

Challenge Worksheet



Geophysics of Earthquakes

Lab 5: Table-Top Earthquakes

- Your Mission:** (1) Use a plank of wood, bricks, sandpaper, and an elastic cord to mimic earthquake motions.
(2) Calculate the magnitude of the “earthquake” you create.

Your Supplies:

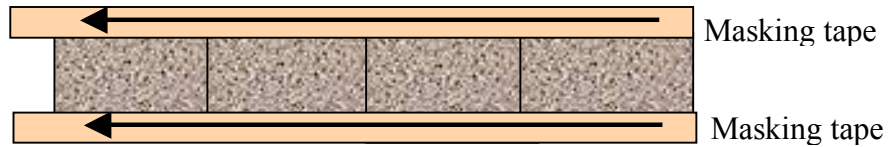
- 1 brick
- 1 elastic bungee cord
- 1 spring scale
- 4 sheets of sandpaper
- role of masking tape
- 1 meter stick
- 2 markers
- 1 pen/pencil
- graph paper

Assembly:

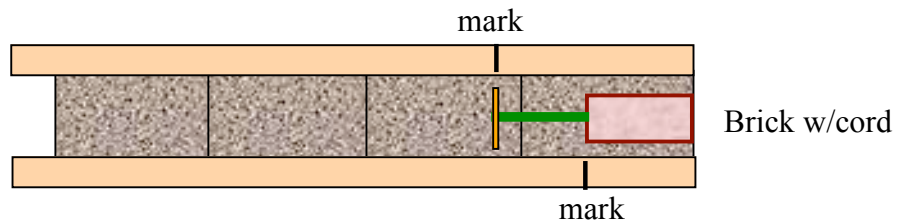
1. Beginning at one end of your long board, tape one piece of sandpaper securely to the board. Take your 2nd piece of sandpaper, slightly overlap it with the piece already taped (about 1 cm), and securely tape this piece to the board. Repeat for the 3rd and 4th pieces of sandpaper. Note: it is important to start at one end and slightly overlap each piece of sandpaper. This way, when the brick moves across the sandpaper, it does not catch on an edge.



2. Next you will tape down the sides of the sandpaper. Beginning at the ending edge of your 4th piece of sandpaper, use your role of masking tape to extend a long strip of tape from the 4th piece to the 1st piece of sandpaper. Do this on both sides of the sandpaper.



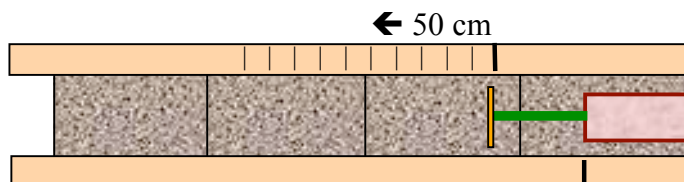
- Next, connect the elastic (bungee) cord to the neon rope wrapped around your brick. Take your pen/pencil and hook the other end of the elastic cord to it. Place your brick at the far edge of your 4th piece of sandpaper and align the end of the brick with the edge of the sandpaper. Extend your elastic cord out in a straight line. Using your markers, place a mark on the masking tape at the location of the front end of the brick. Place another mark on the opposite strip of masking tape at the location of the front end of the elastic cord.



- Place your meter stick at the start of the **brick mark** and measure out 50 cm. Place small tick marks on the tape (with your marker) at every 1 cm and larger tick marks at every 10 cm. Label your measured marks at 10cm, 20cm, 30cm, etc.



- Now place your meter stick at the start of the **elastic cord mark** and measure out 50 cm. Repeat as in the previous step and label your measured marks at 10cm, 20cm, 30cm, etc.



