Bell Ringer: Mechanical Advantage of an Inclined Plane – ID: 13491

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Work and Energy

- *Calculate the mechanical advantages and efficiencies of simple machines.*

Activity Overview

In this activity, students explore the relationship between resistance force and effort force for an inclined plane. Based on the exploration, students derive a formula for the mechanical advantage of this simple machine.

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, List & Spreadsheet, Data & Statistics

Teacher Preparation

Before carrying out this activity, you should review with students the concepts of force, torque, and static equilibrium. Note that the calculations in this activity assume frictionless systems. More advanced students may benefit from a discussion of the effects of including friction in the calculations.

- *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 "13491" in the search box.***
- *For a more extensive exploration of this content, use activity 9745: Mechanical Advantage. Activity 9745, 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 9745 at education.ti.com/exchange.*

Classroom Management

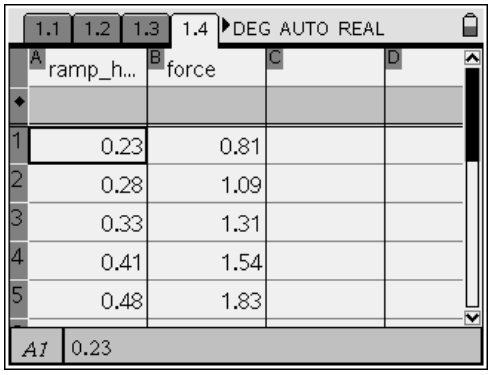
- *This activity is designed to be **student-centered**, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and 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 questions will guide student exploration during this activity:

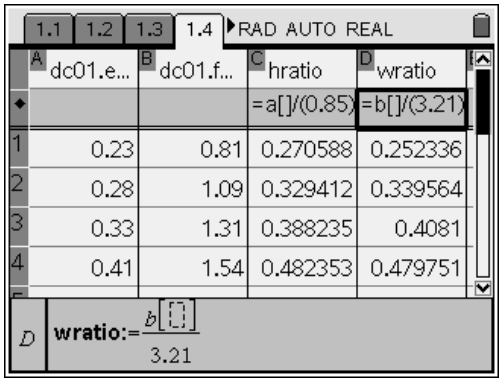
- What is mechanical advantage?
- What factors affect the mechanical advantage of an inclined plane?
- How can we calculate the mechanical advantage of an inclined plane?

The purpose of this activity is to provide students with an opportunity to explore the general concept of mechanical advantage and to derive the formula for the mechanical advantage of an inclined plane.

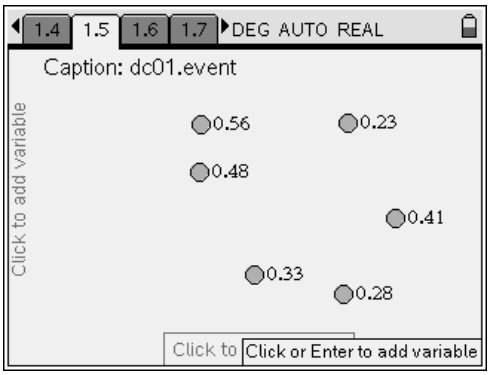
Step 1: Students should open the file **PhysBR_week13_MA_incl_plane.tns** and read the first three pages. (Students can press /¢ and /¡ to move between pages in the .tns file.) They should then move to page 1.4, which shows force data collected for a cart on a ramp. To collect the data, a toy cart was placed at the top of a ramp. A force sensor was connected to the cart. The force (in newtons) required to keep the cart from sliding down the ramp was recorded in column B (**force**). The height of the ramp (in meters) was recorded in column A (**ramp_height**). The length of the ramp was 0.85 m, and the weight of the cart was 3.21 N.

