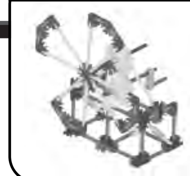


The Crank Fan:

An example of the use of a spur gear system.

OBJECTIVES

Students will:

1. Understand and describe the transfer of motion through a spur gear system.
2. Investigate the relationship between gear size, speed of rotation, and force.

MATERIALS

Each student group will need:

- 1 K'NEX Gears Building Set with Building Instructions booklet
- Masking Tape
- Dot stickers (optional)
- Student Journals

You will need:

- Pictures and examples of different spur gear systems. (Suggestions: music box; electric fan; hand-held can opener; gear operated toy.)
- K'NEX gears for students to examine before they begin the building activity. (Remove a sufficient number of gears from **each** K'NEX Introduction to Simple Machines: Gears set so that each student has access to 2 gears.)
- 2 large rubber balls (optional.)
- Cardboard and Popsicle sticks (optional)

NOTE: As described below, this activity may take more than 45 minutes.

PROCEDURE

Introduction

- If this is the students' first experience with gears, you may want to demonstrate the transfer of energy from one object to another. Using two large rubber balls, have a student roll one ball into the other. Ask the students to describe their observations. Use the following questions to help them identify what took place:
  - What did the first ball do to the second ball?
    The first ball pushed the second ball.
  - When was the exact moment that the pushing took place?
    The first ball pushed the second ball when the two balls came into contact.
  - What was transferred from one ball to the other?
    Motion, energy, force.
- Distribute 2 gears to each student. Encourage them to think about how they would describe a gear and to explore how gears fit together.
- Begin the lesson by discussing and expanding what the students have discovered about their gears. You may choose to accept their operational definition for how the gears operate, or formalize the terms they use in describing the gears and how they fit together.
  Gears are wheels with teeth around their outer rim. The teeth of one gear fit between (mesh with) the teeth on the other gear.

- Explain that gears are simple machines that transfer energy in the form of motion from one location to another. Use a child's gear toy or a gear train that you construct from cardboard to demonstrate what happens when you rotate one gear that is in contact with a second gear.

Suggestion: Use circles of cardboard and carefully glue Popsicle sticks to them to represent gears. Make sure that the Popsicle sticks are evenly spaced around the circles. It is easier to make a pair of gears that are the same size than gears that have different numbers of teeth. Mount the gears to a larger piece of cardboard with pushpins, making sure that they mesh and rotate easily.

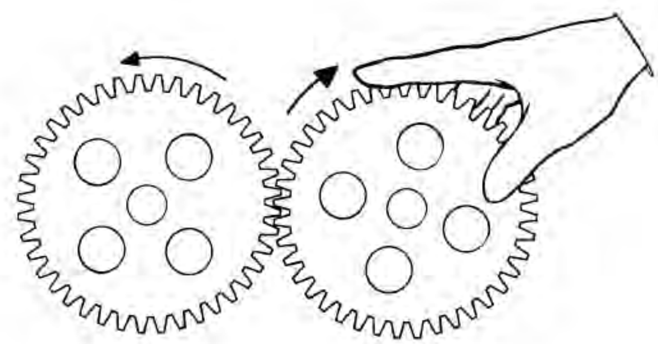
- Distribute pieces of tape or dot stickers. Instruct students to place a small piece of tape (or dot sticker) on each of the two K'NEX gears they used earlier so they can observe the direction that the gears move. Ask students to lay the gears on a piece of paper on their desk and to mesh the gear teeth together. Ask one student to put a pencil point in the hole on each gear to hold them in place while the other student turns one gear.

- Ask the students how they are able to move only one gear and cause the second gear to also move.

As one wheel turns, its teeth push against those on the other gear wheel. See diagram below.

- Encourage the students to see how many gears they can put together into a gear train. They should sketch and label the direction of rotation of each gear.

- This is an excellent opportunity to introduce formal terms that the students should use during their experiments with gears. This activity lends itself to the introduction of **driver gear, driven (or follower) gear, and gear train.**



- Ask the students to describe in which direction each of their gears turned.

If the first gear wheel is turning in one direction, it will push the second gear wheel in the opposite direction.

