geoPHYSICS

Warm-ups for your physics classes

Presented at NSTA 2010 – Philadelphia, PA

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www.iris.edu

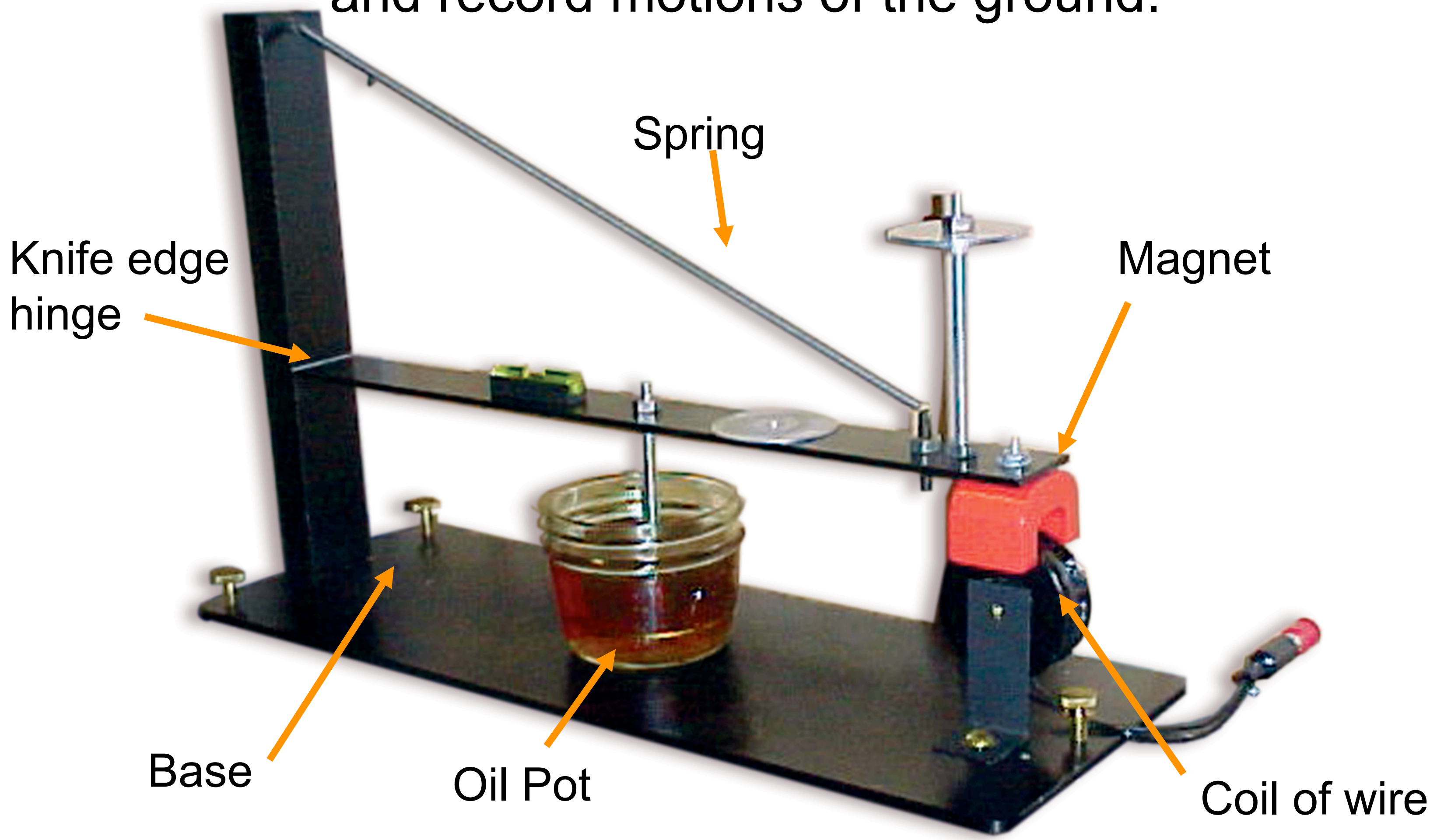
Intended use…

- Anticipatory Set
  - Focus attention
  - Relate to previous learning
    - Access students past knowledge
    - Provide valuable diagnostic info
  - Foundation for new learning
- Closing Questions
  - Application/Synthesis questions
  - Provide valuable diagnostic info

Format of slides

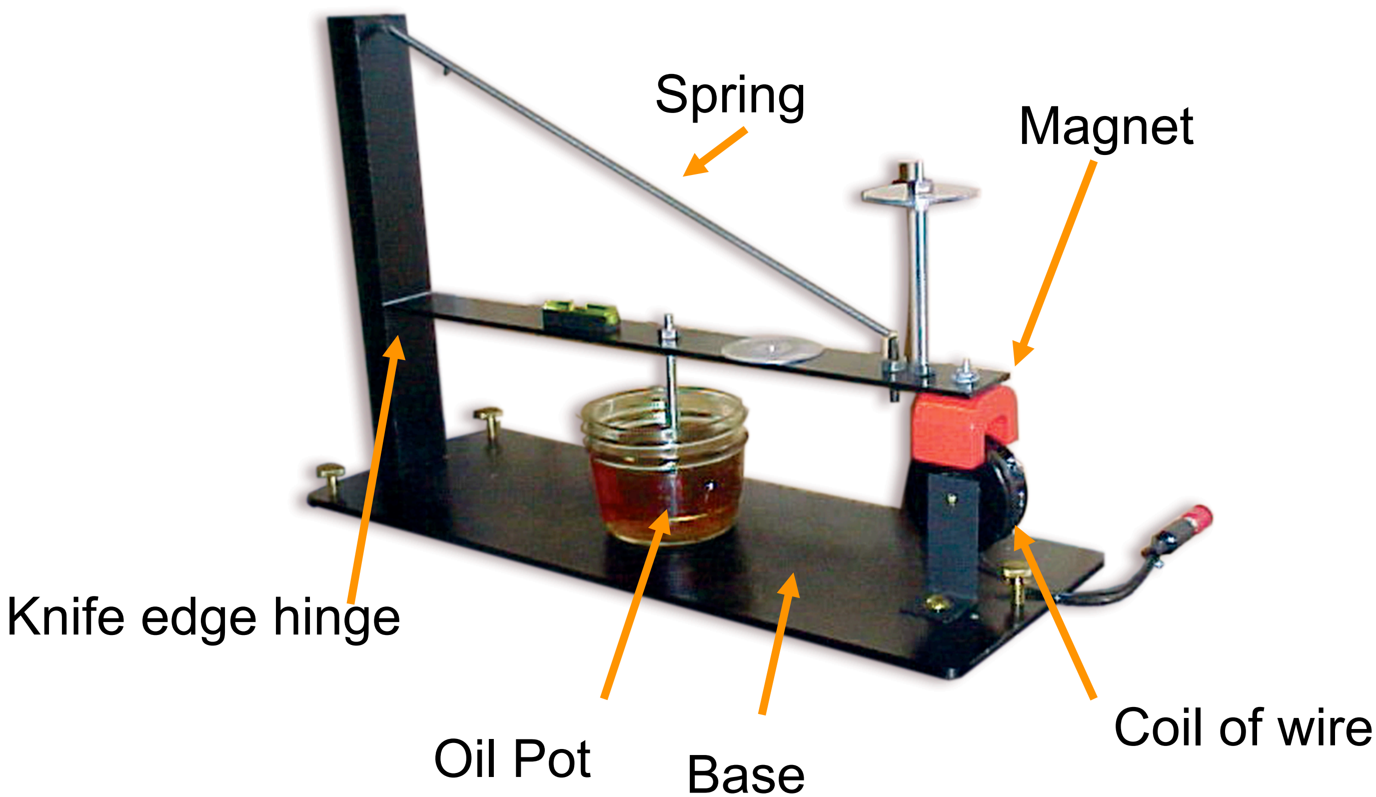
- Question on one slide
- Answer on a second slide
- Detailed answer in speaker notes of Q slide
- Abbreviated answer on A slide

Seismometers, like the one below, are instruments that measure and record motions of the ground.

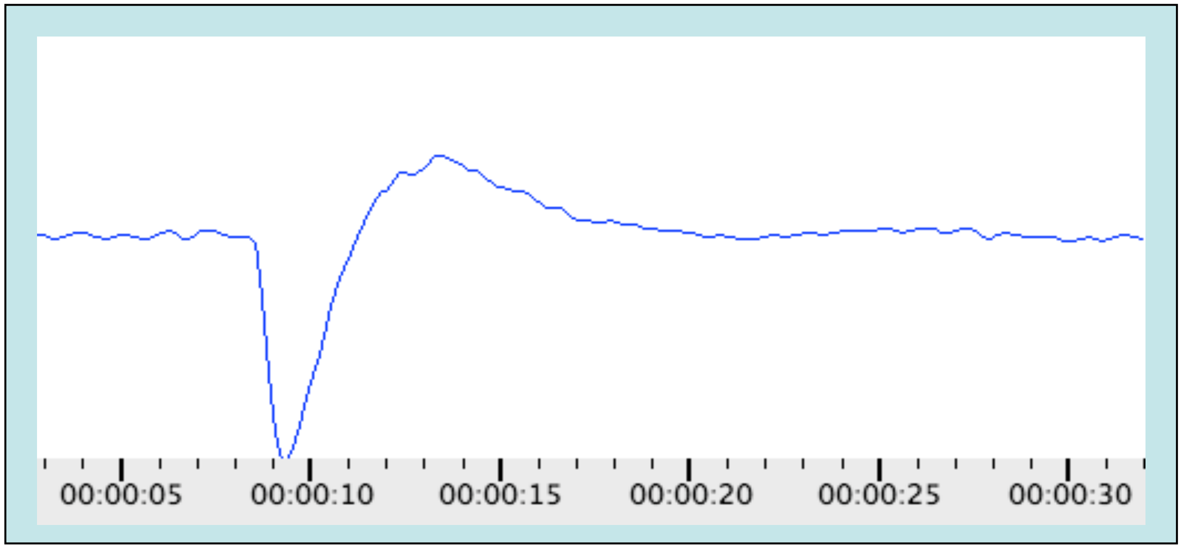


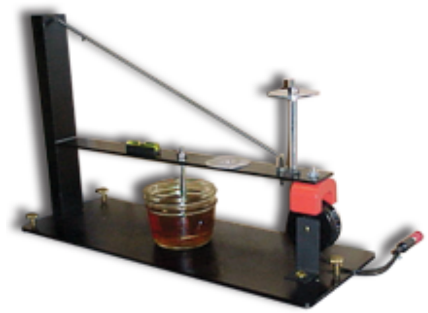
Study the design of the seismometer above. Where are its moving parts? How does it demonstrate Newton's First Law of Motion?