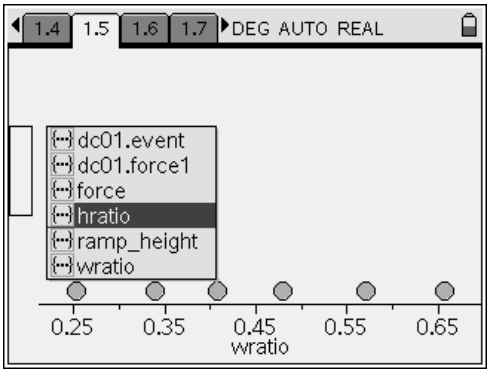


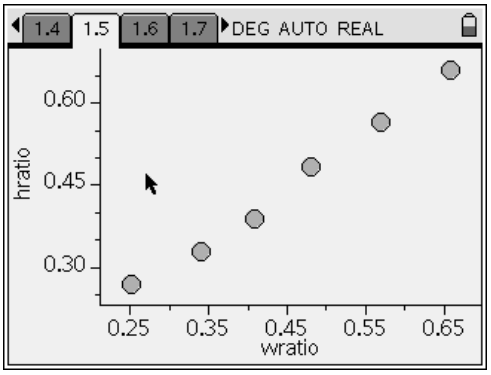
Step 2: Next, students should define the variables **hratio** (Column C) and **wratio** (Column D). The variable **hratio** should be the ratio of the height of the inclined plane at each data point to the length of the ramp (0.85 m). The variable **wratio** should be the ratio of each measured force value to the weight of the cart (3.21 N). To label each series, students should type the name of the series into the label cell in the relevant column. (Students can use the NavPad to move between cells.) They should press · to move to the formula bar. They should then enter the correct expression in each column (**=a[]/0.85** in column C and **=b[]/3.21** in column D). When they have entered each formula, they should press ·. (To enter brackets, students should press /(and then press ¢ on the NavPad to exit the bracket.)



Step 3: Next, students should move to page 1.5, which contains an empty *Data & Statistics* application. They should make a plot of **hratio** vs. **wratio**. To make the plot, they should use the NavPad to move the cursor to the *x*-axis. They should click once. A list of possible variables should pop up. They should use the NavPad to select **wratio** and then click once. They should then move the cursor to the *y*-axis, click, and choose **hratio** from the menu. Once both variables have been selected, the graph should appear. Once students have graphed the data, they should answer question 1.



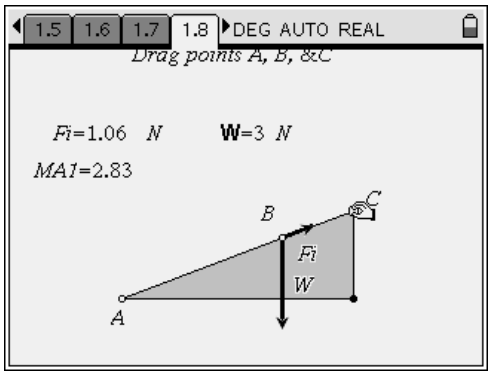


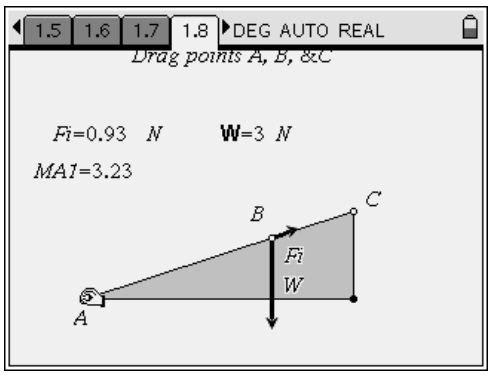


Q1. What does the shape of the graph of **hratio** vs. **wratio** imply about the relationship between the height of an inclined plane and the amount of force required to move an object up the plane?

A. *The data should fall along a straight line. This implies that, as the inclined plane's height increases, the amount of force required to move the object up the plane (as a fraction of the object's weight) increases proportionally. Note: The equivalence of these two ratios assumes that there is no friction in the system.*

Step 4: Next, students should read the text on page 1.7 and then move to page 1.8, which shows an inclined plane. Here the weight of the box, **B,** is 3 N. Students can drag point **B** up the incline, drag point *A* to change the slope, or drag point *C* to change the height of the plane. (To drag a point, students should use the NavPad to move the cursor to the point. The cursor should change to an open hand. Students should press and hold X until the cursor changes to a closed hand. They can then use the NavPad to drag the point. To release the point, students should press X again.) The effort force (**W**), resistance force (*Fi*), and mechanical advantage (*MA1*) are given in the simulation. Students should vary the height and slope of the inclined plane and observe the effects on the mechanical advantage. Then, they should answer questions 2–4.





