It's All Uphill Lab

Teacher's Guide

Topic:

Work, Energy and Power

The following information is provided to the student:

Question:
What effect does varying the angle of incline have upon the force needed to pull a cart up a hill at a constant speed to the same height? What effect does a varying incline angle have upon the work done?

Purpose:
To determine the effect of the angle of incline upon the force needed and upon the work done when pulling a cart up an incline to the same height at a constant speed.

A complete lab write-up includes a Title, a Purpose, a Data section, and a Conclusion/Discussion of Results. The Data section should include the provided table and graphs. A single sample calculation of the work should be shown in an organized manner. The Conclusion/Discussion should answer both questions posed in the Purpose and reference specific details from the data and graphs which provide the evidence for such a Conclusion; the link between the evidence and the conclusion should be clearly explained.

Materials Required:

Wood board or incline; cart; computer interfaced force probe; meter stick; protractor; mass balance.

Description of Procedure:

A wood board is elevated at one end by resting it on a chair so as to form an inclined plane. A cart is placed upon the inclined plane. A force probe is used to pull the cart at a constant speed from the floor along the inclined plane to the height of the seat top. The force is exerted parallel to the inclined plane. The force and the displacement are measured. The height of the chair is also measured so that the angle of incline can be calculated using trigonometry. The process is repeated for several different incline angles between 20 degrees and 70 degrees. Finally, the mass of the cart is measured.

Alternative Materials and Procedure:

A force scale could be used in place of the computer interfaced force probe. Any object - lab table, box, chair seat can be used to prop up the board to form the incline. The object which is used to prop up the board becomes the destination to which the cart is pulled.

Safety Concern:

There is always a higher than usual level of risk associated with working in a science lab. Teachers should be aware of this and take the necessary precautions to insure that the working environment is as safe as possible. Student *horseplay* and off-task behaviors should not be tolerated.

The Laboratory

Suggestions, Precautions, Notes:

1. The force can be measured in any equilibrium situation - pulling the cart up the inclined plane at a constant speed or holding the cart at rest.
2. Emphasize to the students that they are to pull the cart to the same height each time - not to the end of the wooden board. Also emphasize to students that the force should be exerted parallel to the inclined plane.
3. It is very common for students to use the incline angle as the Θ value in the $W = F \bullet d \bullet \cos\Theta$. The Θ value in the equation is the angle between the F and the d vectors - 0° in this lab. Drawing a diagram on the board and labeling the F and the d vector parallel to the inclined plane helps students to overcome this hurdle.
4. Results are very convincing of the conclusions that the force and inclined angle are directly related and that the work is the same value despite changes in the incline angle. The measurement of the mass of the cart makes it possible to calculate the potential energy change and compare it to the average value of the work (a post-lab activity).
5. Another helpful post-lab activity involves deriving the equation relating work to the change in potential energy using the equation for work. At a constant speed, the applied force is equal to $m \bullet g \bullet \sin\Theta$ and the displacement is $\Delta h / \sin\Theta$. Putting this together, the work is

$$W = F \bullet d = (m \bullet g \bullet \sin\Theta) \bullet (\Delta h / \sin\Theta) = m \bullet g \bullet \Delta h$$

The next lab - It's All Uphill - The Sequel - targets this relationship. If you are doing this lab, you may wish to save the derivation until later.

Auxiliary Materials:

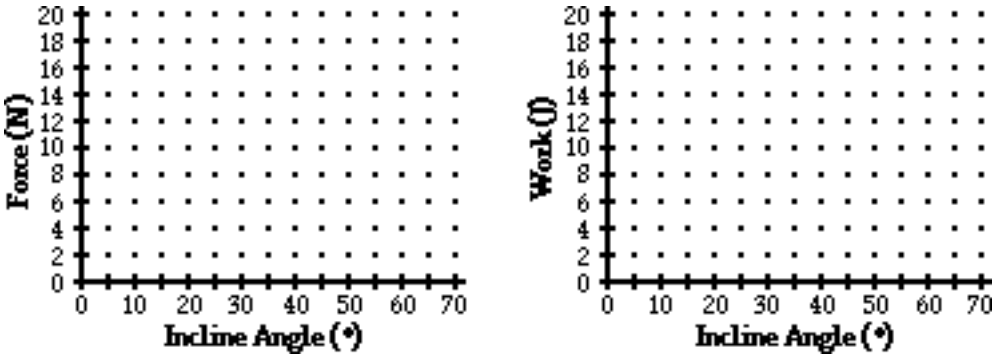
The following page is provided to the student for completion and inclusion in the Data section of their lab notebook.

Mass of Cart = _____ kg **Height of Seat Top = _____ m**

Incline Angle (°)	Force (N)	Displacement (m)	Work (J)

Graph:

Construct a hand-plot of force vs. incline angle and work vs. incline angle. Sketch the best-fit line through the data.



Scoring Rubric:

E1.	**It's All Uphill Lab**	**Score**
____	Included, labeled and organized all parts of the lab report.	
____	Data section includes provided table and graph. Data are reasonably accurate. Graph is accurately completed. An organized and labeled sample calculation is provided.	____/____
____	Conclusion/Discussion answers the *question* posed in the Purpose; *answer* is consistent with collected data and the graph; conclusion is correct. Reference to the Data section is made in an effort to explain the evidence which supports the conclusion.	

Connections to The Physics Classroom Tutorial:

The following readings are a suitable accompaniment to this lab:

http://www.physicsclassroom.com/Class/energy/u5l1a.cfm

http://www.physicsclassroom.com/Class/energy/u5l1aa.cfm

Connections to Minds on Physics Internet Modules:

Sublevel 1 of the Work and Energy module is a suitable accompaniment to this lab:

http://www.physicsclassroom.com/mop/module.cfm