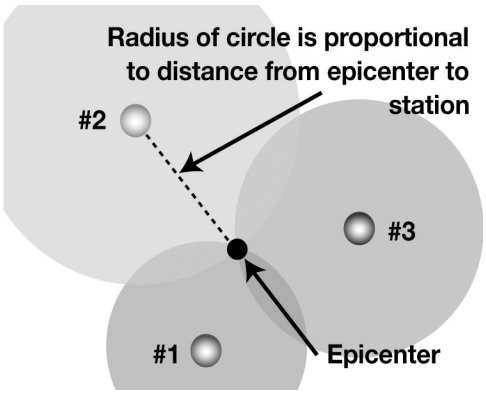
Name: _____ Date: _____

CONTENT 20.1

# 20.1 Finding an Earthquake Epicenter

READ

The location of an earthquake's epicenter can be determined if you have data from at least three seismographic stations. One method of finding the epicenter utilizes a graph and you need to know the difference between the arrival times of the P- and S-waves at each of three seismic stations. Another method uses a formula and you need to know the arrival times and speeds of the P- and S-waves. The only other items you need to find an epicenter are a calculator, a compass, and a map.



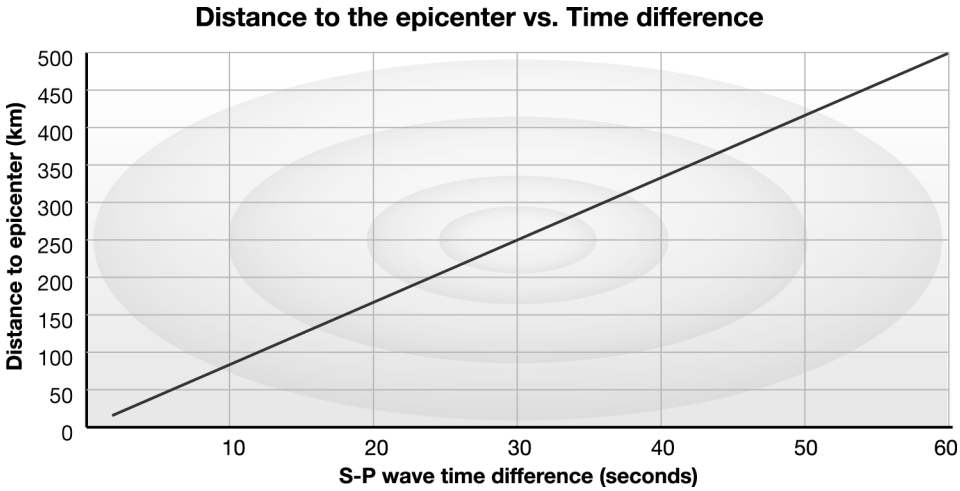

PRACTICE 1

## Finding the epicenter using a graph

Table 1 provides the arrival time difference between P- and S-waves. Use this value to find the distance to the epicenter on the graph. Record the distance values in the table in the third column from the left.

**Table 1: Seismic wave arrival time and distance to the epicenter**

| Station name | Arrival time difference between P- and S-waves | Distance to epicenter in kilometers | Scale distance to epicenter in centimeters |
|---|---|---|---|
| 1 | 15 seconds | | |
| 2 | 25 seconds | | |
| 3 | 42 seconds | | |



