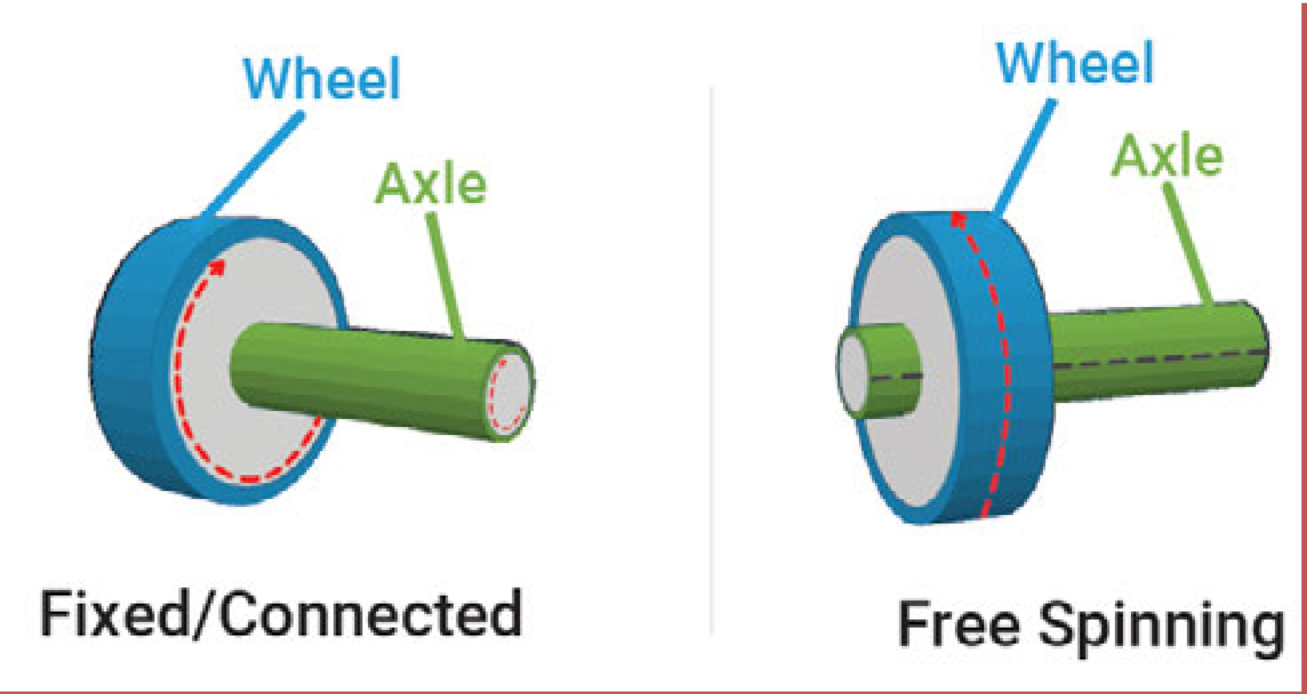
Engineering Discoveries:

Wheel & Axle

The Wheel & Axle

A wheel & axle is a simple machine that consists of a **wheel** that is connected to a smaller wheel, which is referred to as an **axle**. The axle can be fixed to the center of a wheel, or it can be placed through the center of a wheel, allowing the wheel to rotate freely around the axle.



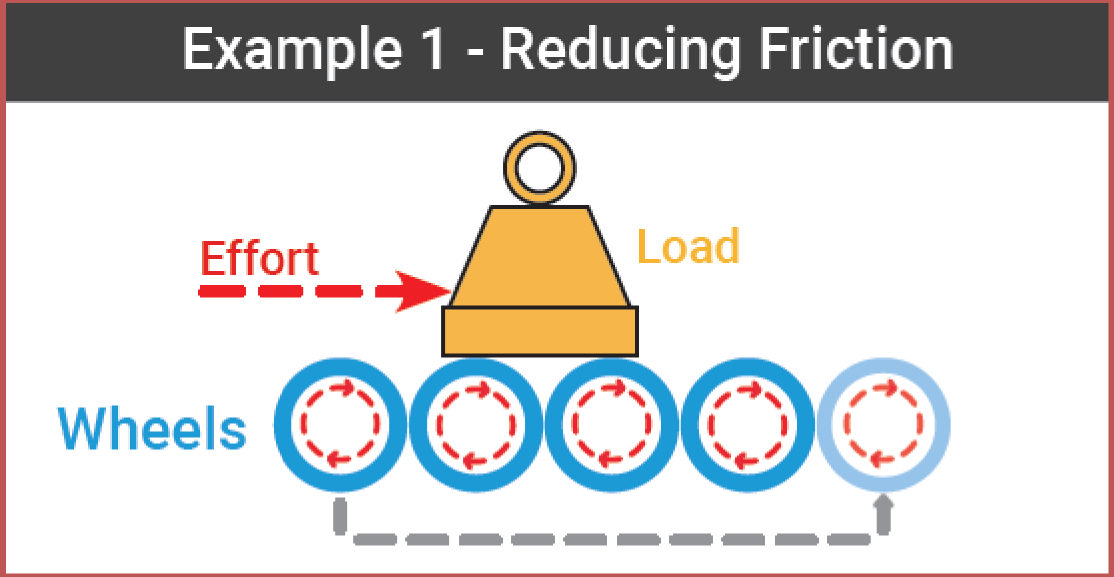
Purpose

A wheel & axle can be used to make work easier by **reducing friction** or by **creating mechanical advantage.**

Reducing Friction

A **wheel** reduces the amount of effort needed to move a load by reducing the amount of friction between the load and the ground or surface. The wheel allows contacting surfaces to roll rather than dragging or sliding over each other. In **example 1**, a load is being rolled over a series of wheels instead of just being pushed or pulled across the surface or ground. As the load moves forward, wheels are taken from the back and placed in the front to keep the load moving forward.

To eliminate the need to constantly place wheels in front of a load to keep it moving forward, an **axle** can be placed through the center of a wheel, which allows the wheel to rotate freely around the axle. In **example 2**, a load has been placed on a platform that is attached to two axles. The wheels rotate freely around the axles, allowing the load to easily move forward.

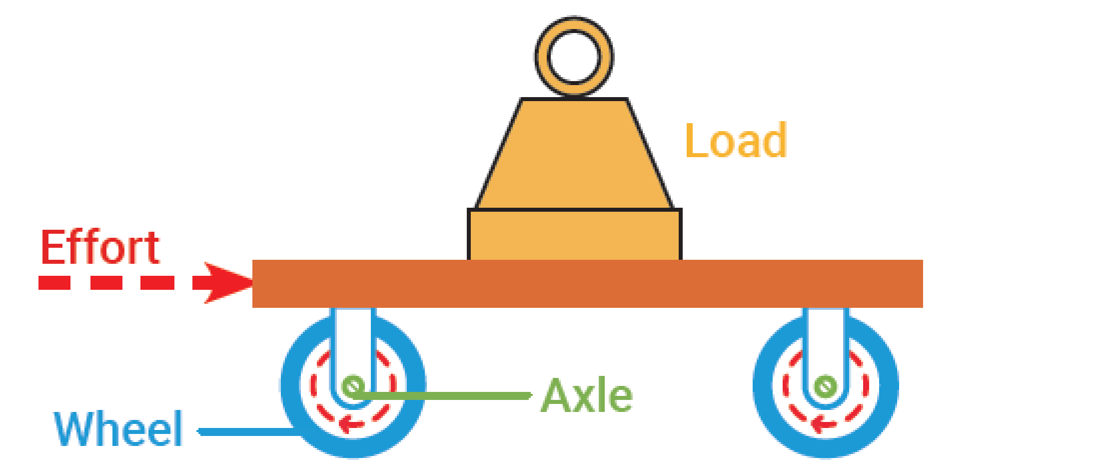


Airport security

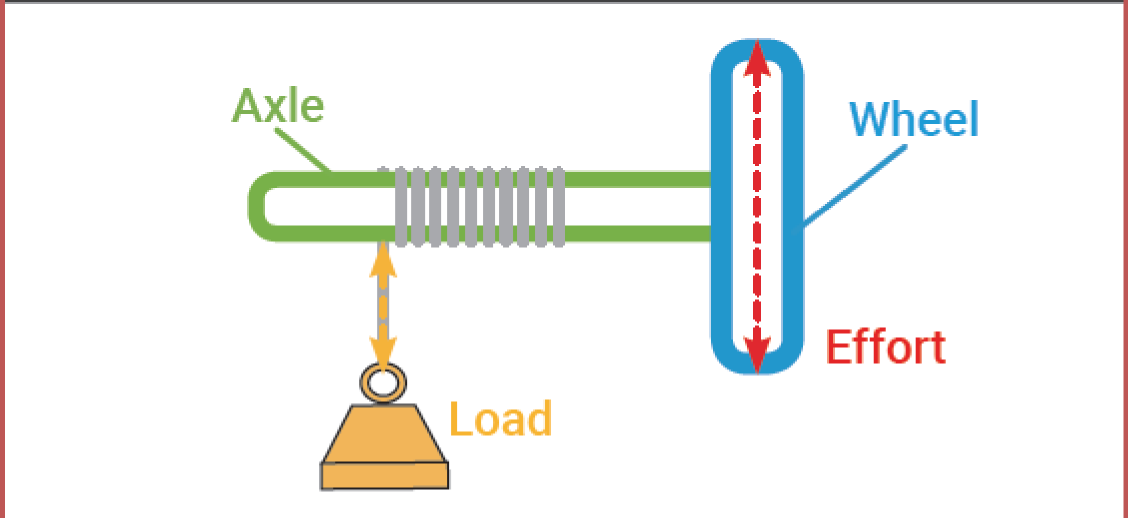
Conveyor belt

Roller slide

Example 2 - Reducing Friction

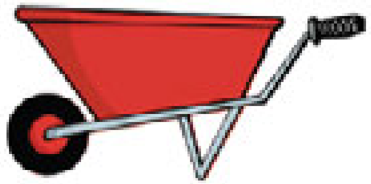


Example 3 - Mechanical Advantage



Bicycle Wheel

Wheelbarrow



Steering Wheel

Screwdriver

Well

Gears

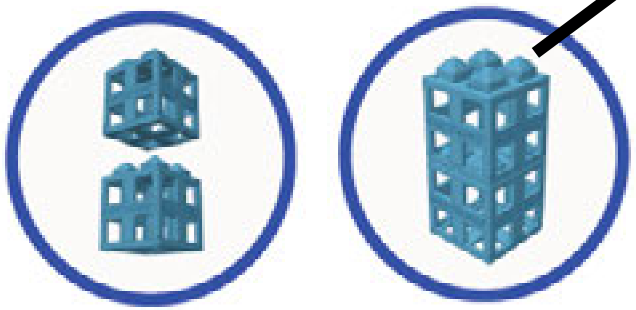
Building Basics

Building Basics with Rokenbok

The following tips will be helpful when using the Rokenbok Student Design and Engineering System.

Connecting/Separating ROK Blocks:

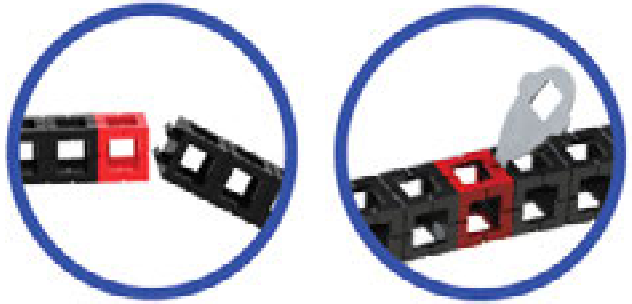
ROK Blocks use a friction-fit, pyramid and opening system to connect. Simply press pyramids into openings to connect.
To separate blocks, pull apart.



Pyramids or connectors

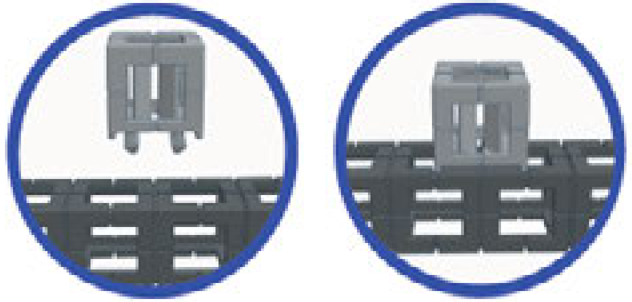
Connecting/Separating Rokenbok Components

Smaller Rokenbok components use a tab and opening system to connect. Angle one tab into the opening, and then snap into place.
To separate, insert key into the engineered slot and twist.



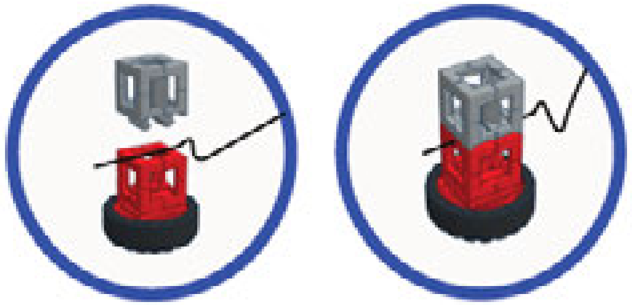
Snapping Across Openings

The tabs on Rokenbok components can also be snapped across openings to provide structural support to a design. This will also allow certain designs to function correctly.



