

Let's Do Science

Grade Four

Wheels and Levers



4

Wheels and Levers

Science Alberta Programs for Your Classroom



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Wheels and Levers Before You Begin

In this unit and the following grade 4 unit—Building Devices and Vehicles that Move—students learn that even complicated-looking machines are made up of simple machines: levers, wheels, rollers, pulleys, gears and inclined planes. They discover how these simple machines make work and movement easier by changing the speed or force of movement.

The students also learn different techniques that can be used to transfer motion from one simple machine to another. As they work with these components, they explore the functions each simple machine can perform and develop a sense of how individual components can be combined to form a more complex device.

Topic B: Wheels and Levers

(Suggested time: 5-6 weeks)

This unit provides opportunity for students to explore a variety of simple tools and mechanical devices before tackling more extended tasks in the following unit. The materials for this unit can include recycled toys, which provide many examples of simple machines found individually or in combination with others. Some purchased materials can be helpful, especially sets of gears that mesh with one another, and sets of wheels, axles and pulleys.

Kits of mechanical materials can be used in extending the learning experiences within this and the following unit, but are not required.

Background Information

This is a unit on wheels and levers, two simple machines that assist us in performing work. Let's first look at what "work" means in the strict scientific sense of the word, then investigate exactly how levers and wheels lessen the amount of force we must exert to do specific tasks.

Scientifically speaking, *work* is what occurs when an object is moved over a distance by using force. This unit focuses specifically on work carried out against the force of gravity—the tendency of objects with mass to attract one another. In the immediate environment of Earth, all objects are attracted toward the Earth's centre. In order to make one of these objects go in the opposite direction, we must expend energy to "lift" it. We must do work.

Although the work needed to accomplish a given task is fixed, simple machines decrease the amount of force you must contribute to get the job done, or they increase the *mechanical advantage*. They accomplish this by:

- increasing the distance through which you apply force;
- adding the force of gravity to the force you are exerting; or
- changing the direction of the force you are applying in order to take advantage of the force of gravity.

Lever

exist in a variety of forms that make use of one or more of these approaches. All levers consist of three parts: a part where you apply force, a fulcrum and a part where the object is moved (see Fig. 1). The *fulcrum* provides a pivot point that changes the direction in which the force is exerted. By pushing down instead of lifting up, you take

advantage of your own weight (gravity's contribution to the force being applied).

You can gain further mechanical advantage from a lever by making the distance from the object to the fulcrum considerably shorter than the

distance from the fulcrum to the point where you are applying force—the basic idea behind a pry bar. Although you have to exert less force, the same amount of work gets done because you must apply your force through a greater distance (see Fig. 2).

When we think of a lever, more often than not we picture a setup

Figure 1.
The three parts of a lever.

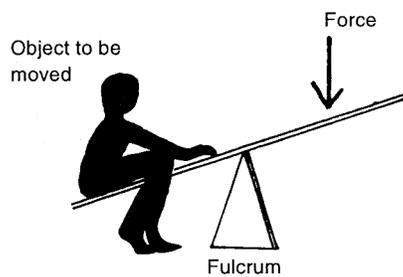
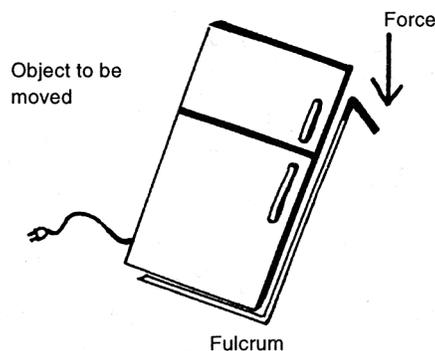


Figure 2.
Short distance between the
object to be moved and the
fulcrum.



as shown in the previous example. However, levers come in a wide variety of shapes and configurations. Consider a nut cracker, where the fulcrum (the hinge) is at one end of the lever instead of somewhere in the middle. Or what about compound levers like scissors, pliers and tongs? These tools (see Fig. 3) pivot two lever systems around one fulcrum (the hinge again).

