Static Friction

Name:

Group Members:

Date:

TA's Name:

Learning Objectives:

I. Applying Newton's second law to investigate the model of static friction.
II. Understanding the factors that do and don't affect the coefficient of static friction.

Apparatus: Wooden box, aluminum track, wooden board, meter stick, and protractor, 500g mass

Part A: Predict and Test

1. Predict what will happen if the block is placed on the aluminum track and the angle of the track is slowly increased little by little.

2. Now place the block on the track and slowly increase the angle. What do you observe?

3. Why did it behave that way? Why did it slide at a large angle but not at a small angle?

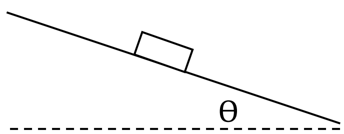
Part B: Forces on a Block at Rest on an Inclined Surface

4. Identify and label the system that you want to study. Then select your coordinate system. Then draw free body diagrams for the case where the block is not moving.

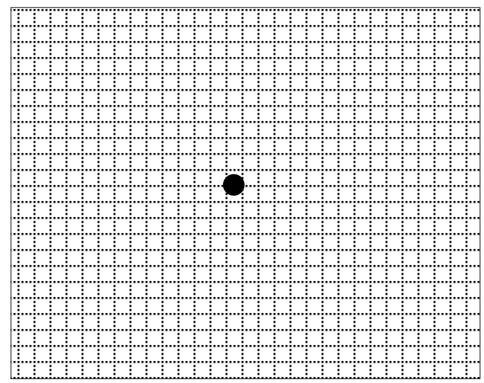
<u>When the block is at rest</u>

Identify the system ________________________________

For inclined surfaces we use a tilted coordinate system. Indicate the directions of your x and y axes on the drawing below:



Draw the free-body diagram below



5. Is your free body diagram consistent with the block being in equilibrium? Explain.

6. Now apply Newton's second law in the *x*-direction to the situation in Question 4 with the block not sliding. To do this, use your free-body diagram to identify the *x*-components of each force and write them on the left side of the equation. Remember to pay attention to the sign since the component may be in the *+x* or *–x* direction. Also determine the acceleration in the *x* direction for the situation where the block is not moving and substitute in on the right side of the equation.

$$\Sigma F_x = ma_x$$

7. Rearrange your equation in Question 4 to solve for the static frictional force, f_s. , needed to keep the block from sliding.

$f_s =$ ____________________________

8. The equations you wrote in Questions 6 and 7 should be true even when the angle is changed as long as the block does not slide. Use your equations to determine what happens to the static frictional force on the block as the angle is increased but the block is still not moving. Explain your findings.

9. Now apply Newton's second law in the y-direction to the situation in Question 4. To do this, use your free-body diagram to identify the y-components of each force and write them on the left side of the equation. Remember to pay attention to the sign since the component may be in the $+y$ or $-y$ direction. Also determine the acceleration in the y direction for the situation and substitute in on the right side of the equation.

$$\Sigma F_y = ma_y$$

10. Rearrange your equation in Question 9 to solve for the normal force, n.

$n =$ ____________________________

11. The equations you wrote in Questions 7 and 10 should be true even when the angle is changed since the block never moves in the y-direction. Use your equations to determine what happens to the normal force on the block as the angle is increased but the block is still not moving. Explain your findings.

12. You learned in class or in the textbook that the static frictional force has a maximum value, $f_{s,max}$, which is given by the product of the coefficient of static friction (μ_s) and the normal force, that is, $f_{s,max} = \mu_s n$. The coefficient of static friction is a constant in any given situation and characterizes the interaction of the two surfaces involved, in this case the interaction of the block surface with the track surface. For our situation, there should be a particular angle for which the static frictional force needed to hold the block in place (you found a formula for this in Question 7) equals the maximum static frictional force available (which is μ_s times the normal force you found in Question 10). Substitute the formulas you found in Questions 7 and 10 for f_s and n into the equation below.

$$f_s = f_{s,max} = \mu_s n$$

13. In our case we can measure this particular angle since this is the largest angle we can tilt the track before the block slips. Call this angle as θ_{max}. However, we don't know the value of the coefficient of static friction. Rearrange the equation above to get an equation for μ_s.

Write the symbolic expression for static frictional coefficient you found:

$\mu_s =$ ________________________________

What are the units of μ_s? ____________________________

14. The expression you found in question 13 tells us that we can measure the coefficient of static friction by measuring the maximum angle θ_{max}. Does it mean that coefficient of static friction between the block and the track depends on the angle θ_{max}? Explain.

Check with your TA before continuing.

Part C: Measuring the coefficient of static friction

15. We are going to examine following effects on the coefficient of static friction.
    a. Effect of mass of the wooden box
    b. Effect of the type of material pair in contact
        - wood on aluminum: wooden box on aluminum track
        - wood on wood: wooden box on wooden board

    We use two different inclines, one made from aluminum and the other made from wood. Design an experiment to measure the static frictional coefficient between the incline (either for the aluminum track or the wooden board) and the block. Use the wooden side of the box. After testing out your procedure describe it below. You can increase the mass of the block by putting an extra mass on the wooden block.

16. **Data and calculation**: For each incline and with and without added mass to the wooden box, repeat your procedure five different times placing the block at different starting positions on the incline. Then calculate the average and the uncertainty in your value of the coefficient for each of the two materials. Note: If you use the tangent function in Excel you must change the angles from degrees to radians first.

Select five different positions on the track from the bottom	Wooden box on aluminum track				Wooden box on wooden board			
	Angle		Calculated coefficient of static frictional		Angle		Calculated coefficient of static frictional	
	Box only	Box+ mass	Box only	Box+ mass	Box only	Box+ mass	Box only	Box+ mass
1								
2								
3								
4								
5								
	Avg. μ_s =				Avg. μ_s =			
	Uncertainty =				Uncertainty =			

17. Based on the average and uncertainty you determined, in what range of values will the actual value of μ_s be for the wood and aluminum?

Wooden box only (wood on aluminum)	Wooden box + mass (wood on aluminum)
___________ $< \mu_s <$ _____________	___________ $< \mu_s <$ _____________

18. Based on the average and uncertainty you determined, in what range of values will the actual value of μ_s be for the wood and wood?

Wooden box only (wood on wood)	Wooden box + mass (wood on wood)
___________ $< \mu_s <$ _____________	___________ $< \mu_s <$ _____________

19. Compare the values of μ_s calculated for material pair "wood on aluminum" for with different masses of the box. Do they agree within our experimental uncertainties? That is to say, do the ranges overlap? Explain.

20. Compare the values of μ_s calculated for material pair "wood on wood" for with different masses of the box. Do they agree within our experimental uncertainties? That is to say, do the ranges overlap? Explain.

21. Compare the values of μ_s calculated for material pair "wood on wood" and "wood on aluminum." Are the values μ_s same or different? Explain how you reached the conclusion.

Part D: Conclusions

22. What does the coefficient of static friction NOT depend on? That is, what can we change about the situation that makes the coefficient stay the same?

23. What determines the coefficient of static friction in a particular situation? That is, what can we change about the situation that would make the coefficient change? Give an example.

24. How is the static frictional force related to the coefficient of static friction?

25. Can the static frictional force change even though the coefficient of static friction stays the same? If so, give an example from this experiment.

26. Is it correct to make a statement like "The coefficient of static friction of aluminum is 0.5?" If yes why? If not why not?