EXPERIMENT MANUAL

CATAPULTS & CROSSBOWS

THAMES & KOSMOS

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››› SAFETY INFORMATION

››› **Warning!** Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long cords may become wrapped around the neck.

››› **Warning!** Do not aim at eyes or face.

Do not aim the projectiles (crossbow bolts and foam balls) toward other people or animals. Make sure people and animals are well out of the potential path of the projectiles.

Do not use any objects as projectiles other than the crossbow bolts and foam balls included with this kit. The barrel of the crossbow has a specially designed cross-sectional shape that allows only the crossbow bolts included with this kit to be inserted and fired.

››› Keep the packaging and instructions as they contain important information.

››› Store the experiment material and assembled models out of the reach of small children.

››› IMPORTANT INFORMATION

Dear Parents,

Physics is an exciting and varied science that is not hard to understand, especially when you use fun models to demonstrate physics principles in action. It can be a lot of fun to figure out the astonishing physical phenomena that we encounter every day and to put this understanding to use.

This experiment kit and the working models you can build with it introduce your child to physics concepts including energy, motion, and forces. With its wealth of simple examples, your child will gain basic insights into the world of physical units and laws — which will help him or her to understand and engage more deeply in the lessons taught in school.

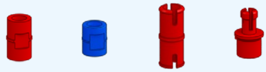
The individual experimental models are assembled step by step using an adjustable building system. It will require a little practice and patience at first. And your child will be particularly happy to have your help with the models that he or she finds more difficult.

Some of the experiments will require common items from your household, including a dish, tape, measuring stick, coins, tissue, paper clips, and a stopwatch. Help your child select these items.

We wish you and your child lots of fun experimenting, discovering, and learning!

TIPS

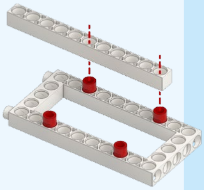
ANCHOR PINS AND CONNECTORS



Take a careful look at the different assembly components. Red anchor pins, blue anchor pins, joint pins, and shaft plugs all look pretty similar at first glance. When you assemble the models, it's important to use the right ones. The blue anchor pins are shorter than the red ones.

CONNECTING FRAMES AND RODS

Use the anchor pins to connect frames and rods.

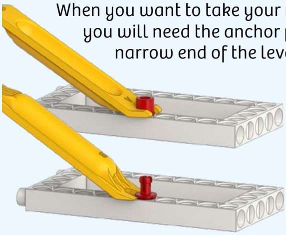


AXLES

The building system contains axles (also called shafts) of various lengths. When assembling the model, always be sure that you're using the right one.

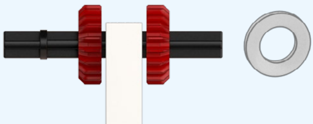
ANCHOR PIN LEVER

When you want to take your model apart again, you will need the anchor pin lever. Use the narrow end of the lever to remove the red anchor pins. You can use the wide end to pry out shaft plugs.



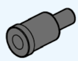
PULLEYS AND GEARS

If pulleys or gears are mounted too tightly against other components, they can be hard to turn. If you leave a gap of about 1 mm between the gear or pulley and an adjacent component, it will turn easily. In some of the models, a washer is used to ensure this kind of spacing. (There are no gears included in this kit.)



SHAFT PINS

When disassembling models, you can use the shaft pin as a tool to push the 30-mm tube out of a hole.

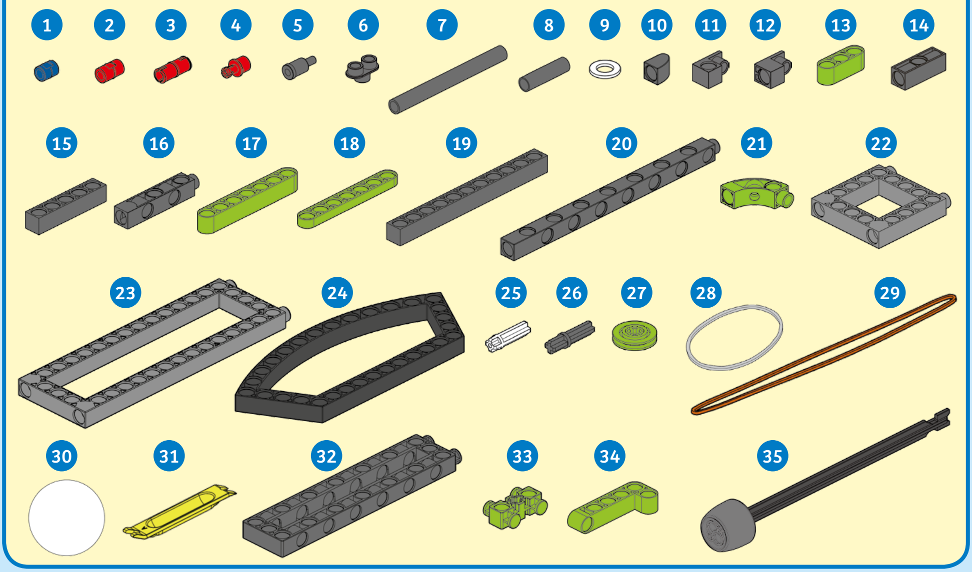


››› KIT CONTENTS

GOOD TO KNOW! If you are missing any parts, please contact Thames & Kosmos customer service.

US: techsupport@thamesandkosmos.com
UK: techsupport@thamesandkosmos.co.uk

What's inside your experiment kit:



Checklist: Find – Inspect – Check off

✔	No.	Description	Qty.	Item No.
○	1	Short anchor pin, blue	6	7344-W10-C2B
○	2	Anchor pin, red	15	7061-W10-C1R
○	3	Joint pin	4	1156-W10-A1R
○	4	Shaft plug	4	7026-W10-H1R
○	5	Shaft pin	1	7026-W10-J3D
○	6	Two-to-one converter	4	7061-W10-G1D
○	7	Tube, 80 mm	1	7337-W16-A1D
○	8	Tube, 30 mm	5	7400-W10-G1D
○	9	Washer	6	R12#3620
○	10	Nose piece	1	7402-W10-C2D
○	11	90-degree converter - X	2	7061-W10-J1D
○	12	90-degree converter - Y	2	7061-W10-J2D
○	13	3-hole wide rounded rod	2	7404-W10-C1G2
○	14	3-hole cross rod	4	7026-W10-X1D
○	15	5-hole rod	4	7413-W10-K2D
○	16	5-hole dual rod C	2	7026-W10-S3D
○	17	7-hole wide rounded rod	2	7404-W10-C2G2
○	18	7-hole flat rounded rod	2	7404-W10-C3G2

✔	No.	Description	Qty.	Item No.
○	19	11-hole rod	1	7413-W10-P1D
○	20	15-hole dual rod	1	7413-W10-H1D
○	21	Curved rod	12	7061-W10-V1G3
○	22	Square frame	2	7026-W10-T2S2
○	23	Large frame	1	7413-W10-J1S1
○	24	Curved frame	2	7392-W10-I1D
○	25	Motor axle	1	7026-W10-L1W
○	26	Axle, 30-mm	2	7413-W10-N1D
○	27	Small pulley	4	7344-W10-N3G
○	28	Rubber band, small	1	R10-02
○	29	Rubber band, large	3	R10-28
○	30	Large foam ball	3	K30#7366-2
○	31	Anchor pin lever	1	7061-W10-B1Y
○	32	13x3 Frame	2	7406-W10-A1D
○	33	3-hole bolt rod	2	7406-W10-B1G
○	34	5-hole L rod	2	7406-W10-B2G
○	35	Crossbow bolt	3	7406-W85-A-US

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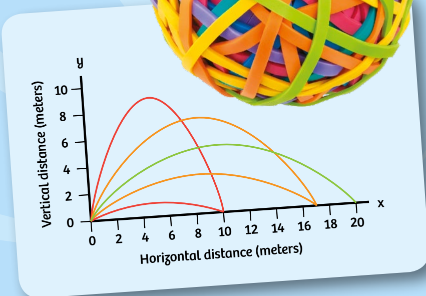
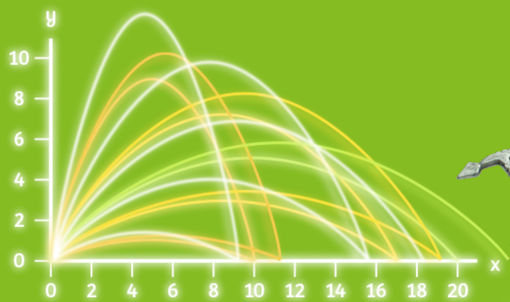


Physics with Crossbows and Catapults



PREPARATION

Setting up a target

YOU WILL NEED

› *metal pie pan or other durable dish*
› *tape*
› *measuring stick or tape measure*

Low accuracy and low precision

Low accuracy and high precision

HERE'S HOW

1. Place a metal pie pan upside down on the floor. This is your bull's eye target.
2. Place a piece of tape 10 to 15 feet away from the pie pan. This is where you will stand when testing out your catapults and crossbows.

WHAT'S HAPPENING?

When you do the experiments with your crossbow, you should think about the accuracy and precision of where your bolts and projectiles land. **Accuracy** is how close your results (or shots) are to your target value — in this case, the center of the target. **Precision** is how often you are able to get the same value, or have your projectile land in the same place. Look at the pictures to the right to see how accuracy and precision are related. Accuracy and precision are both critical concepts in the scientific world.

As you perform the experiments for each model, think about how the changes affect your precision and accuracy. Keep a record of your results for the different experiments.

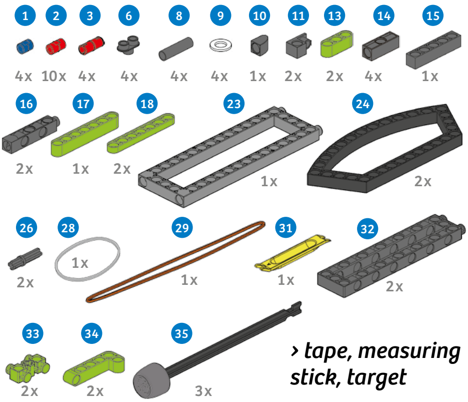
High accuracy and low precision

High accuracy and high precision

EXPERIMENT 1

Classic crossbow

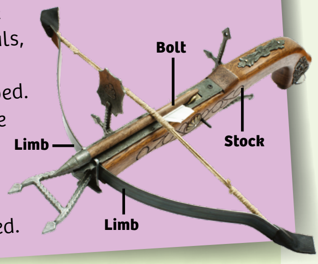
YOU WILL NEED



› *tape, measuring stick, target*

Background

The crossbow is a bow that has been turned on its side and mounted to a piece of wood called a stock. Instead of arrows, a crossbow shoots projectiles called bolts. The crossbow was very popular throughout ancient Europe and Asia because it was faster to learn how to shoot accurately with a crossbow than it was with a regular bow. The crossbow has undergone many modifications throughout its long history. These modifications came as different materials, knowledge, and techniques developed. You will build some of these different modifications and see how crossbows changed.



