

TABLE-TOP EARTHQUAKES

Summary

We are going to use a plank of wood, a brick, sandpaper, and an elastic cord to mimic earthquake mechanics. Although pulled with a constant velocity, the brick will repeatedly slide and then stop. We will use a vibration sensor connected to a computer to record and view the intermittent motion. This intermittent sliding motion mimics the intermittent fault slippage that characterizes the earthquake fault zones.

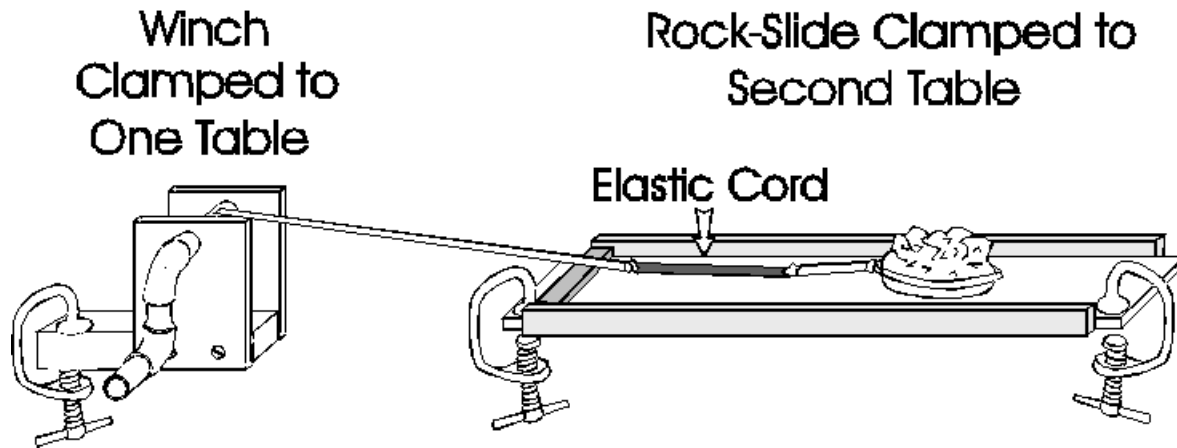
Math stuff!!!!

Background

Plate Tectonics. Plate tectonics is the study of the consequences of the slow motion between the plates that make up the outer shell of the earth. There are about a dozen major plates and they are about 50 km thick. The temperature and material properties at the base of the plates are such that they can slip steadily without producing any earthquakes. However, when a plate itself is deformed, due to mountain building, for example, or when one plate must slide past another, earthquakes are produced. For years, and in some cases as much as many hundreds of years, very little slip may occur across a portion of one of the boundaries between two plates that are in relative motion with respect to each other. During this time both plates are deformed and bent elastically near the boundary, and all the while the stress in the region is increasing. Eventually, during an earthquake, the plates quickly slide past one another and the stress is greatly reduced. Earthquakes involve rapid slippage on a fault to cause waves of vibrations to be radiated outward. The vibrations can be felt and, if the fault intersects the surface of the earth, the resulting displacement can be observed directly. This process of slow deformation followed by rapid release is called *elastic rebound*.

Energy, friction and waves. At first the rock does not move, so the energy is stored in the elastic cord. The more the elastic cord is stretched, the more energy is stored within it, and the greater the force on the rock. When the **static friction** that is holding the rock in place is exceeded, the rock will start sliding. Because **sliding friction** is less than static friction, the rock will continue sliding some distance until the force from the elastic cord is equal to the sliding friction that is resisting motion of the rock. The energy that was slowly stored up within the elastic cord is quickly released and converted into kinetic energy of the moving rock. As the rock slides along, its kinetic energy is dissipated by heating up the sliding surfaces and by radiating energy in the form of **elastic waves**. The geophone detects these elastic waves as they pass by, and they are displayed on the seismogram.