Experiment 1. Plate Motion vs. Fault Slip

1. In your designated groups, establish who will do the following jobs:

1 Puller

1 Observer

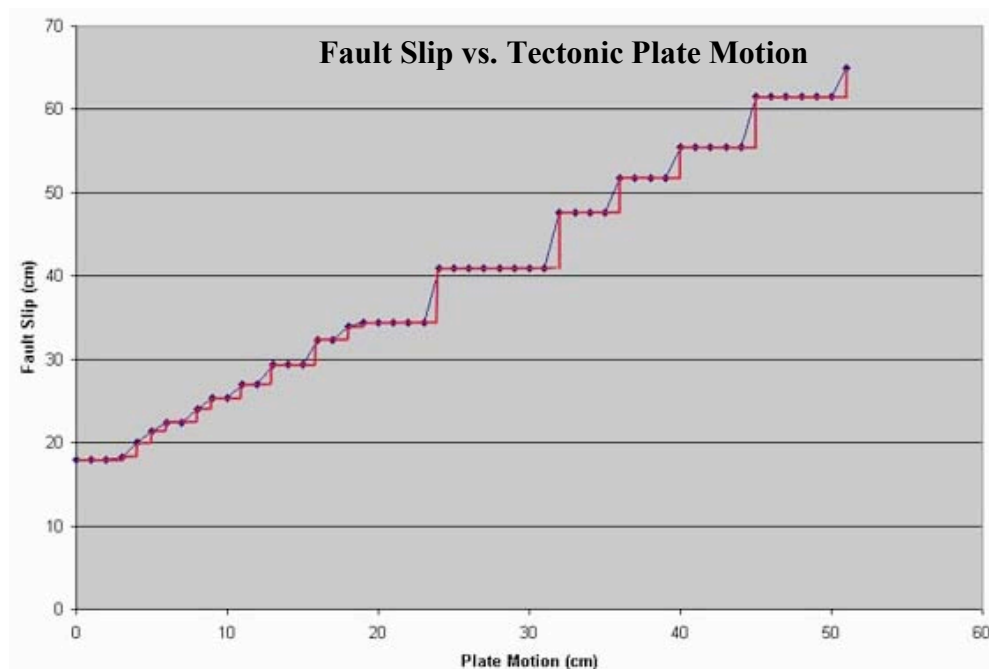
1-2 Recorders

One person will pull the brick, one person will observe the distances that the brick moves, and one (or two) will take notes and record the data using **Experiment 1 Data Table** provided.

2. The puller will start with the elastic cord + pencil-pully in hand with barely any tension in it. When everyone is ready, **the puller** moves the end of the elastic cord 1cm. The puller will hold the end steady and slowly say “one centimeter” out loud. This is the “Pull Distance” in the **Experiment 1 Data Table**. **The observer** will read out the position of the leading edge of the brick. **The recorder(s)** will write these numbers down in the column marked “Slip Distance” on the Experiment 1 Data Table. More than likely, your brick will not have moved. If this is the case, record ‘0 cm’ for this measurement and continue.

Then **the puller** will pull the end an additional cm and say “two centimeters” out loud. Again, **the observer** will read out the position of the leading edge of the brick and **the recorders** will write this down. Repeat for 50 centimeters.

3. Next, the recorder(s) should share their recorded data from Experiment 1 Data Table with the rest of the group.
4. Using the graph paper provided, you will next make a graph of the slip distance (representing fault slip) versus the pull distance (representing tectonic plate motion). First place dots (data points) at each measurement. Then connect the dots with a stair-step line as demonstrated in the figure below. Make your horizontal axis be the slip distance and your vertical axis be the pull distance. Be sure to label your axes: “Tectonic Plate Motion (cm)” and “Fault Slip (cm)”. Here is an example:



Questions:

1. In 2-3 sentences, describe the experiment that you just performed and the cause-effect relationship between the brick and the elastic cord. What do these two materials represent in the real Earth?
2. How is friction related to the movement of the brick?
3. Do you expect the motion of the block would be the same if the experiment were repeated?
4. Why is the motion of the end of the elastic cord a good substitute for plate motion?
5. Why is the motion of the brick a good substitute for fault slippage?

Experiment 2. Measuring Magnitudes

1. Now you will perform a series of measurements using the brick, sandpaper, and spring scale to measure the mass required to pull the brick. You will set up this experiment in the same way that you did the previous, with 1 puller, 1 observer, and 1(2) recorders. The objective of this experiment is to measure the mass of the pulled brick (with the spring scale) at the moment the brick finally slips (an earthquake!). You will record your data in **Experiment 2 Data Table**.