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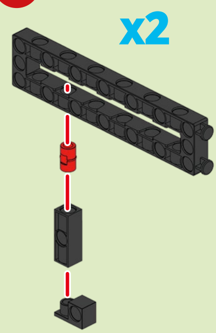

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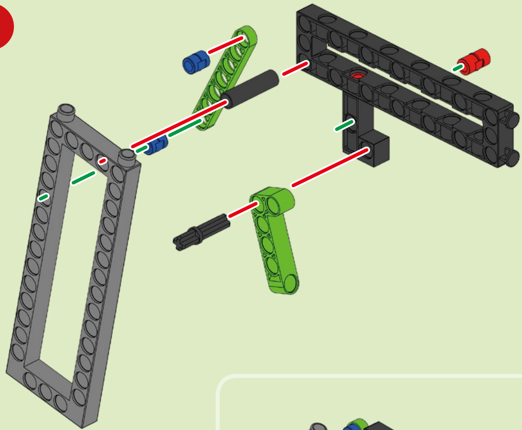

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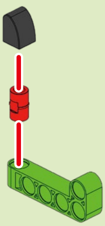

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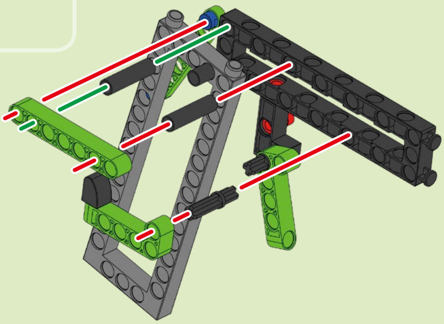

EXPERIMENT 1

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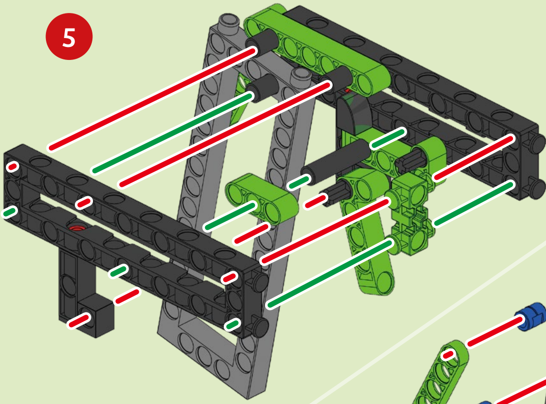

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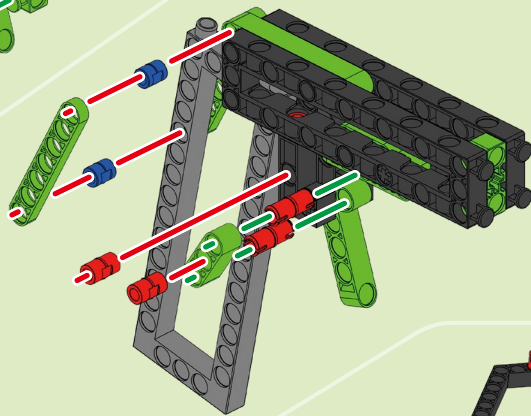

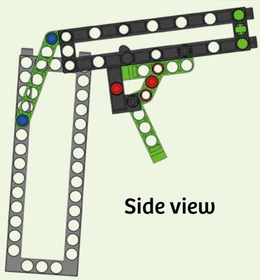

Side view

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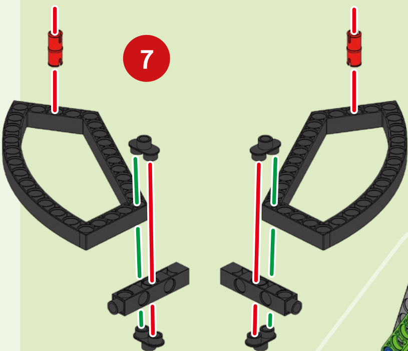

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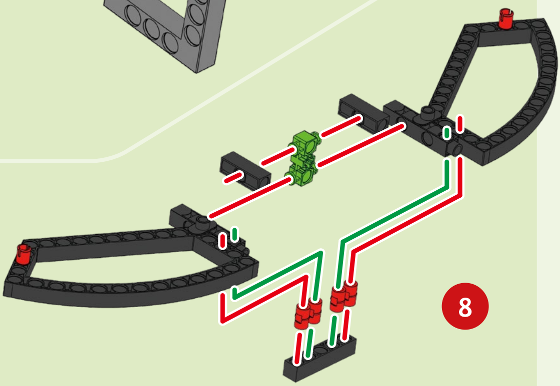

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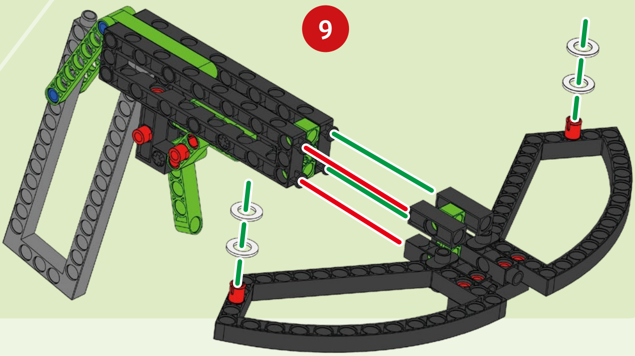

EXPERIMENT 1

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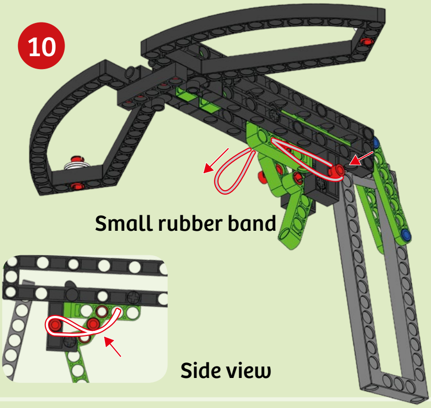
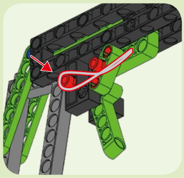


Small rubber band

Side view



Other side

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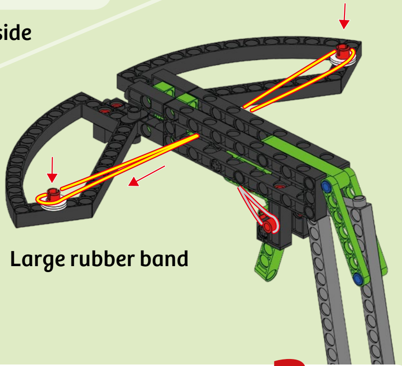


Large rubber band

12 Take one side of the rubber band and loop it once around the red pin a second time. What happens to the rubber band when you do this?

13 Stand at the mark you set up in the preparation steps.

14 Load a bolt into the crossbow by lining up the bolt with the plus-sign-shaped hole. Make sure the large rubber band is pushed inward by the bolt. Push the bolt inward until it locks into place.

15 Hold the crossbow horizontally. Shoot the bolt towards the target. Mark where the bolt lands using a piece of tape

16 Repeat the steps three times, each time looping the rubber band an additional time. Hold the crossbow at the same height and distance from the target when shooting the bolt. Measure and compare the distances the bolts traveled.

Why does the bolt get shot out of the crossbow when you pull the trigger? Why does the bolt fly farther when you stretch the rubber band more?

WHAT'S HAPPENING?

When the rubber band is stretched it wants to return to its original shape. This property is called **elasticity.** To stretch the rubber band requires **energy**.

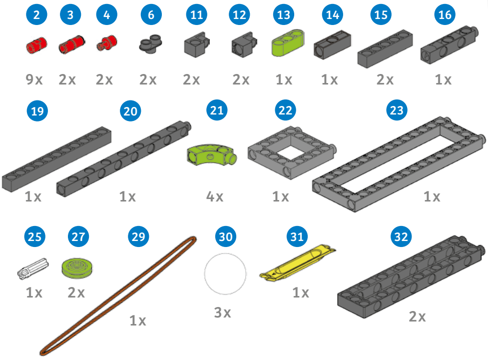
When the rubber band is stretched, like before shooting the bolt, all the energy is stored energy, or **potential energy**. When you pull the trigger releasing the rubber band, the potential energy is converted into **kinetic energy,** or the energy of motion. This is why when you stretch the rubber band more, the bolt flies farther — because you are adding more energy to the rubber band. In a real crossbow, the energy is stored in the limbs.

The string is a very important part of a crossbow, and in early crossbows it wore down after use. It could even be damaged by the rain. Ancient crossbows used various materials such as linen or sinew formed into a braided cord to form the string.

EXPERIMENT 2

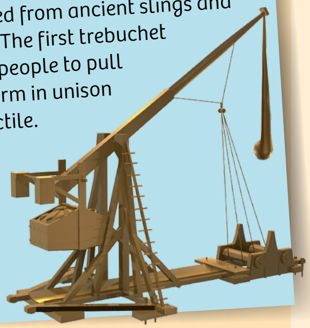
Trebuchet one

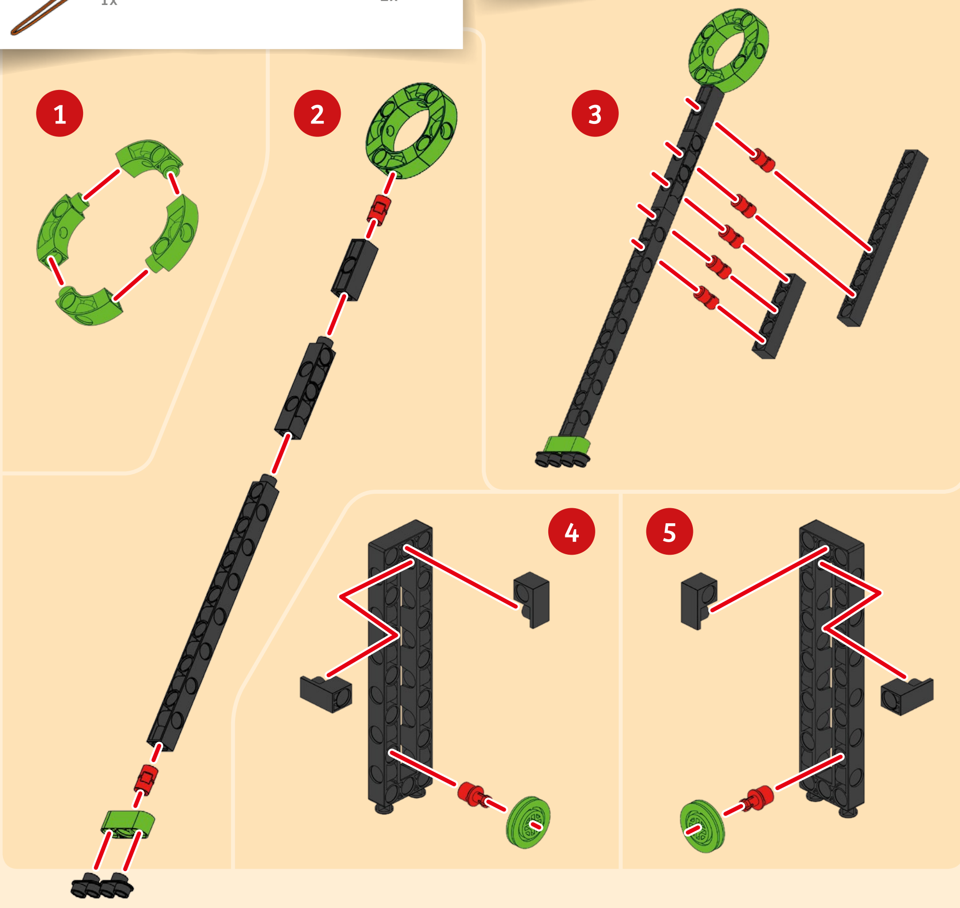
YOU WILL NEED



Background

The trebuchet can be thought of as a giant seesaw where one side is pulled down causing the other side to go up and release a mass. Trebuchets developed from ancient slings and originated in China. The first trebuchet required a group of people to pull down on the lever arm in unison to launch the projectile. However, it was found to be more efficient to use a large mass that was lifted up and then dropped.





