STEM & Robotics Produino Set

E40.1 STEM Lessons

The **STEM & Robotics Produino education set** is specially designed for Secondary school children of ages 12+ but is ideal for older students of 12-16+ and even vocational schools and hobby engineers. With innovative experimental activities it covers the core subjects of STEM and moves into advanced programming with textual coding. Besides its main controller, it embeds an additional Arduino processor that enables open DIY projects. The set comes in a convenient plastic storage tub that contains a large number of ENGINO® structural and technical parts and high-level of robotic devices such as the unique Produino controller. It has 2 DC motors, a servo motor, a touch sensor, 2 IR sensors, a color sensor, an ultrasonic sensor and a gyroscope/accelerometer sensor. Besides the programmable screen, it conveniently has a built-in large breadboard for making your own circuitry. It allows the construction of more than 30 STEM and Robotic models.

Engino® EDUCATION

12-16

Edition: 10/22

Lesson: Movable weight scale

First-class lever

I bet all of you have been to the doctor for a general check-up! Do you remember getting on a weird device with movable beams and some strange numbers written on them? What do you think is that device and how does it work exactly? You are about to find out by carrying out the following experiment.

Discover:

- What is a first-class lever?
- How does a balance beam scale work?

Materials Needed:
- Engino® STEM and Robotics PRODUINO.
- Beans, pebbles or any other small materials.

Procedure:

1. Build the **movable weight scale** model.

2. Complete **exercises 1** and **2.**

3. Try to balance the model with the help of the movable part (the part that contains a wheel) and count the distance from the fulcrum in squares, starting from the unit piece near the fulcrum.

4. Now, we will need some small materials to put as weights on the scalepan (weighing pan). These could be pebbles, beans, erasers or even other Engino parts that are included in your set. Put 3 or 4 of these materials on the scale and observe what happens.

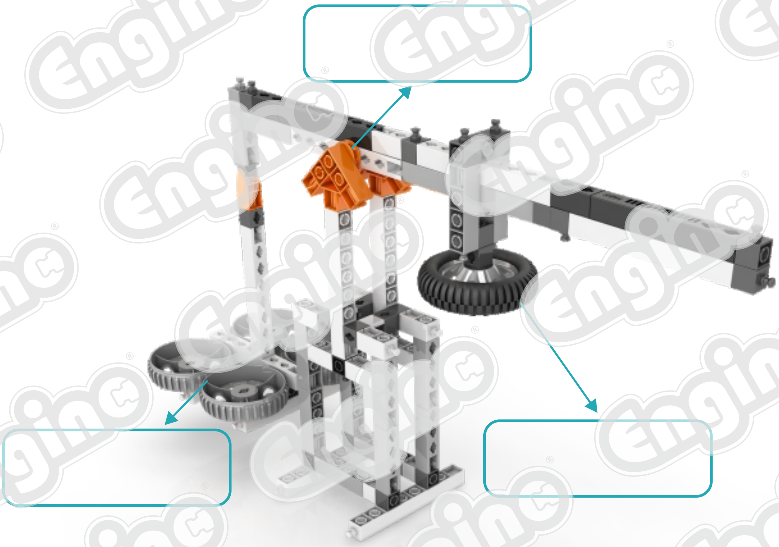
5. You will probably see that the balance is lost and the scale is leaning on the scalepan's side. Restore the balance again by adjusting the movable weight.

6. Place some more materials on the loading base until it's fully loaded and try to balance the beam again. Is it possible? Why does this happen? Answer **question 3** according to your experimentations.

7. Complete **exercise 4.**

Engino® "movable weight scale" model

1. Look at your Engino® "movable weight scale" and fill-in the boxes with these words: **load, effort, fulcrum.**



2. Which one of the three elements (load, fulcrum, effort) of the lever above is placed between the other two? What class of lever is this?

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3. How does a balance beam scale work?

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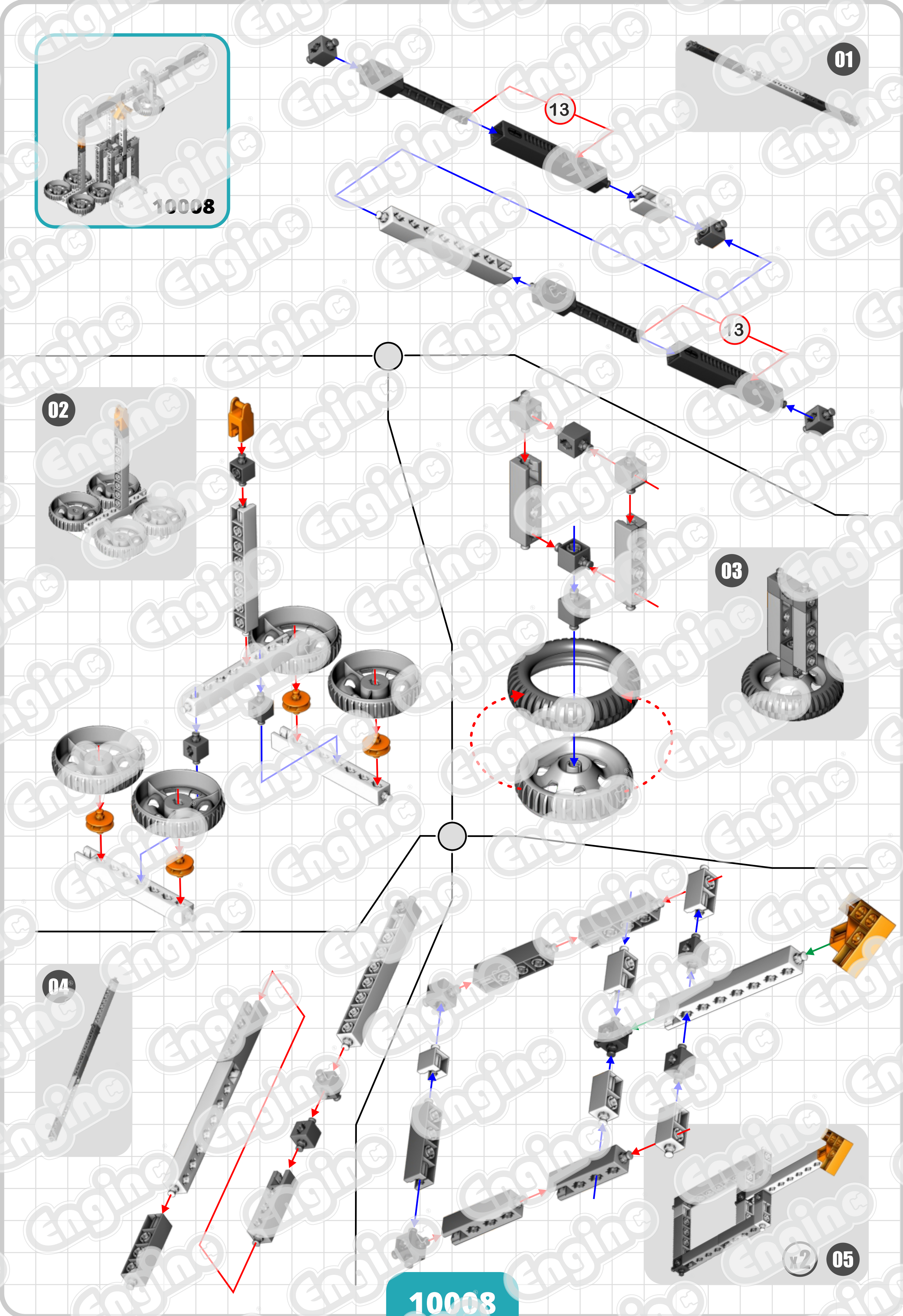
4. In the following images you can see some examples of first-class levers. Take a look at the pictures and show with arrows where the load, the effort and the fulcrum are applied.

Claw hammer

Scissors

Pliers


10008
13
01
13
02
03
04
x2
05


01
02
03
04
05
05
06
06
07
07
move the wheel
to balance the scale!

Lesson: Parking gate

Third-class lever

Parking gates are everywhere! They are conveniently positioned in airports, business buildings, big supermarkets and lots of other places in order to control who enters or exits the parking lot. But how do they work? What class of lever are they and how can we modify them?

Discover:

- What is a third-class lever?
- What is the relationship between force and distance?

Materials Needed:
- Engino® STEM and Robotics PRODUINO

Procedure:

1. Build the **parking gate model, but do not add step 6** just yet. Try opening the parking gate. How much force did you use?

2. Now **add step** 6 from the instructions. Try to open the gate again, feeling the amount of effort you apply this time. Is it the same as before? The model now contains two levers! What classes of levers are they?

3. Take a look at the assembly of step 1 which we have just added and note that the pulley is joined at the center of the rod. Move that pulley in positions 1, 2, 3 and 4 (as you can see in the picture on the right) and try to open the gate each time. Can you feel the difference in the amount of effort you apply? In which position do you need less force? Complete the table in **exercise 1** and answer **exercise 2**.

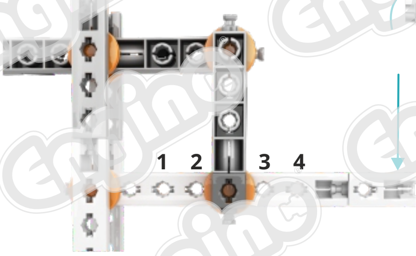
4. Now, let's improve our parking gate even more! If you look closer, you will notice that the rod we apply the force on is protruding from one side. So, we need to move the rod to reach the same length as the rod above. This way the gate will be safe and we can still open it.

5. The solution for this is simple! Just move the protruding rod five squares to the left and link both rods with the linkage as you can see in the picture on the right.

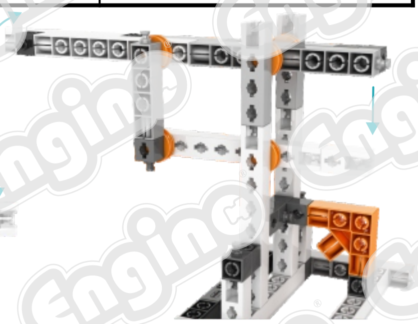
6. By making this simple arrangement you have managed to change the lever's class for each rod. Before the change, the above rod was a first-class lever and the lower rod was a second-class lever. What class of lever are these rods now? Complete **exercises 3** and **4**.

1. Complete the following table according to your observations in step 3 of the experiment. Use the words **easiest, easy, medium, hard** for the Force (effort) you applied to open the gate and **shortest, short, medium, long** for the distance (height) that the gate has covered, for each position (1-4).

Position	Force	Distance of the gate
1		
2		
3		
4		



Change the position of the pulley in these four places



“Safer” parking gate model

2. What do you observe in the table above? What is your conclusion about the relationship between force and distance?

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3. Find the two types of levers on your last model and draw them with simple sketches in the boxes below. Write the type of lever and show each element with arrows.

Upper lever	Lower lever
This is a ....-class lever	*This is a ....-class lever*

4. How can we change the class of a lever?

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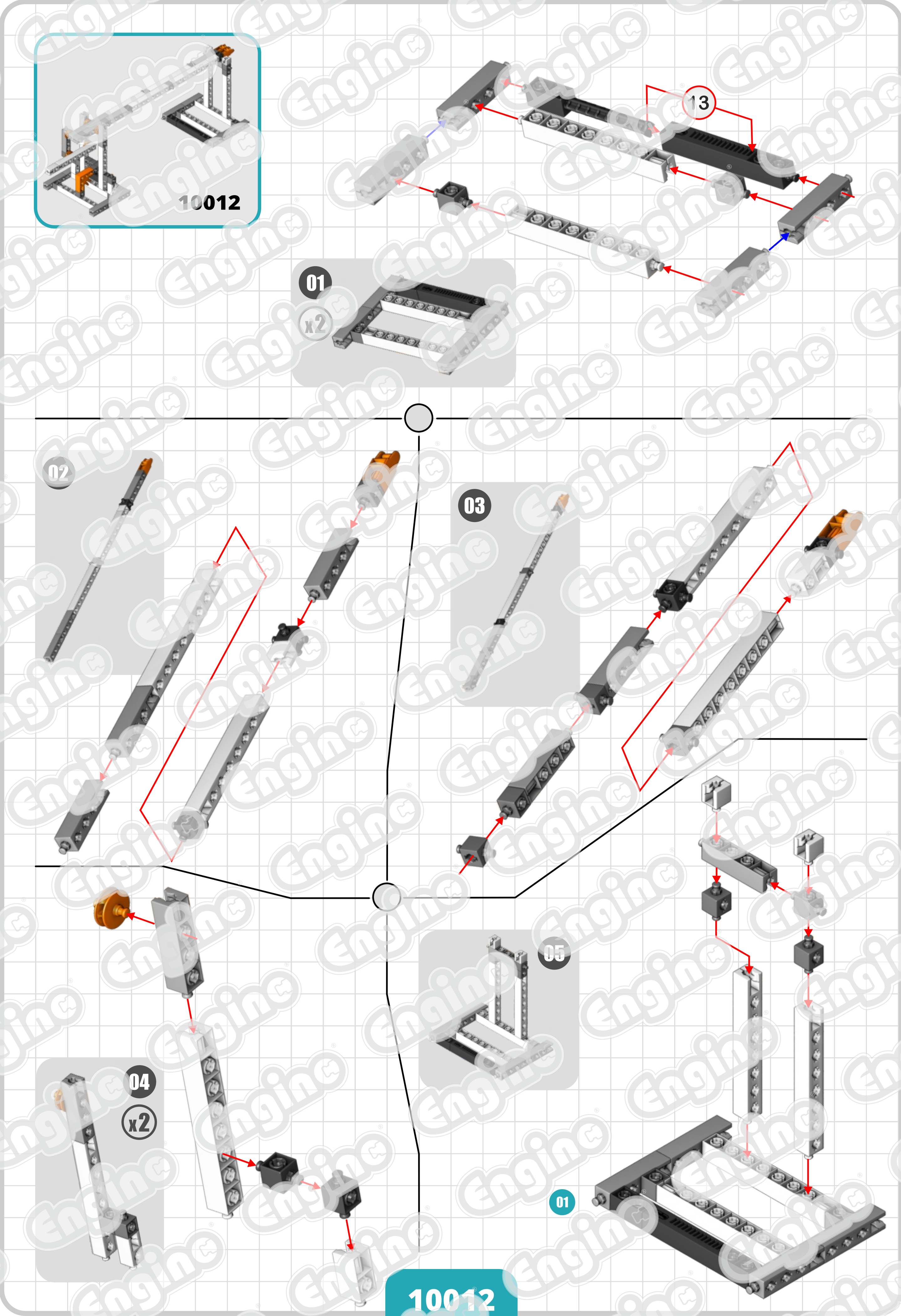
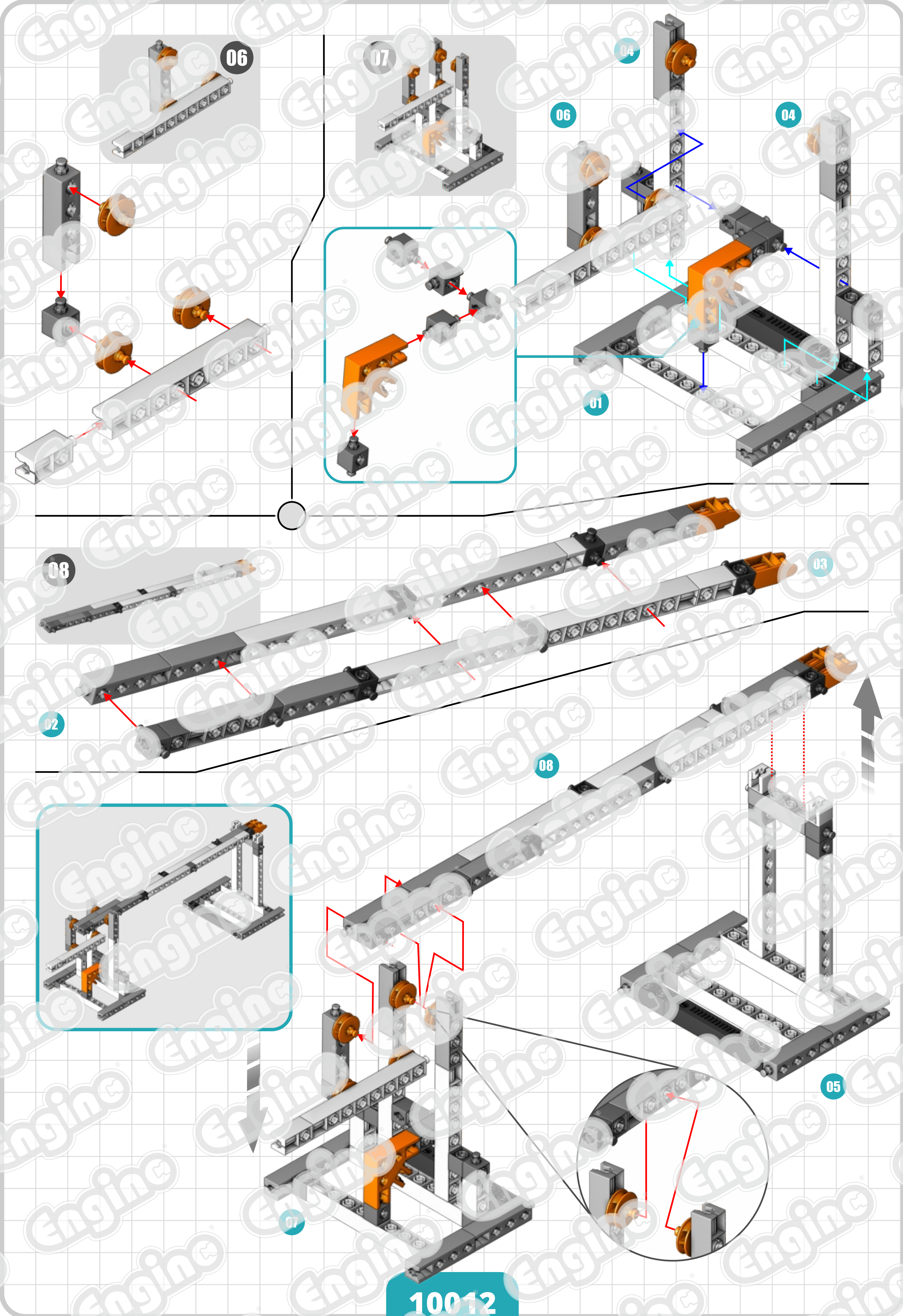

10012
13
01
x2
02
03
04
x2
05
01


06
07
04
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07
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Lesson: Experimental ramp

Study of different cases

Have you ever seen a car being towed? If yes, it must have been a dreadful experience for the owner I am sure! But from that, probably you noticed a ramp car lifting the car and taking it away! How does this device manage to lift heavy cars or objects so easily? Perform the next experiment and find out!

Discover:

- How does inclination relates to the lifting force and the distanced travelled by the load?
- What is Work and how can you calculate it?

Materials Needed:
- Engino® STEM and Robotics PRODUINO.

Procedure:

1. Build the model of the **experimental ramp** (ignore case 2 and case 3 steps in page 11). Place your ramp on a high desk, leaving enough space for the rope to move.

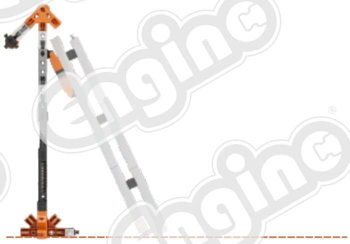
2. In **case 1**, measure the length of your ramp by counting the number of Engino large grey rods on the top of the inclined side. Write your result in the space provided. Then, put one wheel on the hook and observe whether the experimental "vessel" moves up the ramp. If not, connect another wheel on the first one with the help of an orange pulley, to increase the weight. Repeat the same procedure until the "vessel" starts moving up the ramp. Write down the **minimum** number of wheels you need.

3. In **case 2**, add at the end of the ramp the parts shown in **page 11 (case 2)**. Now your ramp is longer, but not as steep. Like before, measure the number of Engino beams and the minimum number of wheels needed for the "vessel" to start moving up the ramp.

4. In **case 3**, add once more at the end of the ramp the parts shown in **page 11 (case 3)**. Now your ramp is even longer and has an even gentler slope. Repeat the same procedure as before and write your results in the appropriate places.

Engino® "experimental ramp" model

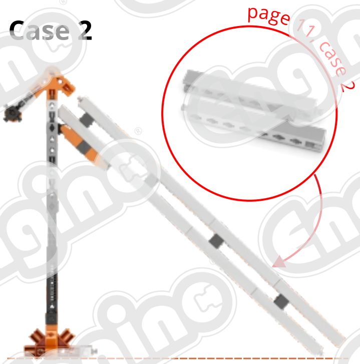
Case 1



☐ Number of beams

Number of wheels ☐

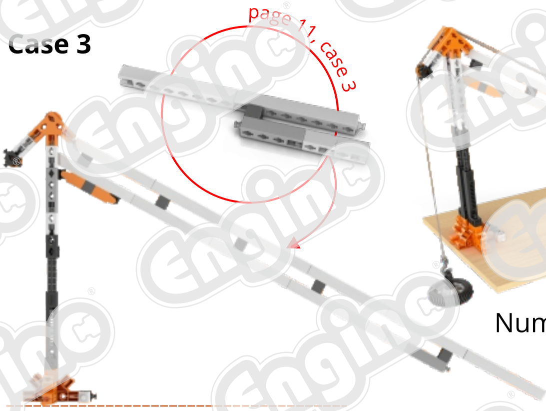
Case 2



☐ Number of rods

Number of wheels ☐

Case 3



☐ Number of rods

Number of wheels ☐

1. At which case did you use the least weight to make the vessel move up the ramp? Why?

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2. Multiply the number of wheels used to make the vessel move with the number of beams used (showing the length of the plane) for each case. What do you observe?

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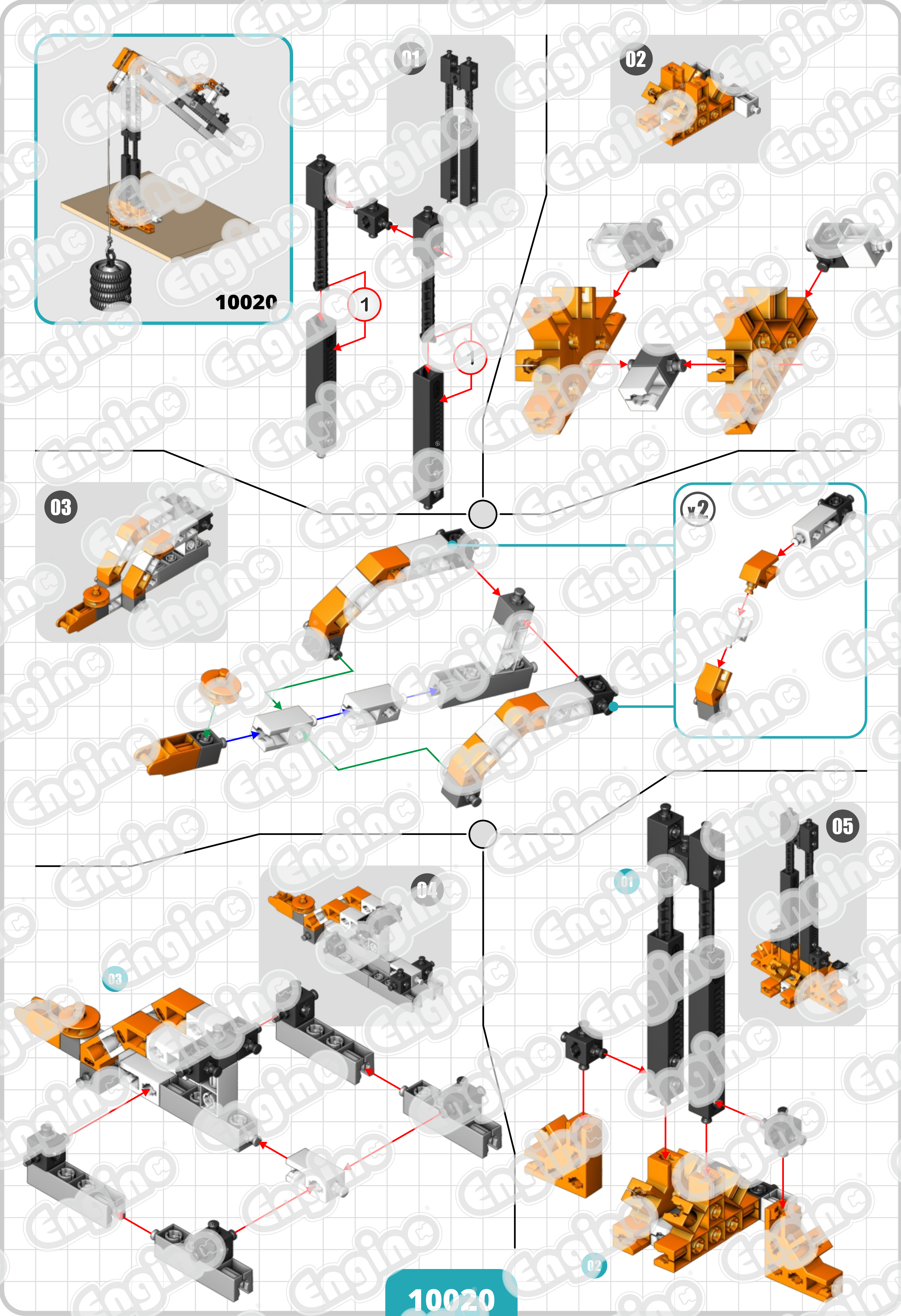
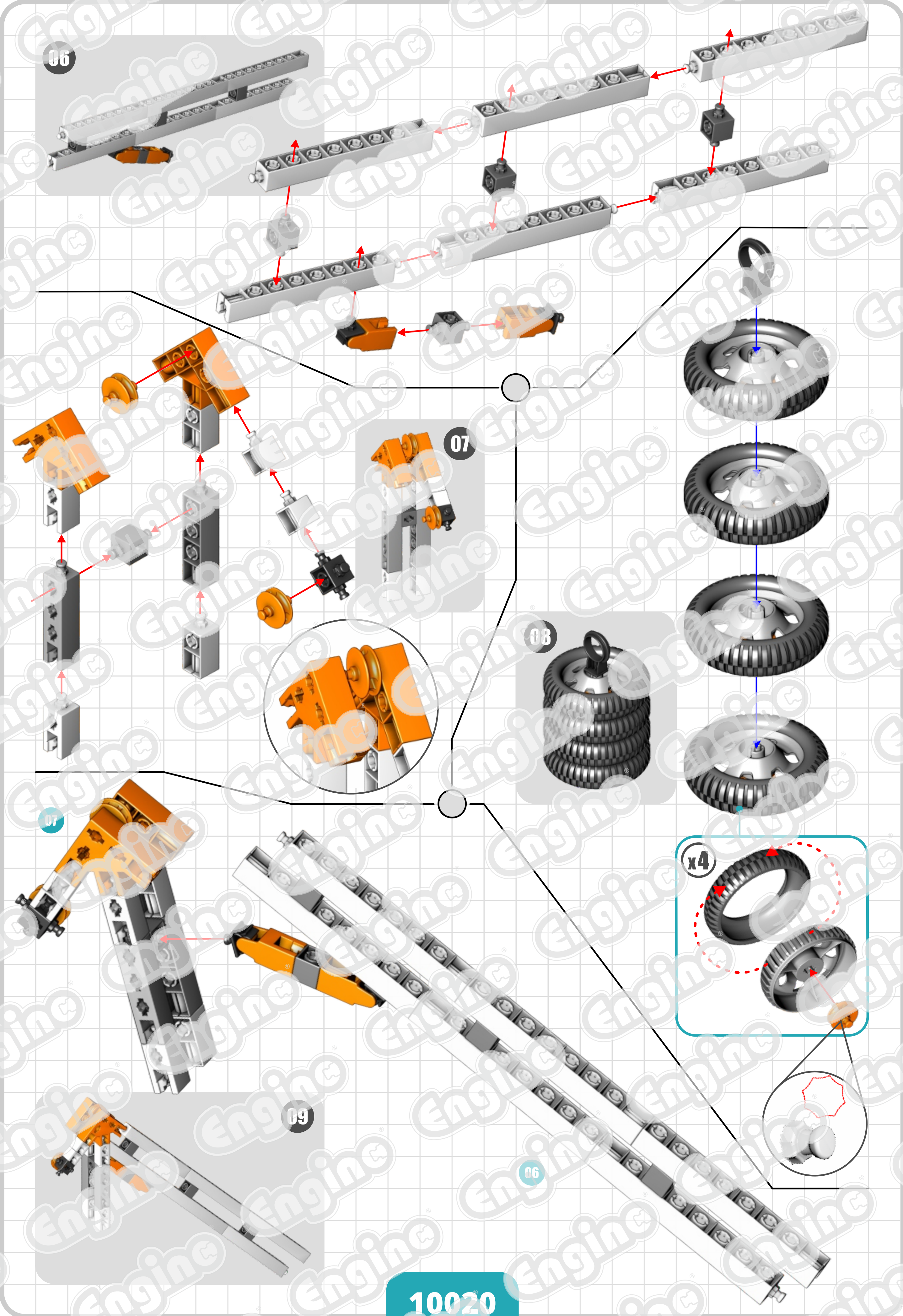
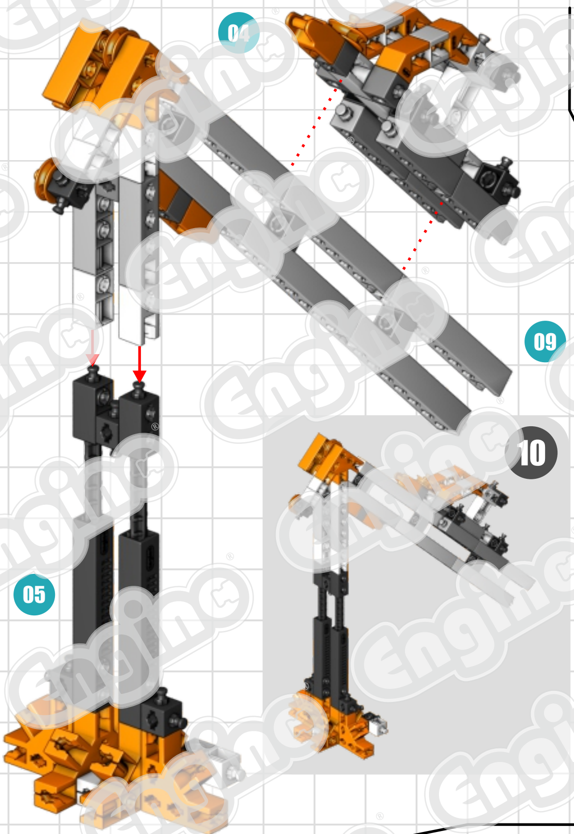
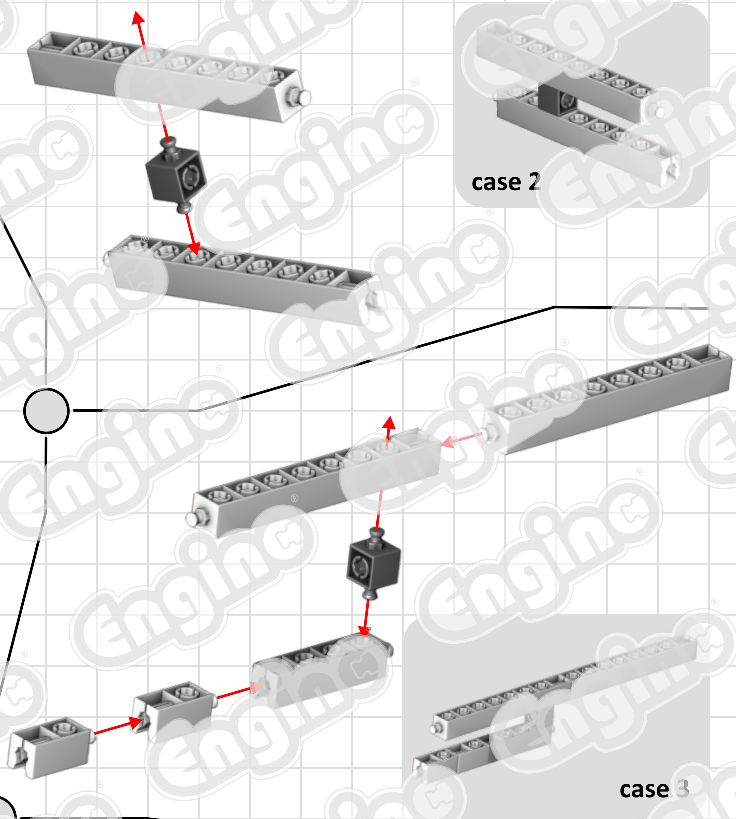
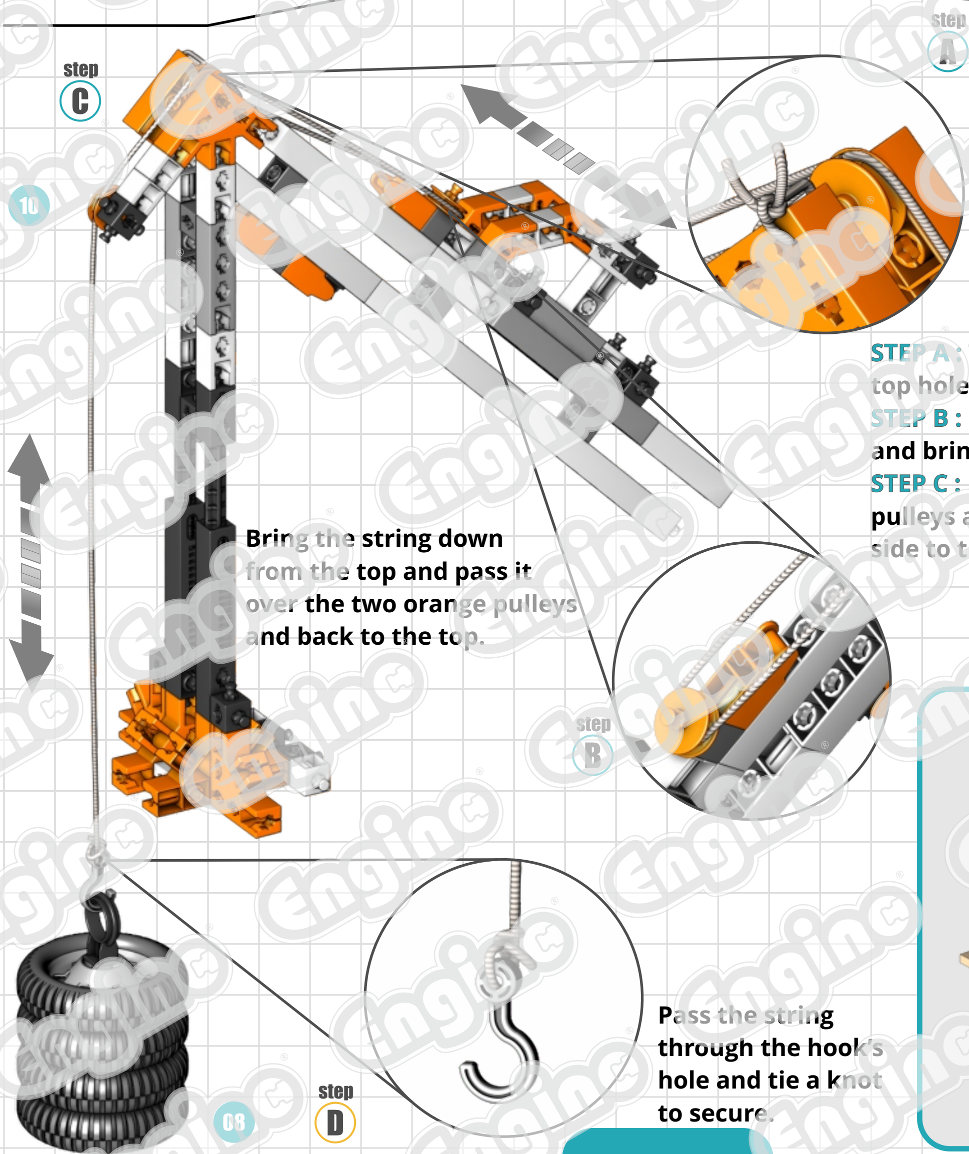


10020
01
1
1
02
03
x2
04
03
05
01
02

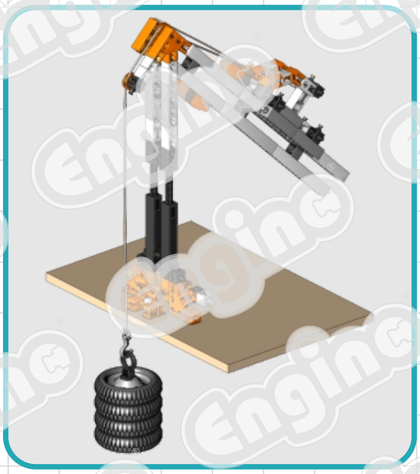

06
07
08
x4
07
09
06







STEP A : Tie one end of the string in the top hole and bring it down the ramp.
STEP B : Pass it around the vessel's pulley and bring it back to the top.
STEP C : Lay the string over the two top pulleys and bring it down on the other side to tie on the hanging hook.



Lesson: Oil drill

Relation of force and speed

The use of a crank as a handle, even though it has many applications, it does not take advantage of the full potential of the mechanism. However, the oil drilling machine (pumpjack) uses cranks not as handles, but as parts of the entire drilling mechanism. How? Let's build the next model and find out!

Discover:

- What is the relationship between a crank's position and the difficulty in rotation?
- What is the relationship between the force (difficulty in rotation) and the speed?

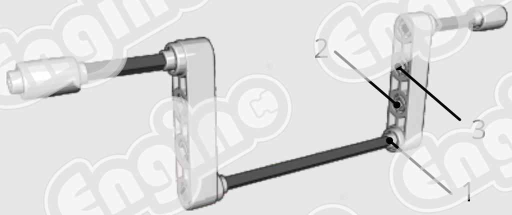
Materials Needed:
- Engino® STEM and Robotics PRODUINO
- Ruler.

Procedure:

1. Build the **oil drill** model.

2. In this model, there are two cranks: the input and the output. Identify them and write their names in the picture at the bottom.

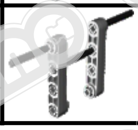
3. For **case 1**, the middle axle is inserted in the first hole of both the output and the supporting cranks (see number 1 in the picture below). Turn the input crank, feeling the force applied and observing the speed of the piston pump. Then, with the help of a ruler, measure the maximum distance which the piston pump is moving along the vertical axis (simulated by the extendable rod).



4. For **case 2**, insert the middle axle in the second hole of the cranks (indicated with number 2) and turn the input crank. Repeat the same observations (speed, force and distance). Note that the extendable rod is not fully inserted in now, so measure the maximum travel distance accordingly.

5. For case 3, remove the middle axle and insert it in the third hole of the cranks (indicated with number 3) and follow the same procedure as before. Again, be careful when taking your measurement, by placing your ruler at the appropriate point.

1. Complete the following table with your measurements and compare the force and speed for each case.

Case	Handle's Position	Piston's pump distance	Force (difficulty in rotation)			Piston's Pump Speed		
			Easy	Medium	Difficult	Slow	Medium	Fast
1.								
2.								
3.								

2. Look carefully at the "Handle's position" column and the "Piston's pump distance" column and write down your conclusions about the relationship between the position of the handle and the distance the piston pump travels.

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3. Now, write down your conclusions about the relationship between the difficulty in turning the crank ("FORCE") and the speed of the piston pump.

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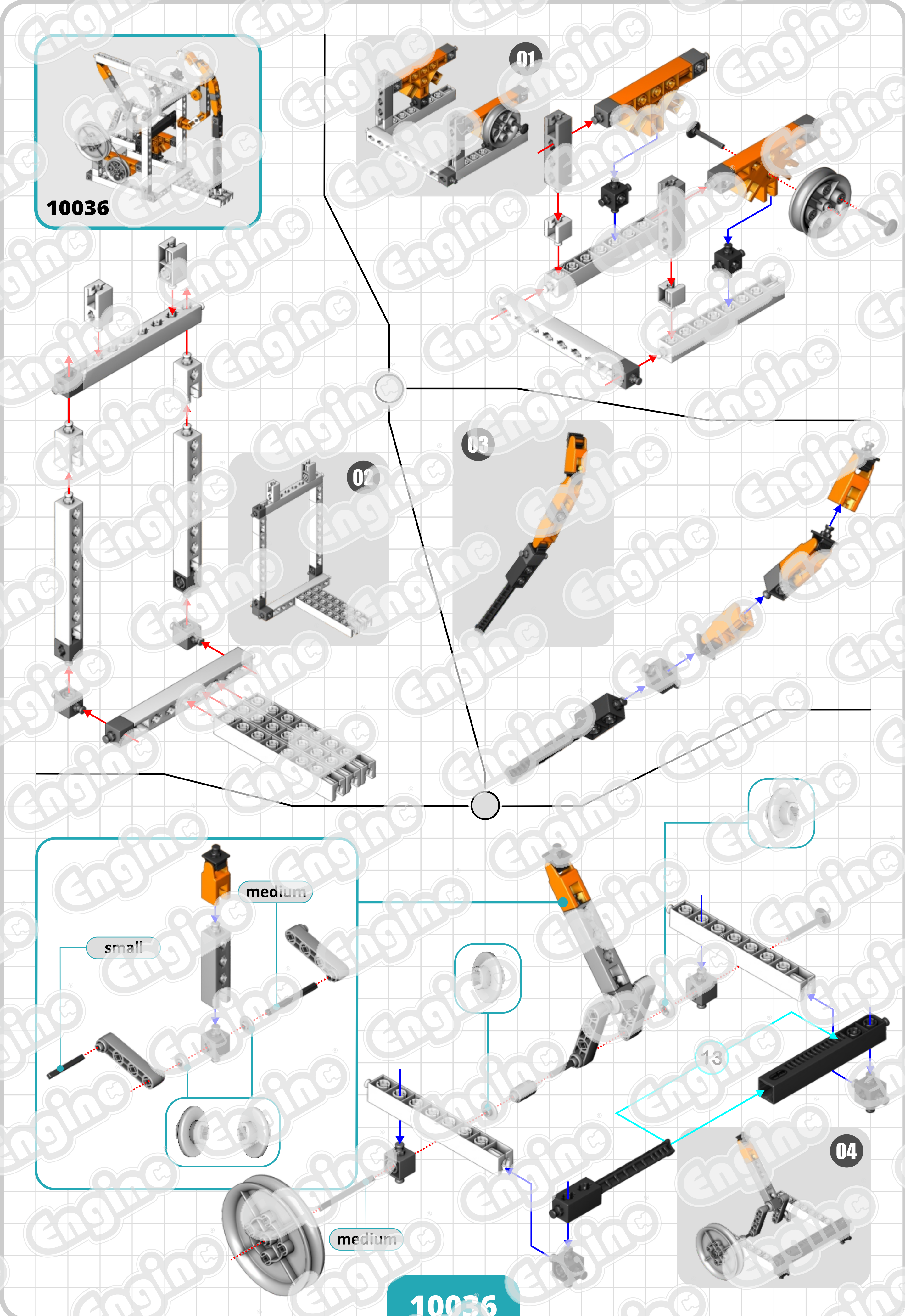
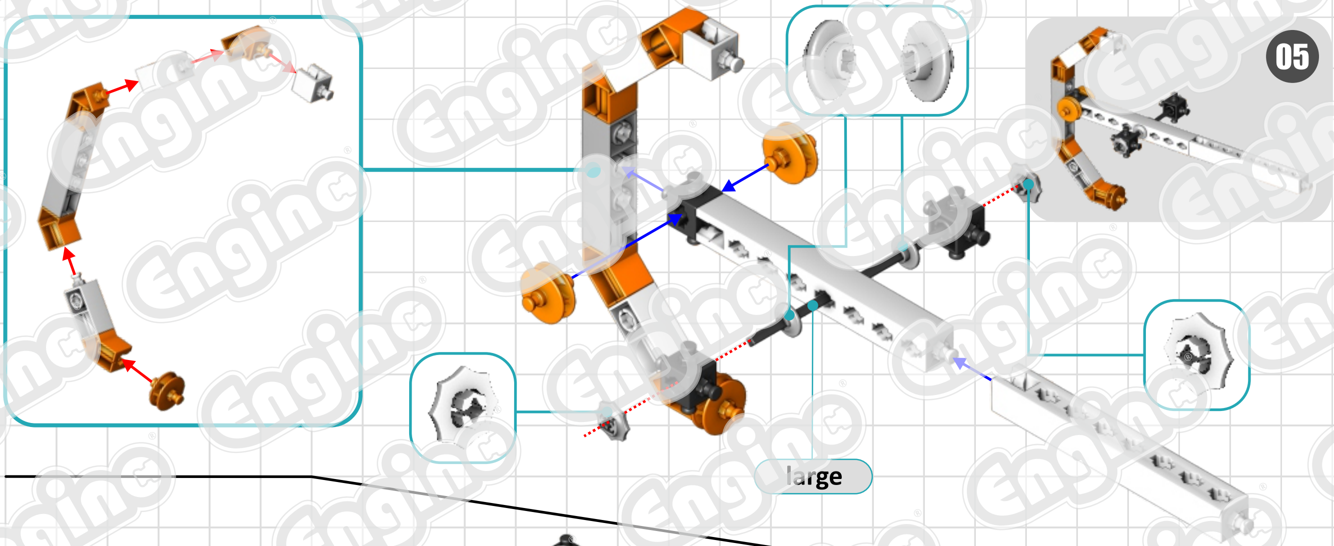
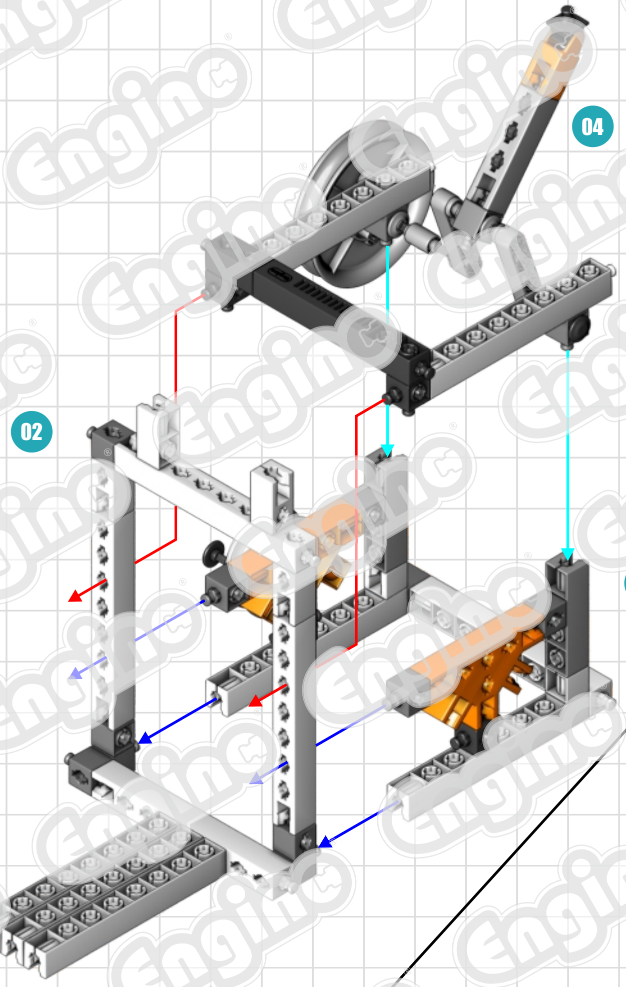
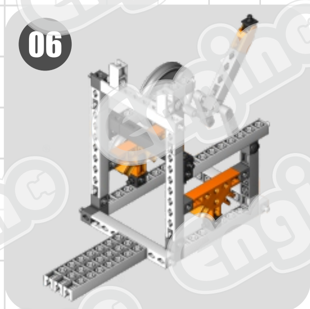
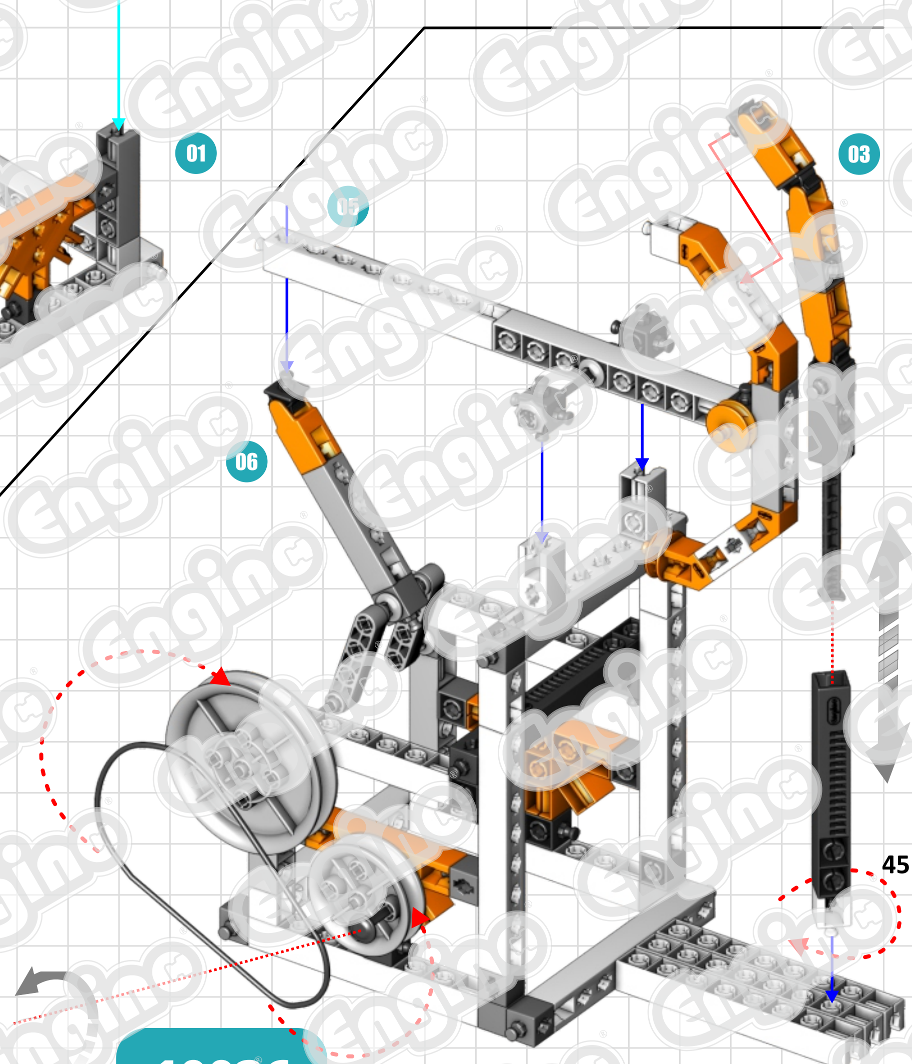
Engino® "oil drill" model

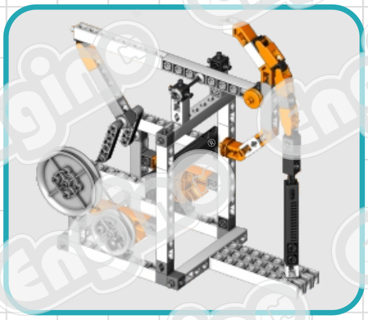

10036
01
02
03
04
medium
small
medium
13


05
large


04
02
01


06


03
05
06
45°



Lesson: Screw press

Mechanical advantage of screws

The extraction of olive oil is a procedure occurring since antiquity. Our ancestors ingeniously designed olive presses, that were manually operated and consisted of a huge wooden screw that moved a big plate, which then pressed the olives inside a barrel. The same principle is applied even today in modern presses.

Discover:

- How to calculate the mechanical advantage of a screw?

Materials Needed:

- Engino® STEM and Robotics PRODUINO.
- A ruler.

Procedure:

1. Build the **screw press** model.

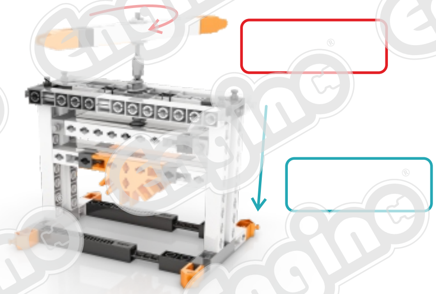
2. Play a bit with your model and identify the type of motions that occur as well as the input and output forces. Complete **exercise 1**.

3. Turn the handle until the screw is completely removed from the press. Then take your ruler and a piece of string from your Engino package, in order to make measurements and calculate the mechanical advantage of the screw press model, in two cases.

4. For **case 1**, take the string and pass it tightly around each thread from one end of the screw to the other. Hold the two ends, stretch the string on a ruler and measure **screw's threaded length** in mm (see picture in exercise 2). Then measure the whole **screw's length** again in mm (as in next picture) and complete **exercise 2**.

5. Case 2 is a bit more tricky. First, we need to find out the circumference of the screw, which is the ratio of screw's threaded length (found in case 1) to the number of crests. **Crest** is one complete round of the teeth. Then we need to measure the **pitch** in mm, which is the distance between the crests of adjacent teeth. The ratio of the pitch to the circumference is the mechanical advantage of the screw. Complete **exercise 3** (using the given formulas) and the conclusion in **exercise 4**.

1. Can you complete the boxes below with the **input** and **output** forces of the screw press model? Also, in the space provided, write the types of motions involved.



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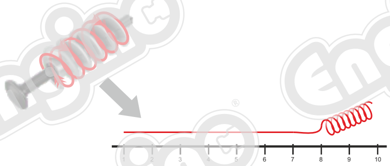
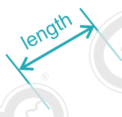
2. Complete the gaps below according to your measurements in case 1 (step 4 of the experiment). Then calculate the **mechanical advantage** (M.A.) of the screw press model by making use of the formula below.





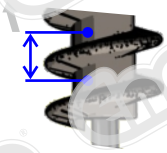
screw's threaded length = ... mm   screw's length = ... mm

$$\text{M.A.} = \frac{\text{screw's threaded length}}{\text{screw's length}} = \frac{\quad}{\quad} \Rightarrow \text{M.A.} = \boxed{\quad}$$

3. Complete the formula and the gaps below according to your measurements in case 2 (step 5 of the experiment). Then calculate the **mechanical advantage** (M.A.) of the screw press model by making use of the last formula.

$$\text{circumference} = \frac{\text{screw's threaded length}}{\text{number of crests}} = \frac{\quad}{\quad} = ...$$

pitch = ...mm



$$\text{M.A.} = \frac{\text{circumference}}{\text{pitch}} = \frac{\quad}{\quad} \Rightarrow \text{M.A.} = \boxed{\quad}$$

4. Both answers should be the same if your measurements were taken carefully, because in exercise 2 the M.A of the screw press is calculated in full scale, whereas in exercise 3 is calculated by isolating a single thread. Write in the space provided what the above mechanical advantage practically means in reference to the distances travelled and force applied.

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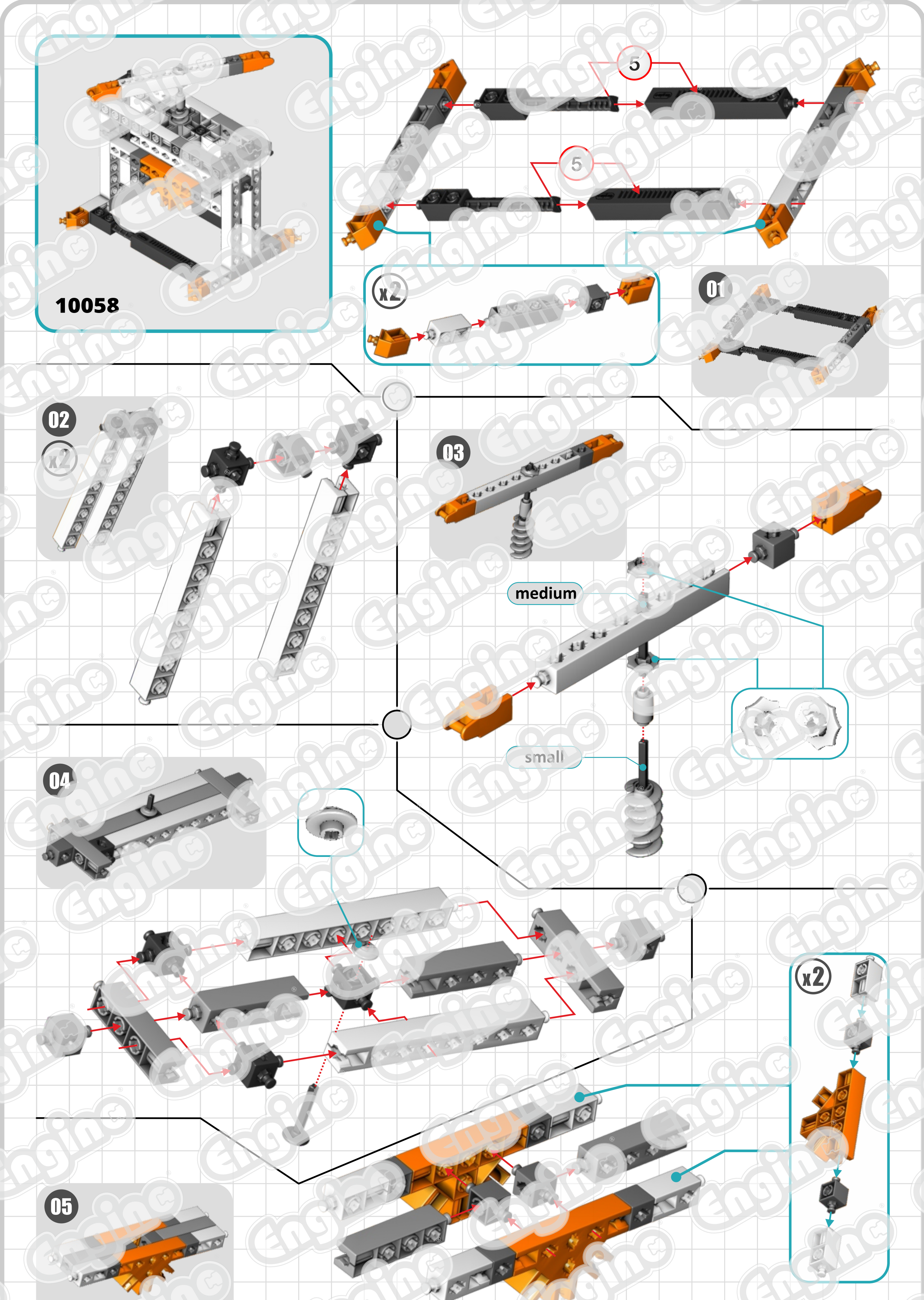
10058
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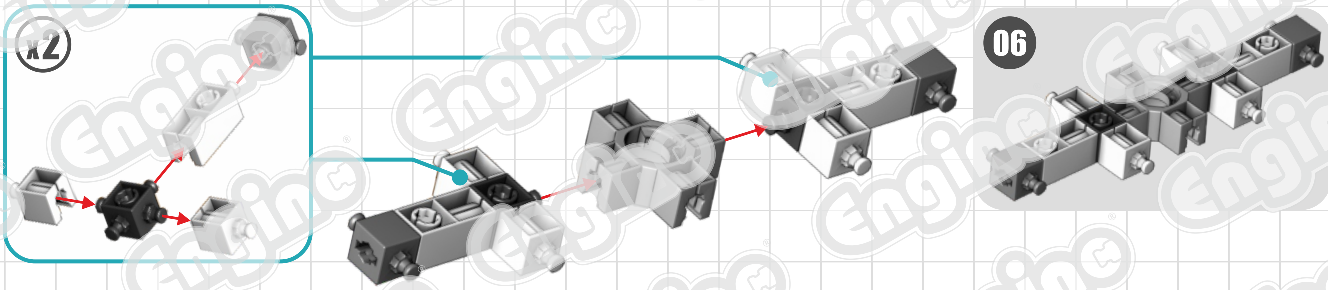
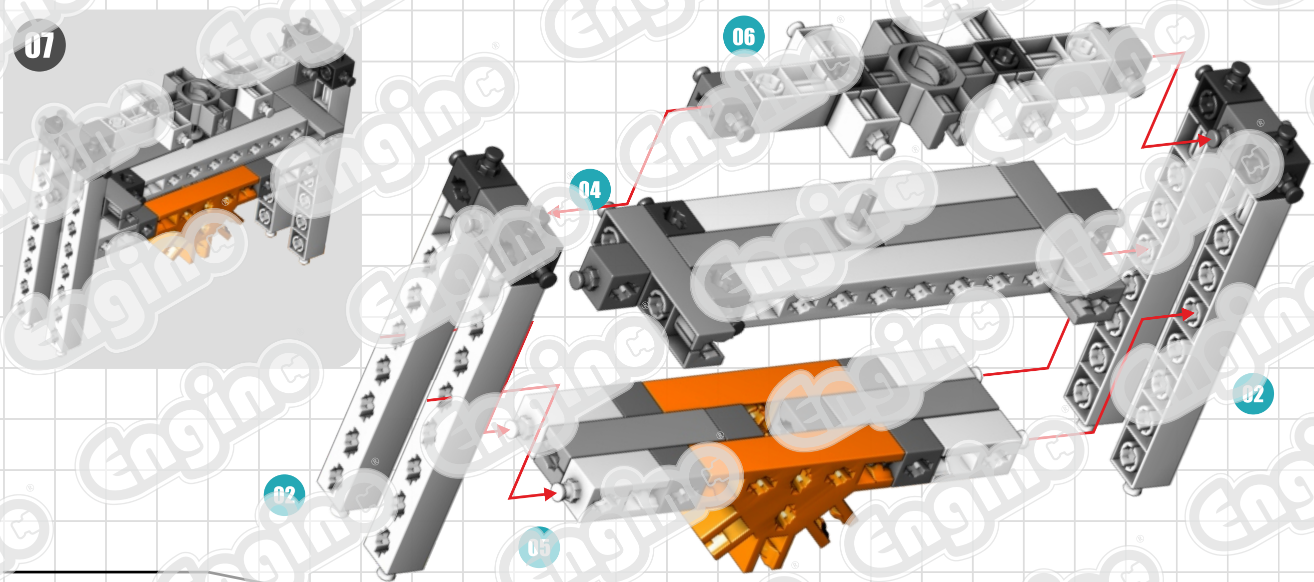

x2
06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06
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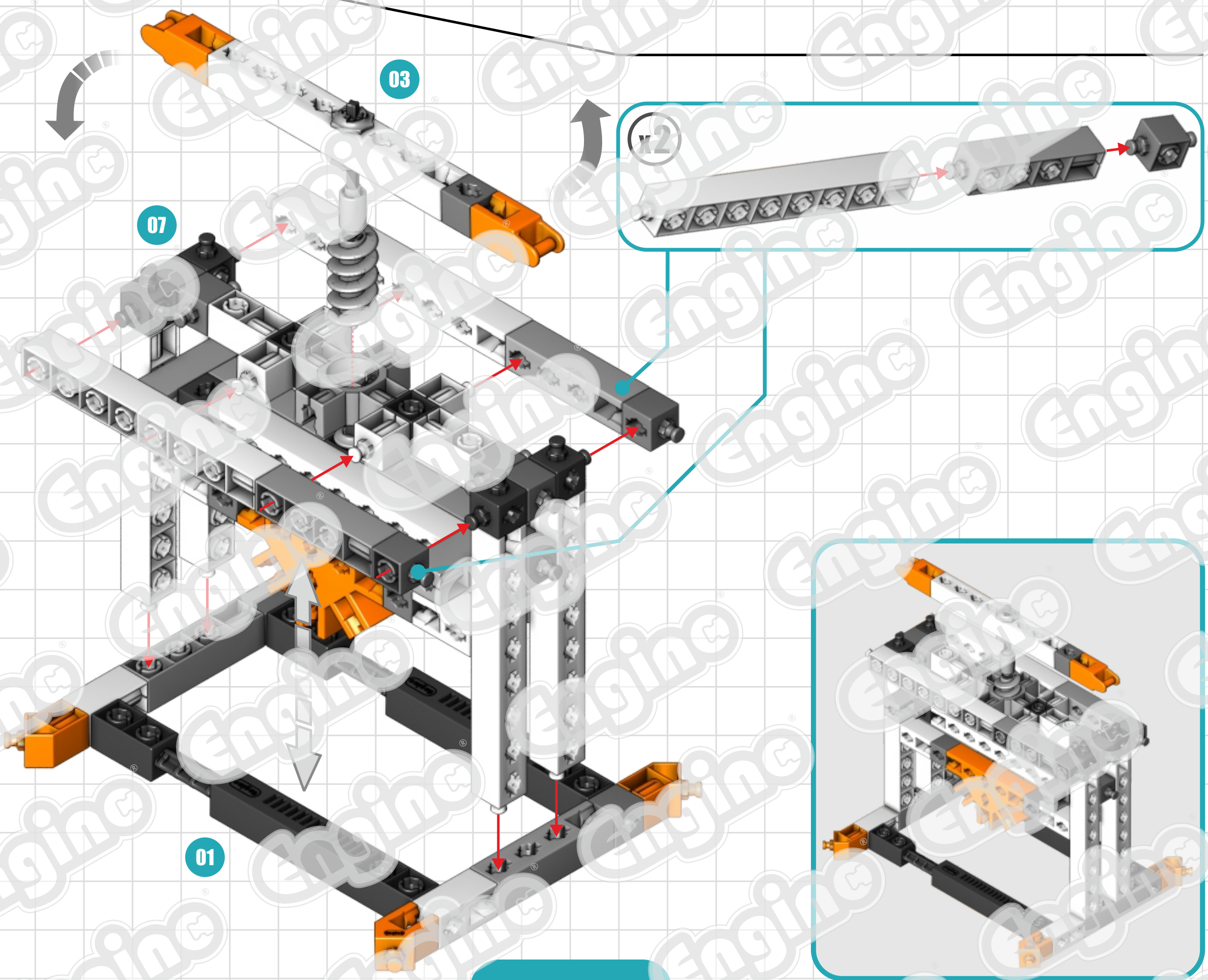
02


03
07
x2
01

Lesson: Cable Bridges

Cable-stayed and suspension bridge

Truss and arch bridges are limited in short distances, making them useless when connecting the shores of very wide rivers. However, modern technology allows huge spans by using cables. One example of cable bridge is the Rio-Antirio bridge in Greece extending for 2.5 Km!

Discover:

- What are the two major types of cable bridges?
- What are their greatest advantages?

Materials Needed:
- Engino® STEM and Robotics PRODUINO.

Procedure:

1. Build the **cable-stayed bridge** up to step 12 (before adding the strings). Push down the deck to test its rigidity.

2. Complete the bridge by adding the strings as in the **last step in page 27**. You can use one string per side, starting from the grey part of the pillar, passing it around the orange pulleys and finishing on the other grey part of the opposite pillar. Test the bridge now and complete **exercise 1**.

3. In **exercise 2**, draw the forces acting on the bridge and the strings. Do you notice how the strings transfer the force from the centre of the bridge to the pillars? However, there is a problem with this model, as the strings pull the pillars inwards. Try to think of a way around this.

4. Dismantle the cable-stayed bridge and follow the instructions to build a model of a **suspension bridge**. Then answer **exercises 3** and **4.**

The Golden Gate Bridge in San Francisco is an example of a suspension bridge.

1. Push down the deck of the bridge and test its rigidity. Once you connect the supporting strings and have them tightened, push down the deck again. How strong is the bridge now as compared to the previous step and why?

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2. Draw the forces acting on the bridge and the strings in the right figure. Then write below your solution, so that the pillars stop moving inwards.

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3. Draw the forces acting on the suspension bridge model in the image below. Write 3 similarities between the two types of cable bridges: cable-stayed and suspension.

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4. What are the 2 major advantages of the cable bridges as compared to truss and arches?

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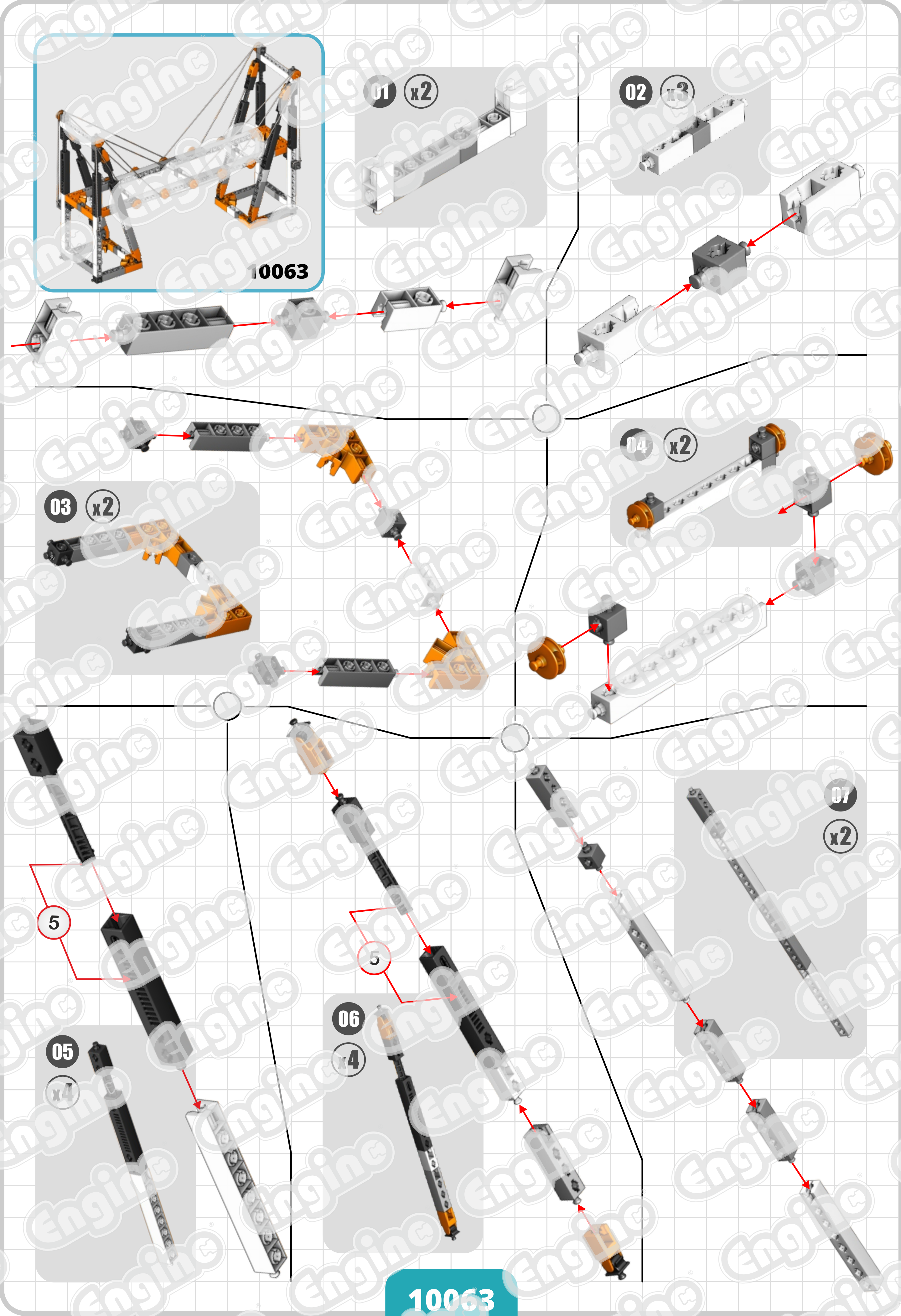
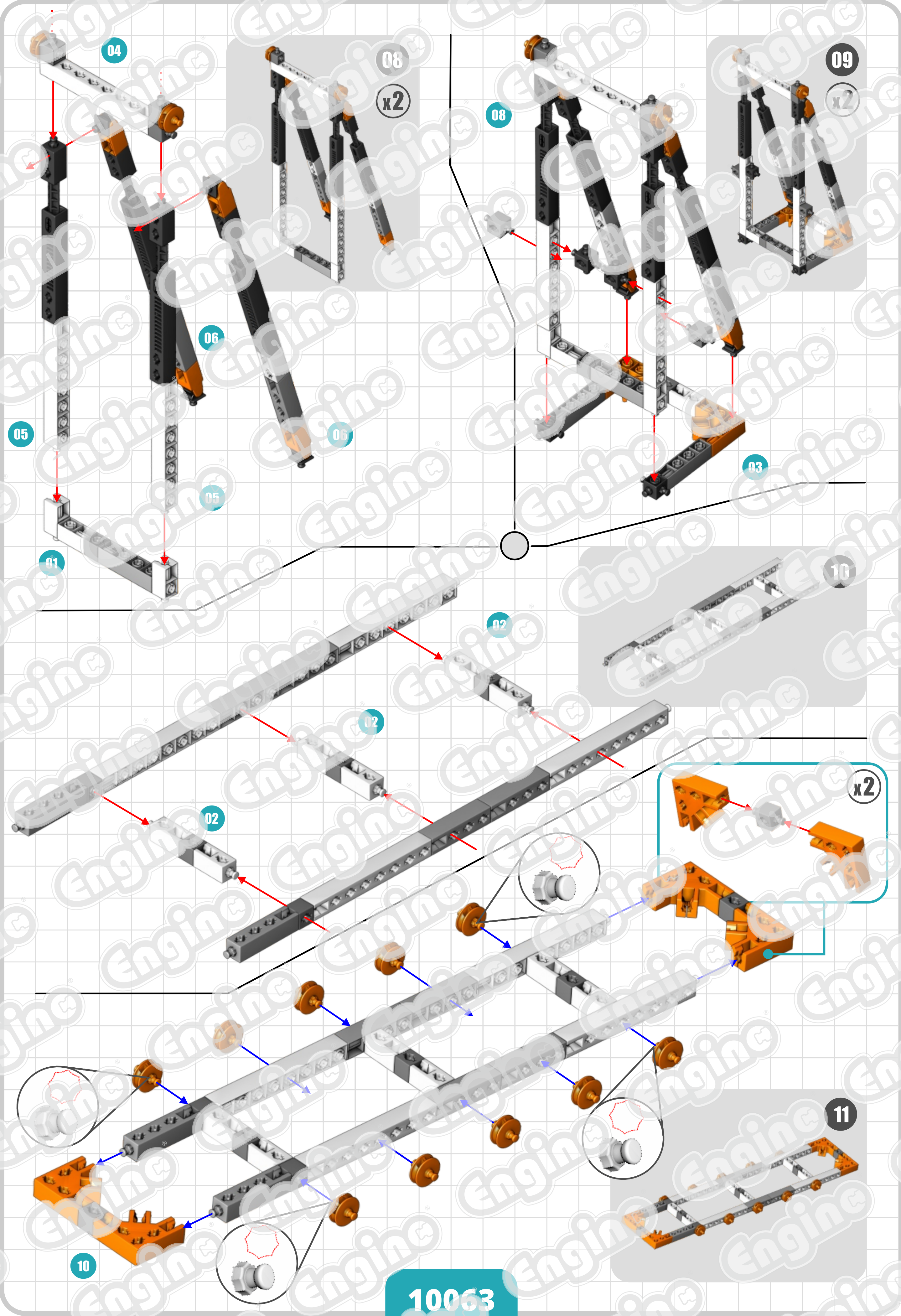
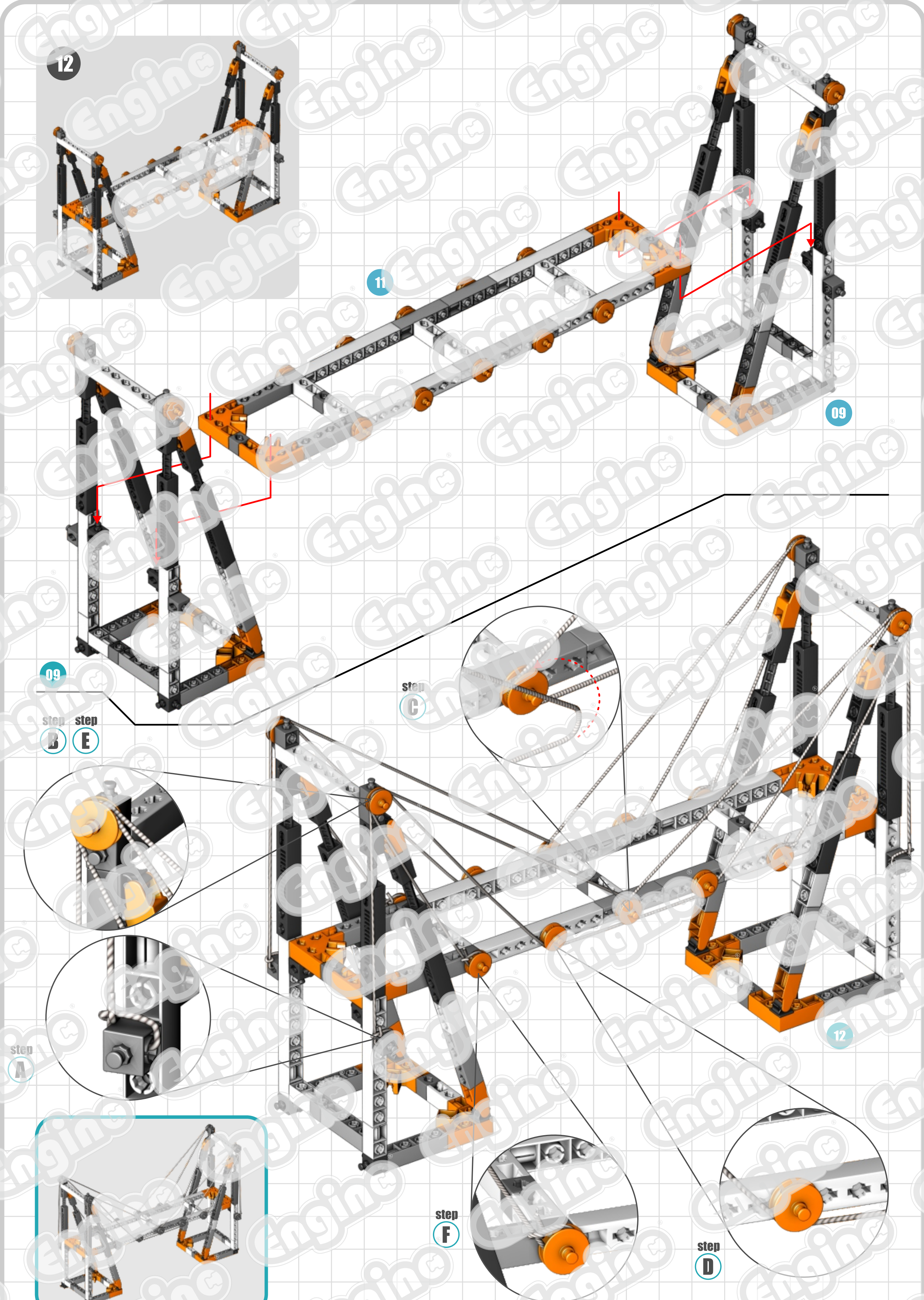

10063
01 x2
02 x3
03 x2
04 x2
5
5
05 x4
06 x4
07 x2


04
08
x2
08
09
x2
06
05
06
05
03
01
10
02
02
02
x2
11
10


12
11
09
09
step
C
step
B
step
E
step
A
12
step
F
step
D

Lesson: Folding platform

Screw and nut mechanism

Cleaning windows of the 3rd floor can be a very dangerous job! Indeed, any job that requires working in height is considered as dangerous. Such hard jobs can be achieved a lot easier and safer by using folding platforms. Their best feature is that they can easily lift up people, fold and unfold with low effort!

Discover:

- How can rotational motion be converted to linear?
- How does the screw and nut mechanism work?

Materials Needed:
- Engino® STEM and Robotics PRODUINO.
- Empty shoe box.
- A ruler.

Procedure:

1. Build the **folding platform** model.

2. The model uses the screw and nut mechanism. Identify these 2 main elements of that mechanism in **exercise 1**.

3. Play for a while with your model, so that you understand how it works and how the platform is raised. Do **exercise 2**.

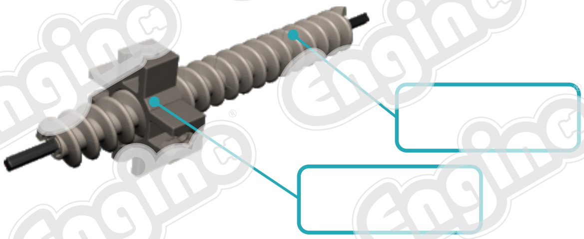
4. Firstly, fully fold the platform. Use some form of weight, like for example an empty shoe box, and load it on your platform. Measure how many times you turn the crank (crank's revolutions) until the platform is fully raised and opened. Write your results in **exercise 3**.

5. Use a ruler to measure the height that the platform has raised. Also how much the nut moves and complete the rest of **exercise 3**.

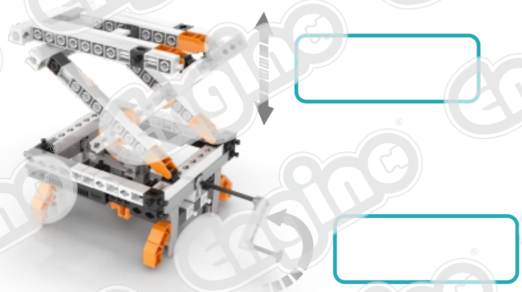
6. Make the appropriate calculations as explained in **exercise 4** and write your conclusions.

7. Complete **exercise 5**.

1. Write the correct name in each box, either **screw** or **nut.**



2. What types of motion can you identify on your model? Write their name next to each arrow.



3. Fill in the boxes with your measurements.

CRANK'S REVOLUTIONS

PLATFORM'S LIFTED HEIGHT

NUT'S DISTANCE

4. Multiply the crank's revolutions times the nut's distance. What do you observe?

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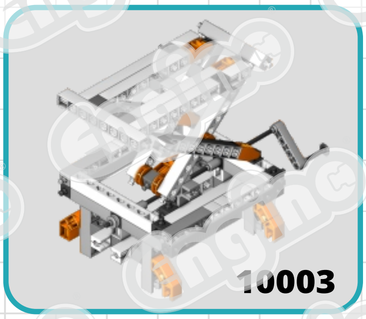
5. Fill in the gaps using the words from the box.

linear, screw, rotational, nut, reciprocal

The mechanism of .... and .... is used to convert .... motion to ....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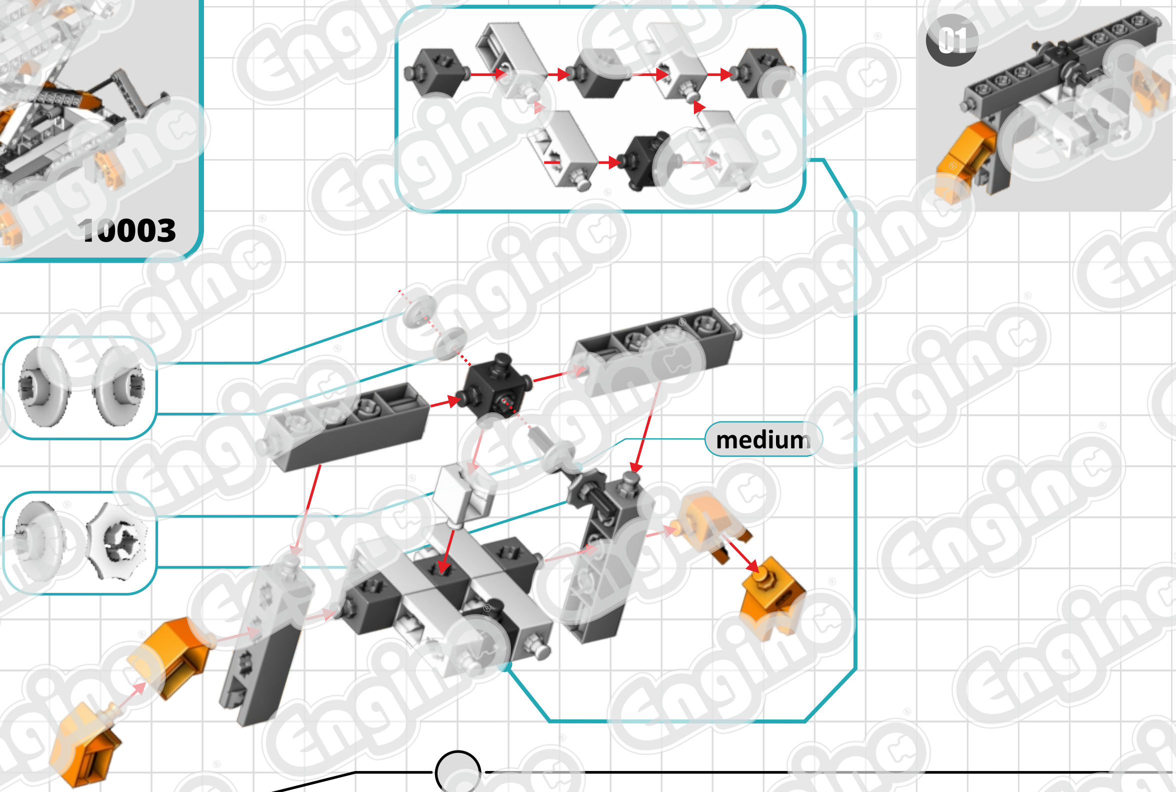
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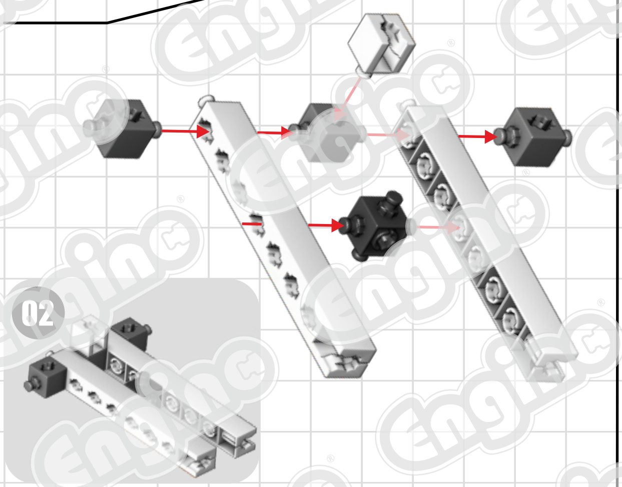
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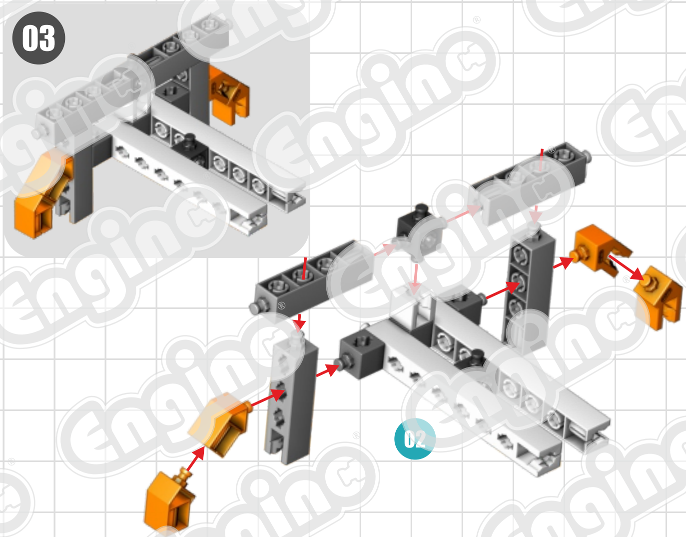
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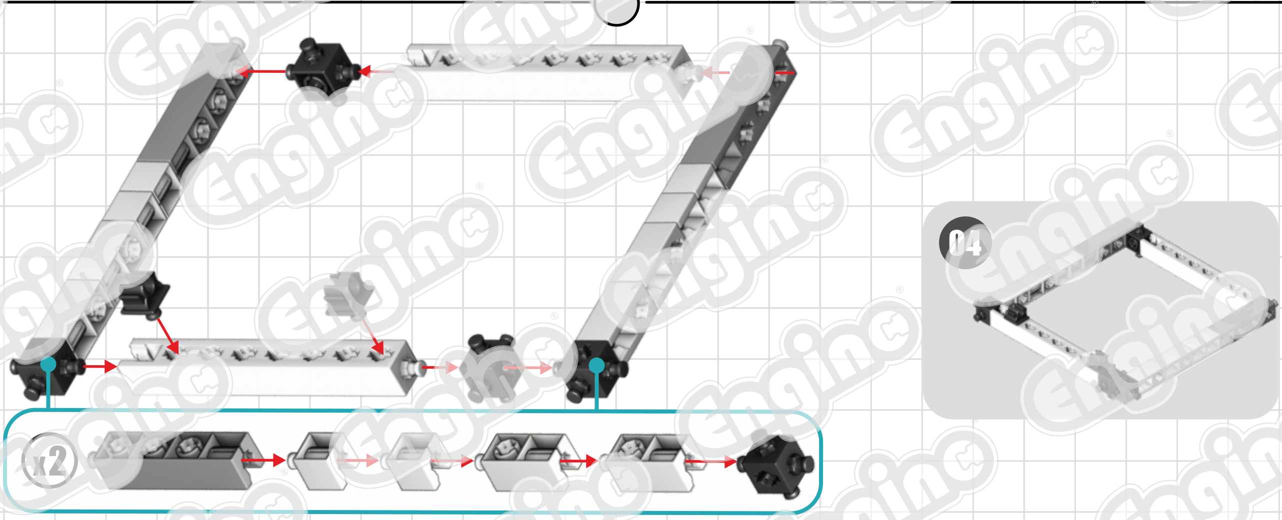
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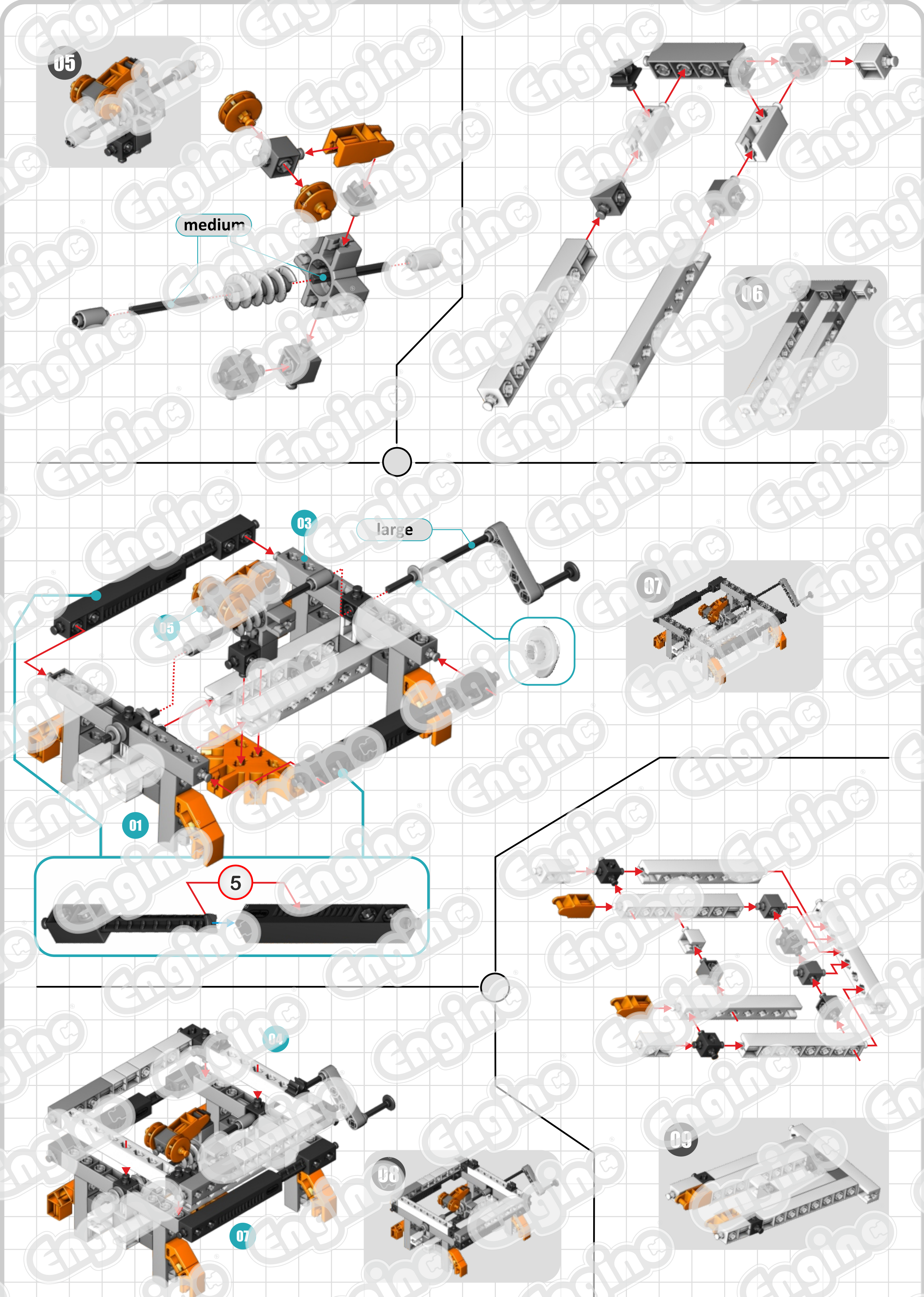
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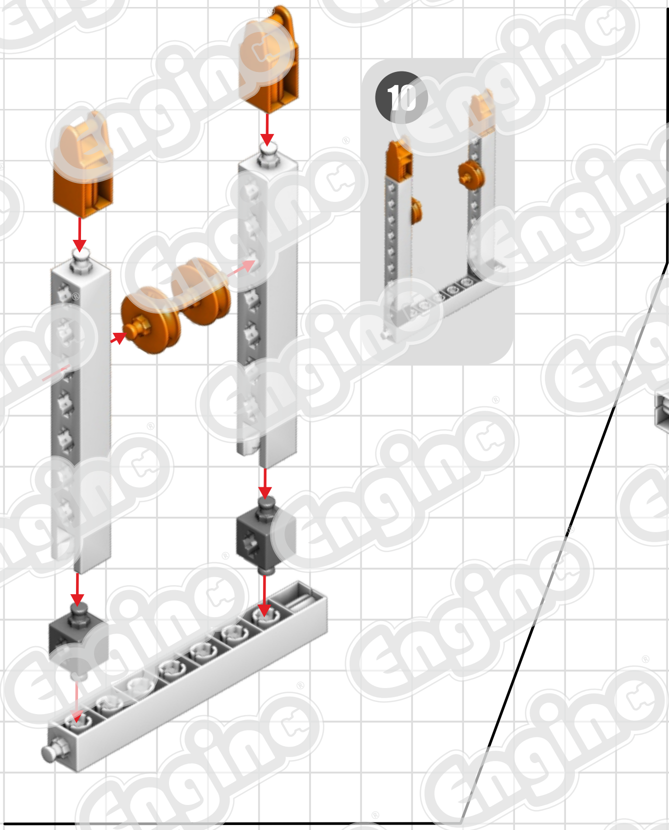
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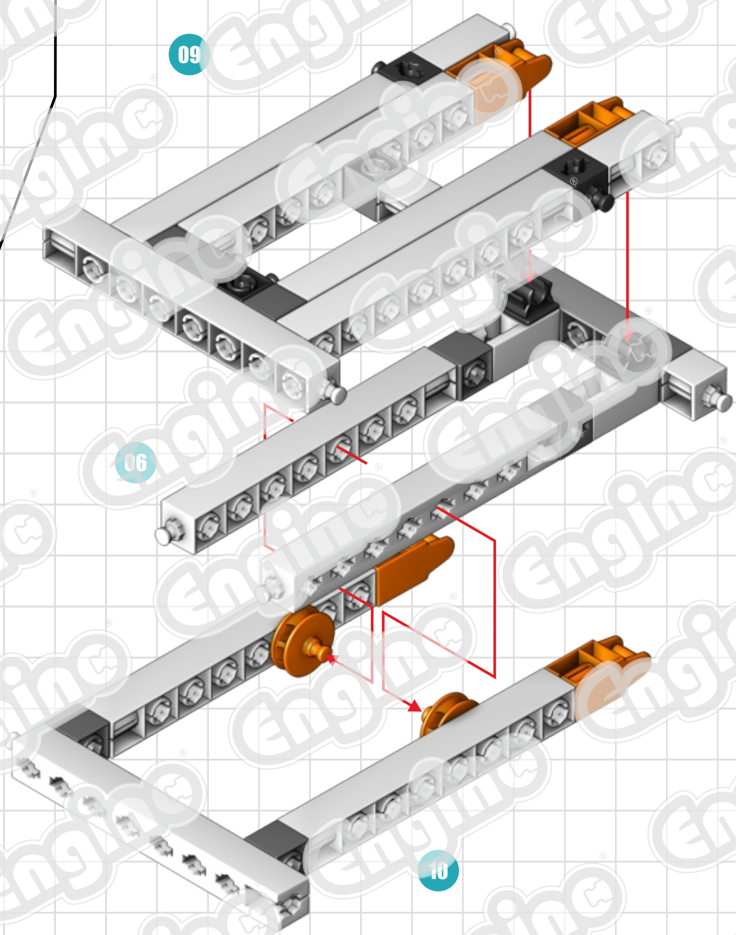
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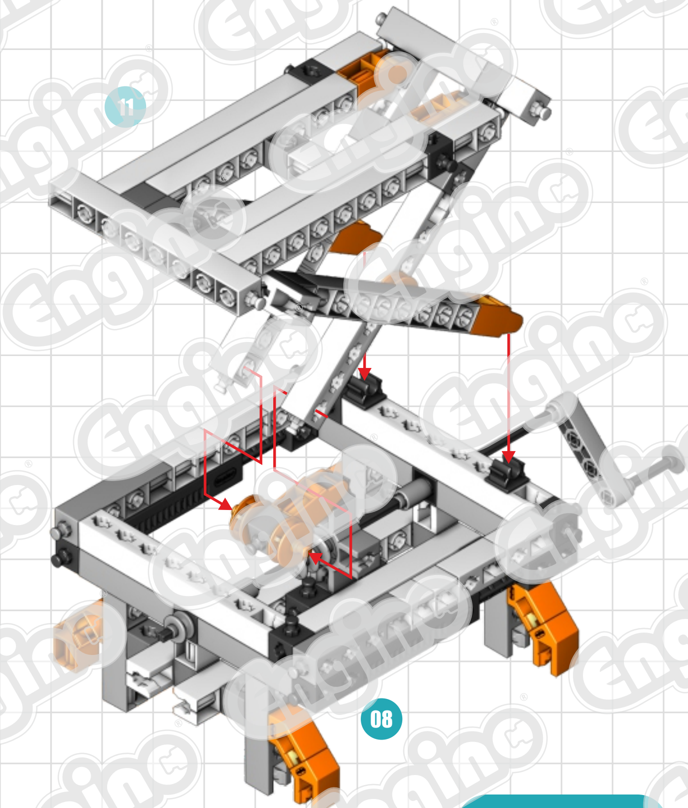
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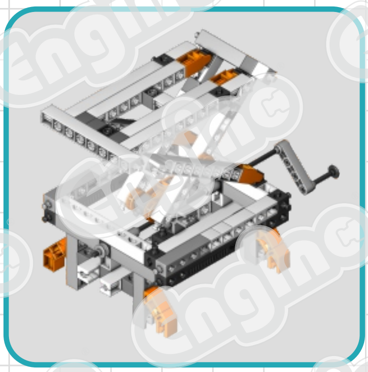

Lesson: Crane bridge

Relation of force and speed

If you ever traveled to the Swiss Alps, maybe you came across the Landwasser railway bridge. It was built using a very impressive machine back in 1902. In order to transfer the necessary materials to the top of the bridge, an innovative crane was assembled, which operated with pulleys. How did it work?

Discover:

- How can we control speed and power by combining different sizes of pulleys?

Materials Needed:
- Engino® STEM and Robotics PRODUINO.
- Small bag with sand or beans.

Procedure:

1. Build the **crane bridge** model.

2. Use two tables to support the bridge, so that a gap is created, allowing the hook to be lowered as far as the string goes. Fill a small bag with sand or beans and hang it from the hook. This will be used as load.

3. Put the load on the hook and wind up the string until it becomes tight. Once the crane starts pulling the weight, begin measuring the full rotations of the crank until the weight is lifted completely. Fill-in the table on the right for **case 1**. Remember the amount of force you applied and the lifting speed, so you compare it with the other 3 cases.

4. Assemble the crank at the positions showing in **cases 2, 3 and 4** (see table). The numbers in the picture below indicate the position that the driver pulley needs to be assembled for each case. Try to assemble the pulleys in such a way that the rubber band is tight enough to transfer the rotation. Note that the follower pulley is always on the axle which winds up the string.

Place the driver pulley in the appropriate number for each case

5. Compare each case by marking the appropriate boxes for force and lifting speed. Then complete **exercises 2** and **3**.

1. Complete the following table with your measurements and observations. Write, in the first row, the number of crank revolutions for each case until the weight is completely lifted. Put a checkmark in the appropriate cell of the table regarding the difficulty in turning the crank and the speed by which the load is lifted.

		Case 1	Case 2	Case 3	Case 4
FOLLOWER PULLEY / *DRIVER PULLEY*		*Small*  *Large*	*Medium*  *Large*	*Large*  *Small*	*Large*  *Medium*
DRIVER PULLEY'S REVOLUTIONS					
FORCE (difficulty in rotation)	Easy				
	Medium				
	Difficult				
	Most difficult				
LIFTING SPEED	Fastest				
	Fast				
	Medium				
	Slow				

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

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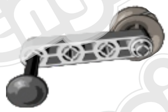
3. Remove the large pulley, the crank and the rubber band from the model. Assemble the crank on the top axle of the small pulley (see icon) so that you can directly turn the axle to wind up the string. Do you feel any difference? How many revolutions are needed?



