STEM Mechanics Master Set

E97.1 STEM Lessons

The **STEM Mechanics Master set** is the ultimate combination of the main subjects of Simple Machines and Physics, including Levels, Pulleys, Gears, Linkages, Newton's Laws, Energy conversion, Solar Power and Structures. The patented geometry of ENGINO® components allows connectivity to all directions of the 3D space, enabling users to easily create technical models. This unique set enhances creativity and imagination while also teaching a variety of STEM principles. A geared DC motor with a large solar panel is included for animating the ENGINO® builds, converting solar energy to electricity. The set comes with a library of high-precision gears, pulleys and axles for changing speed, force and direction of motion. From this set, besides open projects, students can find digital instructions for 100 working models and amazing animated contraptions such as cars, cranes, bridges!

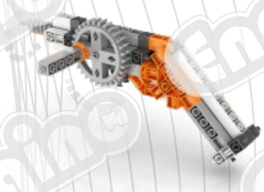
Including Themes:

- Levers & Linkages

- Wheels, Axles & Inclined Planes

- Pulley Drives

- Gears & Worm Drives

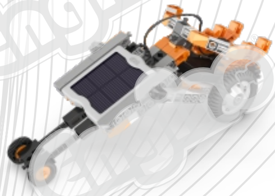


- Cams & Cranks

- Newton's Law

- Structures

- Solar Power



Engino® EDUCATION

9-12+

Edition: 10/22

Lesson: **Moving cabin**

Newton's first law of motion

The ingenious English mathematician and physicist Sir Isaac Newton (1642 - 1727) was the first to fully understand how objects actually move, expressing his three famous *laws of motion*. For this and many other discoveries he is recognised as one of the most influential scientists of all times.

Discover:

- How a force causes movement?
- What is Newton's first law of motion?

Procedure:

1. Build the **moving cabin** model.

2. Place the model on a flat surface. Obviously it does not move by itself. Explain why in **exercise 1**.

3. Place the **cabin in the middle** and move your vehicle smoothly, holding it by the large rod on the edge. Observe how the cabin moves and answer **question 2**.

4. Keep the **cabin in the middle** and push the vehicle **sharply** this time. Observe again how the cabin moves and answer **question 3**.

5. For the final test, you are going to imitate an accident. Place the **cabin on one edge** and push the vehicle **sharply** from the large rod onto a wall or any other strong obstacle. **Be careful not to push too hard and have pieces flying around, as there is a risk of injury!** Make sure you **pick up any falling pieces**. Write your observations about the vehicle and how the cabin moved in **exercise 4**.

6. Read carefully Newton's first law of motion on the right and explain all your findings according to it about the cabin's motion in **exercise 5**.

Push the model onto a wall and observe the cabin's movement.

1. Explain why the model stands still in step 2 of the experiment in reference to the sum of forces applied.

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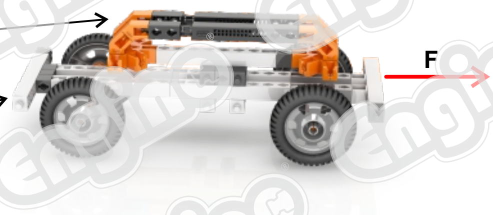
2. When the model is **moving smoothly** in step 3, how does the cabin move? Draw the sum of forces in the picture below.



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3. When the model is **pushed sharply** in step 4, how does the cabin move?

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4. What happens to the vehicle when you **push it onto to the wall** in step 5? How does the cabin move this time?

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5. Read Newton's first law of motion and discuss your findings according to it about the cabin's movement in steps 2, 3, 4 and 5.

Newton's first law of motion:
"Every object remains at rest or continues to move at a constant velocity, unless acted upon by an external force."