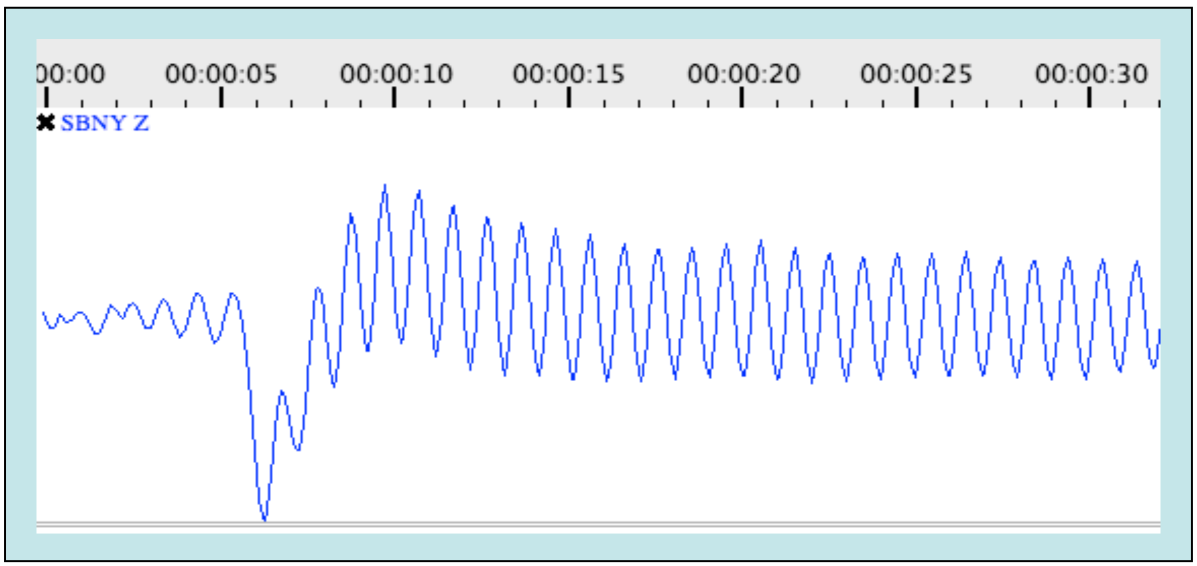
The red magnet or mass is decoupled from the base of the seismometer through the knife edge hinge and the spring. When the seismometer is acted upon by an external force, in this case an earthquake, initially the mass remains at rest while the base of the seismometer or the ground is set into motion.

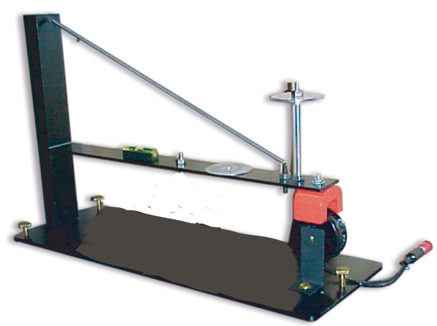


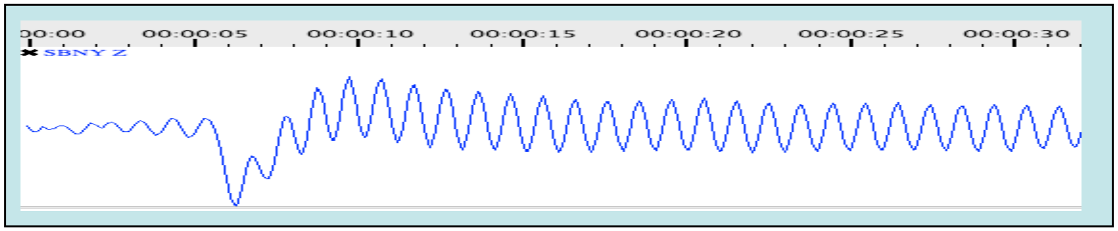
What is different about the two seismographs and their recordings show below? Both experienced the same force. How does this illustrate the second half of Newton's First Law.



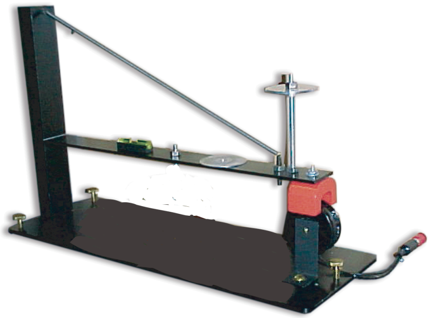






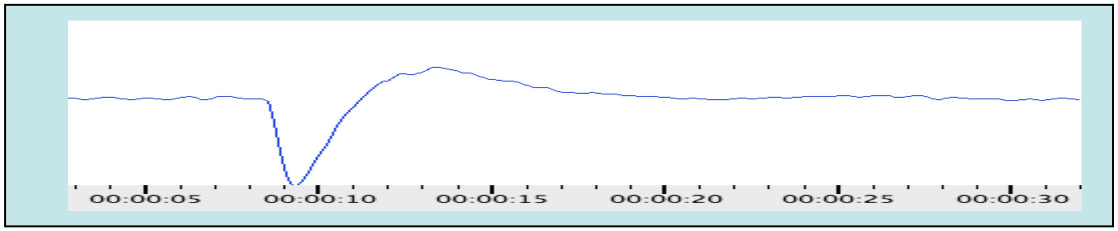


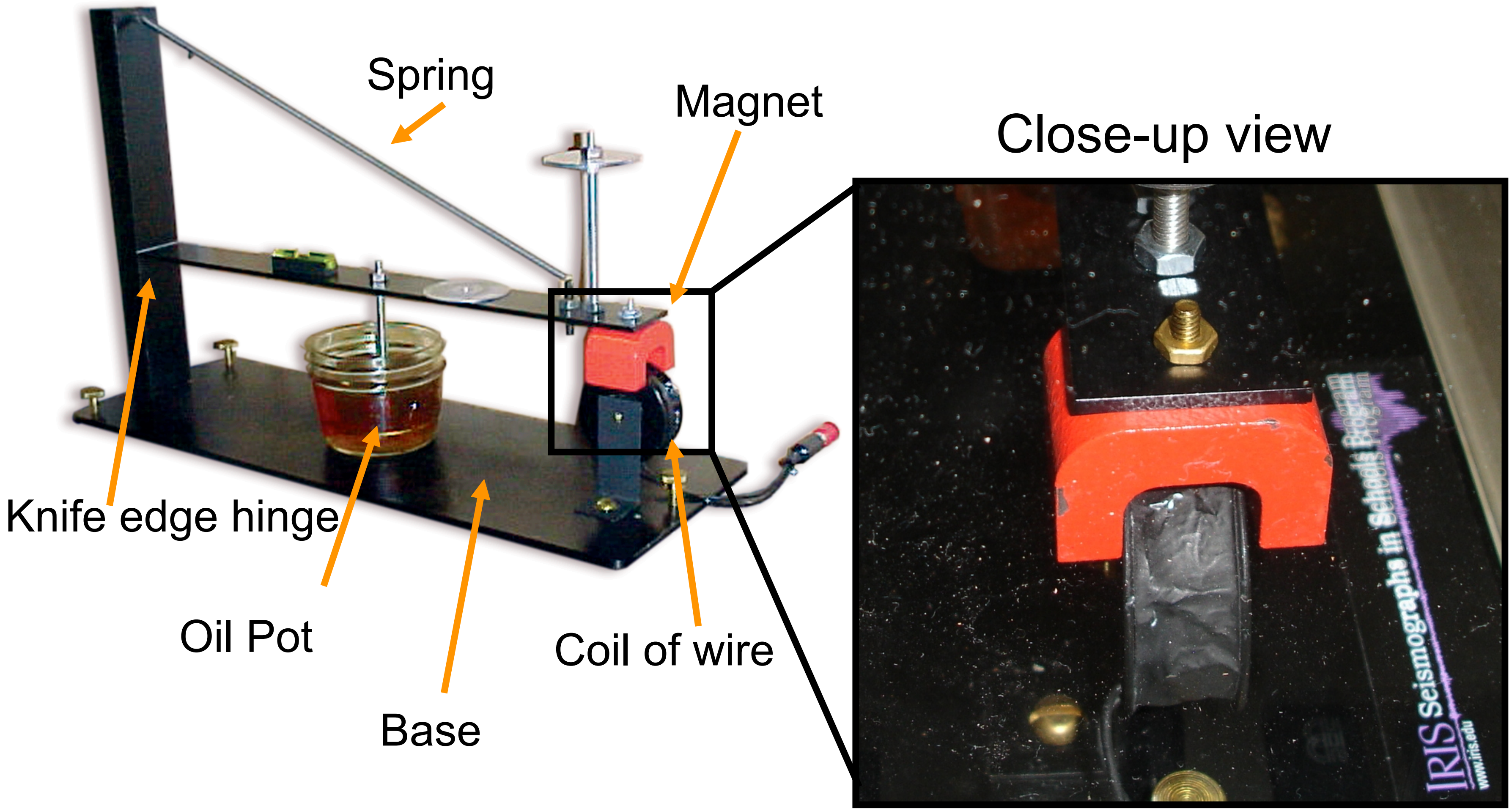
The oil pot is missing



Without the oil pot, the momentum of the mass continues on with only a small amount of friction to slow it down.

