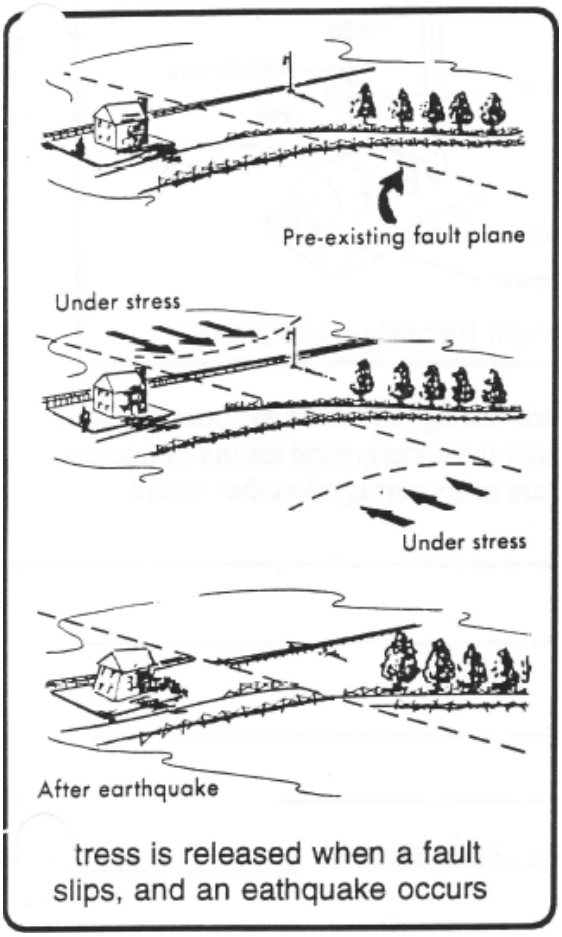
Name:_____ Class:_____ Date:_____ EN:____

EARTHQUAKES



Earthquakes occur when forces within the Earth become so great that the ground breaks along zones of weakness, known as geologic faults. The energy waves that radiate from these breaks are the vibrations that we feel as earthquakes.

At 5:36 pm on Friday, March 27, 1964, the residents of Anchorage, Alaska felt the gentle rolling motion that marked the onset of one of the most violent earthquakes in modern history. Over the next five minutes, the Earth surged and buckled as people ran for safety. The rumbling and breaking sounds of the Earth were replaced by crashing sounds of falling buildings and screams of people injured and trapped by rubble. Then, as quickly and as mysteriously as it began, the movement of the Earth stopped.

Seismologists say, "Earthquakes don't kill people. Buildings do!" In most earthquakes, the greatest loss of life and property happen in the collapse of man made structures where they have been built on loose sediments. One side of Anchorage's main shopping street overlooking Cook Inlet was lost in a massive landslide. Cities along the Pacific coast were lashed out by Earthquake generated ocean waves known as tsunami ("tidal waves") as much as twenty meters high. Fortunately, Anchorage did not suffer the fires that destroyed San Francisco after the Earthquake of 1906, or the landslides that buried dozens of people in the Wyoming earthquake of 1959.

1. What causes earthquakes?_____

2. In movies, you sometimes see people fall into great cracks that open to swallow their victims, and then close in on them. Even in the greatest earthquakes, this kind of accident is very rare. What events associated with earthquakes do cause the greatest loss of life and property?

