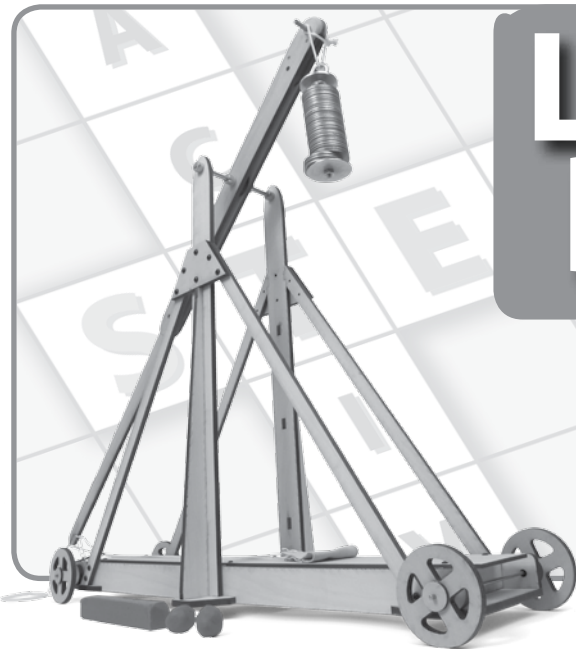


Large Trebuchet Demonstrator



PITSCO
EDUCATION

Introduction

Pitsco Education's student kits for the trebuchet and catapult have become popular ways to demonstrate physics principles, apply mathematics, and practice construction skills. It can be used indoors or outdoors.

The Large Trebuchet Demonstrator is ideal for teachers to demonstrate how a trebuchet works and the associated

science principles before students build their own smaller kit.

Another way to use it is to compare its performance to the smaller Trebuchet Kit. Based on this information, have students project the performance of even bigger theoretical models. See page 8 for more ways to use it.

Materials Included

- 7 sheets of 1/4" basswood parts
- 2 sheets of 1/8" basswood parts
- 20 – #6 x 1/2" screws
- 6 – #4 x 3/8" screws
- 3/4" brass tubing
- 2 axles
- 6 shaft collars
- 4 – 3/4" dowels
- 2-1/2" dowel
- 2 – 7" axles
- 4 – axle bushings
- 6-1/2" steel rod
- 1-1/2" steel rod (for hook)
- 4 – nylon spacers
- Screw eye
- Sling material
- Sling template
- String
- Twine
- Release pin
- 6 split rings
- 30 flat washers
- 1 large washer
- 5" eyebolt
- 4-1/2" clear tube
- Nut
- Clay

Items Required (not included)

- HD Bond or similar white glue
- CA glue (optional)
- Glue stick
- Small Phillips screwdriver
- Needle-nose pliers
- Scissors
- Allen key 3/32"
- Ruler
- Fine-point marker
- Sandpaper or small wood file
- Digital scale or balance (optional)
- Safety glasses

Gluing Tips

- Face glue is used to glue two or more pieces of wood together by applying glue to the face of each part.
- Edge glue is used to glue two or more pieces of wood together by applying glue to the edge of each part.
- HD Bond II white glue works for most of this model's construction. However, it requires a few minutes of drying time and should be allowed to thoroughly dry before using the Demonstrator. CA glue dries much quicker and holds well, but it is easy to get it on your hands or to accidentally stick parts together.
- To secure knots in the twine, CA glue works well as it seeps a bit into the threads; HD Bond will also work.

Attaching the Hook

1. Pop out Part A. Gather the 1-1/2" steel rod, string, needle-nose pliers, HD Bond (or CA glue), and sandpaper or wood file.
2. Sand or file down the edges on top of the narrow end of Part A (Figure 1).

