Level A Investigations

A-1 The Lever

How does a lever work?

This Investigation introduces the students to gears and angles. Students work with pairs of gears and determine the rule that relates the number of turns of one gear to the number of turns of another.

A-2 Gears

What are gears and how do they work?

This Investigation introduces the students to gears and gear ratios. Students work with pairs of gears and determine the rule that relates the number of turns of one gear to the number of turns of another.

A-3 Compound Gear Machines

How can you build machines with higher gear ratios?

Students learn how to calculate gear ratios for complex gear machines. First, they discover that placing a third gear between a pair of gears does not change the original gear ratio. Next, students experiment with stacking two gears on a single axle, creating an inner pair of gears and an outer pair of gears. They learn that multiplying the inner gear ratio by the outer gear ratio will give them the overall gear ratio for their compound gear machine. Finally, they build their own complex gear machine and find its gear ratio.

A-4 Designing Gear Machines

How can you design machines with different ratios?

Students use the skills they have learned to design gear machines. They begin with a simple number theory exercise to determine which gear ratios are possible using the CPO gears. Next, they design their own gear machine using mathmatical principles. Finally, they build and test their own gear machines.

Level B Investigations

B-1 Levers, Torque and Mechanical Advantage

How do levers work?

This Investigation uses the levers to explore mechanical advantage and simple machines. The concept of torque is developed, and students become familiar with units of Newton-meters and foot-pounds. It also applies the equilibrium principle to all three types of levers as the students construct each type and compare its measured mechanical advantage to the projected value.

B-2 Gears and Rotating Motion

How do simple gear machines work?

This Investigation extends the concept of torque to rotating machines. The students construct simple and compound gear machines and measure rotation to determine the law of gearing.

Level B Investigations (continued)

B-3 Compound Gear Machines

How can you build machines with higher gear ratios?

In this Investigation, students learn to build compound gear machines and calculate the gear ratios. Next, they use number theory to determine which gear ratios are possible using the CPO gears. Finally, they design and test their own machines.

B-4 Machines with Gears and Levers

How does a bicycle work?

Students explore combinations of gears and levers to help them understand how a bicycle works. They build machines using two gears and two levers, and develop a mathematical rule for making the two levers balance. After completing this activity, students should be able to calculate gear ratios on a multi-speed bicycle and to explain which gear ratios are most useful for pedaling uphill, and which gear ratios are most useful for pedaling on a level surface.

Level C Investigations

C-1 Rotational Motion

How is the speed of a rotating object measured?

Students use a timer and photogates to measure the speed of a rotating gear. They learn to express the speed in revolutions, radians, and degrees per unit time. The difference between linear and rotational speed is discussed. In the optional activity, students are given the opportunity to relate rotational speed to the frequency of sound, using a solar cell, a laser pointer, and a small speaker/ amplifier.

C-2 Center of Gravity and Equilibrium

How can the weight of the Lever be determined using the principle of rotational equilibrium?

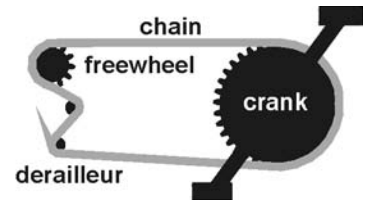
Students use their understanding of rotational equilibrium to solve a problem. They identify forces contributing to clockwise and counter-clockwise torque in the lever. Next, they write an equation relating clockwise and counter-clockwise torque that will allow them to solve for the weight of the lever. They test their equation with two different configurations of the lever and then compare their results with the weight of the lever found experimentally.

Question: How does a bicycle work?

In this Investigation, you will:

1. Explore what happens to forces that are applied through gear machines.
2. Identify a mathematical rule that predicts how to balance a machine with gears and levers.

Bicycles use gears *and* levers to enable the muscle power from your legs to turn the rear wheel. The connection between the crank and the freewheel is made with a chain so that the gear ratio can be changed while the bicycle is moving. Modern bicycles have between one and 24 different speeds. Each speed corresponds to a different gear ratio.



