

EARTHQUAKE WAVES

Teaching Guidelines

<p>Subject: Mathematics</p> <p>Topics: Algebra, Earth Science</p> <p>Grades: 7 - 12</p>
<p>Concepts:</p> <ul style="list-style-type: none"> • P wave, S wave
<p>Knowledge and Skills:</p> <ul style="list-style-type: none"> • Can substitute values in a linear equation • Can solve a linear equation for a given variable.

When an earthquake occurs, it causes two different kinds of vibrations to travel through the ground: P waves and S waves.

P waves are similar to sound waves: the vibration of the wave is a pattern of compressions along the direction of travel. Imagine what you would see if you stretched out a Slinky™ along the floor and then quickly pulled one end farther away from the other end and pushed it towards the other end. That would create a P wave, traveling down to the other end of the Slinky™.

S waves are different: the vibration is a pattern of sideways motion, as would occur if you stretch out a rope and then quickly shake one end from side to side.

P waves travel faster than S waves. Suppose an earthquake starts at a specific location, and there is a town 50 kilometers away. The P waves of the earthquake will arrive at the town first, since they travel faster, and the S waves will arrive a little later.

This can be important because S waves carry much more energy—and more destructive power—than P waves. Because of that, the P wave can serve as a useful warning for the arrival of the S wave. This leads to the question: what is that warning time?

If something is moving at a constant velocity, there is a simple relationship between that velocity, the distance traveled, and the time it takes it travel that distance:

Equation 1: **$v = d/t$**

v = velocity

d = distance

t = time

If you know the velocity (v) and the distance (d), you can compute the time by rearranging the above equation:

Equation 2:
$$t = d/v$$

v = velocity

d = distance

t = time

From this equation it is not difficult to work out the relationship below:

Equation 3:
$$t_{\text{warning}} = d/v_s - d/v_p$$

t_{warning} = time between arrival of P wave and S wave, seconds

d = distance from location of earthquake to your location, kilometers

v_s = velocity of S wave, km per second

v_p = velocity of P wave, km per second

Refer to this last equation in answering these questions:

- 1) Suppose you are 50 kilometers from the location of an earthquake. If the P wave travels at 10 km per second and the S wave travels at 5 km per second, what is t_{warning} ?
- 2) Suppose you are 180 kilometers from the location of an earthquake. If the P wave travels at 15 km per second and the S wave travels at 4 km per second, what is t_{warning} ?
- 3) Suppose the S wave from an earthquake is traveling at 6 km per second, and the P wave is traveling at 12 km per second. If you observe that the difference of time in their arrival at your location is 30 seconds, how far away did the earthquake start?
- 4) Suppose you are 240 km from the center of an earthquake, and you observe that the S wave of an earthquake arrives 24 seconds later than the P wave. If the P wave is traveling at 15 km per second, what is the velocity of the S wave?
- 5) Show how equation 2 can be derived from equation 1.
- 6) Explain how equation 3 is derived.

1. 5 seconds
2. 33 seconds
3. 360 km
4. 6 km per second

Answers