How is earthquake magnitude measured?

Active Reading

15 Identify As you read, underline how magnitude is related to earthquake strength.

Seismograms can also provide information about an earthquake's strength. The height of the waves on a seismogram indicates the amount of ground motion. Ground motion can be used to calculate **magnitude**, the measure of energy released by an earthquake. The larger the magnitude of an earthquake is, the stronger the earthquake. Seismologists express magnitude by using the Richter scale or the Moment Magnitude scale.

By Using the Richter Scale

The Richter scale measures the ground motion from an earthquake to find the earthquake's strength. Each time the magnitude increases by one unit, the measured ground motion is 10 times greater. For example, an earthquake with a magnitude of 5.0 on the Richter scale produces 10 times as much ground motion as an earthquake with a magnitude of 4.0.

By Using the Moment Magnitude Scale

The Moment Magnitude scale has largely replaced the Richter scale. Moment magnitude measures earthquake strength based on the size of the area of the fault that moves, the average distance that the fault moves, and the rigidity of the rocks in the fault. The Moment Magnitude scale is more accurate for large earthquakes than the Richter scale is. The moment magnitude of an earthquake is expressed by a number. The larger the number is, the stronger the earthquake was. The largest earthquake ever recorded took place in Chile and registered a moment magnitude of 9.5.

16 Identify After the Chilean earthquake in 1960, which has been the strongest earthquake in the last 100 years?

Year	Location	Moment Magnitude
2011	Tōhoku, Japan	9.0
2010	Port-au-Prince, Haiti	7.0
1994	Northridge, California	6.7
1964	Prince William Sound, Alaska	9.2
1960	Southern Chile	9.5

The 1964 earthquake on Kodiak Island, Alaska, measured 9.2 on the Moment Magnitude scale.

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How is earthquake intensity measured?

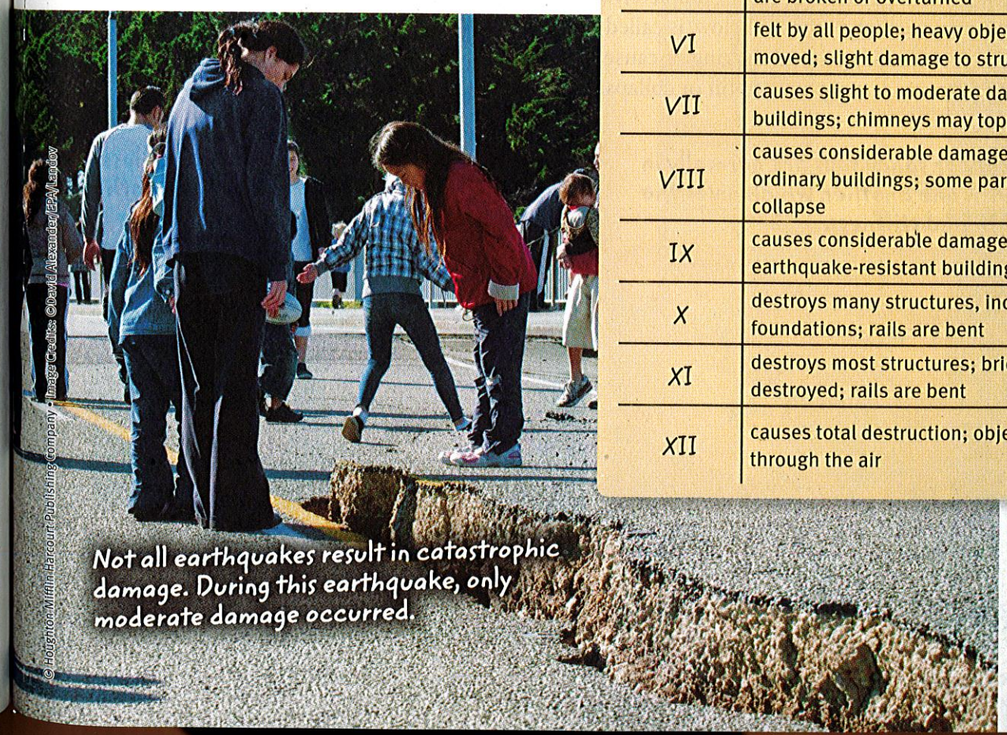
The effects of an earthquake and how the earthquake is felt by people are known as the earthquake's **intensity**. An earthquake's magnitude is different from its intensity. Magnitude measures how much energy is released by an earthquake. Intensity measures the effects of an earthquake at Earth's surface.

The Modified Mercalli scale is used to describe an earthquake's intensity. The scale ranges from I to XII. Earthquakes that have an intensity value of I are barely noticeable. Earthquakes that have an intensity value of XII cause total destruction. Intensity values vary from place to place and are usually highest near the epicenter of the earthquake.

Visualize It!

17 Infer Describe the damage that you see in the photograph. What Modified Mercalli scale rating would you give this earthquake?

