Gear Down for Speed

Subject Area(s)	Physics, Math
Associated Unit	None
Associated Lesson	None
Activity Title	Gear Down for Speed
Header	Insert Image 1 here, right justified

Image 1

ADA Description:

Caption: None

Image file name:

Group Size	3-4
Expendable Cost per Group	US $0
Grade Level	8
Time required	35-40 minutes

Summary

Using the Lego Mindstorms kit, a simple robot will be constructed and used to explore the relationship between gears, speed and torque. The motion of the robot is governed by attaching wheels to motors, such that the robot is permitted to move in all directions. Students will measure the linear distance traveled by the robot in a specified time, calculate its speed and gauge impact of adding gears to the speed of the robot. Furthermore, students will be introduced to a mathematical relationship between the speed and gear ratios and use it to predict the speed of the robot.

Engineering Connection

The concepts of gear ratios are apparent in all areas of our industrial society. The use of gear ratios is a fundamental element in many mechanical engineering applications. For example, and device that uses a motor, such as an automobiles, elevators, generators, watches and even a bicycle employs the concepts of gear ratios to operate at maximum efficiency. This experiment is designed to show how gears can be used to influence the motion of the wheels of the robot while keeping the output from the motor the same.

Engineering Category

Category 3: Engineering analysis and partial design

Keywords
Lego Mindstorms NXT, robots, gears, speed, programming, circles, circumference, area of a circle.

Educational Standards
- New York City, science, 2010, PS 5.1f: Demonstrate how mechanical energy may cause change in motion through the application of force or the use of simple machines such as: levers, pulleys, inclined planes; wheel and axle.
- New York State, math, 2010, 3.PS.4: Act out or model with manipulatives activities involving mathematical content from literature.
- New York State, math, 2010, 3.PS.12: Use physical objects to model problems.
- New York State, math, 2010, 3.PS.16: Analyze problems by identifying relationships.
- New York State, math, 2010, 5.PS.10: Work in collaboration with others to solve problems.
- New York State, math, 2010, 5.PS.12: Use trial and error and the process of elimination to solve problems.
- New York State, math, 2010, 5.PS.14: Analyze problems by observing patterns.

Pre-Requisite Knowledge
Basic programming with Lego Mindstorms NXT
**Basic understanding of circles and the relationships between diameter and circumference.

Learning Objectives
After this activity, students should be able to:
- Calculate the circumference of a circle
- Demonstrate the relationship between the linear distance traveled by a circular object and the circumference of a circle.
- Demonstrate the application of the appropriate gear ratios to maximize speed.

Materials List
Each group needs:
- Lego Mindstorms Education NXT Base set (www.legoeducation.com, $279.95)
- Computer (PC or MAC)
- Masking Tape
- Tape measure

Introduction / Motivation

Gears are typically employed in everyday devices to help transmit motion between parts of the device. Although they may come in various shapes and sizes, they typically have cut or cogs that allow them to mesh or be connected with other gears. When two or more gears are used in tandem, a mechanical advantage is produced that can be used to change the speed, direction and magnitude of a power source (such as an electric motor). Most commonly, meshed gears transfer rotational motion from the driver gear (attached to power source, for example the motor) to the driven gear

(meshed with the driver gear). However, it is possible to transmit the motion form the motor in other direction, such as connecting the driver gear to a non-rotating rack.

When using gears, it is common practice to gauge the transference of energy from one gear to the next by computing the gear ratio. Since the circumference of the gear is proportional to the number of teeth on gear, the gear ratio can be computed as:

$$\text{Gear Ratio} = \#\text{ of teeth on Driven Gear} / \#\text{ of Teeth on Driver Gear} \quad (1)$$

where the driver gear is attached to the motor and the driven gear is meshed to the driver. For example, in the following setup, the driver gear has 24 teeth, and the driven gear has 8 teeth. Computing the gear ratio as described in equation (1) yield a gear ration of 1/3. This means that for every turn of the driver gear, the driven gear turns 3 times.

