Bell Ringer: Friction on the Soles of Your Shoes – ID: 13417

Time required
15 minutes

Topic: Force and Motion

- *Calculate the frictional force and the coefficient of friction between two surfaces.*

Activity Overview

In this activity, students will use precompiled data to calculate the coefficient of friction between a shoe and the floor.

Materials

To complete this activity, each student or student group will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank paper*

TI-Nspire Applications

Graphs & Geometry, Notes, Calculator

Teacher Preparation

Before carrying out this activity, review with students the concepts of static and kinetic friction.

- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains a data analysis and answers to the questions.*
- ***To download the student .tns file, solution .tns file, and sample data set, go to education.ti.com/exchange and enter "13417" in the search box.***
- *For a more extensive exploration of this content, use activity 11121: Friction: Your Friend or Your Enemy? Activity 11121, which is longer than this bell ringer and involves data collection and analysis by the students, was designed for a full-length class period. You can download the files for activity 11121 at education.ti.com/exchange.*

Classroom Management

- *This activity is designed to be **student-centered**, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

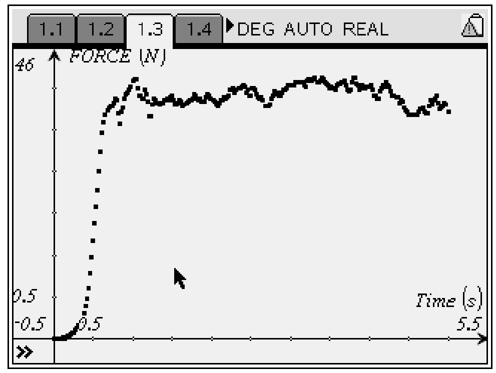
The following question will guide student exploration in this activity:

- What are the coefficients of static and kinetic friction between a shoe and the floor?

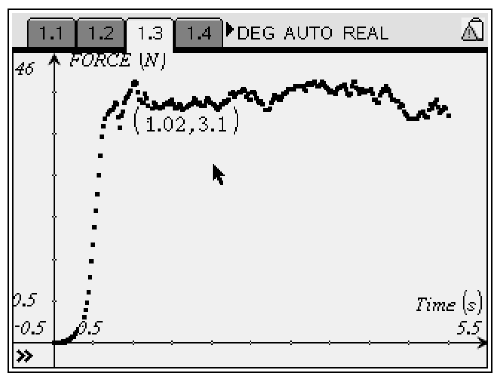
Students will use a precompiled data set to determine the force required to start a shoe sliding across the floor, and to keep it sliding across the floor at a constant speed. They will use these data to calculate the coefficients of static and kinetic friction between the shoe and the floor.

Step 1: Students should open the file **PhysBR_week08_Shoe_Friction.tns** and read the first two pages. (Students can press ctrl ► and ctrl ◄ to move between pages in the .tns file.)

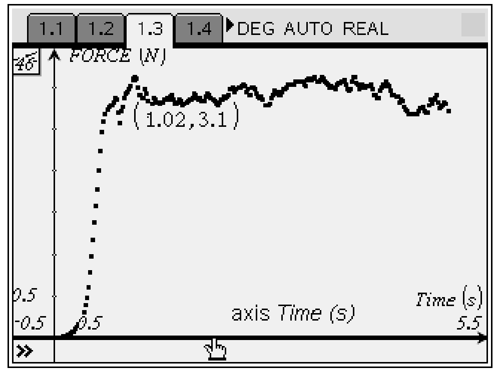
Step 2: Students should move to page 1.3, which shows a sample data set. These data were collected using a force sensor attached to a women's size 8 hiking boot. The boot had a weight of 5.7 N. The boot started at rest and was pulled with increasing force until it began to move across a wooden floor. Once it began to move, it was pulled across the floor at a constant speed. The graph on page 1.3 shows the force applied to the boot as a function of time.