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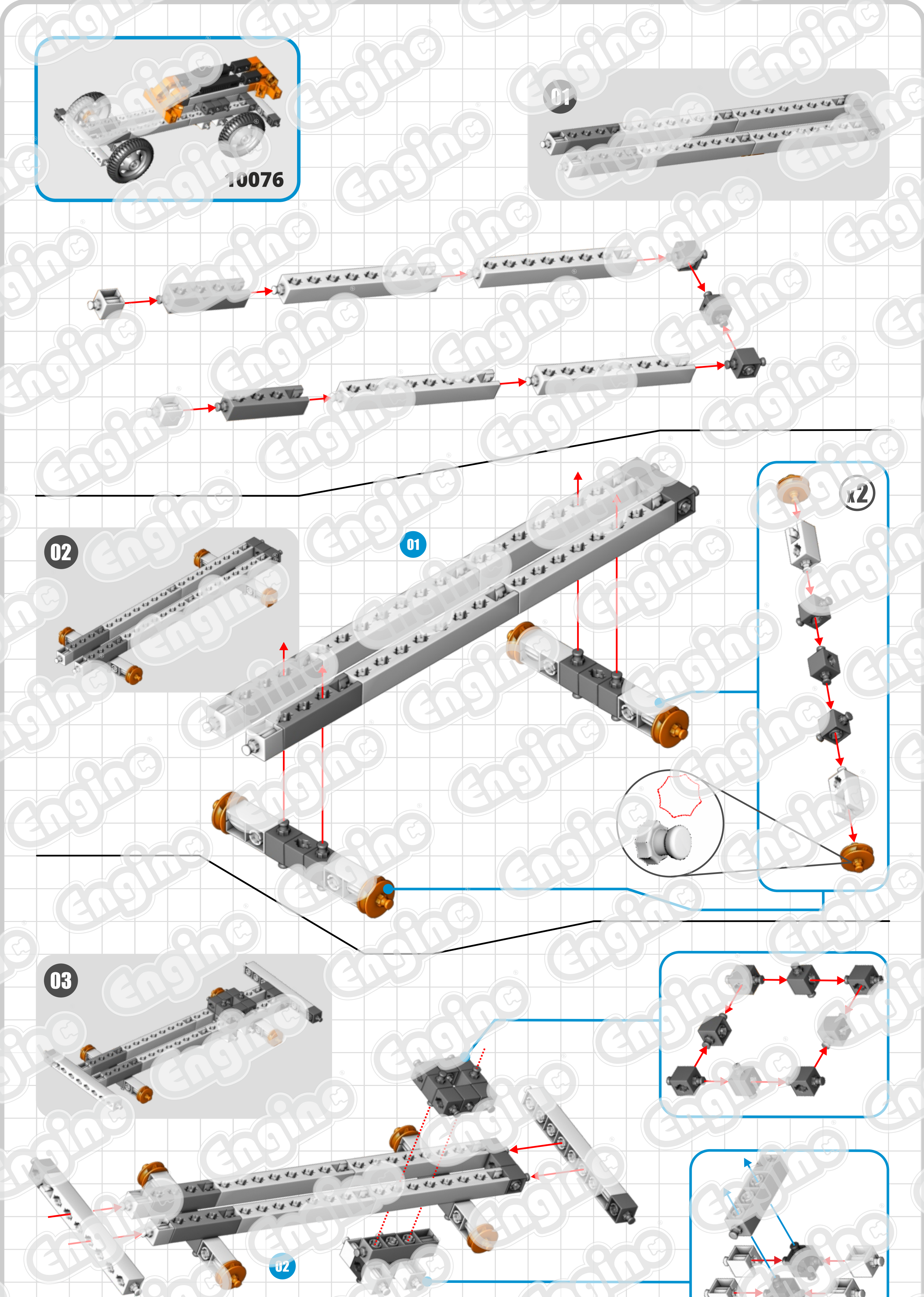
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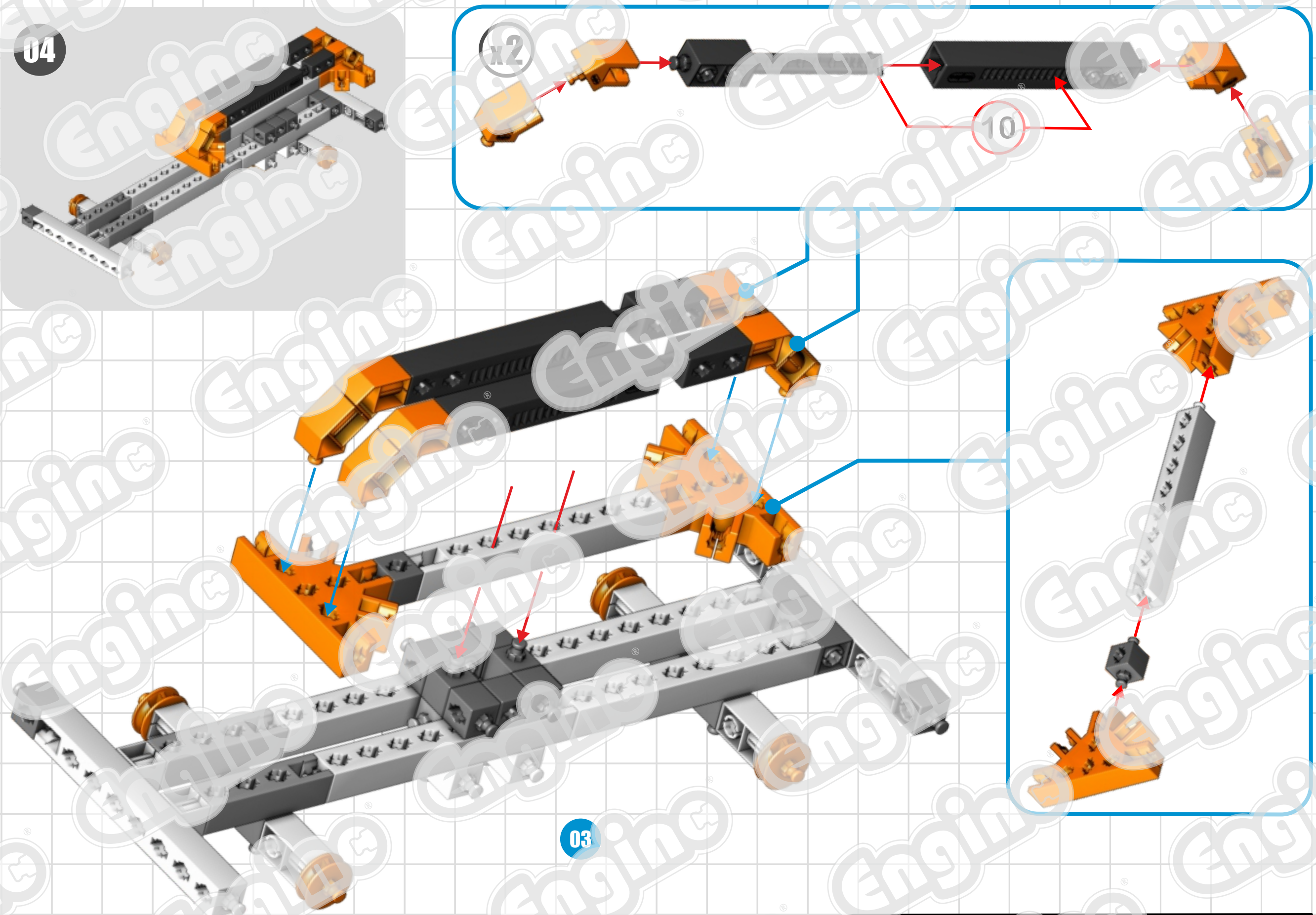
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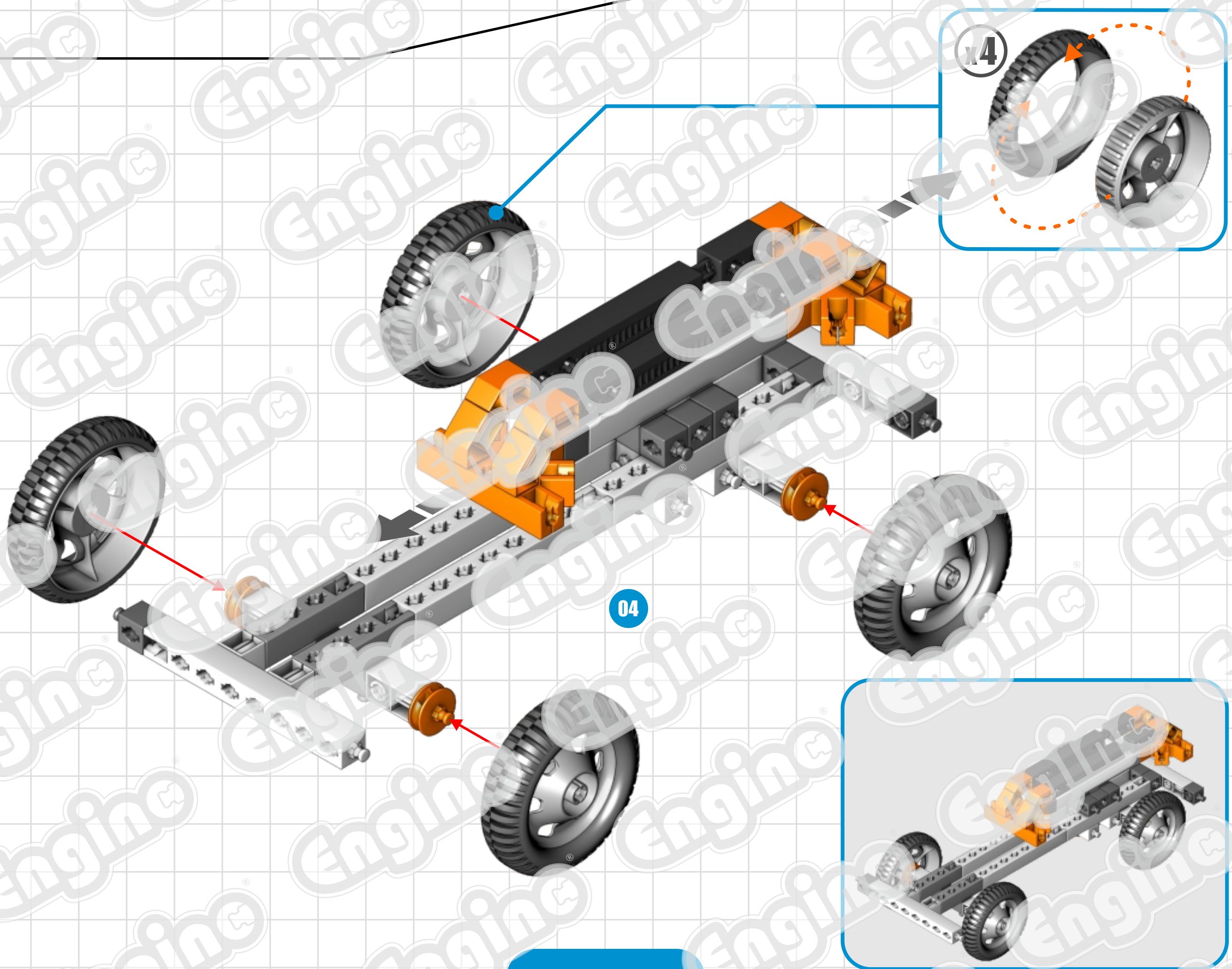
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Lesson: Rocket launcher

Escape velocity

The first man-made object to attain escape velocity from Earth was the spacecraft "*Luna 1*", sent to space in 1959. Escape velocity is the minimum kinetic energy that an object should obtain to surpass the potential energy from gravitational pull. Experiment with your own Engino® rocket!

