Earth Science
Notes—Ch. 11 Earthquakes

NAME: _____

PERIOD: ____

I. Why do earthquakes occur?
   a. Pieces of the earth suddenly shift.
   b. The crust is mostly cold and brittle rock compared to the hot rock deeper inside.
   c. This crust is full of large and small cracks called _____.
   d. These faults can be _____ long
   e. Usually you cannot see the cracks because they are buried deep underground.
   f. Also, the pieces of crust are compressed together very tightly.
   g. Powerful forces cause these crustal pieces to move very slowly.
   h. The plates may get stuck together for many years.
   i. The forces pushing on the plates can cause them to break apart and move suddenly.

II. When do they slip?
   a. They slip when the rocks past their _____ _____
   b. They move along _____.
   c. The rocks remain bent after an earthquake.

III. Why do most earthquakes occur near plate boundaries?
   a. Forces inside of the earth including:
      i. _____
      ii. _____
      iii. _____
   b. The movement occurs as an earthquake.

IV. WHERE DO MOST OCCUR?
   a. _____% of EQ occur along the pacific plate
   b. _____% of EQ occur along the Mediterranean-Asiatic belt
   c. _____% occur within interiors of plates or along oceanic ridge systems.

V. Types of faults
   a. *Most earthquakes occur along plate boundaries.*
   b. *Different forces produce different fault types.*
   c. *What are the three forces?*
      i. ***Compression***—*force that* _____.
      ii. ***Tension***—*stress that causes* _____.

iii. ***Shear***—*force that causes slippage and the rocks on either side of the fault to* _____.

d. Normal Fault

i. *What type of force?* _____

ii. Rock above the fault surface moves _____

Normal Fault Diagram

e. Reverse Fault

i. *What type of force?* _____

ii. *Rock above the fault is* _____

Reverse Fault Diagram

f. Strike-Slip Faults (Transform Fault)

i. Rocks on either side of the fault are moving past each.

ii. There is no upward or downward movement

Strike-Slip Fault (Transform) Diagram

iii. San Andreas Fault

i. Probably the best known example of a strike slip fault

ii. Largest Fault in California

iii. _____ Km through the state

iv. So, is California going to fall into the Pacific? (Why or why not?)

VI. What is a Seismic Wave?

a. **Seismic Wave**—_____

_____

b. There are three types:

i. _____ Waves

ii. _____ Waves

iii. _____ Waves

VII. Earthquake Terminology

a. Before we explain the three types of waves, we need some basic terminology.

b. Focus (plural = foci)—_____

i. Most are within _____Km of the earth's surface.

ii. Some have been recorded as deep as _____ Km

iii. Waves travel outward in all directions

c. ***Epicenter***—_____

_____

VIII. Types of Waves

a. Primary Waves (P Waves)

i. Waves of energy released during an earthquake.

ii. Rock _____and _____as the wave moves.

P Wave Diagram	S Wave Diagram

b. Secondary Waves (S Waves)

i. Waves of energy released during an earthquake.

ii. Causing particles in rocks to move at _____

_____.

c. Surface Waves
    i. Waves of energy released during an earthquake.
    ii. They reach Earth's surface & travel outward from the epicenter in all directions.
    iii. Cause the most damage.
        i. 2 Types
            1. **Love Waves (Q-Waves)**
                I> Move rock particles in a backward rolling motion and a side-to-side, swaying motion

Surface (Love) Wave Diagram

            2. **Rayleigh Waves**
                I> Rock particles move in a rolling motion.
                II> The slowest moving wave

Surface (Rayleigh) Wave Diagram

    iv. Why do surface waves cause so much damage?
        i. _____
        ii. _____
    v. When do surface waves occur?
        i. Surface waves are produced when the earthquake energy reaches the Earth's surface.
        ii. They travel: outward from the _____.
        iii. This is the point: directly above the focus.
d. How can we locate an epicenter?
    i. Seismic waves all travel at different speeds.
        i. _____waves are the fastest.
        ii. _____waves are slower.
        iii. _____waves are slower yet.
    ii. How can we use this information?

i. _____

_____

ii. Example: Biking

IX. History of the Seismograph Station

a. After serious earthquakes in China, the Chinese scientist and mathematician invented the first seismograph in 132 A.D. to predict the next one.

b. He called it an _____

i. When the ground shook, it moved a _____inside the jug.

ii. The pendulum pushed: a lever that opened the _____.