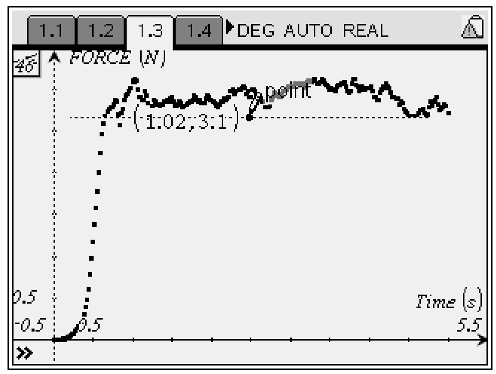


Step 3: First, students will determine the force of static friction acting on the shoe. The force of static friction is equal to the maximum pulling force needed to start the shoe in motion. It is the maximum value of the force on the graph. To find this value, students should use the **Graph Trace** tool (**Menu > Trace > Graph Trace**) to trace the data points. To use the **Graph Trace** tool, students should first select it from the menu. They should then press ► to move through the data points on the graph. When they reach the maximum force value, they should press enter to mark the point. For the sample data set, the maximum force is 3.1 N.

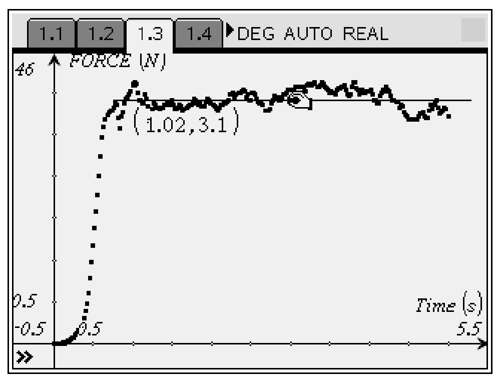


Step 4: Next, students will determine the force of kinetic friction acting on the shoe. The force of kinetic friction is equal to the pulling force needed to keep the shoe moving across the surface at a constant speed. It is approximately equal to the average value of the force in the region of the graph that is roughly horizontal. To determine this value, students should first construct a horizontal line parallel to the *x*-axis (**Menu > Construction > Parallel**). (To construct the parallel line, students should first select the **Parallel Line** tool. They should then use the NavPad to move the cursor until the *x*-axis of the graph is highlighted. They should click once (press [click]) to select the *x*-axis as the reference line—that is, the line that the constructed line should be parallel to. They should then use the NavPad to drag the cursor up to the roughly horizontal region of the graph. They should click once near the center of the horizontal region. A horizontal line should appear on the screen. Students should then press [esc] to exit the tool.)

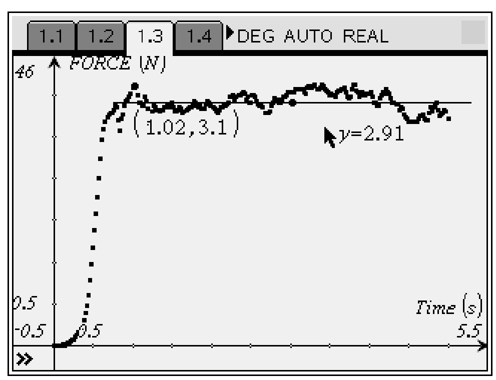




Step 5: Next, students should drag the horizontal line so that it represents the average of the horizontal portion of the graph. (To drag the line, students should use the NavPad to move the cursor until the line is highlighted; the cursor will change to an open hand. They should press and hold [click] until the hand closes. They can then use the NavPad to drag the line anywhere on the screen. They should press [click] once more to release the line.)



Step 6: The force of kinetic friction is the *y*-intercept of the line. Students can use the **Coordinates and Equations** tool (**Menu > Actions > Coordinates and Equations**) to find the equation for the line. (To use the tool, students should first select it from the menu. They should then use the NavPad to move the cursor so that it points to the line. The equation for the line will appear on the screen. Students should click once to select the line, and then a second time to label the line with its coordinates.) For the sample data set, the average pulling force is approximately 2.9 N.