Discover:

- How can we convert elastic to kinetic energy?
- What is Escape Velocity?

Procedure:

1. Build the **rocket launcher** model. Pass the rubber band twice through the rings and under the triggering component. Tie it firmly at one of the rings. **Be careful** as the band or model **may break under very high tension.**

2. For safety reasons, make sure that nobody is standing above the launcher, as the projectile may cause injury.

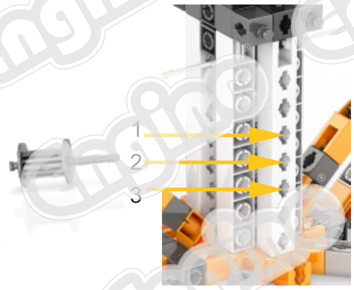
3. For **test 1**, generate 3 launches by locking the trigger in 3 different positions as shown in the table of exercise 1. To generate a launch, pull down the rocket and use the reel-axle system into the proper hole to lock the trigger. Release it with a quick move, and observe the height of the rocket. Fill the table of **exercise 1** with your observations using the words ***low***, ***high*** and ***sky-high***. Also, answer **question 2.**

4. For **test 2**, use **position 3 and keep that constant** for your launches. You will change the length of the launcher's arms. For **case a**, add a small rod to both arms and execute a launch. Observe the height of your rocket. Add a medium rod for **case b** and relaunch the rocket to observe its height. Adjustments can be seen on the pictures on the right. Complete the table of **exercise 3** using the words **high** and **sky-nigh.**

5. Answer **question 4** thinking about the tension of the rubber band for both tests.

1. Complete the table according to your observations from test 1 using the words ***low***, ***high*** and ***sky-high***.

Trigger position	Rocket's height
1	
2	
3	



Use the reel-axle tool to lock the trigger in 3 different positions

2. What is the formula to calculate the energy of a spring? Which factor (of the formula) changes when you stretch it?

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3. Complete the table according to your observations of test 2 using the words ***high*** and ***sky-high***.

Case	Extra parts	Rocket's height
a		
b		

arms for case a

arms for case b

4. Compare the results for the cases when you noted "sky-high". In which test did the rocket launch to higher position? Why?