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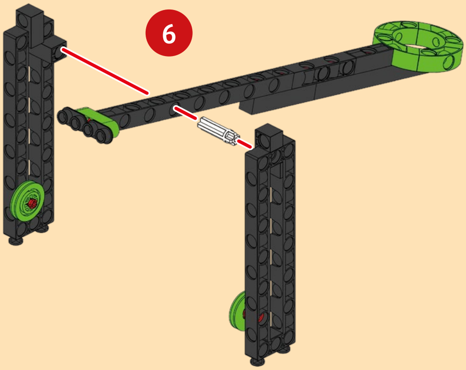

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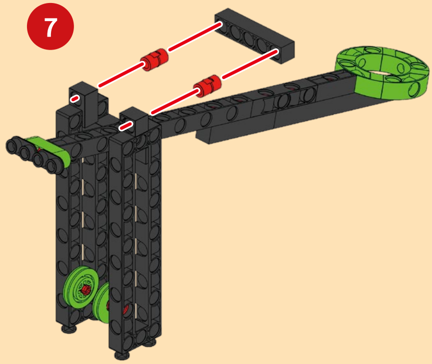

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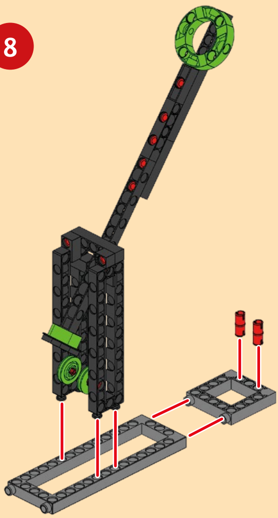

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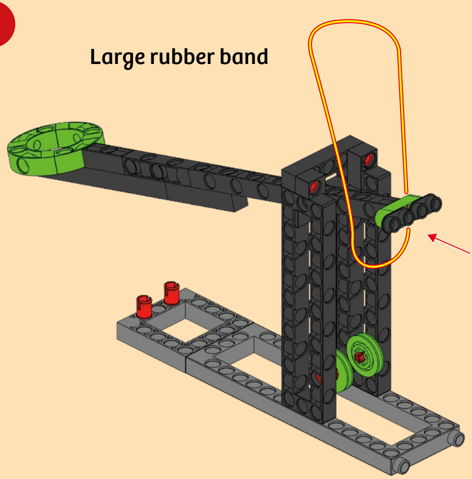

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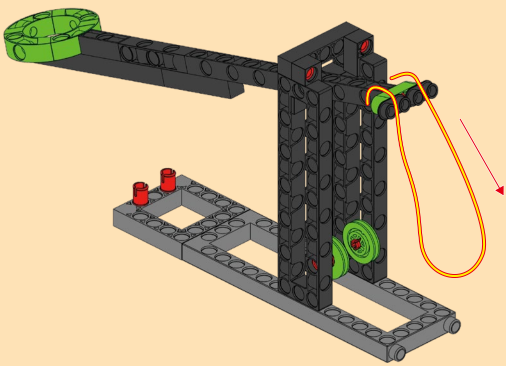
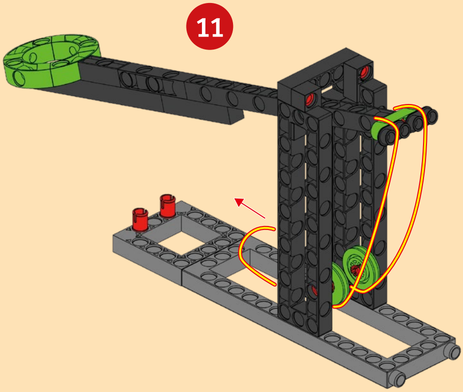
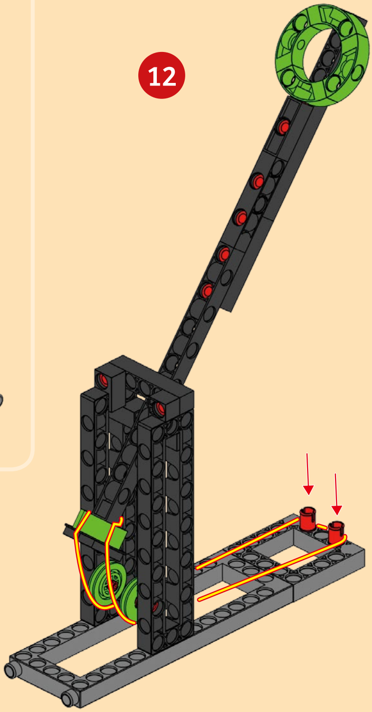


EXPERIMENT 2





13 Load a foam ball into the circular green holder.

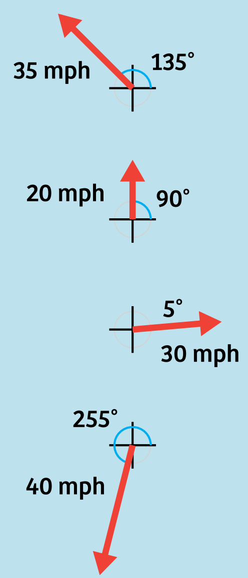
14 Pull the arm back.

15 Let it go. Watch how fast the ball flies through the air.

WHAT'S HAPPENING?

In physics, a very important concept is the **vector.** Normally quantities only have one part or component, such as 5 pounds or 30 minutes, which indicates the size or magnitude of something such as weight or time. These numbers are called **scalars.** A vector quantity however has two parts: a **magnitude** and a **direction.** The magnitude tells how large the vector is, and the direction shows which way the vector points.

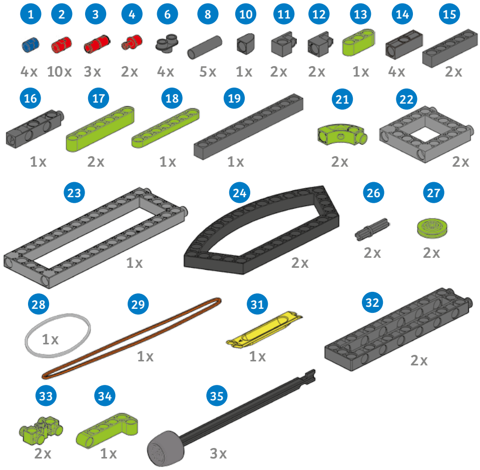
An example of a scalar quantity in physics is the **speed** of an object, while a vector would be the **velocity** of an object. When you are in a car the speed is how fast the car is going, such as 30 miles per hour, which is given by the speedometer. While the velocity of the car is both the speed and the direction of the car, e.g. 60 miles per hour north.



EXPERIMENT 3

Scorpion

YOU WILL NEED



Background

The scorpion was a Roman artillery piece. It was used as a sniper weapon rather than a siege weapon. It was able to accurately hit a target within a distance of 100 meters when the projectile was shot horizontally.

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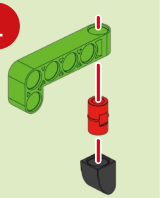

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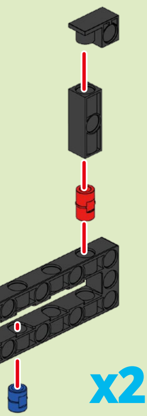

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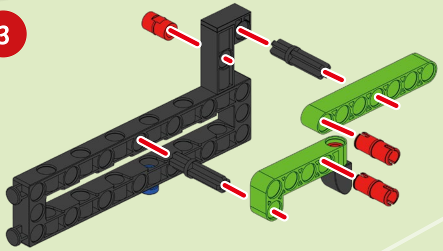

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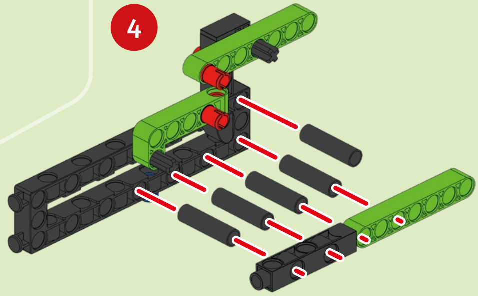

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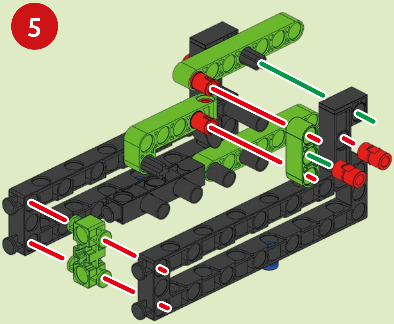
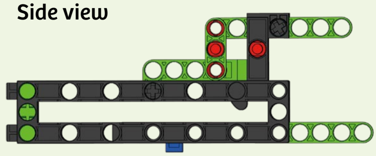


Side view



EXPERIMENT 3

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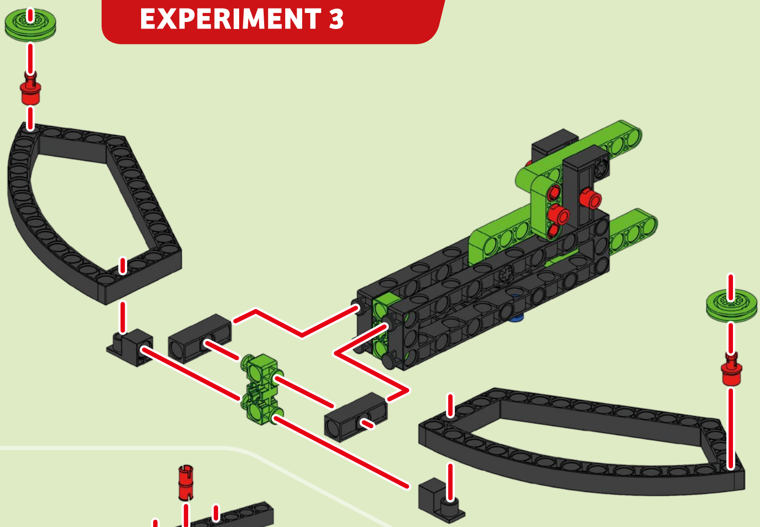

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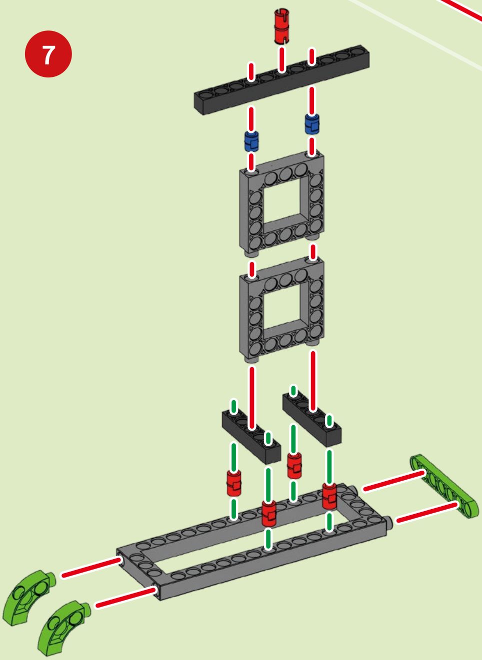

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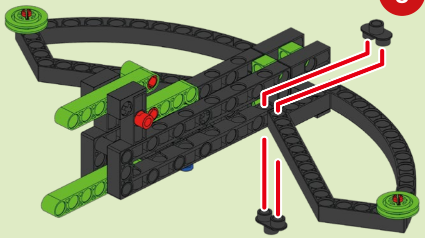

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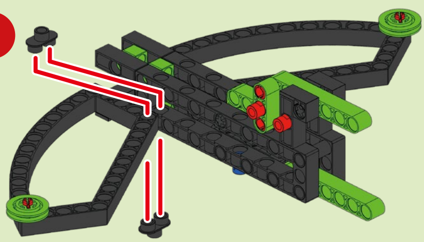

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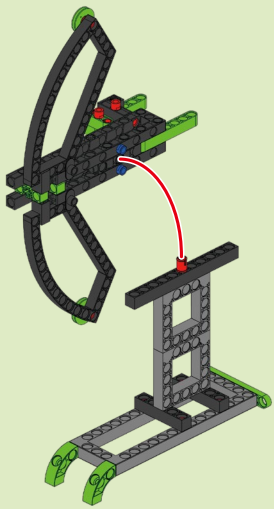
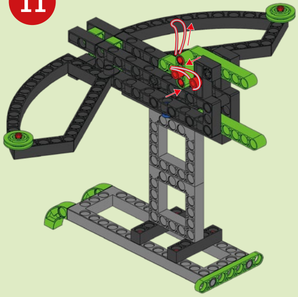
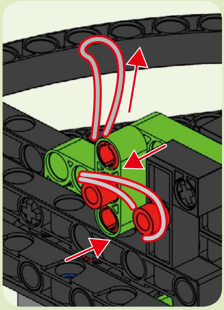
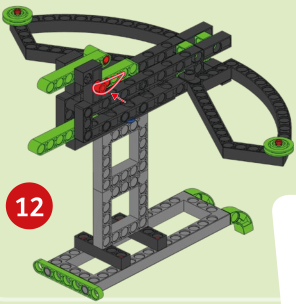


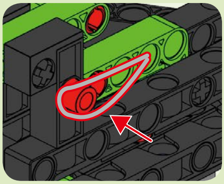
EXPERIMENT 3

11 Small rubber band









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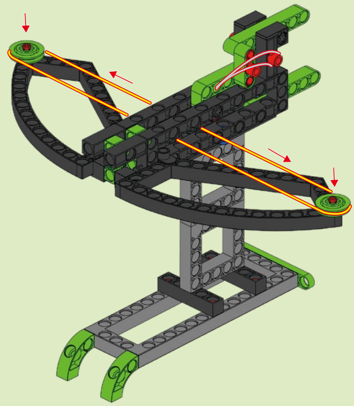
13 Large rubber band



14 If you were to drop the bolt and the foam ball from the same height and at the same time which one do you think would hit the ground first? Why? Now try it!