To begin, remove the pencil from the end of your elastic cord and replace it with the spring scale. Place your brick at the beginning of the sandpaper as you did in the previous experiment (at 0-cm mark on masking tape). **The puller** will pull on the spring scale slowly until the brick eventually slips (Earthquake #1). **The puller** will read out the mass recorded by the spring scale (kg) and **the recorder(s)** will record the data in the Experiment 2 Data Table (**column 2**). **The observer** will also read out the slip distance (cm) of the brick and **the recorder(s)** will record the data (**column 3**). Repeat this exercise for a total of 5 “earthquakes”.

2. Now you are going to compute the amount of displacement (or slip) of the brick from each earthquake. The slip of the brick represents the displacement in the Earth during an earthquake. To compute earthquake displacement, take the slip distance (recorded in column 3 of your data table) corresponding to each earthquake and subtract the distance recorded in the box above it. Enter these numbers in **column 4** of your data table under “Earthquake Displacement”. *** Note, convert your measurements from centimeters to meters before entering them in your data table! ***

For example, if the Slip Distance of Earthquake #1 was 10 cm, then

$$\text{Earthquake Displacement} = 10 \text{ cm} - 0 \text{ cm} = 10 \text{ cm} = 0.1 \text{ m}$$

3. Next, you need to calculate the pull force required to move the brick (and hence, cause the earthquake). To do this, convert the mass of the pulled brick to a **pull force (F_p)** using the following equation:

$$F_p = m \cdot g$$

F_p = Force of pull (kg m/s² or Newtons (N)) – or force of earthquake!

m = mass of pulled brick recorded by spring scale (kg) (column 2)

g = acceleration of gravity = 9.8 m/s²

Enter these numbers in **column 5** of your data table under “Force of Earthquake”.

For example, if the Mass of pulled brick was 2 kg, then

$$\text{Force of Earthquake} = 2 \text{ kg} \cdot 9.8 \text{ m/s}^2 = 19.6 \text{ kg m/s}^2 = 19.6 \text{ N.}$$

4. Now you are ready to compute the energy released by each earthquake. One way to define energy is

$$\text{Energy} = \text{Force} * \text{Displacement}$$

Energy = Energy of the Earthquake (N-m)

Force = Force of Earthquake (N)

Displacement = Displacement of Earthquake (m)

Using the information in columns 4 & 5 of your data table, calculate the energy released by each earthquake and place in **column 6**.

5. Finally, you are ready to compute the Energy Magnitude of each earthquake. The energy magnitude of the small “earthquakes” generated by the sliding brick can be computed if we know the energy (**E**) released during the event.

The Energy Magnitude of an earthquake is defined by the following equation:

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

Using the energy (E) values in column 6 of your data table, compute your earthquake Energy Magnitudes and record them in **column 7**.

Don’t be surprised if the magnitude you calculate is negative. The events created by the slipping brick are **VERY SMALL**. Only real earthquakes generate enough energy for the magnitude equation to produce positive results. The larger the event, the less negative the magnitude.

Questions (continued):

6. What was the average of your earthquake Energy Magnitudes generated by the brick and sandpaper experiment?
7. What are the units of Energy Magnitude?

8. An alternative way to calculate earthquake magnitudes is by the **Seismic Moment Equation**, which is then used to calculate the **Moment Magnitude**.

$$\text{Seismic Moment} = M_0 = L \times H \times D \times R$$

L = Fault Length (m)

H = Fault Height (or depth) (m)

D = Earthquake Displacement (m)

R = Rigidity of Earth's Crust = $30 \times 10^9 \text{ N/m}^2$

Measure the length of you brick in meters. This is your fault length (L).

L = _____ m

Measure the height of you brick in meters. This is your fault height (or depth) (H).

H = _____ m

Now use the Earthquake Displacement measurements from your data table (column 4) and calculate the seismic moments for each of your earthquakes:

Earthquake #1 **M_0 = _____**

Earthquake #2 **M_0 = _____**

Earthquake #3 **M_0 = _____**

Earthquake #4 **M_0 = _____**

Earthquake #5 **M_0 = _____**

To compute Moment Magnitude (M_m), use the following equation:

$$M_m = \log M_0 / 1.5 - 10.73$$

Earthquake #1 $M_m =$ _____

Earthquake #2 $M_m =$ _____

Earthquake #3 $M_m =$ _____

Earthquake #4 $M_m =$ _____

Earthquake #5 $M_m =$ _____

9. What was the average of your earthquake Moment Magnitudes?

10. How do your Moment Magnitudes compare to your Energy Magnitudes?