Inclined Plane

Fall 2013

Goal: To learn that simple machines can multiply the input force. To find the Mechanical Advantage of different simple machines.
Fits Tennessee State Stds:

> GLE 0707.11.1 Identify six types of simple machines
> GLE 0707.11.2: Apply the equation for work in experiments with simple machines to determine the amount of force needed to do work.

Materials:

10 short ramps - pieces of foam board (length 25cm)
10 medium length ramps - pieces of foam board (length 38cm)
10 longer ramps - pieces of foam board (length 51cm)
10 wooden blocks (2x4, with eye-screw and mason's line)
10 5-Newton Spring Scales
10 skinny PVC pipes
10 fat PVC pipes
20 right angle paper triangles per (2 different sizes)
10   rulers
20 screws, 2 different pitches
1 3" styrofoam block, 10cm height

Write vocabulary words on board: simple machine, work, mechanical advantage, height, inclined plane, angle of inclination,

I. Introduction

- Ask students to name the six classes of simple machines. *Inclined plane, wedge, screw, lever wheel and axle/pulley*
- Ask students why we use machines. *to make work easier*
- A simple machine is an object that allows us to do work more efficiently, ie they make work easier for us.

- **Ask students to define work:** is defined as the force it takes to move an object a certain distance.
- In this lesson we will compare the amount of work it takes to move an object without a simple machine to the amount of work it takes while using a simple machine.

Ask students: What is an Inclined Plane?

> It is a flat surface that is higher on one end. In other words, it is sloped.

Ask students to give you some examples.

> A road up a hill, a ladder leaning against a house, a skateboard ramp…

What is its purpose?

> The purpose of an inclined plane is to move something from a lower height to a higher height.
> They help reduce the force needed to lift an object up
> They help reduce the work necessary to move an object to a different vertical height.
> **Ask students:** what is easier, lifting a piano up and into a moving van, or pushing it up a 20 foot long ramp? *Using the ramp.*

Write the definitions of work on the board:

work = force x distance   **W = Fxd**
Work is only done when the **force** exerted on an object is done over a **distance.**

The Law of Conservation of Energy states that energy cannot be created or destroyed.
- So the work done by a machine cannot be greater than the work done on the machine.
    - work input = work output
    - OR, input force x distance = output force x distance
    - So when the distance is increased, the input force decreases.
- Machines do NOT decrease the amount of **work** you have to do, but change the way a **force** is applied.
- They make work easier by allowing a force to be applied over a greater distance or by changing the direction of the input force.

BUT, as with all simple machines, there is always a trade-off.
Look at the ramp diagrams on the observation sheet.
- Which ramp is shorter? *(Ramp #1)* Which one is longer? *(Ramp #2)*
- Which ramp would take less effort to use to push the piano up? (*Ramp #2*)

In an inclined plane the trade-off is **distance**. In order to use less effort by using the ramp, you need to travel a longer distance.

Look around your school for examples of ramps.
A really good example is a handicap ramp – it is longer than the distance used by taking the steps.
The steeper the ramp, the more effort it takes to get a wheelchair up the ramp. If the ramp is gently inclined, then it is easier get wheelchair up the ramp.
Tell students that the Egyptians used ramps to move the heavy stones to up from the ground to build the pyramids.

Ask students if they can explain the term mechanical advantage.
Answers should include:
- The mechanical advantage of a machine is the number of times the machine multiplies the input force
- Mechanical advantage tells you how much effort the user saves by using a machine. The more times a machine multiplies the input force, the easier it is to do the job. After all, machines are only helpful if they make our work easier to do.
- For example, a mechanical advantage of 2 multiplies an input force twice which means that you only exert half the force required to get the job done without the machine; a mechanical advantage of 3 multiplies your input force three times which means you only exert one third of the effort to do the job.
- The greater the mechanical advantage of a machine, the smaller the amount of force we need to accomplish a task. A good mechanical advantage is greater than 1.