Conversely the motion of the boom is acted upon by an external force, in this case the oil pot, and plunger resist it, thus damping out the motion.





How does the amplifier, which can't "see" the seismometer, tell if the magnet on the end of the boom is moving and how it is moving?

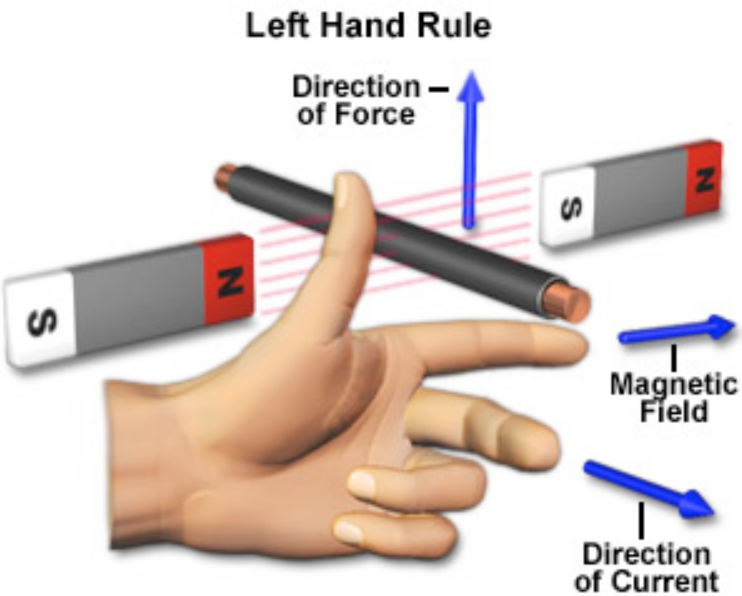


Image: National High Magnetic Field Laboratory

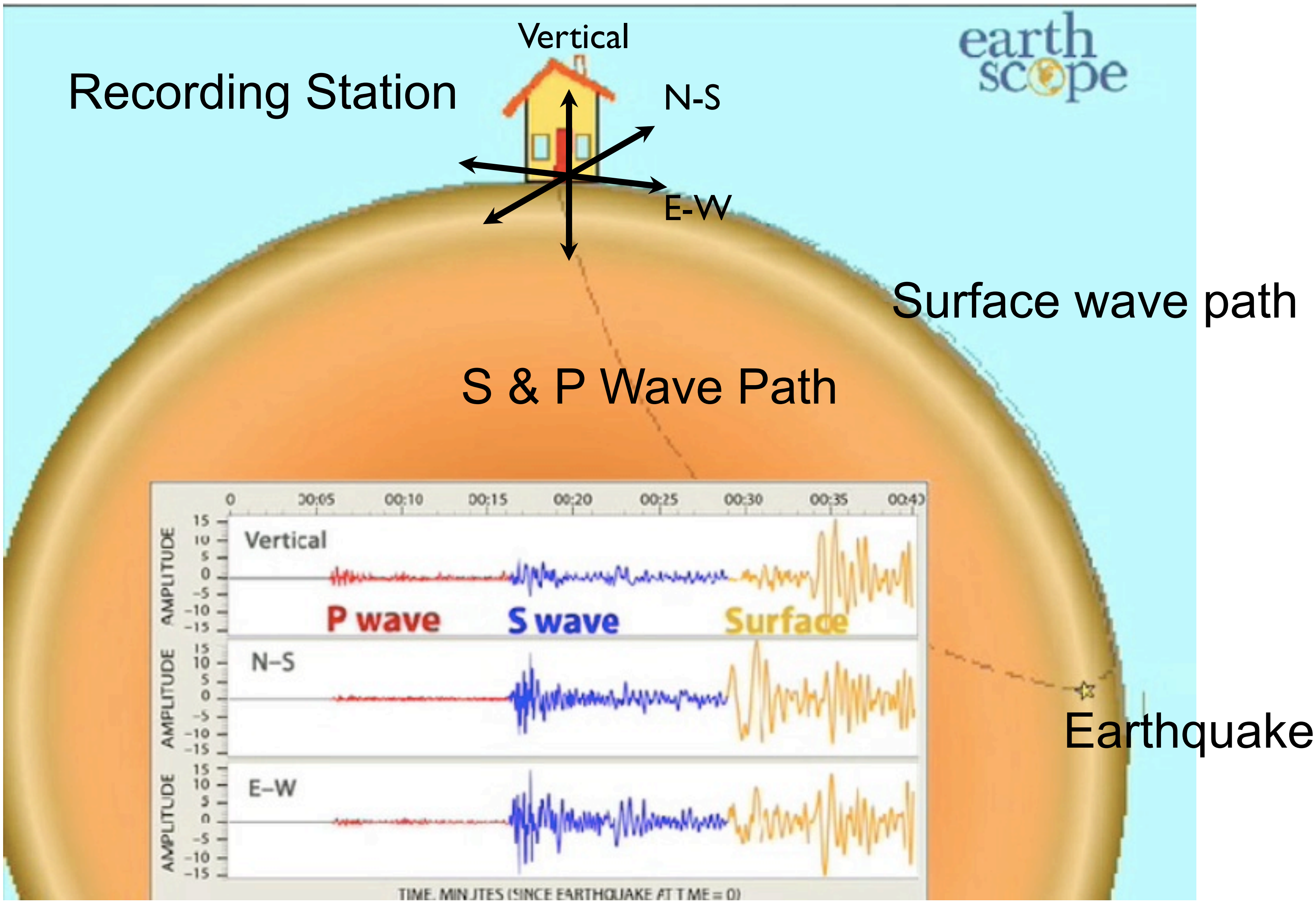
Electromagnetic Induction

1) Polarity of the voltage depends on the direction of the magnet motion relative to the coil.

2) The amplitude of the voltage depends on how fast the field lines cross the coil, which means the voltage amplitude depends on the velocity of the magnet relative to the coil.

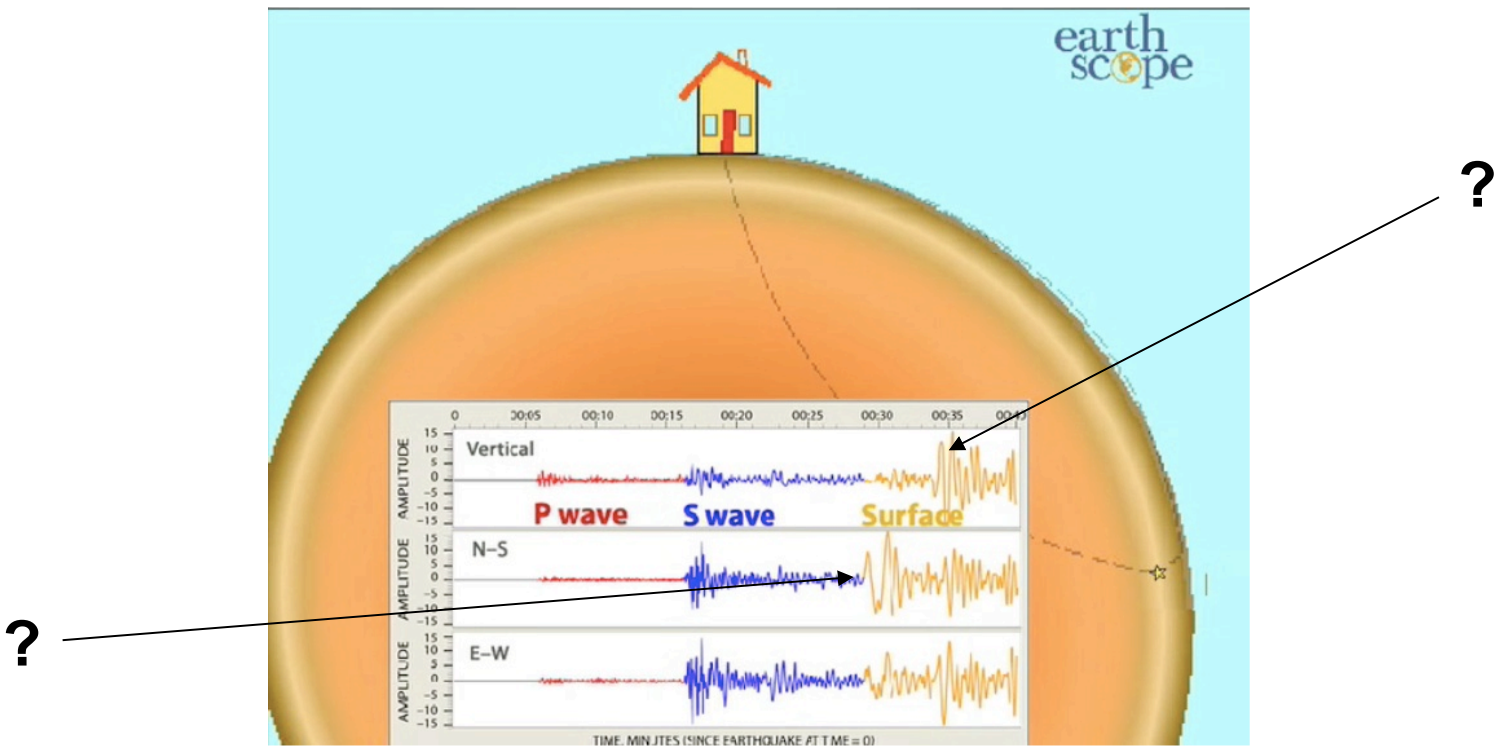
Thus a seismograph is a velocity sensor and the maximum voltage (and velocity) occurs at the center of the oscillation while the displacement of the magnetic relative to the coil is zero.

