JoVE: Science Education

Friction

--Manuscript Draft--

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Overview: The goal of this experiment is to examine the physical nature of the two types of friction (static and kinetic). The procedure will include measuring the coefficients of friction for objects sliding horizontally as well as down an inclined plane.

Friction is Friction is not completely understood but it is experimentally determined to be proportional to the normal force exerted on an object. If a microscope~~you~~ zoomed in on two surfaces that were in contact it would reveal~~you~~ ~~would notice~~ that their respective surfaces are very rough on small scales which prevents surfaces from sliding past one another easily. -Combining ~~combined~~ the effect of rough surfaces with the electric forces between the atoms in the materials, may account for the frictional force.

There are two types of friction. Static friction is when an object is not moving and it takes some force to get an object in motion. Kinetic friction is when an object is already moving but slows down due to the friction between the sliding surfaces.

Principles of Friction:

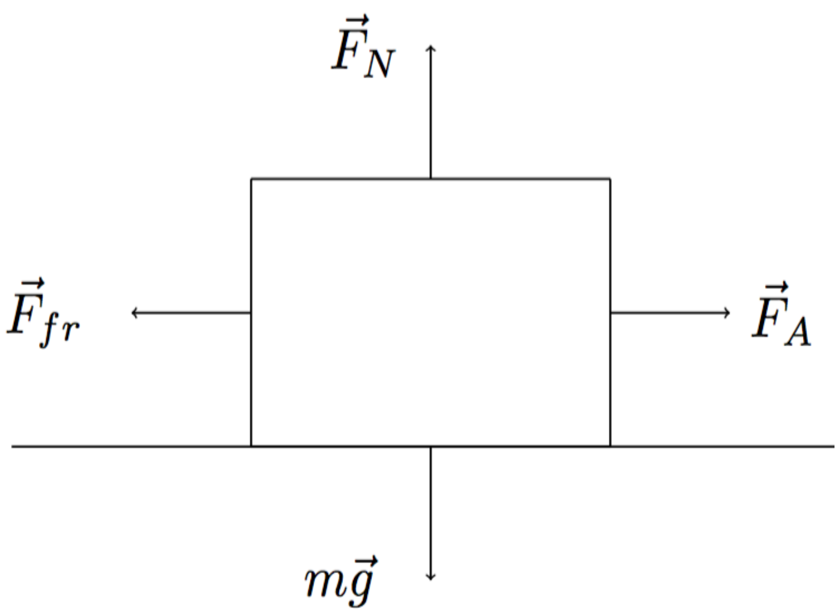

Figure 1

~~In~~ Figure 1 shows ~~we see~~ four forces acting on an object which sits on a horizontal plane. $\vec{F_A}$ corresponds to some applied horizontal force. $m\vec{g}$ is the force of gravity on the object which is matched equally but in the opposite direction by the normal force $\vec{F_N}$. The normal force is a result of a surface acting on an object in opposition to gravity. The normal force is why a book doesn't simply fall through a table it is resting on. Finally, opposing the applied force is the frictional force $\vec{F_{fr}}$. The frictional force is proportional to the normal force

$$\overrightarrow{F_{fr}} = \mu_k * \overrightarrow{F_N} \text{ (Equation 1)}$$

where μ_k is the coefficient of friction.

The coefficient of friction must be measured experimentally and is a property that depends on the two materials that are in contact. There are two types of coefficients of friction, kinetic friction μ_k when objects are already in motion and static friction μ_s when an object is at rest and needs a certain amount of force to get it moving. For an object sliding along a path~~, either horizontally or down an inclined plane,~~ the normal force is equal to the weight $m\vec{g}$ of the object. Therefore the frictional force depends **only on the coefficient and the mass** of an object.

If the object is on an inclined plane then the normal force $\overrightarrow{F_N}$ is perpendicular to the incline and is not equal and opposite to the weight $m\vec{g}$ as can be seen in Figure 2.