   _____

3. What is a "tsunami"? _____

4. Where should buildings be constructed if we what them to survive major earthquakes?

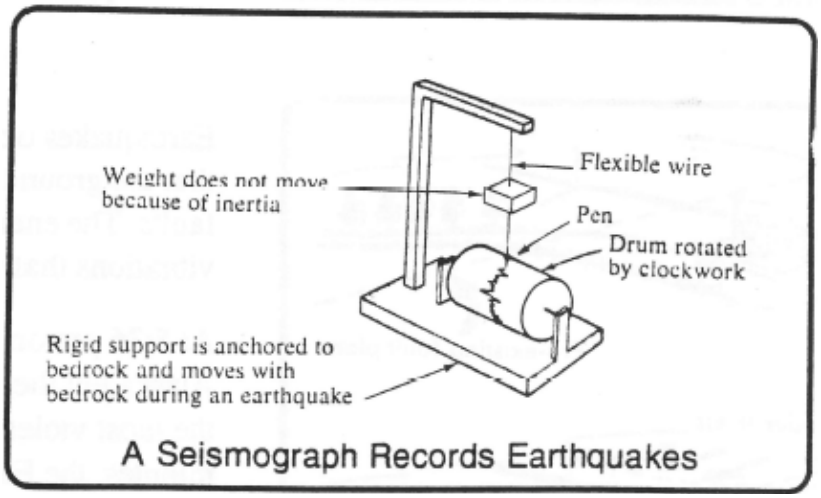
   _____

5. What geologic structures are associated with earthquakes?

   _____

In 1902 the Italian geophysicist, Giuseppe Mercalli, devised a relative scale to measure earthquakes. This scale was based upon first hand observations, or published reports of the effects of the earthquake. On the Mercalli scale, an earthquake of intensity I would be so slight that it would felt by very few people. The most intense seismic events rate XII and cause total destruction in structures that are not reinforced by steel frames.

In 1935, a scale of absolute magnitude was proposed by Charles Richter if the California Institute of Technology. On this scale, an earthquake of magnitude I could be observed only with sensitive instruments like the seismograph in the diagram to the right. With each increase of I on this scale, the earthquake would be felt ten times stronger. The greatest earthquake in modern history occurred in the Pacific Ocean off Chile in 1960. It had a Richter magnitude between 9 and 10. That seems to be about the limit of terrestrial rocks to hold stress before they break.



A Seismograph Records Earthquakes

When the United States and the Soviet Union negotiated a ban on atmospheric testing of nuclear weapons in 1963, both nations set up a sensitive network of seismic recording stations to monitor the underground testing of nuclear weapons. These seismic stations have allowed scientists to record and measure many earthquake that would otherwise have been unnoticed.

6. What instruments are used to record and measure earthquakes? _____

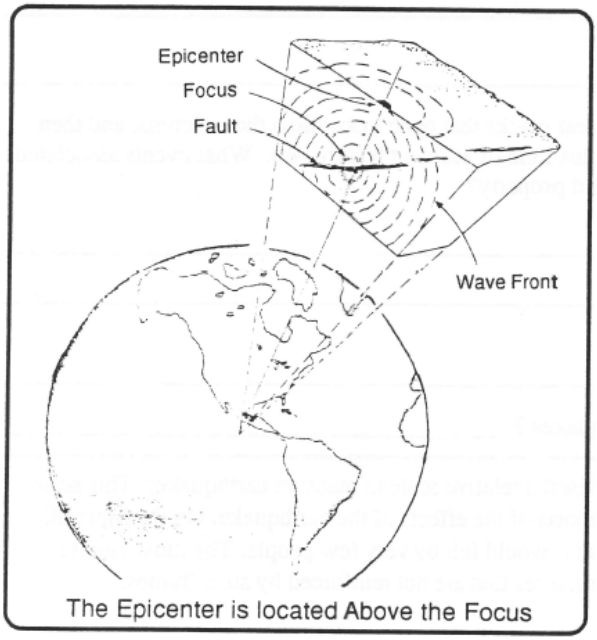
7. How does the Mercalli scale differ from the Richter scale?_____

_____

8. The strongest earthquakes probably have a Richter magnitude of about _____

9. How much stronger is an earthquake of magnitude 7, than an earthquake of magnitude 6? _____

10. What political event in the 1960s was a benefit to seismologists?_____



The Epicenter is located Above the Focus

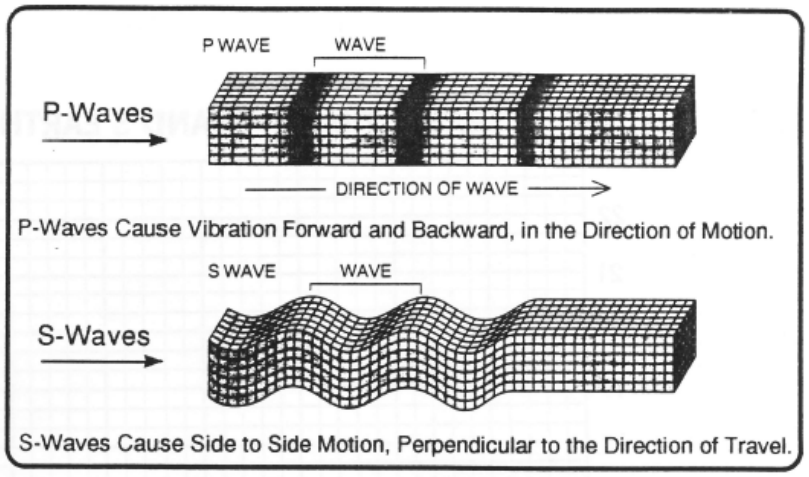
The place underground where the rock actually breaks is known as the focus of the earthquake. Directly above the focus, on the surface of the Earth, is the epicenter. The earthquake will be felt most strongly by people at the epicenter. (←See the diagram.)