Which type(s) of seismic waves are transverse and which are longitudinal? What makes you think so?

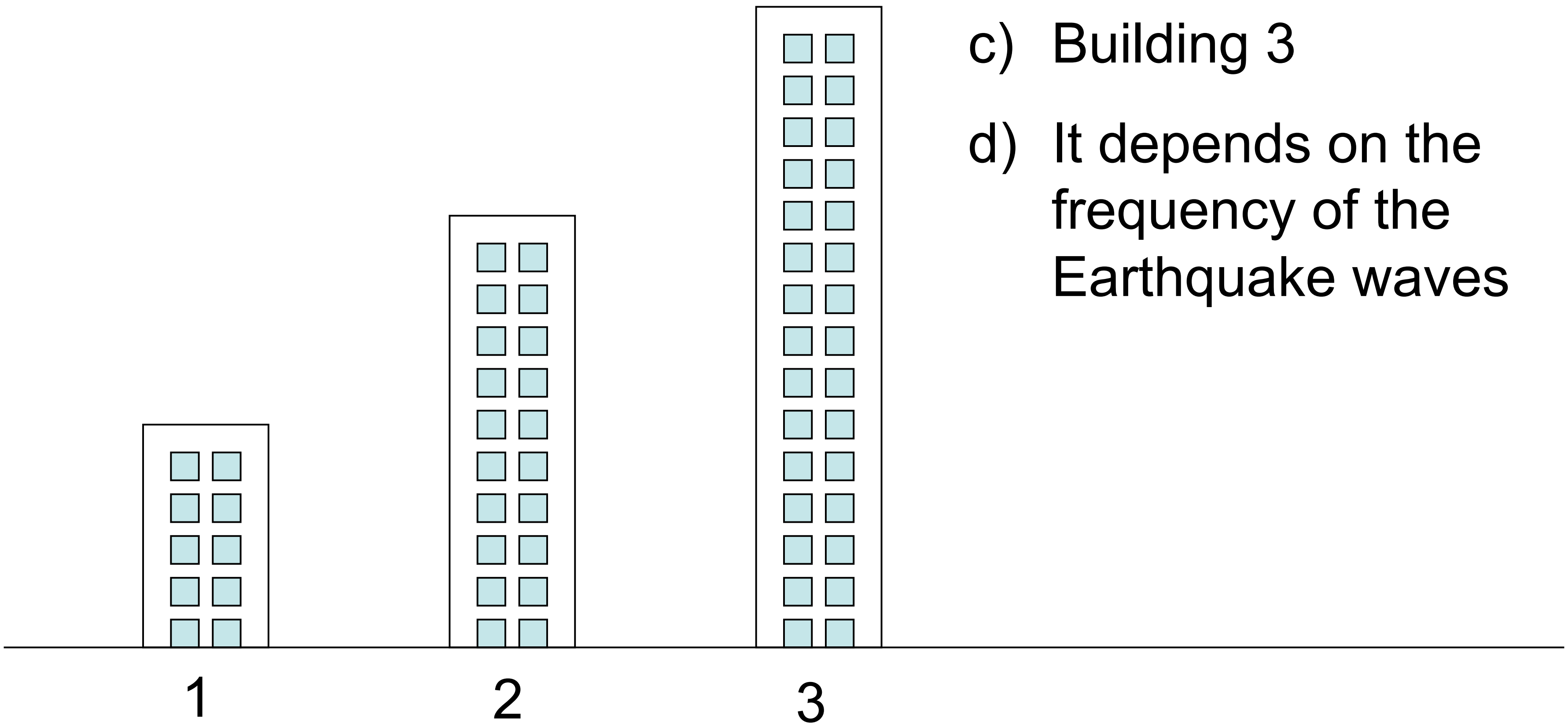


The P wave (Longitudinal) shows motion primarily on the vertical axis which is nearly parallel to the direction it is traveling.

The S wave (Transverse)shows motion primarily on the two horizontal components which are perpendicular to the direction the wave is traveling.



Assuming the same construction and materials, which building would be the safest from shaking during and earthquake and why?



a) Building 1

b) Building 2

c) Building 3

d) It depends on the frequency of the Earthquake waves

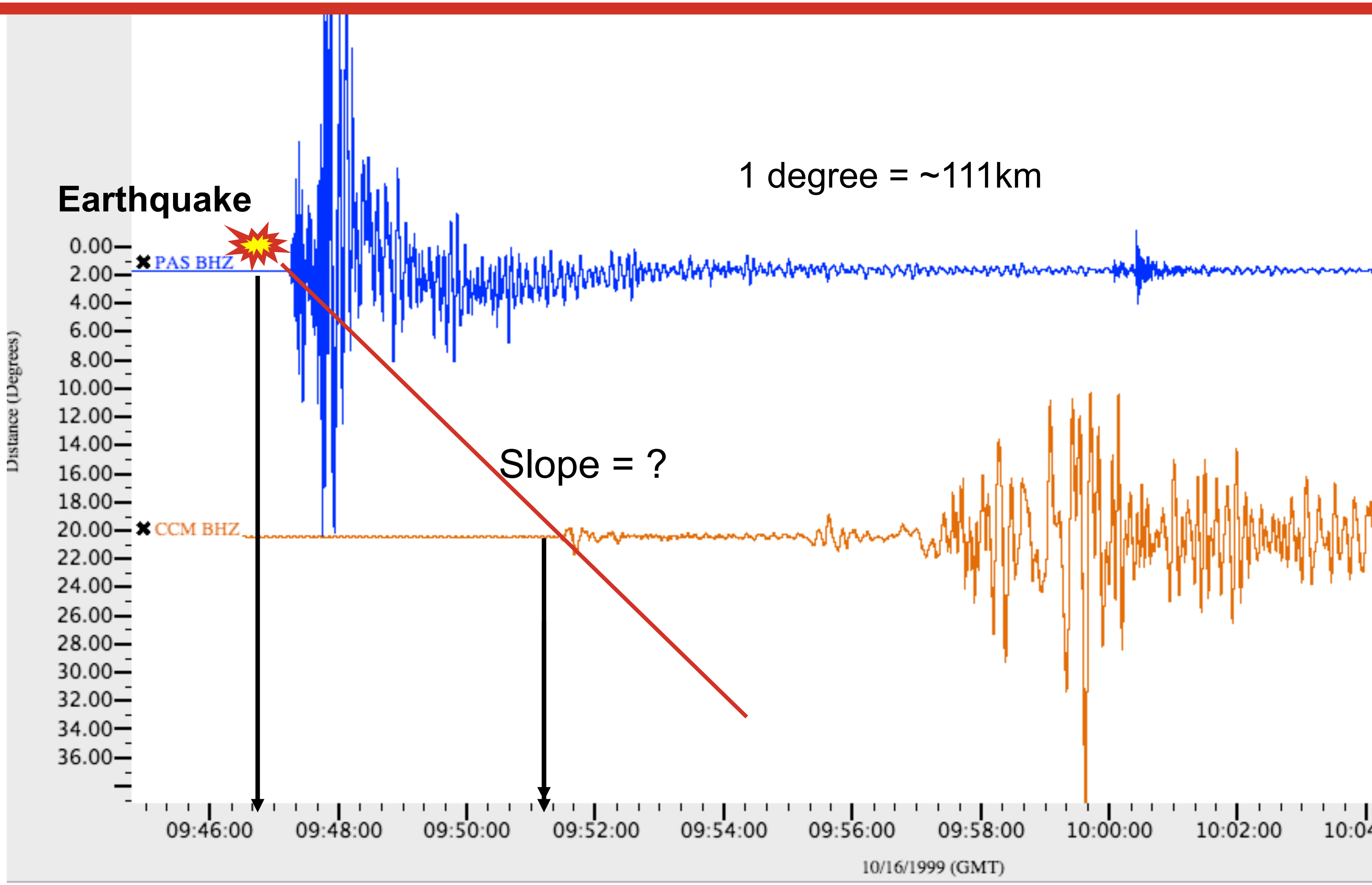
Answer = D. It depends on the frequency of the Earthquake waves.

A buildings resonance frequency can be roughly estimated 10Hz divided by the number of floors ~ Natural Resonance

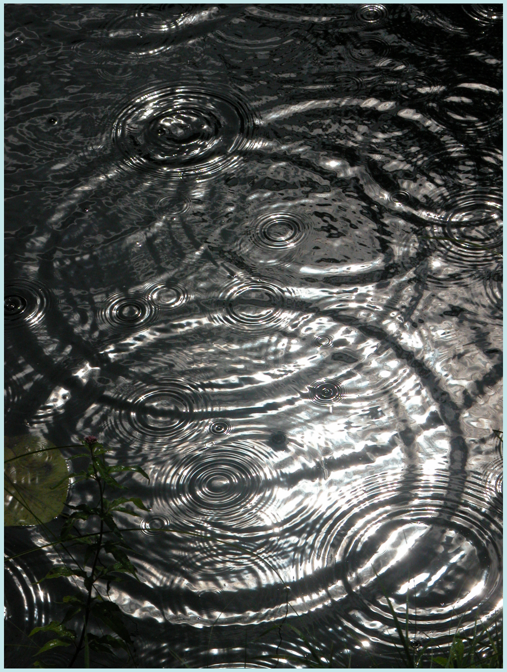
Therefore if an earthquake were to cause ground shaking at 2Hz, building 1 would be most affected.

