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

- use a TI Graphing Calculator, a LabPro or CBL 2 interface, and a Force Sensor to measure force
- compare forces
- calculate work and efficiency
- make conclusions using the results of the experiment

MATERIALS

LabPro or CBL 2 interface
TI Graphing Calculator
DataMate program
Vernier Force Sensor
smooth board (at least 0.5 m long)
wooden block with a hook
books
metric ruler
paper clip

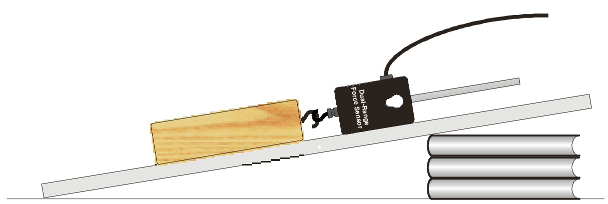

Figure 1: Using the Dual-Range Force Sensor

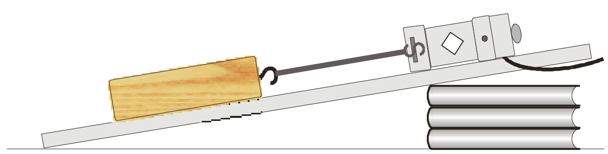

Figure 2: Using the Student Force Sensor

PROCEDURE

Using an Inclined Plane

1. Set up a stack of books as shown in Figures 1 and 2.

2. Get a board and set up an inclined plane as shown in Figures 1 and 2. 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 for data collection.
   a. Connect the Force Sensor to Channel 1 of the LabPro or CBL 2 unit.
   b. If you are using a Dual-Range Force Sensor, there is a force range switch on the probe body; set the switch to the lowest setting (*5 N* on some versions, *10 N* on other versions).
   c. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.

5. Turn on the calculator and start the DATAMATE program. Press CLEAR to reset the program.

6. Set up the calculator and interface for the correct Force Sensor.
   a. If the calculator displays the correct Force Sensor in CH 1, proceed directly to Step 7. If it does not, continue with this step to set up your sensor manually.
   b. Select SETUP from the main screen.
   c. Press ENTER to select CH1.
   d. Choose FORCE from the SELECT SENSOR list.
   e. Choose one of DUAL R FORCE (5N), DUAL R FORCE (10N), OR STUDENT FORCE as appropriate for your Force Sensor from the FORCE list.
   f. Select OK to return to the main screen.

7. 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 (3.0 seconds).

8. Determine the mean (average) force (in N) to pull the block up the inclined plane.
   a. Press ENTER to return to the main screen.
   b. Select ANALYZE from main screen.
   c. Select STATISTICS from the ANALYZE OPTIONS.
   d. Press ENTER to select the left boundary.
   e. Now select the other edge. Move the cursor to the right edge of the graph. Press ENTER, and wait while the calculator selects the data.
   f. Read the mean force from the calculator. Record the value in your Data Table.
   g. Press ENTER, and select RETURN TO MAIN SCREEN.

Without an Inclined Plane

9. Now determine the force needed to lift the wooden block.
   a. Repeat Step 7 as you slowly lift the block the same height as the inclined plane.
   b. Repeat Step 8 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. We suggest that you include one of the extension ideas in the required part of this experiment.

2. 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.

3. 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.

4. The student procedure has directions for using either the Student Force Sensor or the Dual-Range Force Sensor. We recommend that you delete the directions for the Force Sensor you are *not* using—to do this, use the word-processing files included on the CD that comes with this book. See *Appendix A* for more information about these files.

5. The Dual-Range Force Sensor has a low range (-5 to 5 N or -10 to 10 N) and a high range (-50 to +50 N). Students will use the low range for this experiment. Earlier versions of this sensor will have a 5 N switch setting, while later versions have a 10 N setting—alert students to choose a 5 N or 10 N calibration in Step 6 of the procedure that corresponds to the switch setting on your sensors. If you have Student Force Sensors, there is only one range with a single calibration value.

6. For even better results, you can have students *zero* the Force Sensor. They can do this immediately after completing Step 6 of the procedure. They should position their Force Sensor horizontally on the inclined plane, as shown in Figures 1 or 2 of the student procedure, and follow this procedure:
   a. Select SETUP from the main screen.
   b. Select ZERO from the setup screen.
   c. Select CHANNEL 1 from the SELECT CHANNEL screen.
   d. With the Force Sensor on stationary on the inclined plane, wait for the force reading on the screen to stabilize, and then press ENTER.
   e. Students are now ready to collect data, as instructed in Step 7 of the procedure.

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	1.20 m
Height of inclined plane	0.24 m
Force (average) to pull object	1.58 N
Force (average) to lift object	4.90 N

ANSWERS TO QUESTIONS

1. It takes less force to move the object using the inclined plane.
2. W = F x d = 1.58 N X 1.20 m = 1.90 N•m
3. W = F x d = 4.90 N X 0.24 m = 1.18 N•m
4. It takes more work to move the object using the inclined plane.
5. Efficiency = 1.18 N•m/1.90 N•m = 62.1%
6. Friction causes the work to move the object with the inclined plane to be greater than the work needed to lift it the same vertical distance.