Intensity	Description
I	felt by very few people under especially favorable conditions
II	felt by few people at rest; some suspended items may swing
III	felt by most people indoors; vibrations feel like passing trucks
IV	felt by many people; windows or dishes rattle
V	felt by nearly everyone; some objects are broken or overturned
VI	felt by all people; heavy objects are moved; slight damage to structures
VII	causes slight to moderate damage to buildings; chimneys may topple
VIII	causes considerable damage to ordinary buildings; some partial collapse
IX	causes considerable damage to earthquake-resistant buildings
X	destroys many structures, including foundations; rails are bent
XI	destroys most structures; bridges destroyed; rails are bent
XII	causes total destruction; objects tossed through the air



Not all earthquakes result in catastrophic damage. During this earthquake, only moderate damage occurred.

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Damage Control

What factors determine the effects of an earthquake?

The effects of an earthquake can vary over a wide area. Four factors determine the effects of an earthquake on a given area. These factors are magnitude, the local geology, the distance from the epicenter, and the type of construction used in an area.

Magnitude

Recall that an earthquake's magnitude is directly related to its strength. Stronger earthquakes cause more ground motion and, thus, cause more damage than weaker earthquakes. As an earthquake's magnitude increases, the intensity of an earthquake is commonly higher.

Local Geology

The amount of damage caused by an earthquake also depends on the material through which seismic waves travel. In general, solid rock is not likely to increase an earthquake's intensity. However, seismic waves can become more dangerous when they travel through loose soils and sediments that are saturated with water. When water-saturated soil or sediment is shaken by seismic waves, the soil and sediment particles become completely surrounded by water. This process, which is shown below, is called *liquefaction*. Liquefaction can intensify ground shaking or cause the ground to settle. Settling can cause structures to tilt or collapse.

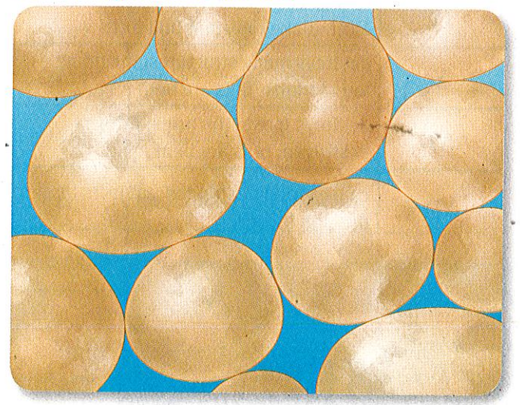
18 Apply Why would it be potentially dangerous to build a home or building on loose soil or sediment?

_____

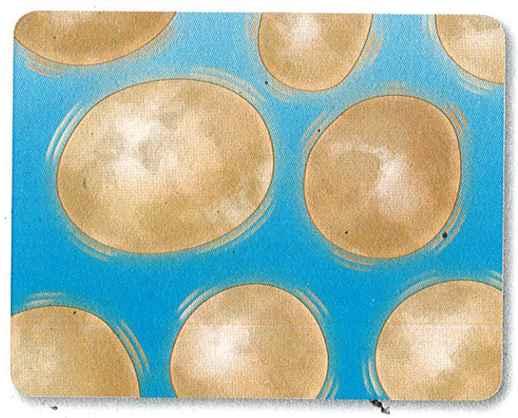
_____

_____

Grains in silty or sandy soils are normally in contact with one another, which gives the soil strength and stiffness.



When ground shaking occurs, the grains lose contact with one another, and the strength of the soil decreases.



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Distance from the Epicenter

Surface waves, which move along Earth's surface, are the most destructive of all seismic waves. The more energy a surface wave carries, the stronger the ground motion will be and the more damage the wave will cause. However, surface waves decrease in size and energy the farther that they travel from the epicenter of an earthquake. Therefore, the farther an area is located from the epicenter, the less damage it will suffer.

Building Construction

The materials with which structures are built also determine the amount of earthquake damage. Flexible structures are more likely to survive strong ground shaking. Structures that are made of brick or concrete are not very flexible and are easily damaged. Wood and steel are more flexible. Taller buildings are more susceptible to damage than shorter buildings. This diagram shows technologies in use that control how much tall buildings sway during earthquakes. Other technologies are designed to prevent seismic waves from moving through buildings.

Visualize It!

19 Apply How are mass dampers and active tendon systems similar in the way they protect a building from earthquake damage?