## Locating the epicenter on a map

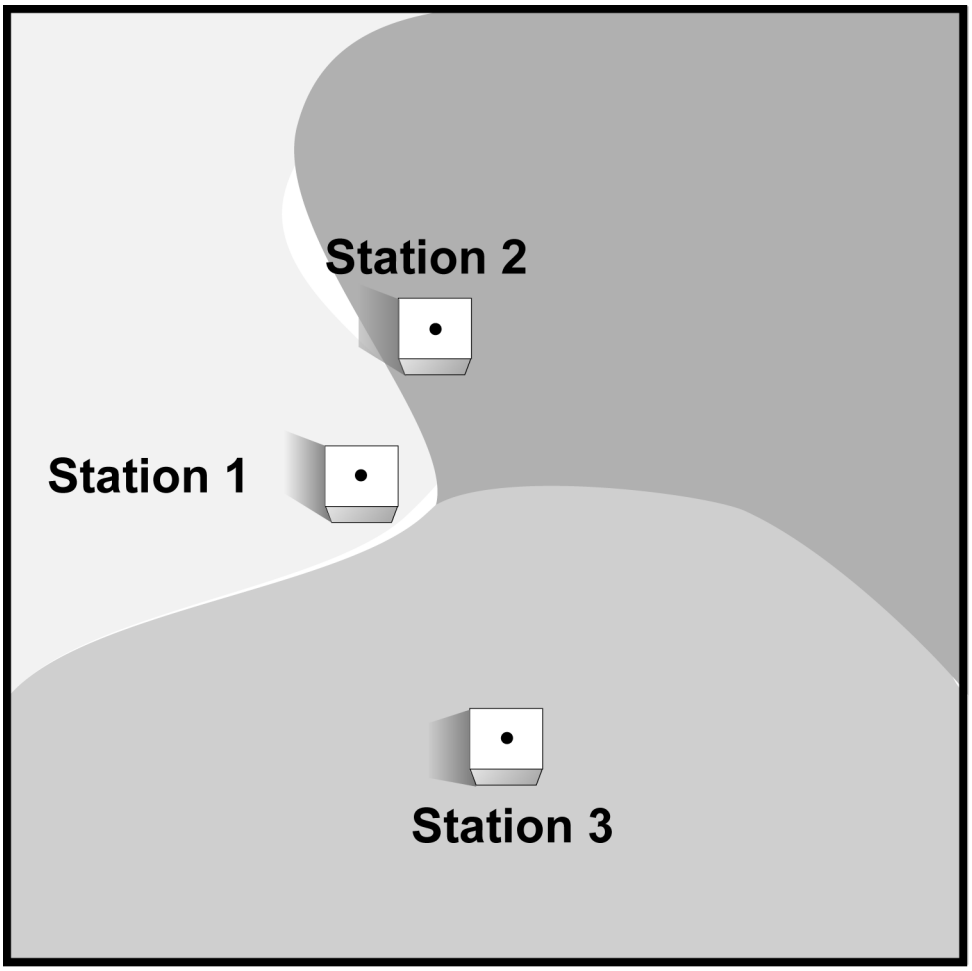
Once you have determined the distance to the epicenter for three stations in kilometers, you can use a map to locate the epicenter. The steps are as follows:

**Step 1:** Determine the radius of a circle around each seismographic station on a map. The radius will be proportional to distance from the epicenter. Use the formula below to convert the distances in kilometers to distances in centimeters. For this situation, we will assume that 100 kilometers = 1 centimeter. Record the scale distances in centimeters in the fourth column of Table 1.

$$\frac{1 \text{ cm}}{100 \text{ km}} = \frac{x}{\text{distance to epicenter in km}}$$

**Step 2:** Draw circles around each seismic station. Use a geometric compass to make circles around each station. Remember that the radius of each circle is proportional to the distance to the epicenter.

**Step 3:** The location where the three circles intersect is the location of the epicenter.



**EXAMPLE**

## Finding the epicenter using a formula

To calculate the distance to the epicenter for each station, you will use the equation:

$$\text{Distance} = \text{Rate} \times \text{Time}$$

Table 2 lists the variables that are used in the equation for finding the distance to the epicenter. This table also lists values that are given to you.

**Table 2: Variables for the equation to calculate the distance to the epicenter**

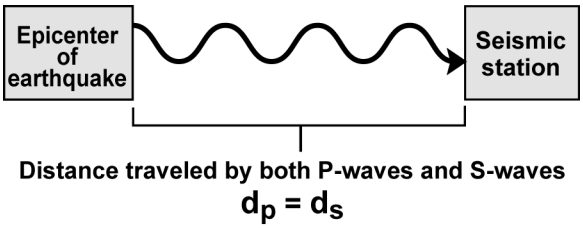
| Variable | What it means | Given |
|---|---|---|
| $d_p$ | distance traveled by P-waves | $r_p = 5$ km/s |
| $r_p$ | speed of P-waves | $r_s = 3$ km/s |
| $t_p$ | travel time of P-waves | $d_p = d_s$ |
| $d_s$ | distance traveled by S-waves | |
| $r_s$ | speed of S-waves | |
| $t_s$ | travel time of S-waves | |

