

## 4.1

## Forces in Machines



Question: How do simple machines work?

**1 Identifying input and output forces**

Watch a demonstration of a simple machine made with ropes and pulleys.

- a. What is the definition of a simple machine?

---

---

---

---

- b. With your class, brainstorm additional examples of simple machines. For each machine you come up with, identify the input and output force.

---

---

---

---

---

---

---

---

**2 Setting up the ropes and pulleys**

Follow the procedures in your Investigation guide to complete part 2. There are no questions to answer.



**Safety Tip: Don't pull sideways or you can tip the stand over!**

**3 Investigating the ropes and pulleys**

Follow the procedures in your Investigation guide and record your data in the table on the next page.

Number of support strands	Force to lift bottom pulley block (N)
1	
2	
3	
4	
5	
6	

a. As you add more supporting strands, what happens to the force needed to lift the bottom block?

---



---

b. How does the amount of input force required to lift the bottom block change with the string arrangement? Can you identify a mathematical rule?

---



---



---



---



---

#### **4** What did you learn?

a. How are all simple machines alike? How is a lever different from a ropes and pulleys machine? (Think about input and output force.)

---



---



---



---

b. What is the relationship between the number of strings on the ropes and pulleys and the amount of input force required to lift the bottom block?

---



---



---

Name: \_\_\_\_\_

## 4.2

## The Lever



Question: How does a lever work?

**1**

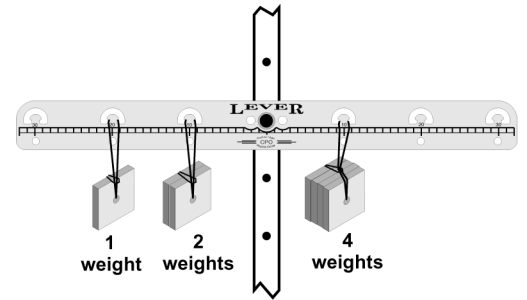
### Setting up the lever

There are no questions to answer in part 1.

**2**

### Levers in equilibrium

- a. The lever is in equilibrium when all the weights on one side balance all the weights on the other side. Hang the weights as shown to the right. Does the lever balance?



- b. What variables can be changed to balance a lever?

---

---

---

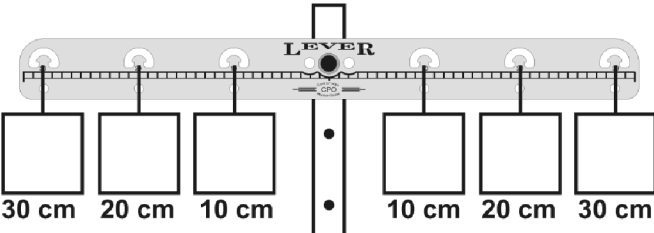
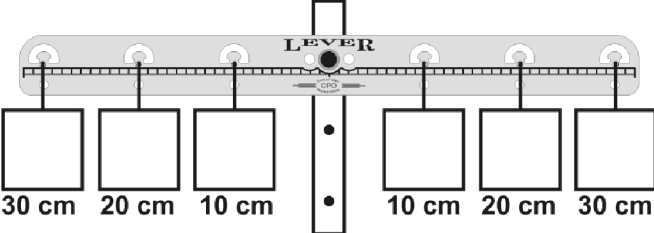
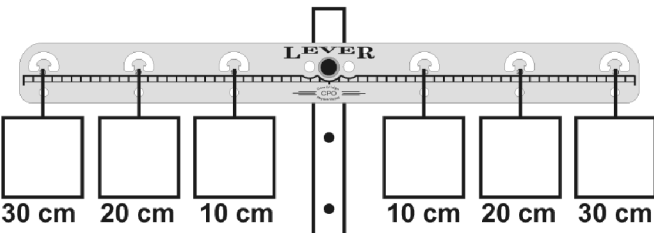
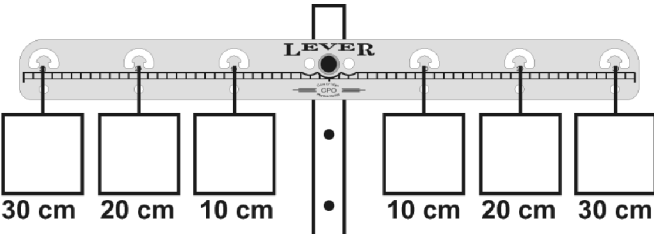
---

---

**3**

**Trying different combinations to balance the lever**

Make different combinations of weights and positions that balance. Use the chart below to write down the numbers of weights you put in each position. If you want to conduct more than four trials, write your results below the chart.