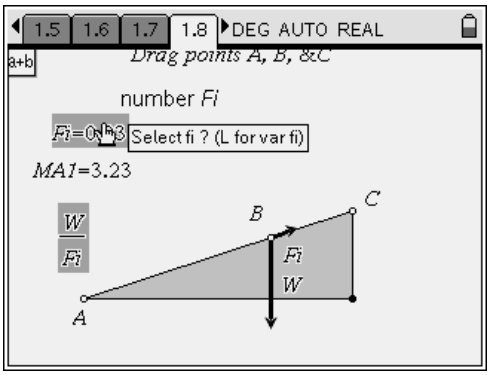
Q2. How can you increase the mechanical advantage of the inclined plane?

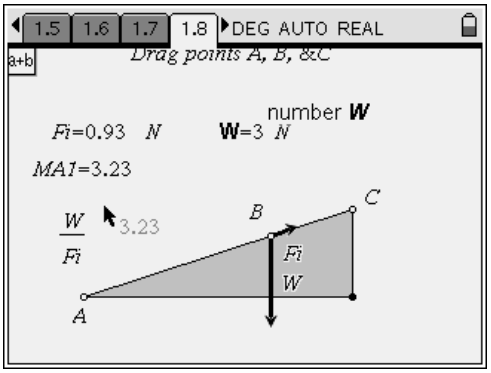
A. *by increasing the length of the sloped side of the inclined plane or by decreasing the height of the inclined plane*

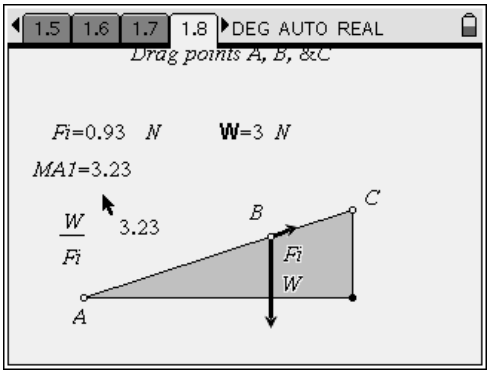
Q3. What is the formula for calculating the mechanical advantage of this inclined plane?

A. *The mechanical advantage of a machine is defined as the ratio of the resistance force to the effort force. For this inclined plane, the resistance force is* Fi, *and the effort force is* ***W****. Therefore, the mechanical advantage of this inclined plane is equal to* $\frac{W}{\text{Fi}}$*. Encourage student discussion of how they identified the effort and resistance forces.*

Q4. Verify the formula you figured out in question 3 using the simulation on page 1.8.







A. *Students should use the* ***Text*** *tool (****Menu > Actions > Text****) to enter* $\frac{W}{Fi}$ *somewhere on page 1.8. To use this tool, they should first select it. They should then click once (press* X*) on an empty area of the page to place a text box. They should enter the expression* $\frac{W}{Fi}$ *in the text box. To enter the expression, students should first insert a fraction template by pressing* /p*. They should then type* W *into the top box on the template. They should use the NavPad to move to the lower box, and then type* Fi*. When they have entered the expression, they should press* · *to exit the expression. Then, they should use the* ***Calculate*** *tool (****Menu > Actions > Calculate****) to determine the value of this ratio. After they select the* ***Calculate*** *tool, they should click on the expression* $\frac{W}{Fi}$*. They will be prompted to select values for* W *and* Fi*. They should click on the value of* **W** *for* W *and the value of* Fi *for* Fi*. After students have selected values of* W *and* Fi*, they should click on a blank spot on the page to place the calculated value of mechanical advantage in that location. Finally, they should compare the value they obtain with the value given for* MA1 *to confirm that their derived formula is correct.*

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 for inclined planes of different heights.

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(Student)TI-Nspire File: *PhysBR_week13_MA_incl_plane.tns*