Watch the video: “Earthquake Simulations”

<http://somup.com/cbfjnkWPT>

Fill in the blanks on each page based on the simulation:

#### **What's an Earthquake?**

Earthquakes occur because of a sudden release of stored \_\_\_\_. This energy has built up over long periods of time as a result of \_\_\_\_\_ forces within the earth. Most earthquakes take place along \_\_\_\_\_ in the upper 25 miles of the earth's surface when one side rapidly moves relative to the other side of the fault. This sudden motion causes shock waves (\_\_\_\_ waves) to radiate from their point of origin called the **\_\_\_\_** and travel through the earth. It is these seismic waves that can produce ground motion which people call an earthquake. Each year there are thousands of earthquakes that can be felt by people and over one million that are strong enough to be recorded by instruments. Strong seismic waves can cause great local damage and they can travel large distances. But even weaker seismic waves can travel far and can be detected by sensitive scientific instruments called **\_\_\_\_\_**.

#### **What are Earthquake (Seismic) Waves?**

A seismic wave is simply a means of transferring energy from one spot to another within the earth. Although seismologists recognize different types of waves, we are interested in only two types: P (\_\_\_\_\_) waves, which are similar to sound waves, and S (\_\_\_\_\_) waves, which are a kind of shear wave. Within the earth, \_\_\_ waves can travel through solids and liquids, whereas \_\_\_ waves can only travel through \_\_\_\_\_.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with \_\_\_\_\_\_ and rock type. P waves travel between 6 and 13 km/sec. S waves are \_\_\_\_\_ and travel between 3.5 and 7.5 km/sec.

#### **What's a Seismogram?**

|  |  |
| --- | --- |
| SampleSeismogram | A highly simplified simulated recording of earthquake waves (a \_\_\_\_) can be seen to the left. Study this sample seismogram and be sure you can identify these parts: * P-waves and the P-wave arrival time
* S-waves and the S-wave arrival time
* S-P interval (expressed in seconds)
* S-wave maximum amplitude (measured in mm)
 |

**Note:** This seismogram is a simulation. The actual records of earthquake waves are far more complicated than what is presented here. As P and S waves travel through the earth, they are reflected by various \_\_\_\_\_ of the earth (such as the core-mantle \_\_\_\_\_). This interaction produces additional seismic waves (phases) which will be detected by seismographs. Once you successfully complete this tutorial, you will be given links to some seismology labs, where you can see real seismograms.

#### **How is an Earthquake's Epicenter Located?**

In order to locate the \_\_\_\_\_ of an earthquake you will need to examine its seismograms as recorded by \_\_\_\_\_\_ different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). (In the figure above, the S - P interval is about \_\_\_ seconds. The vertical lines are placed at \_\_\_ second intervals.) The S - P time interval will then be used to determine the distance the waves have traveled from the origin to that station.

The actual location of the earthquake's epicenter will be on the perimeter of a circle drawn around the recording station. The radius of this circle is the \_\_\_\_\_ distance. One S - P measurement will produce one epicenter distance: the direction from which the waves came is unknown. \_\_\_\_\_ stations are needed in order to "triangulate" the location.

Choose any TWO of the following regions to generate a set of seismograms for an earthquake and then click on “Submit Choice” to the right.

1. San Francisco Area

2. Southern California

3. Japan Region

4. Mexico

Let’s Make an Earthquake Data Table 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station:  | S – P Interval | Distance | Amplitude | Magnitude |
| 1 |   | sec | km | mm |   |
| 2 |   | sec | km | mm |
| 3 |   | sec | km | mm |

Let’s Make An Earthquake Data Table 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station:  | S – P Interval | Distance | Amplitude | Magnitude |
| 1 |   | sec | km | mm |   |
| 2 |   | sec | km | mm |
| 3 |   | sec | km | mm |

### Richter Magnitude

#### Magnitude Explained

So far you have worked on locating the epicenter of an earthquake. The next questions to ask are "How strong was this particular earthquake and how does it compare to other earthquakes?"

There are many ways that one could evaluate the relative strength of an earthquake: from the \_\_\_\_\_\_ of repairs resulting from damage, from the length of rupture of the earthquake fault, from the amount of ground \_\_\_\_\_\_, etc. But determining the strength of an earthquake using these kinds of "estimators" is full of potential problems and subjectivity. For example, the cost of repairs resulting from a strong earthquake in a remote region would be much less than that of a moderate earthquake in a populated area. Furthermore, the degree of damage would depend greatly on the quality of construction. Also, only a few earthquakes produce actual ground ruptures at the surface.

