Subject Areas
Algebra, data analysis & probability, measurement

Associated Unit
None

Associated Lesson
None

Activity Title
Timing a Speedbot!

Header
Image   Insert Figure 1 here, right-justified

Figure 1

ADA Description: Picture of Wile E. Coyote and the Road Runner cartoon characters

Caption: Wile E. Coyote chasing the Road Runner! Who's faster?

Image file: wile_e_coyote_and_road_runner.jpg

Source/Rights: http://images.picturesdepot.com/photo/w/wile_e_coyote_and_road_runner_wallpaper-29519.jpg

Grade Level
5 (4 – 6)

Activity Dependency
None

Time Required
60 minutes for lesson, 45 minutes for data analysis/follow-up

Group Size
3

Expendable Cost per Group
$0

Summary
Students work in groups using a timer or stopwatch to measure the speed of an NXT robot. The robot can be started and stopped by using a touch sensor and it is programmed to display the distance it has traveled in centimeters after it stops. Using the gathered data, students complete a worksheet to determine the mean speed of an NXT robot at a given motor power.

Engineering Connection
Communicating measurements is one of the most important tasks of an engineer. In today's technical applications, new types of units are frequently created to highlight a process of interest. These new units are called *derived units*. Derived units are generated from combinations of existing units, usually the *base units*, fundamental units for properties such as mass and length. Converting between different derived units which are used to measure the same physical property is an important and fundamental engineering task which may require multiple conversion factors and addition or subtraction of offset values. In this lesson we introduce understanding of derived units by using a moving robot and a stopwatch to measure speed, one of the most common derived units (distance/time).

Engineering Category
Category 1. Relating science concepts to engineering.

Keywords
Derived units, division, length, measurement, Mindstorms, NXT, robot, speed, stopwatch, time

Educational Standards
NYC Science Scope & Sequence Standards:
Process Skills: General Skills
vii. Estimate, find, and communicate measurements, using standard and nonstandard units.

NYS Standards
M3.1a Use mathematics in scientific inquiry.
S2.1d, S3.1a,b Employ tools to gather, analyze, and interpret data.
S3.1 Design charts, tables, graphs, and other representations of observations in conventional and creative ways to help them address their research question or hypothesis.
S3.1a Organize results, using appropriate graphs, diagrams, data tables, and other models to show relationships.

NYS Core Curriculum General Skills
– Safely and accurately use the following measurement tools:
- metric ruler
- balance
- stopwatch
- graduated cylinder
- thermometer
– Use appropriate units for measured or calculated values.

Pre-Requisite Knowledge
Metric units of length, units of time, division

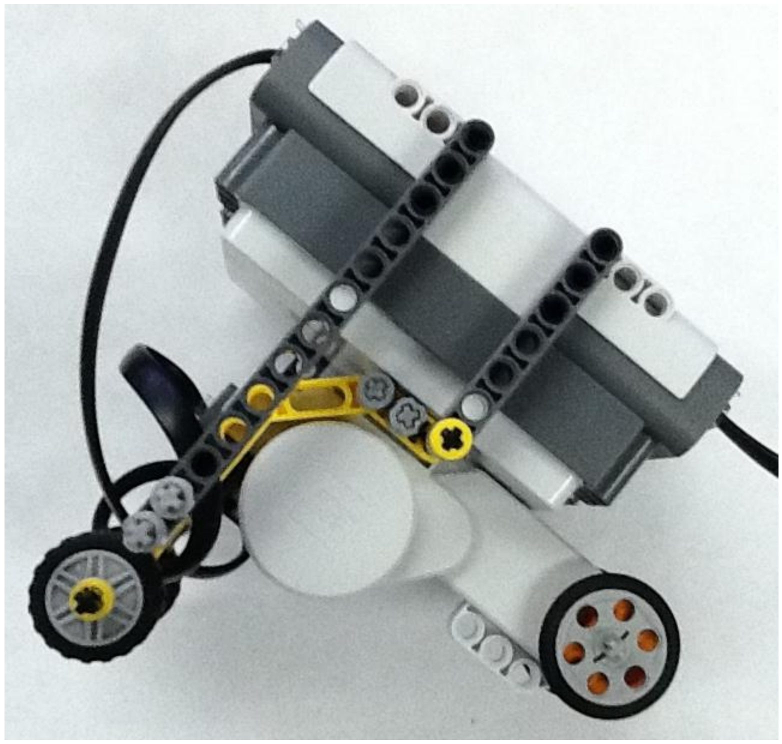
Learning Objectives
After this lesson, students should be able to:

- Define speed using the speed equation (speed = distance ÷ time)
- Measure the speed of an object moving in a straight line by measuring the distance traveled and time elapsed and dividing
- Identify a unit of speed
- Generate a unit of speed by combining different units of length and time appropriately

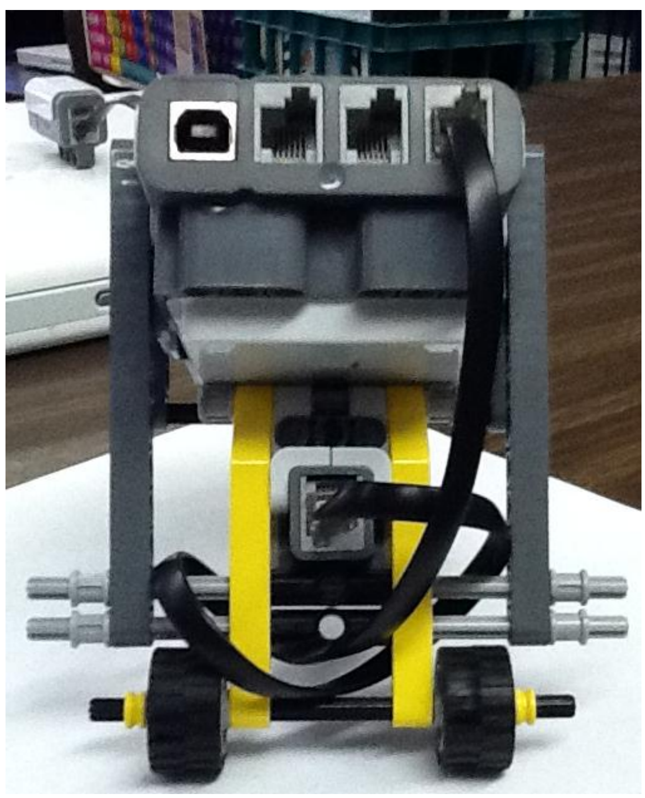
Materials List
Each group needs:

- An NXT robot capable of moving in a straight line (see below for a sample robot)
- Speedbot data worksheet
- Stopwatch or timer

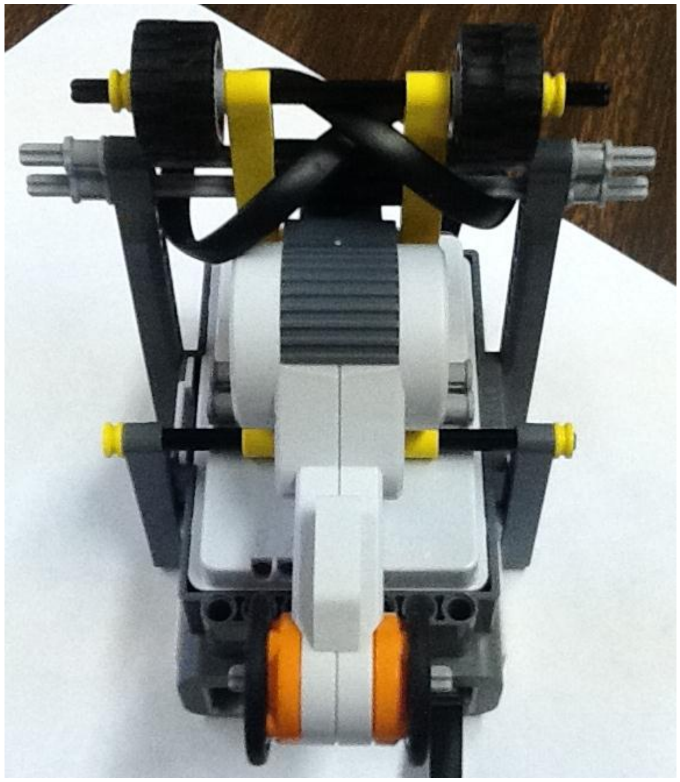
Image   Insert Figure 2 (a), (b), and (c) here, centered



(a)



(b)



(c)

Figure 2

ADA Description: Setup example of Lego robot created to measure and display distance traveled in centimeters, shown by (a) side, (b) back, and (c) bottom views. Not shown is a touch sensor connected to port 1.

Caption: Figure 1. Design of a Lego NXT speedbot which displays the distance traveled in centimeters on the screen and logs the time elapsed internally. Shown in (a) side, (b) back, and (c) bottom views.

Image files: speedbotside.jpg, speedbotback.jpg, speedbotbottom.jpg

Introduction/Motivation

Speed is a property of objects that can be easy to compare. When you look at moving objects, some of them appear to be moving faster or slower than others. However, suppose that you want to compare the speeds of two objects that are similar in speed or not traveling right next to each other. How can we numerically measure speed to compare the speeds of multiple objects? Can we use one of the base units, such as a meter, a mile, or an hour to measure speed? The answer is no, because using a base unit does not convey information about how fast something is traveling. A snail and a car can both travel for 2 hours or for a distance of 10 meters, but neither measurement on its own allows you to compare their speeds. Many people have seen one type of unit which is used to measure speed when you are traveling in a car—miles per hour (mph).

Let's look at the unit miles *per* hour more carefully. What does this mean? Let's try to figure this out using an example. Suppose I have 10 cookies to serve and 2 people to eat them. How could you figure out how many cookies each person is going to get? The answer is by dividing 10 cookies by 2 people and calculating that the answer is 5 cookies for each person. I'm sure some of you would love to be in that situation! Another way to say that is 5 cookies *per* person. The word "per" is a substitute for the words "for each." Using mathematical symbols, we would write:

$$10\ cookies\ \div 2\ people =\ 5\ cookies\ per\ person$$

Another way to write this is in fraction form:

$$10\ cookies\ \div 2\ people = \frac{10\ cookies}{2\ people} = \frac{5\ cookies}{1\ person}$$

This can also be written as:

$$5\frac{cookies}{person}$$

Let's go back to our speed unit, miles per hour. What have we learned the "per" stands for? In a unit, "per" means *division*. Miles per hour means miles traveled for each hour that passes, which is calculated using the following formula:

$$miles\ per\ hour =\ miles\ traveled\ \div hours\ elapsed$$

In fraction form:

$$miles\ per\ hour = \frac{miles\ traveled}{hours\ elapsed}$$

If a car travels 60 miles in 2 hours, then its speed is:

$$\frac{60\ miles}{2\ hours} = \frac{30\ miles}{1\ hour} =\ 30\frac{miles}{hour} = 30\ miles\ per\ hour$$

We can generalize this to create more units of speed. What type of unit is a mile, meaning, what does it measure? A mile is a unit of length or distance. What type of unit is an hour? An hour is a unit of time. The general formula for speed is:

$$speed = \frac{distance\ traveled}{time\ elapsed}$$

When doing long division, it is written as:

$$speed = time\ elapsed\sqrt{distance\ traveled}$$

Using this formula and our miles per hour example, we can find a general formula for spotting and using units of speed:

$$unit\ of\ speed = \frac{unit\ of\ length}{unit\ of\ time}$$

Any units of length and time can be used in the formula above to create a new unit of speed. The unit of speed that a scientist or engineer chooses depends on the distances and times being measured. This formula also shows something important about different types of units. A unit of length or a unit of time is called a base unit. (Write the term on the board.) Base units are used to measure the most basic observable properties of an object or situation. These include things like length, mass, or the amount of time that has passed. (Ask the students to name different units of time and length that they know of. Include centimeters and seconds on the list. List as many as the students can think of and a few more.) Other properties, such as speed, are defined in terms of combinations of base units. These types of units are called derived units. (Ask them to combine the units to create 2 or 3 different units of speed.)

In today's activity, we are going to use Lego NXT robots and stopwatches to measure speed. The Lego speedbot can be controlled using a touch sensor. The speedbot will report the distance it has traveled in units of centimeters (cm). The time it takes will be measured using a stopwatch. Then, you will find the speedbot's speed by dividing the distance traveled by the measured time elapsed. Each group will have a robot that has a different set speed. By measuring the speed over multiple trials, each group will be able to determine the NXT robot's mean speed in centimeters/second for a given motor power.

Vocabulary/Definitions

Word	Definition
Time elapsed	The length between the starting and stopping point of a moving object
Distance	The amount of time that passes between the robot starting and stopping
Base units	Units used to measure fundamental properties such as length or time
Derived units	Units used to measure properties, such as speed or volume, that are measured by a combination of base units

Procedure

Background

The students must be able to do long division using integer divisors up to 15. The activity can also be limited to larger or smaller divisors at the teacher's discretion.

Before the Activity

The teacher must construct and program one speedbot for each group. Each robot should be programmed to start moving when a touch sensor is pressed and released. The robot should move at constant speed until the touch sensor is pressed again, when it stops. However, the robot should not respond to the touch sensor for the first 3 – 4 seconds in order to reduce the effect of rounding errors on the calculated speed. The robot should also display the distance traveled on the main screen, in centimeters, and keep displaying this distance after the robot stops until the touch sensor is pressed a second time to end the program or start again. Finally, the robot should be programmed to stop after a certain amount of time to avoid an extremely large divisor in the speed equation and to avoid hitting obstacles. A sample program is included with this activity which performs all of these functions using the speedbot pictured above or any similar one-motor robot which uses the wedge belt pulley/wheel 4185 as the drive wheel. This robot plays a sound during the first 4 seconds when it will not respond to the touch sensor. From 4 – 15 seconds, the robot can be stopped with the touch sensor. At 15 seconds the robot will stop on its own. The teacher can change these time values depending on the desired range. The teacher can use the program to change the robot's set speed and before class the teacher should save multiple instances of the program for each group using a different set speed.

Important note:

- The sample program displays an accurate measurement in centimeters using only the wedge belt wheel/pulley 4185, as pictured in the sample speedbot. A different construction or wheel size may require a different conversion factor between motor rotations and centimeters, which can be measured using the wheel diameter or the number of centimeters traveled per motor rotation by the robot. Make sure that you test your robot for accuracy over a distance of 1 meter (the robot should be at least 99% accurate).

One copy of the speedbot data worksheet must be made for each group. A group can have up to eight members. Create stations for each role in each group. Each group must have one robot controller, one timer, and one data recorder per trial. However, the group size can range from 2 – 8 (one person can be timer and data recorder when working in pairs). One copy of the speed equation worksheet should be made for each student.

With the Students

1. Explain the speedbot's function and behavior to the students, including the minimum and maximum time limits.
2. Assign students into groups and provide each group with one robot, one stopwatch or timer, and one worksheet.
3. Choose two students to do an example run, with one student controlling the robot and the other student timing it. Tell the students that they must stop the robot before the time limit or it will stop on its own.
4. Have each group do a trial run to get practice before the experimental run.
5. The students should go through each station one after another until each of them has been to every station once. The group speed worksheet should have enough entries for each student in the group to have at least one chance to control the robot. The data recorder for each trial should enter the data for that trial into the appropriate row in the worksheet as well as his or her name and the timer's name.

Attachments

Speedbot data worksheet (pdf)
Speedbot data worksheet (docx)
Speed equation worksheet (pdf)
Speed equation worksheet (docx)
Post-activity evaluation (pdf)

Post-activity evaluation (docx)
Role assignments sheet (pdf)
Role assignments sheet (docx)
Lego Mindstorms NXT program file for one group (rbt)

Safety Issues
None.

Troubleshooting Tips

- You can use the Role Assignment Sheet to label each station or modify it to make your own roles

Investigating Questions
What is the most accurate way to measure the speedbot's speed? (Answer: for each trial, let the robot move until it times out. That way the time is always known to be exactly 15 seconds or whatever timeout period the teacher selects).

Assessment

- Pre-Activity Assessment
  Before the activity, have the class list any units of speed that they may know. Next, have the students list all the units of length and time that they know. Ask the students if they know the formula for determining speed before giving it to them.
- Activity Embedded Assessment
  During the activity, observe the group's cooperation skills, how well they share, and how efficiently they complete the task.
- Post-Activity Assessment
  Once the students have collected the data, review how to do long division with them. Depending on the division skill level of the students and the accuracy of the stopwatch used, the students may have to round the results before dividing. Go over rounding with them if necessary. The time should be rounded to the nearest second, while the distance and speed can be rounded to the tenths or hundredths place. If the students do not know how to do long division with a decimal dividend, review it with them or round to the nearest centimeter and use fractional remainders. Have students individually complete the speed equation worksheet with their group's data, either in class or for homework. Collect work to ensure calculators are not used.

Activity Extensions

In a follow-up activity, each group can determine the mean value for the speed of its robot. Once each group has determined a mean value, the class can make a plot of robot speed vs. motor power.

Activity Scaling

- Younger classes can stop after finding the speed for each trial. Classes which are developing division skills can round the distance values displayed by the NXT to the nearest centimeter.
- Older/advanced students should use the exact distance values displayed by the NXT and each group should find the mean speed of its speedbot. Classes familiar with long division can attempt to start the speed equation worksheet during the activity.

Additional Multimedia Support

None

References

None

Redirect URL

None

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