Your Notes: 2

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Calculating the Mechanical Advantage for an Inclined Plane
- ▪ Explain to students how to calculate the mechanical advantage.
  The mechanical advantage can be found by using the following equation (put on board):

  Mechanical advantage (MA) = $\dfrac{\text{Output force (in Newtons)}}{\text{Input force (in Newtons)}}$

Remember that **work input = work output**
Since work = force x distance
Then **input force x distance (input) = output force x distance (output)**
  F (input) x d (input) = F (output) x d (output)
Rearranging the equation,
  $\dfrac{\text{F (input)}}{\text{F (output)}} = \dfrac{\text{d(output)}}{\text{d (input)}}$

Since Mechanical advantage (MA) = $\dfrac{\text{Output force (in Newtons)}}{\text{Input force (in Newtons)}}$

Then MA = $\dfrac{\text{(length of slope)}}{\text{(height of plane)}}$

The mechanical advantage of an inclined plane depends upon its *slope* and height.

Look at triangle ramps again (below). Calculate the MA for the 2 ramps (see worksheet).

No Ramp	Ramp #1	Ramp #2

C | A (No Ramp)

C — 10M — 15M — A — B (Ramp #1)

C — 10M — 30M — A — B (Ramp #2)
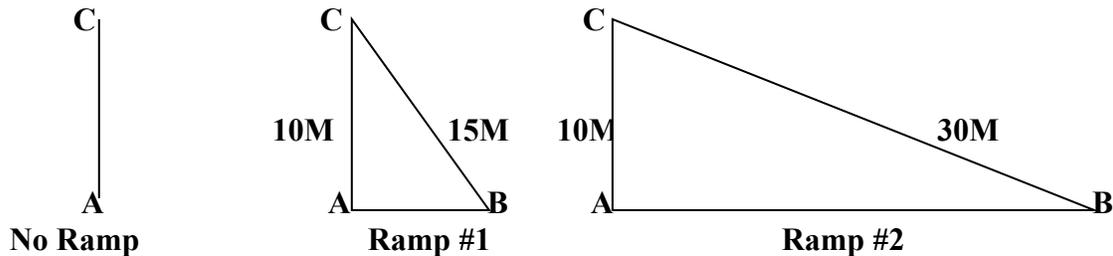
Make sure that the students understand that there is a tradeoff for less input force; the force is exerted over a greater distance.
- ▪ Point to the variables on the board as you explain what mechanical advantage is.
Keep this discussion brief and return to mechanical advantage later in the lesson.

II. Inclined Plane

Materials (per group):
1 wooden block with string attached
1 5-Newton spring scale
1 ruler
3 pieces of foam board (length 51, 38 and 25 cm long)
1 Styrofoam block (10cm height)
Your Notes: 3

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Using the Spring Balance
Have students examine the spring balance.
1. Have students arrange the handle so it hangs properly (some handles may have slipped).
2. Instruct students to hold the spring balance by the handle.
3. Notice that the spring balance goes from 0 to 500g and 0-5 Newtons.
4. **<u>Tell students that they will be recording measurements in Newtons.</u>**
5. The zero needs to be checked and possible adjusted.
6. Show students how to adjust the zero by gently twisting the plastic screw on the top of the scale until the blue plastic disc inside the tube and the zero marking are aligned. Tell students that the plastic disc should always start out even with the 0 mark.
7. Tell students that they must "zero the balance" each time they measure.
8. Check to make sure student groups do this correctly. Some students may need help in reading the increments of the scale on the spring balance.