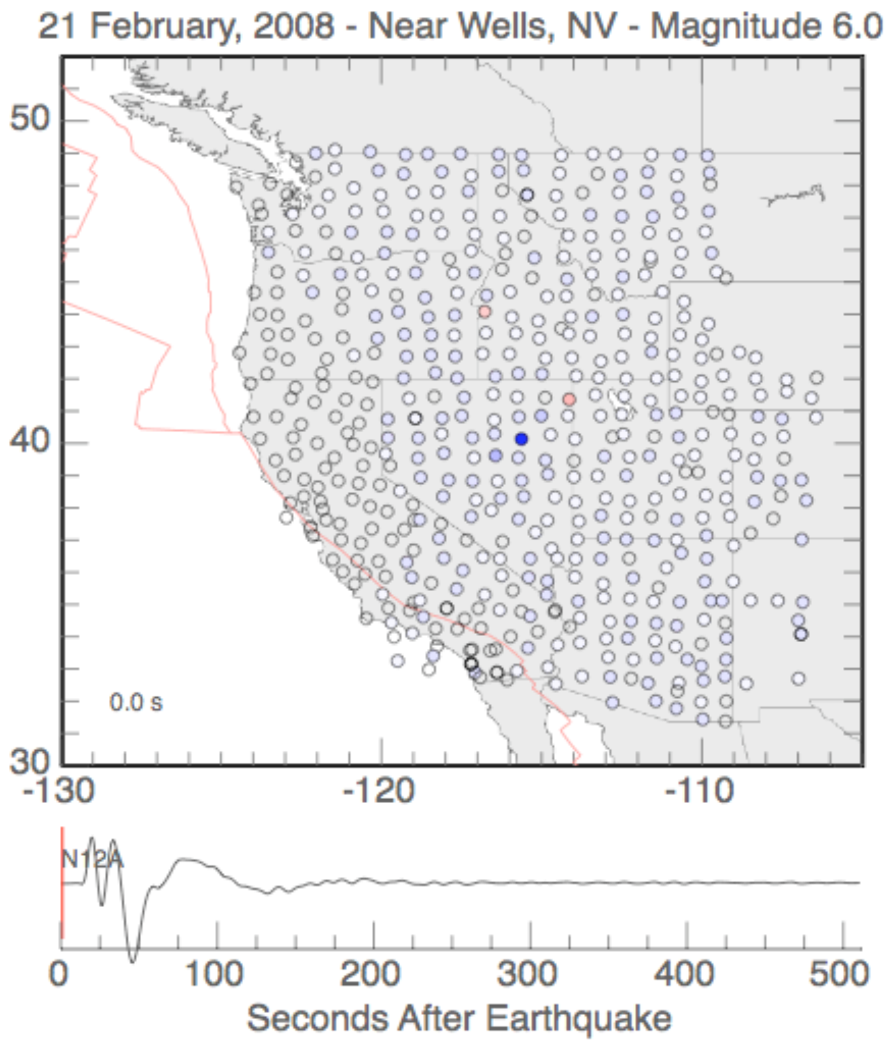
If you began to record a nearby large earthquake on your seismograph in Los Angeles, could you use your cell phone to call your friend in St. Louis and alert them to run to the seismograph to watch? WHY?

Yes. Cell phones signals are part of the electromagnetic spectrum and as a result travel much faster (at the speed of light in a vacuum) than seismic waves through the ground.

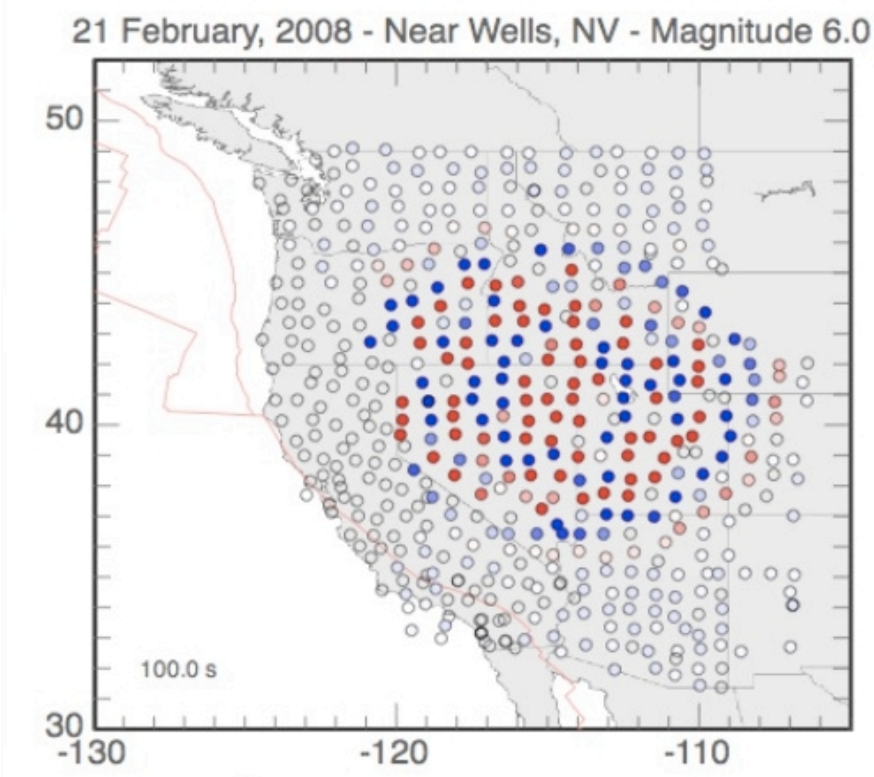


Unlike the water drop below the seismic waves shown at the right do not radiate out evenly. Why? What might the study of this phenomenon lead to?





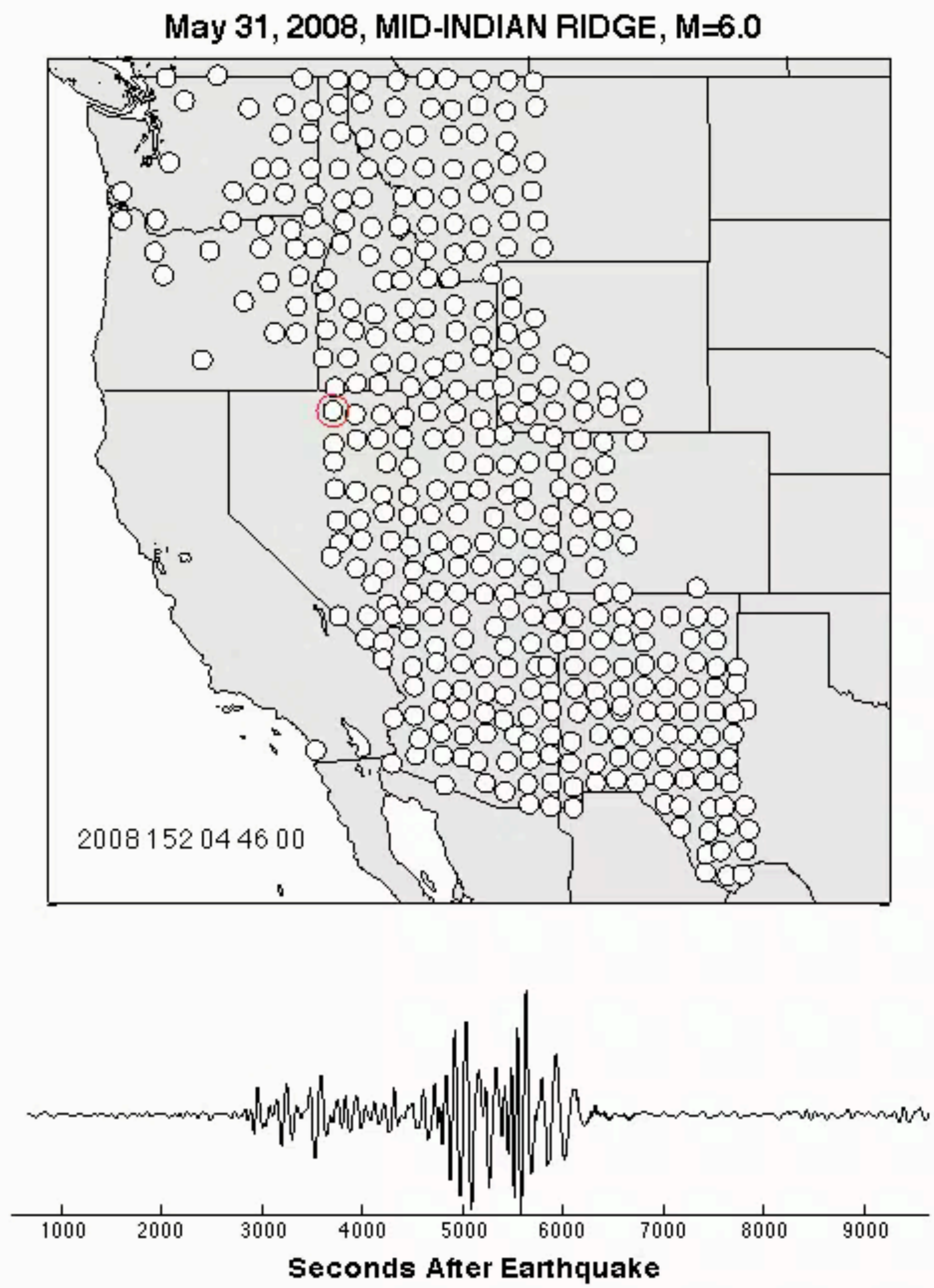
Each circle in the map above represents a seismometer and the colors change to reflect variations in the signal amplitude crossing the array.



The seismic waves at the left do not radiate symmetrically because the velocity along the wave front varies.