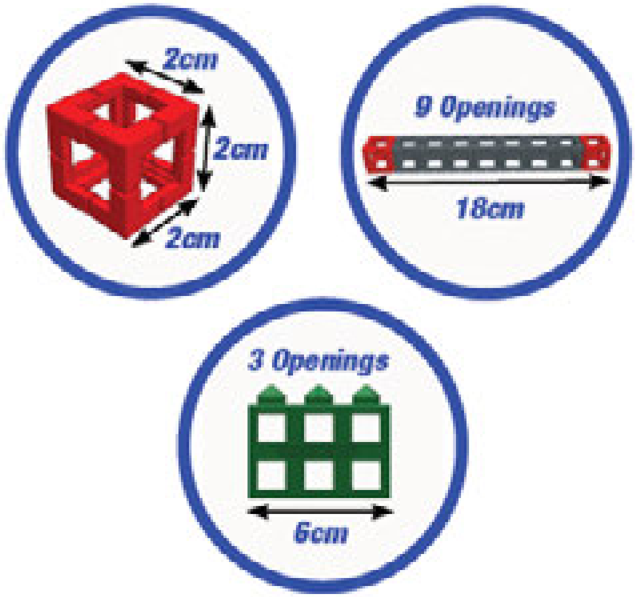
Attaching String:

In some instances, string may be needed in a design. Lay string across opening. Snap any Rokenbok component with tabs or pyramids into opening. Make sure tabs run perpendicular to string for a tight hold.

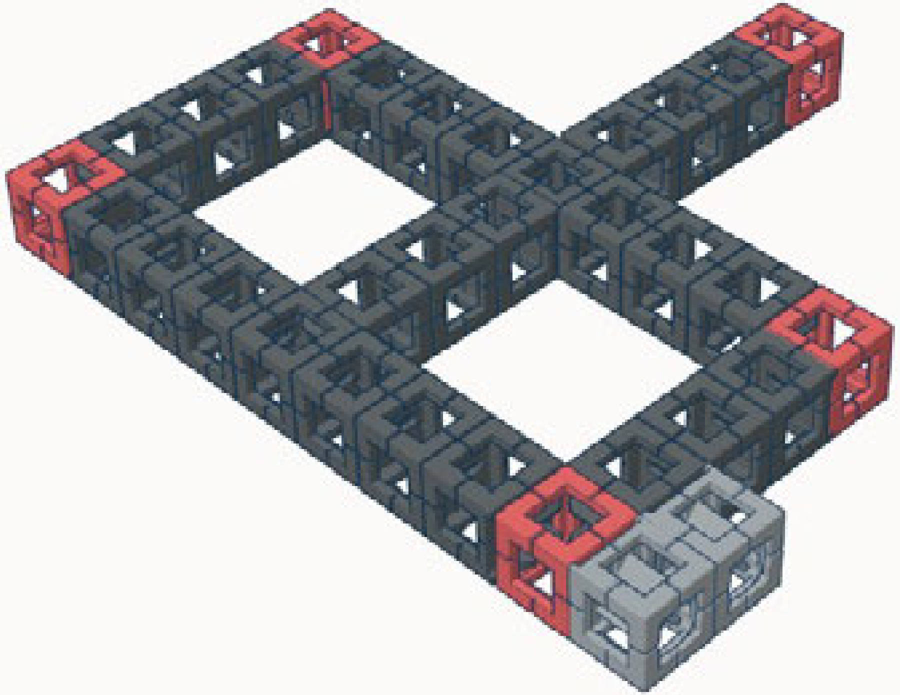


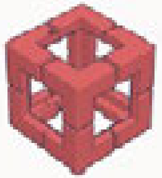
Measuring:

The outside dimensions of each Rokenbok connector block is 2cm³. This means the length, depth, and height are all the same.
To determine the size of a Rokenbok build in cm, simply count the number of openings and multiply by two. Repeat this process for length, depth and height.