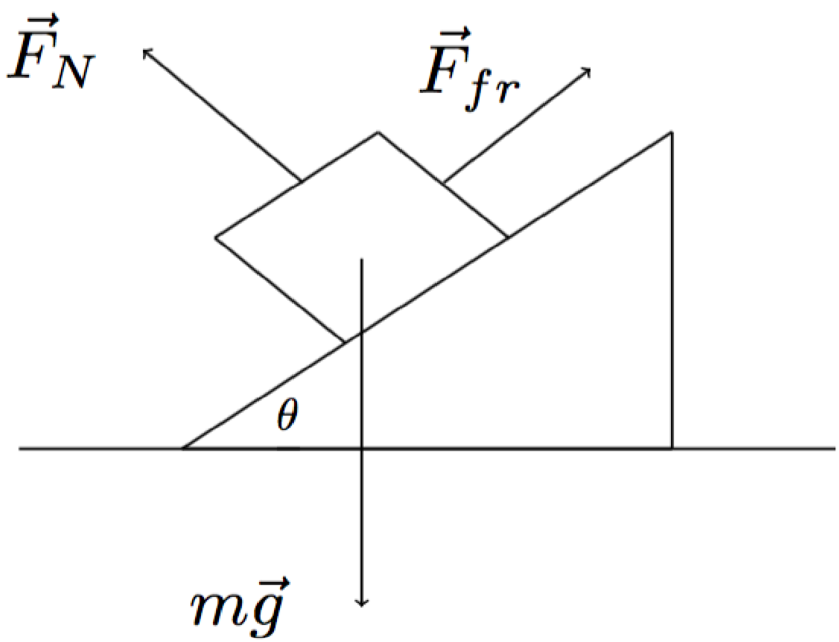

Figure 2

In this case only a component of $m\vec{g}$ is equivalent to the normal force depending on the angle θ

$$\overrightarrow{F_{fr}} = \mu_k * \overrightarrow{F_N} = \mu_k * m\vec{g} * cos(\theta) \text{(Equation 2)}$$

The angle of repose (θ_R) is defined as the point at which the force of gravity on an object overcomes the static friction force and the object begins to slide down an inclined plane. A good approximation for the angle of repose is

$$tan(\theta_R) = \mu_s \text{(Equation 3)}$$

Procedure:

1. Measure coefficients of friction.

   1.1) Using a scale measure the mass of block A and B.

   1.2) Connect the force scale to block A. Pull the scale horizontally and note the reading just before the block begins to slide. Just before it begins to slide the maximum amount of static friction is resisting the movement. Use the force reading to calculate μ_s for block A. Do this five times and record the average value.

   1.3) For block B do the same as step 1.1.

   1.4) Pull block A across the table at a constant speed. If the speed is constant then the force reading on the scale should be equal to the frictional force. Calculate μ_k for block A. Do this five times and record the average value.

   1.5) For block B do the same as step 1.4.

2. Effect of weight on the force of friction.

   2.1) Place block A on top of block B and repeat step 1.4 five times taking the average value. ~~By what factor did the frictional force increase/decrease?~~Calculate the factor by which the frictional force increased/decreased.

   2.2) Place block B on top of block A and repeat step 1.4 five times taking the average value. ~~By~~Calculate the ~~what~~ factor by which ~~did~~ the frictional force increased/decreased.~~?~~

3. Effect of surface area on force of friction.

   3.1) Turn block A onto the side that has a smaller surface area. This is the side where the middle has been cut out and only the edges touch the table.~~.only the edges touch the table~~ Measure the force of friction and compare it to the measured value in step 1.2. ~~By what factor did the force of friction increase or decrease?~~Calculate the factor by which the frictional force increased/decreased.

4. Angle of repose.

   ~~The angle of repose is the point at which the force of gravity on an object overcomes the static friction force and the object begins to slide down an inclined plane.~~

   4.1) Place block A on the adjustable incline plane starting at an angle of 0 degrees. Raise the angle slowly until the block begins to slide. Using a protractor measure the angle of repose and then calculate the force of static friction just before the block began to slide. Do this five times and record the average values.

   4.2) Repeat 4.2 with block B.

Representative Results:

Part 1

Block	μ_s	μ_k
A	0.5	0.3
B	0.6	0.4

Parts 2 & 3

Measurement	$\overrightarrow{F_{fr}}$ (Newtons)	% Difference
Block B on A	1.8	With $\overrightarrow{F_{fr}}$ from Part 1.4 = 20
Block A on B	2.1	With $\overrightarrow{F_{fr}}$ from Part 1.5 = 5
Small surface area	1.1	With $\overrightarrow{F_{fr}}$ from Part 1.4 = 10

Part 4

Block	Angle of repose (θ_R) (degrees)	$\overrightarrow{F_{fr}}$ (Newtons)
A	30	0.9
B	35	1.4

The results obtained from the experiment match the predictions made by Equations 1 and 2. In part 1 the static friction was larger than the kinetic friction. This is always the case as it requires more force to overcome friction when an object is not already in motion. In part 2 it was confirmed that the force of friction was proportional to the weight of both the blocks and the coefficient of kinetic friction of the block in contact with the table. The results of part 3 confirmed that the surface area does not effect the force of friction. In part 4 the angle of repose can be approximated by Equation 3.

