LAB Exercise #5 Submit by 5pm Wednesday March 2, 2016
Fracture, Faults, and Friction - An Empirical Look at Stresses that Cause Fracture

Objective of lab

- Construct a failure envelope for sand using the wooden frame apparatus
- Examine Byerlee's friction law with a sliding block
- Put our failure criteria to the test by looking at an experimental system (the sandbox) in which we cause materials to fault

Format of lab

We will need all of the lab time to complete the two experiments. Complete the tasks listed above during the lab period and then use the data you collect to answer the questions that accompany each experiment. Submit your answers clearly organized with the data.

Some conversion factors that may come in handy:

Unit	Conversion
1 pound-force (lbf)	4.44822 Newtons (N)
1 lbf	32.174 lb ft s^{-2}
1 kg	2.205 lb
1 meter	3.281 ft

Brittle Fracture, a Quantitative Approach

Many people are interested in calculating when a material will break. The topic is of particular interest to earth scientists -- geomorphologists calculate the forces that lead to landslides, earthquake geologists evaluate the likelihood of a fault rupturing, and structural geologists reconstruct paleostress fields from field observations of fractures and faults. The Mohr-Coulomb criteria is an empirically derived method for determining when a material will fail (break) under shear.

Coulomb fracture criterion states:

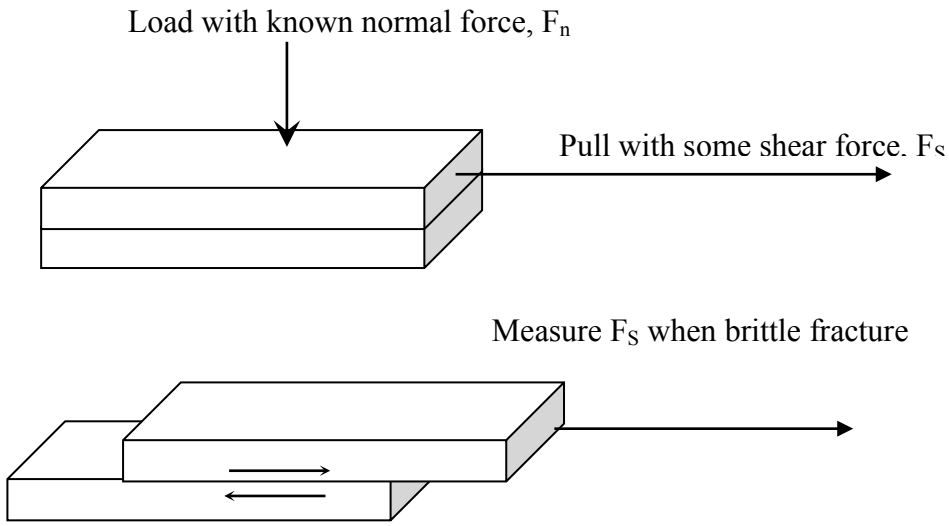
$$|\sigma_S^*| = c + \mu\sigma_N \; and \; \mu = \tan\varphi$$

σ^*_s is the **critical shear stress** - (the shear stress that causes the material to fracture)
σ_n is the applied **normal stress**
φ is called the **angle of internal friction**
μ is called the **coefficient of internal friction**.
c is the **cohesion** - (resistance to fracture along a surface with no normal stress, or the "stickiness").

The onset of **frictional sliding** is similar to the Coulomb fracture criteria except it will pass through the origin, i.e., the cohesion is zero. See (T&M 8.3 and 8.4)

Experiment #1 Coulomb failure envelope of sand and Byerlee's friction (45 pts)

- Let's apply the Coulomb failure criteria to sand in order to see how well it works:
  Take two wooden frames, fill them with sand, and top with a piece of wood



Be sure in your experiment to measure critical parameters (like surface area) in case you need them later. Make a table of the values you collected during the experiment, converting all values to metric (i.e. Newtons, kilograms, meters, ...) and answer questions 1-3:

1. Plot the shear, σ_s, versus normal, σ_n, stress acting on the sand in the frame. (5 pts)

2. What is the equation of the line and what information can you get from it? What are the values of μ and φ for this system? Does the line pass through the origin? What does this tell you about the material properties of sand? (7 pts)

3. When analyzing the data from this experiment, what considerations should you have regarding the validity of the experimental setup? Could the experiment be designed better? How? Is sand a good analogue for rock? If not, what might be a better material to use? (8 pts)

Now lets look at Byerlee's friction law with a 'stick-slip' experiment. We will apply different normal forces to the block and measure the shear force required to initiate sliding on the preexisting fault surface. Use these data to complete questions 4 - 5.

4. Construct a plot of shear, σ_s, versus normal, σ_n, for the frictional sliding data and fit a line to the results. Be sure to make this pass through the origin. (5 pts)

5. What is the equation of the line and what information can you get from it? What is the value of μ for this system? Describe how the normal and shear stress are related (8 pts)

6. Describe in 4-5 sentences Coulomb failure and Byerlee's friction. Be sure to include any insight gained from the data collected and results analyzed (12 pts)

Experiment #2 — the sandbox (40 pts)

- This part of the lab involves creating normal and thrust faults in a "sandbox" by applying stresses to fine sand with a marker layer to observe the deformation.

  Use the digital camera to image the situation in the sandbox at distinct intervals in its evolution. Start with an initial picture and record the experiment at various intervals from there. Indicate at what point you are making the sketch (relative to the position of the metal partition, *d*). Measure *d* with a ruler. Draw a sketch of interesting features in the boxes on page 4. **Don't forget to include a scale bar in your image!**

Answer the following for the sandbox experiment. Be sure to include the tabulated data collected.

7. Describe the topography in the normal fault section of the experiment. What fault-related features are being created here? (5 pts)

8. What is the dip of the normal faults? What factors would cause this angle to change? (i.e. what could we have changed about the experiment to produce a different angle?) (5 pts)

9. In what sort of tectonic regimes might you find normal faults? (3 pts)

10. What is the dip of the developing thrust faults? (3 pts)

11. Where does the second thrust develop relative to the first? Does the first thrust continue moving after the second is activated? What happens to the first thrust as the second begins to move? (5 pts)

12. **Principal stresses:** Why do the faults form where they do? Relate the orientation and slip on the faults to the directions of the two principal stresses, σ_1 and σ_3. (7 pts)

13. **Fault orientation:** Draw a schematic Mohr circle for each situation (normal and thrust sections). You don't have actual values for stress magnitude, but please consider the relative magnitude of the normal and thrust cases. Why do the faults form in these particular orientations? (12 pts)

Hints:

- Consider this to be a two-dimensional situation.
- Use one of the digital sandbox images and indicate the directions of the principal stresses on the image.

Include diagrams of the observed deformation during the experiment. Include a scale and label the important features you observe.

d =

d =

d =

d =

14. **DISCUSSION:**
Include a 500 word summary (~2 concise paragraphs) that describe the importance of the experiment. (15 pts) Please use a word processor and print this portion of the assignment.

Here are some questions you might want to address. The write up is not limited to these points, please include all information you find relevant to the experiment and results.

What does this type of experiment tell us about the processes and mechanisms acting on rocks in nature? For example, is this sort of experiment useful to geophysicists looking at properties of deep mantle rocks?

What aspects, in particular, do you consider useful?

What assumptions do geologists make when applying experimental observations to reality?

Are these assumptions valid?

How well does the Coulomb criteria work?

What do you think? Are there any other types of experiments that you can think of that would test other aspects of rock deformation, brittle or ductile? You could even design your own experiment…