Do Machines Save Energy?

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Topic

Conservation of energy: machines and friction

Time

1 hour

Safety

Please click on the safety icon to view the safety precautions. Adult supervision is necessary if you are using a wood block, which must have a hole drilled in it.

Materials

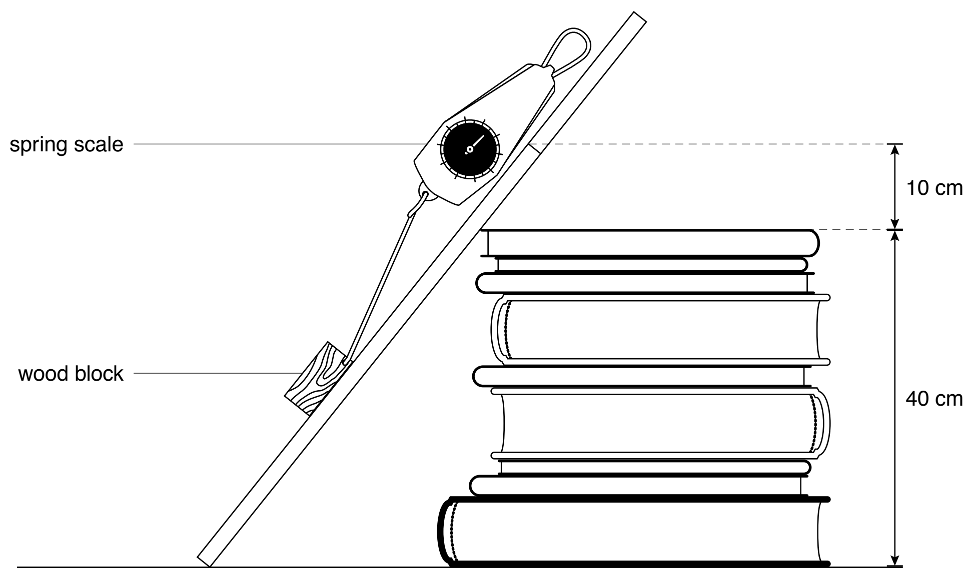
- wood block, about 2 in. 2 4 in. 2 6 in., or a cardboard box about this size (a box from a bar of soap works) and some material—such as sand, nails, or pennies—to put in the box for weight
- 20-cm light string
- spring scale
- ring stand and ring or enough books to make a stack 40 cm high
- board 1 in. 2 4 in. (or wider) and 80 cm long
- meterstick
- pencil

Procedure

1. The inclined plane is a simple machine made out of a flat, rigid surface that is placed at an angle to the horizontal. It is used to move objects from one level to another. Instead of lifting an object vertically, you can use this machine to slide or roll the object up to the desired height. To make an inclined plane out of your board, adjust the ring stand so that the ring is about 40 cm from the floor, or pile books to about this height. Draw a pencil line across the board 60 cm from one end. Lean the board against the stand or books so that the pencil line is 50 cm from the floor measured vertically.
2. If you are using a wood block, ask an adult to drill a hole in the bottom corner. If you are using a box, use the pencil to make a hole in the corner.
3. Put a loop of string through the hole.
4. Weigh the wood block or box with the spring scale, and record this weight on data table 1 as *F*, the force needed to lift the block.
5. Using the board as a ramp, drag the block or box up the ramp with the spring

DATA TABLE 1		
Work put out by machine		
(*D*) Height of ramp (cm)	(*F*) Force needed to lift block	(*W*) Work output $W = F \times D$
40		
30		
20		
10		

scale, and record the reduced weight shown on the scale on data table 2 as *F*, the force needed to pull the block (see illustration). Be sure to read the weight while the block is in motion, not as you first start up.



6. Repeat step 5, adjusting the height of the stand or books as needed to test ramp heights of 40, 30, 20, and 10 cm (measured vertically from the floor to the pencil line across the board).
7. On data table 1, calculate the amount of work put out by the machine in raising the block to each height by multiplying *F* (the force needed to lift the block) by *D* (the height of the inclined plane; work = force 2 distance). On data table 2, calculate the work put into the machine by the operator (you) when you dragged the block up the plane to each different height, by multiplying *F* (the force needed to pull the block) by *D* (the length of the plane, 60 cm).

DATA TABLE 2		
Work put out by machine		
(*D*) Height of ramp (cm)	(*F*) Force needed to lift block	(*W*) Work output $W = F \times D$
40		
30		
20		
10		

8. For each height tested, which is greater, the work done by the machine or the work done by the operator?
9. How could you use the theory of energy conservation to explain your answer to the question.
10. At each height tested, which is greater, the force needed to lift the weight to a given height or the force needed to drag it to that height?
11. If machines use more work, or energy, than they put out in accomplishing their tasks, how do they help us? How did the simple machine you used, the inclined plane, make the job of raising the block or box easier?

What's Going On

The work done by the operator is greater than the work put out by the machine in every case. The theory of the conservation of energy states that energy cannot be created or destroyed. The machine must use some energy to overcome the friction between the block (or box) and the board. The operator must put in enough energy (or work) to overcome the friction *and* allow the machine to put out enough energy to accomplish its task. If a machine enabled a person to do less work, it would have to be creating energy, and that would violate the theory. For each height tested, the force needed to lift the object to that height is greater than the force needed to drag it there up the inclined plane. In general, machines decrease the amount and/or change the direction of force needed to perform a given task. The inclined plane works by employing a smaller amount of force over a longer distance. This makes work easier to do, even though more work (force 2 distance) is actually required.

Connections

Generally, we think of machines as energy savers, but the theory of the *conservation of energy* contradicts this notion. This theory states that energy cannot be created or destroyed. Because all machines have moving parts that rub against some other surface, some of the energy put into a machine must be used up to overcome friction, reducing the amount of work the machine can put out. Even though machines may make work easier to do, more energy must actually be put into the machine than it puts out when it accomplishes its work. In this experiment, you calculated the amount of work put into a machine and the amount of work it puts out to accomplish a task, to see if these amounts differ as the theory of energy conservation predicts.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say "be careful with hot liquids" or "don't cut yourself with the knife" does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don't use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES