5. Graph the data. Place distance in meters on the x -axis, and time in seconds on the y -axis. Draw a straight line that approximately fits the data points for S-wave time–P-wave time – P-wave time. What is the speed of the S-wave modelers in m/s? What is the speed of the P-wave modelers in m/s?

6. Compare these speeds to the speeds of P- and S-waves. P-waves travel about 6,000–8,000 m/s and S-waves travel about 3,500–4,500 m/s through Earth’s crust and upper mantle.

Analyzing S- and P-Waves *continued***PART II—LOCATING AN EARTHQUAKE EPICENTER**

7. Agree upon an “epicenter” within the $6\text{ m} \times 6\text{ m}$ square or $3 \times 3\text{ m}$ square if space is limited, and mark this location with tape. Position 3 timers at three corners of the square to represent seismograph stations, and mark their locations with tape.
8. The 6 students modeling P- and S-waves should stand at the epicenter, with one P-wave modeler and one S-wave modeler facing each of the 3 stations. On “Go,” all proceed from the epicenter toward their assigned station at the speeds used in Part I. Each timer should start the stopwatch when the fast-walking student arrives, and stop timing when the slow-walking student arrives. Record this difference in Table 2.

TABLE 2: THE DIFFERENCE BETWEEN S-WAVE AND P-WAVE TRAVEL TIME TO THREE STATIONS AND INFERRED DISTANCES TO EPICENTER

Station	Difference between S-Wave and P-wave travel time (s)	Inferred Distance from Epicenter to Station (m)
1		
2		
3		

9. On the graph created in step 5, mark the time difference recorded in Table 2 for Station 1 on the y -axis. Draw a horizontal line to the P-wave time minus S-wave time line. From this point, draw a vertical line to the x -axis. The location on the x -axis is the inferred distance from the epicenter to Station 1. Record this number in Table 2. Repeat for Stations 2 and 3.
10. Construct a map of the $6\text{ m} \times 6\text{ m}$ area on graph paper. Mark the positions of the 3 stations. Use a compass to draw a circle around each station. Put the compass point on the station, and make the radius of the circle the distance to the epicenter found in step 9 and recorded in Table 2. The point at which the three circles intersect is the epicenter of the earthquake. Compare the actual location of the epicenter identified in step 7 with the epicenter you have just calculated. How close are the two measurements? What are possible reasons that they may not agree?

11. If your circles in Procedure step 10 did not intersect, give your best approximation of the location of the epicenter based on the circles you have drawn. What is a possible reason that the circles did not intersect?

Analyzing S- and P-Waves *continued*

Analysis

- 1. Describing Events** Compare the movement of P- and S-waves through Earth from an earthquake epicenter.

- 2. Analyzing Data** Why is it necessary to have data from at least three seismograph stations to determine the epicenter of an earthquake?

- 3. Analyzing Data** Why is the S-wave – P-wave travel time the most significant measurement in determining the epicenter of an earthquake?

Conclusions

- 4. Analyzing Graphs** Study the graph of travel times created in this lab. As the distance to each station increases, what happens to the difference in S- and P-wave travel times?

- 5. Evaluating Methods** How could the techniques and procedures you used in this lab to locate the earthquake epicenter be improved to produce a more accurate result?
