Experiment
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An Inclined Plane

An inclined plane is a slanted surface used to raise objects. The sloping floor of a theater, a road over a mountain, and a ramp into a building are examples of inclined planes. In this experiment, you will use a Force Sensor to measure the force needed to lift an object and the force needed to pull the same object up an inclined plane. You will then calculate and compare work done in raising the object to the same height by lifting it and pulling it up an inclined plane.

OBJECTIVES

In this experiment, you will

- Measure force.
- Compare forces.
- Calculate work and efficiency.
- Make conclusions using the results of the experiment.

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier Force Sensor
smooth board (at least 0.5 m long)
wooden block with a hook
books
metric ruler
paper clip

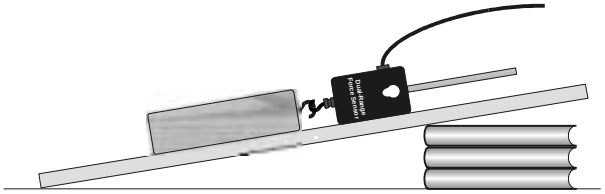

Figure 1

PROCEDURE

Using an Inclined Plane

1. Set up a stack of books as shown in Figure 1.

2. Get a board and set up an inclined plane as shown in Figure 1. Measure the length of the board (in meters) and record this value in the data table. Measure and record the height of the inclined plane (in meters).

3. Get a wooden block with a hook on one end. Partly straighten a paper clip—leaving a hook at each end. Use the paper clip to attach the wooden block to your Force Sensor.

4. Prepare the Force Sensor, data-collection interface, and calculator for data collection.
   a. Turn on the calculator.
   b. Set the Force Sensor range switch to 10 N.
   c. Connect the Force Sensor, data-collection interface, and calculator.
   d. Start the EasyData application, if it is not already running.
   e. Select [File] from the Main screen, and then select **New** to reset the application.

5. Slowly pull the wooden block up the inclined plane. The Force Sensor should be held parallel to, and about 2 cm above, the surface of the inclined plane, as shown in Figure 1 and 2. Once the wooden block is moving at a steady rate, select [Start] to begin data collection. Continue pulling the wooden block until data collection is complete.

6. Determine the mean (average) force (in N) to pull the block up the inclined plane.
   a. When data collection is complete, a graph of force versus time will be displayed. Select [Anlyz], and then select **Statistics…**
   b. Before moving the cursor, select [OK] to set the left bound at 0 s.
   c. The cursor will move to the right edge of the graph. Ensure it is on the last data point and select [OK].
   d. Read the mean force. Record the value in your data table.
   e. Select [OK] and then [Main] to return to the Main screen.

Without an Inclined Plane

7. Now determine the force needed to lift the wooden block.
   a. Repeat Step 5 as you slowly lift the block the same height as the inclined plane. **Note**: After selecting [Start] to begin data collection, select [OK] to overwrite the latest run and start collecting data.
   b. Repeat Step 6 and record the value of the force (in N) needed to lift the wooden block.

DATA TABLE

Length of inclined plane	_____ m
Height of inclined plane	_____ m
Force (average) to pull the block up the inclined plane	_____ N
Force (average) to lift the block	_____ N

PROCESSING THE DATA

1. Does it take more or less force to move the block using the inclined plane? Explain.

2. A formula for calculating work is

$$W = F \times d$$

where W = work (in N•m), F = force (in N), and d = distance (in m). Use this formula to calculate work done using the inclined plane. Here, F = the average force needed to pull the block up the inclined plane and d = the **length** of the inclined plane.

3. Calculate work done in lifting the block. Here, F = the average force needed to lift the block and d = the **height** of the inclined plane.

4. Does it take more or less work to move the block using the inclined plane?

5. A formula for calculating the efficiency of a machine is

$$\text{efficiency} = \frac{\text{work output}}{\text{work input}} \times 100$$

Use this formula to calculate the efficiency of the inclined plane. Here, work output = the work done lifting the block, and work input = the work done pulling the block up the inclined plane.

6. What causes the difference between the work needed to pull the block up the inclined plane and the work to lift it to the same height? Discuss ways to decrease this difference.

EXTENSIONS

1. Study how changing the inclined plane slope changes force.
2. Design an experiment to study your answer to Question 6.
3. Determine the mechanical advantage of the inclined plane.

TEACHER INFORMATION

An Inclined Plane

1. There are several different combinations of equipment that will work for measuring force. The most common method, which uses the USB port on TI-84 Plus calculators, is to connect a Force Sensor to an EasyLink. For more information on EasyLink refer to *Appendix G*.

   The other method, which works for both the TI-83 Plus and TI-84 Plus families of calculators, is to use a Force Sensor connecetd to a LabPro or CBL 2.

2. We suggest that you include one of the extension ideas in the required part of this experiment.

3. The smooth-surface boards used for the inclined plane should be at least 0.5 m long. We use boards that are 1.2 x 0.25 m.

4. A 5 cm x 10 cm x 15 cm piece of wood works well. Insert a hook in the center of one end. Other flat-surface objects can be substituted.

5. The Dual-Range Force Sensor has a low range (–10 to 10 N) and a high range (–50 to +50 N). Students will use the low range for this experiment.

6. For even better results, you can have students *zero* the Force Sensor. They can do this immediately after completing Step 4 of the procedure. They should position their Force Sensor horizontally on the inclined plane, as shown in Figure 1 of the student procedure, and follow this procedure:
   a. Select [Setup] from the Main screen, and then select **Zero...**
   b. With the Force Sensor on stationary on the inclined plane, wait for the force reading on the screen to stabilize, and then select [Zero].
   c. Students are now ready to continue with the procedure to collect data.

7. Illustrate proper technique for pulling an object up an inclined plane with the Force Sensor before the experiment. Remind your students not to pull the object too fast.

8. Your students should get better results using the Force Sensor and average force values than with spring scales.

SAMPLE RESULTS

Length of inclined plane	xxxx
Height of inclined plane	xxxx
Force (average) to pull object	xxxx
Force (average) to lift object	xxxx

ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.