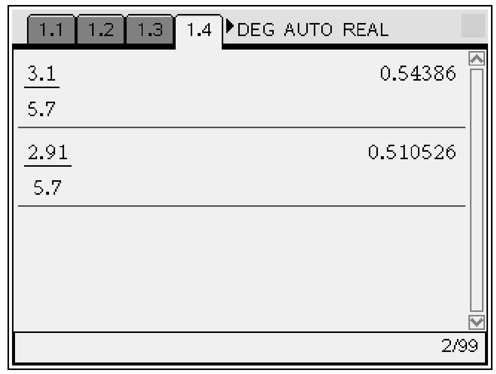
Step 7: Next, students should use their collected data to calculate the coefficients of static and kinetic friction on the shoe. They can use the equation $\mu = \frac{F}{W}$ to calculate the coefficients of friction (in this equation, F is the pulling force and W is the weight of the shoe). The sample data set was collected using a hiking boot with a weight of 5.7 N. Therefore, the calculations are as follows:

$$\mu_s = \frac{3.1}{5.7} = 0.54$$

$$\mu_k = \frac{2.9}{5.7} = 0.51$$

Students should use the *Calculator* application on page 1.4 to calculate the coefficients of friction.

If you wish, you can have students derive the equation $\mu = \frac{F}{W}$ from the definition of weight ($W = mg$) and the law of friction ($\mu = \frac{f}{N}$, where f is the frictional force and N is the normal force).



Step 8: Finally, students should answer questions 1–4 on pages 1.5–1.8. Students can use the *Calculator* application at the bottom of each page to perform the calculations necessary to answer each question. To switch between the question and the *Calculator* application, students should press (ctrl)(tab). Alternatively, students may answer the questions on blank paper. For all questions, students should assume that the shoe is resting on or being pulled along the same type of floor as the one used to collect the data set.

Q1. If the weight of the shoe used to collect the data set were decreased to 4.3 N, what would be the maximum static frictional force between the shoe and the floor?

A. *The coefficient of friction is independent of weight. Therefore, as weight decreases, maximum frictional force decreases according to the equation* $\mu = \frac{f}{N}$*, where* N *is the normal force and* f *is the frictional force. The normal force on the shoe is equal to its weight (because it is resting on a horizontal surface). Therefore, the normal force on the lighter shoe is 4.3 N. The coefficient of static friction is 0.54, so frictional force can be calculated as* $f_s = \mu_s N = (0.54)(4.3\ N) = 2.3\ N$.

Q2. If the weight of the shoe used to collect the data set were increased to 7.3 N, what would be the maximum kinetic frictional force between the shoe and the floor?

A. *The normal force on the heavier shoe is 7.3 N. The coefficient of kinetic friction is 0.51, so frictional force can be calculated as* $f_k = \mu_k N = (0.51)(7.3\ N) = 3.7\ N$.

Q3. If the weight of the shoe used to collect the data set were increased to 8.2 N, how much force would be required to start the shoe moving?

A. *From step 7,* $\mu = \frac{F}{W}$, *where* F *is the pulling force and* W *is the weight of the shoe.*

Therefore, $F_s = \mu_s W = (0.54)(8.2\ N) = 4.4\ N$.

Q4. If the weight of the shoe used to collect the data set were decreased to 4.8 N, how much force would be required to keep the shoe moving?

A. *For the lighter shoe,* $F_k = \mu_k W = (0.51)(4.8\ N) = 2.4\ N$.

Suggestions for Extension Activities: If you wish, you may have students use a Vernier Dual-Range Force sensor and EasyLink™ or Go!® Link interface to collect their own force data. You may also have students confirm that mass does not affect coefficient of friction (e.g., by adding mass to the same shoe and repeating the data collection).

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(Student)TI-Nspire File: *PhysBR_week08_Shoe_Friction.tns*