LAB # 5 - Coefficient of static friction

Introduction
It is a common observation that once set in motion objects invariably came to rest. Throw a book across a table, it will slide to a stop. Even a hockey puck on a slippery ice surface will EVENTUALLY come to rest. This was a significant hindrance to understanding the laws by which the Universe behaves, leading Aristotle to mistakenly conclude that the natural state of motion was rest. But, as Galileo and Newton established, the natural state of motion is constant velocity, obtained whenever the net force on an object is zero. So, we can clearly conclude that the net force on a book sliding to a stop is NOT zero (why?). The unseen force that so misled Aristotle is what we refer to as friction. The ultimate cause of friction in most cases is the attraction that molecules in one surface have for the molecules in the other, and is generally a quite tough problem to analyze from first principles. (Analyzing this problem from first principles means to write Newton's law for all the molecules in one surface and the other, with all the forces involved). There is much scientific work on this (why might that be?), and the science of studying the forces that arise when surfaces rub past each other is called tribology (the related study of the frictional forces that arise when liquids rub past each other is called rheology). Friction is more often handled by what are called empirical methods. In short, empirical methods are those in which you measure things rather than trying to calculate them using Newton's laws - in fact, science is a continuous back-and-forth dynamic between both methods.

Friction is generally grouped in two classes; kinetic, in which the two surfaces are in relative motion and static, in which they are not.

Empirically, it is often (but not invariably) found that the maximum static frictional force is directly proportional to the normal force of contact between the two surfaces in question (why is this different from saying that the static frictional force is proportional to the normal force?). That is, an empty sled is easier to get sliding than a heavily loaded one. The constant of proportionality is called the coefficient of static friction, and the empirical statement above can be written:

\[ f_{S,\text{MAX}} = \mu_S N \]  

where \( f_{S,\text{MAX}} \) is the maximum static frictional force, \( \mu_S \) is the coefficient of static friction, and \( N \) is the force of contact between the two surfaces. (How is this different from the false statement that \( f_S = \mu_S N \)?) The point of this lab will be to test the statement given in Eq. 1, and if it is true, to find the constant of proportionality.

The Lab
To determine the maximum static frictional force, it is necessary to determine the point at which an object just begins to move under the influence of some external force which the static frictional force opposes. That is, what is the largest external force that the static frictional force can oppose? This is the maximum static frictional force. (How is this different from the static frictional force?). Consider the figure, which shows an object at equilibrium on an inclined plane. It can be seen that the static frictional force obeys:
\[ f_s = mg \sin \Theta \]  

where \( \Theta \) is the angle between the vertical and a line perpendicular to the plane, and \( mg \) is the weight of the object. Further, it is clear that the normal force obeys:

\[ N = mg \cos \Theta \]  

Finally, it should be clear that if the angle is increased until the object just begins to slide, the maximum static frictional force will have been achieved. If this is repeated for a many weights, \( mg \), a set of data relating \( f_{s,\text{MAX}} \) to \( N \) can be constructed. Clearly, you will need to know the weight of the object and the angle between the vertical and a line perpendicular to the inclined plane. An appropriately prepared graph of \( f_{s,\text{MAX}} \) and \( N \) will allow you to assess the validity of Eq. 1 and obtain the coefficient of static friction.

**Conclusion**

In your discussion of this lab, you must consider what graph will give you the information you need. That is, what should the ordinate and the abscissa of the graph be to help you answer the questions you want to answer? (What are the questions you want to answer?) Once that determination is made, what should the graph look like if Eq. 1 is true? Consider your graph and whether it confirms or denies Eq. 1. Under what conditions does it make sense to define a coefficient of static friction? Does your data tell you that those conditions are present in your experiment? If it does make sense under your experimental conditions, what is the value of the coefficient? Finally, if the experimental conditions are such that a coefficient of static friction exists, under what conditions can you use that coefficient to find the static frictional force?