Experiment 6: Friction

In previous labs we studied Newton's laws in an \ideal" setting, that is, one where friction and air resistance were ignored. However, from our everyday experience with motion, we know that friction must be taken into account for a realistic description of practical situations - it is something we cannot ignore. Frictional forces act between two surfaces and oppose their relative motion. They occur because of surface irregularities, such as defects, and molecular forces (or bonds) between the materials. In this lab we will study frictional forces between various objects on di erent types of surfaces.

There are two types of friction: kinetic and static. Kinetic friction is the friction between surfaces in relative motion. When sliding an object across another surface, microscopic bumps and defects tend to impede and resist the motion (even the smoothest surfaces are rough on the microscopic scale). This is the type of force that brings a rolling ball to rest or a coasting car to a stop. Experimentally, it is observed

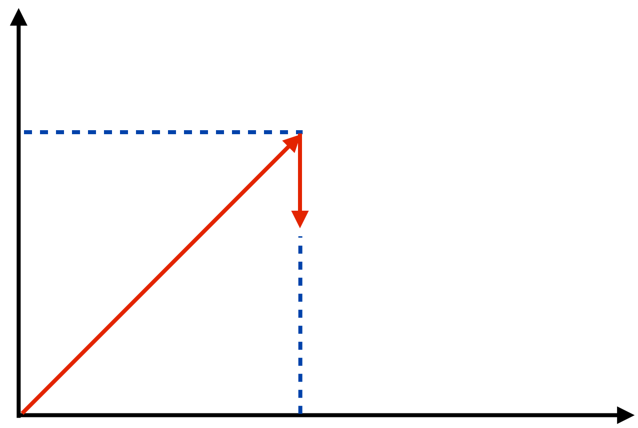


Figure 1: Force of friction (fr) as a function of an external force F applied to an object that is initially at rest.

Experimental Objectives

The purpose of this lab is to construct a relationship between frictional forces and the normal force on an object, to calculate the kinetic and static coefficients of friction for various objects and surfaces and to ultimately gain a solid understanding of static vs kinetic friction.

In this lab you are given a pulley sensor that can measure acceleration, a force sensor, string, friction carts with different surfaces (cork, felt, and plastic), and different surfaces (carpet, construction paper, and the table top) to drag the carts on.

1: Coefficient of Kinetic Friction

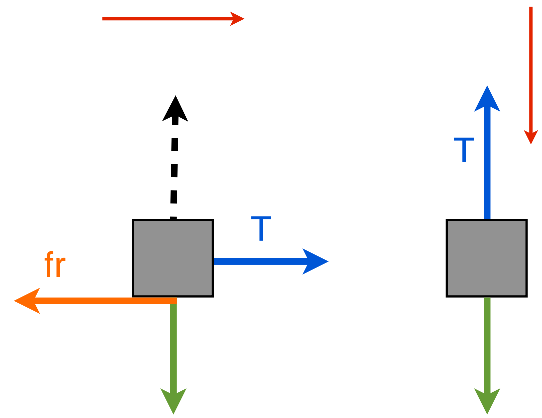
To study and calculate various coefficients of kinetic friction, we will use a pulley system as shown in Figure 2(a). The pulley is equipped with a photogate sensor that allows you to measure and graph the velocity of the masses as a function of time via the computer software. With the velocity graph you can obtain the acceleration of the mass system by finding the slope of the appropriate linear fit, similar to the Atwood's machine lab (Lab 5). Looking at the free body diagrams of our system (Figure 2(b)), we can write Newton's second law for each mass as

$$m_1 a = T - fr \tag{3}$$

$$m_2 a = m_2 g - T \tag{4}$$

Here we have assumed that the accelerations of the two masses are same by neglecting any frictional effects on the pulley making T (the tension in the string) uniform. The kinetic frictional force fr is given by

$$fr = \mu_k F_N = \mu_k m_1 g \tag{5}$$



(a) (b)

Figure 2: (a) Pulley system used to calculate u_k. (b) Free body diagrams for the pulley setup. W_i is the weight of the object and fr is the frictional force.

The system of equations (Eqs. 3-4) can be solved for the acceleration in terms of the masses ($m_1; m_2$), g, and $_k$

$$a = (m_2 \quad {}_k m_1)\text{qob2ix.636 T 1.6u2m41}$$

3: Coefficient of Kinetic Friction by Force Sensor

We can check our μ_k values obtained from the first experiment by making use of the force sensor.

> Devise and experiment to measure the coefficient of kinetic friction using the force sensor. Record the force, normal force and obtain μ_k graphically. How do your values compare with those from experiment 1? Repeat this experiment for the various carts with 3 different masses. *Hint:* This part may be difficult at first, but draw a free body diagram of the cart and force sensor and then convince yourself why you want the cart to move with a constant velocity (look at the velocity graph as a guide).

A full lab report is not necessary for this lab. Answer the questions on the following page and turn it in with your signed data sheet.

<u>PHYS 123, Lab 6 Questions</u>

Name: CWID:

Write your answers on a separate sheet and attach your signed data sheet when turning it in. You must show all of your work for full credit. Make it clear to me you understand what you're doing. Any graphs or tables should be made via computer software and attached to this handout.

1. Answer the following questions using the data you acquired in this experiment:

   (a) For the first experiment, create a data table for the different masses ($M_1; M_2$), the acceleration, and the calculated coefficient of friction μ_k. Remember to label the cart types (felt, cork, plastic) in your table and describe the surface.

   (b) Do your measured values of μ_k make sense? Compare them with sample coefficients of friction (for various materials) found in your textbook.

   (c) For the second experiment, what is the force that you are measuring? Create a plot of this measured force vs the normal force of the friction cart. Find its slope and explain what it represents.

   (d) For the third experiment, make a data table consisting of the cart masses, any applied force, and the normal force. Using your data, create a graph that represents the coefficient of friction.

   (e) How does your coefficient of friction from the third experiment compare with the one you obtained from the first experiment? What are the sources of error?