Bell Ringer: Mechanical Advantage of a Single Fixed Pulley – ID: 13507

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 a single-fixed-pulley system. They examine data on the effort and resistance forces for various loads on the pulley system. They use these data to determine the mechanical advantage of the pulley system.

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, students should be familiar with the definition of mechanical advantage and the equations that can be used to calculate it.

- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on page 5 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 "13507" in the search box.***
- *For a more extensive exploration of this content, use activity 11568: Mechanical Advantage of Pulleys. Activity 11568, 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 11568 at education.ti.com/exchange.*

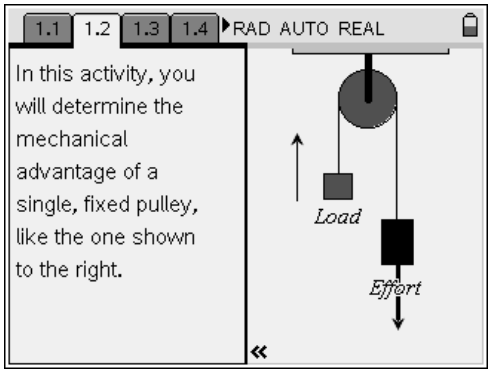
Classroom Management

- *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 the relationship between effort force and resistance force when you pull a load in a single-fixed-pulley system with constant speed?
- What is the mechanical advantage of a single fixed pulley?
- Why is a single fixed pulley used to lift heavy loads?

The goals of this activity for students are a) to observe and compare the magnitude and direction of the effort force and resistance force of a pulley system; b) to determine the mechanical advantage of a single-fixed-pulley system; and c) to determine the reasons for using a single-fixed-pulley system. Students study pre-collected data on effort force for various loads in a single pulley system, analyze these data, calculate the mechanical advantage in each case, and make conclusions about the usefulness of the single pulley system.



Step 1: Students should open the file **PhysBR_week14_MA_pulley.tns** and read the first two pages. (Students can press ctrl ▶ and ctrl ◀ to move between pages in the .tns file.) They should then move to page 1.3, which shows force data collected for a single, fixed pulley. To collect the data, a mass was hung from one side of the pulley. A force sensor was connected to the other side of the pulley. The force (in newtons) required to move the mass upward at a constant rate was recorded in column B (**e_force**). The mass was recorded in column A (**mass**).

Step 2: Students should study the data on page 1.3 and the diagram on page 1.2. They should then answer questions 1 and 2.

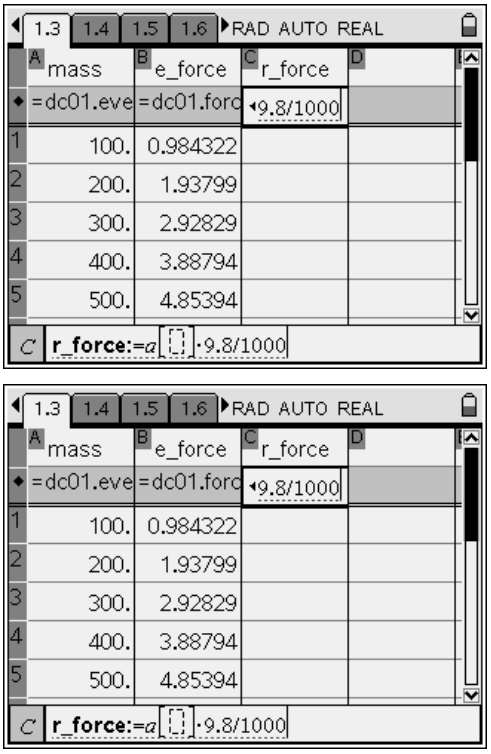
Q1. How could you calculate the mechanical advantage of this pulley?

A. *Mechanical advantage can be calculated in two ways: using forces or using distances. Mechanical advantage is equal to the ratio of the resistance force to the effort force or to the ratio of the effort distance to the resistance distance.*

Q2. The series **mass** gives the resistance mass in grams for each trial. How can you calculate the resistance force in newtons for each trial?

A. *The resistance force (F_r) is the weight of the attached mass. To calculate it, students should use the formula W = mg, where* m *is the mass in kilograms and* g *is acceleration due to gravity (9.8 m/s^2). Since the mass data are recorded in grams, students will need to divide the mass by 1,000 before multiplying it by 9.8.*

Step 3: Next, students should move back to page 1.3 and define the variable **r_force** in Column C. The variable **r_force** should be the resistance force for each trial. To label the series, students should type the name of the series into the label cell in Column C. (Students can use the NavPad to move between cells.) They should press enter to move to the formula bar. They should then enter the correct expression to calculate the resistance force (**=a[]·9.8/1000**). When they have entered the formula, they should press enter. (To enter brackets, students should press ctrl { } and then press ▶ on the NavPad to exit the bracket.) Column C should now display the resistance force for each trial. Students should study the data and then answer questions 3 and 4.