1



5x
Block


2x
Beam


4x
Half Beam

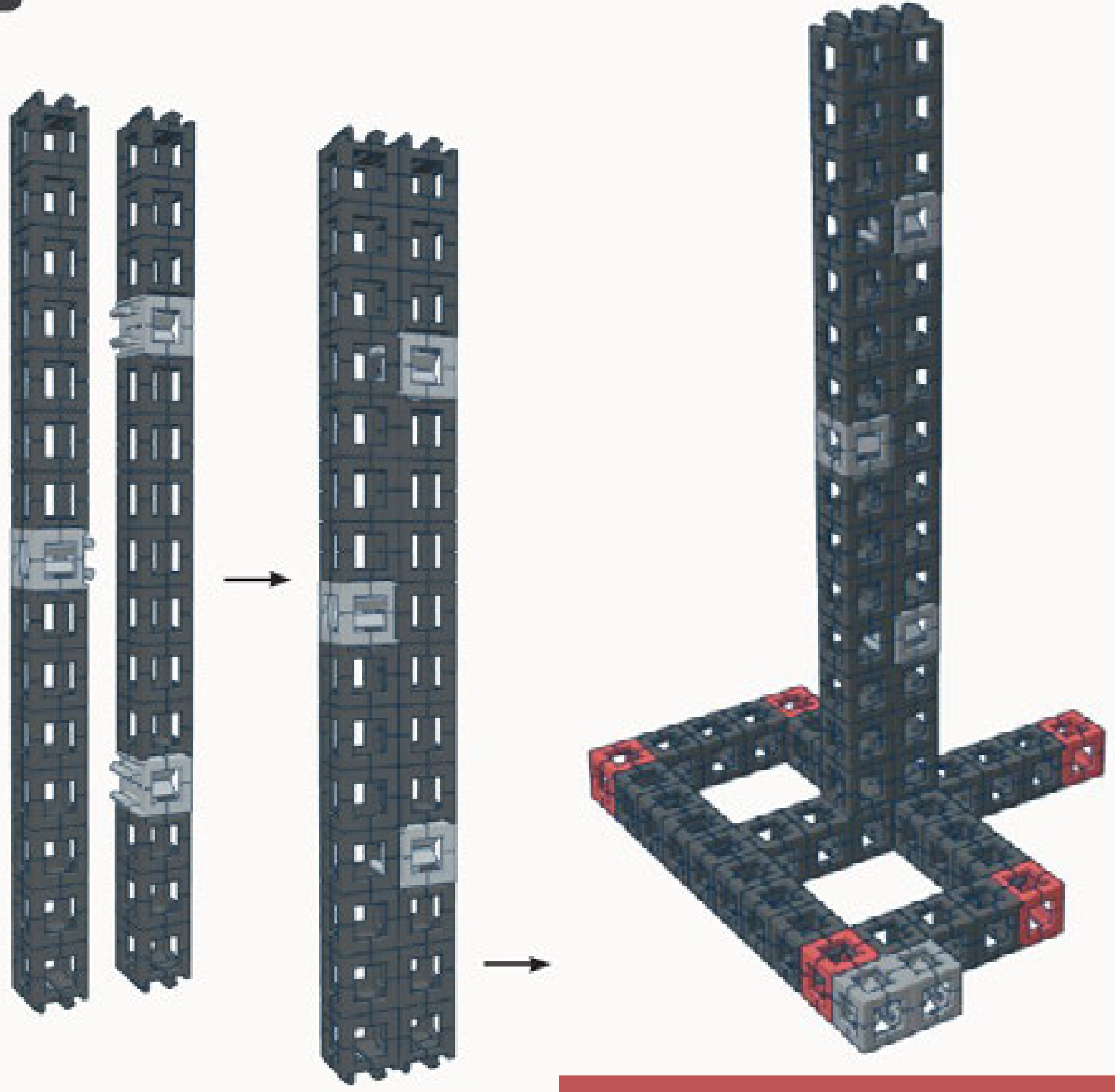

2x
Single Snap Block


3x
Beam

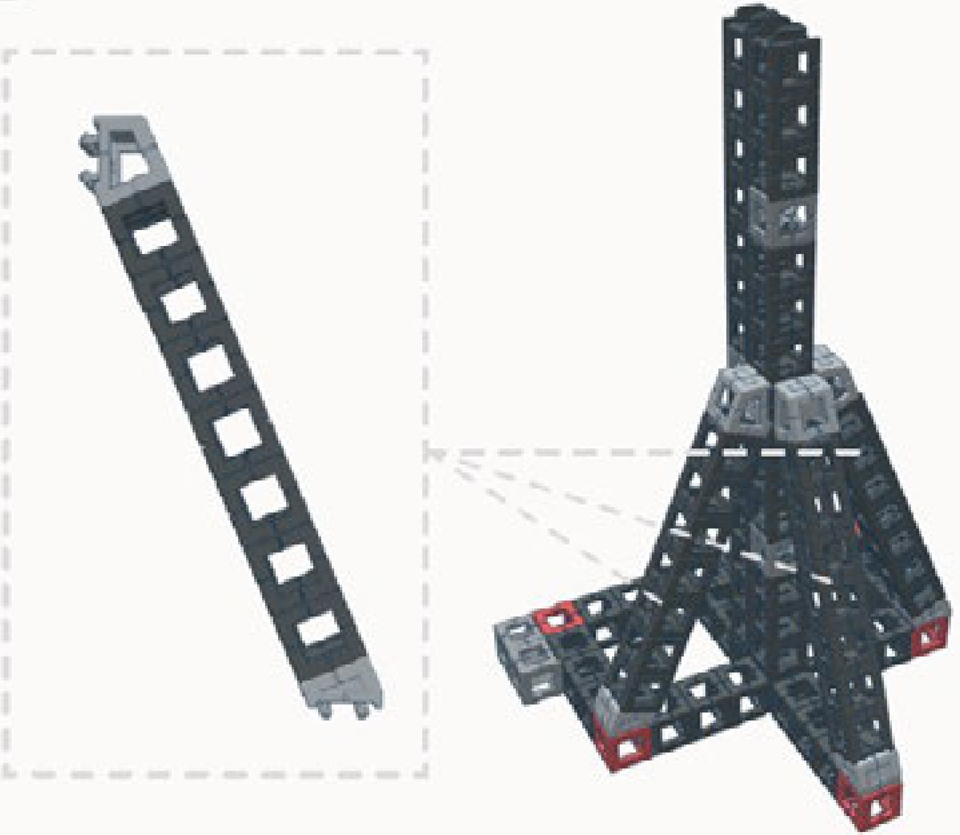
2x
Half Beam

3x
Single Snap Block

2



3

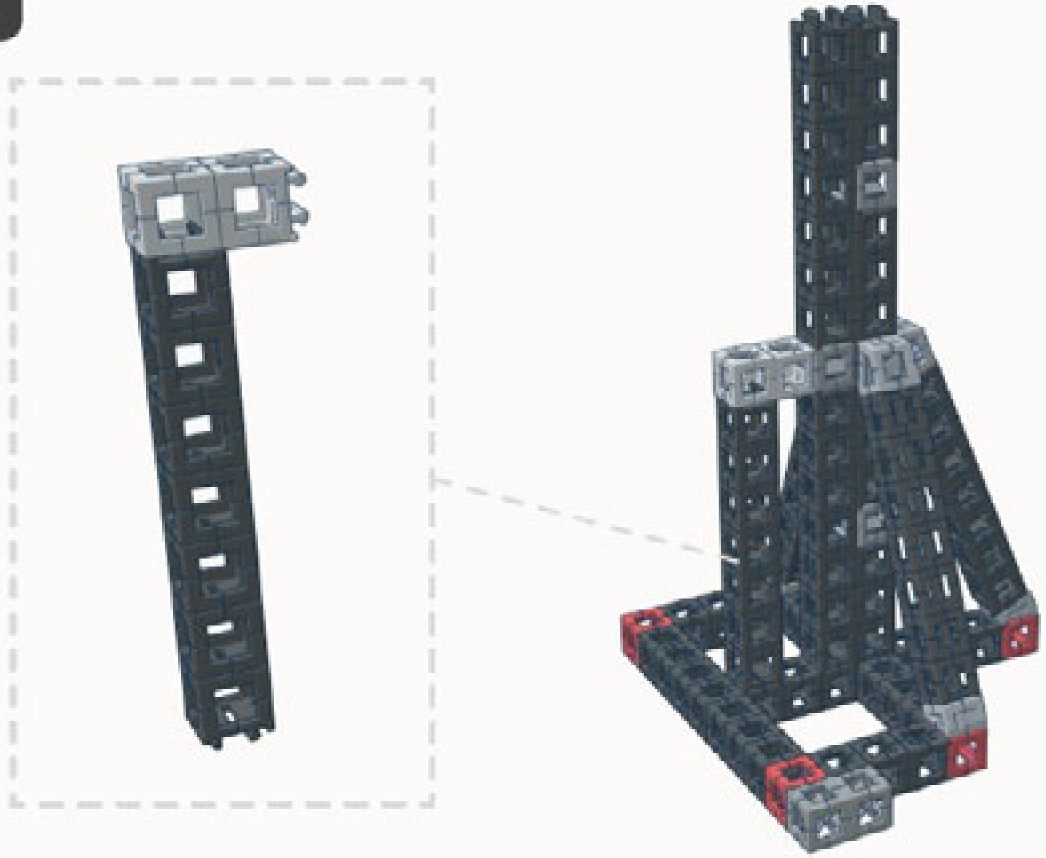


3x
Beam

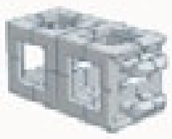
3x
60° Block

3x
30° Block

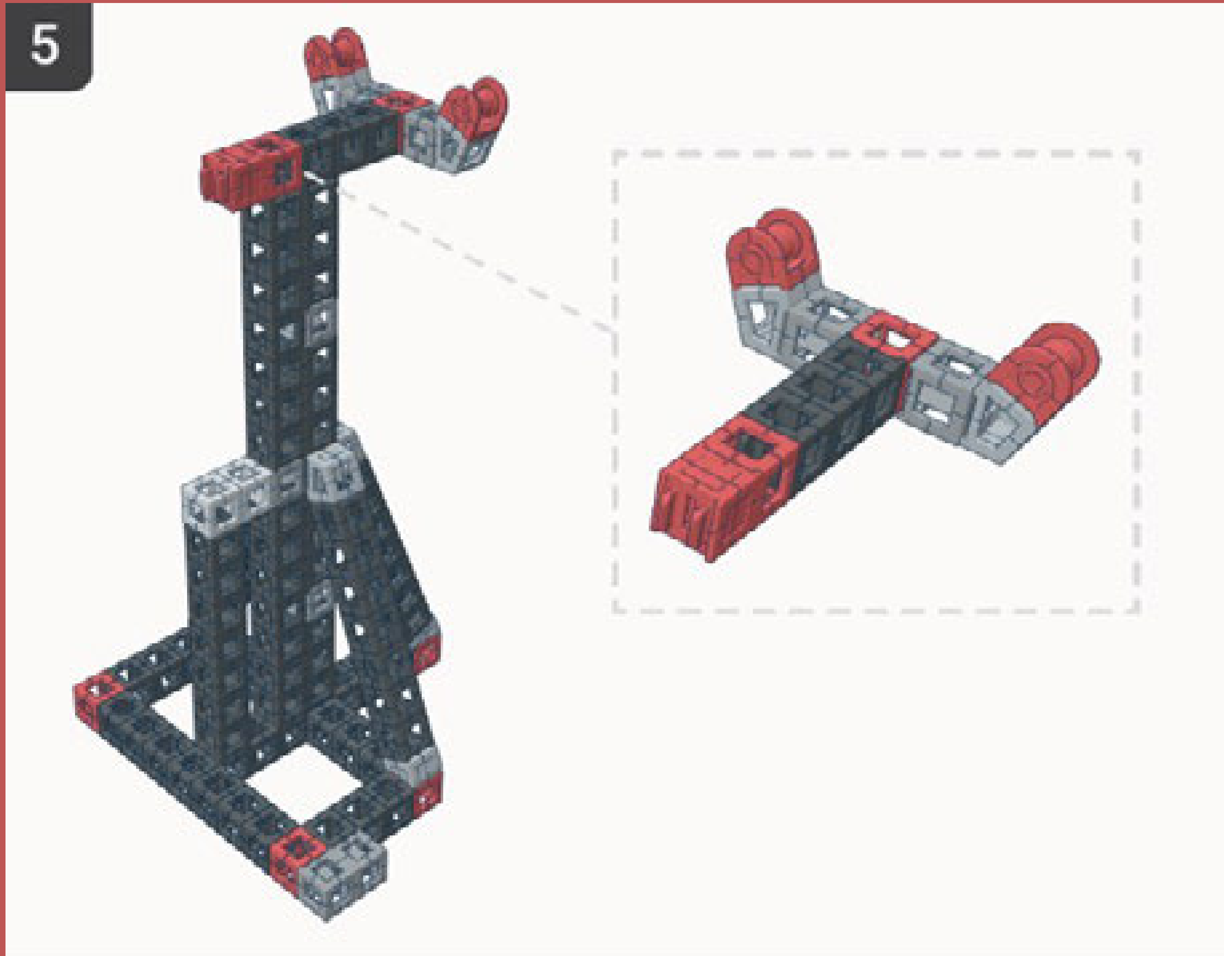
4



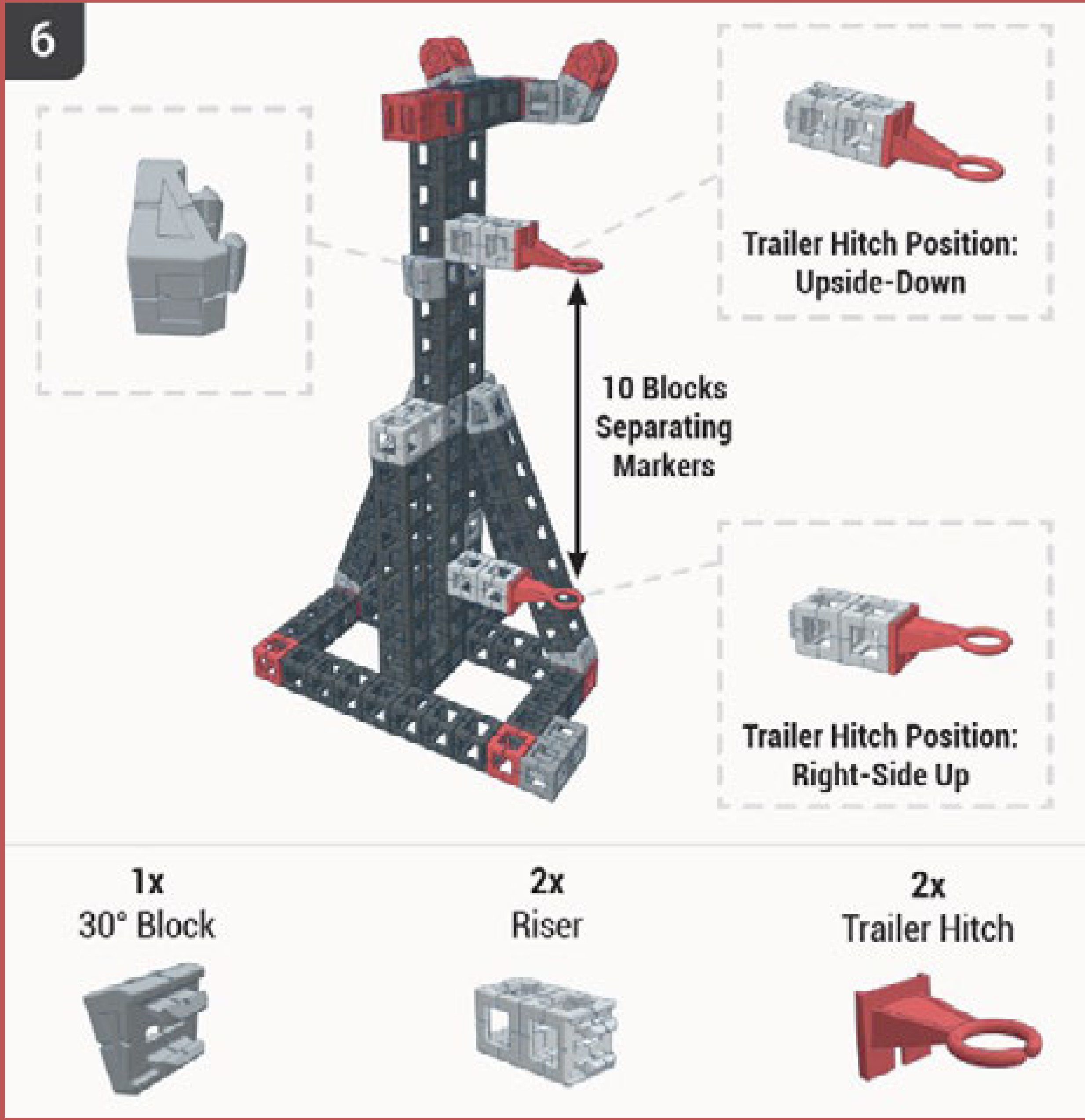
1x
Riser

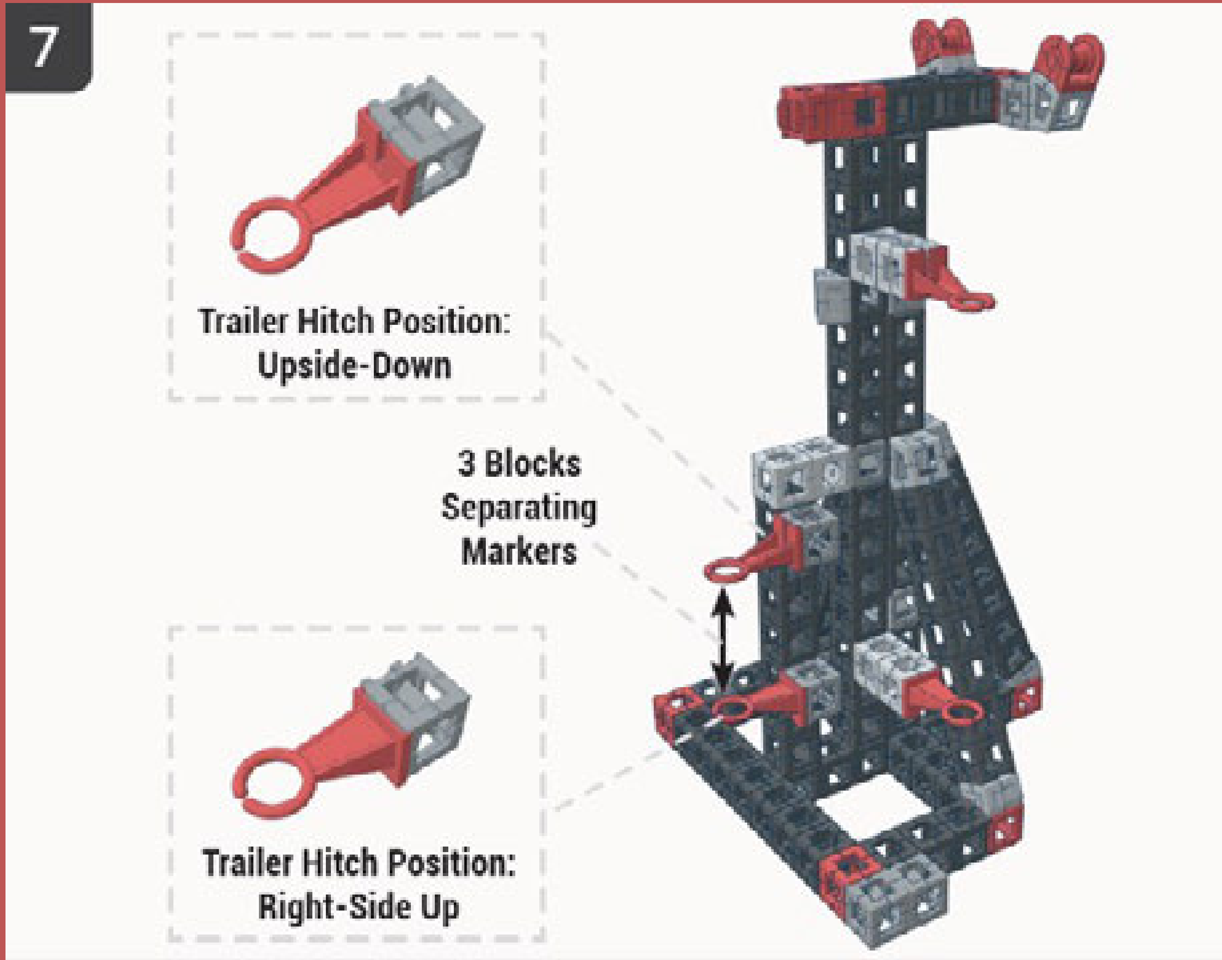


1x
Beam

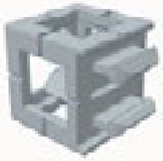


2x Pulley	2x Block	1x Half Beam	2x 60° Block	1x Axle Block	2x Single Snap Block


6
Trailer Hitch Position:
Upside-Down
10 Blocks
Separating
Markers
Trailer Hitch Position:
Right-Side Up
1x
30° Block
2x
Riser
2x
Trailer Hitch