Energy radiates from the focus as vibration waves. The speed of these waves is directly proportional to the rigidity of the rock through which they travel. The study of earthquakes, both man made and natural, has given geologists some of our most important information about the interior of the Earth.

Earthquakes generate primary, secondary and surface waves. These waves travel through the solid Earth like sound and light waves radiate through air. But each type of waves has its own special characteristics.

Primary ("P") waves travel the fastest. P-waves are longitudinal waves, like sound, because the waves pass as a series of compressions and expansions. P-waves cause the Earth to vibrate back and forth in the direction of travel, in a push-pull motion. Like sound, P-waves can travel through both solids and liquids.

Secondary ("S") waves are a little slower than P-waves. Like light, S-waves are transverse waves that cause side to side vibrations making the ground move perpendicular to the direction of travel. For this reason, S-waves are also known as shear waves. S-waves cannot travel through liquids.



Vibration Directions of P and S-Waves

Surface waves are the last to arrive. (This is partly because they because they travel through less rigid, more flexible rocks near the surface of the Earth.) Like waves on water, surface waves involve a combination of longitudinal and transverse vibrations. Surface waves cause the most damage and loss of life.

11. The epicenter of an earthquake is directly above the _____

12. As P and S-waves travel deeper within the Earth, the speed of these energy waves_____

13. Which kind of seismic waves cause the most damage to man made structures? _____

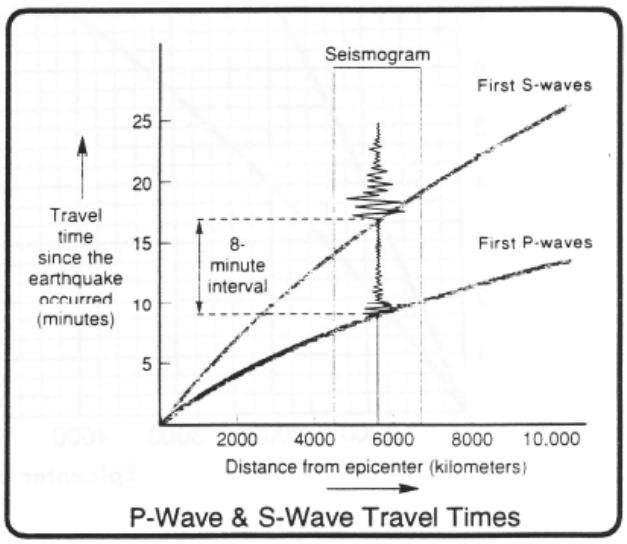
14. When an S-wave passes, the ground vibrates _____