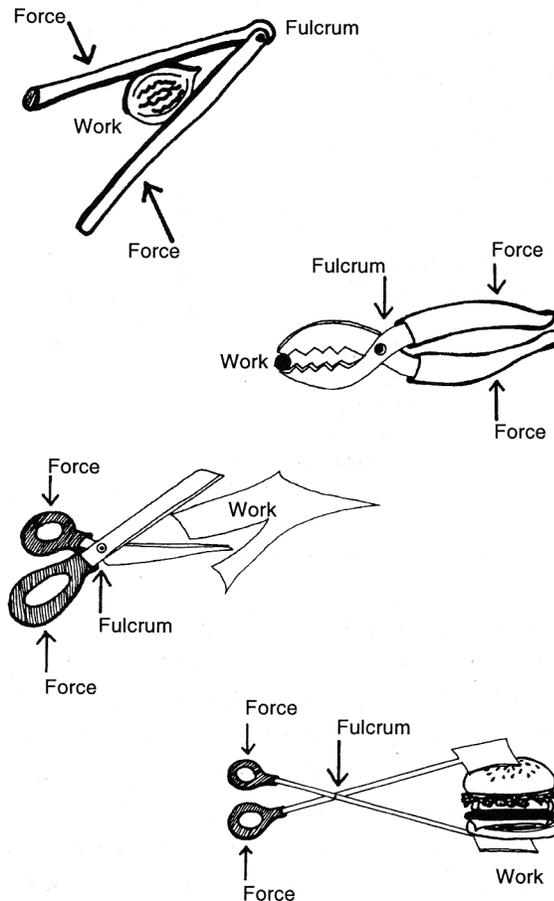


Figure 3.
 Different types of levers.

Wheels and rollers are other systems used to move objects. They are affected by friction, which can increase or decrease the work required to move objects. They are used to transport loads across surfaces because their curved shape minimizes their area in contact with the surface. This minimizes the friction encountered and thus the work needed to move the load. Compare the difficulty of pushing a large rock across a yard to the ease of transporting it in a wheelbarrow. A certain amount of friction is desirable, however. Without it, the

wheel or roller has no way to roll. Without traction, the wheel or roller simply spins in place, like a bald tire on a patch of ice.

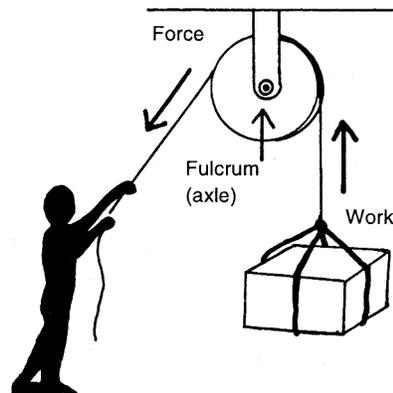
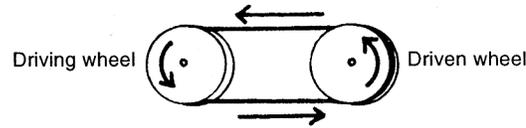


Figure 4.
 A fixed-pulley lever.

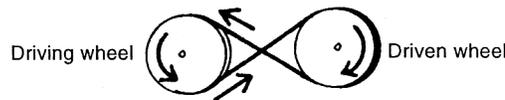
When a wheel has a groove on the outer edge and turns freely on an axle attached to a stationary position, you have a form of wheel and axle called a *fixed pulley*. This system uses rope wrapped over a wheel-and-axle system to change the direction force is applied (see Fig. 4). Gravity works for you, not against you.

Figure 5.
Gear systems.

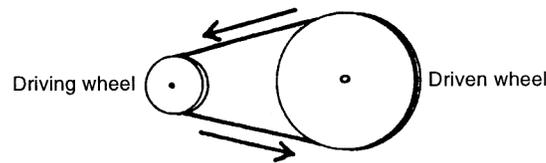
a. Transfer of motion.



b. Reversed motion.



c.



The two wheels in Fig. 5a are of the same size and are connected by a belt. In industry the belt would be quite wide and heavy. You may have seen this arrangement with a farm tractor and an old threshing machine. Note that the rotation of the driving wheel and the direction of rotation of the driven wheel are the same. The two wheels are of the same size and they would therefore turn

at the same speed. Frequently, wheels used in these arrangements are *pulleys* which have a V-shape along their edge to accommodate the belt and keep it in position.

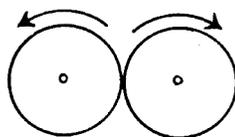
The two wheels in Fig. 5b are the same size and connected by a belt which has been crossed. The effect of this arrangement is to have the driving wheel and the driven wheel go in opposite directions.

