



# TeachEngineering

STEM Curriculum for K-12

**HARE AND SNAIL CHALLENGES**



Subscribe to our newsletter at [TeachEngineering.org](https://TeachEngineering.org) to stay up-to-date on everything TE!

Brought to you by



# PRE-ACTIVITY QUIZ

1. **What are some design considerations to make a fast robot?**
  
  
  
  
  
  
  
  
  
  
2. **What are some design considerations to make a slow robot?**

# PRE-ACTIVITY QUIZ ANSWERS

1. What are some design considerations to make a fast robot?  
**Make the robot very light, that is, use a minimal number of parts.**  
**Make the wheels turn faster.**
2. What are some design considerations to make a slow robot?  
**Make the robot very heavy, that is, use many and heavier parts.**  
**Make the wheels turn slower.**

# CHALLENGES TRACK SPECS

- Make the track a **straight** path
- Make the track **5 to 15 feet** in length
- Make the track about **3 feet wide**
- Clearly identify the **start** and **finish** lines

**start**

**finish**



- Use a **stopwatch** to time the races

# DAY 1: HARE CHALLENGE

*50 minutes*

To construct a LEGO MINDSTORMS NXT robot and program it to travel the given track as fast as possible.

*THE FASTEST ROBOT WINS!*

- Use the concepts from the gear lesson we just completed:
  - What gear ratio should you use?
  - What happens to torque when you have a high gear ratio?
- Let's review those concepts once again quickly before you start the challenge.



# WHAT IS A GEAR?

## Lesson Review

A gear is a **wheel with teeth** that meshes with another similar gear that is typically larger or smaller.

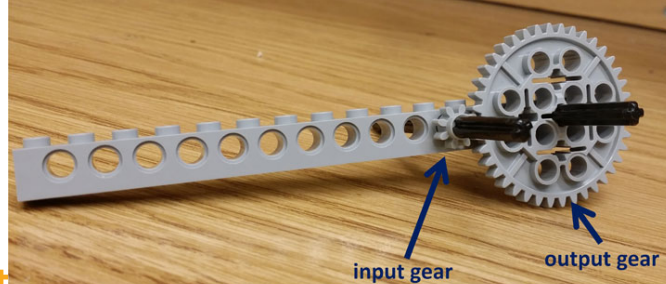
- Gears come in various sizes and types.
- Depending on the situation, one gear may work better than another.
- What are gears used for?
  - Changing **speed**
  - Changing **direction of motion**
  - Changing **torque**



# MOST COMMON GEAR: SPUR GEARS

## Lesson Review

*Look at the photograph below. The small (input gear) has 8 teeth and the large (output gear) has 40 teeth. Assume that  $X$  turns of the small one causes 1 turn of the large one. What is  $X$ ?*



In this case, the gear ratio is defined as  $1:X$  (output:input). Notice that this is in the same ratio as the number of teeth, that is, 8:40 or 1:5.

# GEAR RATIO: EFFECT ON SPEED & TORQUE

## Lesson Review

- Imagine two 40-teeth gear contacting each other. *When one 40-tooth gear turns once, how many times will the other 40-tooth gear turn?* **Answer = 1**
- Now, imaging replacing one of the 40-tooth gears with an 8-tooth gear, with the 40-tooth gear turning the 8-tooth gear. *When the 40-tooth gear turns once, how many times will the 8-tooth gear turn?* **Answer = 5**

In this last case (8-tooth connected to 40-tooth), the 40-tooth gear's axle will have 5 times the torque (rotational force) than the 8-tooth gear's axle.

So, although the large gear turns slowly,  
it can push more!



# WHAT IS TORQUE? WHY IS IT IMPORTANT?

## Lesson Review

- Think of **torque** as a rotational force, that is, a force that **causes rotation** and not forward movement.
- For the same motor power setting, more torque in a machine (such as a bicycle or car) leads to lower speeds, and less torque leads to higher speeds. This is because  
**power = torque \* speed.**
- So, when we increase speed from the input to the output gear, we decrease torque by the same amount!
- So, in any design you develop, you must decide which is more important: **speed or torque, or maybe both...**  
and then select the appropriate gear ratio!

Now, begin the hare challenge!

# DAY 2: SNAIL CHALLENGE

*50 minutes*

To construct a LEGO MINDSTORMS NXT robot to travel the same track as *slowly as possible*.

***THE SLOWEST ROBOT WINS!***

- Use the concepts from the gear lesson that you just used with the hare challenge.
- Important factors:
  - Robot weight
  - Motor power setting



# POST-ACTIVITY QUIZ

- 1. What did you find as the most effective design elements to make your robot a) faster and b) slower?**
  
  
  
  
  
  
  
  
  
  
- 2. What are some problems you faced when you designed a fast robot for the Hare Challenge?**

# POST-ACTIVITY QUIZ ANSWERS

1. What did you find as the most effective design elements to make your robot a) faster and b) slower?

a) **FASTER: increasing gear ratio, increasing motor power, decreasing robot weight**

b) **SLOWER: decreasing gear ratio, decreasing motor power, increasing robot weight**

2. What are some problems you faced when you designed a fast robot for the Hare Challenge?

**When you make a light robot, it is not structurally stable and can fall apart. You also lose torque, making the robot unstable.**

# HARE CHALLENGE SOLUTION

- In the Hare Challenge, use the minimal number of parts on the LEGO robot, that is, **keep the weight low**.
- Then attach the largest gear (40-tooth) to the motor and the smallest gear (8-tooth) to the wheel. It doesn't matter what gears are in between the 40-tooth gear and 8-tooth gears since they act as idler gears.
- Use the **maximum power setting** on the motor.
- If an **odd** number of gears, have the program tell the robot to go forwards.
- If an **even** number of gears, have the program tell the robot to go backwards (in order to make the robot move forwards since even # of gears reverses direction).
- Expect some trial and error to be necessary.

# SNAIL CHALLENGE SOLUTION

- In the Snail Challenge, **make a heavy LEGO robot** (use as many parts as possible) since heavy machines move slowly with the same motor.
- Then attach the smallest gear (8-tooth) to the motor and the largest gear (40-tooth) to the wheel. It doesn't matter what gears are in between the 8-tooth gear and 40-tooth gears since they act as idler gears.
- Use the **minimum power setting** on the motor.
- If an **odd** number of gears, have the program tell the robot to go forwards.
- If an **even** number of gears, have the program tell the robot to go backwards (in order to make the robot move forwards since even # of gears reverses direction)
- Expect some trial and error to be necessary.

# VOCABULARY

- **design:** Loosely stated, the art of creating something that does not exist.
- **gear:** A rotating machine part with cut teeth that mesh with another toothed part in order to transmit torque; in most cases, the teeth on both gears are identical in shape.
- **torque:** The tendency of a force to rotate an object about its axis or pivot.

