Bell Ringer: Work and Power – ID: 13490

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Work and Energy

- *Calculate work given constant force and displacement in one dimension.*
- *Use the equation for power to solve problems involving power, work, and time.*
- *Compare force, work, energy, and power.*

Activity Overview

In this activity, students use a simulation of a box on an inclined plane to explore the relationship between power, work, and time. They move the box up the plane using various forces and at various velocities. They observe how power changes as force and velocity change.

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

Teacher Preparation

Before carrying out this activity, you should review with students the concept of work. Make sure they understand the difference between work and force applied and the relationship between force, displacement due to the force, and work done by the force.

- *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 sample answers to the questions.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter “13490” in the search box.***
- *For a more extensive exploration of this content, use activity 9898: Work and Power. Activity 9898, which is longer than this bell ringer, was designed for a full-length class period. You can download the files for activity 9898 at education.ti.com/exchange.*

Classroom Management

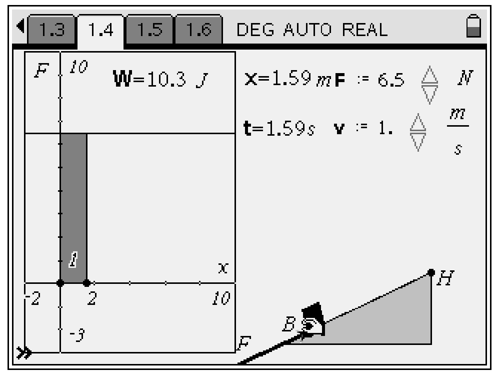
- *This activity is designed to be **student-centered**, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and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

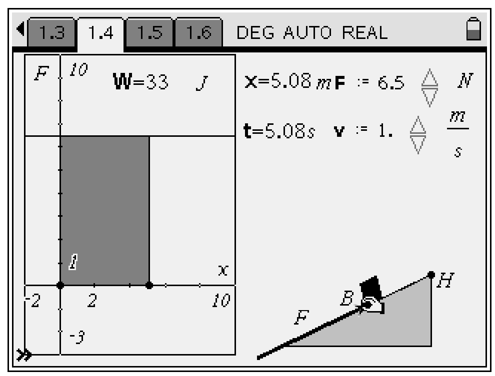
The following questions will guide student exploration during this activity:

- What is power?
- What is the relationship between work and power?
- How does power depend on force and speed?

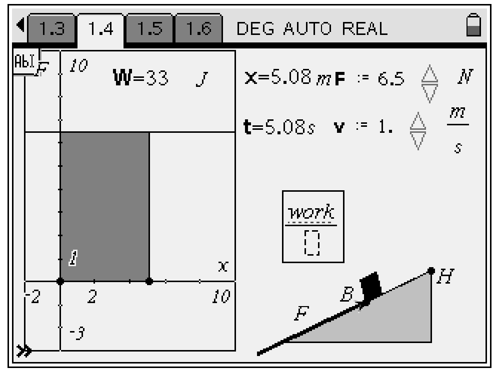
The purpose of this activity is to provide students with an opportunity to explore the general concept of power as the rate at which work is performed by a force and to analyze several specific cases of motion. Students explore the relationships between work, power, and time. This helps students understand the definition of power as the ratio of work to time.