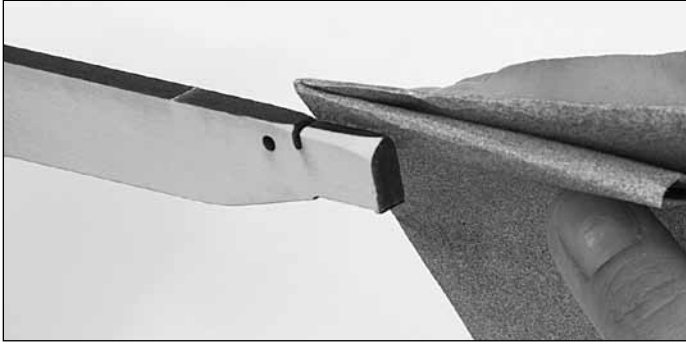


Figure 1

3. About 1/8" from an end of the hook, carefully bend a 90-degree angle with the pliers (Figure 2). Lay the hook between the rounded edges with the angled end in the groove. Apply a little glue to hold the hook in place.

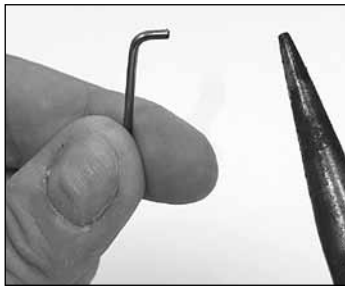


Figure 2

4. Lay the string alongside the hook with the long end hanging off the end of Part A. Start winding the string around the hook and arm, working back from the end (Figure 3). Apply glue over the string to hold it on both sides. Snip off any extra string.

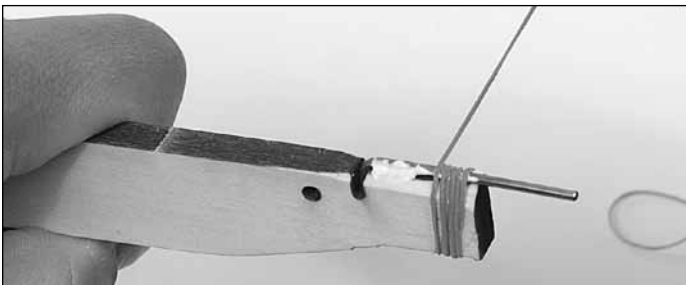


Figure 3

Building the Arm

1. Pop out and gather all the Parts B, C, and D. Also gather the brass tubing and the dowels.
2. Lay one Part B flat on the work surface. On one end are two holes. Glue two 3/4" dowels into these holes so the dowel ends are flush with the side of Part B facing the work surface (Figure 4).

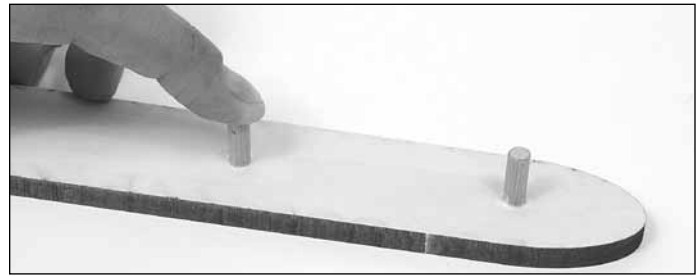


Figure 4

3. On the other end are three holes that make a triangle – glue the other two 3/4" dowels into the two holes closest to the center of Part B. Now, insert the brass tubing into the center hole on Part B.
4. On top of the dowels at the wide end of Part B, face glue Part C so its shape lines up with the shape of the end of Part B. Over the brass tubing, face glue Part D to Part B (Figure 5).