Assembly



Setup and Operation

1. The geophone does not have to be on or right next to the rock-slide. In fact, it is better to have it a few feet away so that it is clear that the vibrations from the sliding rock must travel some distance along the tabletop to reach the sensor.
2. The distance between the winch and the rock-slide should be adjusted so that the shock cord does not begin to wind onto the winch; this maintains a constant elastic component during the entire travel of the rock or brick.
3. Next try pulling the rock or brick along with the winch. The speed should be such that it takes 30 seconds to a minute to move the entire length of the rock-slide. If it slides steadily rather than in discrete events (earthquakes), an adjustment is necessary.
4. Try increasing the friction or using a longer or more stretchy section of shock cord. Friction can be increased by gluing coarse sandpaper to the sliding surface of the rock or brick, by using a heavier rock, or by using two bricks, one on top of the other.
5. If the rock slips too far in one event, such as more than half of the entire length of the rock-slide, then decrease the weight of the rock, decrease the length of the elastic cord, or use a less stretchy elastic cord.

When the adjustments are complete, the rock should generate approximately 4 to 10 events per run, and each of these "earthquakes" should be clearly registered on the computer screen display (the seismogram).

Analysis

The seismogram that is displayed on the PC's screen is a graph of the voltage produced by the geophone as a function of time. This voltage is proportional to the vertical velocity of the table at the location of the geophone.

Scale of earthquake magnitude. In seismology, the energy of the vibrations produced by an earthquake can vary enormously. The range of total energy seismic waves produced by earthquakes is approximately 2000 joules (J) to 11,200,000,000,000,000,000. This is a difficult range to deal with on a linear scale. As you can imagine, it is not very convenient dealing with numbers that have such a large range.

On the Richter magnitude scale,

The magnitude of a 2,000 J event = -1.0

The magnitude of a 11,200,000,000,000,000,000 J event = -9.5

The relationship between earthquake energy and magnitude is said to be logarithmic because the equation relating energy and magnitude includes a logarithmic term.

This results in an equation for energy,

$$\log_{10} E = 1.5M + 4.8$$

Therefore, the equation for magnitude is

$$M = \frac{\log_{10} E - 4.8}{1.5}$$

Note that this indicates that an increase of one unit of magnitude results in 32 times greater energy release.

Earthquake Energy as a Function of Magnitude			
Magnitude	Energy Equivalent Weight of TNT*	Energy in joules (1 J = 1 newton meter)	Notes
-3.0	0.001 ounces	2 J	1.5 foot pounds (18 inch pounds)
-2.0	0.032 ounces	63.1 J	47 foot pounds
-1.0	1.0 ounces	2E+03 J	1,500 foot pounds
0.0	32 ounces	63.1E+03 J	
1.0	63 pounds	2E+06 J	

2.0	1 ton	63.1E+06 J	Only felt nearby.
3.0	32 tons	2E+9 J	
4.0	1 kton	63.1E+9 J	Often felt up to 10's of miles away.
5.0	32 ktons	2E+12 J	
6.0	1,000 ktons	63.1E+12 J	
6.9	22,700 ktons	1.41E+15 J	1995 Kobe, Japan, Earthquake
7.0	32,000 ktons	2E+15 J	
8.0	1 Mtons	63.1E+15 J	
9.0	32,000 Mtons	2E+18 J	
9.2	64,000 Mtons	3.98E+18 J	1964 Alaska Earthquake - Second largest instrumentally recorded earthquake
9.5	180,000 Mtons	11.2E+18 J	1960 Chile - Largest instrumentally recorded earthquake

*This is the approximate amount of TNT that would be required to generate high-frequency seismic waves of similar amplitude to those from an earthquake of each magnitude. This is based on the observation that a 1-kton explosion is approximately equivalent to a magnitude 4 earthquake (Evernden and others, 1986).

Computing Magnitude.

The magnitude of the small "earthquakes" generated by the sliding rock can be computed if we know the energy released during the event.