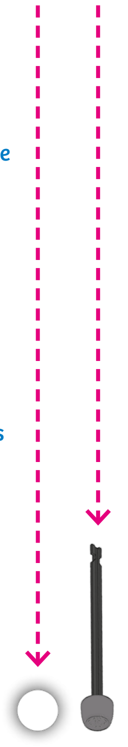
15 Place the scorpion on a flat surface such as the end of a table. Hold one of the foam balls at the same height as the end of the bolt. At the same time, shoot the bolt and release the foam ball. Listen for when the projectiles hit the floor. Repeat this experiment several times. What do you notice?

WHAT'S HAPPENING?

Maybe you thought that the heavier crossbow bolt would hit the floor long before the lighter foam ball. Or maybe you thought that because the crossbow bolt would travel a longer distance it would take longer to hit the ground. In the experiment you found that the foam ball and bolt hit the ground at about the same time!

The reason that the foam ball and the bolt hit the ground at the same time is that all small objects fall with the same acceleration. **Acceleration** is the change in velocity of an object. So acceleration is also a vector quantity like velocity. Because acceleration is a vector quantity, an object can accelerate if its velocity is increasing, decreasing, or changing direction. For example, a car is accelerating when it is speeding up, slowing down, or going around a corner.

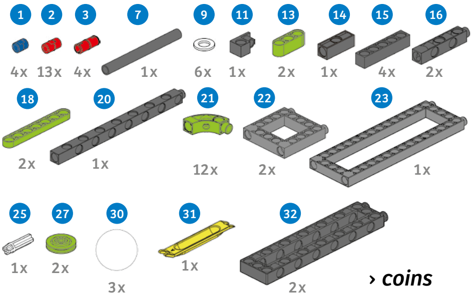
The reason that the objects fall at slightly different rates is due to the influence of **air resistance**. If the foam ball and bolt were dropped in a **vacuum**, they would hit the ground at exactly the same time!

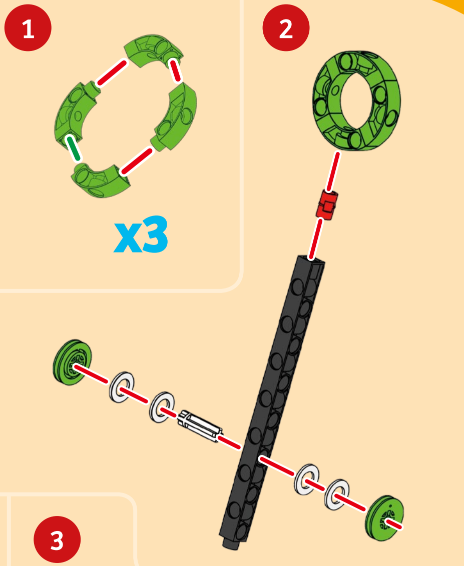


EXPERIMENT 4

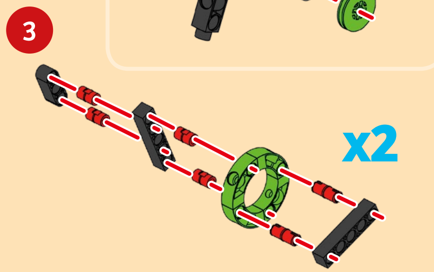
Weighted catapult

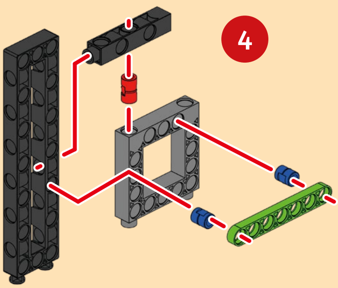
YOU WILL NEED

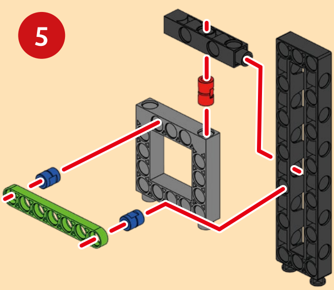


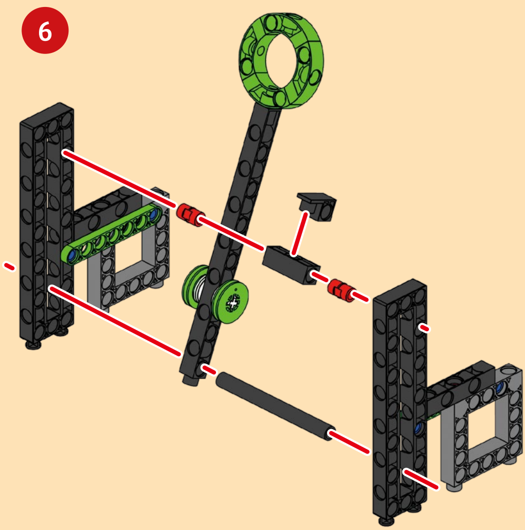


Note! This model has two compartments on the sides that hold coins. The coins act as counterweights. The compartments are on vertical tracks, so gravity pulls them straight down, launching the ball.









EXPERIMENT 4

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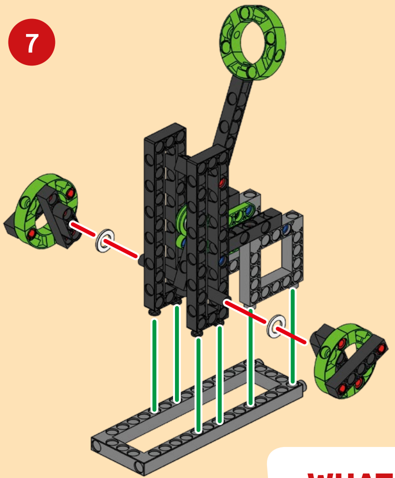

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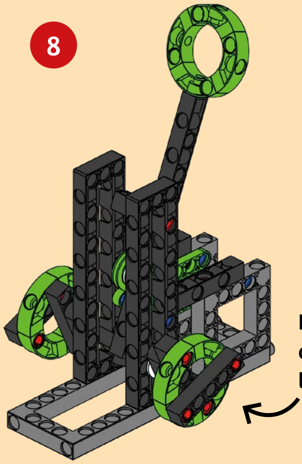


9. Place a foam ball into the ball holder, lift up the weights, and then quickly let them drop.

10. Experiment with different masses in the arms of the catapult. See how this affects the distance that the ball travels.

11. Try dropping the weight from different heights. How does this affect how far the ball travels?

Why do you think that when you place more coins in the side compartments of the catapult the foam ball travels farther? Why does the foam ball go farther when you drop the coins from a greater height?

WHAT'S HAPPENING?

When you place more coins into the side compartments of the catapult you are adding **mass** to the arms of the catapult. Mass is the amount of matter within an object. Mass is commonly used interchangeably with the term weight, but in physics mass and weight are two different concepts. **Weight** is the force on an object due to **gravity** and can be calculated using the equation:

$$W = m \times g$$

where g is the acceleration due to gravity, m is the mass, and W is the weight. Since weight is a force, it is a vector quantity, with a direction that points toward the ground. The value of g on Earth is 9.81 m/s^2 while on the Moon it is 1.63 m/s^2. So, the same object would weigh less on the Moon, but still contain the same mass!

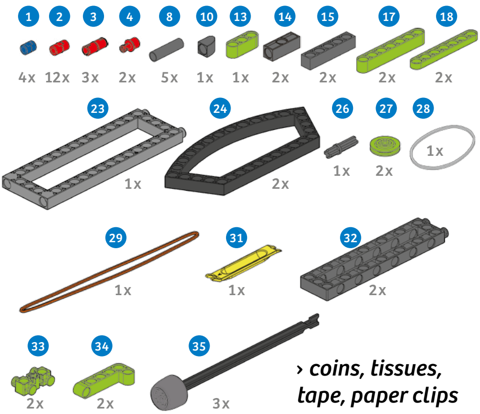
When you are dropping the weight from different heights, like when you stretch the rubber band, you are converting **potential energy** into **kinetic energy**. This is a different form of potential energy as it comes from the height of the coins, not the stretching of a rubber band. Thus it is given the name **gravitational potential energy**. The amount of gravitational potential energy can be calculated by multiplying the weight by the height above the ground:

$$PE_{gravitational} = W \times height$$

EXPERIMENT 5

Reverse-draw crossbow

YOU WILL NEED

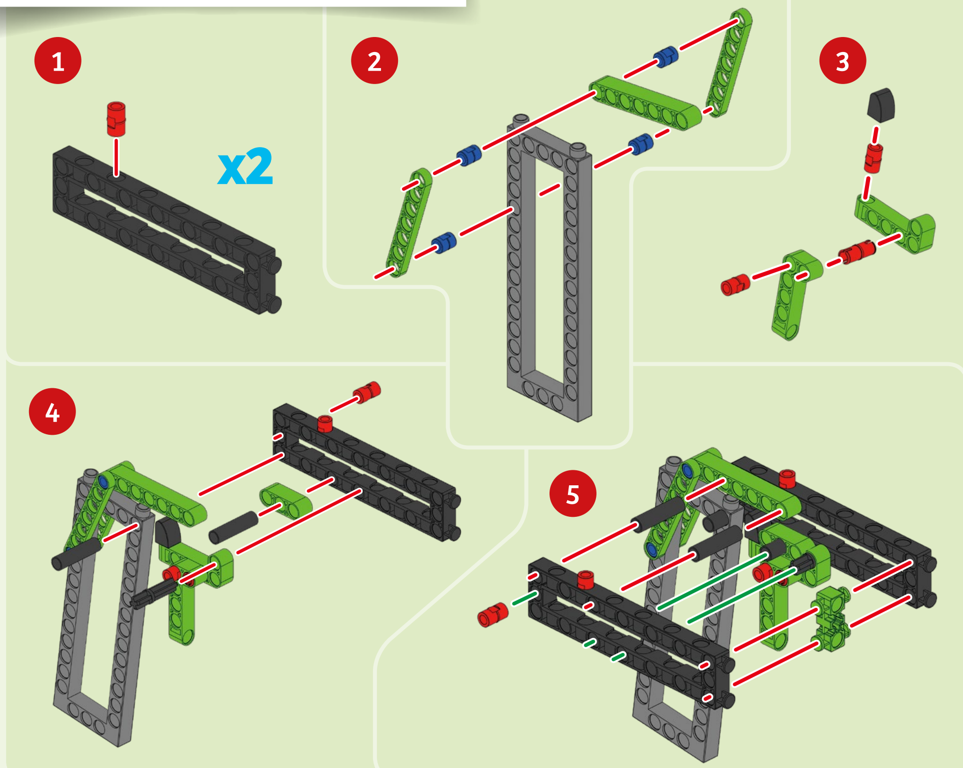


› *coins, tissues, tape, paper clips*

Background

A modern innovation in crossbow design is the placement of the limbs at the rear of the stock. This arrangement provides several advantages over the classic crossbow design. After building the model compare the two designs.

One advantage is that the modern crossbow allows the string to be in contact with the bolt for a longer amount of time. This means that more energy is transferred from the string to the bolt, giving it a greater velocity.



