Flipping Physics Lecture Notes:

2017 #2 Free Response Question - AP Physics 1 - Exam Solution
http://www.flippingphysics.com/ap1-2017-frq2.html

A student wants to determine the coefficient of static friction between a long, flat wood board and a small wood block.

(a) Describe an experiment for determining the coefficient of static friction between the wood board and the wood block. Assume equipment usually found in a school physics laboratory is available.

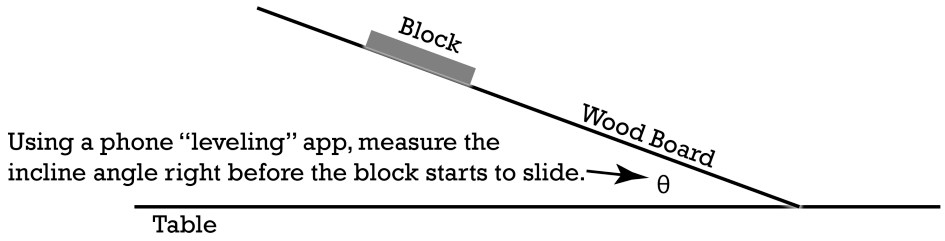
i. Draw a diagram of the experimental setup of the board and block. In your diagram, indicate each quantity that would be measured and draw or state what equipment would be used to measure each quantity.

ii. Describe the overall procedure to be used, including any steps necessary to reduce experimental uncertainty. Give enough detail so that another student could replicate the experiment.

(b) Derive an equation for the coefficient of static friction in terms of quantities measured in the procedure from part (a).

I have an entire video where I demonstrate this experiment and solve this problem. "Introductory Static Friction on an Incline Problem" https://www.flippingphysics.com/static-friction-incline.html I would suggest watching that for a more detailed solution to parts (a) and (b). I am going to do a shorter solution here.

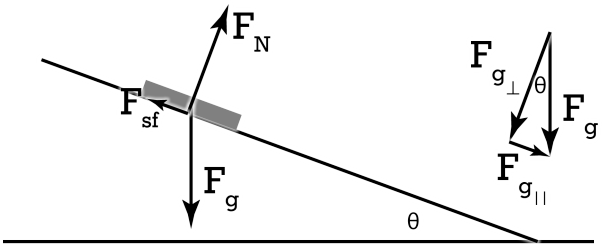
Part i:

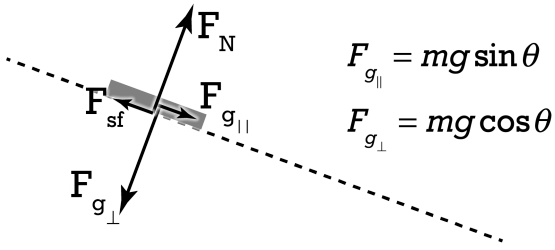


Part ii:

- *Begin by calibrating the phone "leveling" app.*
- *Place the block on the wooden board and slowly raise one side of the board.*
- *Record the incline angle at the moment right before the board begins to slide.*
- *Repeat 10 times with the block at various locations on the board.*

*Grading note: According to the scoring guidelines, you gain one point out of three for part ii "*For including a valid method for reducing experimental error*". It might be easy to overlook the part of the question where it clearly states to include "*any steps necessary to reduce experimental uncertainty*". My statements to put the block "at various locations on the board" and to calculate the "Measures" app both reduce uncertainty. So please, read every question carefully.*





Part (b): Draw the free body diagram of the forces acting on the block as the incline angle is being increased. Break the force of gravity into its components in the parallel and perpendicular directions. Then:

$$\sum F_{\perp} = F_N - F_{g_{\perp}} = ma_{\perp} = m(0) = 0 \Rightarrow F_N = F_{g_{\perp}} = mg\cos\theta$$

$$\sum F_{\parallel} = F_{g_{\parallel}} - F_{sf} = ma_{\parallel} = m(0) = 0 \Rightarrow F_{sf_{\max}} = F_{g_{\parallel}} \Rightarrow \mu_s F_N = mg\sin\theta$$

$$\Rightarrow \mu_s\left(mg\cos\theta\right) = mg\sin\theta \Rightarrow \mu_s\cos\theta = \sin\theta \Rightarrow \mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

Another grading note: "In order to earn full credit for part (b), all terms (variables) must be indicated in the diagram and/or procedure of part (a)." In other words, if θ does not appear in your diagram in part (a), you will not get full credit for part (b). *So again, read every question carefully. (No more please.) In fact, if you have the time, I suggest that, after you think you have completed each question, you should go back and read through the question one more time to make sure you answered every piece of every question.*

A physics class consisting of six lab groups wants to test the hypothesis that the coefficient of static friction between the board and the block equals the coefficient of kinetic friction between the board and the block. Each group determines the coefficients of kinetic and static friction between the board and the block. The groups' results are shown below, with the class averages indicated in the bottom row.

Lab Group Number	Coefficient of Kinetic Friction	Coefficient of Static Friction
1	0.45	0.54
2	0.46	0.52
3	0.42	0.56
4	0.43	0.55
5	0.74	0.23
6	0.44	0.54
Average	0.49	0.49

(c) Based on these data, what conclusion should the students make about the hypothesis that the coefficients of static and kinetic friction are equal?

____ The static and kinetic coefficients are equal.
_X_ The static and kinetic coefficients are not equal.
Briefly justify your reasoning.

When looking at the average values only, that seems to be true, however, lab Groups 1, 2, 3, 4, and 6 show a rather consistent relationship of $\mu_k < \mu_s$. However, Lab Group 5 shows $\mu_k >> \mu_s$, which gives an average such that $\mu_k = \mu_s$. However, it appears something went wrong during Lab Group 5's experiment; therefore, that data should either be thrown out or Lab Group 5 should repeat their experiment correcting sources of extreme error. Excluding Lab Group 5's data shows a rather consistent relationship of ***$\mu_k < \mu_s$****.*

Another grading note: A correct answer with no reasoning or incorrect reasoning ears zero points for part (c). I've said it before, I say it again. When they ask you to justify your reasoning, you have to justify your reasoning!!

(d) A metal disk is glued to the top of the wood block. The mass of the block-disk system is twice the mass of the original block. Does the coefficient of static friction between the bottom of the block and the board increase, decrease, or remain the same when the disk is added to the block?

____ Increase ____ Decrease _X_ Remain the same Briefly state your reasoning.

According to our answer to part (b), the coefficient of static friction equals the tangent of the incline angle right before the block starts to slide. Mass is not in that equation, so the mass of the block should have no effect on the measured coefficient of static friction. Therefore, ***μ_s remains the same****.*

*Another another another grading note: As long as the argument is valid, the The CollegeBoard accepted all three answers here. For example, "*The increased normal force will cause smoothing of the surfaces, decreasing the coefficient of friction*." Or "*The increased normal force will cause the surfaces to become gouged, increasing the coefficient of friction.*" This, again, highlights the importance of explaining your answer carefully and thoroughly.*