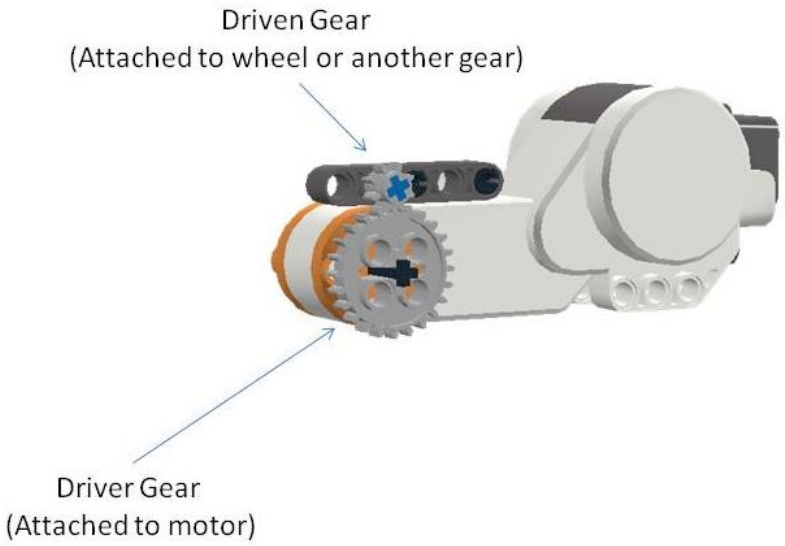

Figure 1
ADA Description: Schematic of two meshed gears.
Caption: Figure 1: Two meshed gears. The driver gear is attached to the NXT motor, and the driven gear is meshed with the driver gear.
Image file name: Driver_and_driven_gears.jpg

Although there are several types of gears that are accompanied with the Lego MIndstorms NXT kit, this activity will use primarily the spur and bevel gears. Some of the Lego Mindstorms NXT gears and their applications are:

Spur Gear

A cylinder or disk with the teeth projecting radially. Spur gears can only be meshed if fitted on a parallel axes.

Bevel Gear (double)

Shaped like a right, circular cone with its tip cut off. Bevel gears can be meshed along parallel axes as well as various angles in between 0 and 180 degrees.

Crown Gear

A special type of bevel gear whose teeth project at 90 degrees to the plane of the gear. Crown gears can only mesh accurately with bevel gears.

Worm Gears

A worm and gear set is typically used to achieve a compact, high torque, low speed gear ratio. Worm gears can be used with Spur or Double Bevel Gears and can function in a self locking manner, where the worm can always drive the gear, but the gear may not necessarily be allowed to drive the worm.

Rack and Pinion

A rack is a toothed bar or rod that can be meshed with a spur or bevel gear (pinion). Using this setup, Torque is converted from a rotational force in the driver gear to a linear one.

When using gears, is important to realize that there is no free lunch, that is, you can't get something for nothing. In cases where a lower gear ratio is used to make the robot go faster, there is a hidden cost involved. The cost is paid for in the available amount of torque (or rotational force) the robot has. This tradeoff between speed and torque is an important factor that must be considered when designing a robot for an intended use. For example, if the robot in required to lift a heavy load or climb a steep incline, then torque may be a priority and the gears should be used in a high gear ratio. On the other hand, if the robot is intended to be used in a race along a flat surface, then

a low gear ratio should be used. For this activity, the focus will be primarily on the relationship between gear ratios and speed.

The relationship between gear ratio and speed can be developed based on the following equation:

Gear ratio 1 x Speed 1 = Gear ratio 2 x Speed 2 (2)

That is, if the gear ratio and speed of the robot is known for one setup (gear ratio 1 and speed 1), then the speed of the robot could be determined for another gear ratio configuration.

Vocabulary / Definitions

Word	Definition
Gear Ratio	Ratio of size of the driven gear to the size of the driver gear
Speed	The rate of change of position with respect to time.

Procedure

Before the Activity

- Construct the Taskbot according to the attached building instructions.
- Load the attached Lego Mindstorms program: “Moving Forward”.
- Distribute attached experimental worksheet

*Keep the size of the wheels the same during the lesson

1. Using masking tape, tape off a start point for the robot.
2. Measure the diameter of the wheel of the robot and compute its circumference using the formula:

   Circumference = pi x Diameter
3. Configure the Taskbot with a 1/1 gear ratio.
4. Download the “Moving Forward” program, and record the distance the robot travels in 3 seconds.
5. Calculate the speed of the robot for this gear ratio configuration using the formula:

   Speed = Distance / Time

   These values will be used as speed 1 and gear ratio 1 in equation (2)
6. Using equation (2) and the values form step 4, calculate the speed for two more gear ratios: 1/3 and 3/5
7. Configure the Taskbot with a gear ratio of 1/3 and calculate its speed (as in steps 1-4).
8. Repeat with a gear ratio of 3/5.
9. Compare the value for the calculated speed with the recorded speed.

Assessment

Activity Embedded Assessment

Analysis

Students should compute the circumference for the wheels used for their robot. Students should compare the values of the calculated speeds to the measured speed. Once the three different gear ratios have been examined, students should develop their own configurations to maximize speed. To achieve this, students should be considering several factors: using more than two gears, changing the size of the wheels and using the gears in along three axes, using three motors, etc.

Attachments

Gear_down_for_speed_worksheet.doc
Gear_down_for_speed _program.rbt

Activity Extensions

None

Additional Multimedia Support

None

References

1. Dictionary.com. Dictionary.com, LLC. Accessed August 2, 2009 (Source of some vocabulary definitions, with some adaption) http://dictionary.reference.com/
2. Lego.com. The Lego Group. Accessed August 2, 2009 www.Minstorms.lego.com
3. Mindsensors.com. Mindsensors.com 2005-2009. Accessed August 2, 2009 www.mindsensors.com

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