Summary: In this experiment ~~we measured~~ the coefficients of static and kinetic friction were measured for two different blocks sliding. The effect of mass of the force of friction was examined along with the effect of surface area. Lastly the angle of repose for a block on an inclined plane was measured.

Applications: Friction is everywhere in our daily lives. In fact you would not be able to walk without it. If you tried walking on a frictionless surface you would go nowhere. It is only the friction between the bottom of your feet and the ground as your muscles push against the ground that propels you forward.

In almost every aspect of industry engineers are trying to reduce friction. When two surfaces are in contact there will always be friction. This can take the form of heat, for example rub your hands together quickly and you can feel the heat which can damage machines. Friction forces also oppose the motion of objects and can slow done mechanical operations. Therefore things like lubricants are used in order to decrease the coefficient of friction between two surfaces.

Some coefficients of friction

Materials	μ_k
wood on wood	0.2
brass on steel	0.44
rubber on concrete	0.8
lubricated ball bearings	< 0.01

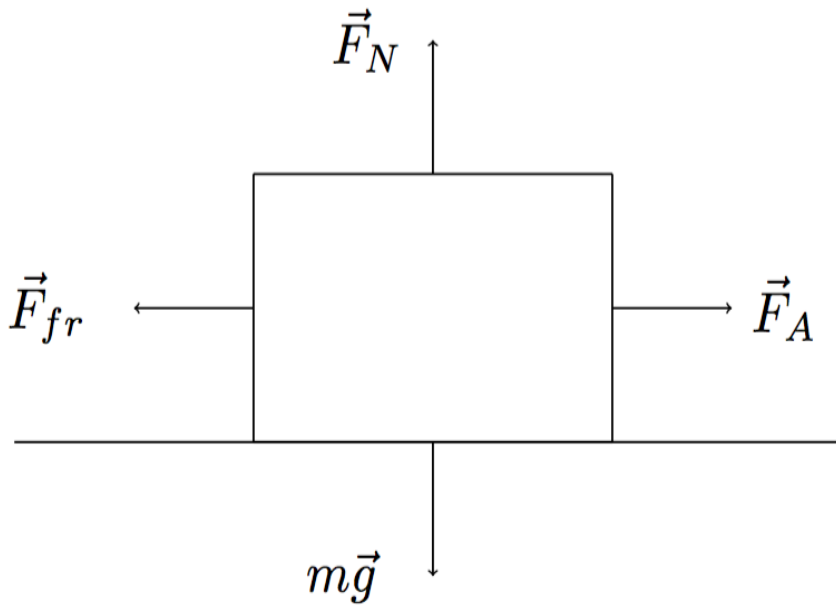

Figure 1

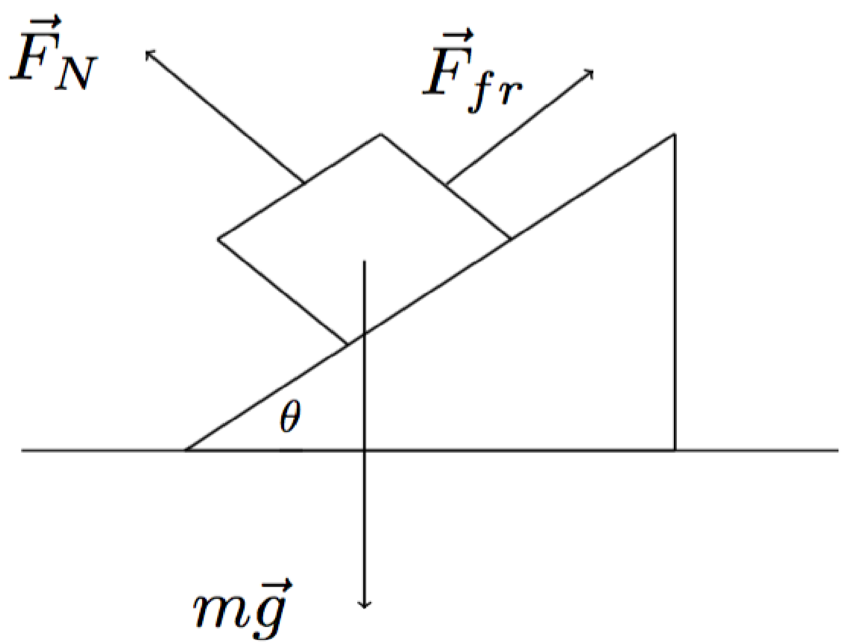

Figure 2