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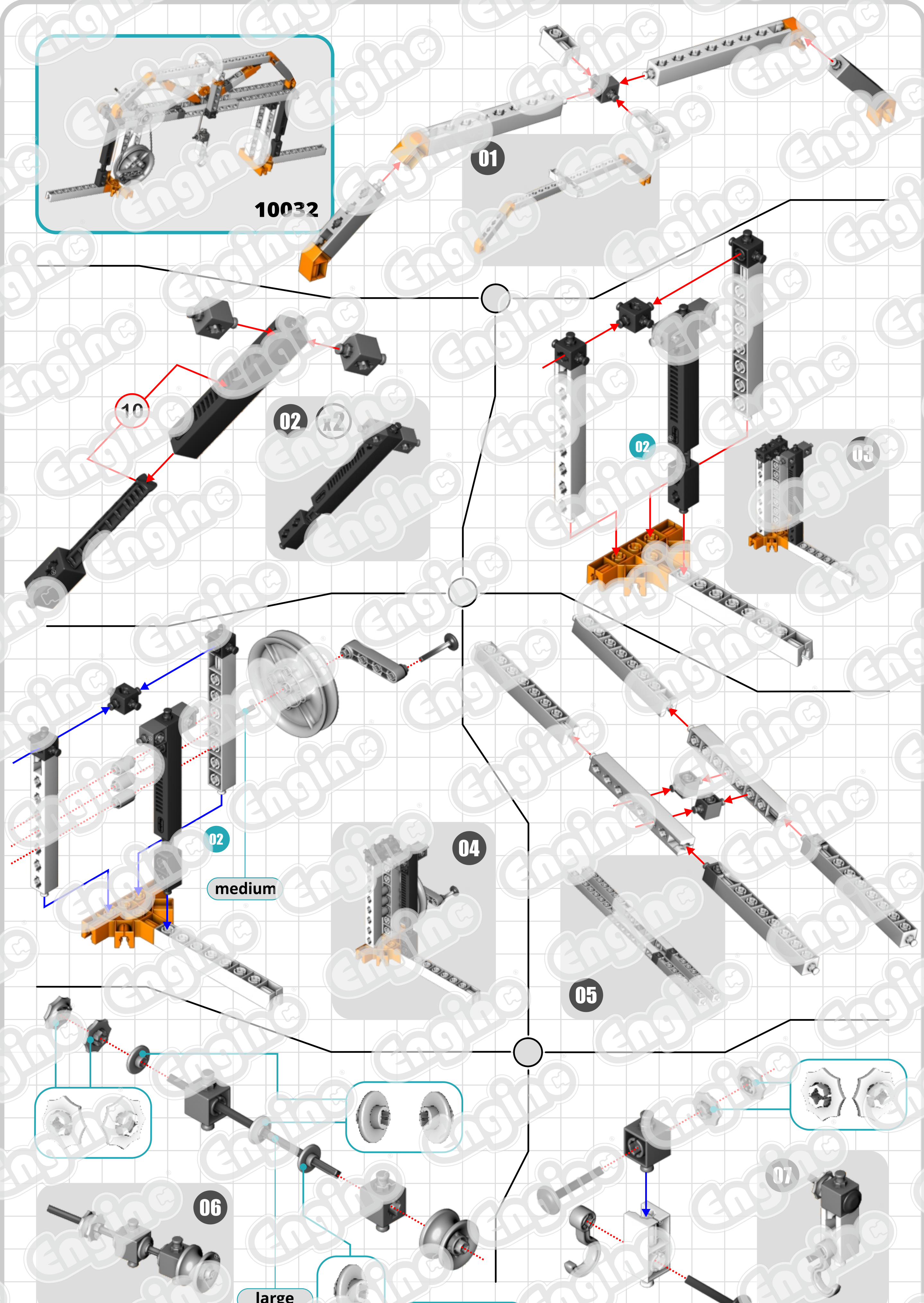
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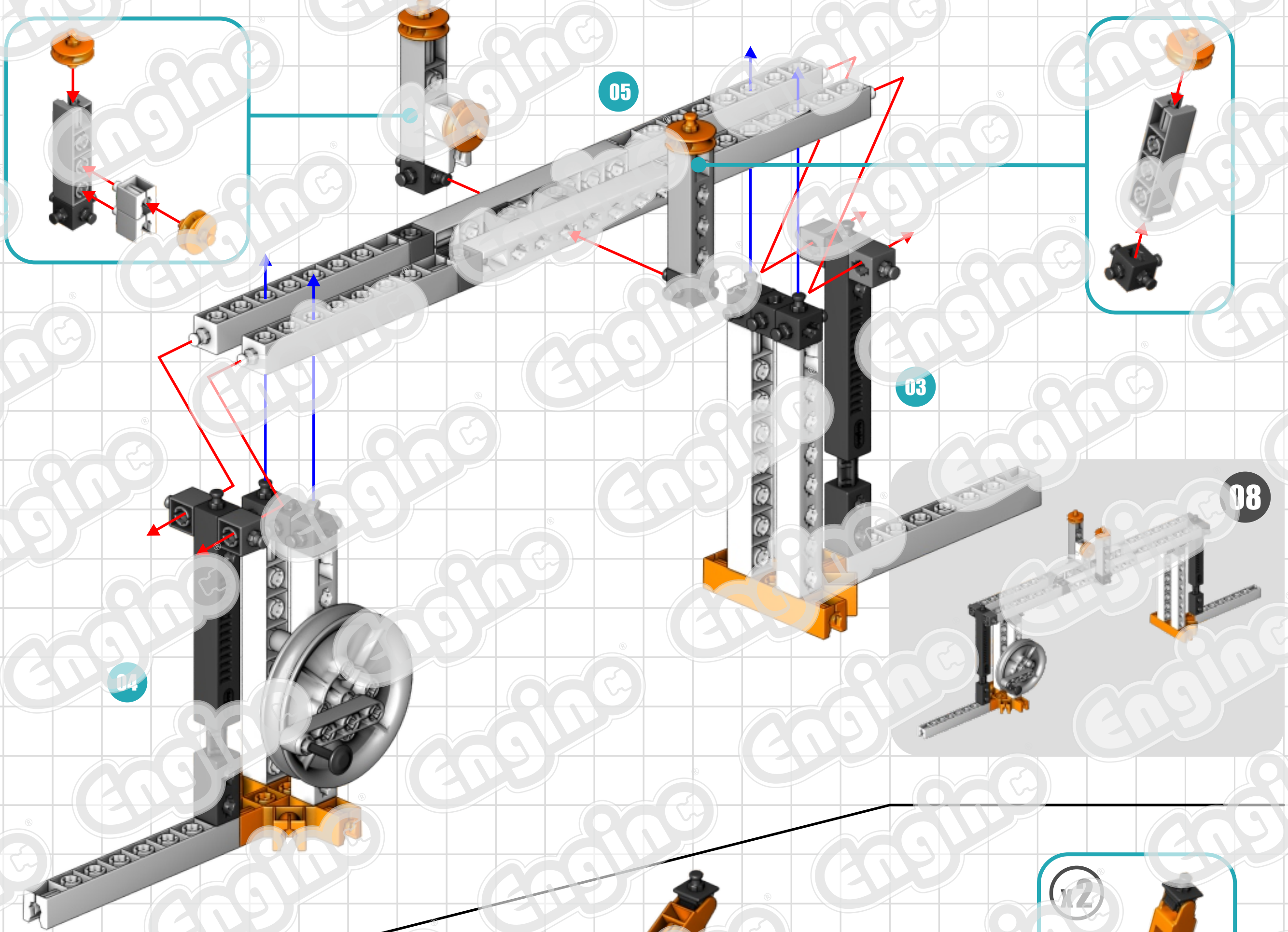
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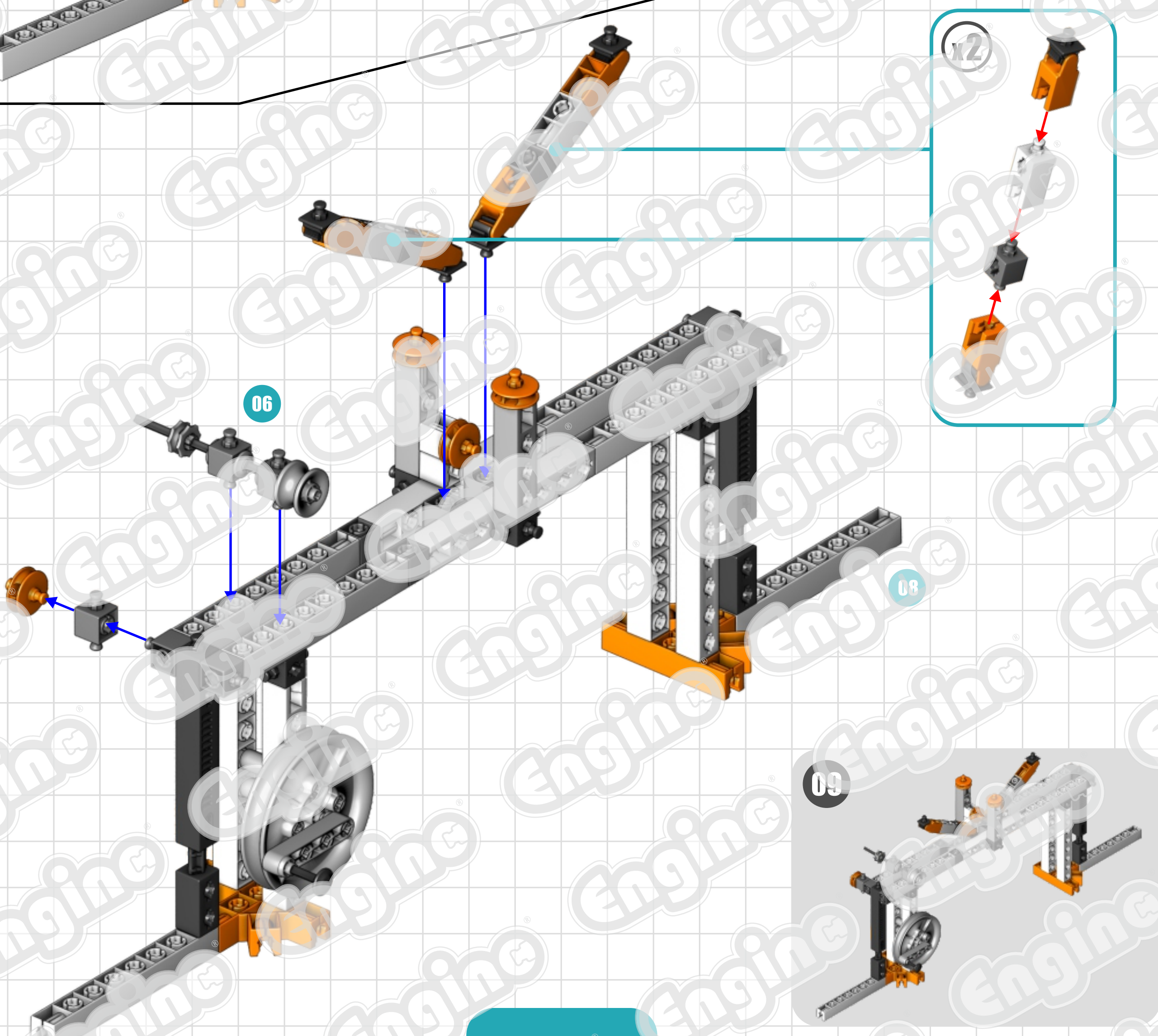
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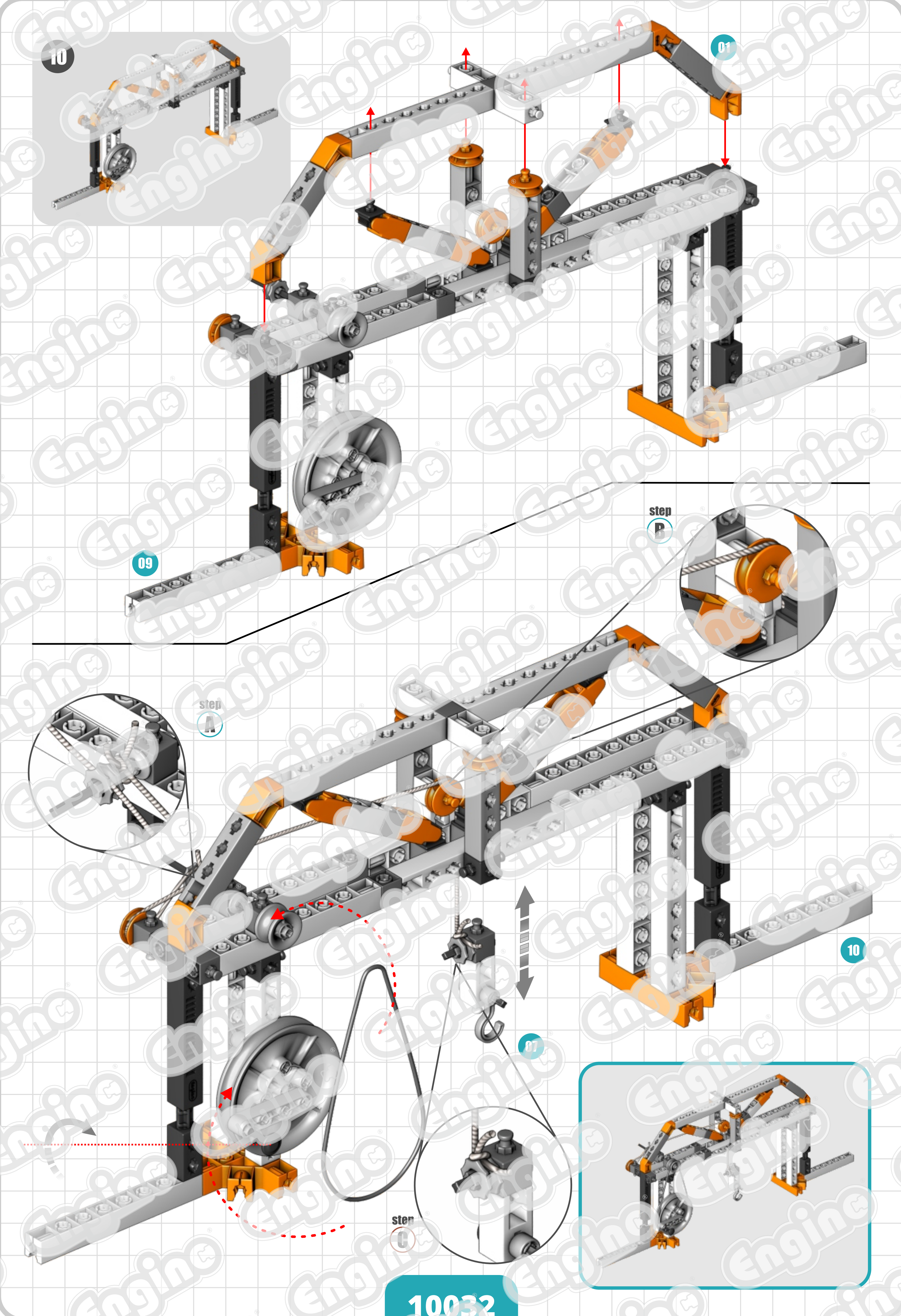
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Lesson: Wheelbarrow

Second-class lever

Have you ever heard of a wheelbarrow race? It is a game in which teams of two players race each other. One member of the team plays the role of the driver and holds on to the other member's ankles who moves upside down with his hands! The team that reaches the finishing line first wins.

Discover:

- What is a second-class lever?
- How does a wheel-barrow work?

Materials Needed:
- Engino STEM & Robotics Mini.
- Beans, rocks or any other small materials.

Procedure:

1. Build the **wheelbarrow** model.

2. You have just built yourself a useful carrying device! Use your model a bit to carry your erasers, sharpeners and pencils that you have lying around on your desk. Can you identify where the effort, the load and the fulcrum are acting on your wheelbarrow? Complete **exercises 1** and **2**.

3. Now, load the wheelbarrow with the materials that you have gathered for this experiment (rocks, beans etc), but make sure that they do not fall out of it. You can place them all inside a small nylon bag first, if you like. Then, try to move your loaded model, feeling the effort that you apply.

4. You can make your model even better and carry much more load if you make some small arrangements with the rest of your Engino parts. Can you think of any? Write them in **exercise 3**, keeping in mind that you are dealing with a lever which works on the principle of Moments.

5. Complete **exercise 4**.

Engino "wheelbarrow" model

1. Look at the picture below of a boy using a wheelbarrow and fill-in the boxes with these words: **load**, **effort**, **fulcrum**.

2. Which one of the three elements (load, fulcrum, effort) of the lever above is placed between the other two?

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3. How can we improve a wheelbarrow device, so that we can carry more load with less effort (write three possible modifications)?