- Ask the students to think of other examples of gears used in their daily lives. Many students will identify the gears on bicycles. This will give you the opportunity to explain that there are several different types of gear systems and that the type used will depend on the job that needs to be done. For example, the gear system on a bicycle is different from the gear system in a can opener.

- Pass a hand-held can opener around the room. Allow the students time to explore the gear mechanism.

- Encourage the students to brainstorm a list of other objects that use gear systems. Record these on the board. Be prepared to show examples if the students are not aware of any gear systems.

- You may wish to introduce the concept of motion and use formal terms to describe the types of motions the students used in the previous activity. Some of the terms you may want to include are: **input motion** (the students' hands turning the first gear), **output motion** (the movement of the second gear caused by the input motion), **rotational motion** (turning about a point), **linear (straight-line) motion.** (Provide the students with an example of linear motion as a comparison to rotational motion.)

Motion refers to an object's change of position over time in relation to a reference point.

- Divide the class into groups made up of 2 to 3 students.

Building Activity

- Distribute a K'NEX Gears building set to each group. Ask the students to open the materials and locate the Building Instructions booklet. If the class has not used K'NEX building materials, review the Building Tips page, particularly the information about the purple connectors. Allow the students some time to explore the materials – it is crucial that they grasp the building concept at this stage so that frustrations are avoided later. Make sure the students return the gears handed out in the earlier part of the lesson to their set.
- Provide some basic guidelines for keeping track of all the pieces in the set so that they will be available for future use. Remind students that they will need about 5 minutes at the end of the class period for clean up.
- Explain that they will build a model of a crank fan that uses a gear system to turn the fan blades. Direct their attention to the photo of an electric fan on Page 2 of the Building Instructions booklet or have an actual example for display in the classroom.
- Ask students to build the model according to the instructions booklet.

Building Tip:

To prevent the 2 red axles from coming loose in their housing we recommend adding gray connectors. (These are the small clips – approximately 2.5 cms. long - with one closed, circular end through which a rod may pass and one open end into which a rod can be snapped.) They should be added in the following locations:

1. At the free end of the upper fan blade axle.
2. On either side of the existing gray connectors on the lower or crank axle.

Inquiry Activity: How is motion transferred through a spur gear system?

Use the following guidelines and script to help the students explore the function of a spur gear system.

Steps

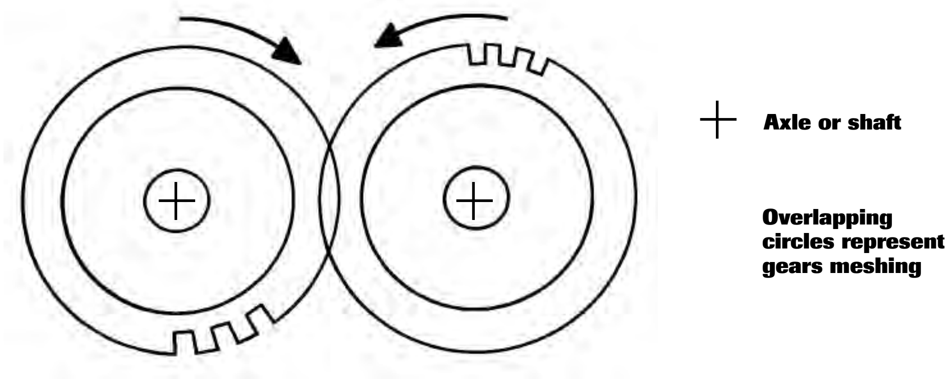
1. (a) When the models are completed, allow the students time to explore. Ask them to locate and identify the gears. They should watch the gear mechanism in operation as they turn the crank.

   (b) Encourage the students to identify any additional simple machines with which they are familiar and that may be present in their fan models.

If your class has already completed the wheel and axle investigations, this is an ideal opportunity to facilitate a quick review of this simple machine.

(c) Ask the students to explain how the gear system turns the fan blades. Help students to see that the fan's gears fit together and that they are in line with one another. Remind students of their earlier investigation where they used the gears in line with each other as the gears lay flat on the table. Explain that in this arrangement, known as a spur gear system, the gears fit together, or mesh, along the same line or in the same plane. In this model the gears are arranged one above the other. You may have to ask students to turn the model on its side so they can see that the gears are in line with each other as they were in the previous activity.