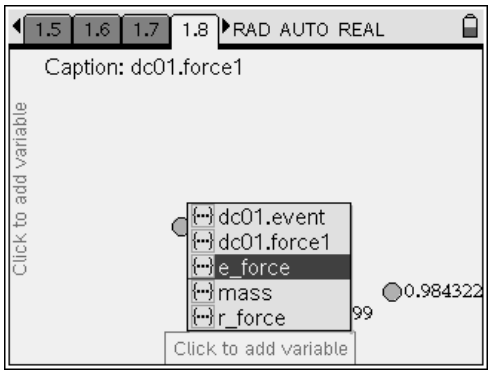
Q3. Compare the effort and resistance force for each mass.

A. *The effort force (F_e) is the downward force applied by pulling on the force sensor. In each case, the magnitude of the effort force is equal to the magnitude of the resistance force (F_r), but the forces have opposite directions.*

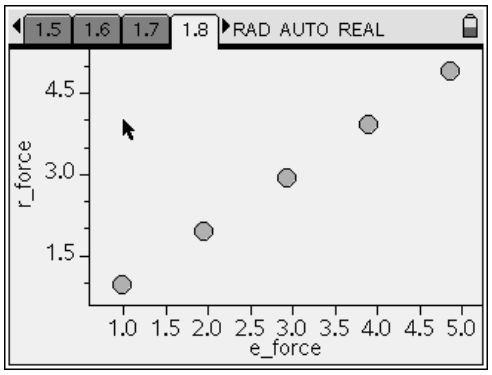
Q4. What is the mechanical advantage of this pulley system?

A. *The mechanical advantage is the ratio of the resistance force to the effort force. It is equal to 1 for a single-fixed-pulley system. If students have done the calculation correctly, this relationship should be obvious—the resistance and effort forces should be nearly equal.*

Step 4: Next, students will confirm their observations of mechanical advantage using a graph. They should move to page 1.8, which contains an empty *Data & Statistics* application. They should use this application to make a plot of *r_force* vs. *e_force*. 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 **e_force** and then click once. They should then move the cursor to the *y*-axis, click, and choose **r_force** from the menu. Once both variables have been selected, the graph should appear.

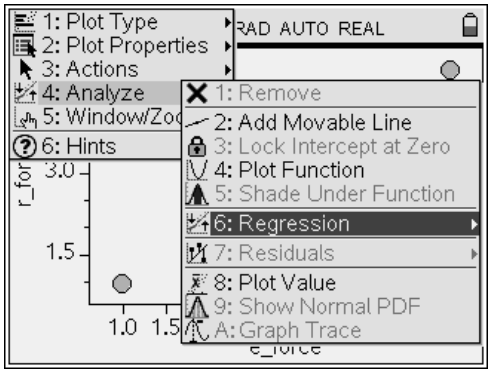


Step 5: Students' data should lie along a straight line. Students should use the **Regression** tool (**Menu > Analyze > Regression > Show Linear (mx + b)**) to find the best-fit line for their data. They should then answer questions 5–7.



Q5. Does this graph agree with your answer to question 4? Explain your answer.

A. *The best-fit line should have a slope of approximately 1. This slope is equal to the mechanical advantage of the pulley system, and it should agree with students' observations.*

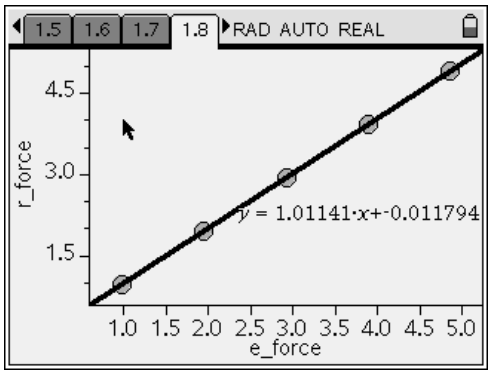


Q6. What is the advantage of using a single fixed pulley to lift a load?

A. *A single fixed pulley changes the direction, but not the magnitude, of the force required to lift the load. Pulling downward is often easier than lifting upward, even if the force applied is the same.*

Q7. Can you think of a way to use a single pulley to produce a mechanical advantage greater than 1?

A. *Students' answers will vary. For a single pulley to have a mechanical advantage greater than 1, the pulley must be able to move. Furthermore, the pulley must be turned upside-down.*



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 a single fixed pulley. Alternatively, you may have students attempt to construct a single-pulley system with a mechanical advantage greater than 1.

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(Student)TI-Nspire File: *PhysBR_week14_MA_pulley.tns*