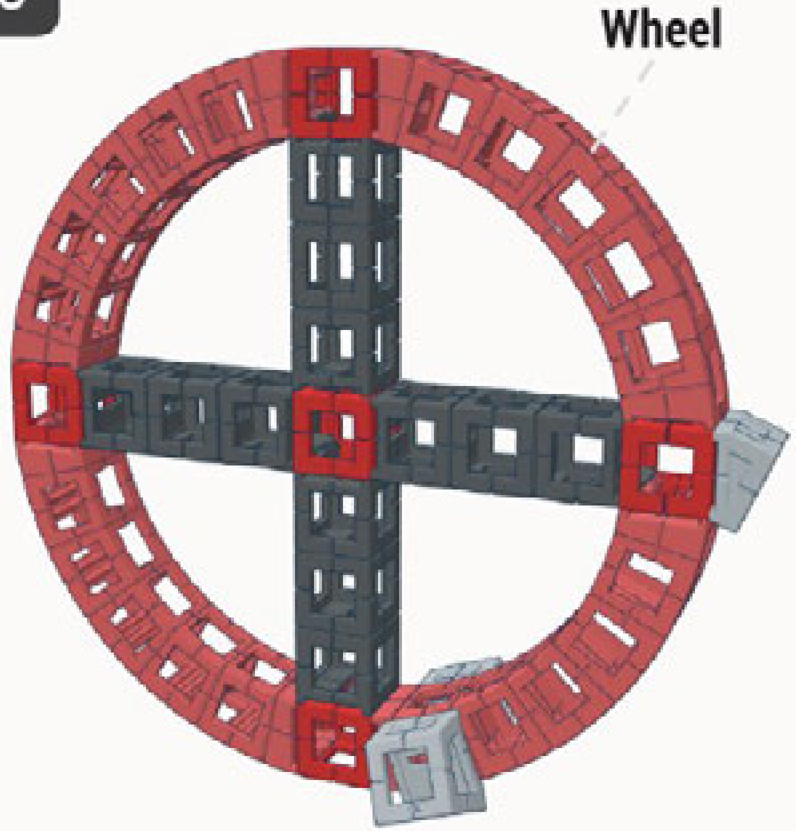


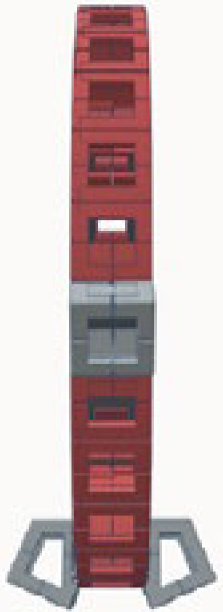
2x
Single Snap Block



2x
Trailer Hitch

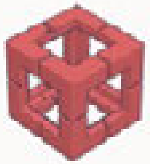
8





Side View

5x
Block

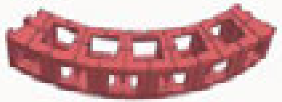


4x
Half Beam

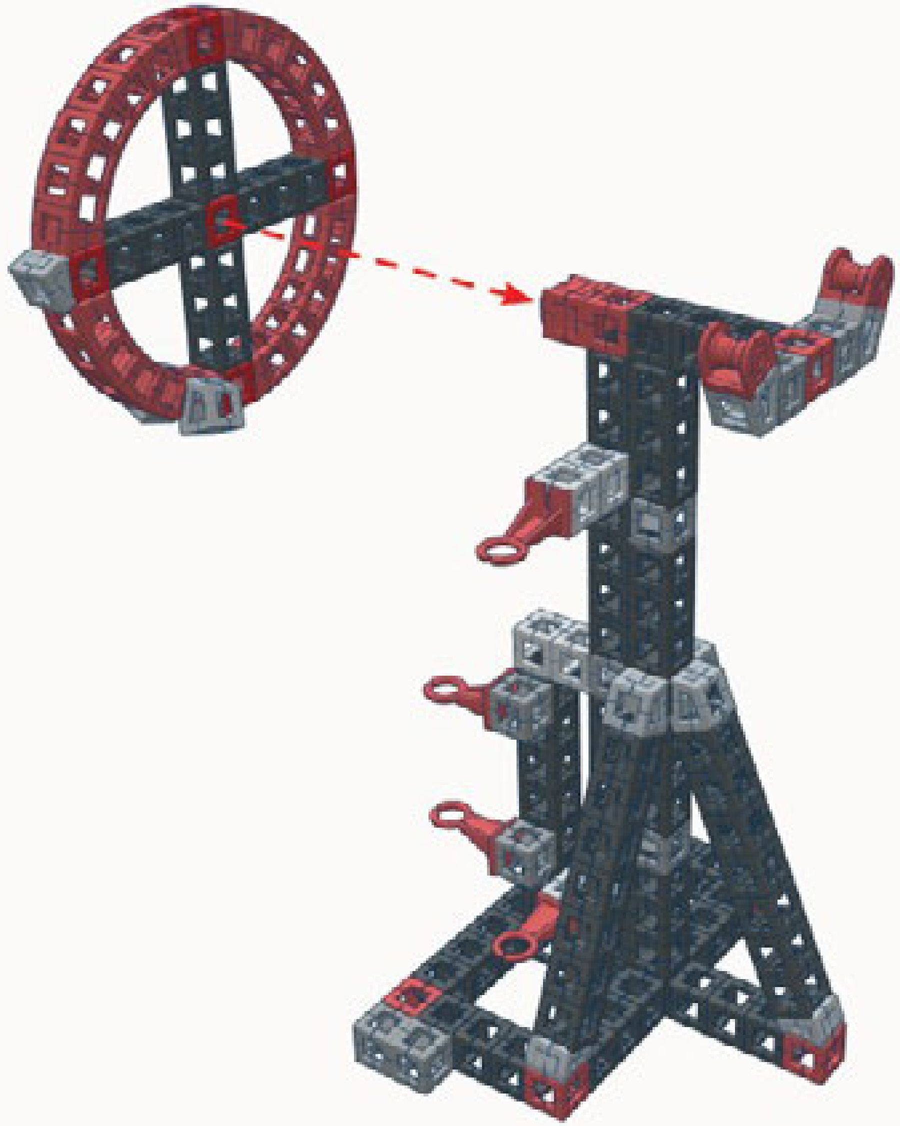
1x
30° Block

2x
60° Block

4x
Small Curved Beam



9



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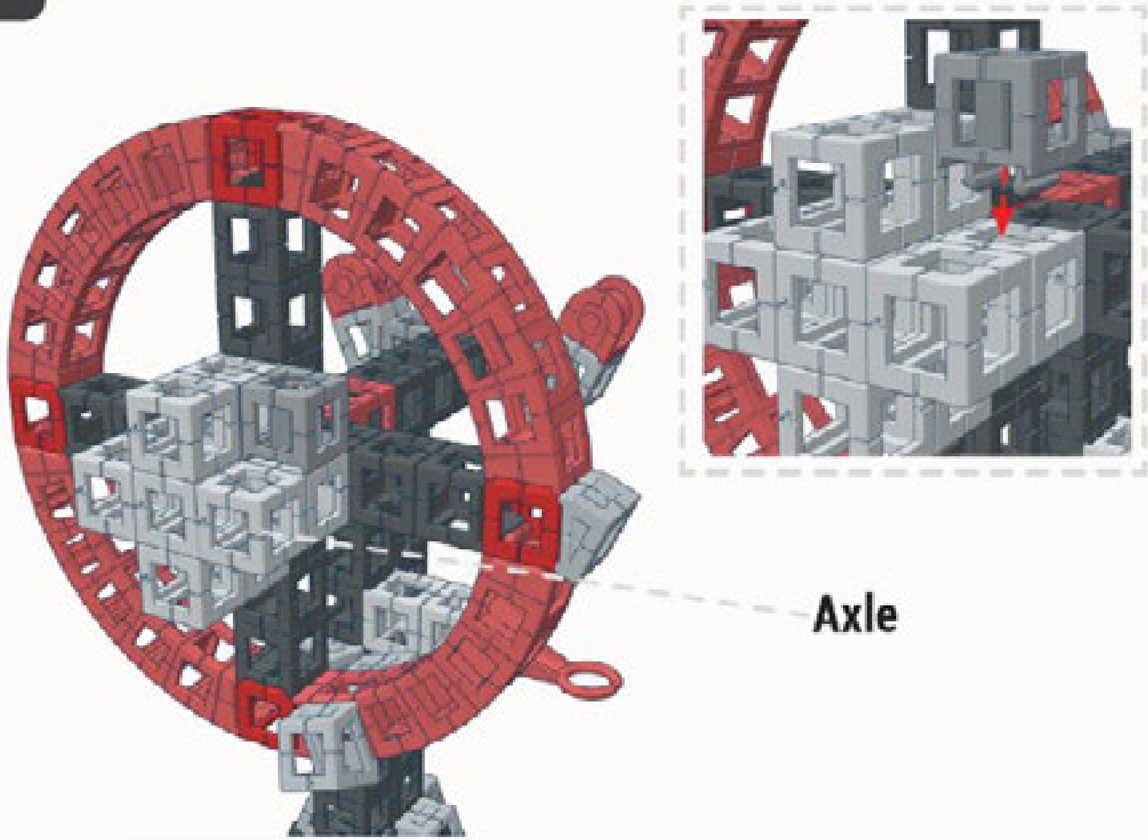
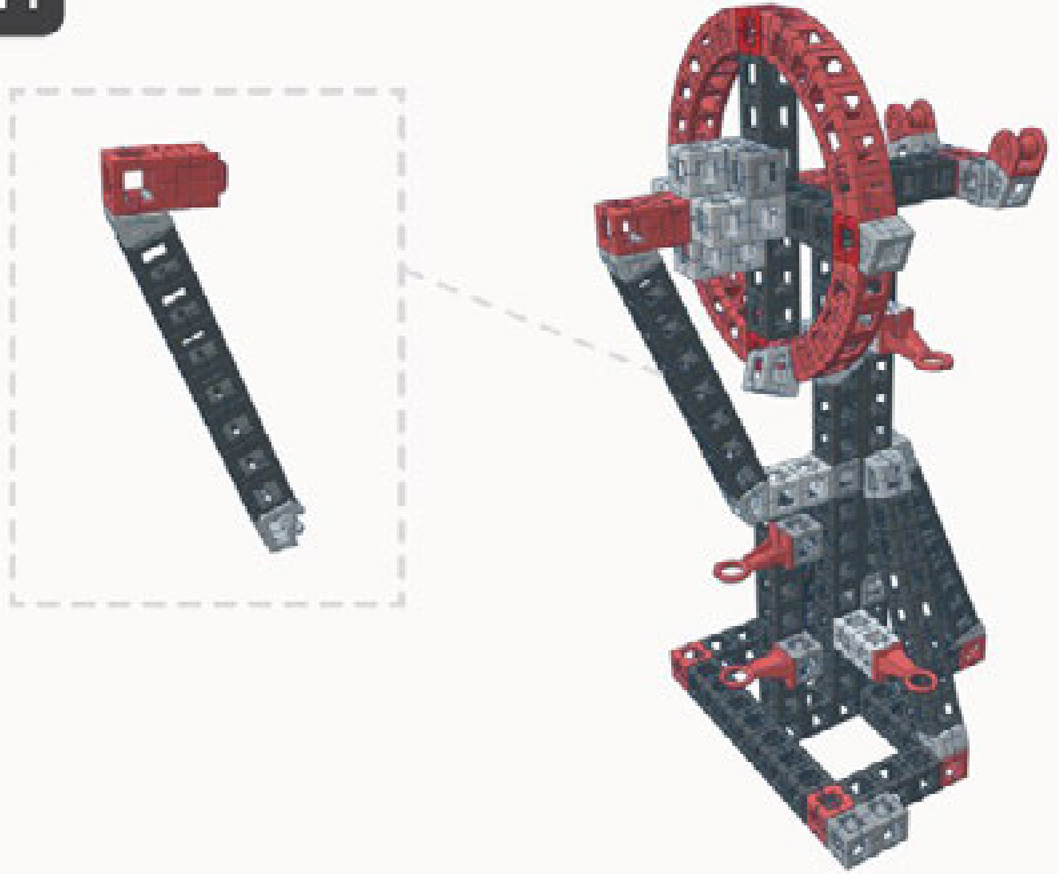


5x
Riser

1x
Single Snap Block

11

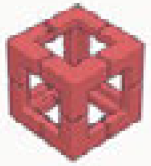


1x
30° Block

1x
Beam

1x
60° Block

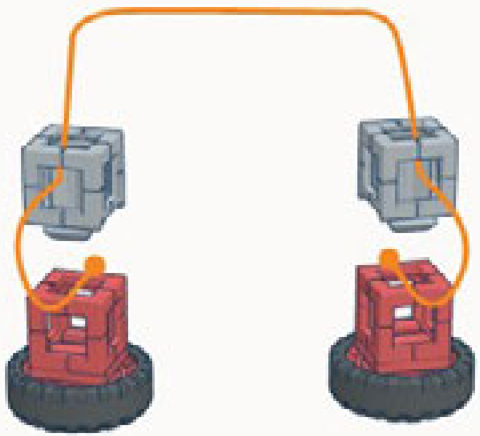
1x
Block

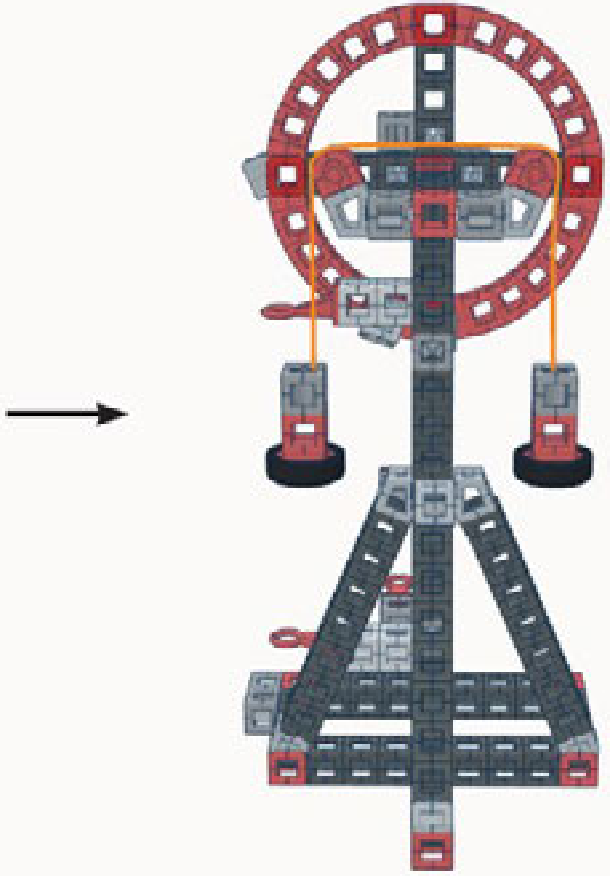


1x
Axle Block

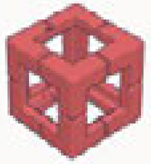
12

Cut a piece of string that is 48cm long. Feed each end of the string through the single snap blocks as shown. Lay string on top of the red connector blocks and snap into place. Once connected, place string of weights over fixed pulleys.





2x
Block



2x
Snap-In Wheel

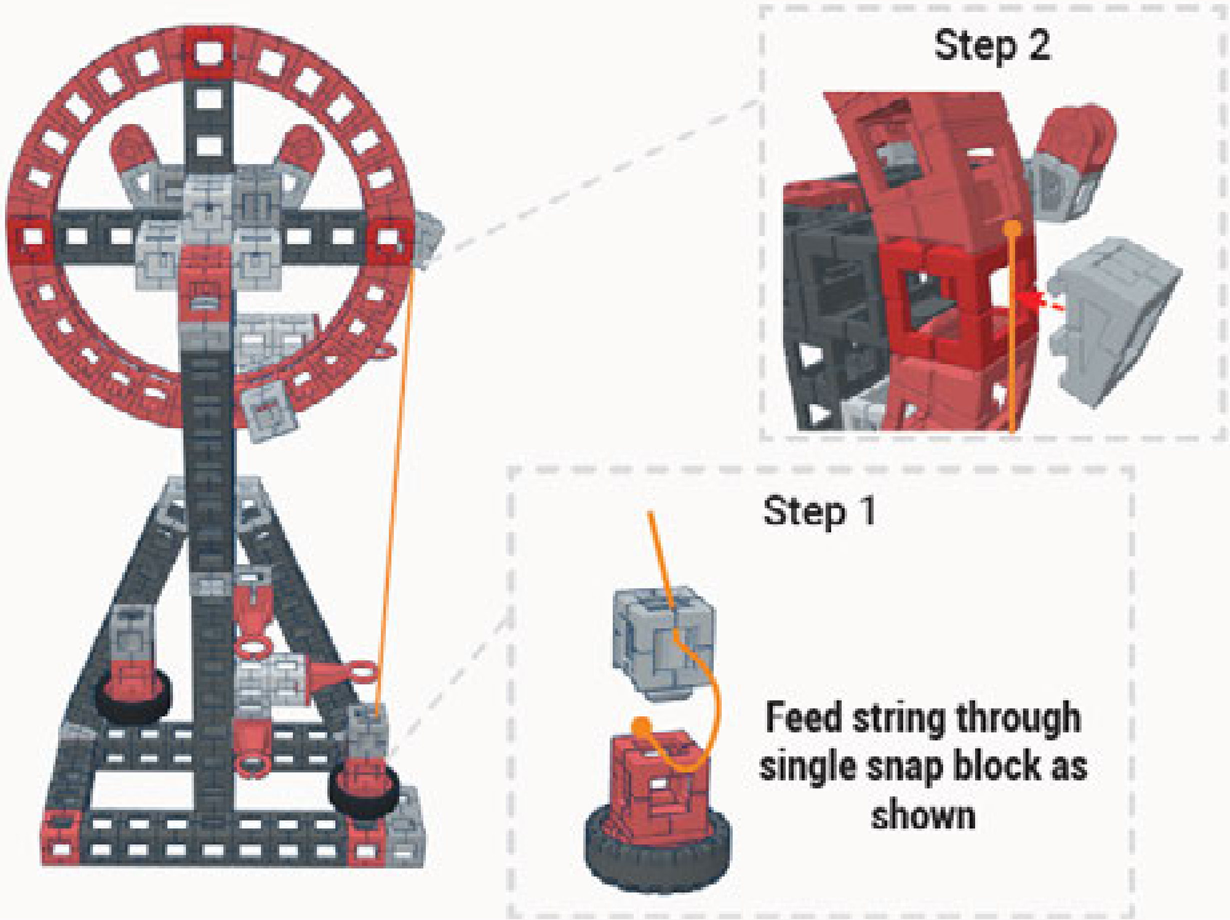
2x
Single Snap Block

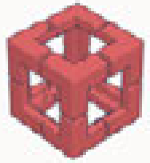
13

Step 1: Connecting Weight 1
Cut a piece of string that is 40cm long. To connect weight 1, feed one end of the string through the single snap block as shown. Lay string on top of the red connector block. Then snap connector block and single snap block together to secure string in place.

Step 2:
Disconnect 30° block from large wheel. Place the other end of string across opening and snap 30° block back into place, to secure string.

Note: *Adjust string if necessary to make sure Weight 1 is resting on the base frame. Make sure string is taut.*



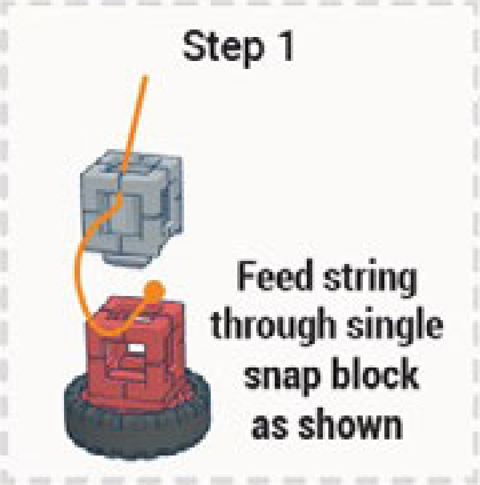


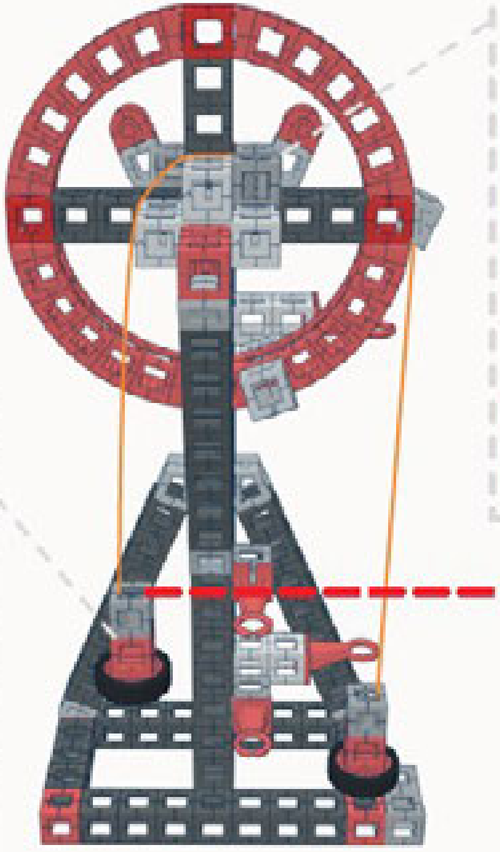
14

Step 1: Connecting Weight 2
Cut a piece of string that is 40cm long. To connect weight 2, feed one end of the string through the single snap block as shown. Lay string on top of the red connector block. Snap connector block and single snap block together to secure string in place.

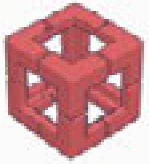
Step 2:
Disconnect single snap block from the axle. Place the other end of string across opening and snap single snap block back into place, to secure string.

Note: *Make sure that tabs on single snap block are perpendicular to the string, as shown. Adjust string if necessary to make sure the top of Weight 2 is even with the middle marker.*





1x
Block



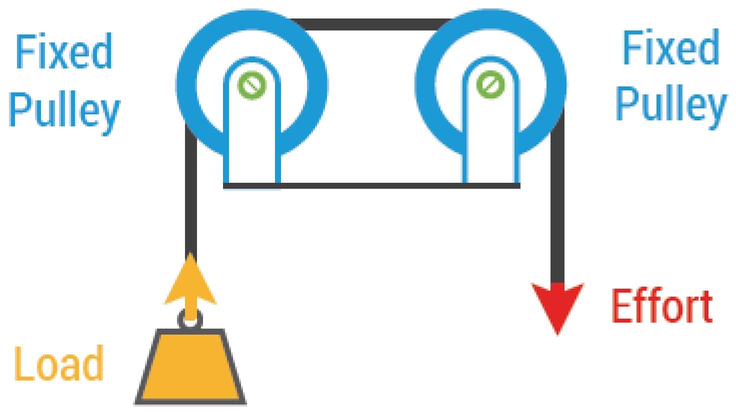
1x
Snap-In Wheel

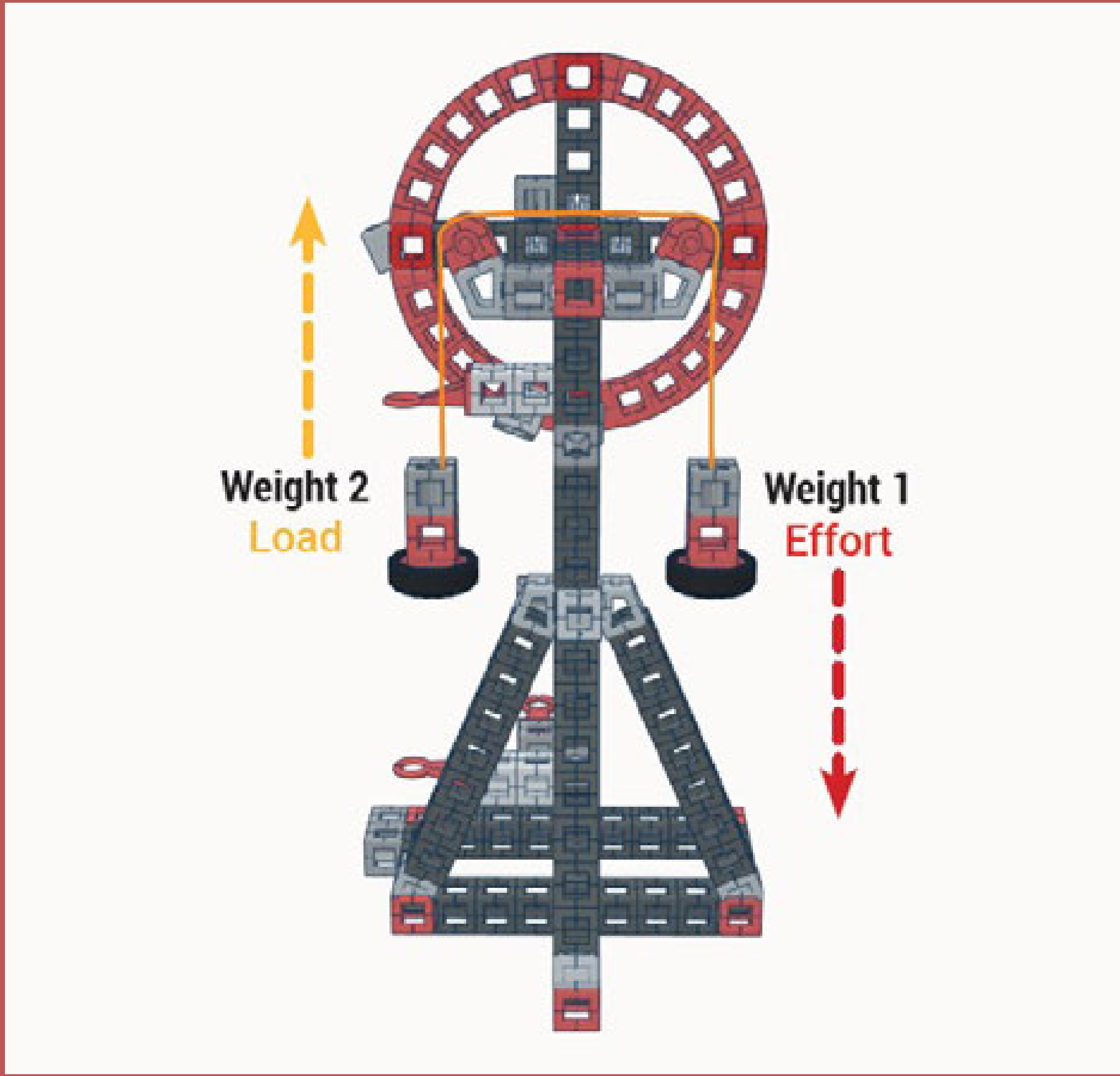
1x
Single Snap Block

Testing Fixed Pulley System

Turn the model so that the string of weights can be tested on the fixed pulley system. Place the string of weights over the fixed pulleys. Observe how the weights balance each other out. Pull down on **Weight 1 (Effort)** and observe how **Weight 2 (Load)** moves in the opposite direction. You will notice that the mass of weight 1 isn't enough to overcome the mass of weight 2 on its own, because this system creates no mechanical advantage.

Fixed Pulley System



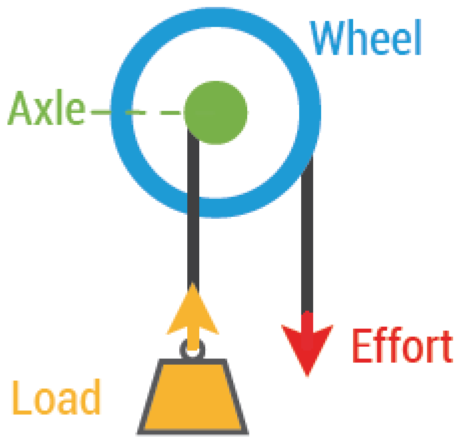

Weight 2
Load
Weight 1
Effort

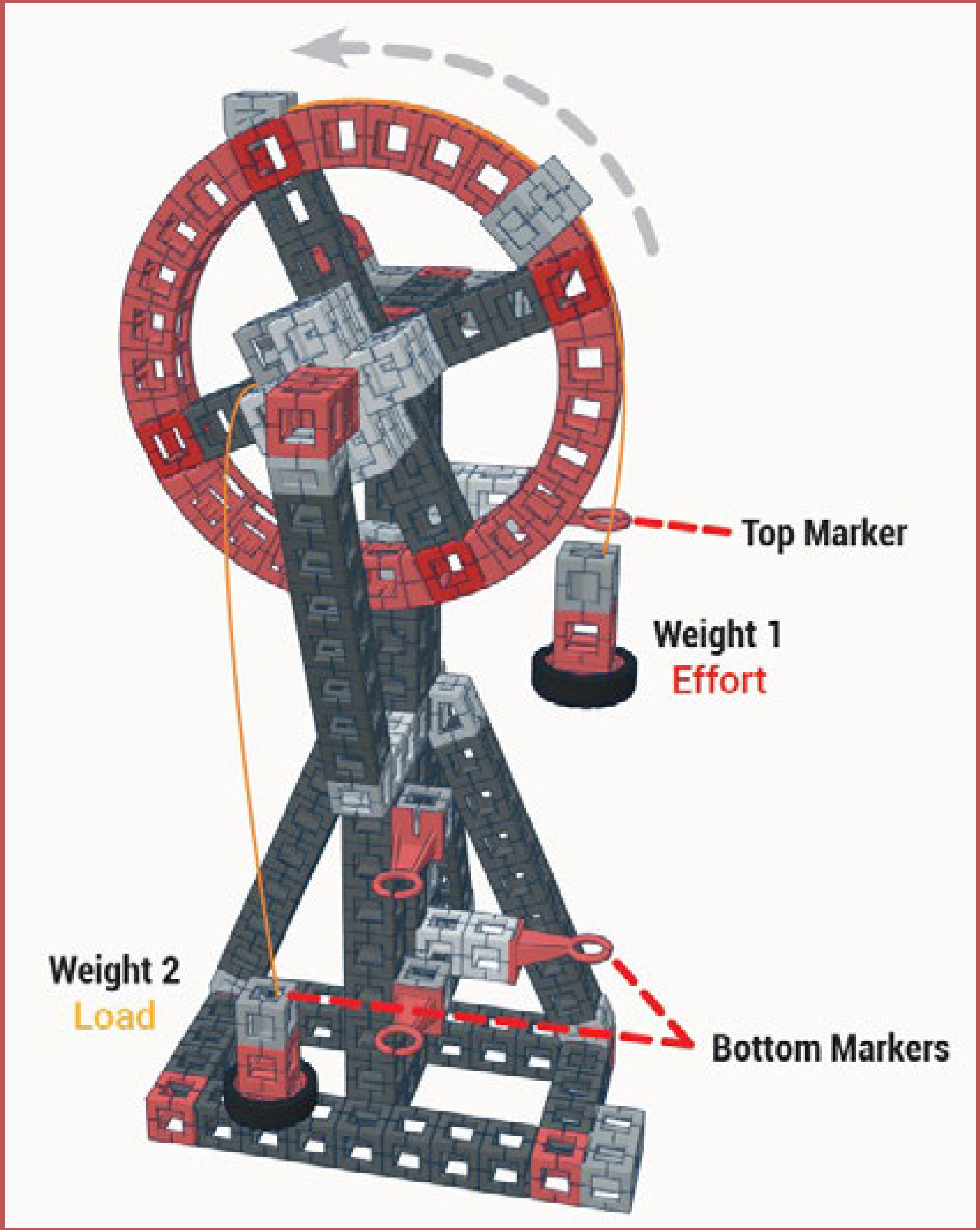
Testing Wheel & Axle

Step 1:
Turn the large wheel so that the top of **Weight 1 (Effort)** is even with the top marker and the top of **Weight 2 (Load)** is even with the bottom markers.

Step 2:
Release the wheel and observe what happens.

Wheel & Axle



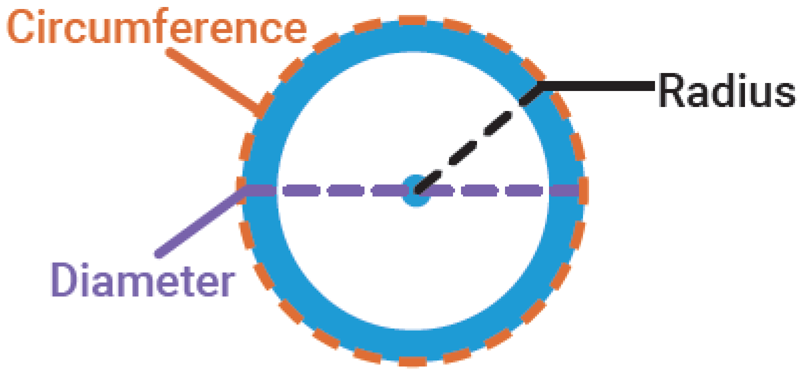

Top Marker
Weight 1
Effort
Weight 2
Load
Bottom Markers

Understanding Mechanical Advantage

The main purpose of a simple machine is to make work easier. This is done by either redirecting motion or creating mechanical advantage. **Mechanical Advantage** exists when the output force of a machine is greater than the input force that was applied to it. To accomplish this, the machine must trade increased time or distance for reduced effort.

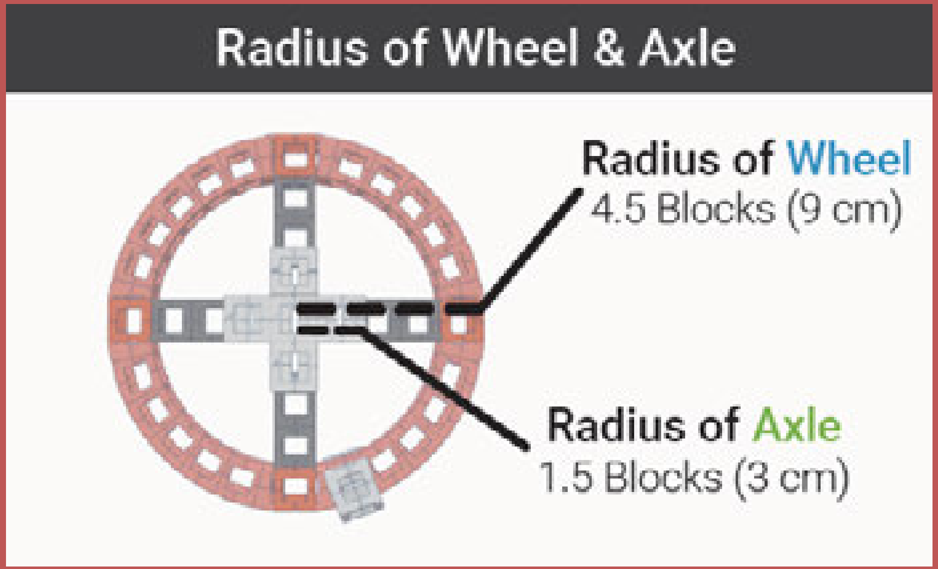
Attributes of a Circle

To have a better understanding of how a wheel and axle creates mechanical advantage, it is important to be familiar with the different attributes of a circle. This includes the **radius**, diameter, and circumference. Since the wheel and the axle are both cylinders (circles with depth), these attributes will be used to calculate the amount of mechanical advantage that exists within a design.



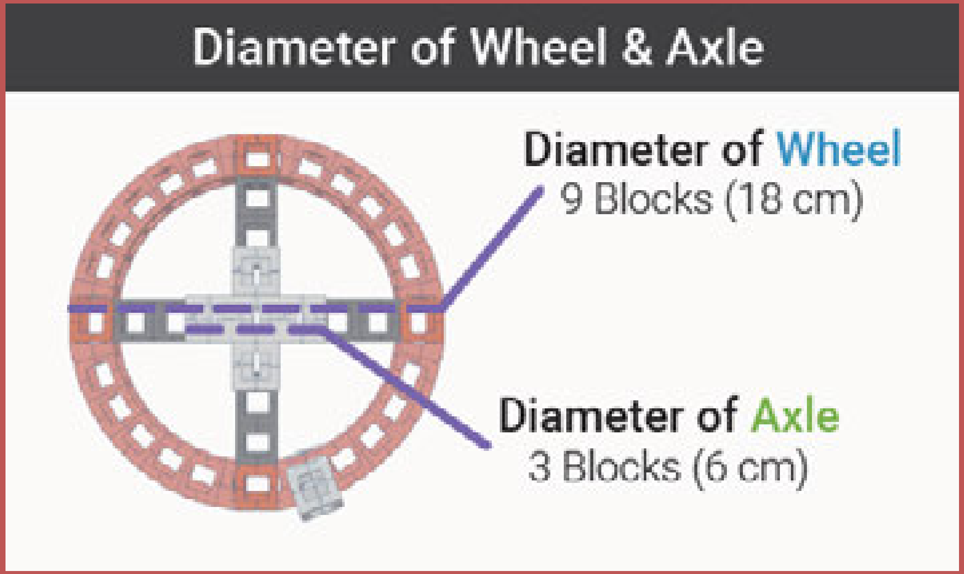
Radius

The **radius** is the distance from the center of a circle to the outside edge. In the Rokenbok model, the **radius** of the **wheel** is 4.5 blocks (9 cm), and the **radius** of the **axle** is 1.5 blocks (3 cm).



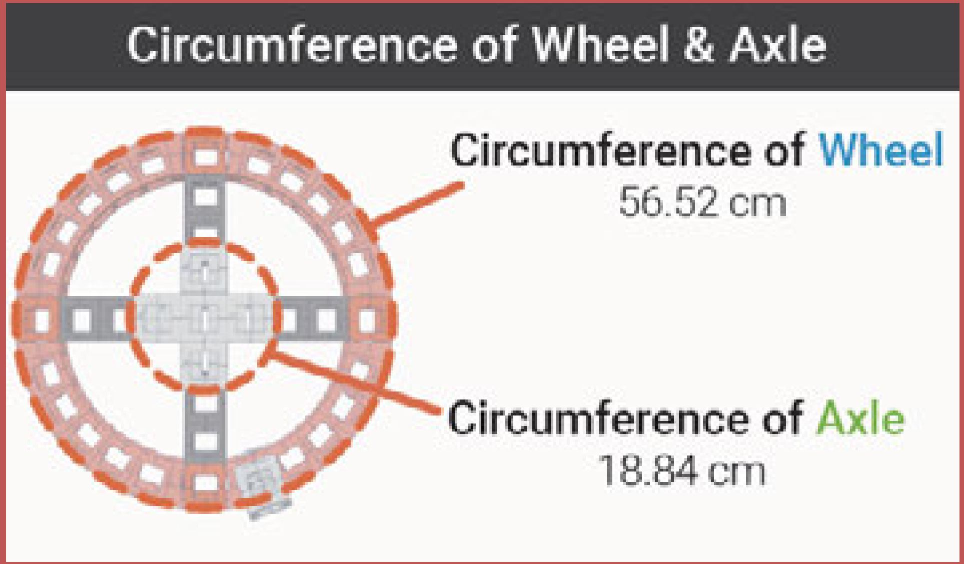
Diameter

The **diameter** is the distance through the center of a circle from one side to another. In the Rokenbok model, the **diameter** of the **wheel** is 9 blocks (18 cm), and the **diameter** of the **axle** is 3 blocks (6 cm). The **diameter** of any circle is always twice the distance of the **radius**.



Circumference

The **circumference** is the distance around the circle. For any circle, dividing its **circumference** by its **diameter** will give the exact same number of 3.141592... The greek letter **Pi (π)** is used to represent this value. Pi is an irrational number, meaning it is a real number that cannot be expressed as a ratio of integers, i.e. as a fraction. Irrational numbers, when written as decimals do not terminate, nor do they repeat. To simplify calculations, Pi is represented as **π=3.14**.



To calculate the **circumference** in a circle, the constant pi (π) is used in the following formula:

Circumference Formula

$$C = 2 \pi r$$

r = radius

In the Rokenbok model, the **radius** of the **wheel** is 9 cm. To determine the **circumference**, multiply (2 x 3.14 x 9 cm) to get 56.52 cm. This means the **circumference** of the wheel is 56.52 cm. The **radius** of the **axle** is 3 cm. To determine the **circumference**, multiply (2 x 3.14 x 3 cm) to get 18.84 cm.

Calculating Mechanical Advantage

The wheel & axle reduces the amount of effort needed to raise a load by creating mechanical advantage. This is done by attaching the load to an axle and applying an effort force to the connected wheel. Since the wheel has a larger circumference, it will travel a further distance than the axle and reduce the amount of effort needed to raise the load. The following two formulas can be used to calculate the mechanical advantage in a wheel & axle:

Formula #1 (Distance)

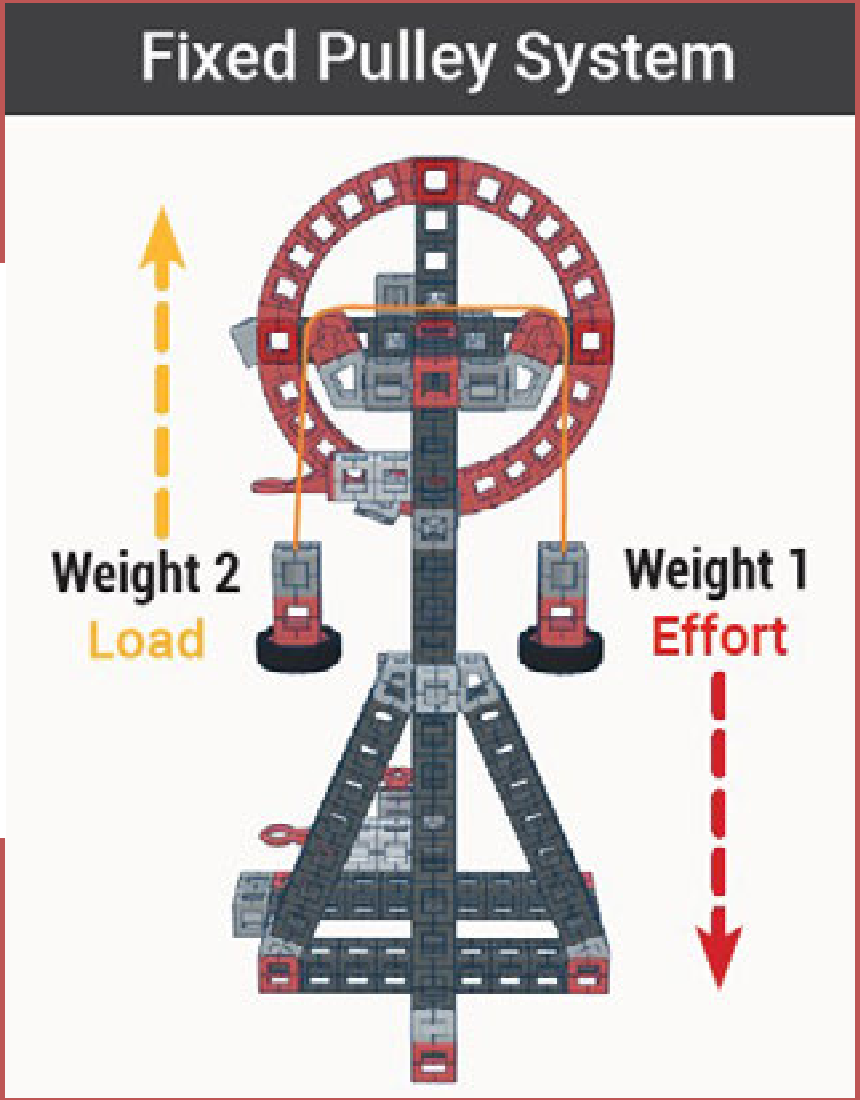
$$\text{Mechanical Advantage} = \frac{\text{Distance effort travels}}{\text{Distance load travels}}$$

Formula #2 (Circumference)

$$\text{Mechanical Advantage} = \frac{\text{Circumference of wheel}}{\text{Circumference of axle}}$$

Fixed Pulley System

In the fixed pulley system, if **Weight 1 (Effort)** is pulled down 8 cm, then **Weight 2 (Load)** will raise 8 cm in the opposite direction. Divide 8/8 and this will give a mechanical advantage of 1:1. This means that for every unit of measurement the effort travels, the load will travel an equal unit of measurement in the opposite direction. This demonstrates how there is no mechanical advantage in a fixed pulley system. In order to raise one of the weights in this example, extra effort or mass would be needed to overcome the mass of the load.



Understanding Wheel & Axle Model

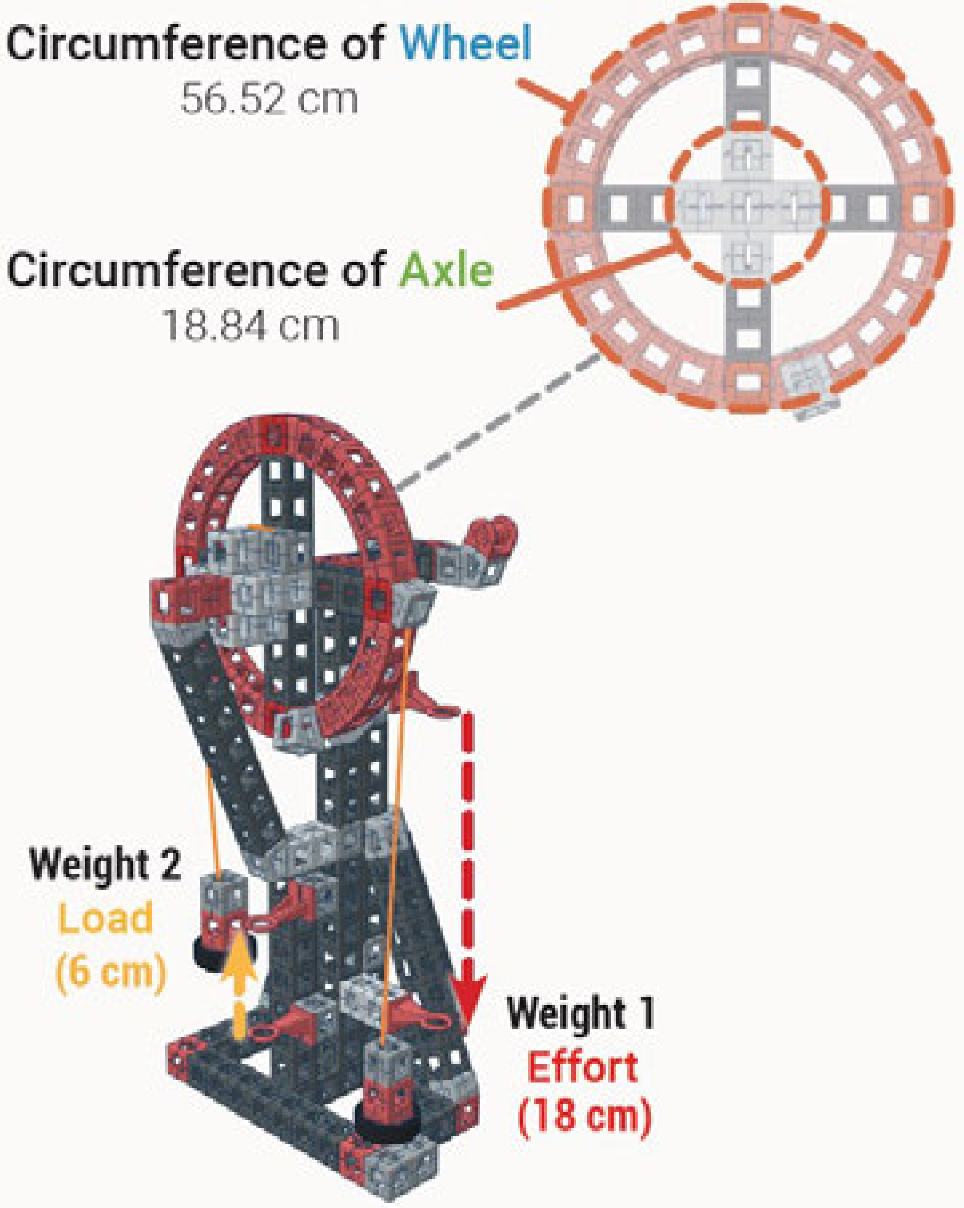
Distance Formula

In the wheel & axle, **Weight 1 (Effort)** is connected to the wheel and travels a distance of 9 blocks (18 cm). **Weight 2 (Load)** is connected to the axle and travels a distance of 3 blocks (6 cm). Divide 18/6 and this will give a mechanical advantage of 3:1. This means that for every three units of measurement the effort travels, the load will travel one unit of measurement in the opposite direction.

Circumference Formula

The circumference of the wheel is 56.62 cm and the circumference of the axle is 18.84 cm. Divide 56.62/18.84 and this will also give a mechanical advantage of 3:1. In this model, the circumference of the wheel is three times larger than the axle. This means the effort will travel three times the distance of the load. **Weight 1 (Effort)** is able to lift **Weight 2 (Load)**, even though they are the same mass. The wheel & axle is able to output a greater force than the input force that was applied to it by trading increased distance for reduced effort.

Wheel & Axle Model



Modify: Wheel & Axle

Now that you have built a wheel & axle that has a mechanical advantage of 3:1 (wheel is three times larger than the axle), modify the wheel or axle to increase the mechanical advantage to 9:1.

Extension Activity

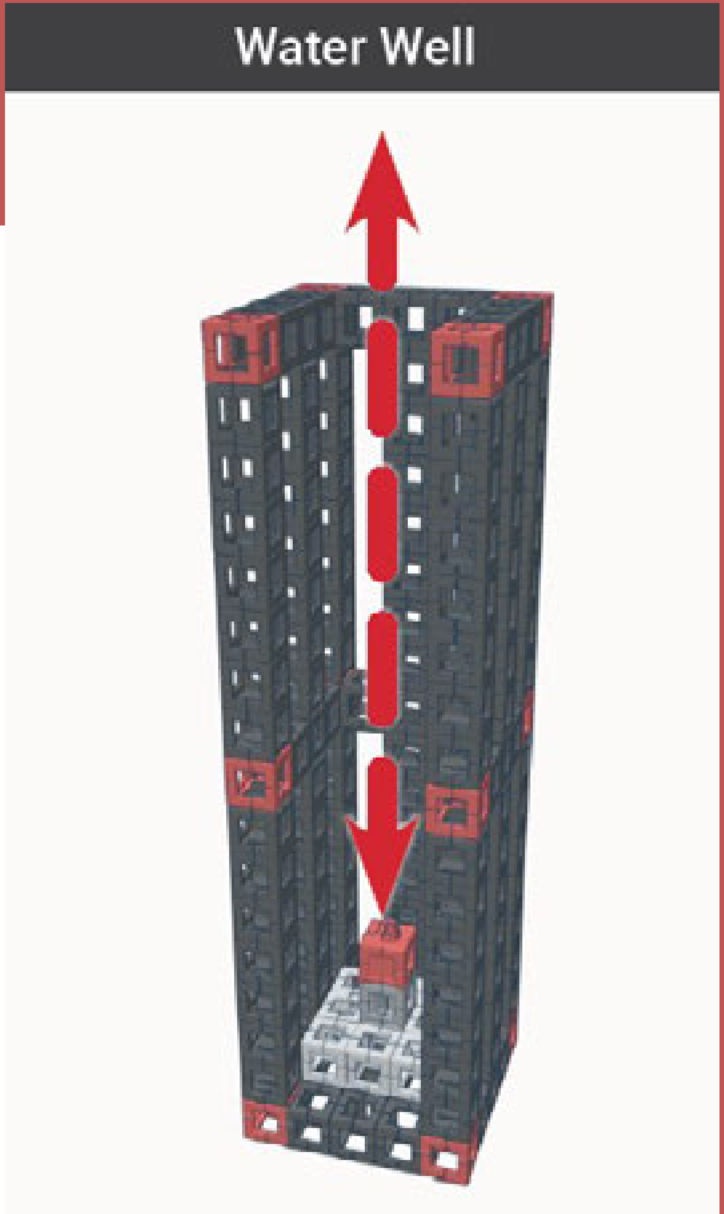
Design Brief: Scenario

A small village relies on getting their drinking water from a deep well, just outside of the village. Currently, a rope is tied to a large water carriage that is raised and lowered into the well. Only the strongest villagers are able to lift it easily. Since the task of retrieving water is very difficult, many people have hurt their backs during the process.

Design & Engineering Challenge

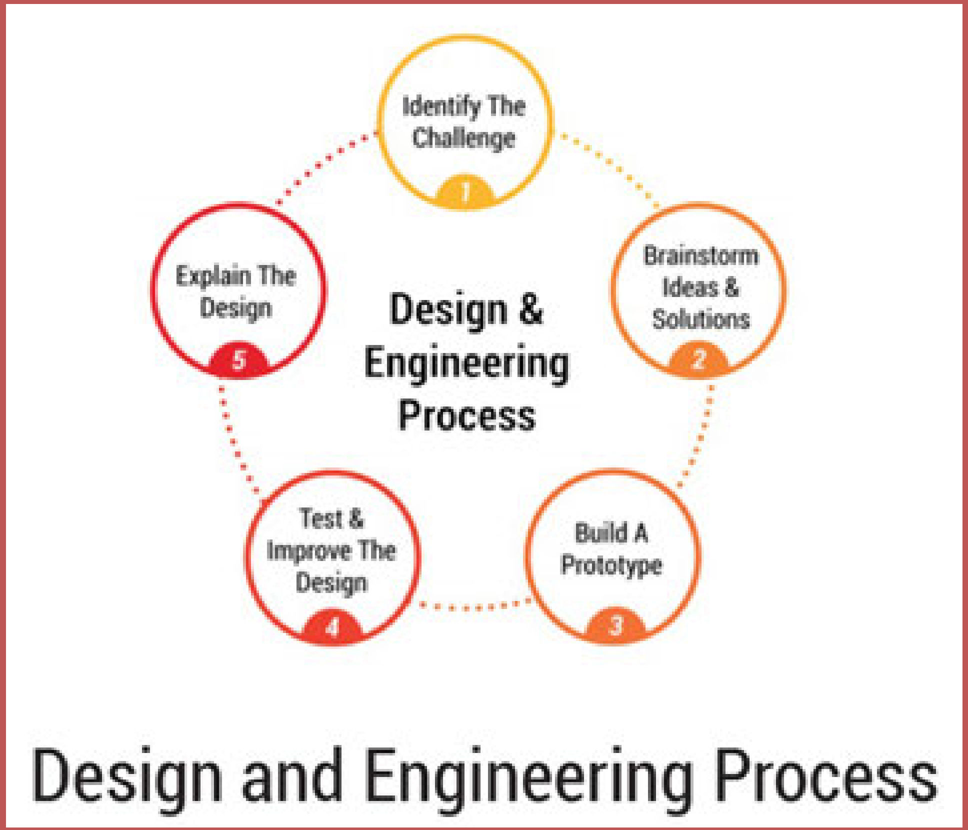
Your challenge is to design and engineer a wheel & axle in the form of a windlass, that is permanetly attached to the top of the water well, and reduces the amount of effort needed to raise and lower a water carriage within the well.