2. (a) Ask the students to draw a diagram of the crank fan in their journals. The gears can be represented symbolically – there is no need for the students to attempt to draw every tooth in the gear wheels. For example:



(b) Encourage the students to give names to the various parts of their model. You can then formalize these and ask them to label their diagram appropriately. Labeled parts will include:

Crank, driver gear, driven gear, and fan blades.

3. The students should respond in their journals to the following:

- Does the fan have moving parts? List the moving parts in your journal.

  Crank, driver gear, driven gear, fan blades.

- Describe how the moving parts that you listed above are connected to each other.

  The crank is connected to the driver gear by an axle. The teeth on the driver gear mesh with the teeth on the driven gear, which is connected to the fan blades by an axle.

- Describe the input motion - the motion they use when they operate the crank.

  The input motion is circular or rotational. They turn their hand in a circle.

- Describe the motion of the gears.

  The gears turn or rotate.

- Draw arrows on your diagram to show the direction each part moves as you operate the fan.

4. Ask the students to attach a small piece of masking tape to the edge of one fan blade and ask them to select a reference point so they can keep track of the fan blade as it rotates. Encourage them to turn the crank.

(a) Ask the students to turn the crank to make one rotation. Have them continue turning the crank but they should vary the speed at which it is turned.

Ask them how they can make the fan turn faster/slower.

Students should observe that the speed of the fan was entirely dependent upon the speed at which the crank was turned.

(b) Suggest that they mark the two gear wheels with either a dot sticker or with a pencil mark. The marks should be made at the point where the two gears mesh. Then ask them to make one slow turn of the crank. What do they notice?

BOTH gears make one complete rotation with one turn of the crank.

(c) Students should note in their journals the sizes of the two gears - driver and driven – used in the model.

They are the same size.

(d) Do they think there could be a relationship between the size of the gears and their findings to (b) above?

The students should be helped to understand that these two gears, that are the same size and meshed together, rotate at the same speed even though they are on different axles.

(e) Ask the students to turn the crank one additional turn, but this time, ask them to notice how far the fan blades travel. One student should count the number of times the blade with the masking tape passes the selected reference point, while the other should focus on making just one full turn with the crank.

The fan blades also make one complete turn with one turn of the crank.

(f) How easy/hard is it to turn the crank with this gear arrangement?

Note: This will generate subjective responses, but will help the students make comparisons when they explore other gear arrangements for the model.

(g) Ask them to summarize what their observations show concerning the distance the two gears and the fan blades turn with one rotation of the crank.

Students should notice that all the moving parts rotate once with one turn of the crank.

NOTE: We recommend that 2 groups work together for Step 5 below. One group should build the model with the large gear as the driver, and the other group should build the version of the model with the small gear as the driver. Having both models available will make comparisons easier.

5. (a) Ask the students to speculate what they think will happen if they use

   (i) a large gear wheel to drive a small gear wheel and

   (ii) a small gear wheel to drive a large gear wheel.

   They should make a note of their responses in their journals.

   (b) Encourage the students to discover if their predictions were correct by rebuilding their models using two gears that are different in size. They should use the diagrams on the right hand side of Page 3 of the Building Instructions booklet as a guide.

   (c) Ask them to think of a way to compare the speed that the fan turns, with the speed of the crank when the big gear is attached to the crank and the small gear is attached to the fan blades.

   Use the technique adopted in Step 4 - put a piece of masking tape on one fan blade and observe where it is before a turn of the crank and then notice how many times the tape passes that same point when the crank is turned one time.

   (d) How easy/hard is it to turn the crank with this arrangement compared to when the gears were the same size?

   All their observations should be recorded in their journals.

   Students should observe that when the big gear drives the small gear, the fan turns more quickly than the crank: 1 turn of the crank results in approximately 6 turns of the fan blades. The crank, however, is harder to turn than it was when the model had both gears the same size.

   (e) Students should then compare the speed at which the fan turns with the speed of the crank, when the small gear is attached to the crank axle and the big gear is attached to the fan blade's axle.