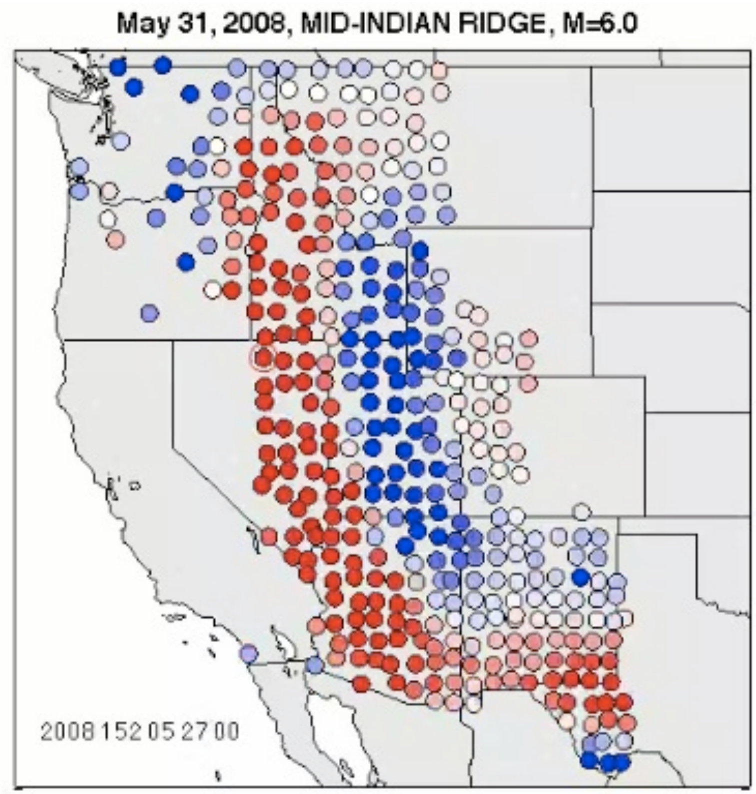
Such variation is caused by changes in the properties (e.g. rigidity and density) of the rocks the waves are traveling through. Seismologist use such variations in seismic wave propagation to infer details about the structure and composition of the unseen inside of Earth.

In this movie, the earthquake is on the other side of the earth. Why does it appear that the wave front is both converging on and expanding from Nebraska?



Each circle in the map above represents a seismometer and the colors change to reflect variations in the signal amplitude crossing the array.

Nebraska is at the opposite point on the Earth from the earthquake (the antipode). If the Earth were completely homogeneous with a single uniform velocity, waves which have spread out on the Earth's surface from the earthquake would converge exactly at the antipode and then expand again.

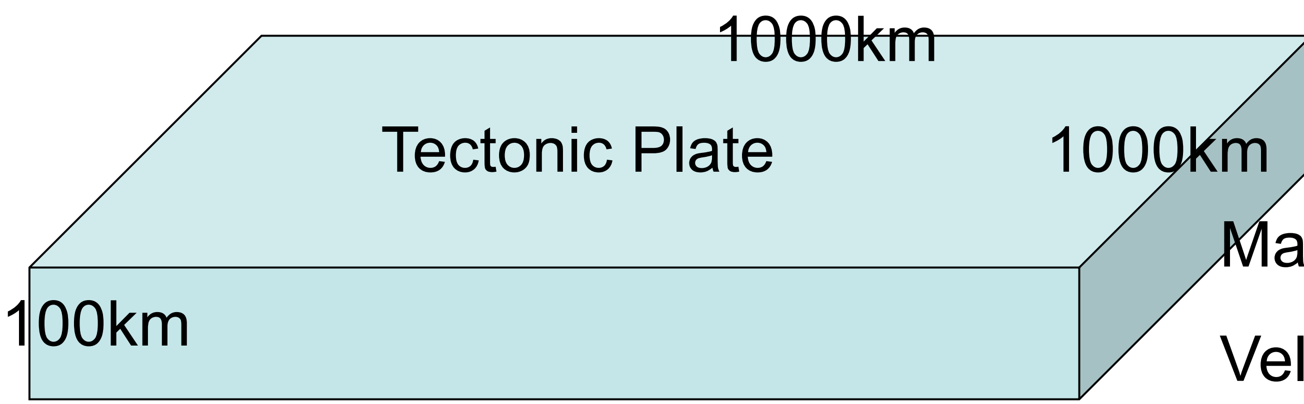


The ability of the waves to cross over each other traveling in different directions is an example of superposition of waves.

Supertanker

Mass - 2 x 10^8 kg

Velocity - 8 m/s



Mass - 3 x 10^{20} kg

Velocity - 1 x 10^{-9} m/s

One moves oil, while the other builds mountains. Which can do more work?

Adapted from D. Forsyth, Brown University

The Supertanker

KE which is proportional to work is equal to $1/2\ MV^2$

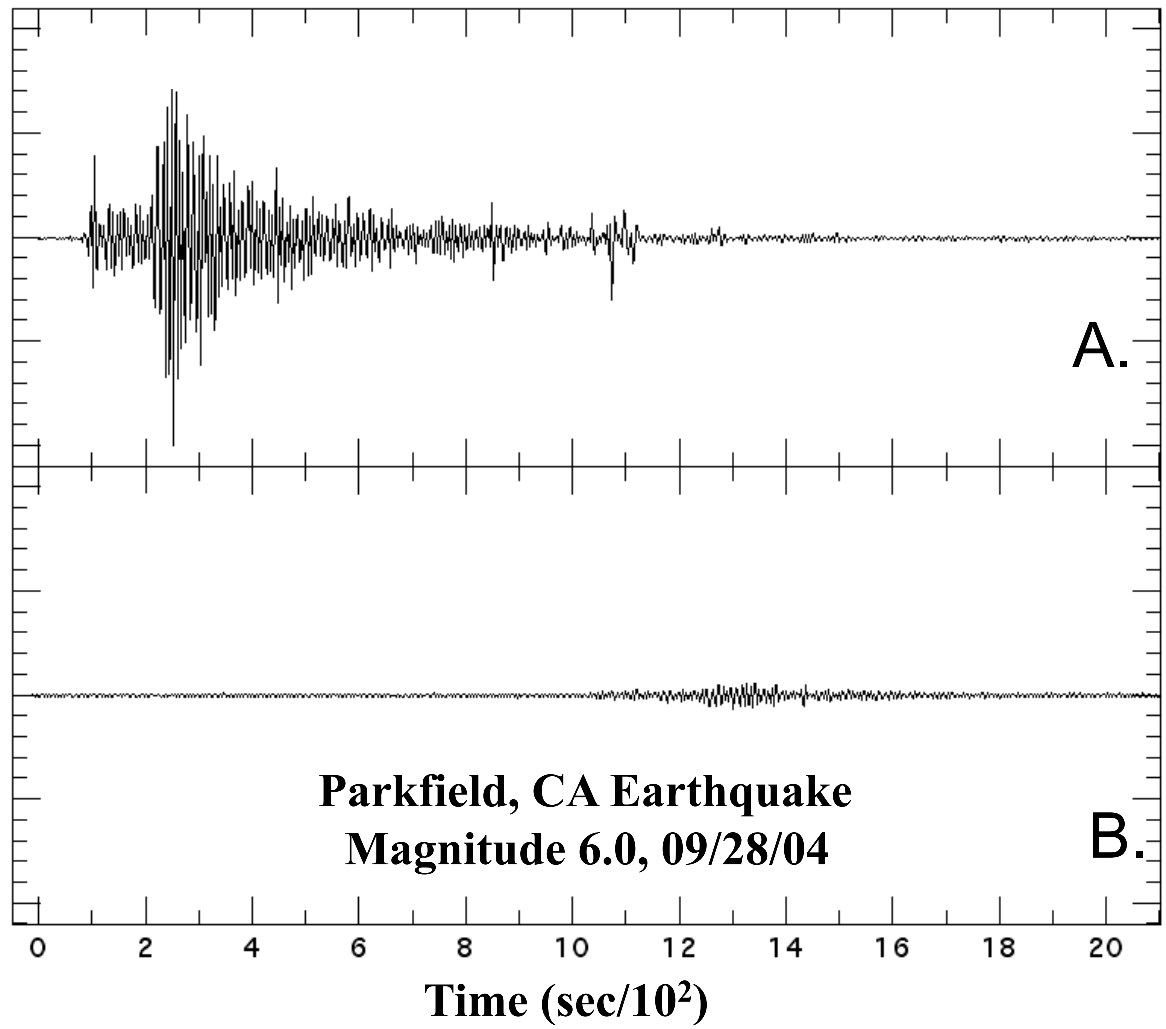
Thus the KE of the supertanker is 6.4×10^9 kg m^2/s^2 while the KE of the plate is 1.5×10^2 kg m^2/s^2

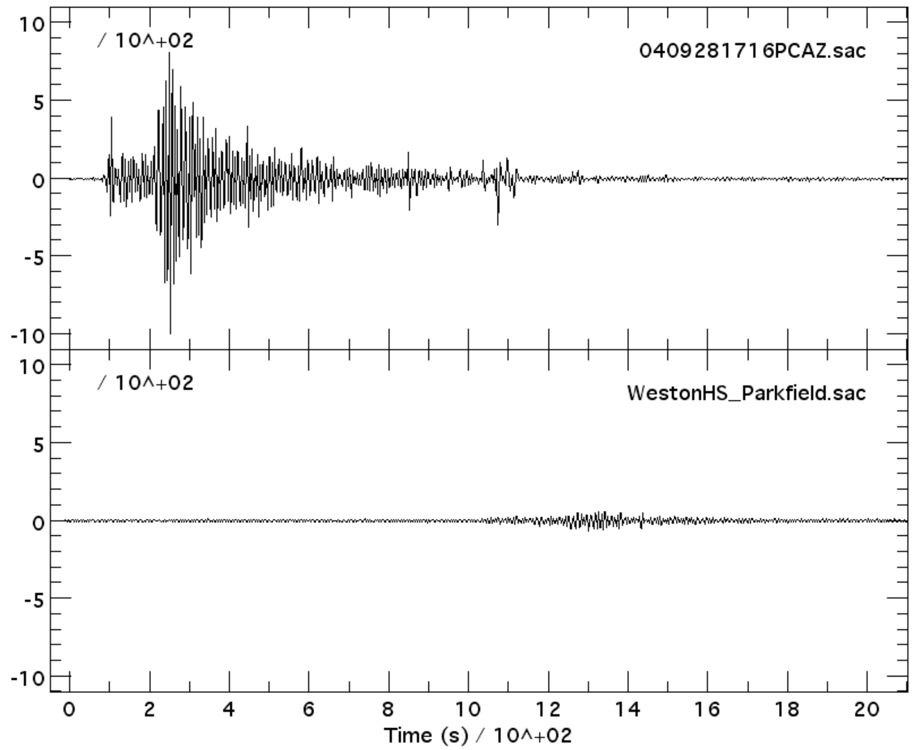
Conclusion: A moving tectonic plate can easily be stopped! Therefore forces in the system must be balanced or the system will accelerate or decelerate rapidly.