_____

_____

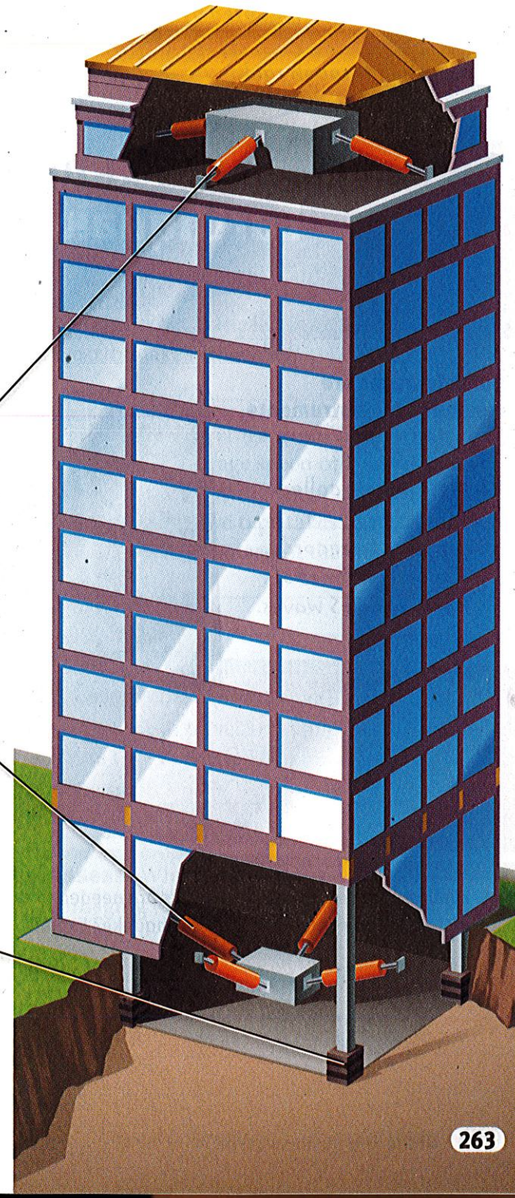
_____

_____

A **mass damper** is a weight placed in the roof of a building. Motion sensors detect building movement during an earthquake and send messages to a computer. The computer then signals controls in the roof to shift the mass damper to counteract the building's movement.

The **active tendon system** works much like the mass damper system in the roof. Sensors notify a computer that the building is moving. Then the computer activates devices to shift a large weight to counteract the movement.

Base isolators act as shock absorbers during an earthquake. They are made of layers of rubber and steel wrapped around a lead core. Base isolators absorb seismic waves and prevent the waves from traveling through the building.



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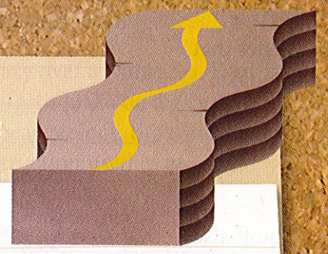
Visual Summary

To complete this summary, fill in the blanks. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Measuring Earthquake Waves

Seismic waves are vibrations that cause ground motion during earthquakes.



20 Seismic waves are caused by _____ traveling through rock.

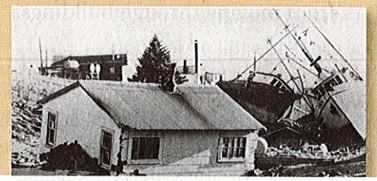
Magnitude is a measure of the energy released by an earthquake.

21 An earthquake's magnitude can be measured using the _____ and the _____ _____

Seismic waves are measured by instruments.

22 Instruments called _____ are used to record the arrival times of P waves and S waves.

Different factors determine the effects of earthquakes.



23 The effects of an earthquake are determined by the earthquake's magnitude, _____, distance from the _____, and _____

Answers: 20 energy; 21 Richter scale, Moment Magnitude scale; 22 seismometers; 23 local geology, epicenter, building construction

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24 Evaluate How many seismometers are needed to determine the location of the epicenter of an earthquake? Explain.

Lesson Review

Vocabulary

Fill in the blank with the term that best completes the following sentences.

1 The tracings of seismometers are called _____

2 An earthquake's _____ is located directly above its _____

3 The _____ of an earthquake is a measure of its strength.

Key Concepts

4 Summarize What causes an earthquake?

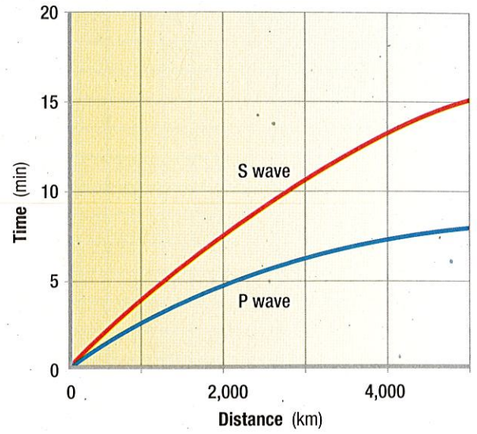
5 Contrast How is the motion of P waves different from the motion of S waves?

6 Compare What is the difference between earthquake magnitude and intensity?

7 Explain How is distance from the epicenter related to the amount of earthquake damage?

Critical Thinking

Use the time-distance graph to answer the following questions.



8 Identify What is the lag time at 2,000 km from the earthquake's epicenter?

9 Calculate The average speed of P waves is 6.1 km/s, and the average speed of S waves is 4.1 km/s. Use the following equation to calculate how long each wave type takes to travel 100 km: 100 km ÷ average speed of the wave = time.

10 Calculate Find the lag time for earthquake waves at 100 km by subtracting the time P waves take to travel 100 km from the time S waves take to travel 100 km.

11 Assess Why would surface waves be more damaging to buildings than P waves or S waves?

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