   (f) How easy/hard is it to turn the crank with this arrangement, compared to when the gears were (i) the same size and (ii) the large gear was the driver?

   Observations should be recorded in their journals.

   Students should observe that when the small gear drives the big gear, the fan turns more slowly than the crank: it takes 6 turns of the crank for the fan blades to make 1 complete rotation. The crank, however, is easier to turn than in either of the other 2 gear arrangements.

6. (a) Discuss their observations of gear systems using different sized gears.

   (b) Ask the students if their observations support the prediction that they each wrote earlier. Encourage the students to support their conclusions using evidence from their investigations.

Applying The Idea

- Review the findings of Step 3 with the class:
  - Did the crank and the gear on its axle move at the same speed?

    They move at the same speed: one turn of the crank (wheel) causes the gear on the same axle to rotate once.

  - Did you notice the same results when you used a smaller gear? A larger gear?

    Yes. Even when gears are a different size, if they are on the same axle they will rotate at the same speed.

  - When you operated the fan using two gears that were the same size, which of these statements was true?

    The driver gear turned faster than the driven gear?

    The driven gear turned faster than the driver gear?

    They both turned at the same speed.

    They turned at the same speed: one rotation of the driver gear turned the driven gear through one rotation.

- Ask the class to summarize these findings about the fan with the same sized gears by completing the following sentences:
- Gears that are on the same axle rotate at the

  ________________ ________________

  same speed

- Gears that mesh and are the same size rotate at the

  ________________ ________________

  same speed

- In this crank fan all the moving parts rotate at the

  ________________ ________________

  because the driver gear and the driven gear are the

  ________________ ________________

  same speed; same size

  - Ask the students to record the advantages and disadvantages of the 2 different gear systems they investigated in Step 4.

    Turning the crank was easier when the small gear turned the large gear. However, the fan turned more slowly than the crank. Although the crank was harder to turn when the large gear turned the small gear, the fan blades turned much faster than the crank.

  - Encourage the students to discuss situations where each gear system would be most useful. Encourage them to include “effort force,” “driver gear,” and “driven gear” in their responses.

    Answers will vary. Possible answer: A small gear turning a large gear would be most useful if the object that must be turned is heavy. Turning a large, heavy object would need less effort force when the driver gear is smaller than the driven gear.

Extending The Idea

(Suggested grade levels are indicated.)

[Grades: 3-4.]

1. Suggest that the students search the Internet for additional information about gear systems. They could conduct a Google® search using the key word: "gear."

[Grade: 5.]

2. (a) Remind the students that they used a crude measurement to compare the input and output speeds of the gear wheels when they completed Steps 4(e), 5(c), and 5(e). Explain that what they discovered was a simple **Gear Ratio**.

   (b) Explain that a more accurate approach is to compare results by counting the number of teeth on each gear wheel. Write the equation for the **Gear Ratio** on the blackboard, dry board, or overhead projector so that it is visible from any location in the classroom.

$$\textbf{Gear Ratio} = \frac{\textbf{Number of teeth on the driven (follower) gear}}{\textbf{Number of teeth on the driver gear}}$$

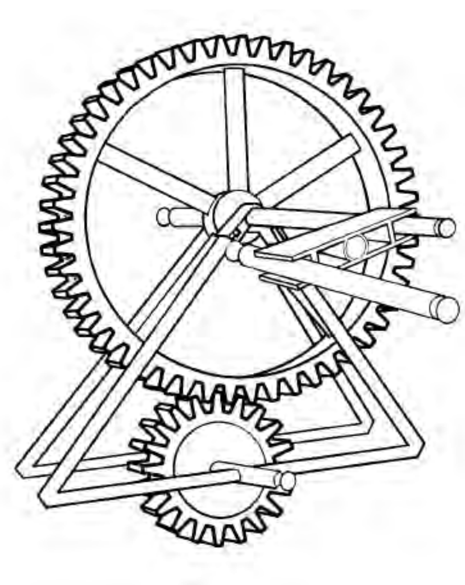
For example: 14/84 gives a gear ratio of 1/6 or 1:6

Explain that a 1:6 gear ratio means that for every complete revolution of the driver gear, the driven gear makes 6 complete revolutions. Or, said another way: the output speed is faster than the input speed.

