Relation between force and speed

Have you ever thought how the huge and heavy cargos are loaded or removed from ships? Dockside cranes are responsible for this process and are essential for every commerce port. In this experiment you can build a similar type of dockside crane model and learn more about gears and how they are used.

Discover:

- What is a gear and how is it used?
- How does the gear's diameter affects speed and power?

Level Of Difficulty ★★★★★

Materials Needed:

- Engino® Simple Machines (STEM40) or Gears & Worm Drives (STEM05).

Procedure:

1. Find the instructions in **page 28** and build the **experimental crane** model. For **case 1** make the first gear assembly of **page 29**.

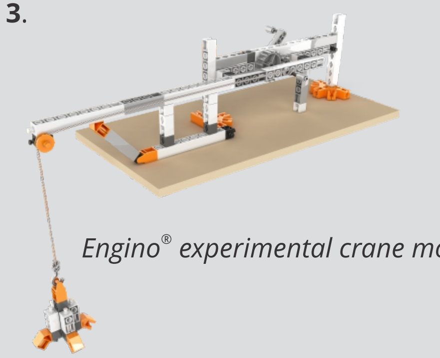
2. Position the experimental crane on a table and lower the load (weight) down to floor level. Then wrap and tie the string around the axle, so it becomes tight. This should be the starting point for every case.

3. Turn the crank and measure how many revolutions are needed until the load reaches the top (orange pulley). Write your answer in the next table for case 1. Also, try to feel the amount of force you have to apply in order to lift the load and observe the lifting speed.

4. Repeat the same procedure for **cases 2, 3** and **4,** in which the gears are assembled as in **pages 30-32**. Try to keep the same turning pace in each case. Write your findings in the table about the crank's revolutions.

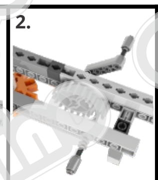
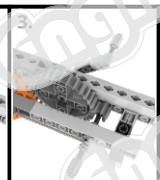
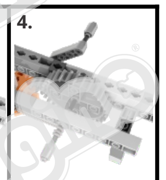
5. Compare the amount of force you used in each case ticking the words **easy**, **medium**, **difficult**, **the most difficult**. Also, compare the lifting speed with the words **slow**, **medium**, **fast** and **the fastest**. Each word should be ticked once.

6. Complete the conclusions in **exercises 2** and **3**.



Engino® experimental crane model

1. Complete the following table according to your measurements and observations. Mark with ✓ the appropriate boxes for FORCE and LIFTING SPEED.

CASES		1. 	2. 	3. 	4. 
Crank's revolutions		*105*	*12*	*7*	*155*
FORCE (difficulty)	easy				✓
	medium	✓			
	difficult		✓		
	the most difficult			✓	
LIFTING SPEED	slow				✓
	medium	✓			
	fast		✓		
	the fastest			✓	

2. Look at the "FORCE" row and the "LIFTING SPEED" row of the table and write your conclusions regarding the relationship between the force applied and the elevation speed of the load.

The different gear assemblies require different amount of force in order to lift the weight. The more force is needed (more difficult in terms of effort), the fastest is the lifting speed of the load and vice versa.

3. Complete the conclusion below using the words in the box.

decrease, smaller, driver gear, driven gear, force, increase

To increase speed, the *driver* *gear* has to be bigger than the *driven* *gear*, while to *decrease* speed the driver gear has to be *bigger* than the driven gear. However, what you gain in speed you lose in *force* and vice versa.

Gear ratio

The gearbox concerns any combination or assembly of gears and can be found in a variety of devices: from the smallest wrist watch to the biggest train! In this experiment we will learn all about this ingenious assembly, which allows us to control the speed of any machine.

Discover:

- What is a gear box?
- What is gear ratio and how is it calculated?

Level Of Difficulty ★★★★★

Materials Needed:

- Engino® Simple Machines (STEM40) or Gears & Worm Drives (STEM05).

Procedure:

1. The base of the **gearbox** will be step **4** of the **experimental crane** in **page 28**. For **case 1** make the first assembly **as shown in the table here**.

2. In the experiment we need to measure how many revolutions the **output shaft** makes when the **input crank** rotates. Two people are needed for this: one should turn the crank slowly with the appropriate number of revolutions (as stated in the table) and the other should measure the output revolutions. You can connect another crank at the shaft of the output gear to help you measure the revolutions with more ease.

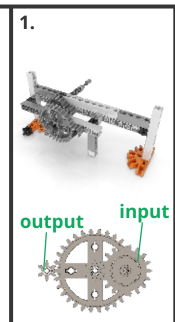
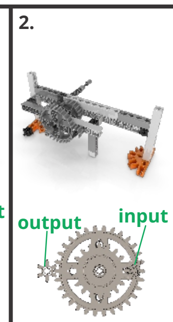
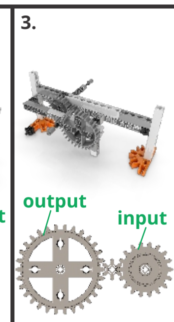
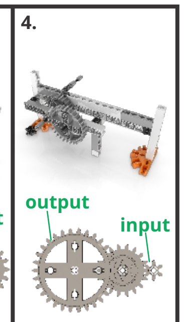
3. For **case 1**, revolve the input crank **1 time** (1 full circle). While measuring revolutions, feel the amount of force you apply.

4. Repeat the same for the other cases. For **case 2**, make the **second gear assembly** and turn the crank **10 times**. For **case 3** make the third assembly and turn the input crank **15 times.** Finally, for **case 4** make the fourth assembly and turn the input crank **30 times.**

5. Write down how difficult it is to turn the crank for each case at the FORCE row, using the words: **easy**, **medium**, **difficult**, and **most difficult**. In the last row divide the INPUT by the OUTPUT revolutions and write it as a simple ratio. Then, answer **question 2.**

6. Measure the number of teeth of each gear: large, medium and small. Then, look carefully at the gear assembly of case 1. There are two pairs: 1) a medium gear connected with a small one and 2) a big gear connected with a small gear. Keep this in mind for **exercise 3.**

1. Complete the following table according to your measurements and observations. After you take all measurements, complete the FORCE row with the word: **easy**, **medium**, **difficult** and **most difficult.** Also, fill in the last row with a simplified ratio of input revolutions to output revolutions.

CASES	1. 	2. 	3. 	4. 
INPUT	**1**	**10**	**15**	**30**
OUTPUT	*15*	*15*	*10*	*2*
FORCE	*most difficult*	*difficult*	*medium*	*easy*
INPUT / OUTPUT	*1:15*	*2:3*	*3:2*	*15:1*

2. Why the gear ratio (input revolutions to output revolutions) is different in each case? What about Torque?

In cases 1 and 2, the output speed is increased and the Torque is decreased, as one gear drives a smaller one. In cases 3 and 4, speed is decreased and Torque is increased as one gear drives a larger one.

3. Make the following calculations concerning the gear assembly of case 1 and compare your result with the input/output ratio you found in the table above. What is the connection between the number of teeth ratio and speed ratio?

gear pair 1 = $\frac{\text{teeth of small gear}}{\text{teeth of medium gear}} = \frac{6}{18}$

gear pair 2 = $\frac{\text{teeth of small gear}}{\text{teeth of large gear}} = \frac{6}{30}$

gear pair 1 x gear pair 2 $= \frac{6}{18} \times \frac{6}{30} = \frac{1}{15}$

*The ratio of the number of teeth (output gear teeth/input gear teeth) is the **same** as the speed ratio (input speed/output speed).*