<p><b>Trial #</b></p>	
<p><b>Trial #</b></p>	
<p><b>Trial #</b></p>	
<p><b>Trial #</b></p>	



- c. In a lever, you can increase the amount of output force by increasing the length of the input arm. When you do this, what must decrease in order to increase output force?

---

---

---

---

---

---

---

---

## 4.3

## Designing Gear Machines



Question: How do gears work?

1

## Two gear machines

Write your data in the table below.

Table 1: Teeth and turns for 3 gear machines

Input Teeth	Input Turns	Output Teeth	Output Turns

2

## Deducing the rule for gears

From your data, derive a mathematical formula which relates the turns of the input gear to the turns of the output gear. The rule also must include the teeth in each gear. State your rule using four variables: Input Teeth, Input Turns, Output Teeth, and Output Turns. This rule is called the *law of gearing* and is the basis for designing machines that use gears. Show your work below.

---



---



---



---



---



---



---



---



---

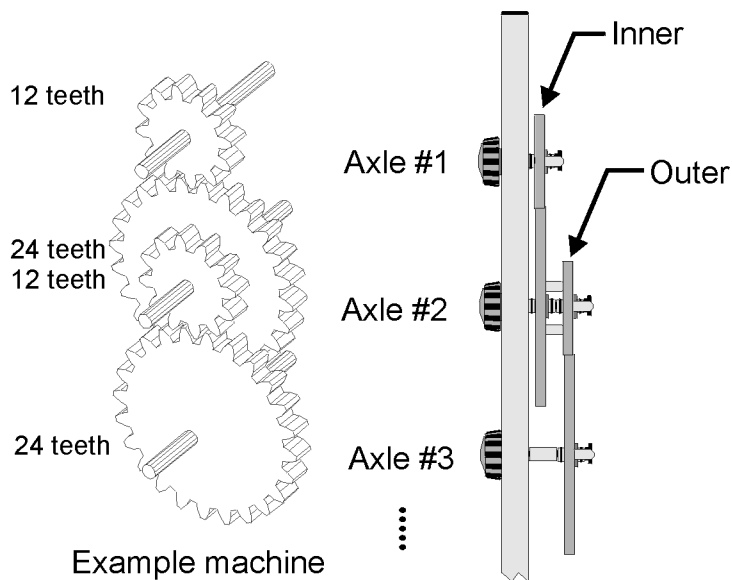


---

**3**

**Complex gear machines**

Use the table below to work out the gear ratios for the complex gear machine.



**Table 2: Gear machine #1**

axle	Inner Position X or number of teeth	Outer Position X or number of teeth
1		
2		
3		
4		
5		

**4**

**Design your own machine**

The gears make ratios containing the numbers 1, 2, and 3 only. These ratios can be combined to make other ratios as long as no factors other than 1, 2, or 3 are used. It would be impossible to build a ratio of 21 with these gears because 21 factors into  $7 \times 3$ . You do not have any gears that can make a ratio of 7.

1. Design and construct a machine that has a ratio of 9:1. Record the design in the table below and show that the ratio works out mathematically.

axle	inner position X or number of teeth	Outer position X or number of teeth
1		
2		
3		
4		
5		

2. Design and construct a machine that has a ratio of 4:1. Record the design in the table below and show that the ratio works out mathematically.