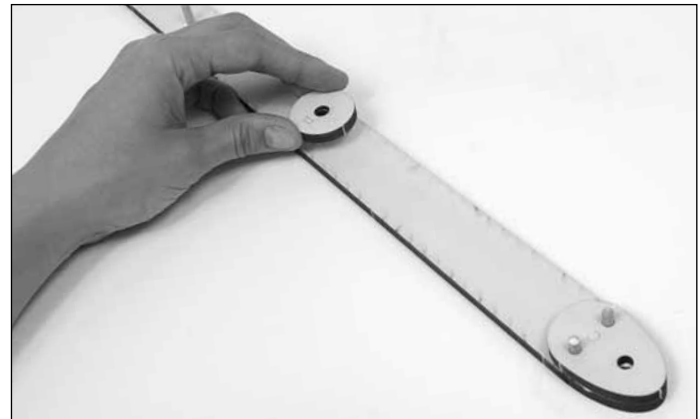


Figure 5

5. On top of the dowels at the narrow end of Part B, face glue Part A to Part B. Over all four dowels and the brass tubing, face glue the second Part B parallel to the first one (Figure 6).



Figure 6

6. Glue the 2-1/2" dowel into the large hole at the bottom of the arm. Make sure it is centered. When the arm is dry, you can round the edges of the wide end with sandpaper or a file. This helps prevent the twine from catching during the launch process.

Constructing the Frame

1. Gather Parts E, F, and G. Glue together one E and F so F is perpendicular to E with their notched ends facing the same direction. Repeat this for the other Part E and F (Figure 7).



Figure 7

2. Glue these into the slots on Part G so the two middle slots on G are not used and the Parts F are facing out (Figure 8). The notches on Parts E will not completely fill the holes they are placed in. Set aside to dry.



Figure 8

3. Gather the two Parts H. Glue a Part H onto Part G so the middle notch of H fills the rest of the hole that is shared by Part E. Repeat this on the other side with the other Part H (Figure 9).

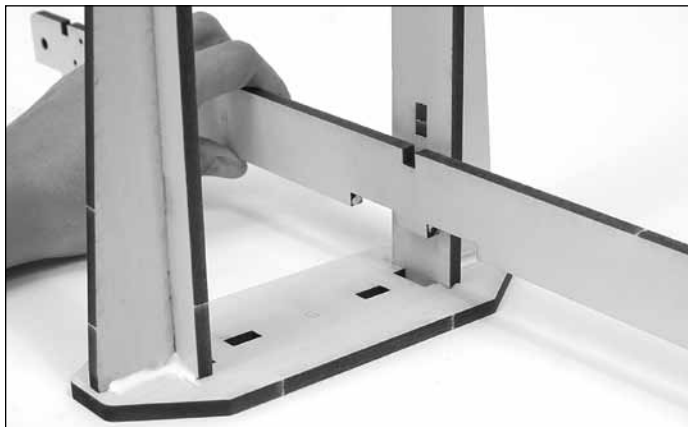


Figure 9

4. Find Parts M and N. Carefully slide M under one end of the Parts H and glue these together. Now slide N under the other end of the Parts H and glue them together (Figure 10). For both of these parts, make sure the end that is slightly angled is facing toward the middle of the trebuchet. Let this assembly dry.

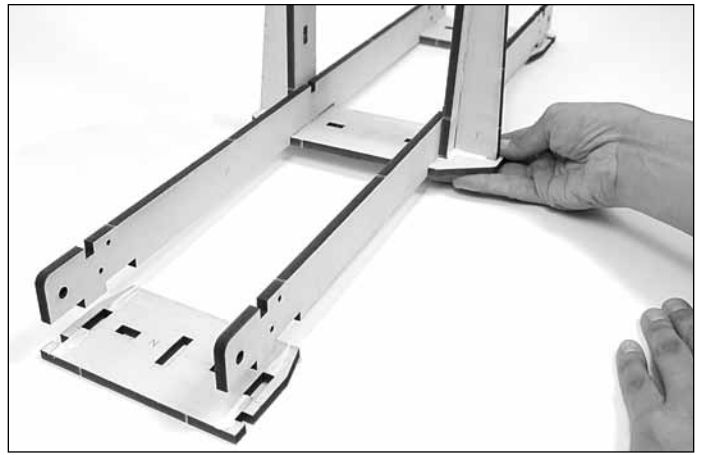


Figure 10

5. Gather the two Parts J. Glue one so the two bottom notches fit into Part M – the side notches will slide into the holes on top of the Parts H (Figure 11). Glue the other J on top of Part G in the same manner.

