Important Concepts . . .

Preview Review

Science *Grade 8* *TEACHER KEY*

W1 - Lesson 4: Gears, Mechanical Advantage, Speed Ratios, and Efficiency

V5-07

Important Concepts of Grade 8 Science

Materials Required

Textbook:
Science in Action 8

Science Grade 8
Version 5
Preview/Review W1 - Lesson 4 TEACHER KEY

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Preview/Review Concepts for Grade Eight Science

TEACHER KEY

W1 - Lesson 4:

Gears, Mechanical Advantage, Speed Ratios, and Efficiency

OBJECTIVES

By the end of this lesson, you should

- identify and describe different types of gears
- do simple calculations for reducing and multiplying gears
- calculate the mechanical advantage, speed ratios, and efficiency of simple machines

GLOSSARY

efficiency - how well something uses energy for its intended purpose

gears - wheels with interlocking teeth used to transfer energy

mechanical advantage - amount by which a machine multiplies force

multiplying gears - gears which increase output speed

reducing gears - gears which reduce output speed

speed ratio - the measure of how the speed of an object is affected by a machine

W1 - Lesson 4: Gears, Mechanical Advantage, Speed Ratios, and Efficiency

Welcome to W1 - Lesson 4. This lesson is designed to teach you about **gears**, **mechanical advantage**, **speed ratios**, and **efficiency**. It should take about 1.5 hours to complete.

Gears

An important simple machine not yet discussed is the **gear**. Gears are wheels with teeth that interlock. The wheel that has an external force applied to it is the **driving gear**; the one that receives force from the driving gear is the **driven gear**. **Sprockets** are gears joined by a chain, as on a bicycle.

When the driving gear is larger than the driven gear, they are called **multiplying gears**. Speed is increased and force decreased using this combination.

See what happens if you use the following multiplying gear combination on a bike.

driving gear (front sprocket) has 48 teeth
driven gear (back sprocket) has 12 teeth

Everytime you push the foot pedal one complete rotation, the front sprocket turns the same. The back sprocket will turn

$$\frac{48}{12} = \textbf{4 turns in the same time}$$

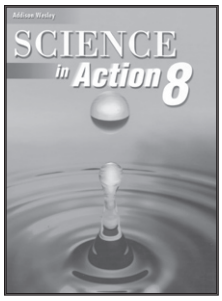
This will turn the back tire four complete rotations, to speed the bike up.

When the driving gear is smaller than the driven gear, they are called **reducing gears**. Speed is decreased and force is increased.

An example of reducing gears can be found in a mechanized display tray. If the driving gear has 10 teeth and the driven gear has 100 teeth, the tray (attached to the driven gear) will turn

$$\frac{10}{100} = \textbf{0.1 times for every turn of the driving gear}$$

In other words, to turn the display once, the driving gear must turn 10 times.



Activity 1

Read and understand pages 274 to 275 in *Science in Action 8*. Then, answer the following questions.

1. A driving gear has 18 teeth, and the driven gear has 6 teeth. How many times does the driven gear turn for every one turn of the driving gear?

   18/6 = 3 times

2. Assume the following information for a bicycle. The front sprocket used has 48 teeth, the back sprocket used has 8 teeth. For every turn of the back sprocket, the back tire (circumference = 2.5 m) also makes one complete turn. How far does the bike move with every turn of the front sprocket?

   48/8 = 6 turns x 2.5 m/turn = 15 m

3. If you were riding a bike in a race, what type of gear combination would you want to use?

   The largest front sprocket and smallest back sprocket possible.

4. If you were riding a bike up a steep hill, what gear combination would you want to use?

   The smallest front sprocket and largest back sprocket possible.

5. What type of gear gives more force than speed?

reducing gears

Machines affect the amount of force applied to an object or load, plus the speed at which a load is moved. Different machines have different efficiencies. The mechanical advantage, speed ratio, and efficiency can be calculated for any machine.

Mechanical Advantage

One of the main reasons we use machines is to do something with less force. In other words, we want to gain a mechanical or force advantage. The **mechanical advantage** of a machine is determined by finding the ratio of output force to input force. The equation used for this is

$$\textbf{Mechanical Advantage (MA)} = \frac{\textbf{Output force}}{\textbf{Input force}}$$

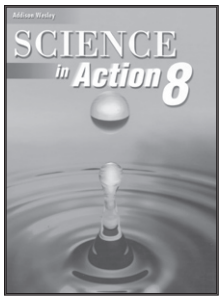
The greater the ratio, the greater the mechanical advantage, and the less the force needed as input. For example, a MA of 6 means the machine applies 6 times the force you put into it; a machine with a MA of 2 applies only 2 times the force you put into it.