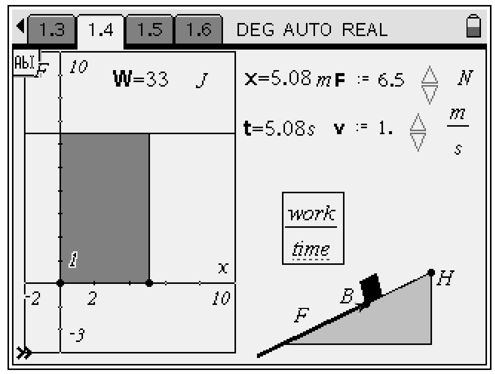
Step 1: Students should open the file **PhysBR_week12_Work_Power.tns** and read the first three pages. Page 1.4 shows a simulation of a block on an inclined plane, together with a graph of force vs. displacement. In the simulation, a constant force *F* is pushing the block up the incline at constant speed *v*. The displacement, *x,* of the block is defined as the distance from the bottom of the incline to point *B*. The time it takes to push the block up the hill through the distance *x* is calculated as $t = \frac{x}{v}$. On the left side of the page, students can observe the graph of force vs. displacement (*f1*(*x*) = *F*). Because force is constant, the graph of *F* vs. *x* is a horizontal line. Students can drag point *B* to simulate the motion of the block up the incline. (To drag point *B*, students should use the NavPad to move the cursor to point *B*. The cursor should change to an open hand. Students should press and hold until the cursor changes to a closed hand. They can then use the NavPad to drag point *B*. To release the points, students should press again.) As point *B* moves up the incline, the work done by the force is calculated as the area under the graph of *f1*(*x*). If desired, the height of the incline can be adjusted by moving point *H*. Students should observe the changes in distance, time, and work that occur as the block is pushed all the way to point *H*.



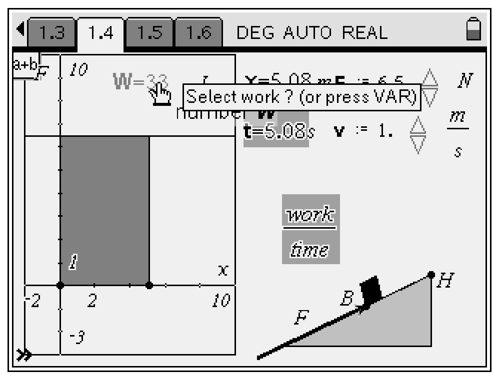


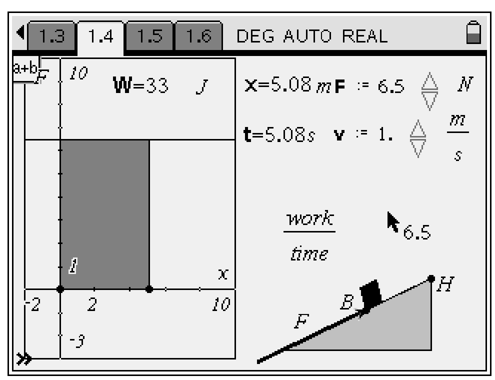
Step 2: Next, students should calculate power for the simulation on page 1.4. First, students should select the **Text** tool (**Menu > Actions > Text**). They should then click once (press click) on an empty area of page 1.4 to place a text box. They should enter the expression $\frac{work}{time}$ in the text box. (You may wish to encourage students to discuss why they must enter this expression in order to calculate power.) To enter the expression, students should first insert a fraction template by pressing ctrl ÷. They should then type *work* into the top box on the template. They should use the NavPad to move to the lower box, and then type *time*. When they have entered the expression, they should press enter to exit the expression.



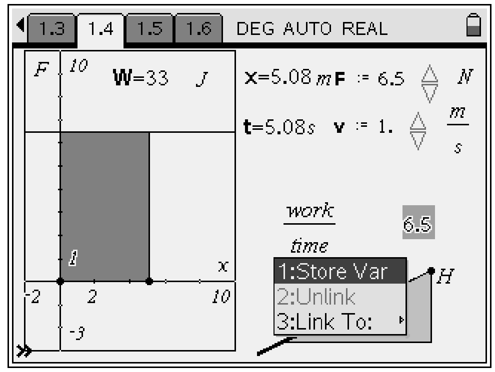


Step 3: After entering the expression in the text box, students should use the **Calculate** tool (**Menu > Actions > Calculate**) to determine the value of the expression. After they select the **Calculate** tool, they should click on the expression they entered in step 2. They will be prompted to select values for *time* and *work*. They should click on the value of **t** for *time* and the value of **W** for *work*. After students have selected values of *time* and *work,* they should click on a blank spot on the page to place the calculated value of power in that location.