A well-known scale used to compare the strengths of earthquakes involves using the records (the seismograms) of an earthquake's shock waves. The scale, known as the **\_\_\_\_\_\_ Magnitude Scale**, was introduced into the science of seismology in 1935 by Dr. C. F. Richter of the California Institute of Technology in Pasadena. The **magnitude** of an earthquake is an estimate of the total amount of \_\_\_\_\_ released during fault \_\_\_\_\_. The Richter magnitude of an earthquake is a number: about \_\_\_ for earthquakes that are strong enough for people to feel and about \_\_\_ for the Earth's strongest earthquakes. Although the Richter scale has no upper nor lower limits, earthquakes greater than 9 in Richter magnitude are unlikely. The most sensitive seismographs can record nearby earthquakes with magnitude of about -2 which is the equivalent of stamping your foot on the floor.

The Richter magnitude determination is based on measurements made on seismograms. Two measurements are needed: the **\_\_\_\_\_ interval and the Maximum \_\_\_\_\_\_ of the Seismic waves**. You already know how to measure the S-P interval.



The following illustration shows how to make the measurement of the S wave's maximum amplitude. The blue horizontal grid lines are spaced at 10-millimeter intervals. In this example the maximum amplitude is about 185 mm.

### The Richter Nomogram

Although the relationship between Richter magnitude and the measured amplitude and S-P interval is complex, a graphical device (a **\_\_\_\_\_**) can be used to simplify the process and to estimate magnitude from distance and amplitude.



In the diagram below the dotted line represents the "**\_\_\_\_\_** " Richter earthquake. This standard earthquake is \_\_\_\_ km away and produces \_\_\_ mm of amplitude on the seismogram. It is assigned a magnitude of \_\_\_. Other earthquakes can then be referenced to this standard.

Note that a 100 km-away earthquake of magnitude 4 would produce 10 mm of amplitude and a magnitude 5 would produce 100 mm of amplitude: 1, 10 and 100 are all powers of 10 and this is why the Richter Scale is said to be "**\_\_\_\_\_**." A change of one unit in magnitude (say from 4 to 5) increases the maximum amplitude by a factor of \_\_\_.

ANSWERS

#### **What's an Earthquake?**

Earthquakes occur because of a sudden release of stored energy. This energy has built up over long periods of time as a result of tectonic forces within the earth. Most earthquakes take place along faults in the upper 25 miles of the earth's surface when one side rapidly moves relative to the other side of the fault. This sudden motion causes shock waves (seismic waves) to radiate from their point of origin called the **focus** and travel through the earth. It is these seismic waves that can produce ground motion which people call an earthquake. Each year there are thousands of earthquakes that can be felt by people and over one million that are strong enough to be recorded by instruments. Strong seismic waves can cause great local damage and they can travel large distances. But even weaker seismic waves can travel far and can be detected by sensitive scientific instruments called **seismographs**.

#### **What are Earthquake (Seismic) Waves?**

A seismic wave is simply a means of transferring energy from one spot to another within the earth. Although seismologists recognize different types of waves, we are interested in only two types: P (primary) waves, which are similar to sound waves, and S (secondary) waves, which are a kind of shear wave. Within the earth, P waves can travel through solids and liquids, whereas S waves can only travel through solids.

The speed of an earthquake wave is not constant but varies with many factors. Speed changes mostly with depth and rock type. P waves travel between 6 and 13 km/sec. S waves are slower and travel between 3.5 and 7.5 km/sec.

#### **What's a Seismogram?**

|  |  |
| --- | --- |
| SampleSeismogram | A highly simplified simulated recording of earthquake waves (a seismogram) can be seen to the left. Study this sample seismogram and be sure you can identify these parts: * P-waves and the P-wave arrival time
* S-waves and the S-wave arrival time
* S-P interval (expressed in seconds)
* S-wave maximum amplitude (measured in mm)
 |

**Note:** This seismogram is a simulation. The actual records of earthquake waves are far more complicated than what is presented here. As P and S waves travel through the earth, they are reflected by various layers of the earth (such as the core- mantle boundary). This interaction produces additional seismic waves (phases) which will be detected by seismographs. Once you successfully complete this tutorial, you will be given links to some seismology labs, where you can see real seismograms.