In Fig. 5c one of the wheels is larger than the other. The smaller wheel in this case will be the one with power on it, thus the *driving wheel*. The larger wheel is the *driven wheel*. This arrangement allows for a change of speed in the driven wheel. For each turn of the driving (small) wheel, the driven (large) wheel will only turn part of a rotation. This allows the large wheel to exert more force.

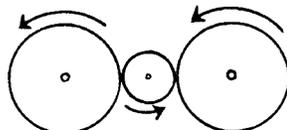
Rather than using a belt to transfer the energy from a source to a machine, the driving wheel and the driven wheel may be connected directly, by contact with each other, or through the use of cogs cut into the wheels, which mesh with each other. This creates a *gear system*.

Figure 6.
Drive systems that use
wheel-to-wheel contact.

a. Wheels turn in opposite directions.



b. The use of an idler wheel to have both large wheels turn in the same direction.



In Fig. 6a two wheels are allowed to make contact with each other. The friction between the wheels causes them to turn. Once again the direction of rotation and speed will depend

on the arrangement of the wheels. This arrangement is not very efficient in transferring power, since it depends on friction, but it is used in some machines.

A gear system uses wheels with cogs cut into them so that each of the gears interlocks in an appropriate way. The underlying principle in the use of gears is similar to other examples used in this section. The gears can be used to transfer power directly, change the flow of power from one direction to another or increase the power or speed of an object.

Figure 7a.
Direct transfer of motion.

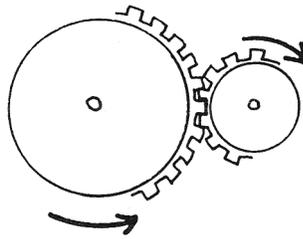
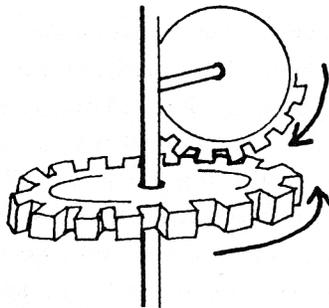


Figure 7b.
Transfer of motion through 90°.



Elementary Science Program of Studies

General and Specific Learner Expectations

The following general and specific learner expectations have been taken directly from the 1996 Elementary Science Program of Studies. The specific learner expectations (SLEs) are referred to by number in the second column of the activities table.

General Learner Expectation

Students will be able to:

Demonstrate a practical understanding of wheels, gears and levers by constructing devices in which energy and motion are transferred.

Specific Learner Expectations

Students will be able to:

1. Explain how rollers can be used to move an object and demonstrate the use of rollers in a practical situation.
2. Compare the wheel and the roller and identify examples where each is used.
3. Construct devices that use wheels and axles and demonstrate and describe their use in:
 - model vehicles;
 - pulley systems; and
 - gear systems.
4. Construct and explain the operation of a drive system that uses one or more of the following:
 - wheel-to-wheel contact;
 - a belt or elastic;
 - a chain; and
 - cogs or gears.
5. Construct and explain the operation of a drive system that transfers motion from one shaft to a second shaft, where the second shaft is:
 - parallel to the first; and
 - at a 90° angle to the first.

Students who have achieved this expectation will be aware of changes in speed and direction that result from different ways of linking components. Introduction of gear ratios, however, is not recommended at this grade level. Students will have an opportunity to develop the concept of ratio as part of their junior high mathematics program.

6. Demonstrate ways to use a lever that:
 - applies a small force to create a large force; and
 - applies a small movement to create a large movement.
7. Predict how changes in the size of a lever or the position of the fulcrum will affect the forces and movements involved.
8. Construct models of levers and explain how levers are involved in such devices as teeter-totters, scissors, pliers, pry bars, tongs, nut crackers, fishing rods and wheelbarrows.

Cross-curricular Connections

Mathematics

- Measuring (mass, circumference and length).

Art

- Create movable art using levers.
- Make catapults.

Language Arts

- Spelling.
- Write instructions on how to build a simple machine.

Children's Alternative Frameworks

It is appropriate to clarify what friction is when discussing rollers, and the idea of reducing friction in making work easier. Children tend to think friction is only the heat that is created when they rub their hands together.

Activities

Classroom teachers have identified the following activities that address the Specific Learner Expectations (SLEs) in the Program of Studies. The list is not prescriptive and teachers may select activities that are most appropriate for their students.

Activities have been listed under two headings: Key Activities and Extension Activities. Key activities are supported by authorized resources and identify “powerful and practical” means for achieving learner expectations. Extension activities represent alternative ways of achieving or supporting learner expectations.

