PHYSICS LAB EXPERIMENT – 6
FRICTIONAL FORCES

OBJECT: The purpose of this experiment is to investigate the properties of the frictional force that exists between two surfaces in contact.

APPARATUS: Aluminum track, wooden blocks and boxes, pulleys, weight hangers and slotted weights, string, glass blocks, steel carts (for rolling friction), balance, dust cloth.

INTRODUCTION: Whenever two objects are in contact a force comes into play which opposes the relative motion of these two objects' surfaces. This force is called force of friction, F_f. Without a force due to friction, a person could not walk nor could a car propel itself along a road. Friction is also a "nonconservative" force, which means that the work done to move two objects against each other against friction is always positive. Friction then reduces an objects maximum speed (i.e. a Mercedes on the autobahn) and also reduces the efficiency of machines. Usually, the energy lost due to friction is converted into energy in the form of heat. When two surfaces are in relative motion, the friction is kinetic friction, $F_{k.}$ When the surfaces are not in relative motion, then the friction acts between them in a direction opposite to the direction in which motion would take place in the absence of friction. This type of friction is called static friction, $F_{s.}$

THEORY: Force of friction F_f is proportional to normal force N. The constant of proportionality is called coefficient of friction μ. In the case of static friction, $F_s \leq \mu_s N$, where μ_s is the coefficient of static friction and N is the normal force. The coefficient of friction does not depend upon the size or the extent of the surfaces but does depend upon the nature of the surfaces in contact.

Similarly, when an object is moving on a surface, kinetic friction comes into play which opposes its relative motion. $F_k = \mu_k N$, where μ_k is the coefficient of kinetic friction and N is the normal force.

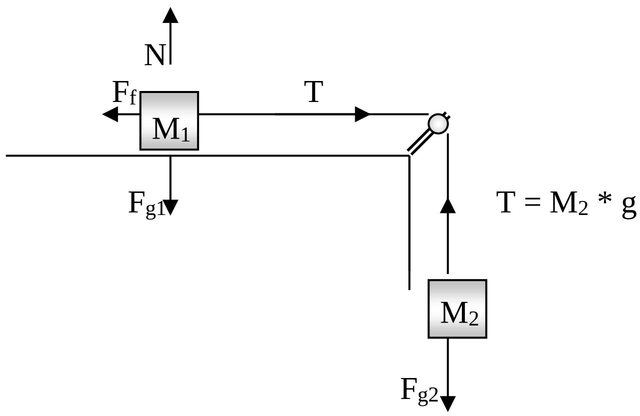
PROCEDURE: (finding the coefficients of <u>kinetic</u> and <u>static</u> friction)

1. Find the mass of the wooden block, M_1. Clean the aluminum track with a dust cloth.
2. Tie the string to the cart, pass the string over the pulley and hang the weights from the other end. Put the block on the aluminum track.
3. Load the weight hanger until the block starts moving with constant speed after giving it a *slight* push. Since there is no acceleration, the net force on the block is zero, which means that the frictional force is equal to the tension in the string. The tension in the string is equal to the weight, M_2g on the hanger. Hence the force of friction is equal to the weight of the block, M_2g. The normal force is M_1g. Knowing these two relations, the coefficient of kinetic friction can be calculated.
4. The normal force can be changed by placing more weight on the block. For each trial, increase the normal force by adding 200g to the block. The frictional force is found in each case as in step 3.
5. Repeat this procedure with the sliding box on its side (see chart below).

6. Repeat the procedure to find the coefficient of static friction, except this time, the block is **not** given an initial push and the weights are recorded when the block is 'on the verge' of moving. This is how the limiting frictional force is recorded. The ratio of the limiting frictional force and the normal force gives the coefficient of static friction.

Plot graphs between force of kinetic friction ($F_k = M_2$*g) and normal force N=(M_1+ m)g. The slope gives you the coefficient of kinetic friction. (**Two graphs**, one for each side of the block.)

Also plot a graph between the force of static friction $F_s = M_2$*g, and the normal force N= (M_1+ m)g. The slope gives the coefficient of static friction.



OBSERVATIONS:

Kinetic friction: μ_k

Mass of the wooden block, M_1 = _______________

Position of block	Mass placed on block (m)	(M_1+m) in kg	Total normal force N; N=(M_1+m)g	Mass M_2	Force of friction; $F_k=M_2g$	$\mu_k = F_k/N = M_2/(M_1 + m)$
Flat	0 g					
	400 g					
	1000 g					
			Average wood-aluminum μ_k =			
On side	1000 g					
	400 g					
	0 g					

Average leather-aluminum μ_k =

Static friction: μ_S

Mass of the wooden block, M_1 = _______________

Position of block	Mass placed on block (m)	(M_1+m) in kg	Total normal force N N=(M_1+ m)g	M_2 in kg	Force to start block moving; $F_s=M_2.g$	$\mu_s = F_s/N = M_2/(M_1+ m)$
Flat	0 g					
	400 g					
	1000 g					

Average μ_S =

Coefficient of the rolling friction: μ_r

For rolling friction, a steel cart is made to roll upon the aluminum track. Since the rolling friction is very low, the normal force is increased by placing heavy weights on the cart. The ratio of the pulling force to the normal force gives the coefficient of rolling friction.

$$\mu_r = F_r/N$$

Mass of the rolling cart, M_1 = ____________ kg

Mass on the cart	Total normal force; N; $N=(M_1+m)g$	Force to start the cart to roll $F_r = M_2 g$	$\mu_r = F_r/N = M_2/(M_1+m)$

Average μ_r =

QUESTIONS:

1. In the case of the procedure for the kinetic friction, why is it necessary for the block to move with constant speed?

3. How does the coefficient of static friction compare with the coefficient of kinetic friction?

4. A block weighing 10 N rests on a smooth wooden surface. If a force of 5.5 N is applied to it when it just breaks away and starts sliding, find the coefficient of friction. Which coefficient of friction is it?

5. A skater with an initial speed of 7.6 m/s is gliding across the ice. Air resistance is negligible. If the coefficient of kinetic friction between the ice and skate blades is 0.15,
   a) Find the deceleration caused by kinetic friction.
   b) How far does the skater travel before coming to rest?

6. A block rests on a horizontal surface and weighs 425 N. A force is applied to the block and has a magnitude of 142 N. The force is directed upward at an angle of θ, relative to the horizontal. The block begins to move horizontally when θ = 60.0°. Determine the coefficient of static friction between the block and the surface.

7. The force of friction between two objects *does not* depend on the area of contact of the two objects, but only on the coefficient of friction and normal force (i.e. $f_k = \mu_k n$, $f_s \leq \mu_s n$). Briefly, but clearly describe why this is the case.

8. The static friction force is *less than or equal to* $\mu_s n$ (i.e. $f_s \leq \mu_s n$) as opposed to being always equal to $\mu_s n$. Briefly, but clearly describe why this is the case.