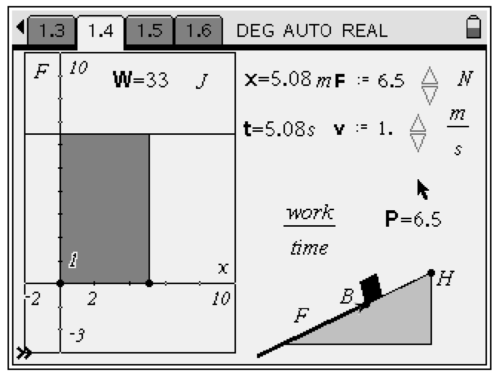


Step 4: Next, students should store the value of work they just calculated in the variable **P**. To do this, students should click once on the calculated value and press sto→ var. They should select **Store Var** and then type **P** and press enter. Then, students should answer questions 1–4.



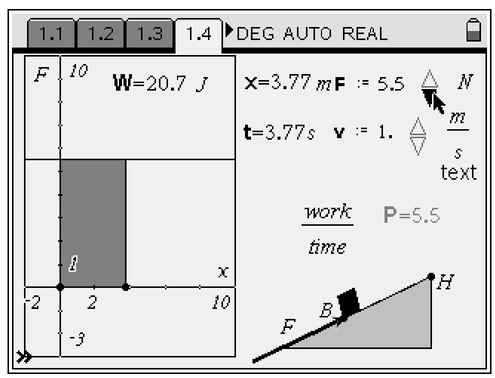
Q1. Predict what will happen to work, time, and power if you increase the force *F* but keep the speed constant.

A. *Students should answer this question without using the simulation on page 1.4. Encourage student discussion of the effects of changing force while keeping speed constant. Also encourage students to think about what must be happening to the mass of the box if force is increasing but speed is remaining constant. (In this simulation, friction is ignored.) Specifically, students should be able to reason that the mass of the box must be increasing if speed remains constant even as force increases.*



Q2. Vary the magnitude of *F* on page 1.4 to verify your prediction.

A. *Students should use the simulation on page 1.4 to test their predictions. To vary the value of* F, *students should click on the up or down arrows next to the value. They should change the value of* F *several times and observe the results. If you wish, you may have the students record their observations in a table like the one shown below.*



(The data in the table below were collected for a constant speed of 2 m/s.) Make sure students record force, work, time, and power values for the situation in which the box has been pushed all the way up the incline.

F, N	*W*, J	*t*, sec	*P*, W
1	6.4	3.2	2
3	19.19	3.2	6
5	31.99	3.2	10
7	44.78	3.2	14

Students should confirm that the time it takes for the box to get to the top of the incline remains constant, because speed and displacement are the same each time. However, the work done increases as force increases. Because work increases but time remains the same, the power increases in direct proportion to force.

Q3. Predict what will happen to work, time, and power if you increase the speed *v* but keep the force constant.

A. *Students should answer this question without using the simulation on page 1.4. Encourage student discussion of the effects of changing speed while keeping force constant. Also encourage students to think about what must be happening to the mass of the box if speed is increasing but force is remaining constant. (In this simulation, friction is ignored.) Specifically, students should be able to reason that the mass of the box must be decreasing if force remains constant even as speed increases.*

Q4. Vary the magnitude of *v* on page 1.4 to verify your prediction.

A. *Students should use the simulation on page 1.4 to test their predictions. To vary the value of* v, *students should click on the up or down arrow next to the value. They should change the value of* v *several times and observe the results. If you wish, you may have the students record their observations in a table like the one shown below. (The data in the table below were collected for a constant force of 3 N.) Make sure students record speed, work, time, and power values for the situation in which the box has been pushed all the way up the incline.*

v, m/s	*W*, J	*t*, sec	*P*, W
2	19.19	3.2	6
4	19.19	1.6	12
6	19.19	1.07	18
8	19.19	0.8	24

The work remains constant, because both force and displacement are constant. The time decreases from trial to trial, because the block is moving faster in each trial. Because work is constant but time decreases, power increases from trial to trial. The increase is directly proportional to the increase in speed. Advanced students may benefit from an exploration of the effects of varying both F *and* v*.*

Suggestions for Extension Activities: If you wish, you may have students vary the height of the ramp and repeat the investigation. Encourage students to relate their results to the gravitational and frictional forces acting on the box.

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(Student)TI-Nspire File: *PhysBR_week12_Work_Power.tns*