For each of the practice problems, assume that the speed of the P-waves will be 5 km/s and the speed of the S-waves will be 3 km/s. Also, because the P- and S-waves come from the same location, we can assume the distance traveled by both waves is the same.

$$\text{distance traveled by P-waves} = \text{distance traveled by S-waves}$$

$$d_p = d_s$$

$$r_p \times t_p = r_s \times t_s$$

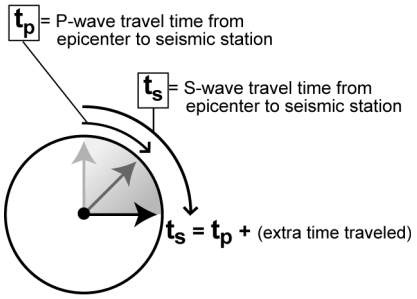



Since the travel time for the S-waves is longer, we can say that,

$$\text{travel time of S-waves} = (\text{travel time of P-waves}) + (\text{extra time})$$

$$t_s = t_p + (\text{extra time})$$

$$r_p \times t_p = r_s \times (t_p + \text{extra time})$$



## PRACTICE 2

For each of the practice problems, assume that the speed of the P-waves is 5 kilometers per second, and the speed of the S-waves is 3 kilometers per second. The first problem is done for you. Show your work for all problems.

1. S-waves arrive to seismographic station A 85 seconds after the P-waves arrive. What is the travel time for the P-waves?

$$\frac{5\text{ km}}{\text{s}} \times t_p = \frac{3\text{ km}}{\text{s}} \times (t_p + 85\text{ s})$$
$$\left(\frac{5\text{ km}}{\text{s}}\right) t_p = \left(\frac{3\text{ km}}{\text{s}}\right) t_p + 255\text{ km})$$
$$\left(\frac{2\text{ km}}{\text{s}}\right) t_p = 255\text{ km}$$
$$t_p = 128\text{ s}$$

2. S-waves arrive to another seismographic station B 80 seconds after the P-waves. What is the travel time for the P-waves to this station?

3. A third seismographic station C records that the S-waves arrive 120 seconds after the P-waves. What is the travel time for the P-waves to this station?

4. From the calculations in questions 1, 2, and 3, you know the travel times for P-waves to three seismographic stations (A, B, and C). Now, calculate the distance from the epicenter to each of the stations using the speed and travel time of the P-waves. Use the equation: distance = speed × time.

5. Challenge question: You know that the travel time for P-waves to a seismographic station is 200 seconds.
   a. What is the difference between the arrival times of the P- and S-waves?
   b. What is the travel time for the S-waves to this station?

6. Table 3 includes data for three seismographic stations. Using this information, perform the calculations that will help you fill in the rest of the table, except for the scale distance row.

**Table 3: Calculating the distance to the epicenter**

| | Variables | Station 1 | Station 2 | Station 3 |
|---|---|---|---|---|
| Speed of P-waves | $r_p$ | 5 km/s | 5 km/s | 5 km/s |
| Speed of S-waves | $r_s$ | 3 km/s | 3 km/s | 3 km/s |
| Time between the arrival of P- and S-waves | $t_s - t_p$ | 70 seconds | 115 seconds | 92 seconds |
| Total travel time of P-waves | $t_p$ | | | |
| Total travel time of S-waves | $t_s$ | | | |
| Distance to epicenter in kilometers | $d_p$, $d_s$ | | | |
| Scale distance to epicenter in centimeters | | | | |

Once you have determined the distance to the epicenter for three stations in kilometers, you can use a map to locate the epicenter. The steps are as follows:

**Step 1:** Determine the radius of a circle around each seismographic station on a map. The radius will be proportional to distance from the epicenter. Use the formula below to convert the distances in kilometers to distances in centimeters. For this situation, we will assume that 200 kilometers = 1 centimeter. Record the scale distances in centimeters in the last row of Table 3.

$$\frac{1 \text{ cm}}{200 \text{ km}} = \frac{x}{\text{distance to epicenter in km}}$$

**Step 2:** Draw circles around each seismic station. Use a geometric compass to make circles around each station. Remember that the radius of each circle is proportional to the distance to the epicenter.

**Step 3:** The location where the three circles intersect is the location of the epicenter.