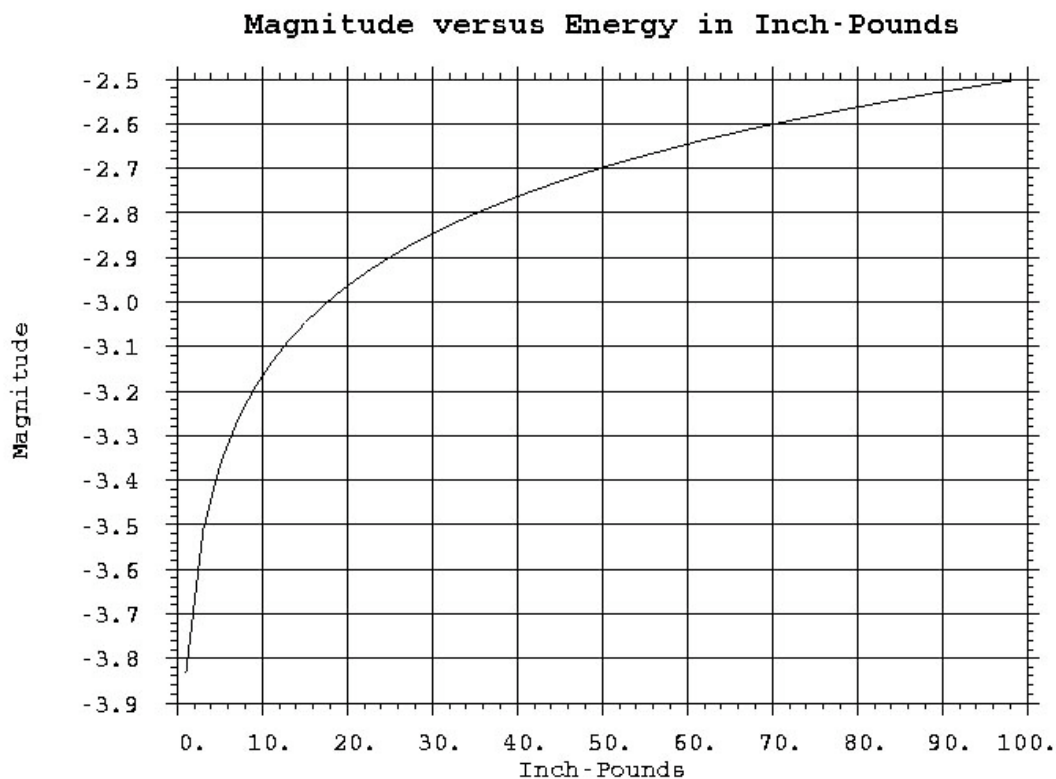
One way to define energy is $Energy = Force * distance$.

We measure the force with a force sensor attached to the elastic cord of the sliding rock. We can measure the distance the rock slips and therefore calculate the energy released. If a small fish scale is linked into the cord, between the winch and the sliding rock, then the force on the rock can be measured (For this exercise we will ignore the portion of the energy that goes into heating

the rock and the board due to friction and assume that all of the energy goes into seismic waves.)

1. Need to layout all the options we want to them to explore
2. Calculate the energy for each slip.
3. Calculate the magnitude for each slip from the energy
4. Plot the magnitude versus enrgy in meter-Newton

Note: the geophone is only necessary if we want to include a portion of the lab that deals with a seismogram. Everything else can be done with the force sensor.



References

Evernden, J.F., Archambeau, C.B., and Cranswick, E., 1986, An evaluation of seismic decoupling and underground nuclear test monitoring using high-frequency seismic data, **Reviews of Geophysics**, v. 24, no. 2, p. 143-215

. In tectonically active regions, the Earth's outer brittle shell, which is about 50 km thick, is slowly deformed elastically along active faults. As the deformation increases, stress also increases, until fault slippage releases the stored elastic energy. This process is called *elastic rebound*.