15. Unlike P-waves, S-waves will not travel through a _____ medium.

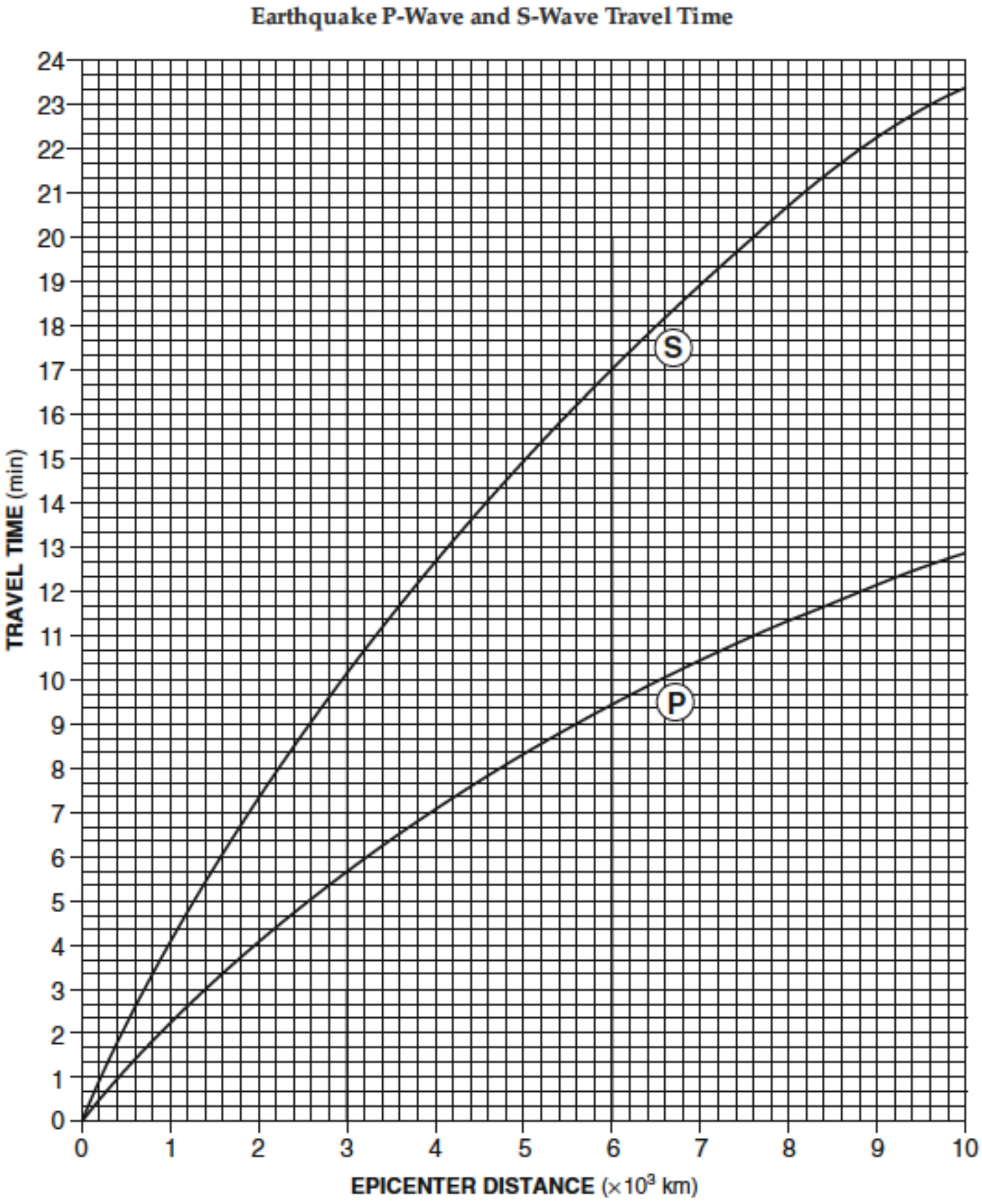
16. How have humans generated strong seismic tremors?_____

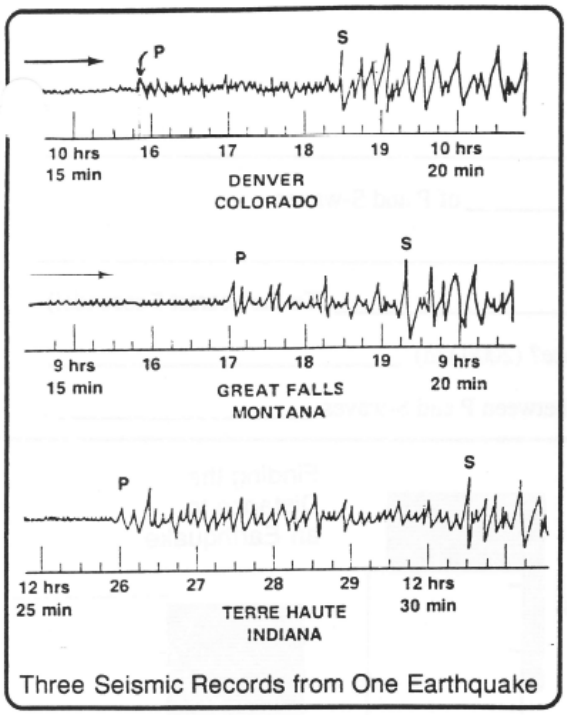
Because P-waves travel faster than S-waves, the greater the distance between the epicenter and the recording station, the greater the time lag between the arrival of P and S-waves. For a nearby earthquake, the P and S-waves arrives with little separation. But for distant events, the time lag will be longer.

Seismologists use this knowledge to determine the location of an earthquake. If the distance between the epicenter and three widely spaced recording stations can be found, the location of the earthquake can be determined. Thus, three recording stations are needed locate the epicenter of any earthquake.



P-Wave & S-Wave Travel Times


Earthquake P-Wave and S-Wave Travel Time
TRAVEL TIME (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
S
P
0
1
2
3
4
5
6
7
8
9
10
EPICENTER DISTANCE (×10³ km)



Three Seismic Records from One Earthquake

The diagram to the left shows three seismic recordings (seismograms) from a single earthquake detected at three different seismic stations.