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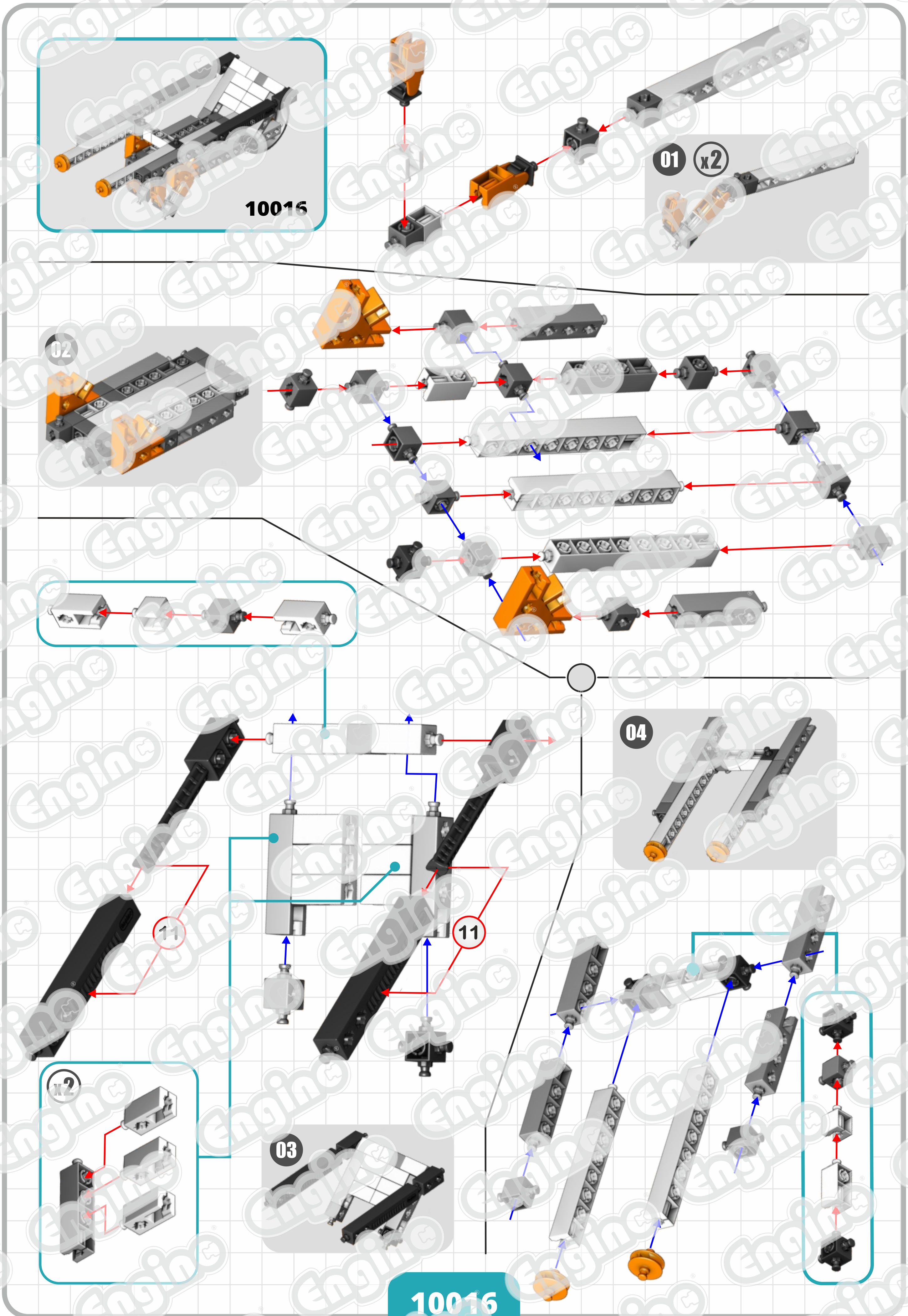
4. Next you can see some examples of second-class levers. Take a look at the pictures and show with arrows where the load, the effort and the fulcrum are applied in each case.

Paper guillotine

Nutcracker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Lesson: **Well**

Axle as a pulley

Since ancient times, wells were used for fetching water. This work was done by sinking a bucket inside the well and bringing it up to the surface using a simple elevation system. Here, we are not going to use our Engino well for getting water, but for experimenting!

Discover:

- How does the axle's diameter affects the lifting force and the distance covered by the load?

Materials Needed:
- Engino® STEM & Robotics PRO.

Procedure:

1. Build the well model. When you tie the rope on the hook and around the axle, make sure that you leave enough length of rope (from floor to table) to lift the "bucket".

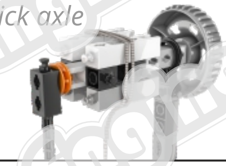
2. Place your model between two desks or chairs, allowing the "bucket" to elevate freely. Play a bit with your model in order to understand how the mechanism works, by turning the wheel.

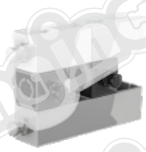
3. Next, lower the "bucket" as much as possible and turn the wheel until it reaches the top of the well. Count the turns you needed for this task and complete the right table, for **case 1**. In order to make your counting easier, mark a point on the wheel with a pencil or pen, counting every time it completes a full circle. While you turn the wheel, feel the effort you need to lift the "bucket".

4. For **case 2**, untie the rope from the axle and remove the two pieces shown below the table. This way, the axle will become thinner. Tie the rope back to its place and repeat the procedure as before, completing the rest of the table, for **number of turns** and effort.

Engino® "well" model

1. Complete the following table according to your observations from the experiment. In the "**turns**" column write the number of turns and in the "**effort**" column write the words **easy** or **difficult**, comparing the amount of effort you applied.

Case	Type of axle	Turns	Effort
1.	*Thick axle* 		
2.	*Thin axle* 		

X2  *Remove these pieces from the axle for case 2*

2. What conclusion can be extracted from your observations above regarding the relationship between number of turns, effort and thickness of the axle?

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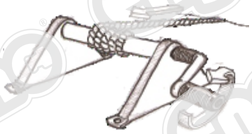
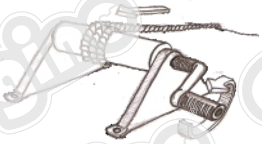
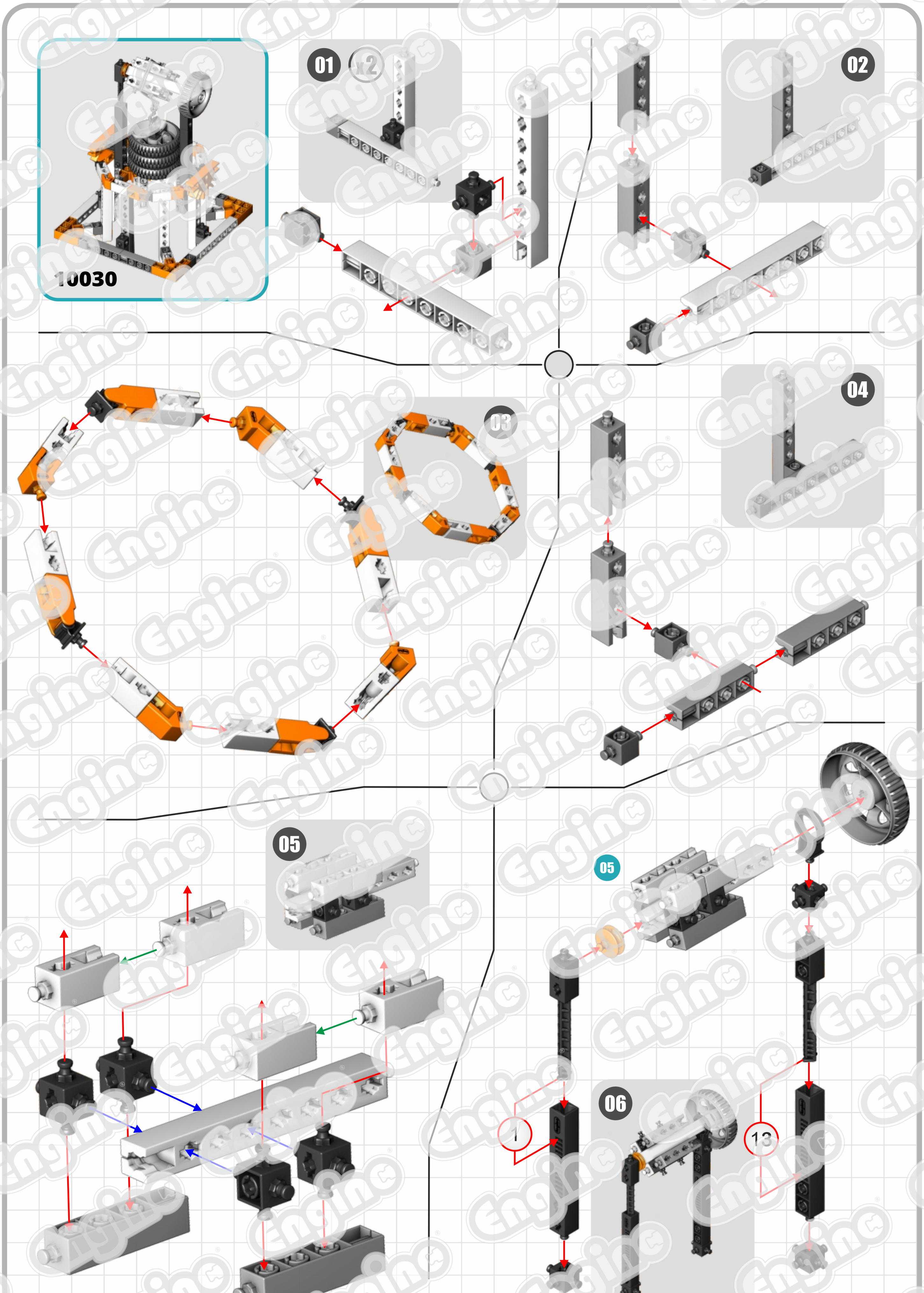
3. Join the pictures with the correct sentences. Each picture should be connected with two sentences, one on the left and one on the right.

Easy Effort • •  • • Medium speed

Hard Effort • •  • • Slow speed

Medium Effort • •  • • Fast speed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x2
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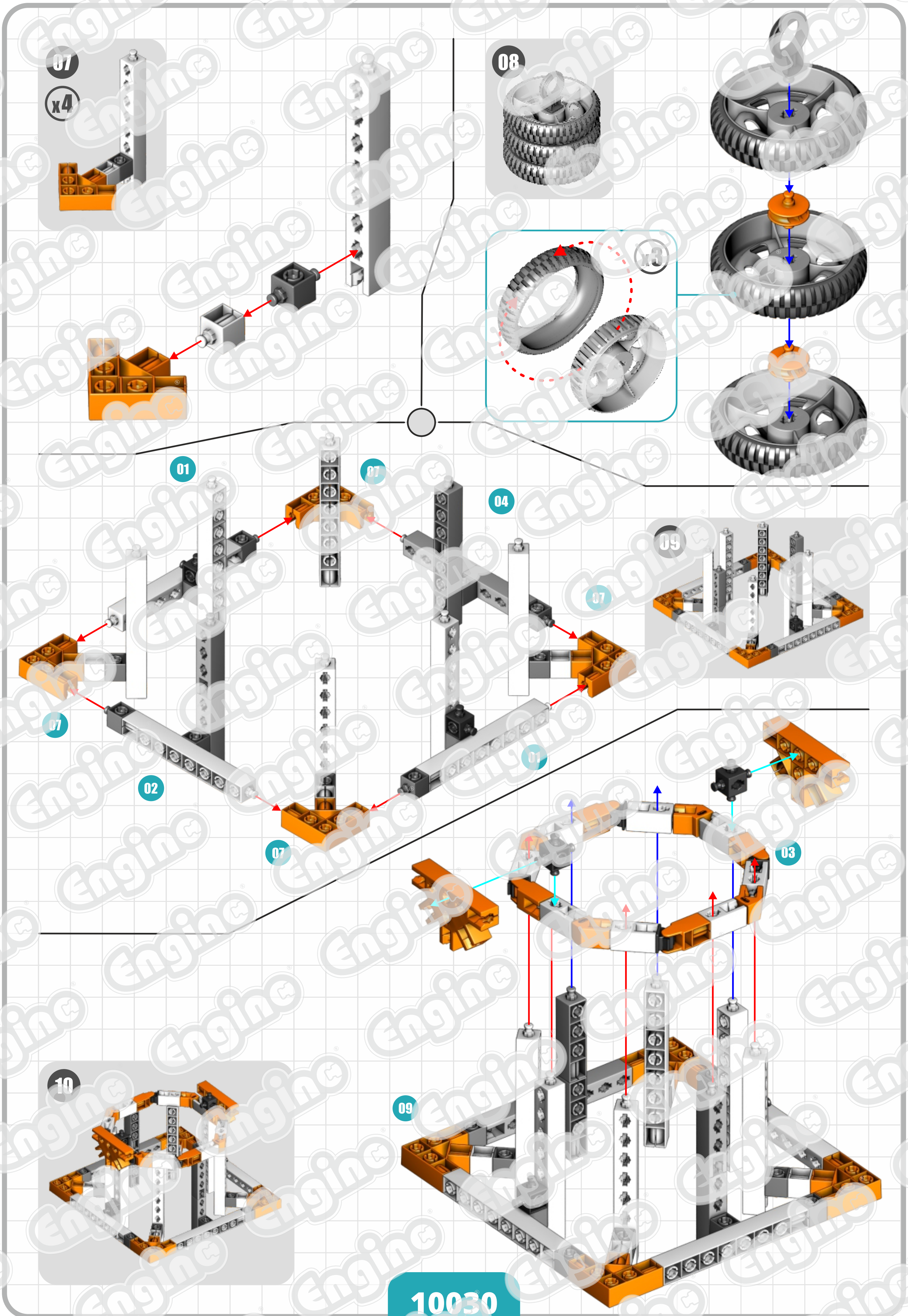
1
13


07
x4
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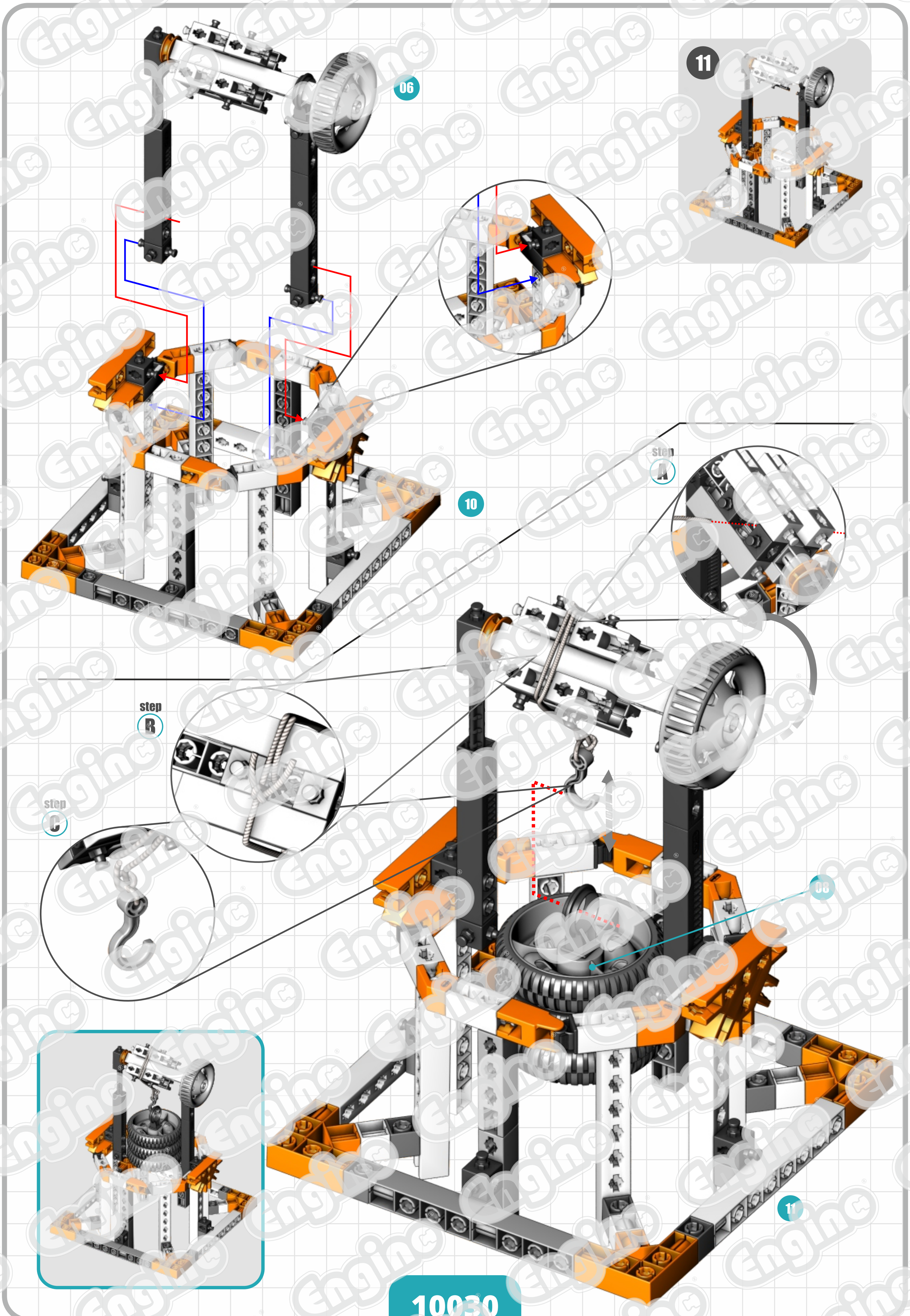
06
11
10
step
A
step
B
step
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