Weighing with the Spring Balance
1. Have students hold the spring balance by the top metal ring.
2. Practice measuring the force needed to lift the wooden block by hooking the spring balance to the hook on the mass and carefully raising the spring balance until the mass is hanging freely (about three inches or 10cm off the table – this is the height of the foam block). Keep arm still to get a good reading. Every student should have an opportunity to use the spring balance to do this.
3. Record the reading in the **Output force** column on the data sheet. (Student readings should be close to 2. Tell students that this is the **Output Force** for all the experiments, and to fill in all the lines in column 1.
4. Readings by different group members should be very close to 2.5N. If the readings are not close to 2.5N, the group should recheck the zero and repeat the exercise. It is important to keep your arm still to get an accurate measurement; otherwise the tab will go below 2.5.
5. Explain that gravity is the force pulling on the spring scale. If you were to remove the mass and pull down on the spring scale, your muscles would be providing the force.

Have the students do the following:
1. Tell the students that they are going to make and test a inclined plane
2. Draw a right triangle on the board, and identify the parts: base, height, and hypotenuse.
3. Make a ramp using the Styrofoam block and the **longer** length ramp. The block forms the height. The ramp forms the hypotenuse.
4. Measure the height of the ramp at the highest point.

Your Notes: 4

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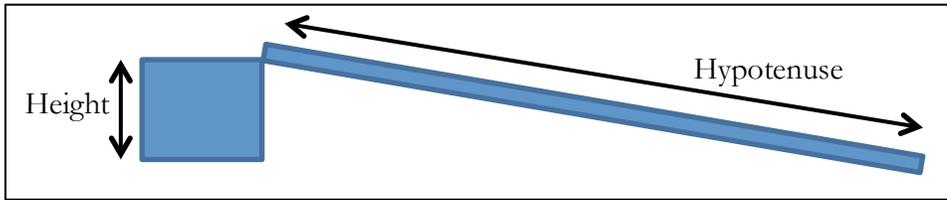
Height

Hypotenuse

5. Enter the height on your data sheet.
6. Measure the length of the ramp. This is the hypotenuse. Enter this value on your observation sheet.
7. Place the block so that it rests on the edge of the ramp.
8. Have your partner hold the ramp and block steady so it cannot move
9. Practice moving the block slowly and smoothly up the plane. You want a constant steady force on the spring balance. Notice that in order to start, you must overcome friction and you may notice a jump in the initial reading on your spring scale. This is okay as long as you get a consistent reading as you pull the block up the ramp.
10. Record the force reading on your observation sheet.
11. Repeat with the 2 shorter ramps.

Ask students: Which method took more force?
- o It takes more force to lift the block without the ramp.
- o Students should see that you need significantly less force to move the wooden block with the ramp compared to lifting the block the same distance without the inclined plane.
- Ask students: What is the disadvantage of using a ramp? *The block has to be moved over a longer distance.*
- What is the MA of this ramp?
- Enter the data and complete the calculations.

II. Screws
Materials (per group):
2 PVC pipes, each of a different diameter
2 triangular pieces of paper
1 ruler
2 screws, different pitches

A screw converts the rotating motion of turning the screw into straight-line motion of the screw into wood or other material.
It takes less force to turn a screw into a hard material than to pound a nail into the same material.

Hand out the materials to each group.
Tell students that a **screw** is another form of an inclined plane.
- Tell students to look at the triangular pieces of paper and point out that it looks like an inclined plane.

Your Notes: 5

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- A screw is simply an inclined plane wrapped around a rod, like a *spiral*.
- Tell the students to picture it like a spiral staircase winding up to the head of the screw.

- When a screw is turned once, it advances by the distance between adjacent screw threads. These threads are what perform the work.

  - This distance is called **the "pitch"** of the thread.
  - The *pitch* of a screw is the distance between adjacent threads on that screw.
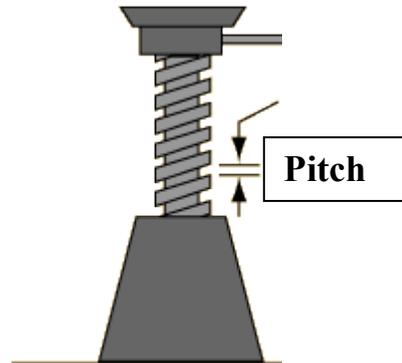
- Typically, the smaller the pitch, the easier the work.