EXPERIMENT 5

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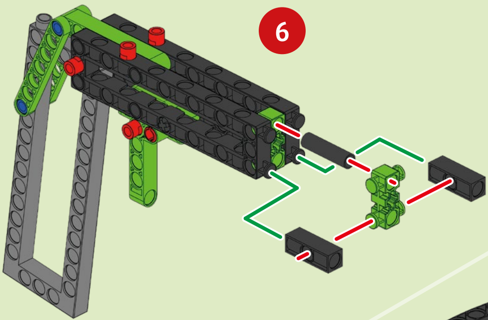

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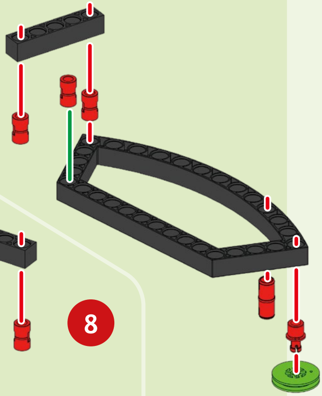

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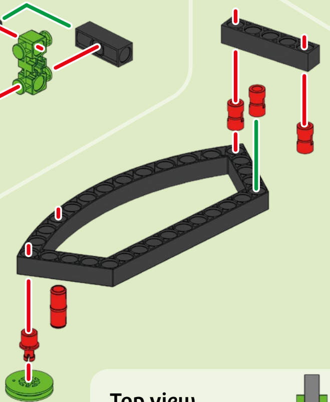

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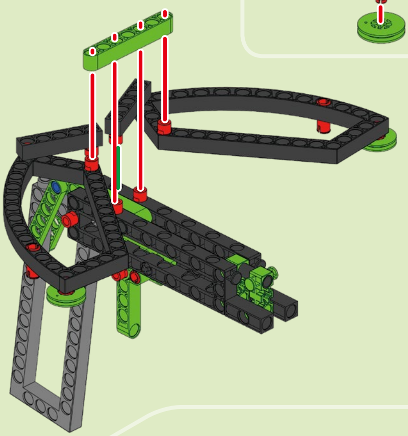

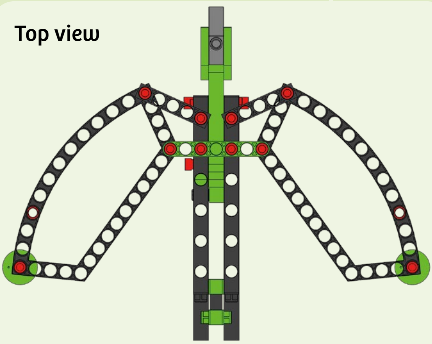

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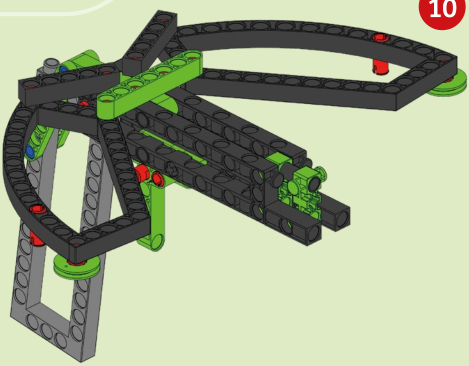

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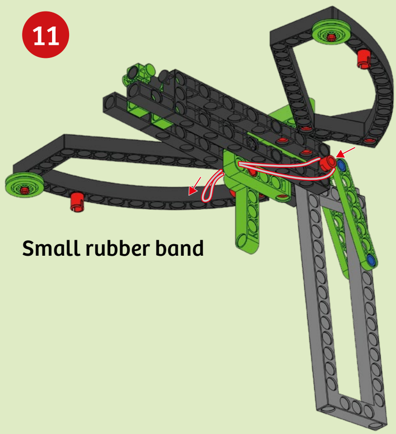

EXPERIMENT 5

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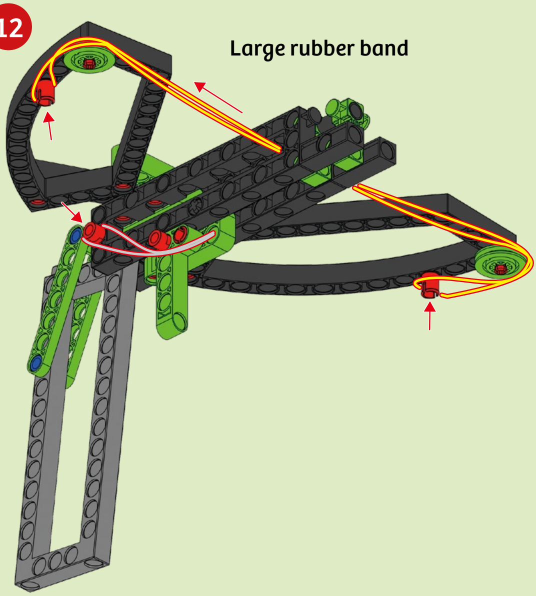
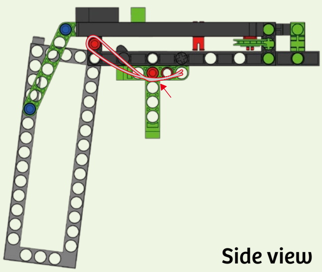




13 Test the elasticity of the rubber band. Make different bundles of pennies (one penny weighs 2.5 grams) and nickels (one nickel weighs 5 grams) using tissue paper and tape.

14 Tape a paper clip to the bundle so you can use it as a hook.

15 Hold the crossbow vertically and hang the weights from the large rubber band using the paper clip. Measure the distance that the rubber band is deformed by each weight, or the distance it stretches downward from its normal position when no weight is applied to it. Make a graph of the weight versus the distance the rubber band deforms. What does the graph look like?

WHAT'S HAPPENING?

A law of physics called **Hooke's law** states that the distance that something elastic, like a rubber band, is stretched or compressed is directly proportional to the amount of force produced. This means that if the rubber band is stretched twice as far (for example, 2 inches instead of 1 inch) then the force produced would double. Using math this is commonly written as:

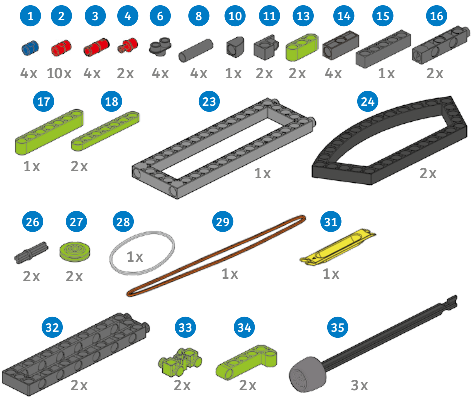
$$F = -kx$$

where F is the force, k is a constant specific to the rubber band used, and x is the distance. In this experiment you measured the force using the different weights.

EXPERIMENT 6

Compound crossbow

YOU WILL NEED



Background

With the development of modern materials and manufacturing process, one of the most common changes in modern crossbows is the use of pulley systems. These crossbows are known as compound crossbows. The pulley system allows for the use of stiffer limbs which transfer more energy into the bolt instead of the movement of the limbs.

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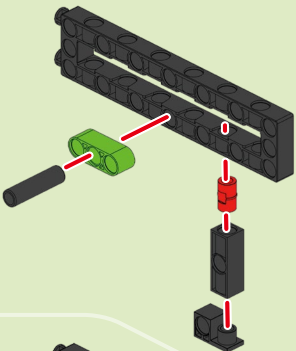

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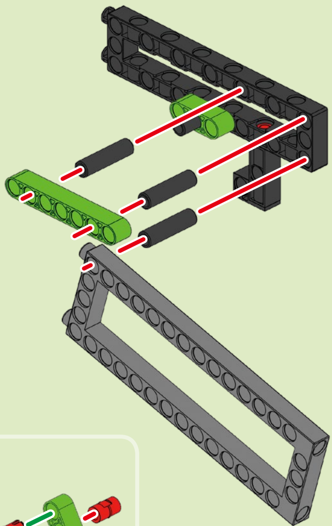

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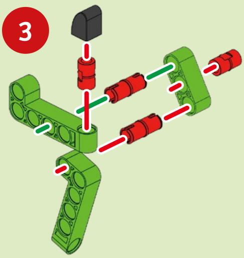

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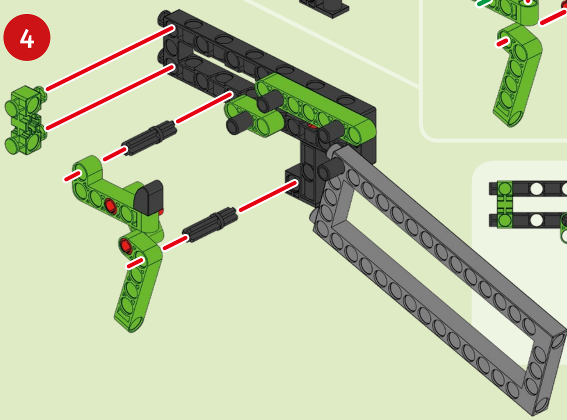
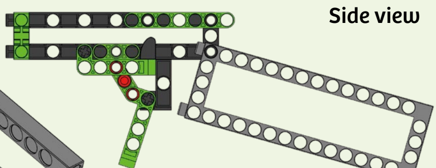


Side view



EXPERIMENT 6

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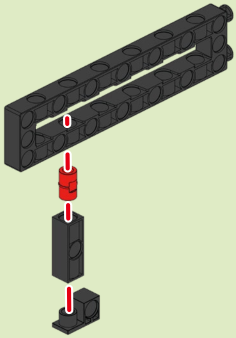

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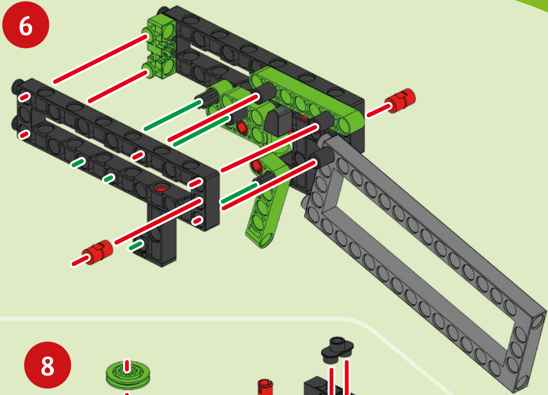

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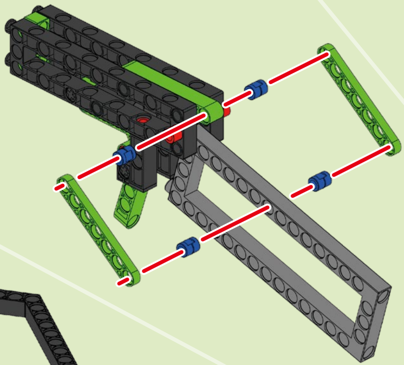

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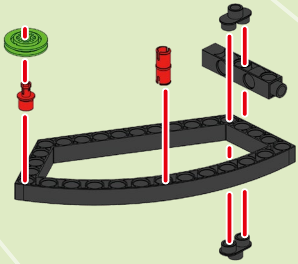

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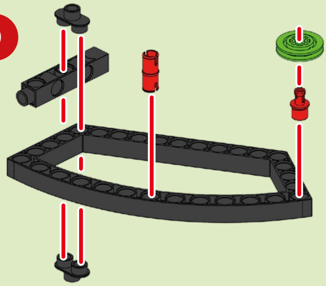

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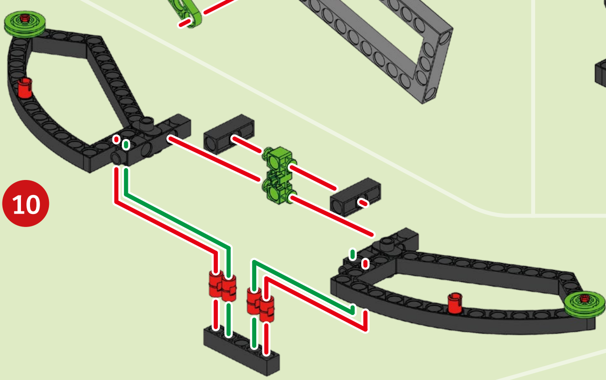

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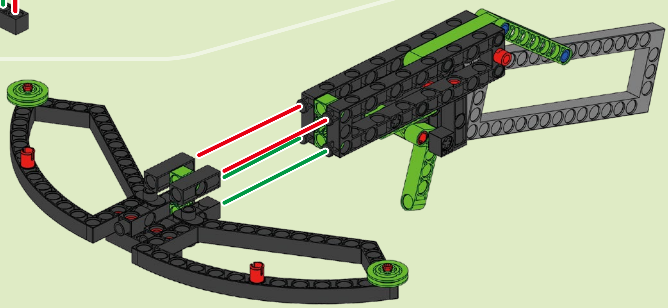

EXPERIMENT 6

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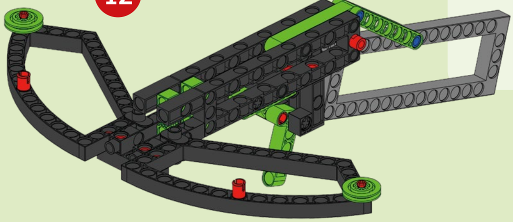

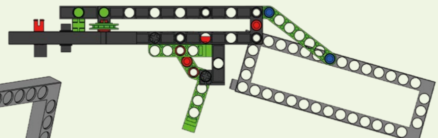

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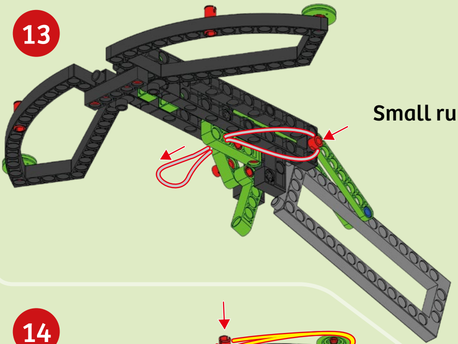
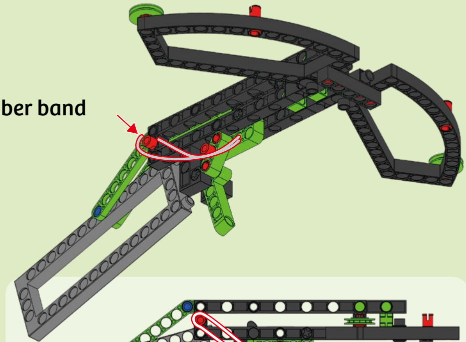
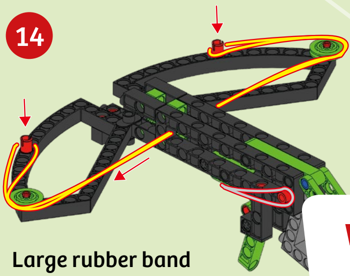
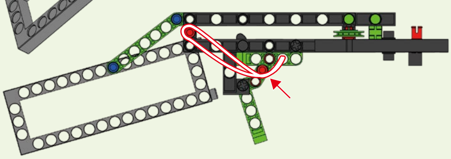




Small rubber band

14





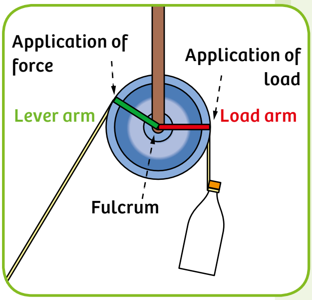
Large rubber band

15 Test out the crossbow by firing some bolts. Notice that when you load the bolt, the rubber band slides around the pulley.