Key Activities

Key Activity	SLE	Print Resources	Essential Materials	Comments
Making objects move in a variety of ways		<i>Explorations in Science, Level 4, On the Move (Making Things Move)</i> , p. 10	books, pieces of paper, paper plate, balloon, wooden block, cylinders of various types, marbles, straws, cardboard, string, elastics, other materials as needed	A good activity to determine students’ knowledge about making things move.

Working with Inclined Planes

Investigating how an inclined plane can make moving a load easier	I	<i>Innovations in Science, Level 3, Roll It (On Track)</i> , p. 15	wooden board, cans, different surface materials	Investigates how the ramp surface and height can affect the rolling of an object.
		<i>Explorations in Science, Level 4, By Means of Machines (A Working Plane)</i> , p. 13	ramp, books, string, spring scale, measuring tape, objects of mass about 1 kg	
		<i>Innovations in Science, Level 4, Technology and You! (So Inclined)</i> , p. 11	ramp, blocks or books, elastics, objects of mass about 1 kg, rulers, tacks	Investigates inclined planes and how the force required to move an object can change due to the angle of the ramp.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Working with Levers				
Investigating seesaws to learn how a lever can be used to lift objects	6, 8	<i>Explorations in Science, Level 4, By Means of Machines (Seesaw Slides)</i> , p. 10	seesaw type of setup	This can be an indoor experiment with a wooden plank resting on a fulcrum.
Investigating different kinds of levers	6, 8	<i>Explorations in Science, Level 4, By Means of Machines (A Lighter Load)</i> , p. 12	ruler, Plasticine, eraser	Understanding the position of the fulcrum and its relationship to effort.
		<i>Innovations in Science, Level 4, Technology and You! (Pushing and Prying)</i> , p. 15	one-metre board, wooden blocks, various weights, metre stick	There are student activity cards to supplement the activities in the Teacher's Notes.
		<i>Blueprints: Technology Key Stage 2 (Gadd & Morton)</i> , p. 14	wood or card strips, paper fasteners, wood block, glue, cardboard	Manipulate paper shapes using levers.
Working with Rollers				
Making and using rollers	1	<i>Explorations in Science, Level 4, On the Move (Making Things Move)</i> , p. 10	a collection of objects of different shapes, weights and materials	A group activity to explore different ways of moving objects of different weights and shapes.
		<i>Innovations in Science, Level 3, Roll It (Rolling Right Along)</i> , p. 5	a collection of objects the students think will roll, wooden board and blocks, measuring tapes, metre sticks, stopwatches	Exploration of different types of rolling objects.
Working with Wheels				
Exploring different kinds of wheels	2	<i>Explorations in Science, Level 4, On the Move (Round and Round)</i> , p. 11	straws, Bristol board, scissors, any type of axle material	An investigation into what makes the best shape for a wheel.
		<i>Explorations in Science, Level 4, On the Move (Big and Round)</i> , p. 12	straws, Bristol board, scissors, any type of axle, different size cylinders	To explore if different-size wheels perform in different ways.
		<i>Innovations in Science, Level 3, Roll It (Wheel Away)</i> , p. 17	pencil, string, boxes, old toys, cardboard, heavy paper, lids, dowels, wooden board	Making wheels of different sizes and materials.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Making and using wheels and axles	3	<i>Innovations in Science, Level 3, Roll It (Wheels and More Wheels)</i> , p. 26 <i>Innovations in Science, Level 4, Technology and You! (Twist and Turn)</i> , p. 18	lumber, dowels, a drill	Explores the twisting power of the wheel and axle.
Making carts and trolleys	3	<i>Explorations in Science, Level 4, On the Move (Round and Up and Down We Go)</i> , p. 13 <i>Explorations in Science, Level 4, On the Move (Rolling Along)</i> , p. 14	straws, Bristol board, scissors, different cylinders, small boxes	Exploring ways in which to make a box move.
Constructing sand and water wheels	2	<i>Explorations in Science, Level 4, On the Move (Other Wheels at Work)</i> , p. 16	water and sand wheels with tables, pails, funnels, containers, paper and Styrofoam plates, Bristol board, glue, scissors, tape	This could work well as a buddy activity with kindergarten students.
Working with Pulleys				
Investigating pulley systems	3	<i>Explorations in Science, Level 4, By Means of Machines (Message Express)</i> , p. 15 <i>Explorations in Science, Level 4, By Means of Machines (Pulleys at Work)</i> , p. 17 <i>Innovations in Science, Level 4, Technology and You! (Super Strength)</i> , p. 23 <i>Blueprints: Technology Key Stage 2 (Gadd & Morton)</i> , p. 16	2 clothesline pulleys, clothespins, a long rope, string, paper, marker pulleys, string paper clips, fishing line, paper cups, stand, pulleys thread spools, dowels, wood, string, weights	Using a pulley as a tool. An investigation into how pulleys can be manipulated to lift a heavier load. Investigates fixed and movable pulleys. Design a simple pulley system.
Investigating belt drive systems	4	<i>Explorations in Science, Level 4, By Means of Machines (Spools and Wheels)</i> , p. 19 <i>Explorations in Science, Level 4, By Means of Machines (Belting Up)</i> , p. 20 <i>Explorations in Science, Level 4, By Means of Machines (Up Down, In Out)</i> , p. 22	scrap lumber, thread spools, hammer, nails, elastics, safety glasses lids, nails, elastics, scrap lumber, hammer, string, rulers lids, nails, boards, straws, cardboard, elastics, string	Investigates the influence of moving parts. Investigates wheels, their direction and speed. Demonstrates how a motion can be changed to another direction.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Working with Gears				
Investigating gears	3, 4	<i>Explorations in Science, Level 4, By Means of Machines (Gearing Up)</i> , p. 23	gears, hammer, nails, scrap lumber	An activity exploring the workings of gears.
	7	<i>Explorations in Science, Level 4, By Means of Machines (A Lighter Load)</i> , p. 12		
	5	<i>Explorations in Science, Level 4, By Means of Machines (Create Your Own Gears)</i> , p. 24		