17. Of P and S-waves, which is larger? _____

18. What is the length of time form one number to the next?

_____

19. Therefore, each of the smallest marks represents

_____

Written records of P and S-wave arrival times are written as HOURS:MINUTES:SECONDS in 24 hour military time. So 08:27:30 would mean 30 seconds past 8:27 in the morning, and 14:00:03 would be 3 seconds past two in the afternoon.

20. In this system, at what time did the great Alaska earthquake hit Anchorage on 3/27/'64? (Hint: Look at the second paragraph on page 1.)

_____

For these and all subsequent arrival times, record each arrival time to the nearest 5 seconds.

21. Record the arrival times of the S (secondary) waves as shown on the seismograms above.

S-waves: Denver _____ Great Falls _____ Terre Haute _____

22. In the spaces below, record the arrival times of the P-waves at these stations.

P-waves: Denver _____ Great Falls _____ Terre Haute _____

In a few minutes you will use the space above ( ) to find the time lag between P and S- waves. However, you must first become familiar with the technique of borrowing from the minutes or hours columns. (Just keep in mind that there are **60 seconds** in each minute and **60 minutes** in each hour.)

Look over the examples in 23-25 before you do the subtractions above.

23. 10:18:30
-10:11:40

24: 18:31:25
-18:28:36

25: 10:01:22
-09:56:31

Now, go back and calculate the time differences in 21 and 22 above. (Three subtractions)

Once the time lags between the P and S-wave arrival time are known, the distance from the epicenter to each seismic station can be found using the P and S-wave travel time graph on page 4 of this activity.

Please look at that graph now. (Page 4)

26. Along the horizontal axis is scale used to measure the distance between the seismograph station and the

27. The vertical axis shows the _____ of P and S-waves.

28. Why is the S-wave line higher than the P-wave line? _____

29. How long does it take for a P-wave to travel 2000 km? _____ (To the nearest 5 seconds!)

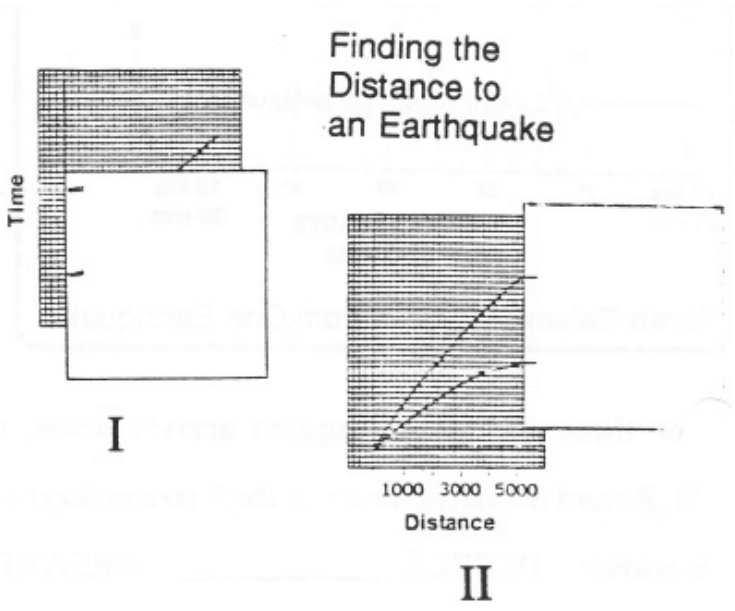
30. How long does it take an S-wave to travel the same distance? (2000 km) _____

31. As the distance from the epicenter increases, the time lag between P and S-waves _____

It is this delay that allows us to find the distance from the epicenter to each recording station using the graph on page 6 (also found in the Earth Science Reference Tables).

Lay a straight line edge of a piece of paper along the vertical axis as shown in the first diagram to the right. Carefully make two marks along the blank edge at 0 minutes and at the 5 minute mark. (Mark your paper now as shown here ->.)

Now move the paper to the place where there is a time difference of exactly 5 minutes between the P and S-wave lines. (See the second diagram ->.) Take care to keep the blank edge exactly vertical.



32. At what distance will the P-waves arrive 5 minutes ahead of the S-waves? _____
(Please take care to be exact. A lack of precision will be a problem on the next lab!)

33. If the P-wave arrives 8 minutes before the S-wave, the distance to the epicenter must be _____

34. For this last question, you will need to refer to the numbers that you obtained in the middle of page 4. How far was this Earthquake epicenter from the three recording stations on page 5?

Denver: _____ Great Falls: _____ Terre Haute: _____