<b>axle</b>	<b>inner position X or number of teeth</b>	<b>Outer position X or number of teeth</b>
<b>1</b>		
<b>2</b>		
<b>3</b>		
<b>4</b>		
<b>5</b>		

3. Design and construct a machine that has a ratio of 18:1. Record the design in the table below and show that the ratio works out mathematically. This ratio may require sharing with other groups since it uses at least 6 gears.

<b>axle</b>	<b>inner position X or number of teeth</b>	<b>Outer position X or number of teeth</b>
<b>1</b>		
<b>2</b>		
<b>3</b>		
<b>4</b>		
<b>5</b>		

**5****What did you learn?**

- a. Suppose you needed to make a ratio of 100:1 using gears. Suggest 3 different designs using 3 different combinations of gears. Draw your designs below. Which of your designs is the smallest? Which has the least gears? (Label your drawings.)



- b. Are there reasons you might want to use two pairs of gears instead of 1 pair, even for small ratios? Think about the direction the input and output gears turn.

---

---

---

---

---

---

---

## 5.1

## Work



Question: What happens when you multiply forces in a machine?

### 1 Setting up the experiment

Follow the procedures in your Investigation guide to complete the experiment. Record you data in the table in part 2.

As the mechanical advantage increases, what happens to the length of the string you have to pull to raise the block?

---



---



---



---

### 2 Data table

Mechanical advantage	Height difference for block (meters)	String length (meters)	Input force (newtons)	Output force (weight of block in newtons)	Work done on block (work output in joules)	Work done by you (work input in joules)

**3****What is work?**

There are no questions to answer in part 3.

**4****Calculating work done**

- a. Calculate the work done on the block. This work is equal to the output force (weight of the block) times the height difference for block. The work done on the block should be the same for all configurations of the strings because the weight of the block and the height it was lifted did not change. You should therefore write the same number in each row of the table under the heading "Work done on block."
- b. Next, calculate the work you did as you pulled on the string to lift the block. In this case, multiply the input force times the string length. For each different mechanical advantage, record the work done on the string under the heading "Work done by you."

**5****The relationship between work and energy**

- a. Marble A can be let back down to lift marble B. The work put into lifting marble A can be recovered and used to lift marble B. Study the picture below carefully. In order for marble A to lift marble B, what must be true about the weights of the two marbles?

---



---

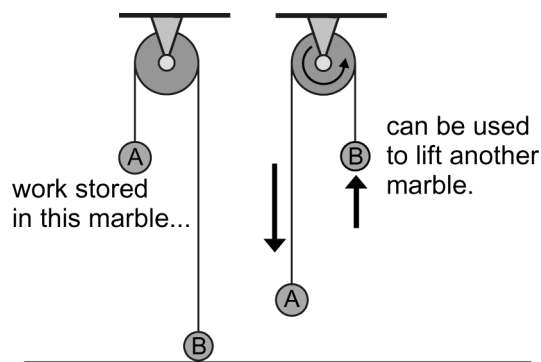


---



---

- b. Using the arrows in the picture below as a guide, describe the forces in terms of strength and direction on marble A and marble B.




---



---



---



---



## 6 The work-energy theorem

An object that has energy has the ability to do work. The total amount of work that can be done is exactly equal to the energy available. This principle is called the **work-energy theorem** and applies to everything in the universe.

- a. Can you think of one everyday example that demonstrates the work-energy theorem?