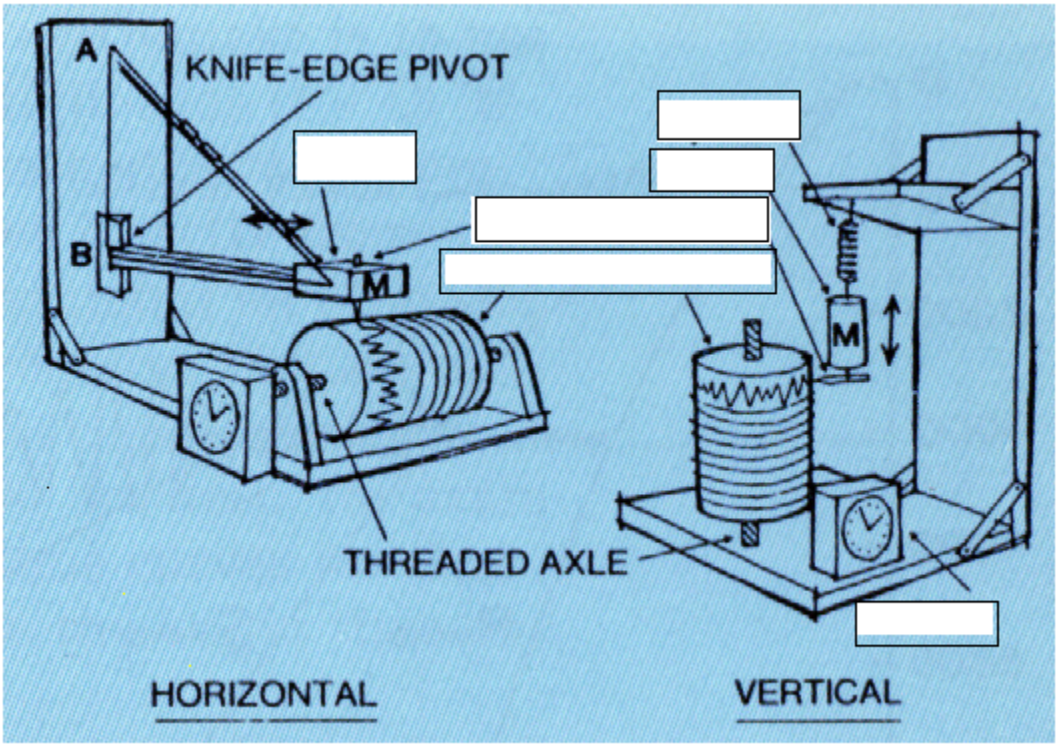
iii. The ball landed in the _____below, sounding an _____.

iv. The opened dragon's mouth: pointed in the direction of the earthquake, notifying the emperor.

X. How does the modern seismograph work?

a. Today's seismographs have a rotating _____ and a _____with an attached pen.

b. Label the diagram of a modern seismograph.