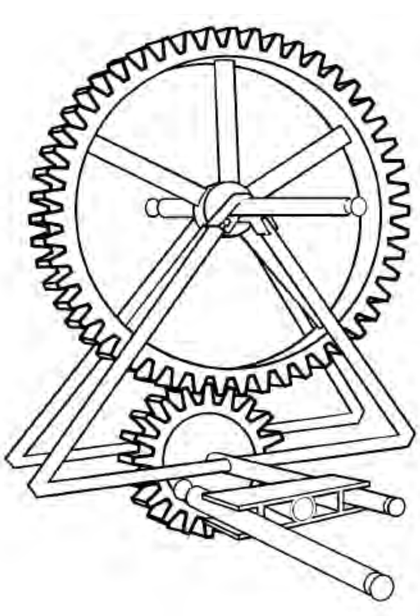
[Grades: 3-5.]

3. (a) Ask all the student groups to remove the fan blades from their crank fans and set them aside.

   (b) Divide the groups so that half have crank fans in which the large gear is the driver gear and the small gear is the driven gear. The remaining groups should have crank fans in which the smaller gear is the driver gear and the larger gear is the driven gear. Students do not need to disassemble their fans. Simply have students attach the crank to the appropriate shaft. (See diagrams below.) In order to watch the speed of rotation of the second gear in the gear chain, students should attach a yellow connector to the end of that gear's axle. (This connector replaces the blades that, if used on the lower axle, will strike the tabletop unless the model is pushed to the very edge.)



Set-up one: Crank on upper axle. Put the yellow connector on the end of the lower axle.



Set-up two: Crank on the lower axle. Put the yellow connector on the end of the upper axle where the blades used to be.

[Grade: 5.]

(c) Ask the students to determine the gear ratio of their crank fan. Students should write the gear ratio in their journals and describe, in their own words, what the gear ratio means in reference to their crank fan.

(d) Encourage the students to tell you what is gained by using this gear train. If students need clarification, ask them whether their fan turns quickly or slowly. You can then take this opportunity to help the students understand they cannot use a machine to gain both speed and force. They can gain speed at the expense of force or gain force at the expense of speed. If you decide to include this there is space provided in the chart below for students to record their findings.

[Grade: 5.]

4. The groups should exchange fans and repeat Step (d) above.

[Grade: 5.]

5. Ask the students to organize their observations and conclusions regarding gears in a table or chart. (See Journal Check below.) It may be helpful to provide a chart such as the one shown here.

GEAR TRAIN SPEED	FAN SPEED VS. CRANK SPEED	GEAR RATIO (APPROXIMATE)	INCREASED OUTPUT SPEED OR INCREASED OUTPUT FORCE
Gears are same size			
Large driver gear moving small driven gear			
Small driver gear moving large driven gear			

[Grade 4-5.]

6. Ask the students to brainstorm how they could change the design of the crank fan so that the crank and the fan turn in the same direction. If necessary, hint that they would have to add something to the mechanism. This will provide you with an opportunity to introduce the concept of the idler gear.

   Allow students time to test their ideas.

The crank and fan would turn in the same direction if a third gear – an idler gear - were added to the gear train between the driver and driven gears.

JOURNAL CHECK:

Students should keep individual journals to record their findings. The following are examples of the types of items that could appear in each student's journal:

- ✔ Diagram of crank fan including labels and arrows.
- ✔ Record of student observations.
- ✔ Predictions.
- ✔ Conclusions.
- ✔ A table such as the one shown below that summarizes their findings.

GEAR TRAIN SPEED	FAN SPEED VS. CRANK SPEED	GEAR RATIO (APPROXIMATE)	INCREASED OUTPUT SPEED OR INCREASED OUTPUT FORCE
Gears are same size.	Fan speed equals crank speed.	1:1	No change.
Large driver gear moving small driven gear.	Fan speed is greater than crank speed.	1:6	Increased output speed.
Small driver gear moving large driven gear.	Fan speed is slower than crank speed.	6:1	Increased output force.