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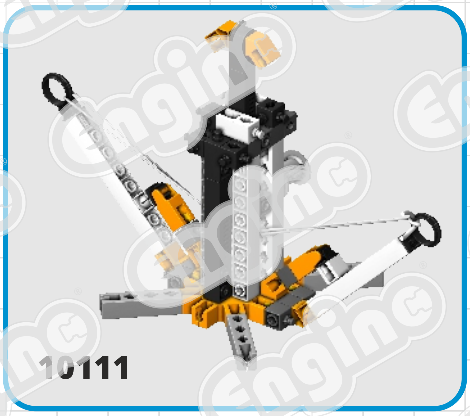
Launch the rocket and observe how high it can reach!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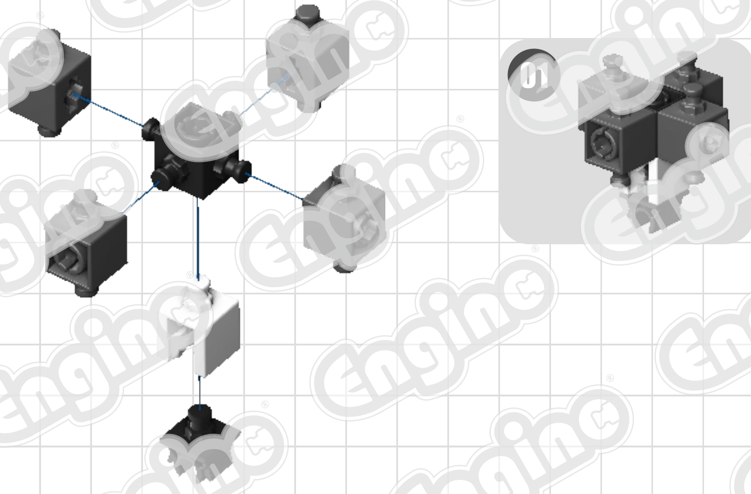
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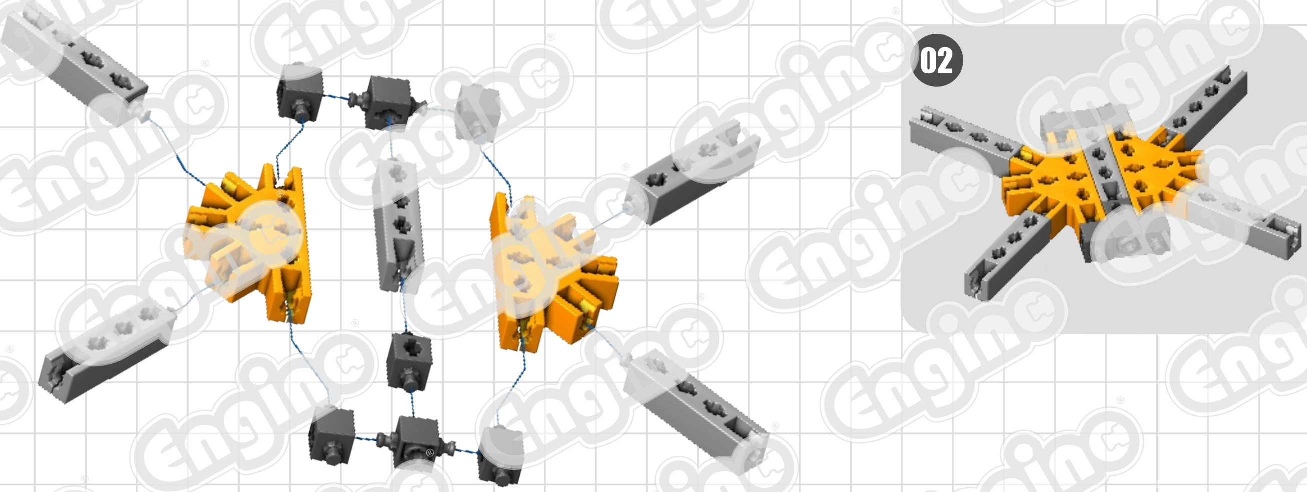
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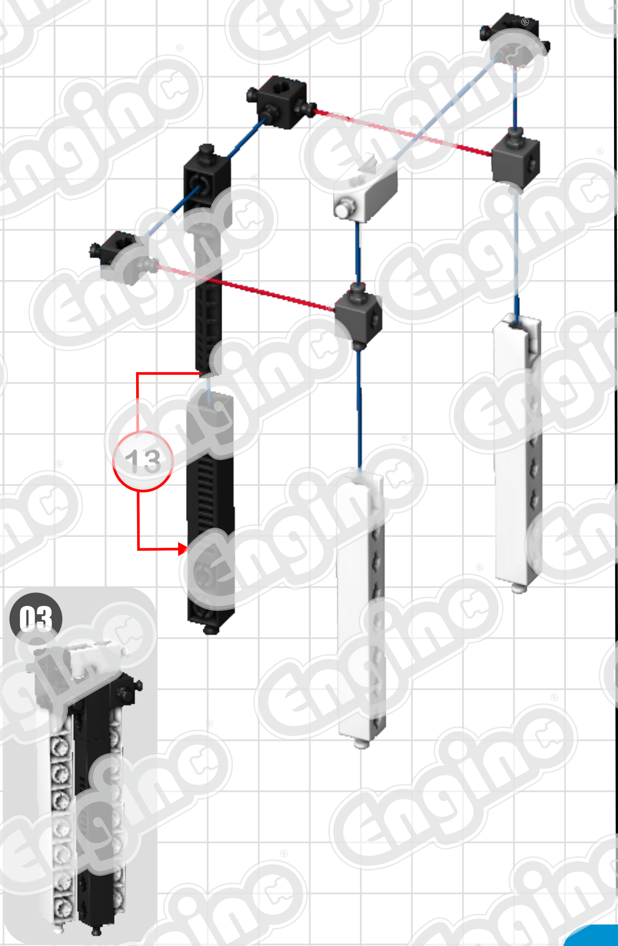
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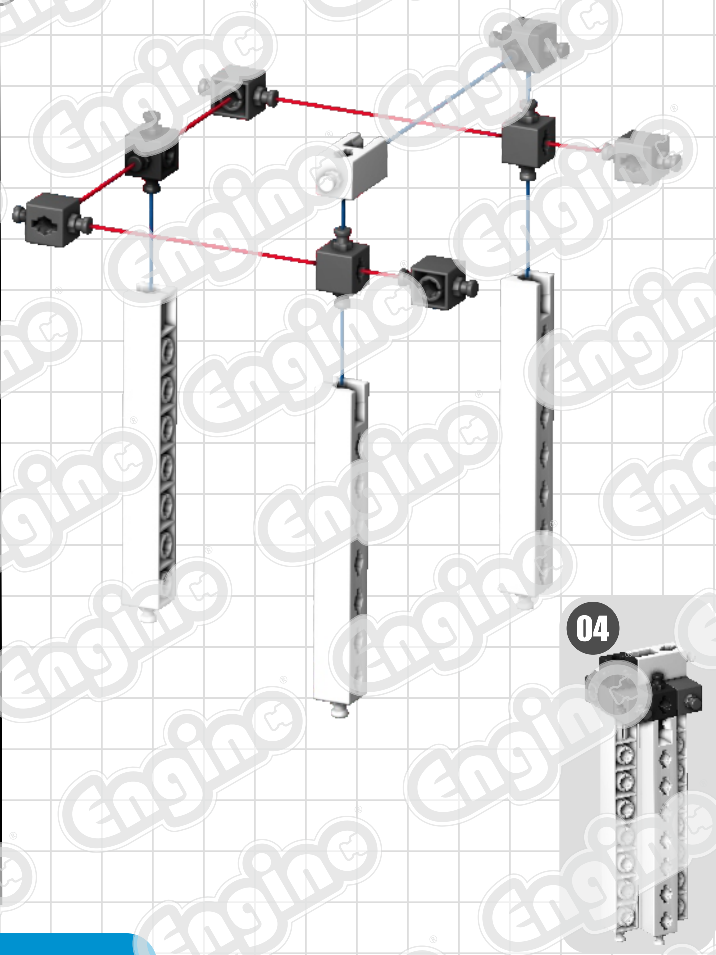
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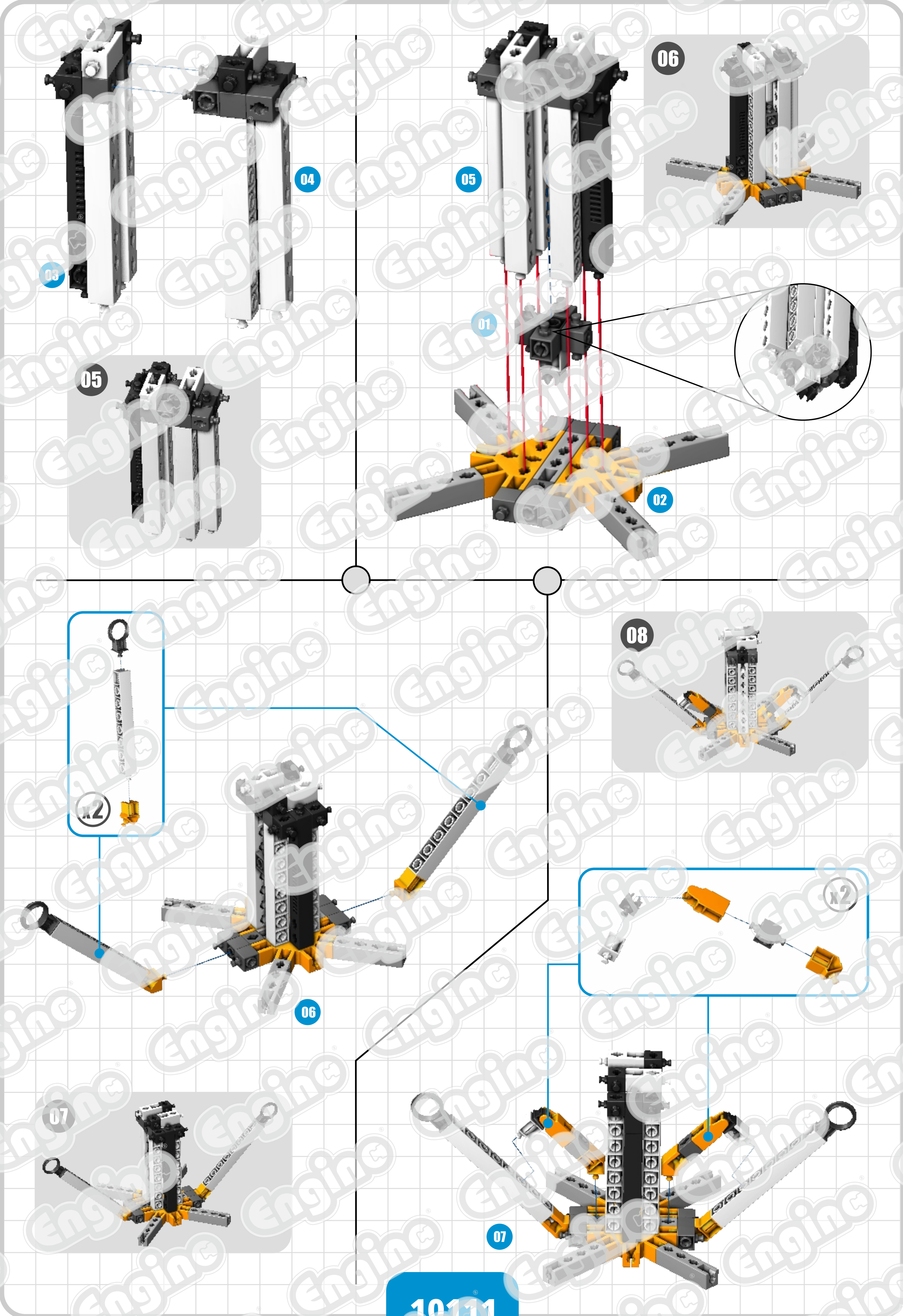
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Lesson: Ballistic Catapult

Newton's second law of motion

Another great scientist contributed to the discovery of the properties of forces and acceleration long before Newton's time: the Italian physicist Galileo Galilei (1564 - 1642). He was rolling balls down various inclined planes and came up with formulas, which were finally explained by Newton centuries after!