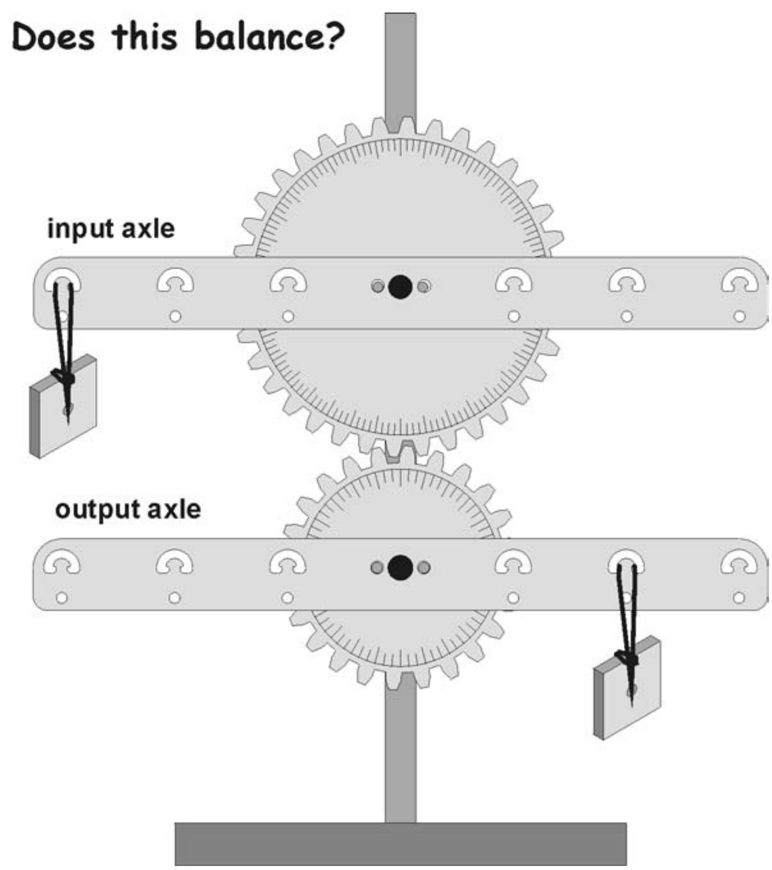
Why do some gear ratios on a bicycle make it easier to pedal than others? Why do some gear ratios allow you to go faster than others?

1 Setting up the experiment

1. You can use the long thumbscrews to attach a gear and lever to the stand on the same axle. The lever must be in the *outside* position.
2. Create machines with gears and levers like the one shown at the right.
3. Add weights to the levers. Move the weights around, and try to find the rule that makes the machine balance.

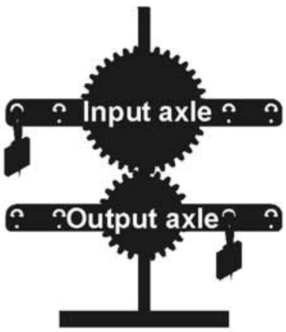
The rule must include the following variables:

- The number of weights on input and output axles,
- The distance that the weights are hung from the center of the levers, and
- The number of teeth in the gears.



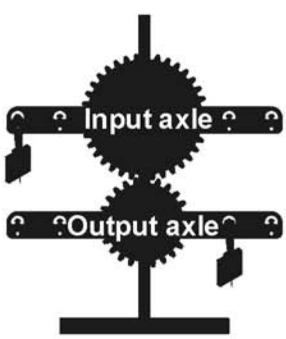
2 Doing the experiment

1. Use the table below to write down any combinations you try that balance the levers. You can try any combinations of two gears and different arrangements of weights.



		Combinations that balance the levers					
Input axle	Teeth						
	Weights						
	Distance						
Output axle	Teeth						
	Weights						
	Distance						

2. From your measurements, you should be able to find a rule that predicts when the lever will balance. The rule should relate the teeth, weight, and distance on the *input axle* to the teeth, weight, and distance on the *output axle*. Write your rule in the form of an equation, just like the gear rule.
3. **Challenge!** Use your rule to fill in the missing blanks in the table below. (Hint: you may need gears with numbers of teeth other than 12, 24, or 36.)



		Combinations that balance the levers					
Input axle	Teeth	24	24		12	96	12
	Weights	4	1	1	4		3
	Distance	30	20	10	30	10	10
Output axle	Teeth	12		36	36	12	
	Weights		2	4		1	9
	Distance	10	10	10	30	10	10

3 What did you learn?

a. If you were pedaling a bicycle up a hill, would you rather have a large input gear and a small output gear *or* a small input gear and a large output gear? Explain your reasoning.

b. If you were trying to go farther with fewer turns of the pedals, which arrangement of input and output gears would you want on a bicycle?

