LAB Exercise #6
Fracture, Faults, and Friction - An Empirical Look at Stresses that Cause Fracture
Due: 03/13/2015

Objective of lab
- Construct a failure envelope for sand using the wooden frame apparatus
- 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.

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.

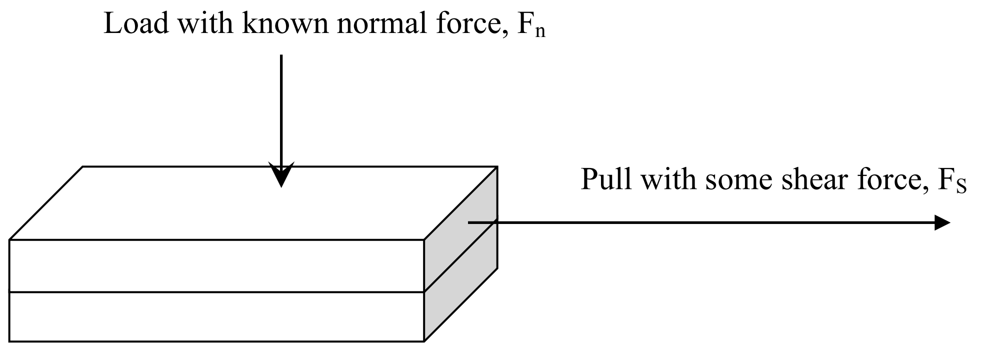
Coulomb fracture criterion states:

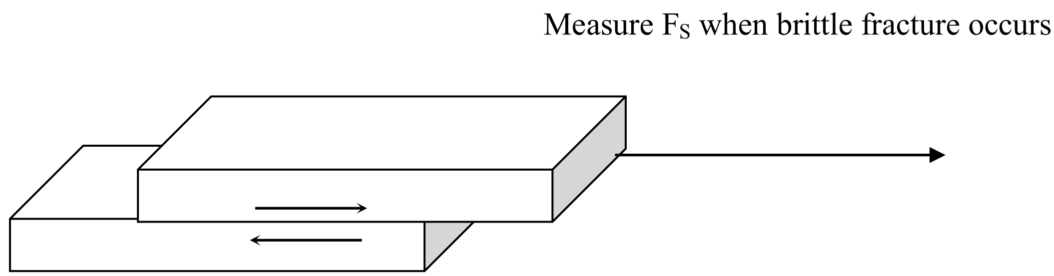
$$|\sigma^*_s| = c + \mu\sigma_n \text{ and } \mu = \tan\varphi \quad \text{(T\&M pg. 212)}$$

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").

Experiment #1 — the failure envelope of sand

- 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





Make a table of the values you collected during the experiment, converting all values to metric (i.e. Newtons, kilograms, meters, …) and answer the following questions:

1. Construct a plot of shear, σ_s , versus normal, σ_n, stress acting on the sand inside the frames. (7 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? (7 pts)

3. Does the line pass through the origin? What does this tell you about the material properties of sand? (7 pts)

4. 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? (7 pts)

5. Is sand a good analogue for rock? If not, what might be a better material to use? (7 pts)

Be sure in your experiment to measure critical parameters (like surface area) in case you need them later…

Experiment #2 — the sandbox

- This part of the lab involves creating normal and thrust faults in a "sandbox" by applying stresses to a mixture of fine sand and clay layers via a metal partition.

Answer the following questions as part of the sandbox experiment lab.

6. 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. **Don't forget to include a scale bar in your image!** You should also hand draw interesting features in the boxes attached. (5 pts)

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. Draw a free body diagram of the fault surfaces (draw a picture of the fault and show all of the forces acting on it). (5 pts)

13. **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)

14. **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)

<u>Hints:</u>

- 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.

d =

d =

d =

d =

15. **DISCUSSION:**
Describe the importance of the experiment. (15 pts)
(Here are some questions that you might want to address) 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 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…