16 Now try removing the pulleys and wrapping the rubber band around the peg. Do you notice any difference in behavior?

WHAT'S HAPPENING?

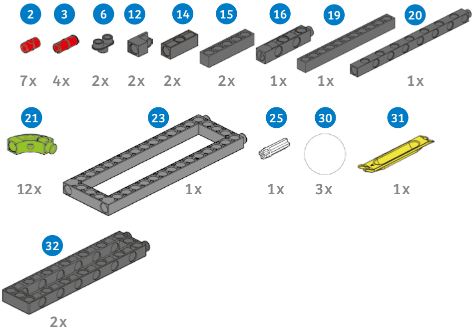
A **pulley** is a wheel on an axle which supports the movement of a cable or rope. The type of pulley used in this crossbow is called a fixed pulley. The fixed pulley is a two-armed lever that rotates around a fulcrum as it does work. Its load arm and lever arm are equally long in this case, so the user does not gain a mechanical advantage. However, this pulley is useful because it changes the direction that the force is applied. Looking at the rubber band you can see that the pulley allows the rubber band to be stretched farther, meaning that there is more energy in the rubber band.

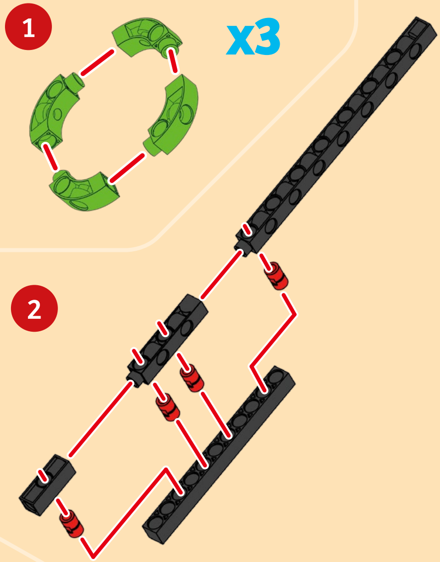


EXPERIMENT 7

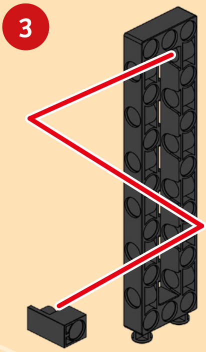
Trebuchet two

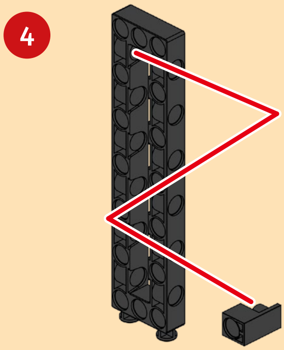
YOU WILL NEED

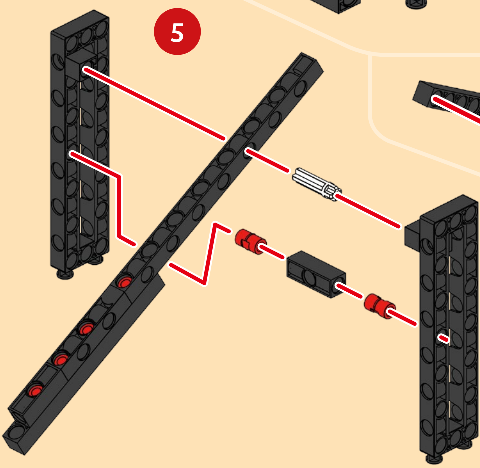


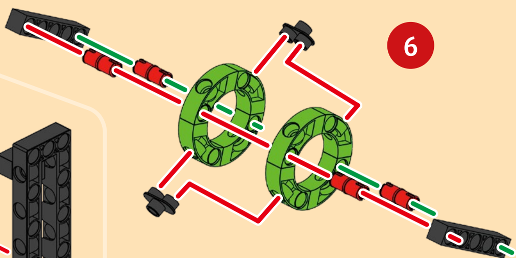


Note! This model has a compartment on one end that hold coins. The coins act as a counterweight. Gravity pulls the counterweight down, launching the ball.









EXPERIMENT 7

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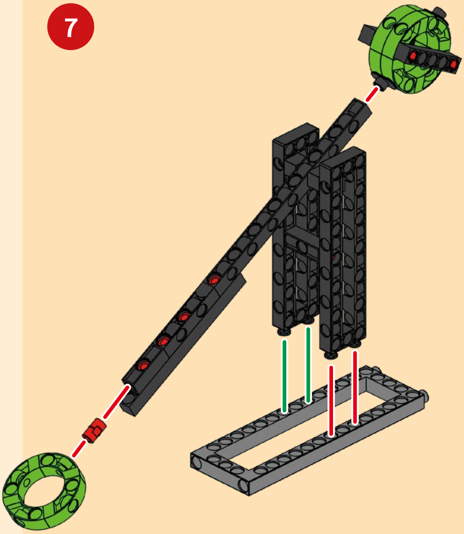

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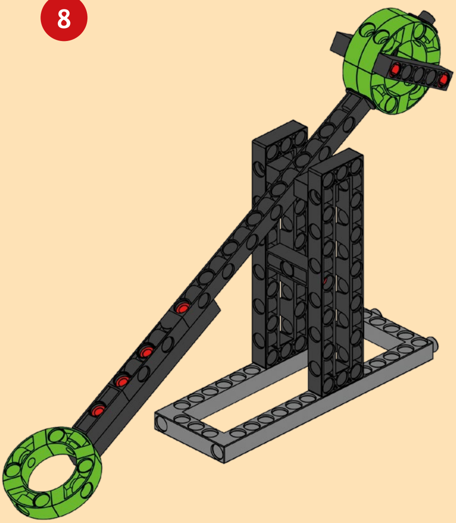
Load coins into the compartment here.



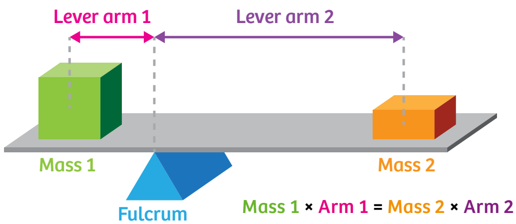
9 Try launching the foam ball a few times with the model set up as shown. Lift up the counterweight and then let it drop.

10 Now try varying the length of the lever arm by changing the hole where the pivot point, or fulcrum, is located. You can also try changing the length of the arm itself. Observe how far the projectile travels after each change.

How could you improve the trebuchet using what you have learned from the crossbow models?

WHAT'S HAPPENING?

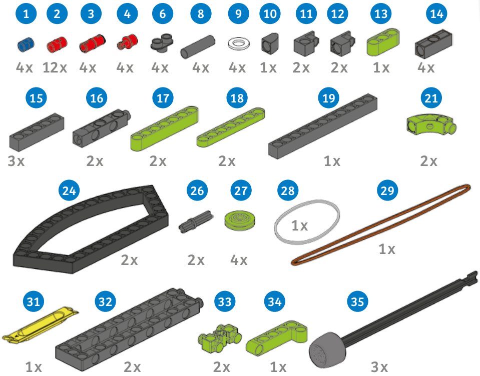
The trebuchet makes use of a simple machine called a **lever.** A lever is a beam that pivots at a fixed point called a **fulcrum.** A lever amplifies an input force to provide a greater output force. The ratio of the output to input force is given by the ratio of the distances from the fulcrum to the point of application of those forces. This ratio is known as the **mechanical advantage** of the lever. From your experiments you saw that the distance the ball travels increases as the main trebuchet arm gets shorter and the load arm gets longer, but then decreases again. This is a result of changing the lever arm and also the angle at which the projectile is fired.



EXPERIMENT 8

Ballista

YOU WILL NEED



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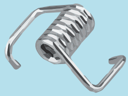
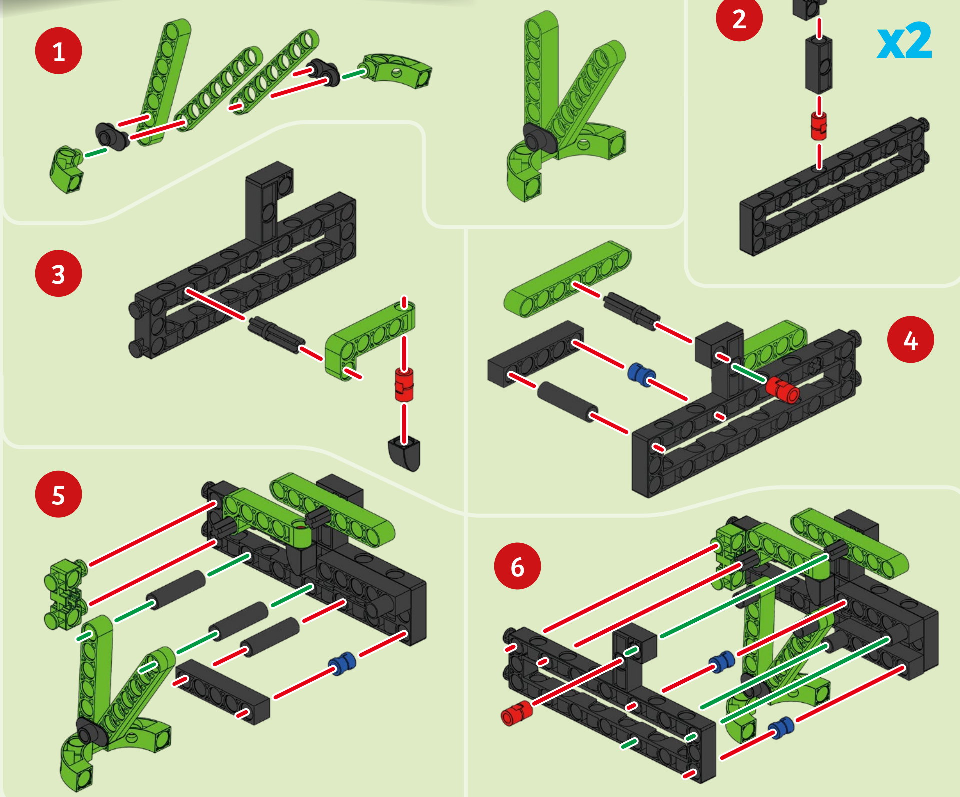


The ballista developed from earlier Ancient Greek handheld crossbows but used a torsion spring to fire instead of a string. Torsion springs apply a force when turned, instead of a normal spring that develops a force when the spring is compressed. An example of a torsion spring you might be familiar with is the spring in a mouse trap.

The torsion spring in a ballista was not a metal spring but a bundle of rope. The torsion spring allowed for the use of lighter projectiles which could reach higher velocities and go longer distances. The ballista was used as a siege weapon to destroy walls or other fortifications.