Extension Activities

Extension Activity	SLE	Print Resources	Essential Materials	Comments
Working with Wheels				
Exploring wheels and axles and how the position of the axle is important to the movement of the wheel.	2	<i>Explorations in Science, Level 4, On the Move (Round and Up and Down We Go)</i> , p. 13	a set of wheels and axle from a toy car, Bristol board, scissors, various cylinders	How a set of wheels behaves when the axle is not in the centre.
Working with Pulleys				
Building a counterbalance	3	<i>Blueprints: Technology Key Stage 2 (Gadd & Morton)</i> , p. 5, 6	thread spools, string, cardboard, weights, dowels	Two activities to demonstrate the use of counterbalances.
Building a water wheel		<i>Innovations in Science, Level 4, On The Move (Spin It)</i> , p. 38	aluminum pie plates, waterproof glue, corks, coat hangers, paper cups, tape, string, pails, containers	Build a waterwheel that can lift a weight.

Extension Activity	SLE	Print Resources	Essential Materials	Comments
Working with Gears				
Building machines using pulleys and gears	3, 4, 5, 6	<i>Explorations in Science, Level 4, By Means of Machines (A Working Combination)</i> , p. 26	The Gear Box kit as needed by the students	<i>The Gear Box</i> is a complete kit of large gears and structural pieces to build an endless variety of machines and vehicles. An exercise to apply all the learned knowledge from this unit.
Making a moving carnival		<i>Explorations in Science, Level 4, On the Move (Carnival Time)</i> , p. 24	materials suggested by the students	An activity that can encompass all aspects of this unit.
General				
Doing mural art		<i>Explorations in Science, Level 4, On the Move (Moving Along in the Future)</i> , p. 26	mural paper, paint and brushes, cardboard, tape, glue, paper fasteners, magnets, markers, scrap material	An art project based on moving objects.
Making a self-propelled roller	1, 2, 4	<i>Innovations in Science, Level 4, On the Move (Do the Twist)</i> , p. 16	paper clips, elastics, empty soft drink cans, large nails, hammer, dowels or pencils, a hook or tweezers, nuts or bolts	Making a pop can that will roll using an elastic band for power.
	3	<i>Explorations in Science, Level 4, By Means of Machines (Crane Building)</i> , p. 27		
	3	<i>Explorations in Science, Level 4, By Means of Machines (Flag Raising)</i> , p. 29		

Assessment

For a broader discussion of science classroom assessment techniques see *Assessing Student Learning* in the introduction of this publication on p. 15. Good places to begin looking for the unit-related ideas are *Explorations in Science* assessment handbooks, *Innovations in Science* teaching notes, Unit tests and Portfolio ideas, Alberta Education sample tests at www.education.gov.ab.ca and Alberta Assessment Consortium at www.aac.ab.ca

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