Energy and the Physical Setting

Simple Machines, Part 2: Trade-off

Last week we started discussing the relationship between energy and simple machines. We left you with the following questions:

Here are some examples of simple machines in action. For each one, see if you can decide:

- Are you multiplying the force or are you changing direction of the force?
- What's the **trade-off**? What price do you have to pay for using the simple machine?

1. You use a hammer to pry a nail out of the wall.
2. You use a ramp to lift a box onto a truck.
3. You use a pulley to raise a flag.

Trade-off

This week, we'll look at this topic of **trade-off**.

Hammer trade-off

Think about using a hammer to pull a nail from a block of wood. The hammer allows you to multiply the force on the nail. Your fingers alone could not exert enough force to pull the nail from the wood.

Now think about the distance the handle of the hammer moves in comparison with the distance the head of the hammer moves.

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As you use the hammer, you exert your smaller *force* (f) through the larger distance (D) on the handle of the hammer. The hammer head exerts its larger *force* (F) through a smaller distance (d) on the nail. If you pull hard enough, the hammer pulls the nail out of the wood. The hammer moves the nail upward. The hammer has done work on the nail.

Work done on the nail by the hammer equals the force the hammer exerted on the nail times the distance through which the nail moved.

W = F x d

In order for the hammer to do work on the nail, you had to do work on the hammer. You exerted a force on the hammer handle and moved the handle downward.

Work done by you on the hammer equals the force you exerted on the hammer times the distance through which you exerted the force.

W = f x D

You are using the hammer to multiply the force you can exert on the nail; but, there are trade-offs.

- One trade-off is that you must exert your smaller force through a larger distance than the distance you move the nail.
- A second trade-off is that you must move the hammer <u>as well as</u> the nail.

If you could pull the nail out of the wall without the hammer, you would have only done the work of lifting the nail and overcoming the friction of the nail rubbing against the wood in the wall. When you use the hammer you must do the work of moving the hammer as well as the work of lifting the nail and overcoming the friction.

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Therefore, when you use the hammer, a bottle opener, a shovel or any **simple machine**, you do more *work* on the simple machine than you get *out* of the **simple machine**. That's because when you use a simple machine, you are doing work both on the machine *and* on the object being moved. Work you do on the hammer is greater than the work done on the nail.

So think about it: why do you use **simple machines**? Oh, yes:

They allow you to multiply force or change the direction of the force you exert.

With these advantages, you are able to do work that was difficult or even impossible without the simple machine.

Ramp trade-off

- **What happens when you push a box up the ramp?**
- **What advantages are you getting? (change in direction or multiplication of force)**
- **What's the trade-off?**

When pushing the box up the ramp, you are changing the direction of the force (from [1] lifting straight up to [2] pushing or pulling up an incline). Can you reverse the order of the pictures above so they match the 1 and 2 listed here? Also, can you label the pictures with 1 and 2 to go along with these? You are also using less force. The force you exert while pushing the block up the incline is less than the force you need to lift the box. If it's a very heavy box you might simply be incapable of lifting it up without help. The **trade-off**? You have to move the box farther, not just straight up from the ground, but all the way up the ramp.

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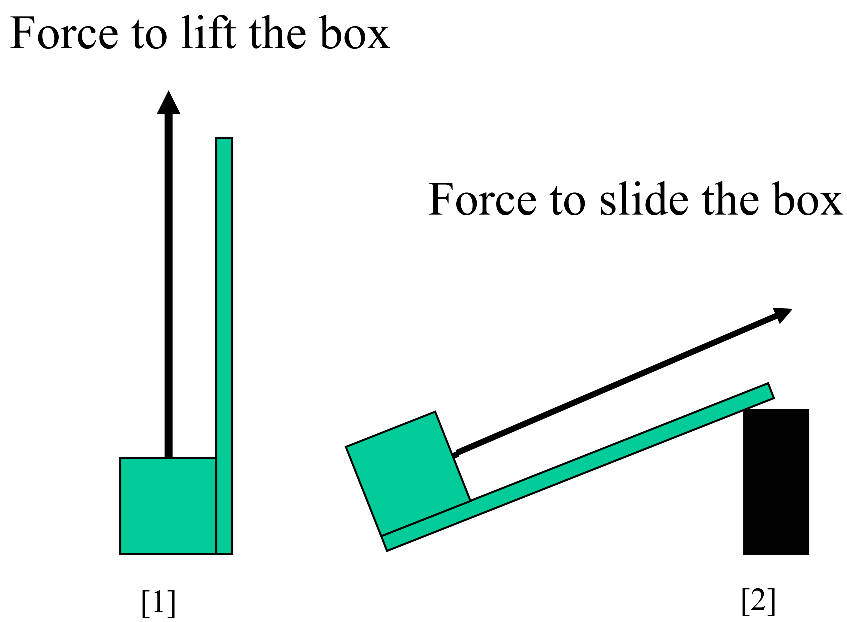