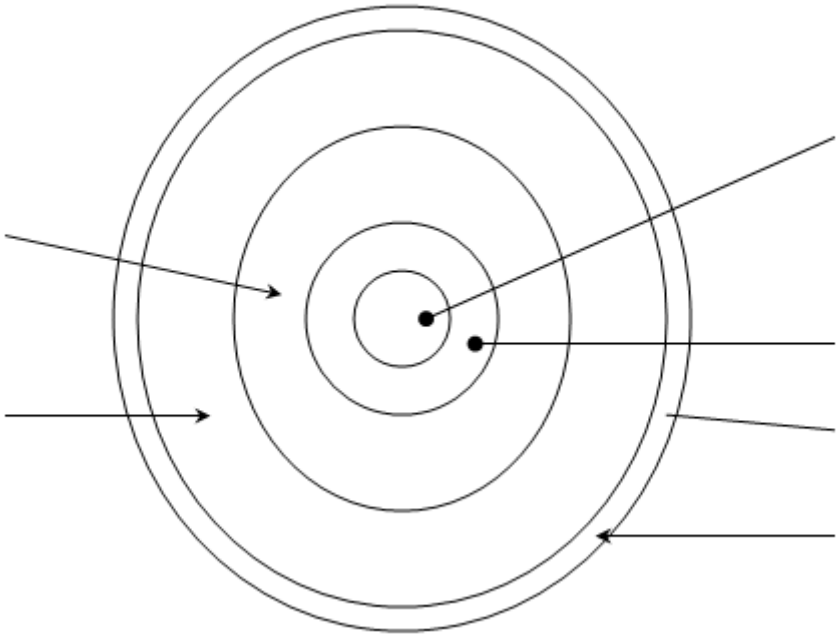
XI. Seismograph Stations

a. Each type of seismic wave reaches a seismograph station at a different time, based on its speed.
b. Which arrives first?
    i.
c. Which arrives second?
    i.
d. Which arrives last?
    i.
e. Since we know rates of travel for P and S waves, we can use a graph to determine distance from an epicenter.
    i. P waves travel at: _____
    ii. S waves travel at: _____
f. Scientist use this to determine the:
    i. _____
    ii. Using this, we can determine distance to the epicenter.
    iii. Data is then compared with other seismic stations.
g. How many seismic stations does it take to locate the epicenter?
    i. If you have one station, how many possible sites are there?
        i. _____
    ii. If you have two stations, how many possible sites are there?
        i. _____
    iii. If you have three stations, how many possible sites are there?
        i. _____
    iv. What would be the advantage of four sites?
        i. _____

XII. Mapping Earth's Interior

a. We know that at certain depths within Earth, that the speed and path of seismic waves change because of _____.

LAYERS OF THE EARTH



i. Crust
    i. Crust (5-60 km)—outer most layer.
        1. Note: upper 100 km of the earth is called the _____ (includes the crust and upper part of upper mantle.
        2. The _____—is the plastic like layer below the lithosphere (also in the mantle).
        3. **Moho Discontinuity**—transition area (not layer) separates the crust from the Mantle.
            I> Seismic waves speed up when they reach the bottom of the crust.
            II> Discovered by and Yugoslavian scientist, _____—he discovered that the waves were speeding up because they were passing into a denser layer of the lithosphere
    ii. Mantle, largest layer, mostly silicon, oxygen, magnesium, & iron. It is divided based on changes of seismic wave speed.
        1. Upper Mantle _____
            I> Upper portion is called the asthenosphere since rock flows.

2. Lower Mantle _____

iii. Outer Core (2270 km)

1. _____

iv. Inner Core (1216 km)

1. _____

_____

2. Pressure from above causes it to be _____

b. Since speeds and paths of waves change with density, we can map out the layers of the earth.

i. Shadow Zone:

_____

_____The reason follows:

i. Secondary Waves—don't travel through liquid.

_____

ii. Primary Waves—are slowed/bent by the liquid outer core.

_____

_____

iii. Simulation

1. Look at what happens when waves hit the bottom of the crust, upper mantle, lower mantle, outer core, & inner core.
2. 1° & 2° waves slow down when they hit the upper mantle (because it is plastic-like)
3. 1° & 2° speed up again as they pass through the solid lower mantle.
4. 1° waves are slowed & deflected when they hit the outer core.
5. 2° waves stop when they hit the outer core. (They can't pass through liquid)
6. 1° waves then speed up again when they travel through the solid inner core.

iv. Shadow Zone—an area between 105° and 140° from the focus, where no waves are detected because of the last 2 facts.

1. 1° waves then speed up again when they travel through the solid inner core.

XIII. Review

a. **Which type of seismic wave does the most damage to property? Why?**

i. _____

_____

b. **Why is a seismic record from three locations needed to determine the position of an epicenter?**

i. _____

_____

c. **Suppose an earthquake occurs at the San Andreas Fault. What area on Earth would experience no secondary waves?**