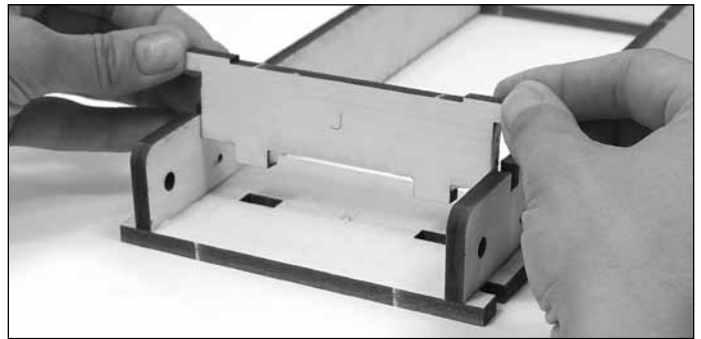


Figure 11

6. Locate Parts K, L, and P. Parts K and L each have a long, narrow notch that will allow you to fit them together like a cross (Figure 12a). Glue this together and wipe away any excess glue. Now, take one P and glue its two notches into the angle on one side of the cross – this should be on the long side. Repeat on the other side with the second P (Figure 12b). These parts will look like mirror images when they are glued together correctly.

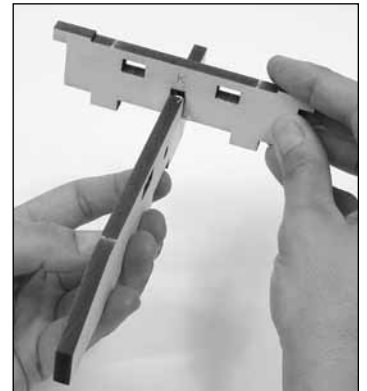


Figure 12a

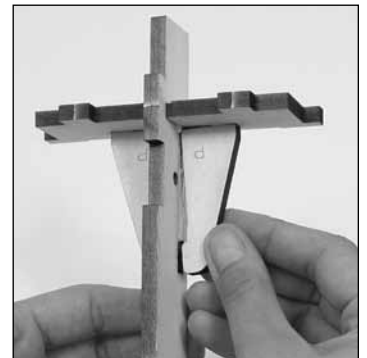


Figure 12b

7. Glue the cross-shaped assembly on top of Parts N and H on one side of the trebuchet. The long end of the cross should point away from the middle of the trebuchet (Figure 13).

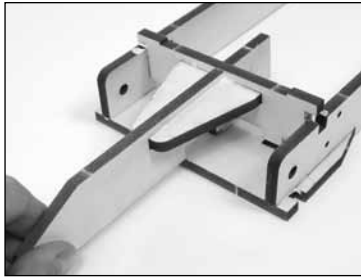


Figure 13

8. Locate the Parts O. About five inches down from the top of the Parts E, you can see there are two small holes. One side at a time, align the middle holes of one Part O to the holes on E. Using two 1/2" screws, screw these together. Repeat this on the other side (Figure 14).



Figure 14

9. Locate the four Part I pieces. Note that both ends of these pieces are angled, but only one has a notch. One at a time, glue these parts so the notched end fits into the notches on the sides of the standing E pieces (on the inside of the Parts O) and the flat side is on top of the M or N pieces (on the outside of the frame or the Parts H) (Figure 15). Using eight 1/2" screws, secure the Parts I to the trebuchet.