Discover:

- What is Newton's second law of motion?
- How force acting upon an object is related to the object's mass and acceleration?

Materials Needed:
- Long rubber band and measure tape.

Procedure:

1. Build the **ballistic catapult** model. Pass the rubber band twice through the holes and tie it in the end.

2. **For safety reasons, is better you conduct the experiment outdoors and make sure noone is standing in front of the catapult when is loaded and ready to shoot. Also, be careful with the rubber band as it can break under high tension.**

3. In all launches is important that **two factors are kept constant:** the tension of the rubber band and the shooting point.

4. For **test 1**, place your catapult at a fixed point and load it with one wheel-pulley assembly (as shown in the table, projectile column). Hold the catapult with one hand and release the medium rod. A second person is required to see the exact point where the projectile touched first. With the help of a measure tape, find the distance between the catapult and that point and write it on the table (**1a**). Repeat the same procedure two more times and write the results for **1b** and **1c**. Then calculate the **average distance** by adding the 3 together and dividing by 3.

5. For **test 2** and **test 3**, add one and two wheel-pulley assemblies and repeat the same as before. Write the results in **2a**, **2b**, **2c** and **3a**, **3b**, **3c** and calculate the average distances.

6. Answer all the questions that follow. When you finish do not disassemble your model, as you will need it for the next experiment also.

1. Complete the table according to your measurements from the experiment.

Test	Projectile (number of wheels)	Projectile's distance (m)	Average distance (m)
1.	 1	(a)	
		(b)	
		(c)	
2.	 2	(a)	
		(b)	
		(c)	
3.	 3	(a)	
		(b)	
		(c)	

2. Compare the average distances in all 3 tests. What do you observe?

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3. Read about Newton's second law of motion below and explain your observations from the experiment. Keep in mind that the force (rubber band's tension) is the same in all cases.

> **Newton's second law of motion:**
> *"The sum of forces **F** acting on an object is equal to the mass **m** of the object multiplied by the acceleration **α** of the object."*
> **F = m.a**

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Lesson: Ballistic Catapult

Newton's third law of motion

Newton's third law of motion is so simple that is surprising how many years it took to be formulated! It is applicable in all situations that forces are involved! The third law explains why balls bounce, why we feel pain when we hit our hand on the table and how rockets can escape Earth's gravitational pull!

Discover:

- What is Newton's third law of motion?
- What is an equal and opposite force?

Materials Needed:
- Long rubber band.
- 6 cylindrical pencils and ruler.
- Bag with sand and weigh scale.

Procedure:

1. Build the **ballistic catapult** or use the one from the previous experiment without the wheels. Pass the rubber band twice through the holes and tie it in the end.

2. For safety reasons, is better you conduct the experiment outdoors and make sure noone is standing in front of the catapult when is loaded and ready to shoot. Also, be careful with the rubber band as it can break under high tension.

3. In all launches it is important that **two factors are kept constant**: the tension of the rubber band and the shooting point.

4. Find a fixed point and set your model above 6 cylindrical pencils (as shown in the picture). Alternatively, you can place your model in a slippery place.

5. For **test 1**, fill the bag with **50 grams** of sand, measured with the weight scale. Alternatively you can use 2 Engino wheel-pulley assemblies (see picture on the right) or other materials. Place your ruler on the edge of the model (last pencil) and shoot the projectile. Then measure how much distance the catapult has moved after the launch and write it on the table in **exercise 1**.

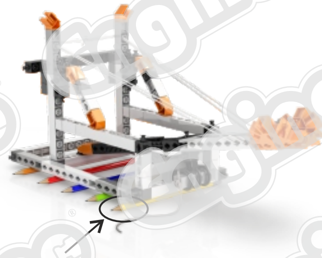
6. Repeat the same procedure for **tests 2** and **3**, altering the weight **100g** and **200g**.

7. Answer the questions that follow according to your results and Newton's 3rd law.

1. Complete the table according to your measurements from the experiment.

Test	Projectile's weight (g)	Catapult's distance (cm)
1.	 50 g	
2.	 100 g	
3.	 200 g	

This assembly is around 25 g and you can use it alternatively to the bag with sand, for small weights.



start measuring the catapult's distance from this point (the last pencil)

2. Compare the measurements from all 3 tests. What do you observe?

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3. Read Newton's third law of motion and explain your findings according to it, about the relation between the projectile's weight and the catapult's distance.

Newton's third law of motion:
"For every action there is an equal and opposite reaction."

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4. Why the projectile travels longer distance in comparison with the catapult?