i. _____

_____

d. **Would China experience primary and secondary waves? Explain.**

i. _____

_____

_____

_____

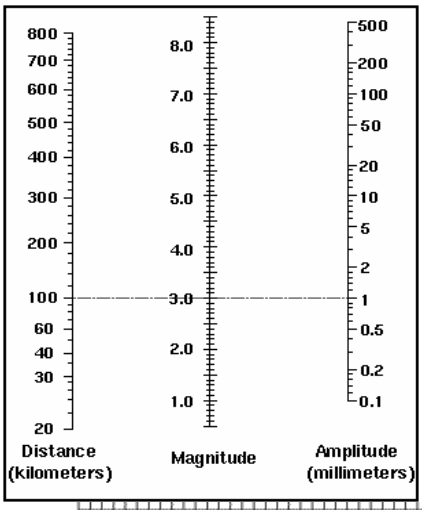
_____

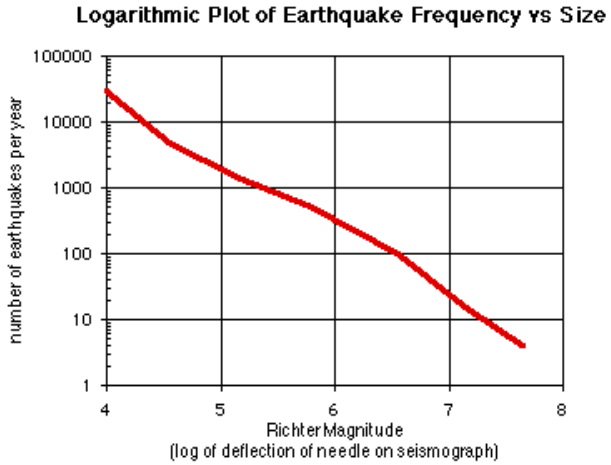
XIV. Scientists who study earthquakes are called _____.

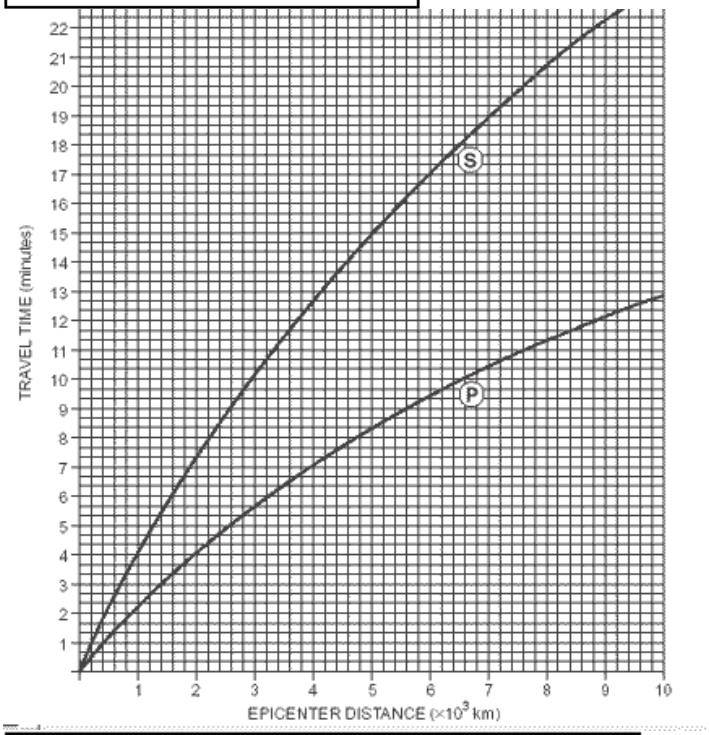
XV. Richter Scale

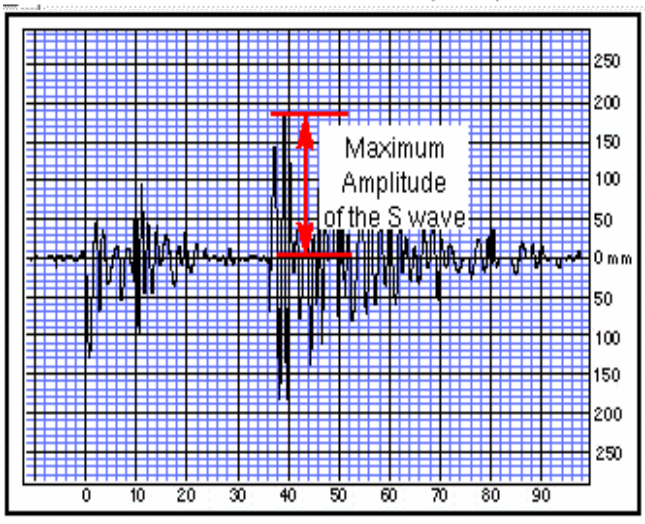
a. Richter Magnitude: _____

_____


800
700
600
500
400
300
200
100
60
40
30
20
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
Distance (kilometers)
Magnitude
Amplitude (millimeters)