So how are mountains built?

Collisions of plates can build mountains only because the forces that drive the plate act continuously over millions of years.

Two recordings of the same earthquake. What is different between them? Where did the energy go?

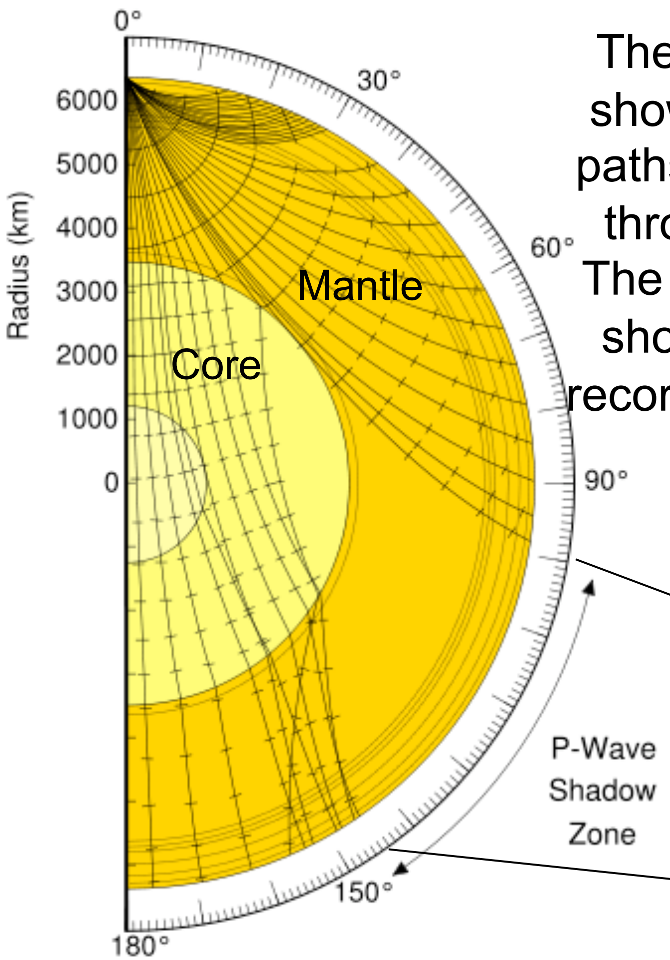




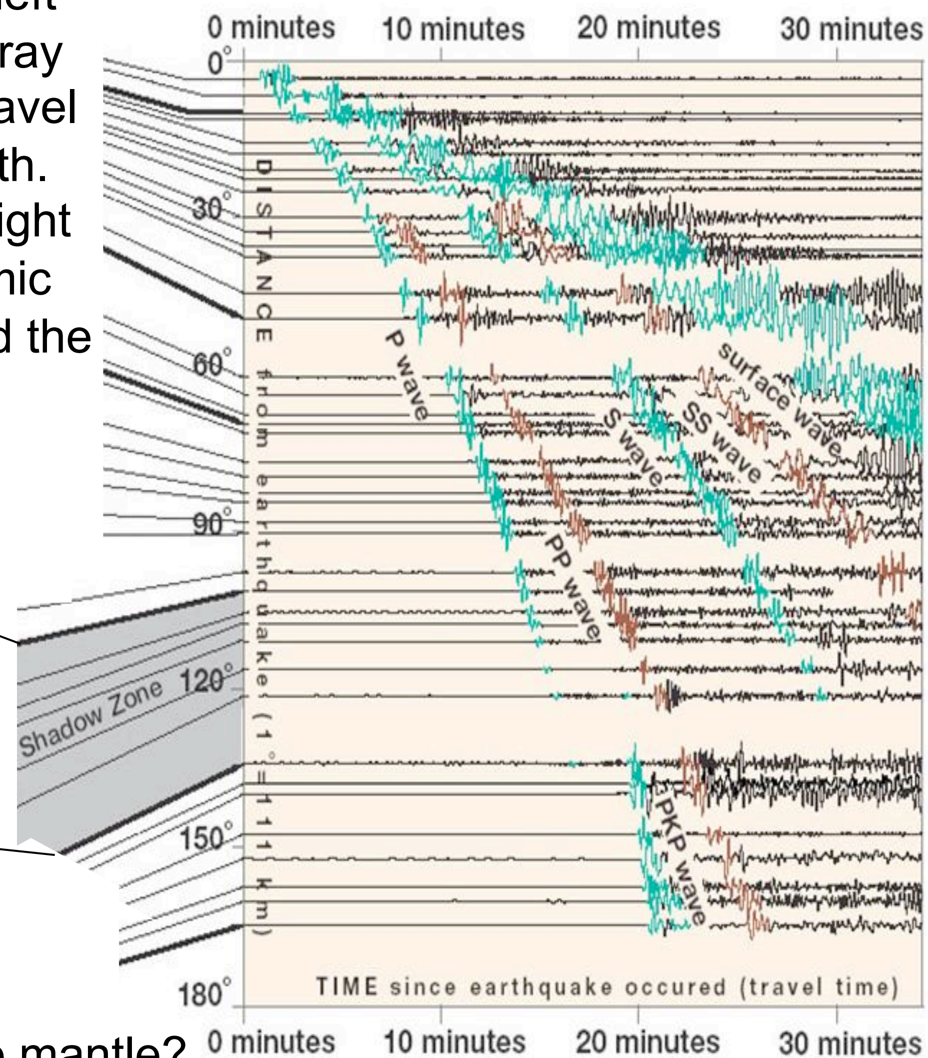
The maximum displacement of the ground (amplitude) at station A is much greater than the maximum amplitude at station B.

Seismic energy decreases with distance for three reasons

1. Energy released by an earthquake radiates in a continuously growing sphere. Conservation of energy results in a ever decreasing energy/area ratio
2. Points acting as Huygen's sources scatter energy
3. Kinetic energy is converted to heat as the material is permanently deformed



The diagram at left shows modeled ray paths P waves travel through the Earth. The diagram at right shows the seismic recordings around the earth.

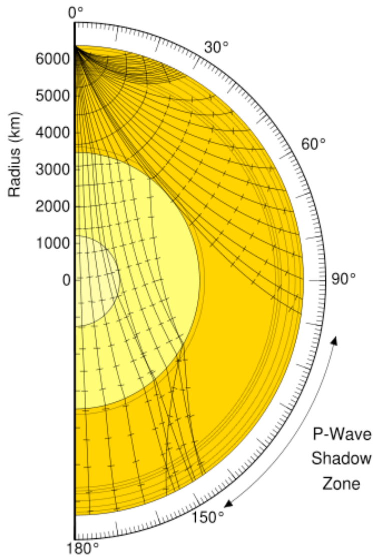


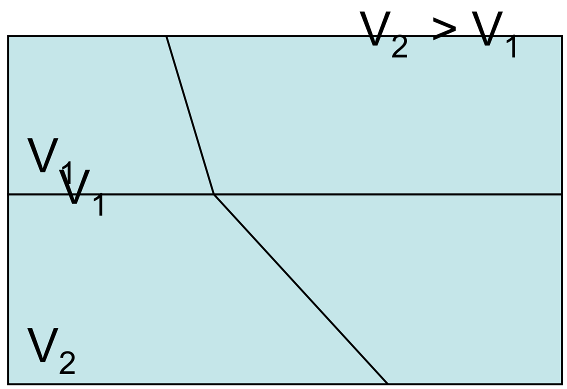
What do the curving ray paths say about the mantle?

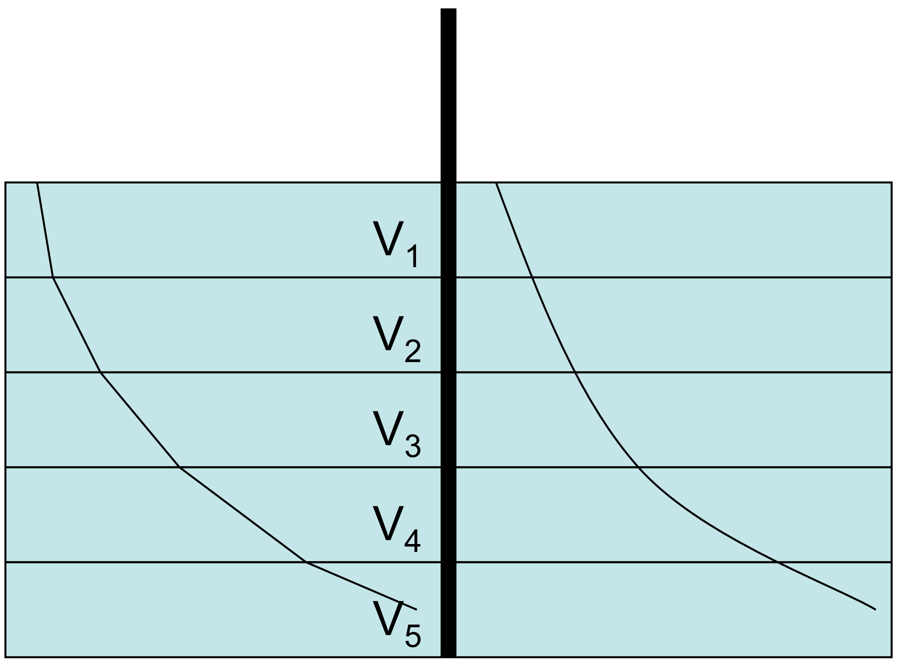
What happens to the velocity of the P waves in the core?

