Phriction Phreaque-Out Part I

Apparatus: board, light pulley, string, scissors, cleaning fluid, paper towels, hockey pucks with hooks, angle indicators, tape, table clamps, mass hangers with slotted mass sets, method for raising and lowering board (could be a human or a system of rods, bases and right angle clamps)

Goal: Determine the value of μ_s between a hockey puck and a board. By determining this in several different ways you should get practice with a variety of FBD's, force equations, and algebra.

Preparation: Thoroughly clean the board and puck surfaces and let them dry for at least 2 minutes. Do not touch the board or puck surfaces after cleaning. **Handle the puck by the sidewall; do not touch the circular faces.** If the puck falls on the ground or a surface gets touched, simply clean it again and wait 2 more minutes.

Use the methods discussed on the next page to determine values for μ_s.

To turn in:
For this week, your intro should start with a sketch of the apparatus and an FBD for method 1 (draw them side by side and don't skimp on the size).
Don't forget to include a coordinate system so I can follow your work.
Then list the force equations centered on their own lines.
Finally, derive equation for μ_s from the force equations.
Repeat this so I have a sketch, FBD, force equations, and derivation for Methods 1, 2a, 2b, and 3.
I won't be looking at grammar, just your diagrams, equations, and derivations.

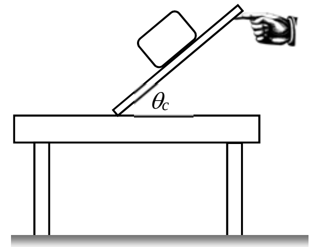
Tabulate your data.
For each measurement, be sure to also tabulate your angles and, for Methods 2a, 2b, & 3, your masses.
In total you should have seven measurements of μ_s:

- One from the average value of θ_c in method 1
- Four from the largest hanging mass before sliding *up* the plane (one each at $0°, 10°, 20°, \& \ 60°$)
- One from the minimum mass before sliding *down* the plane (only do this once at $60°$)

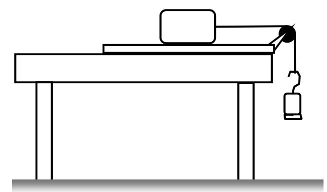
Determine the average and standard deviation of your eight measurements to determine your best estimate of μ_s and the associated statistical error.
Obtain the averages from all other groups in the class. Determine the best estimate of μ_s for the class and the associated statistical error.

Also, do the conclusions questions.

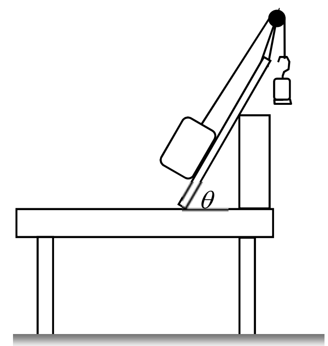
Method 1:
Start with the board horizontal. Place the puck on the board (handle puck by the edges). As slowly and smoothly as possible, raise the board. While you raise the board, monitor the angle indicator. At the instant the puck starts to slip, note the angle. The angle at which slipping onsets is called the critical angle (θ_c). Repeat this experiment for a total of ten trials to get an average value of θ_c. Use this average value of θ_c to determine a value for μ_s between the puck and the board.



Method 2a:
Now attach a string to the puck and run it over the pulley to a mass hanger as shown in the 2nd figure at right. Your set-up should allow you to set the angle and leave the apparatus fixed at that angle for several minutes (see 3rd and 4th figures at right). You will use angles of 0.0°, 10.0°, 20.0°, and 60.0°. Make sure your design can accommodate all of these angles. In some cases it will help if the puck is allowed to travel as far as possible.

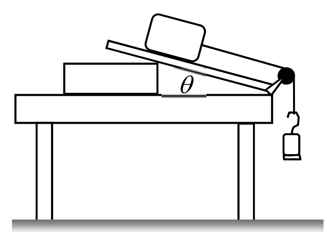


Once you have your appratus set-up, ensure that the string is parallel to the board by making adjustments to the pulley. For each angle, determine the largest possible hanging mass that can be used without causing the puck to slip *up* the plane. I recommend using large masses (say 100 g) to first determine a rough value at which the puck starts to slip. Then take off some mass and go by smaller increments (say 20g) to get a better approximation. Finally, go by 1 g increments to record your most precise value for the m_2 that causes the onset of slipping. Use the values of m_2 that cause slipping onset to determine a value of μ_s for each angle (0.0°, 10.0°, 20.0°, and 60.0°).



Method 2b:
This part uses exactly the same set-up as Method 2a. Using only the 60.0° angle, determine the minimum m_2 needed to prevent the puck from sliding *down* the plane. Use this value of m_2 to determine yet another value for μ_s.

Method 3:
Now consider the similar apparatus shown in the 4th figure at right. Determine the minimum m_2 required to cause the puck to slide down the incline for $\theta = 15.0°$. Use this value of m_2 to determine yet another value for μ_s.



Conclusions:
1) In Method 2 you were asked to adjust the pulley to ensure the string runs parallel to the board. If the string was angled, why does it complicate the force equations used to determine μ_s? In particular, discuss how the normal force (and thus the maximum possible frictional force) is affected.
2) What angle on the Method 2a FBD corresponds to 15.0° in the Method 3 FBD?
3) As you increase the angle in Method 2a, do we predict that μ_s should increase, decrease, or remain constant? Explain or defend your answer.
4) Why do we set the acceleration to zero in all of these FBD's even though the block is sliding? Explain why the approximation $a \approx 0$ is appropriate.