Workshop 6: Gears

1 Getting Started

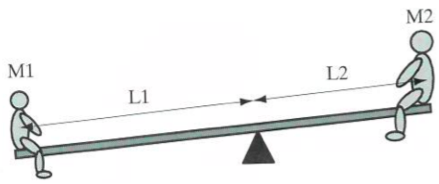
Make sure you have everything you need to complete this lab. To get started you will need the following:

- a LEGO Mindstorms EV3 robot with gears
- a computer with LEGO Mindstorms EV3 software application installed
- a USB cable that connects the robot to your computer
- gears
- Touch Sensor

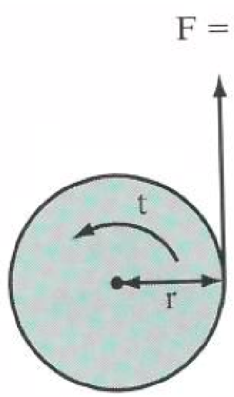
2 Introduction to Gears

2.1 Basics

In this workshop we will go through some basic gearing concepts, like gear ratio and torque transmission. DC motors are high-speed devices. Very few application can make use of the power delivered directly from the output shaft, but the desktop fan is an example. Mechanisms in robots usually require **more torque and less speed**. Gears are the common way to address this problem. Using gears, the **high speed** of the motor is **traded off into torque**.



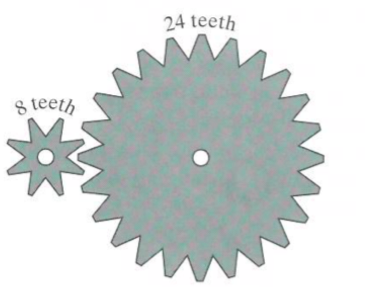
A relevant example is the **playground seesaw**. As you know might know the seesaw generate a downward force **F** equal the product of **their mass (M)** and **their distance (L) from the seesaw's fulcrum**. This basically allows lighter people to displace heavier people simple by increasing the distance from the fulcrum.



Gears work in a similar fashion, the **torque (t)** generated at the centre of a gear is equal to the product of the **gear's radius (r)** and the **force (F) applied at its circumference**.

2.2 Gear ratio and torque transmission

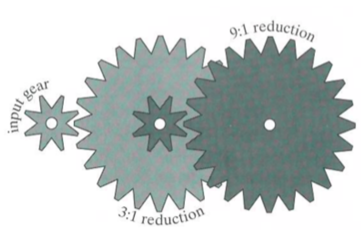
Suppose we have two gears, the 1st gear, has **8 teeth**, the other one has **24 teeth**. So it's clearly seen that the 1st gears radius is one-third of the second one. So in other words the first gear takes three turn to produce one turn in the second gear.



This attribute of the gears can be described mathematically. While the first gear turn **three (1080 degrees)**, the second gear turns **one (360 degrees)**. Each gear has a torque, T_s and T_l, so the work done by the gears is T_s * 1080 and T_l * 360 respectively. And we also know that no work lost or gained when one gears turn another. So these must be equal:

$$T_{large} \times 360 = T_{small} \times 1080$$
$$\frac{T_{large}}{T_{small}} = \frac{1080}{360}$$
$$\frac{T_{large}}{T_{small}} = 3$$

So the **ratio** of the this torque is **3:1**. Generally, the ratios of the gear sizes determines the gear ratios, **if the output gear is larger than the input gear, then the torque increases**. So overall, when a small gear drives a larger one, **torque increases and speed decreases**, when a large gear drives a small one, **torque decreases and speed increases**.

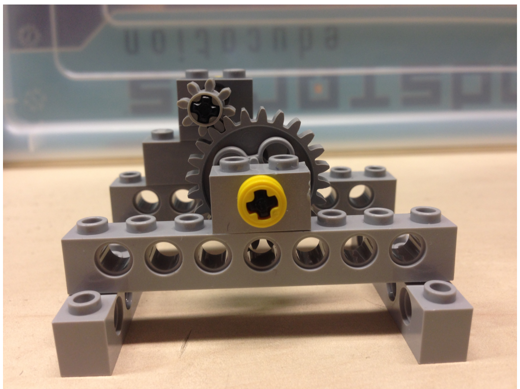


3 Exercise: Gear Rations, Speed and Torque Transmission

As you have seen above, when building complex robots, one of the common needs is to compute the ratio of gears in order to exactly tune the interaction of the movable parts of your machine. With all the different gears and the number of possible combinations, this is not always a trivial task. For this exercise you will need to build simple gears:

3.1 Spur Gears

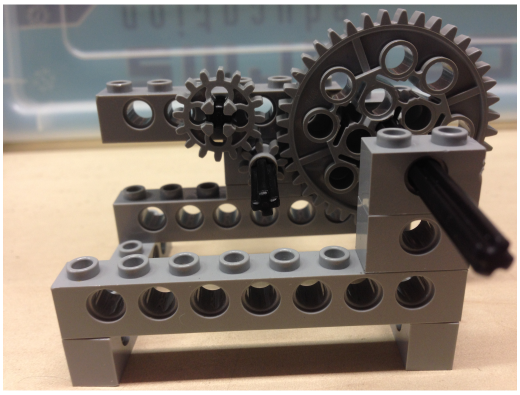
Spur gears is a basic gear operates on axes which are parallel. Build the Spur Gears block and answer the questions:



- What is the **gear ratio** of the Spur Gears
  - if the input gear is the smaller one?
  - if the input gear is the larger one?
- Attach a wheel to the output gear and try to lift a weight with it. Which type of gears needs less effort to lift the weight? Try to measure the weight that you need to lift by using a Newton meter.