If a machine has a MA less than 1, you are putting more force into it than you are getting out of it. In that case, you are probably using the machine to gain a speed advantage.

An example of mechanical advantage is seen in a pulley system. This system required 100 N input force to get 3000 N output force. The mechanical advantage of the machine is

$$\frac{\textbf{3 000 N}}{\textbf{100 N}} = \textbf{30}$$

In other words, you can get out 30 times the effort you put into this machine.



Activity 2

Read and understand page 280 in *Science in Action 8*. Then, answer the following questions.

1. The machine you are using requires an input force of 60 N to put out 300 N force. What is the mechanical advantage of this machine?

$$MA = \frac{300\ N}{60\ N} = 5$$

2. Give an example of where you might want a force advantage.

Answers will vary. An example is when moving a heavy load.

Speed Ratios

Sometimes we want to have an object increase speed. We can use simple machines to do that. A **speed ratio** tells how much a machine affects the speed of a load.

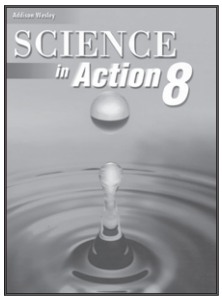
$$\textbf{Speed Ratio (SR)} = \frac{\textbf{Input distance}}{\textbf{Output distance}}$$

The greater the ratio, the SLOWER the load moves and the faster the input part moves. If you want the load to move faster than the input, the speed ratio of the machine must be less than 1.

A speed ratio can be calculated for a class 1 lever. If the end of the load arm moved 0.5 m in the time it took the effort arm to move 2 m, the speed ratio is

$$\frac{\mathbf{2\ m}}{\mathbf{0.5\ m}} = \mathbf{4}$$

In other words, the load moved one-quarter times as quickly as the effort and the effort moved four times as quickly as the load.



Activity 3

Read and understand page 281 in *Science in Action 8*. Then, answer the following questions.

1. Where might you want a speed advantage?

   Answers will vary but an example is in a bike race.

2. To pull a load 2 m using a particular pulley arrangement, the rope must be pulled 12 m. What is the speed ratio of the pulleys?

$$\frac{\boldsymbol{12\ m}}{\boldsymbol{2\ m}} = \boldsymbol{6}$$

Summary: The greater the mechanical advantage a machine produces, the slower it will move the load. Conversely, the less the mechanical advantage, the faster the load will move.

Another way of saying this is the easier it is to move a load a certain distance, the further the input must move to do it. An example is a pulley system with a mechanical advantage of 4. To move its load 1 m, the input rope must be pulled 4 m.

Efficiency

Efficiency is a measurement of how well a machine or device uses energy. The formula to calculate efficiency is

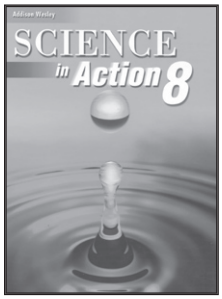
$$\textbf{Efficiency} = \frac{\textbf{Mechanical Advantage}}{\textbf{Speed Ratio}} \times 100$$

or

$$\textbf{Efficiency (\%)} = \frac{\textbf{MA} \times 100}{\textbf{SR}}$$

If a machine has a mechanical advantage of 3 and a speed ratio of 4, its efficiency is

$$\frac{3}{4} \times 100\% = 75\%$$



Activity 4

Read and understand pages 284 to 286 in *Science in Action 8*. Then, answer the following questions.

1. Why are machines never 100% efficient?

   Energy is always lost to heat / friction.

2. What are some ways of dealing with heat caused by friction in machines?

   Lubricants and fans.

3. Explain why the mechanical advantage of a machine is affected by friction, but the speed ratio is not.

Friction affects the amount of force which must be put into the systen and the amount that it puts out.

MA = Output force/Input force

The speed ratio is calculated using input + output distance – not changed by friction.

4. The following information is known about a simple machine.

Input force = 12.0 N	Input distance = 0.5 m
Output force = 5.0 N	Output distance = 1.0 m

What is the efficiency of the machine?

$$MA = \frac{5.0\ N}{12.0\ N} = 0.417$$

$$SR = \frac{0.5\ m}{1.0\ m} = 0.5$$

$$Efficiency = \frac{MA}{SR} \times 100\%$$

$$= 83\%$$

You should now be able to meet all of the objectives listed at the beginning of the lesson. Go through the list to see if there is anything you need to spend more time on.

Extended Activity (Homework)

Look for gears on some machines at home. Determine if they are multiplying or reducing gears.

Answers will vary.