EXPERIMENT 8

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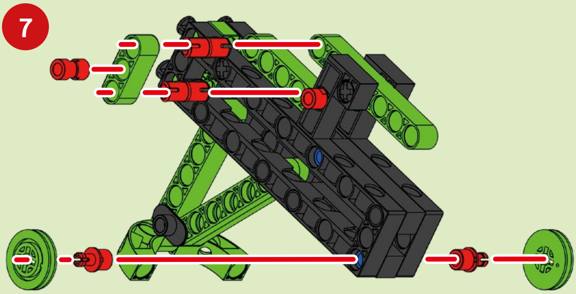

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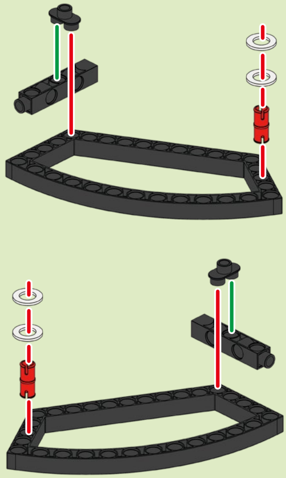

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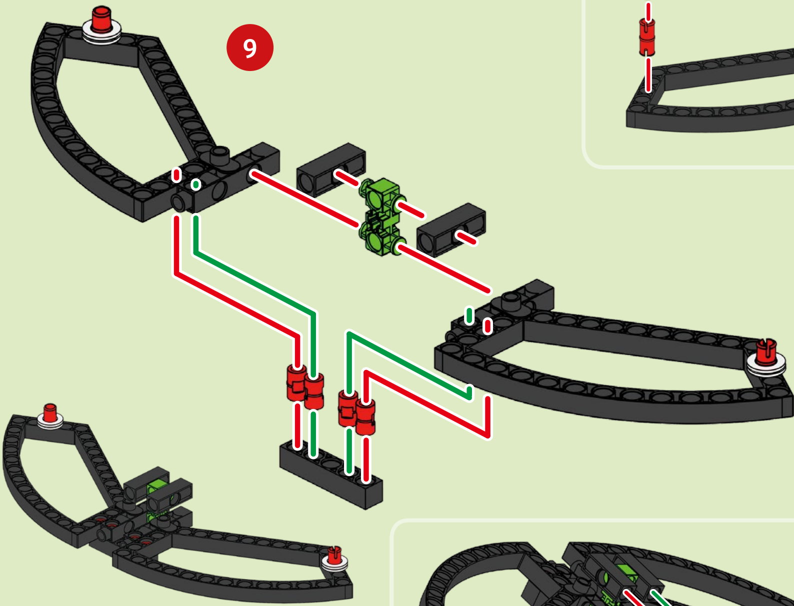

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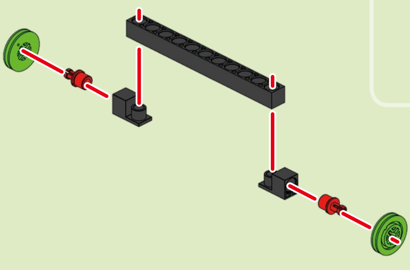

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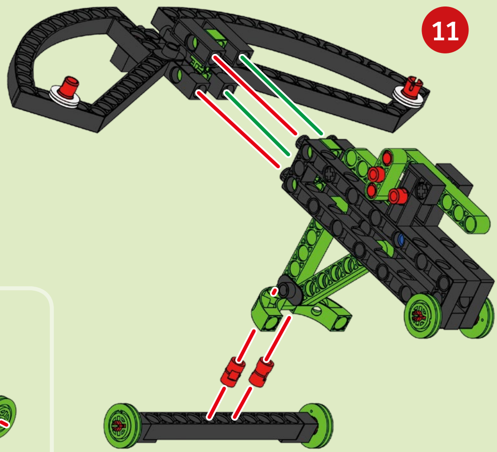
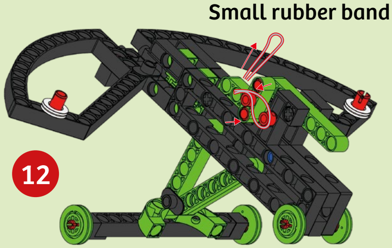
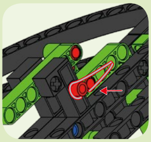
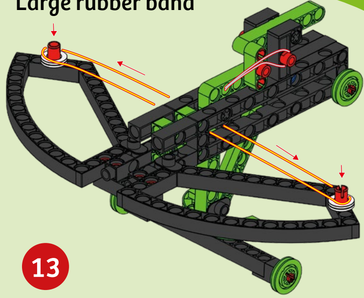


EXPERIMENT 8




Other side



14 Test fire some bolts. Observe the paths that the bolts follow when they are shot from the ballista. Draw a picture of the path that a bolt follows as it flies through the air. How would you describe it?

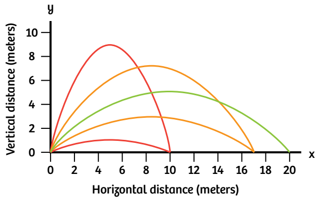
15 Shoot the ballista horizontally and mark the distance that the bolt travels with a piece of tape. Repeat this process holding the ballista at increasing angles (aiming it higher toward the ceiling) each time.

What do you notice about the distances that the bolts travel before they hit the ground when shot at the different angles? What about the heights that the bolts travel? At what angle does the bolt fly the farthest?

WHAT'S HAPPENING?

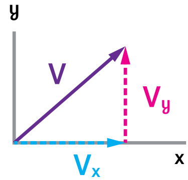
In physics, the motion of an object, called a **projectile,** that has been thrown through the air near Earth's surface is called **projectile motion.** In your experiments, you saw that the bolts followed an arc when they were shot out of the ballista. This arc also changed when the angle at which the bolt was shot changed.

You may have also found that the distance that the projectile traveled before hitting the ground increased as the angle increased, plateaued, and then decreased.



The figure above shows the distance that a projectile might travel if shot at the same velocity but different angles. Notice how the projectile goes the farthest when shot at a **45-degree angle.** Why do you think this is?

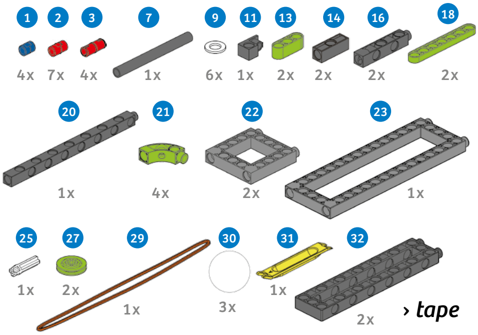
The velocity of the bolt can be broken up into a horizontal and vertical part. When the projectile is shot at a 45-degree angle, the velocity is split evenly between the horizontal and vertical parts. This means that the bolt has the greatest horizontal velocity when it is shot at a 45-degree angle, which means it will go the farthest.



Projectile motion plays an important part in sports such as baseball, basketball, golf, volleyball, and diving. Maximizing the horizontal distance is important for javelin and shot put throws, long jumps, and football kickoffs. Maximizing vertical height is important for a pole vault, high jump, and a jump ball in basketball.

Catapult one

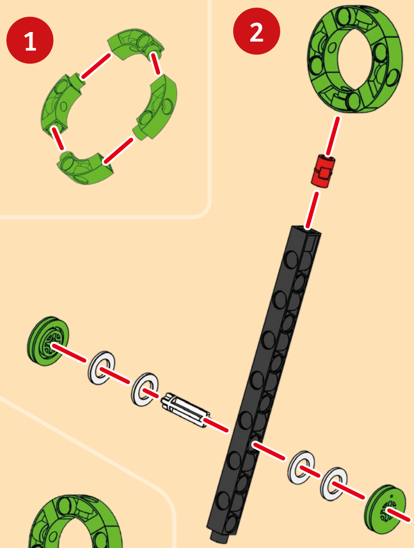
YOU WILL NEED

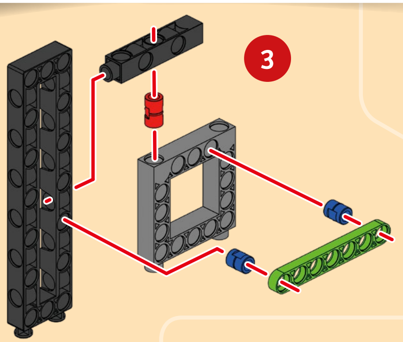


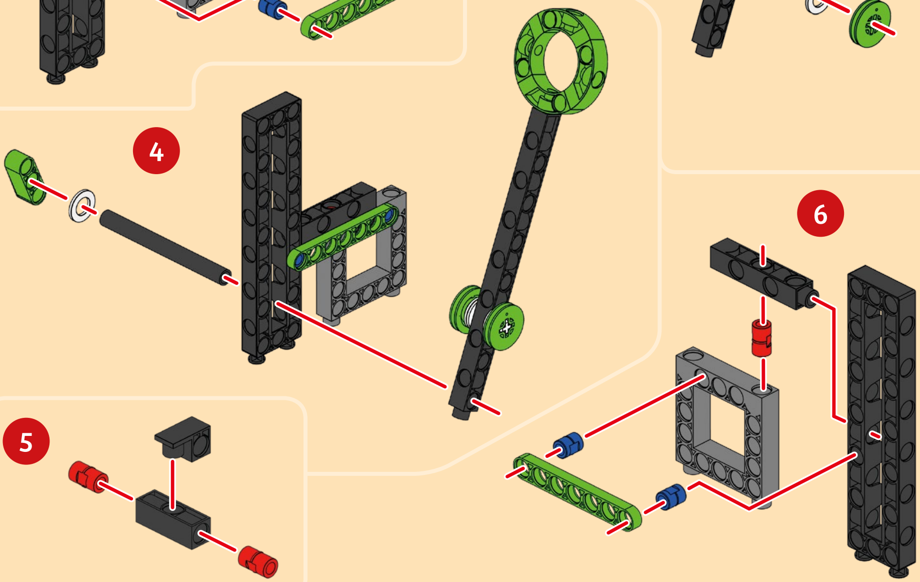
› *tape*

Background

The term catapult comes from the Ancient Greek word *Katapeltes*. The Ancient Greek Dionysius the Elder of Syracuse invented the catapult around 400 BCE. Early catapults were larger versions of crossbows.

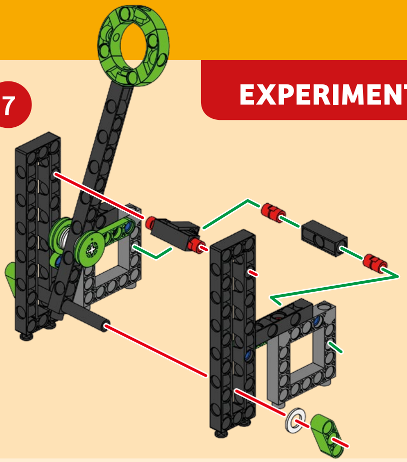






EXPERIMENT 9

7



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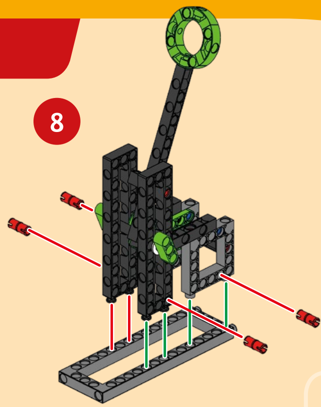

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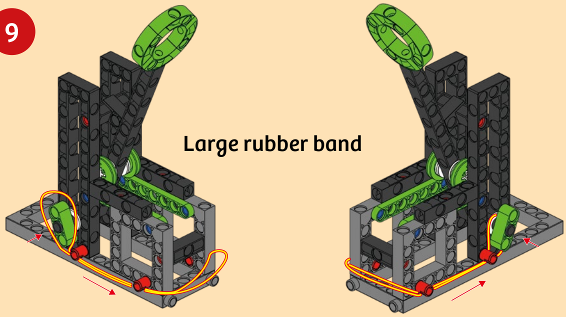

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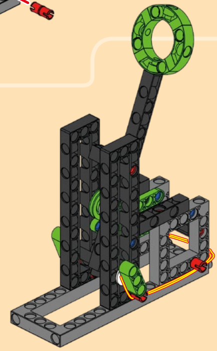
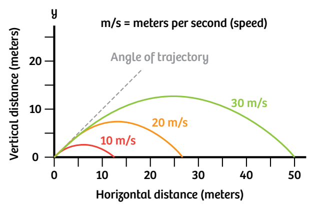


11 Fire foam balls at the target you made in the preparation steps. Vary how far you pull the arm back each time. Mark the distance that the foam ball goes using a piece of tape.