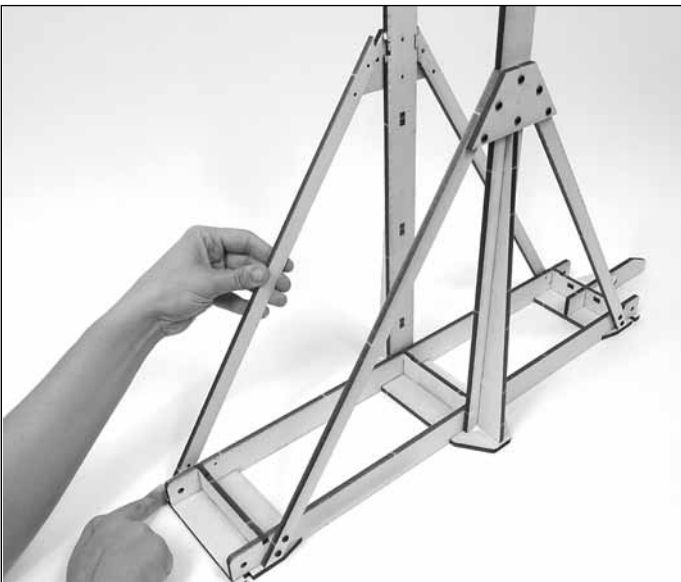


Figure 15

10. Gather the four Parts Q. On the outside corners of the trebuchet frame, you will see a notch just to the side of where the angled Parts I rest. Glue a Part Q into each of these (Figure 16). Let the assembly dry. Insert an axle bushing into the hole of each Part Q from the outside of the frame.

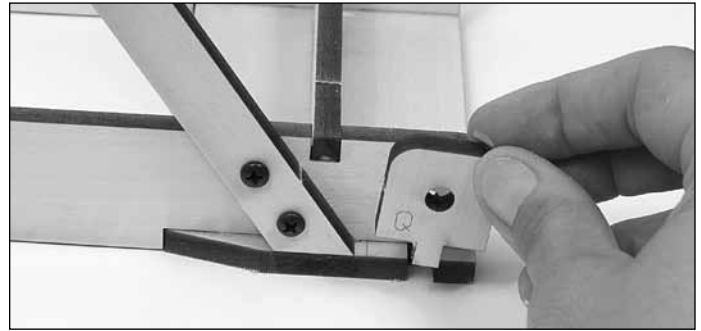


Figure 16

11. Find Part T, which is the floor plate, and place it on top of the base between the standing parts of the trebuchet. Screw these in place with the six 3/8" screws (Figure 17).



Figure 17

12. Collect the eight Parts R and look at them closely. You will notice the parts' wood grain. Take two of them and line them up so their holes match up but their wood grain runs opposite each other (Figure 18). Face glue these parts together, wipe away any excess glue, and set aside to dry. Repeat with the other six parts so that you have four wheels.



Figure 18

13. Find the Parts S and glue one centered on a side of a wheel (Figure 19). Before the glue dries, insert the axle through the Parts R and S to make sure the center holes are aligned correctly. Repeat for the other three wheels and let them all dry.

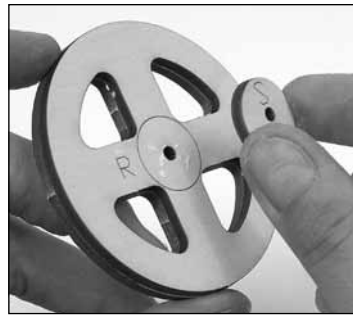


Figure 19

Attaching the Arm & Counterweight

1. To build the counterweight, take the 5" eyebolt and insert it into the clear tube. Holding these together, thread as many flat washers as you wish to use as counterweight over the tube (Figure 20). Place the large washer over the last flat washer and thread the nut over the eyebolt end to secure the weight.