Logarithmic Plot of Earthquake Frequency vs Size
number of earthquakes per year
100000
10000
1000
100
10
1
4
5
6
7
8
Richter Magnitude
(log of deflection of needle on seismograph)


TRAVEL TIME (minutes)
S
P
EPICENTER DISTANCE (×10³ km)


Maximum Amplitude of the S wave
250
200
150
100
50
0 mm
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90

b. If you know the distance to the epicenter and amplitude, you can calculate the magnitude. Let's try to determine the magnitude of the example seismogram in the upper right hand corner.
    i. Calculate the amplitude?

    ii. Calculate the SP Gap?

    iii. Now use the S-P Graph to determine the epicenter location?

    iv. So, what is the magnitude of this earthquake?

c. Charles Richter (1934) developed the scale.
    i. It is based on a _____For every increase in 1 on the scale, the amplitude increases by _____.
    ii. Note: the energy released for each increase of 1.0 is about _____.
    iii. Note: there is no high limit.
        i. However, the strongest recorded Earthquake was in Chile _____
        ii. More than _____EQ with magnitude 2 occur daily.

d. For example: an earthquake of 5 would have amplitude 10 times greater than an earthquake of 4.
    i. Ex: Compare an 8 to a 7.

    ii. Energy released: for every increase in 1, 32 times more energy is released at the focus. Ex: Compare a 5 to a 3.

    iii. Example:
        i. Magnitude 1= energy released by _____ TNT

ii. Magnitude 8 = energy released by _____ of TNT

e. Moment Magnitude
   i. Based on _____.
   ii. Derived by multiplying the _____by the _____and then again by the _____.
   iii. Related to strength and size of fault movement.

f. Mercalli Scale
   i. Giuseppe Mercalli (1902)—invented another way to measure an earthquakes strength.
   ii. This scale uses _____to determine intensity.
   iii. It is not considered as scientific. Some examples follow.
      i. 8—_____
      ii. 6—Slight to moderate damage in well built, ordinary structures. Considerable damage to poorly built structures. Some walls may fall.
      iii. 1 to 2—_____

g. Large and Small Scale Earthquakes
   i. Each year, about _____earthquakes are felt but cause little or no damage—3.0 to 4.9.
   ii. More than 1,000 earthquakes with magnitude _____occur daily.
   iii. See table 1 (Pg 314)
   iv. Most deadly known earthquake: 1556 Shensi, China (Estimate of 9.7), 830,000 deaths.

XVI. Other Problems

a. Liquefaction—

_____

_____

   i. People should avoid building on loose soils in these areas.

b. Tsunamis
   i. Three main causes of tsunamis:
      i. _____
      ii. _____
      iii. _____
   ii. The ocean floor deforms.

iii. This causes a displacement of water.
iv. EQ under the sea causes abrupt movement of ocean floor.
v. The movement pushes against the water, generating a powerful wave that travels to the surface.
vi. After reaching the surface, the waves can travel thousands of km's in all directions.
vii. Once they get near shore, they begin to rise above the surface as high as _____

c. Tsunamis Warning System
   i. The Pacific Tsunami Warning Center—near _____
   ii. Provides predicted tsunami arrival times at coastal areas.
   iii. This warning system is mostly for the Pacific Ocean.
   iv. After the 2004 Tsunami, a expansion of the warning system was proposed.
   v. By 2007, the US will have deployed 27 additional DART (Deep Ocean Assessment & Reporting of Tsunami) Buoys
   vi. This will give the US almost _____
   _____
   vii. Buoys
      i. Anyone can view the data at any of the buoys at anytime.

d. Earthquake Safety
   i. Structures can be built seismic safe.
      i. They stand up to vibrations
      ii. Support buildings with _____ placed under the buildings.
      iii. They are made of alternating layers of _____.
      iv. Buildings should be able to survive an _____earthquake.
   ii. How can we make homes safe?
      1. _____
      2. _____
      3. _____
      4. _____
   iii. What should you do in an earthquake?

i. Move away from windows and any objects that could fall.
ii. Seek shelter in a doorway or under a sturdy table or desk.
iii. If outdoors, stay in open areas away from power lines
iv. Stay away from buildings, chimneys, or other parts that may fall.

iv. What about after an earthquake?
i. Check water and gas lines for damage
ii. Shut off valves if damaged
iii. If you smell gas, leave
iv. Be careful around broken glass and rubble.
v. Stay away from beaches—danger of tsunamis