What do you notice about the velocity (speed) of the projectile when you stretch the rubber band more? What are you changing when you pull the arm of the catapult further back?

WHAT'S HAPPENING?



As you learned in Experiment 1, when you stretch the rubber band more you are adding more potential energy to the rubber band. So when you pull the arm of the catapult further back, and stretch the rubber band more, you are adding more potential energy to the foam ball. This energy is then changed to kinetic energy, or the energy of motion, which can be calculated by the equation:

$$\text{Kinetic Energy} = \tfrac{1}{2}mv^2$$

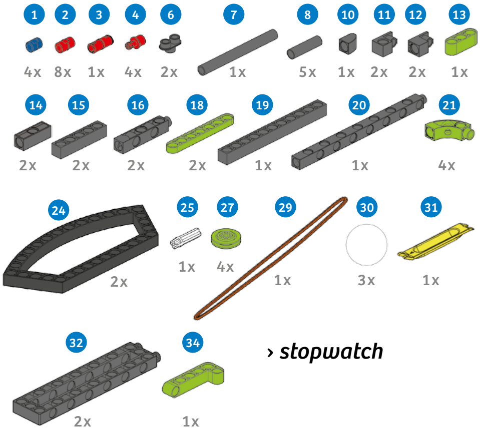
where m is the mass and v is the velocity. Since the mass is staying the same, the only thing that is changing when you are stretching the rubber band more is the velocity. This is why the foam ball goes faster when you pull the arm of the catapult further back.

For the same angle, increasing the velocity at which the foam ball is launched also increases the horizontal distance that the ball travels (the **range**) and the highest point the ball reaches (the **apex**).

EXPERIMENT 10

Mangonel

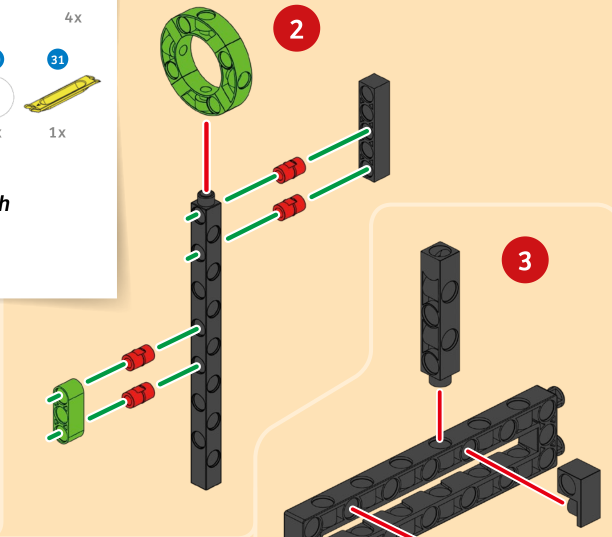
YOU WILL NEED

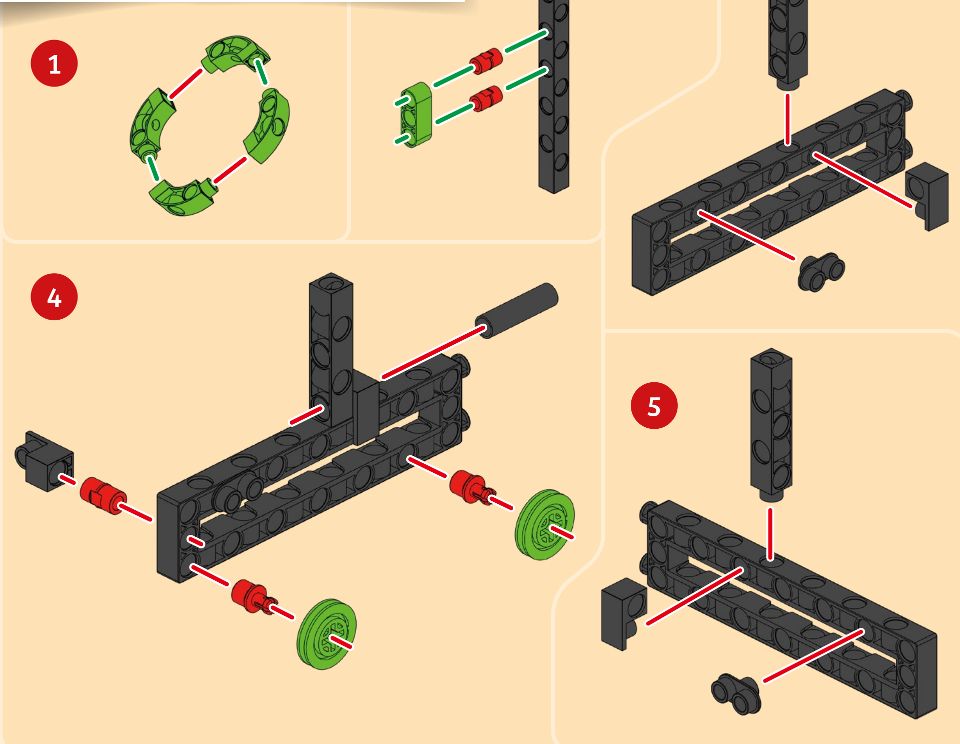


› *stopwatch*

Background

The mangonel is often what people think of when they think of a catapult. Historically, the mangonel was not able to throw projectiles as far or with as great of a velocity as the trebuchet. This is because a lot of the energy goes into accelerating the arm itself which means less energy goes into the projectile.





EXPERIMENT 10

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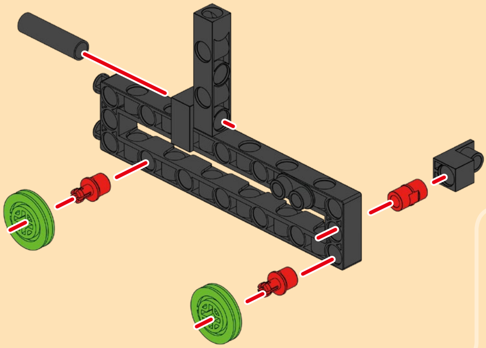

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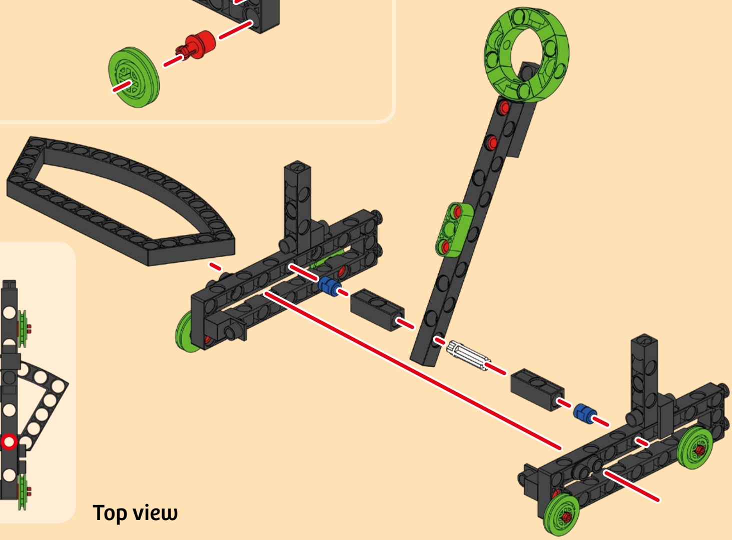

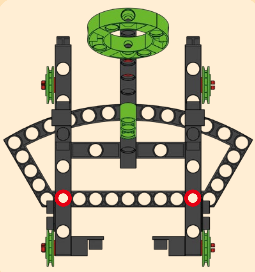

Top view

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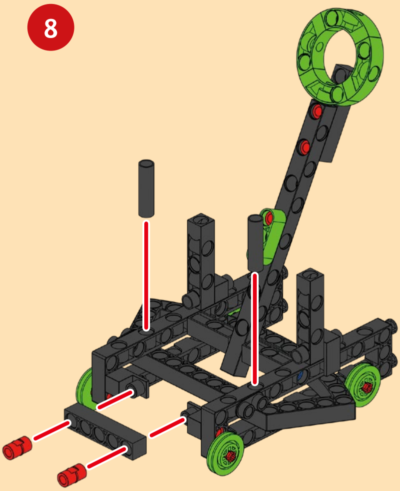

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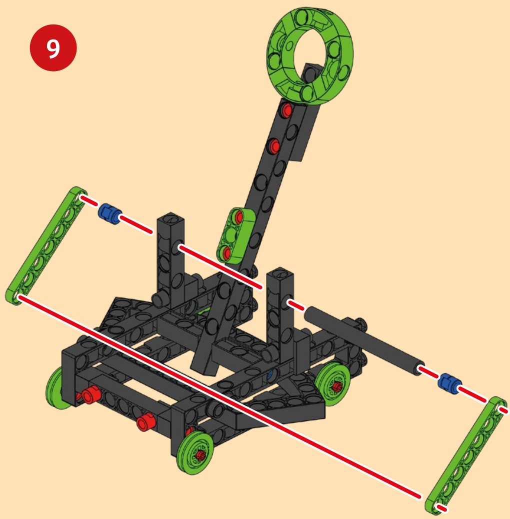
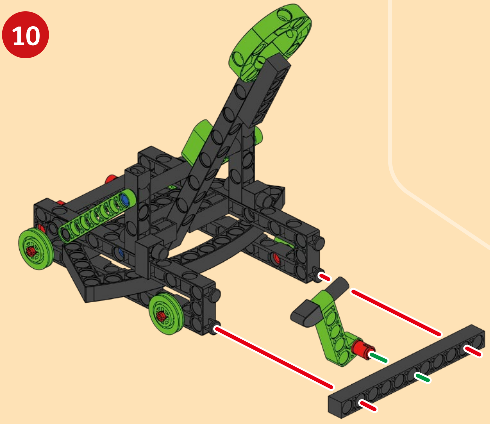
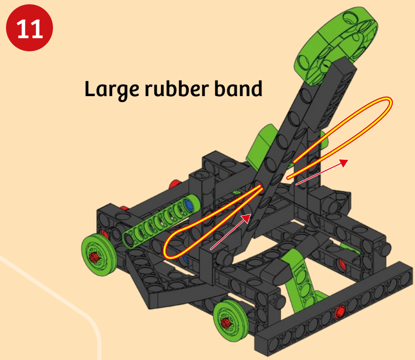
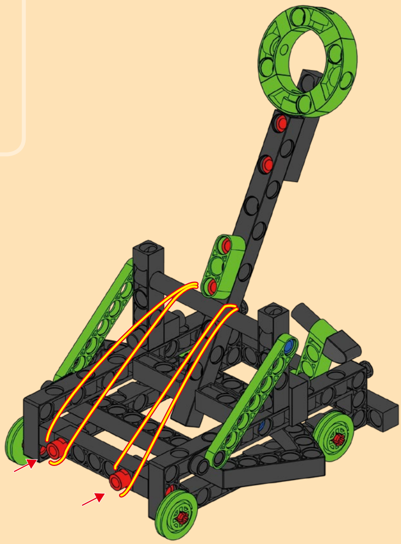


EXPERIMENT 10





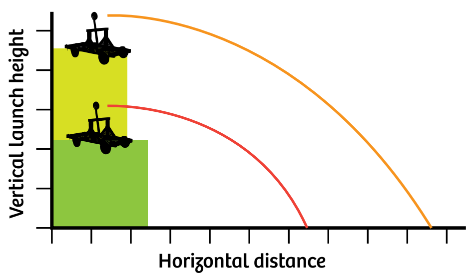


12 Place the mangonel on the floor, load a foam ball, pull back the arm, and fire the ball.

13 Place the mangonel on the end of a table and shoot the foam ball off the table onto the floor. Both times, use the stopwatch to time how long the foam ball is in the air. Compare the results.

WHAT'S HAPPENING?

If everything else remains the same, when the height from which the projectile is shot increases, the **time** that the object is in the air will also increase. Maximizing the time that the object is in the air is important for a tennis lob, a football punt, and diving.



Now use what you have learned and try to build some models according to your own designs!

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