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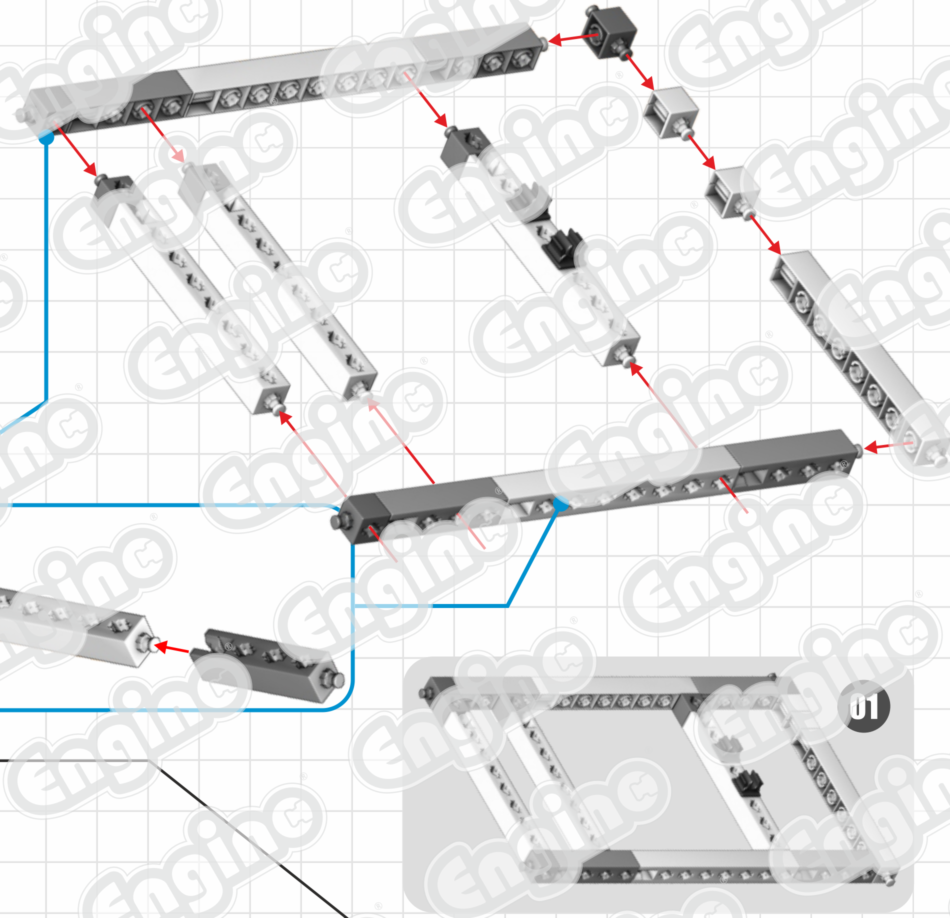
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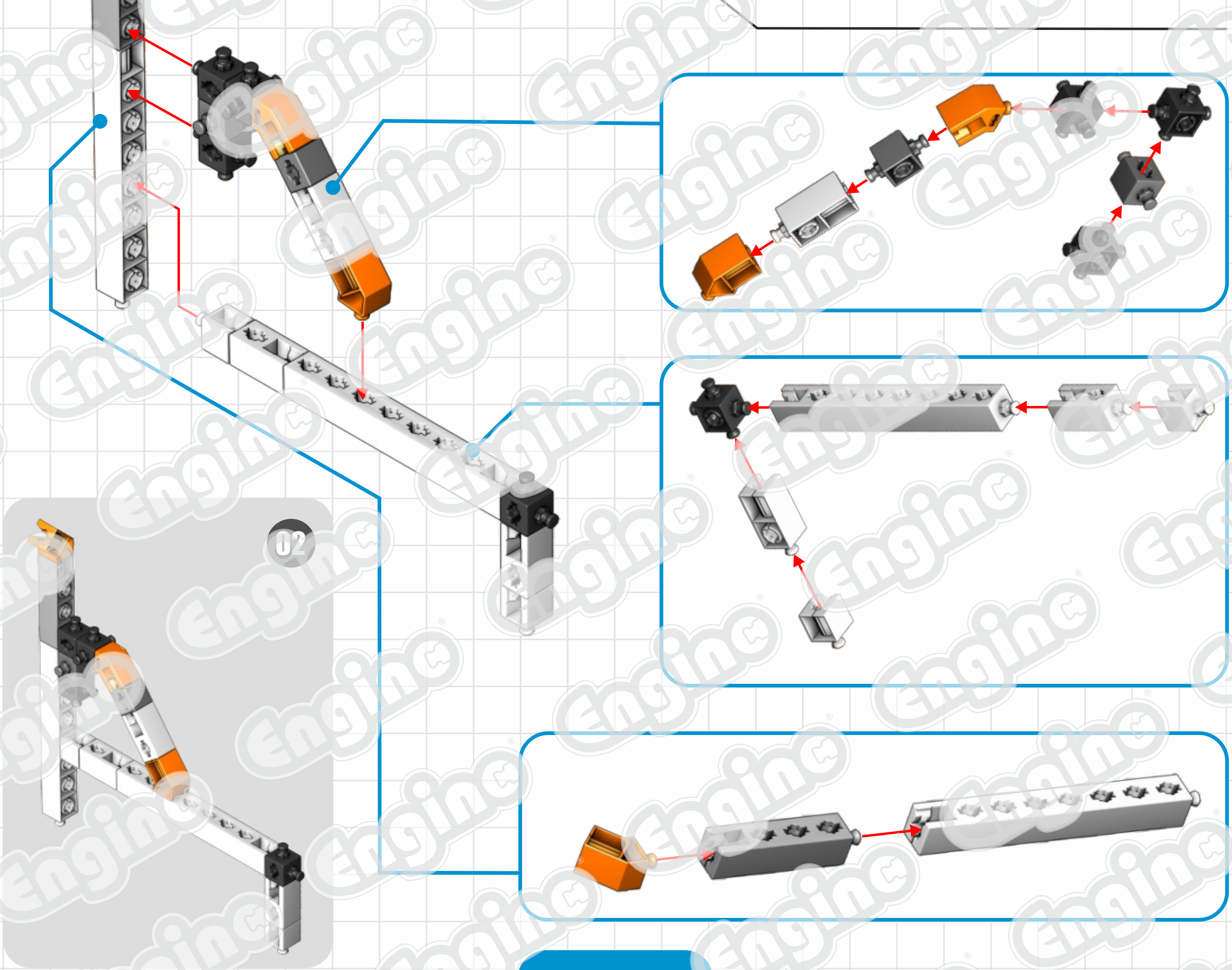
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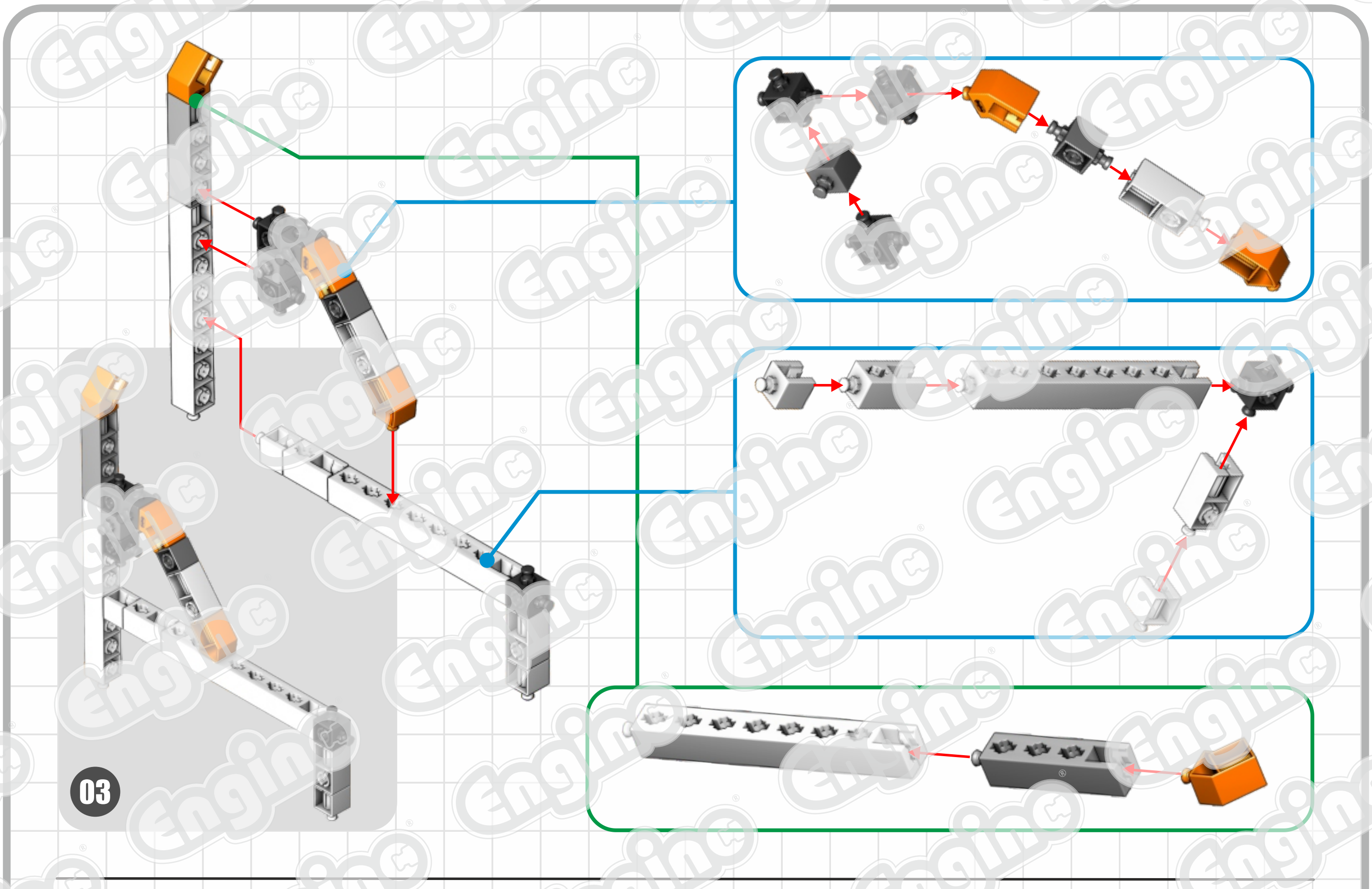