Name:

B-4 Machines with Gears and Levers

B-4

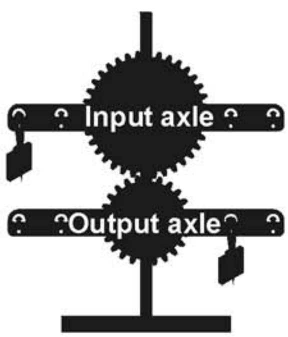
Question: How does a bicycle work?

1 Setting up the experiment

There are no questions to answer in Part 1.

2 Doing the experiment

1. Use the table below to write down any combinations you try that balance the levers. You can try any combinations of two gears and different arrangements of weights.

			Combinations that balance the levers					
	Input axle	Teeth						
		Weights						
		Distance						
	Output axle	Teeth						
		Weights						
		Distance						

2. From your measurements, you should be able to find a rule that predicts when the lever will balance. The rule should relate the teeth, weight, and distance on the *input axle* to the teeth, weight, and distance on the *output axle*. Write your rule in the form of an equation, just like the gear rule.

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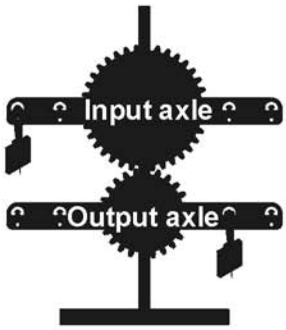

		Combinations that balance the levers					
Input axle	Teeth	24	24		12	96	12
	Weights	4	1	1	4		3
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Output axle	Teeth	12		36	36	12	
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	Distance	10	10	10	30	10	10

3 What did you learn?

a. If you were pedaling a bicycle up a hill, would you rather have a large input gear and a small output gear *or* a small input gear and a large output gear? Explain your reasoning.

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b. If you were trying to go farther with fewer pedals, which arrangement of input and output gears would you want on a bicycle?

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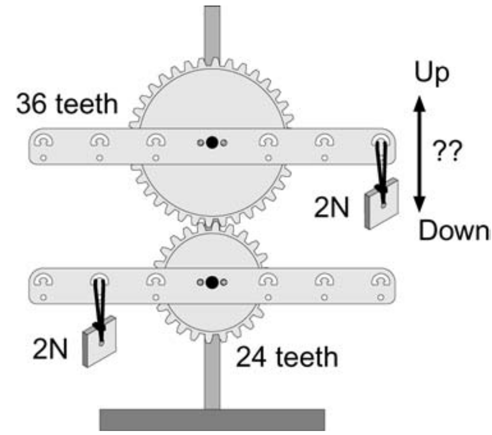
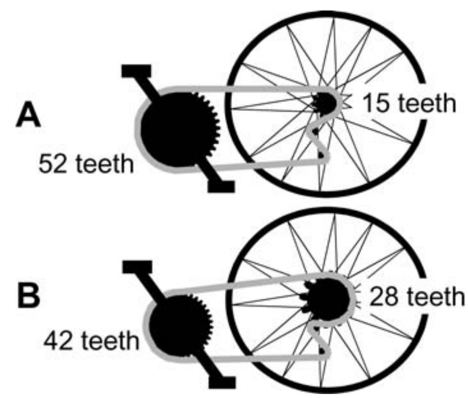
Questions

1. A machine is constructed as shown with a 36-tooth gear, a 24-tooth gear, two levers, and two 2-newton weights. When the top weight is hung in the location shown, will it go up or down? Why?



2. Where could you hang the top weight so that the machine would balance?

3. Which arrangement of gears on a ten-speed bicycle would be more useful for climbing hills?



Extra space for notes:

Curriculum Resource Guide: Gears and Levers

Credits

CPO Science Curriculum Development Team

Author and President: *Thomas Hsu, Ph.D*
Vice Presidents: *Thomas Narro and Lynda Pennell*
Writers: *Scott Eddleman, Mary Beth Abel, Lainie Ives, Erik Benton and Patsy DeCoster*
Graphic Artists: *Bruce Holloway and Polly Crisman*

Curriculum Contributors

David Bliss, David Lamp, and Stacy Kissel

Technical Consultants

Tracy Morrow and Julie Dalton

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Cambridge Physics Outlet
26 Howley Street,
Peabody, MA 01960
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