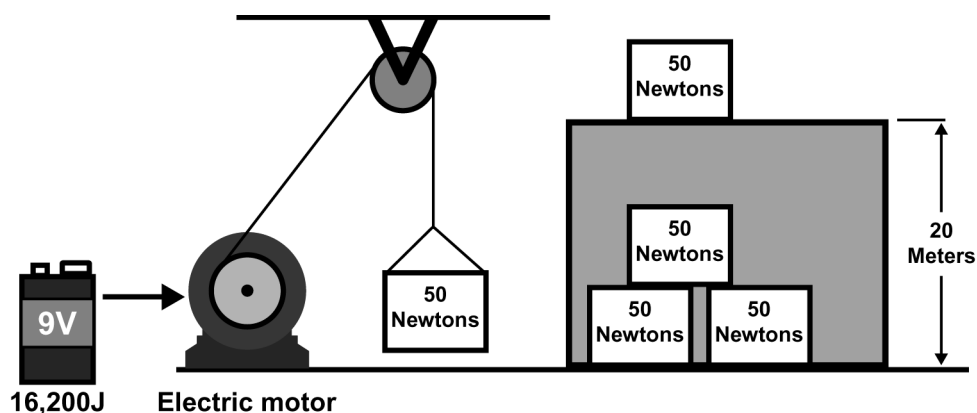
---

---

---

---

---



- b. One way to store energy is in a battery. One 9-volt alkaline battery stores approximately 16,200 joules of energy. Suppose you had a perfect electric motor and a pulley with no friction. How many 50-newton boxes can you lift to a height of 20 meters using the energy stored in the battery? Solve the problem and show your work.

---

---

---

---

---

---

---

---

---

---

Name:

## 5.2

# Energy Conservation



Question: What is energy and how does it behave?

**1**

### Setting up the roller coaster

At which place (or places) on the roller coaster do you think the marble moves fastest? Why?

---

---

---

**2**

### Measuring the speed of the marble

Follow the procedures in your Investigation guide. Record your data in the table below.

Position number	Time, photogate A (sec)	Distance traveled (cm)	Speed of marble (cm/sec)
1			
2			
3			
4			
5			
6			
7			

- a. Did your measurements agree with your hypothesis or did they point to a different hypothesis? If the answer did not agree with your hypothesis, what sort of hypothesis do the observations support about where the marble is fastest?

---

---

---

---

- b. What did you notice about the motion of the marble from the measurements? For example, do you think that going uphill or downhill makes a difference in the speed? Does height affect speed? Which has a larger impact, height or direction (uphill or downhill)?

---

---

---

---

**3**

**Energy conservation**

Follow the procedures on your Investigation guide and record your data in the table below.

Position (cm)	Height (cm)	Time from photogate A (sec)	Distance traveled (cm)	Speed of marble (cm/sec)
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	
			1.9	



**c.** Does the uphill or downhill direction matter to the speed of the marble, or is the height the only contributing variable?

---

---

---

---

**d.** Describe the flow of energy between potential and kinetic along the roller coaster. Your answer should indicate where the potential energy is greatest and least, and also where the kinetic energy is greatest and least.

---

---

---

---

---

---

---

---

Name:

## 5.3

## Energy Transformations



Question: *Where did the energy go?*

**1**

### Kinetic to potential, or potential to kinetic?

For each scenario, specify whether kinetic energy is being changed to potential energy, or potential is being converted to kinetic. Explain your answers.

- a. A roller coaster car travels from point A to point B.

---

---

---

---

---

---

- b. A bungee cord begins to exert an upward force on a falling bungee jumper.

---

---

---

---

---

---

- c. A football is spiraling downward toward a football player.

---

---

---

---

---

---

- d. A solar cell is charging a battery.

---

---

---

---

---

---

Read each scenario below. Then, working with your group, complete the following for each scenario:

- Identify the types of energy involved.
- Identify where potential energy is being converted to kinetic energy or kinetic to potential.
- Make an energy flow chart that shows the energy transformations that are occurring. Use a separate paper (newsprint, if provided) and colored markers to make your flow charts more interesting.

**Be prepared to explain to the rest of the class the reasoning behind your group's ideas, and then to discuss them.**

**Scenario 1:**

In Western states, many homes generate electricity from windmills. In a particular home, a young boy is using the electricity to run a toy electric train.

---

---

---

**Scenario 2:**

A camper is using a wood fire to heat a pot of water for tea. The pot has a whistle that lets the camper know when the water boils.

---

---

---

**Scenario 3:**

The state of Illinois generates most of its electricity from nuclear power. A young woman in Chicago is watching a sports game on television.

---

---

---

**Scenario 4:**

A bicyclist is riding at night. He switches on his bike's generator so that his headlight comes on. The harder he pedals, the brighter his headlight glows.

---

---

---