3.2 Three Spur Gears

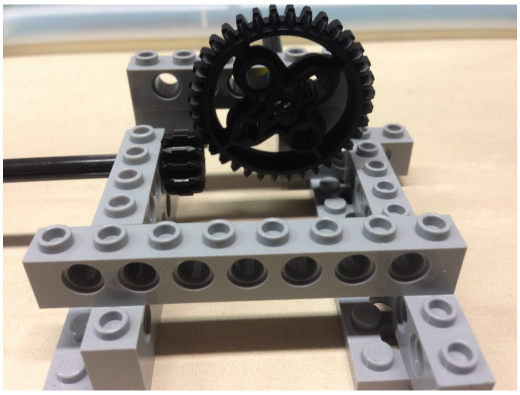
Three Spur gears also operate on axes which are parallel, but using a third gear. **Build the Three Spur Gears block and answer the questions:**



- What do you think how the third gear change the gear ratio and the torque transmission if you keep the same input gear as before?
- What is the **gear ratio** of the Three Spur Gears
  - if the input gear is the smaller one?
  - if the input gear is the larger one?
- Change the input gear to different type and calculate the gear ratio!
- Attach a wheel to the output gear and try to lift a weight with it. Which type of gears needs less effort to lift the weight? Try to measure the weight that you need to lift by using a Newton meter.

3.3 Bevel Gears

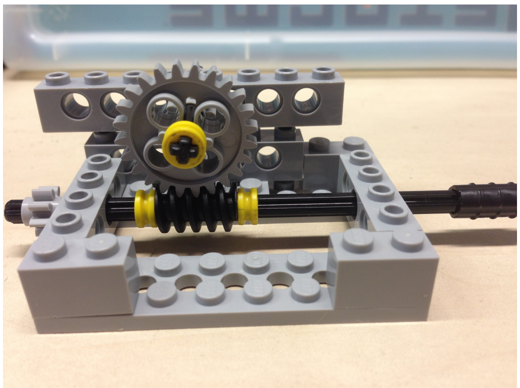
Bevel gears operate on axes which are not parallel. It can be made specifically for axles at virtually any angle, **Build the Bevel Gears block and experiment its behaviour:**



- Is there any difference in gear ration or in torque transmission between the Bevel gears and the Spur Gears?
- Change the input gear to different type and try to rotate it.
- Attach a wheel to the output gear and try to lift a weight with it. Which type of gears needs less effort to lift the weight? Try to measure the weight that you need to lift by using a Newton meter.

3.4 Worm Gear

Worm Gears is one of the most interesting gears in the LEGO kit. The Worm Gear operates on an axle which is perpendicular to a mating spur gear. It also has some special properties. Firstly it can achieve very high gear reductions in a single stage. Secondly, worm gears have much higher friction than the other gear types. **Build the Worm Gear and answer the questions:**



- You can use any type of input gear with the Worm Gear. What is the **gear ratio** of the Worm gear?
- Change the output gear to different type and calculate the gear ratio! Can you spot any relation between the different type of gears?
- How can you compare the **Worm Gear** to a **Spur Gear**? How many teeth does the Worm gear have?
- Attach a wheel to the output gear and try to lift a weight with it. Which type of gears needs less effort to lift the weight? Try to measure the weight that you need to lift by using a Newton meter.

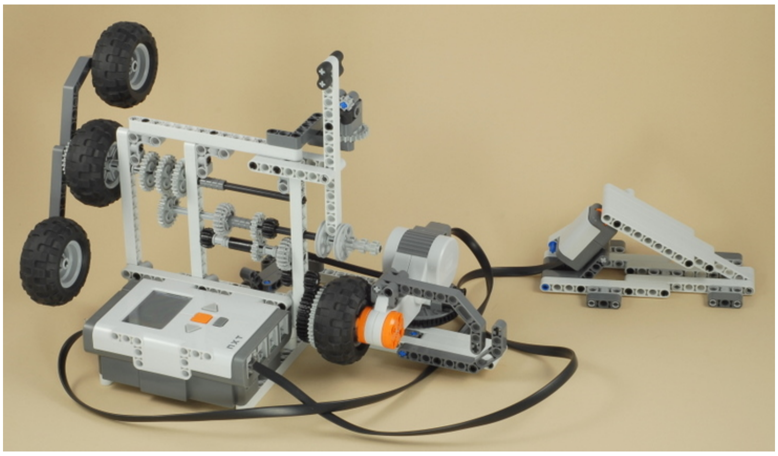
4 Gear research

Do a research!

- How would you be able to transform the gear's rotational motion to translational motion? What kind of gear do you need for it? Think of any real life application for such a gear.
- How is it possible to combine two gears where the speed is made uniform during a part, and varied during another part? Is it possible to use this type of gears in a LEGO EV3 robot? What is this type of speed changes good for? Can you think of any application?

5 Challenge: 3-Speed Transmission with Clutch

For this challenge you will need to build the 3-Speed Transmission with Clutch.



1. Open the website: http://nxtprograms.com/transmission/steps.html in your browser for the building instruction.
2. As you can see on the image above, it's a quite complex LEGO build, so feel free to make it simpler. The important part is the **three different types of gears**, the **shift lever** for changing between the gears and the **EV3 motor**, which is connected to the gears.
3. For extra exercise you might want to to build the pedal to give a smooth speed for the motor, but for this challenge you can connect the touch sensor to the brain and press it for gaining speed.
4. Once you finished, use the **Workshop 7.ev3** application provided!

6 Hard challenge: Automatic Transmission

The exercise above was a 'manual' transmission because you had to shift it by hand. Can you use one of the other motors to make an **automatic transmission** and have the EV3 shift gears for you? During the week, challenge yourself by building the automatic transmission into your previous week's **Self Driving Car**!