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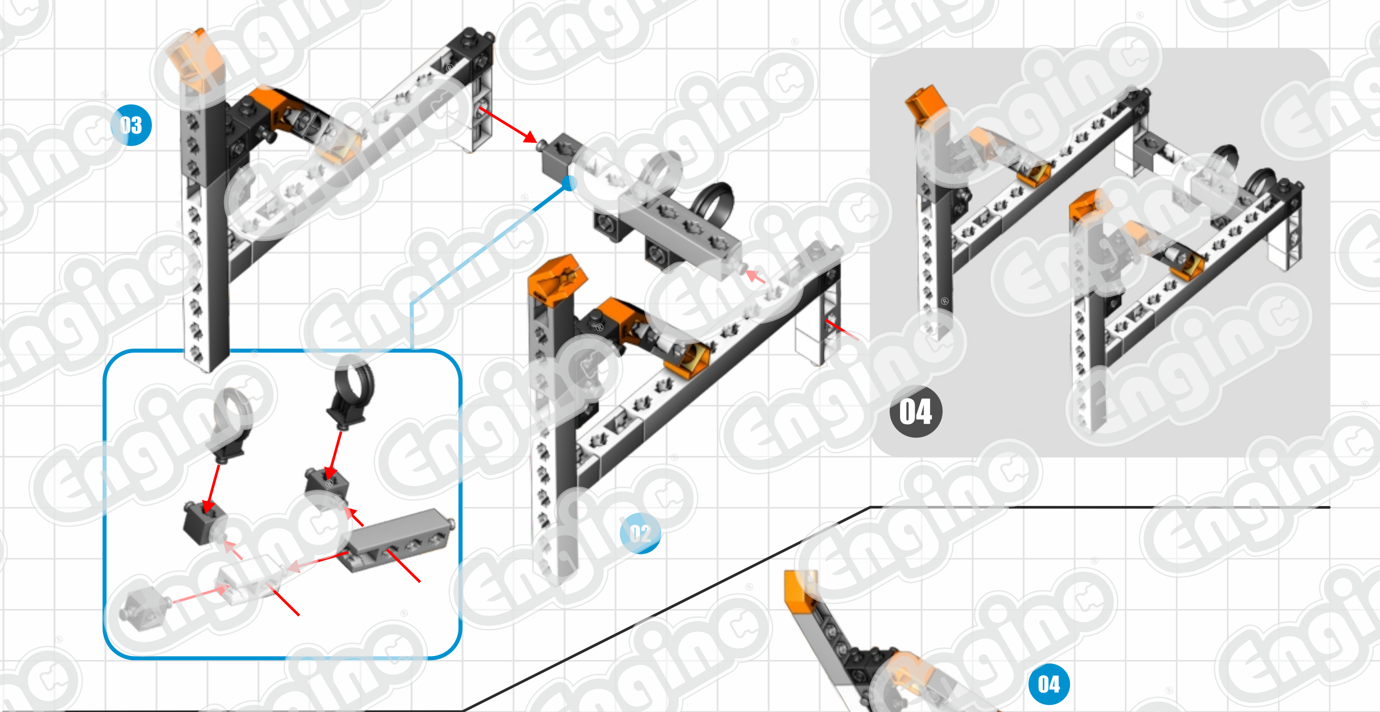
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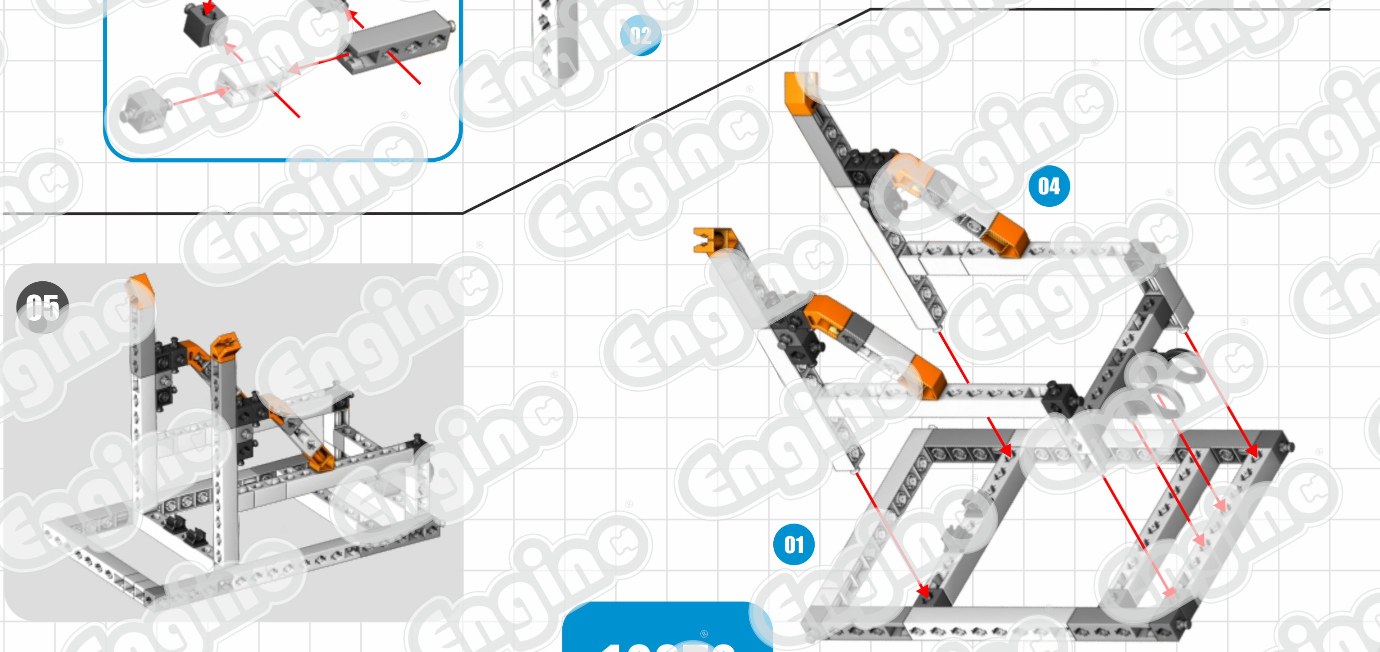
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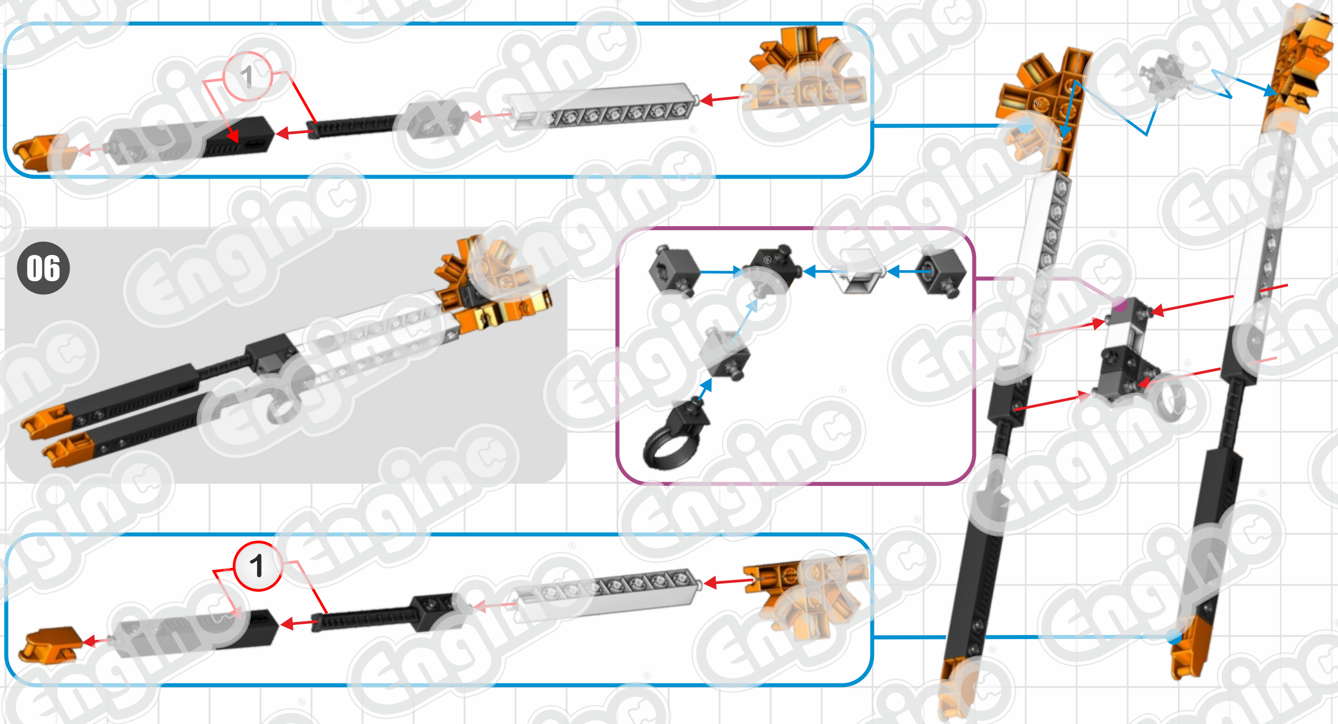