**Instructions to build water well and carriage are on page 13.*

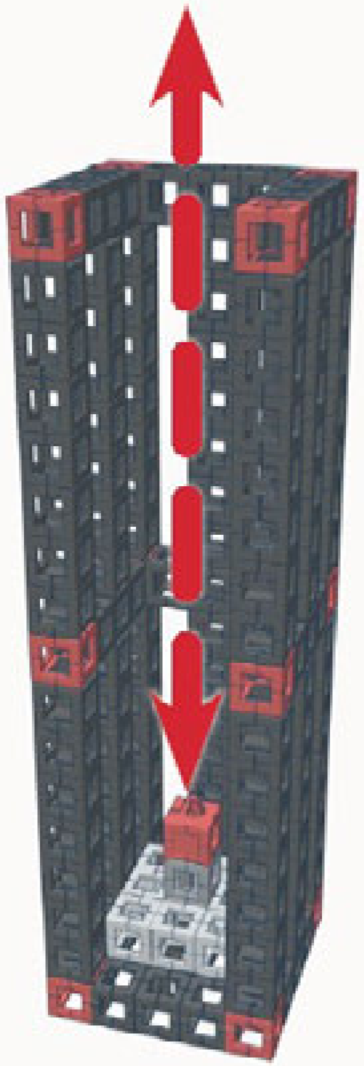


Specifications

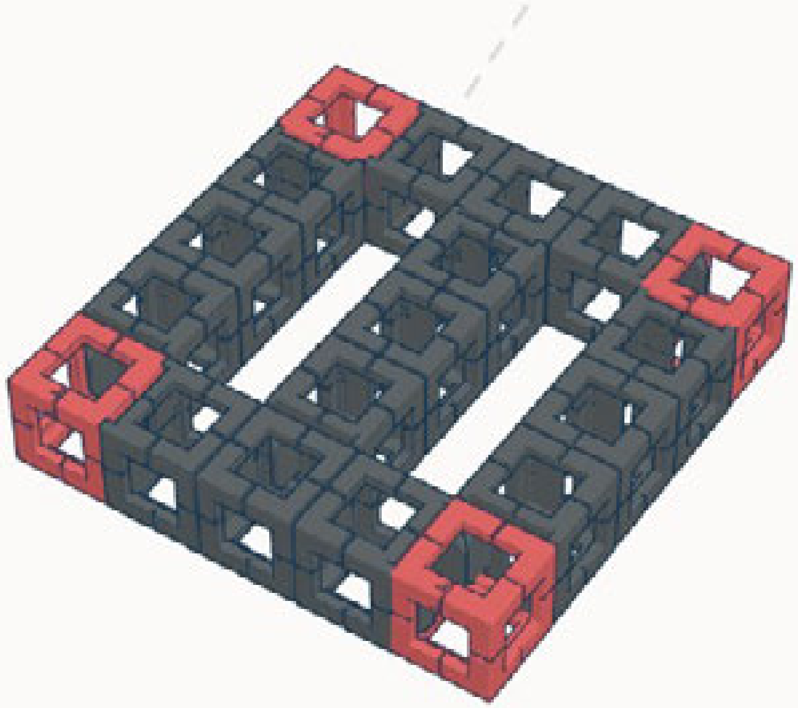
- Students will work in teams to complete this challenge
- Teams must work through each step of the design & engineering process to design, prototype, and refine a custom inclined plane.
- With each building component costing $2, the wheel & axle system must cost less than $140.



Water Well



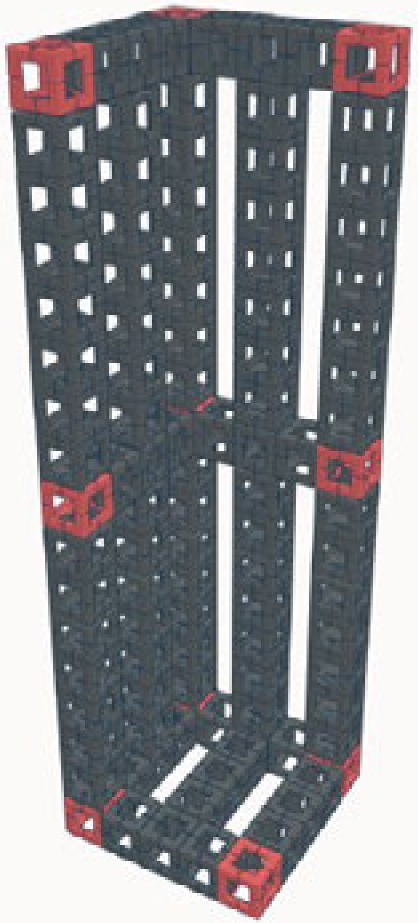
1



4x
Block

5x
Half Beam

2

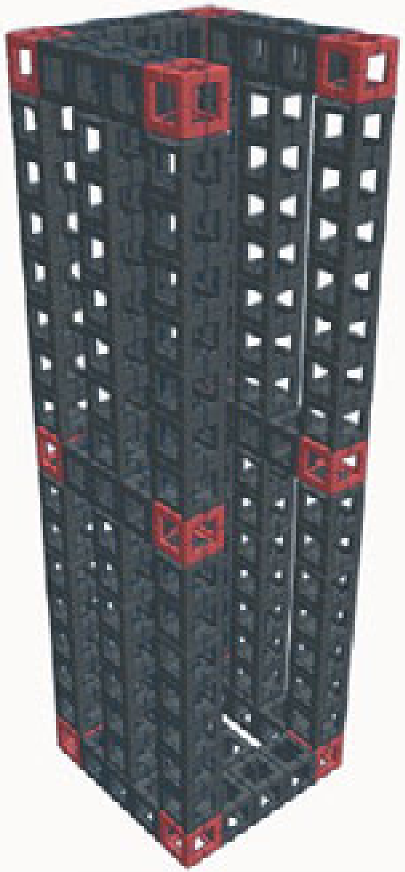


10x
Beam

4x
Half Beam

6x
Block

3

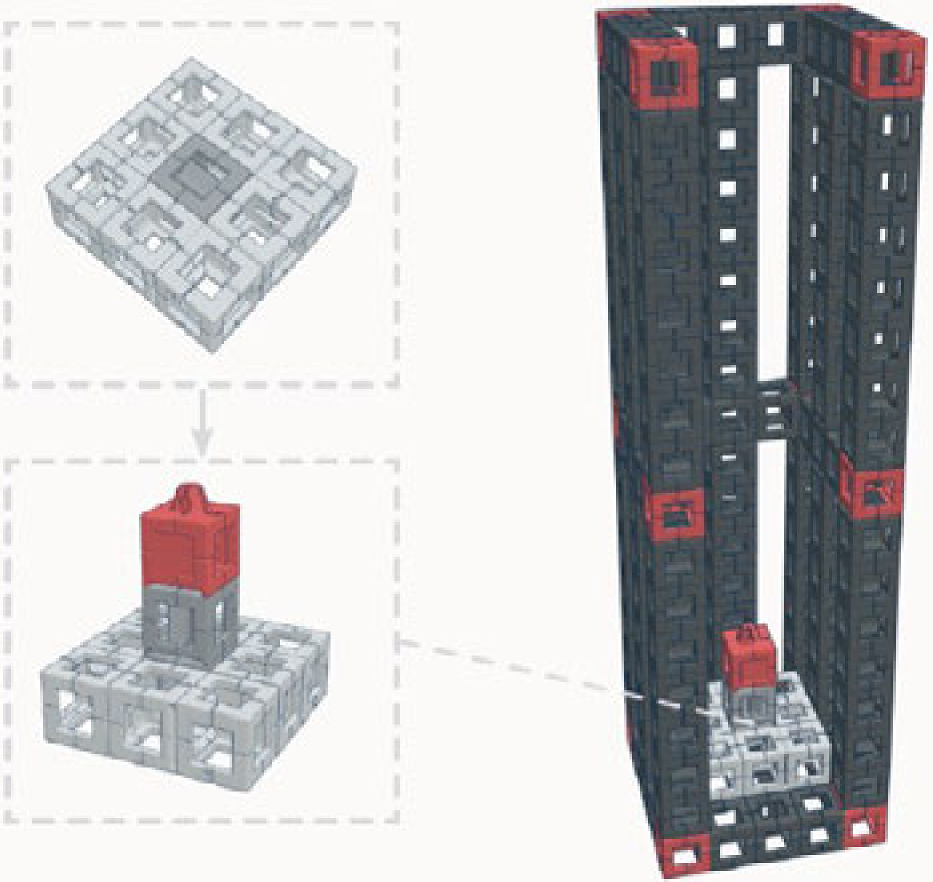


4x
Beam

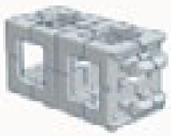
2x
Half Beam

2x
Block

4

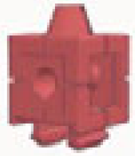


4x
Riser



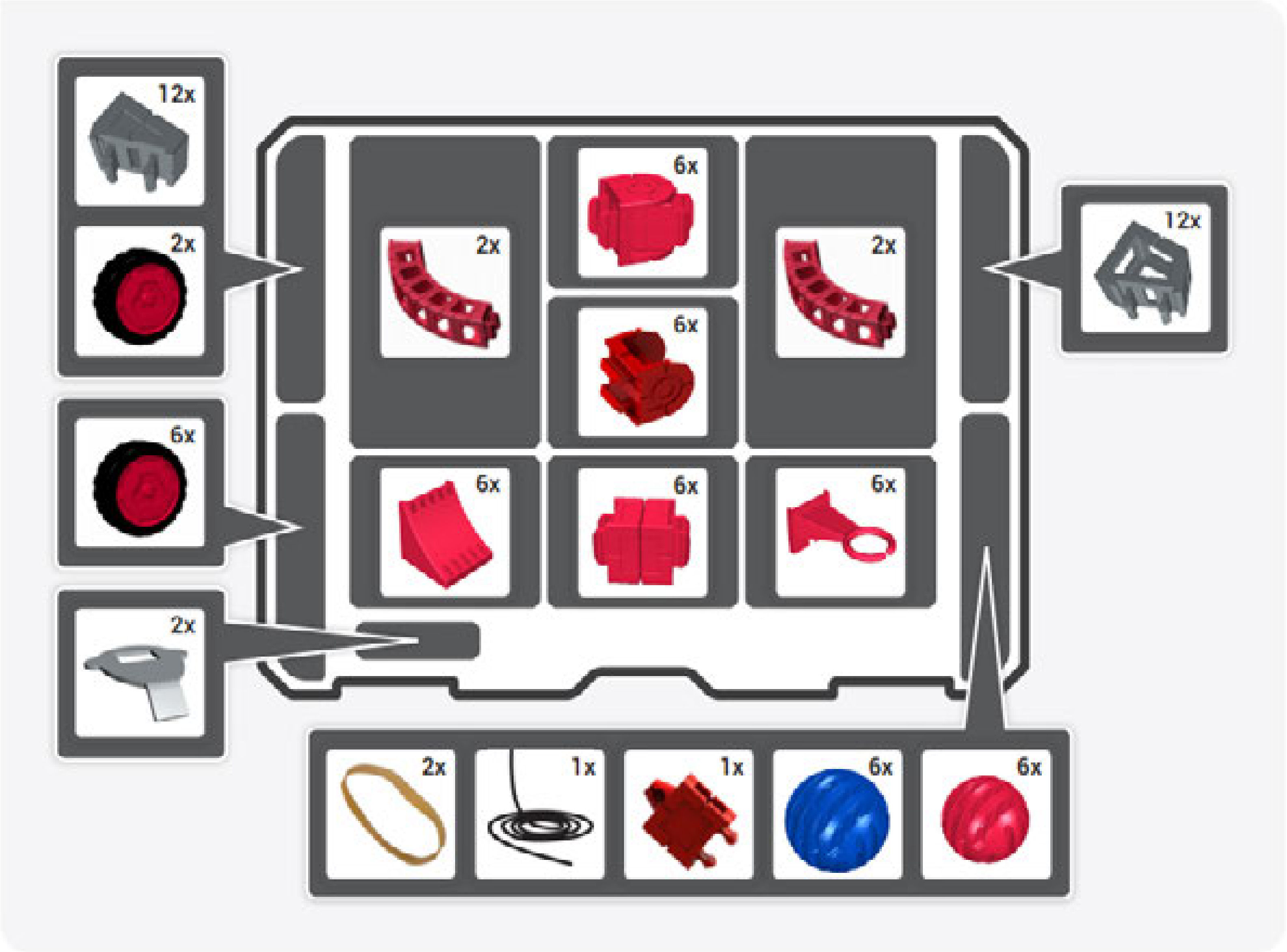
2x
Single Snap Block

1x
String Block



Clean Up

BOTTOM OF MODULE



REMOVABLE
BINS