Why are there no rays in the shadow zone of this diagram yet the data at the right shows P wave arrivals?

What do the curving ray paths say about the mantle?



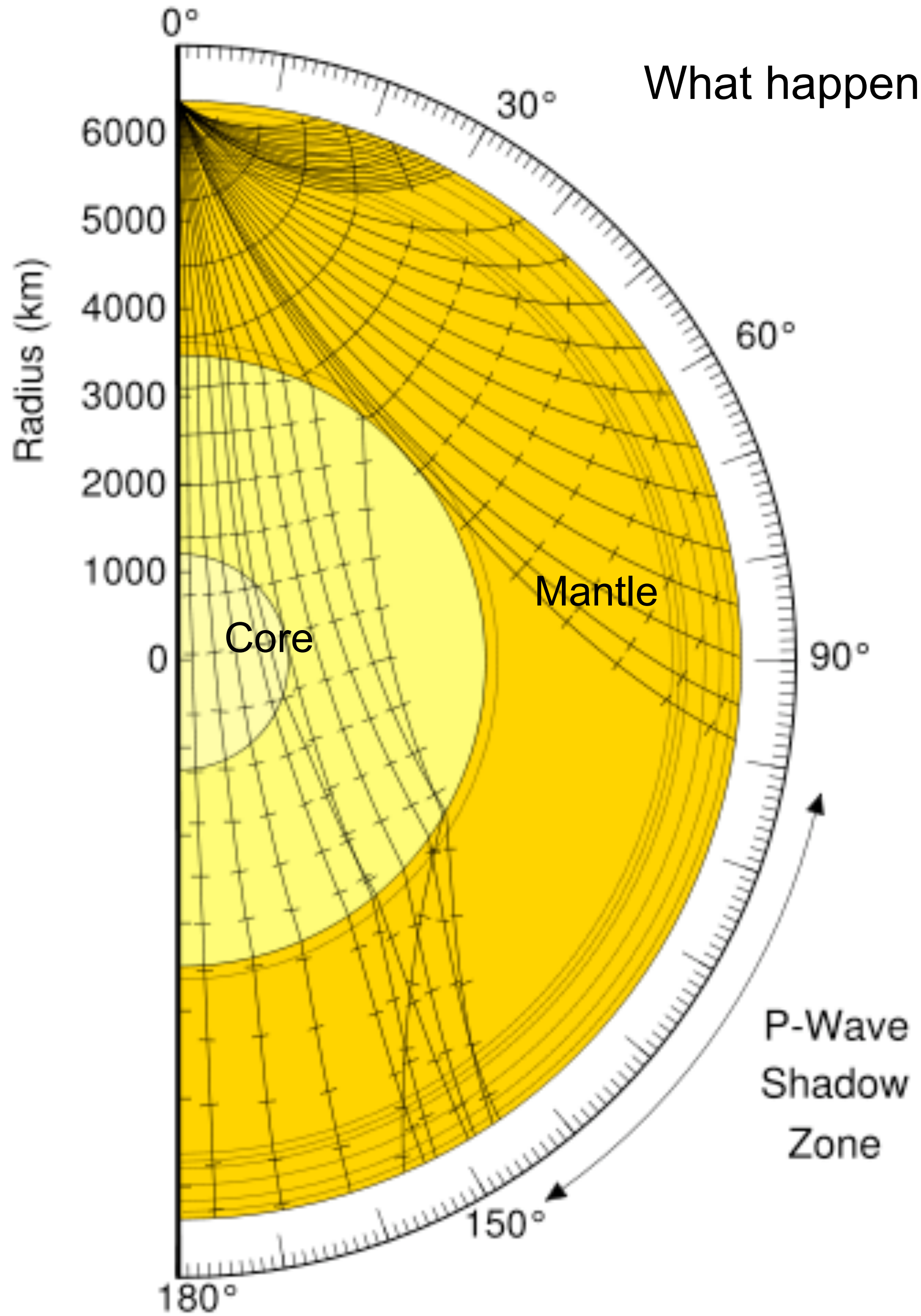




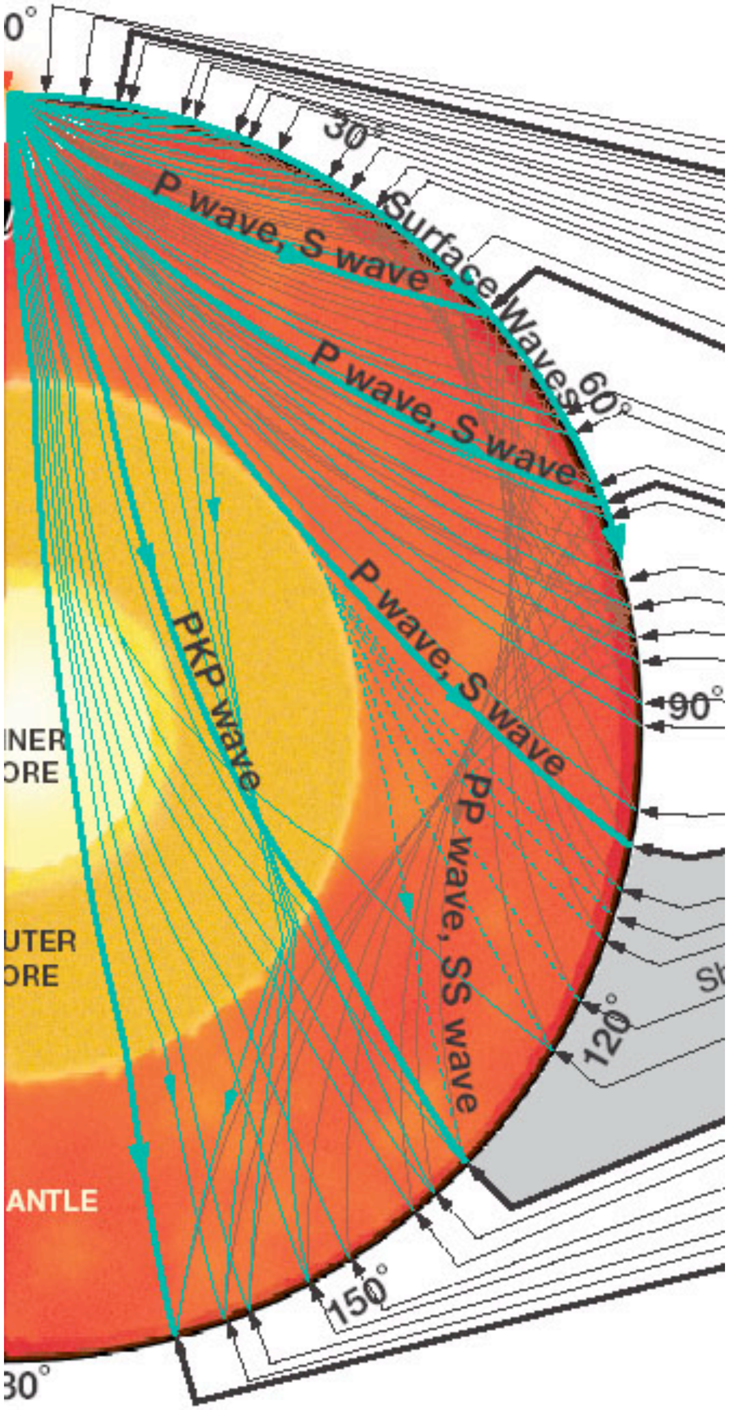
$V_5 > V_4 > V_3 > V_2 > V_1$

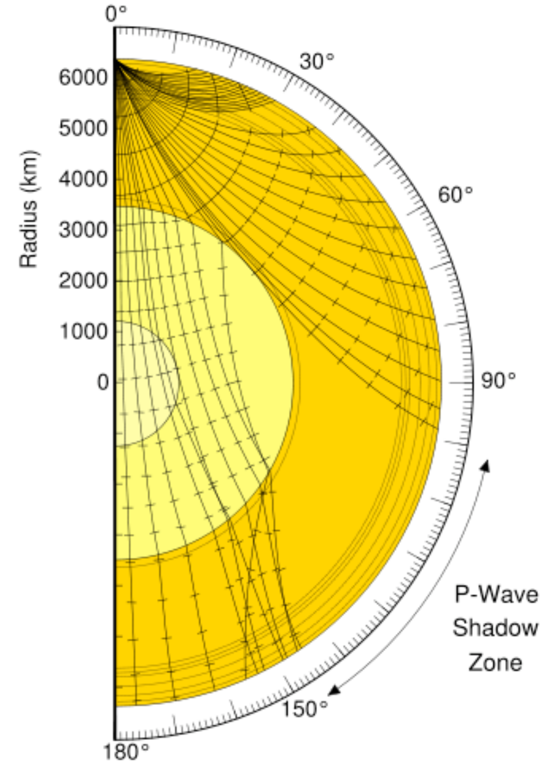
The general increase in seismic wave speed with depth in the Earth causes a P wave to be continuously refracted away from the normal until a point is reached where it is headed back to the surface. At this point, the ray path begins to bend towards the normal as it gets closer to the surface. The continuous increase with depth can be modeled as a series of thin layers, each with a uniform velocity.

What happens to the velocity of the P waves in the core?



A notable exception to the increasing velocity with depth in Earth is the decrease in velocity when going from the mantle to the outer core. This speed decrease bends rays in the other direction and creates a "P-wave Shadow Zone" between about 100 and 140 degrees distance (1 degree = 111.19 km).





The model above doesn't account for waves that diffract around the outer core of the earth. Thus, the P wave shadow zone, like a person's shadow on the surface of Earth, represents an area of low amplitude energy that has diffracted around an object (see figure at left)