#### **How is an Earthquake's Epicenter Located?**

In order to locate the epicenter of an earthquake you will need to examine its seismograms as recorded by three different seismic stations. On each of these seismograms you will have to measure the S - P time interval (in seconds). (In the figure above, the S - P interval is about 36 seconds. The vertical lines are placed at 2 second intervals.) The S - P time interval will then be used to determine the distance the waves have traveled from the origin to that station.

The actual location of the earthquake's epicenter will be on the perimeter of a circle drawn around the recording station. The radius of this circle is the epicenter distance. One S - P measurement will produce one epicenter distance: the direction from which the waves came is unknown. Three stations are needed in order to "triangulate" the location.

Let’s Make An Earthquake Data Tables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station: San Francisco | S – P Interval | Distance | Amplitude | Magnitude |
| 1 | Eureka, CA | 49 sec | 478 km |  285 mm | 7.1 |
| 2 | Elko, NV | 72 sec | 702 km |  60 mm |
| 3 | Las Vegas, NV | 64 sec | 624 km | 100 mm |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station: Southern California | S – P Interval | Distance | Amplitude | Magnitude |
| 1 | Fresno, CA | 35 sec | 340 km |  350 mm | 6.7 |
| 2 | Las Vegas, NV | 39 sec | 380 km |  245 mm |
| 3 | Phoenix, AZ | 61 sec | 600 km | 50 mm |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station: Japan | S – P Interval | Distance | Amplitude | Magnitude |
| 1 | Pusan | 56 sec | 545 km | 90 mm | 6.8 |
| 2 | Tokyo | 44 sec | 430 km |  170 mm |
| 3 | Akita | 71 sec | 695 km | 30 mm |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Recording Station: Mexico | S – P Interval | Distance | Amplitude | Magnitude |
| 1 | Chichuahua | 64 sec | 622 km | 10 mm | 6.1 |
| 2 | Mazatlan | 43 sec | 417 km |  50 mm |
| 3 | Akita | 59 sec | 582 km | 10 mm |

### Richter Magnitude

#### Magnitude Explained

So far you have worked on locating the epicenter of an earthquake. The next questions to ask are "How strong was this particular earthquake and how does it compare to other earthquakes?"

There are many ways that one could evaluate the relative strength of an earthquake: from the cost of repairs resulting from damage, from the length of rupture of the earthquake fault, from the amount of ground shaking, etc. But determining the strength of an earthquake using these kinds of "estimators" is full of potential problems and subjectivity. For example, the cost of repairs resulting from a strong earthquake in a remote region would be much less than that of a moderate earthquake in a populated area. Furthermore, the degree of damage would depend greatly on the quality of construction. Also, only a few earthquakes produce actual ground ruptures at the surface.

A well-known scale used to compare the strengths of earthquakes involves using the records (the seismograms) of an earthquake's shock waves. The scale, known as the **Richter Magnitude Scale**, was introduced into the science of seismology in 1935 by Dr. C. F. Richter of the California Institute of Technology in Pasadena. The **magnitude** of an earthquake is an estimate of the total amount of energy released during fault rupture. The Richter magnitude of an earthquake is a number: about 3 for earthquakes that are strong enough for people to feel and about 8 for the Earth's strongest earthquakes. Although the Richter scale has no upper nor lower limits, earthquakes greater than 9 in Richter magnitude are unlikely. The most sensitive seismographs can record nearby earthquakes with magnitude of about -2 which is the equivalent of stamping your foot on the floor.

The Richter magnitude determination is based on measurements made on seismograms. Two measurements are needed: the **S-P time interval and the Maximum Amplitude of the Seismic waves**. You already know how to measure the S-P interval.



The following illustration shows how to make the measurement of the S wave's maximum amplitude. The blue horizontal grid lines are spaced at 10-millimeter intervals. In this example the maximum amplitude is about 185 mm.

### The Richter Nomogram

Although the relationship between Richter magnitude and the measured amplitude and S-P interval is complex, a graphical device (a nomogram) can be used to simplify the process and to estimate magnitude from distance and amplitude.



In the diagram below the dotted line represents the "standard" Richter earthquake. This standard earthquake is 100 km away and produces 1 mm of amplitude on the seismogram. It is assigned a magnitude of 3. Other earthquakes can then be referenced to this standard.

Note that a 100 km-away earthquake of magnitude 4 would produce 10 mm of amplitude and a magnitude 5 would produce 100 mm of amplitude: 1, 10 and 100 are all powers of 10 and this is why the Richter Scale is said to be "exponential." A change of one unit in magnitude (say from 4 to 5) increases the maximum amplitude by a factor of 10.