Some of the most dramatic evidence that great forces have shaped the Earth are the rocks that one finds deformed in mountain belts. Rocks can be deformed by body forces, nothing more than gravity acting on them. Slumps and landslides are some familiar results of the effect of gravity. But gravity driven deformation can be vastly bigger than we are accustomed to, especially when aided by additional processes, some of which we will explore in this lab. Alternatively, rocks can be deformed by tectonic forces that push them together and crumple them up, forming most of the world’s great mountain ranges, including the Alps, the Himalayas, and the Andes. In both types of deformation, a key ingredient is friction.

In this lab, we will perform two experiments to investigate both of these kinds of deformation. In one, you will deform layers of sand in front of a horizontally driven piston, simulating tectonic deformation that one sees in many mountain ranges. The structures that you create are not unlike those that have been responsible for recent earthquakes in Taiwan and elsewhere. In the other experiment, you will observe some of the key mechanical features that allow great landslides to travel tens or hundreds of kilometers over very gently sloping land surfaces.

The Sandbox Experiment

A sandbox is a Plexiglas-sided box with a moveable piston at one end. You will fill the box with layers of sand, placing markers of white at intervals up the sides.

Procedure

1. Pour sand into the empty sandbox until about 4 cm (~1.5 inches) thick and smooth out the top surface. Sprinkle a narrow strip of white sand just along the glass walls (do not spread across the entire surface of the sand). Repeat three or four times, ending with a layer of sand with no plaster on the top. Smooth out the top surface. The total thickness of sand should be 15 to 20 cm (~6 to 8 inches) thick.

2. Making sure the hydraulic car jack is collapsed all the way, position it with the handle pointing upward at the back end of the model. Be sure that the small turn screw that you use to release the pressure is shut or else it won’t work.
3. Measure and write down the initial dimensions of the model: thickness of the sand, length of the model.

4. Move the piston by pumping the car jack. At several intervals, make the following observations.

**Observations to Make**

Fill in the following table as you carry out the experiment:

<table>
<thead>
<tr>
<th>Displ. of Piston (cm)</th>
<th>Length of model (cm)</th>
<th>Slope of surface</th>
<th># of Faults</th>
<th>Dip angle of faults (record the fault farthest from the piston, as well as any others you can measure)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 cm</td>
<td></td>
<td>0°</td>
<td>0</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Questions to Answer**

1. As you move the piston, does the sand shorten and thicken uniformly or is the deformation of the sand localized along discrete planes?

2. How much displacement of the piston is required before the first fault forms? What is the angle that the fault makes with respect to the horizontal (i.e., the dip)?

3. Do the fault angles change during the experiment? If so, do they get steeper or shallower?
4. Observe and describe the surface of the model as the deformation proceeds. Is it smooth or lumpy? If there are surface irregularities, can you explain them in terms of the deformation that you observe on the sides of the model? What else happens to modify the surface.

5. How does the width of the deformed zone change with time? Where is the deformation concentrated at any particular time.

6. Make a sketch of the either one of the two faces of the sandbox, showing the geometry of the structures formed.

The "Beer Can" Experiment

The "Beer Can" experiment was first proposed by the French fluid mechanics expert M. A. Biot to illustrate how certain factors can substantially affect the friction between a mass and the slope on which it rests. [Editorial note: Biot proposed this experiment back in the 1950's, when beer cans were sturdy affairs. Today's beer cans, while being ecologically much more acceptable (though much less welcome on college campuses), have wimpy thin sides that make them unusable for this experiment, so we are reduced to the ignominious fate of having to use a different can!]

Procedure

1. Take the glass plate provided and place the empty can on one end. Tilt the plate by raising the end on which the can rests. Record the angle of the plate at which the can begins to slide down the tilted glass. [A table is provided, below, for recording the observations.]

2. Cover the plate with a film of water (if the plate is dirty, you will have to clean it with mild detergent first). Repeat step one. Again, record the angle at which the can slides down the plate.

3. Now chill the can by placing it in the cooler with dry ice [Safety note: Do not handle the dry ice with your bare hands or you run a serious risk of rapid frostbite. Use gloves to place or remove the can from the cooler. Dry ice — or frozen carbon dioxide — is much colder than ice made from water!].

4. After two to three minutes, remove the can from the cooler and place the can on the wetted glass plate with the open end facing up. Tilt until the can slides and record the angle as before.
5. Finally, cool the can again, briefly, and place it on the wetted plate, open end down. Tilt until the can slides and record the angle.

**Observations**

<table>
<thead>
<tr>
<th>Condition of Beer Can (besides empty!)</th>
<th>Condition of plate</th>
<th>Angle of plate when can slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Room temperature</td>
<td>Dry</td>
<td></td>
</tr>
<tr>
<td>2 Room temperature</td>
<td>Wet</td>
<td></td>
</tr>
<tr>
<td>3 Cold, open end up</td>
<td>Wet</td>
<td></td>
</tr>
<tr>
<td>4 Cold, open end down</td>
<td>Wet</td>
<td></td>
</tr>
</tbody>
</table>

**Questions to Answer**

1. Discuss the results of your experiment. What are the important factors that are related to how easily the can moves down the slope? Why is the result for the last combination of factors (cold, open end down, wet) so different from the others?

2. Now let's think about the experiment a little more quantitatively. The mechanics of this experiment are shown below in a simplified "free body diagram." The can begins to slide when gravity pulling down on the can overcomes the frictional resistance to sliding (Ff in the diagram). However, because gravity cannot pull the can through the glass plate, there are actually two forces involved: the force pushing the can directly against the glass (the normal force, Fn) and that part of gravity which pulls the can down the slope (the tangential force, Ft). These two forces are related by the angle of the slope, θ, as shown below. The diagram, below, works well for the first three cases, above, but not the fourth case. Describe what additional arrow needs to be added to the diagram, its orientation, and how this influences the results of the experiment.
normal force \( F_n = mg \cos(\theta) \)
tangential force \( F_t = mg \sin(\theta) \)

Frictional resisting force \( F_f = \mu F_n \)
(where \( \mu \) is the coefficient of friction)