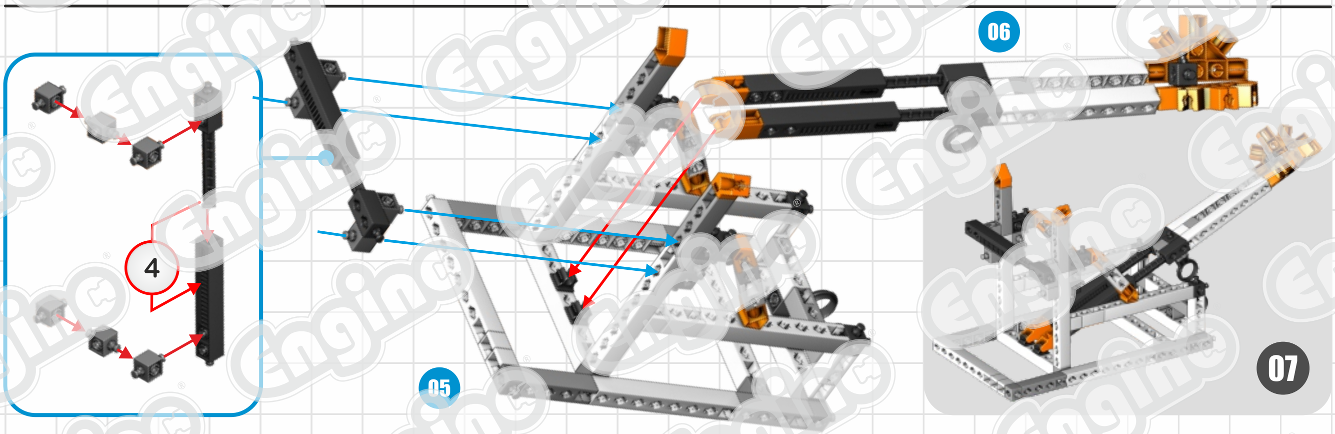

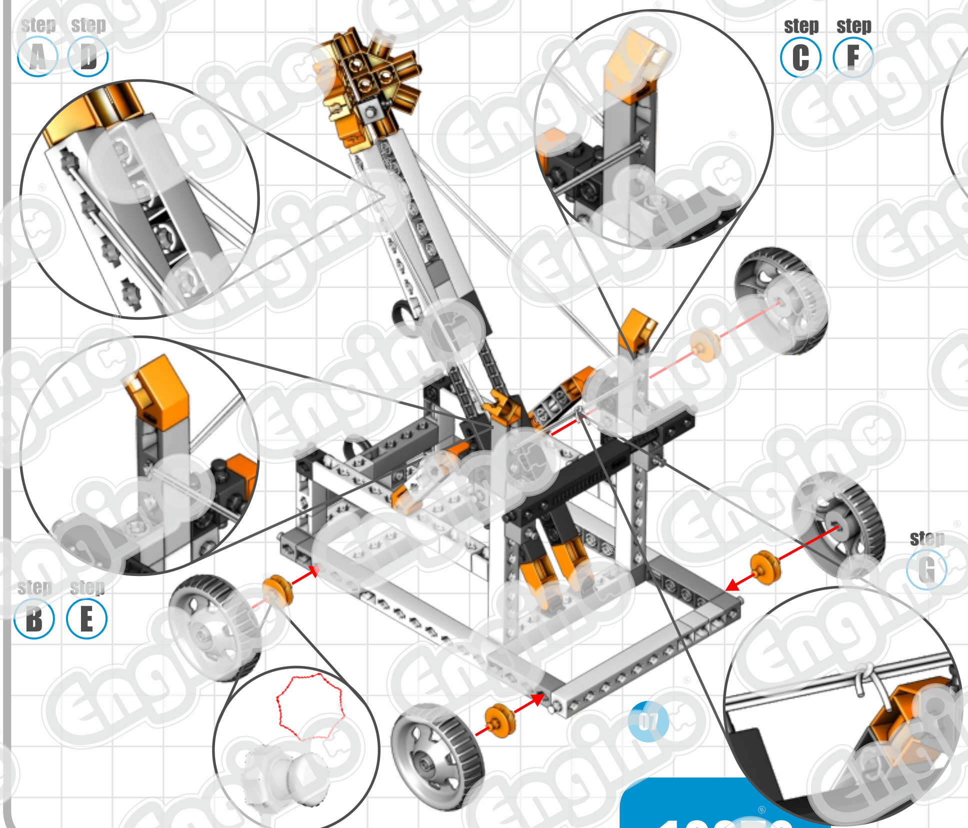

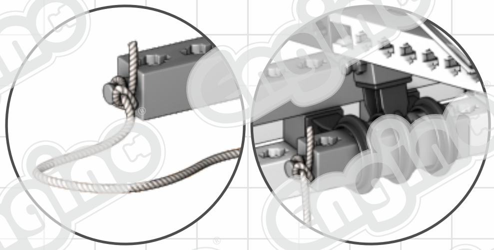

To load the catapult, pull back the sling and slide a medium rod with a string attached to it through the three rings. Pull the string to launch.

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