BUT…there's another **trade-off** for the advantage of using this simple machine: friction. Let's look at a definition of friction:

Friction is a force between an object in motion and one at rest that acts to slow the motion of the object in motion.

What's the trade-off?

In our example, the box is the object in motion. If you lift the box straight up, there would be a little friction between the box and the air you are pushing it through. In the case of the ramp, however, there is a great deal of friction present. The bottom of the box is in contact with the ramp; that produces quite a bit of friction. So friction is another **trade-off** when using simple machines; its importance depends upon the machine used.

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Pulley trade-off

Let's look at the final example: a pulley raising a bottle of water.

One way to use a pulley is to lift an object. The direction of *force* is changed: you pull down on the rope as you lift up the object. Using a pulley to lift a bucket from a well or to raise a flag illustrates how we use simple machines to change the direction of a force. The trade-off? You have to move the rope a long distance in order to lift the bottle; the rope goes all the way up, around the pulley, and down again. Also, in addition to lifting the bottle of water or a bucket or a flag, you have to lift all that rope. It takes work to lift the rope. Even with these trade-offs; it's much more convenient to use the pulley than to sit on top of the flagpole and pull the flag up.

There's another trade-off, though. Yes, you guessed it: friction. When you use a pulley, there is some resistance when the rope or chain moves around the machine. That's why it's common to use some sort of lubrication on pulleys; the grease decreases the resistance.

Let's review

To recap:

- There are ALWAYS **trade-offs**. When you use a bottle opener or a shovel you can multiply the force you can exert. However, in addition to lifting the bottle cap or the stone, you also must lift the bottle opener and the shovel. The added work of lifting the simple machine is a **trade-off**. Friction is another **trade-off**. The amount of resistance varies depending upon the kind of simple machine used.

- We use simple machines to increase the force we apply (on a bottle cap) or to change the direction of the force we apply (lift a bucket from a well or raise a flag). There are ALWAYS **trade-offs**. When you use a bottle opener or a shovel you can multiply the force you can exert. However, in addition to lifting the bottle cap or the stone, you also must lift the bottle opener and the shovel. The added work of lifting the simple machine is a **trade-off**. Friction is another **trade-off**. The amount of resistance varies depending upon the kind of simple machine used.

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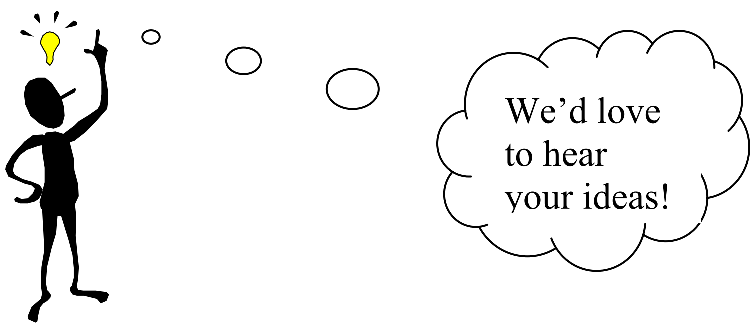
Coming up

Next week we're going to look at one family of simple machines: **inclined planes**. In the meantime, consider this:

We see ramps that access many buildings; these are common and obvious examples of **inclined planes**.

- What are some inclined planes that you come across regularly?

  (Hint: Your kitchen or workshop has some great examples.)



What do the NYS standards say?

Elementary Core Curriculum, Standard 4, The Physical Setting,

Major Understanding states:

- 5.1f Mechanical energy may cause change in motion through the application of force and through the use of simple machines such as pulleys, levers and inclined planes.

Intermediate Core Curriculum, Standard 4, The Physical Setting,

Major Understandings state:

- 5.2f Machines can change the direction or amount of force, or the distance or speed of force required to do work.
- 5.2g Simple machines include a lever, a pulley, a wheel and axle, and an inclined plane. A complex machine uses a combination of interacting simple machines, e.g., a bicycle.

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