Have the students do the following:
1. Take the large PVC pipe and measure its diameter. See figure 2. The radius is ½ the diameter. Record the radius on the observation sheet.
2. Line up and tape the red edge of your triangle against the red end of your large pipe. See Figure 3.
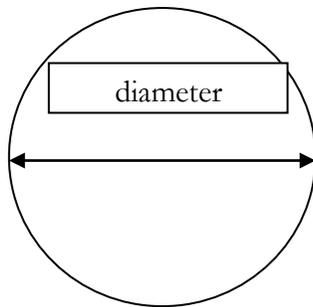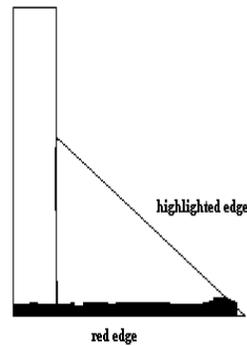

Figure 2.

FIGURE 3

Your Notes: 6

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3. Carefully wrap the triangle around the PVC pipe and hold the corner securely.
4. Measure the pitch of the 'screw.' The highlighted hypotenuse will form a spiral around the PVC pipe. Measure the distance between two adjacent highlighted edges of the right triangle.
5. Record the measurement of the pitch on your observation sheet.
6. Repeat steps 2-5 for the small PVC pipe.

Students should discover that since the skinny PVC pipe has a smaller pitch, it would be more efficient, making work easier.

The mechanical advantage of a screw is found approximately by dividing the circumference of the screw by the pitch of the screw.
For example, if the circumference of a screw is ¼ inch and the pitch is 1/5 inch, then the mechanical advantage is 1.25
       Mechanical advantage of a screw = circumference / pitch

Tell students to measure the pitch on the 2 screws.
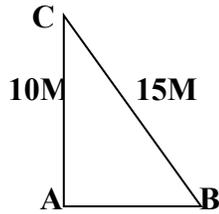
Your Notes: 7

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Observation Sheet
Inclined Plane and Screws

MA = (length of slope)
         (height of plane)
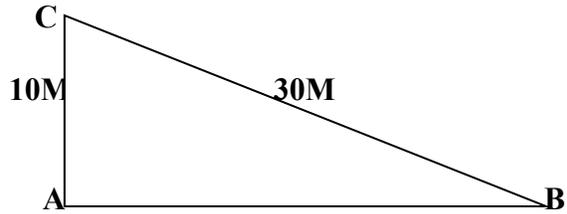
C	C	C
5M	10M 15M	10M 30M
A	A B	A B
	11.18M	28.28M
No Ramp	Ramp #1	Ramp #2
MA=_____	MA =_1.5_____	MA = __3____

Note: Force of Gravity = 9.8 Newtons
            Mass of the wooden block = 0.250 kg

Inclined Plane Data

	Ramp Height (in meters)	Ramp Length (in meters	MA for ramp	Input Force (Newtons)	Work (=length x input force) (in Joules)
Work to pull up (no ramp)	X	X	X	2.5N	
Longest Ramp				Trial 1_____ Trial 2_____ Trial 3_____ Average_____	
Mid-length Ramp				Trial 1_____ Trial 2_____ Trial 3_____ Average_____	
Shortest Ramp				Trial 1_____ Trial 2_____ Trial 3_____ Average_____	

1. Compare the values you get for "Work (to pull up vertically, no ramp)" and "Work (using ramp)". Are they about the same?

2. How is the force required to raise the 0.250 kg block affected by the height of the ramp?

3. What is the mechanical advantage if you were to just pull the block up without using a ramp? How does this compare with the mechanical advantages of the three ramps? What can you conclude about how the length of the ramp affects the mechanical advantage?

Screw Data

	Small PVC Pipe	Large PVC Pipe	Mechanical Advantage M.A. = $(2\Pi r)/p$
Radius (r)			
Pitch (p)			

Inclined Plane Instruction Sheet

I.   Inclined Plane

1. Inspect the spring scale. There is a side marked "Grams" and a side marked "Newtons". You need to use Newtons, because it is direct measurement of force.

2. Look at the right triangle on the board, and identify the parts: base, height, and hypotenuse.

3. Make an inclined plane using the block and the LONGER length of a textbook.. The two blocks form the height. The book forms the ramp or hypotenuse.

4. Measure the height of the ramp at the highest point. See Figure 1.
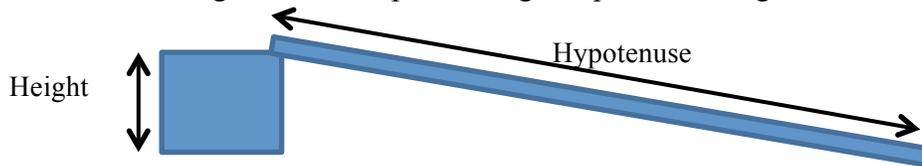
5. Enter the height on your data sheet.

6. Measure the length of the ramp. This is also the hypotenuse. Enter this value on your observation sheet.

7. Place the block so that it rests on the edge of the ramp.

8. Have your partner hold the ramp and block steady so it cannot move

9. Practice moving the block slowly and smoothly up the plane. You want a constant steady force on the spring balance. Notice that in order to start, you must overcome friction and you may notice a jump in the initial reading on your spring scale. This is okay as long as you get a consistent reading as you pull the block up the ramp.

10. Record the force reading on your observation sheet.

11. Repeat with the 2 shorter ramps

12. Calculate the Mechanical Advantage for the ramps.

II. Screws

1. Take the large PVC pipe and measure its diameter. See figure 2. Record the diameter on your observation sheet.
2. Line up and tape the red edge of your triangle against the red end of your large pipe. See Figure 3.
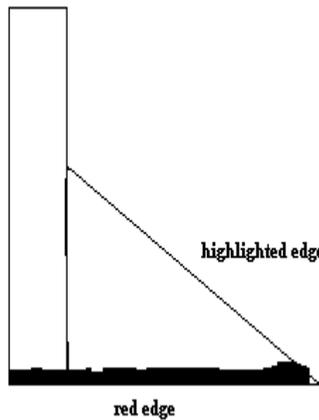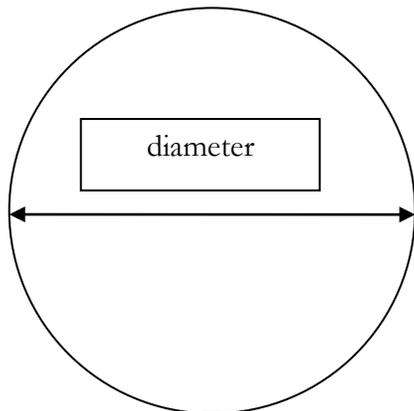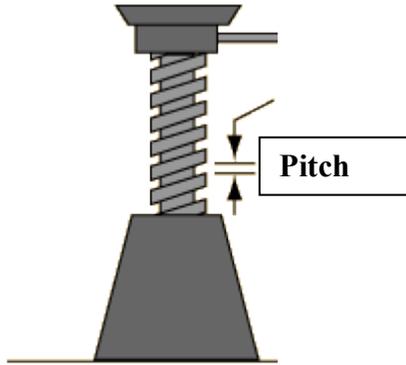
Pitch

diameter

FIGURE 2

highlighted edge

red edge

FIGURE 3

3. Carefully wrap the triangle around the PVC pipe and hold the corner securely.
4. Measure the pitch of the 'screw.' The highlighted hypotenuse will form a spiral around the PVC pipe. Measure the distance between two adjacent highlighted edges of the right triangle.
5. Record the measurement of the pitch on your observation sheet.
6. Repeat steps 2-5 for the small PVC pipe.
7. Calculate the mechanical Advantage for the model screws (the paper and PVC pipe) and the real screws.