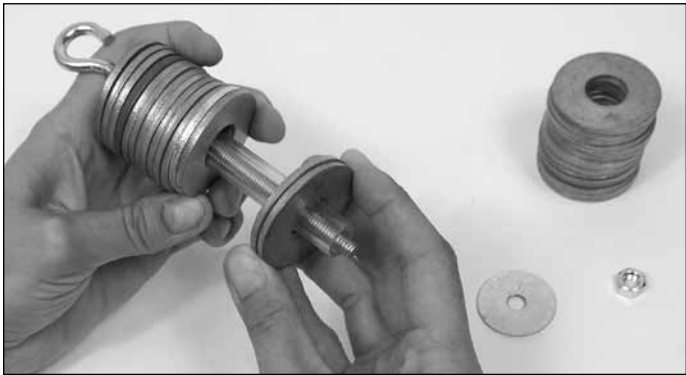


Figure 20

2. Find the screw eye, six shaft collars, 6-1/2" steel rod, Allen key, and needle-nose pliers. Using the wrench, loosen the set screw in each shaft collar.
3. Gripping the screw eye with the pliers or your fingers, carefully screw it in the middle of the angled side of Part L. The screw eye should face so the wide side is in line with Part L (Figure 21).

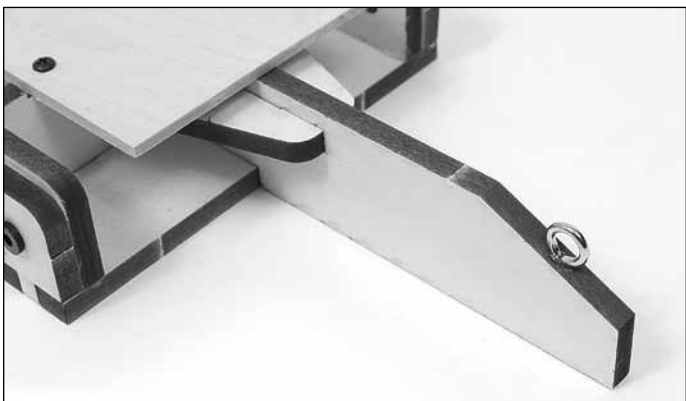


Figure 21

4. Push the steel rod through one of the Part E holes at the top of the trebuchet. Place two shaft collars on the end of the rod between the Parts E. Take the arm you built earlier and slide it onto the rod. Following that, slide two more set collars on the rod (Figure 22). Push the rod through the other Part E hole.



Figure 22

5. Center the rod between the Parts E and then center the arm on the rod. Move a set collar close to either side of the arm and tighten their set screws with the Allen wrench – make sure they aren't so tight against the arm that it cannot spin around the rod. Move the two outside set collars against the inside of Parts E and tighten them firmly.
6. Over each end of the rod outside the Parts E, place a set collar and tighten them firmly (Figure 23).

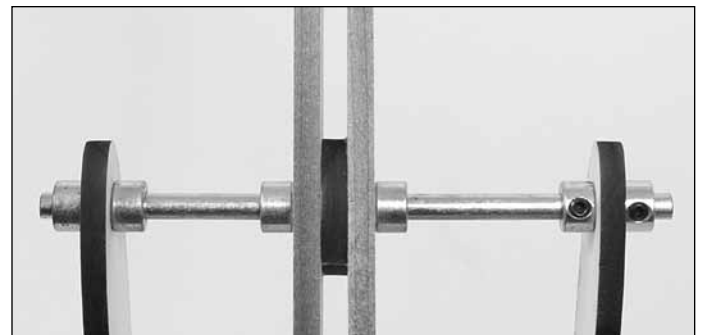


Figure 23

7. Locate the string and scissors – do not confuse the thicker twine for the string. Run the string through the hole at the end of the arm (near the hook). Tie a loop approximately 2" long and firmly knot it (you can use a dab of glue on the knot to ensure it doesn't come loose). Trim the string ends.
8. Find the twine and make a 3" to 4" loop on one end. Knot it securely and cut this loop from the length of twine. You can put a dab of glue on the knot to secure it. Place the loop under the arm end opposite the hook and over the dowel rod ends. Hang the counterweight on the loose end and let it hang down toward the floor plate (Figure 24 on next page).

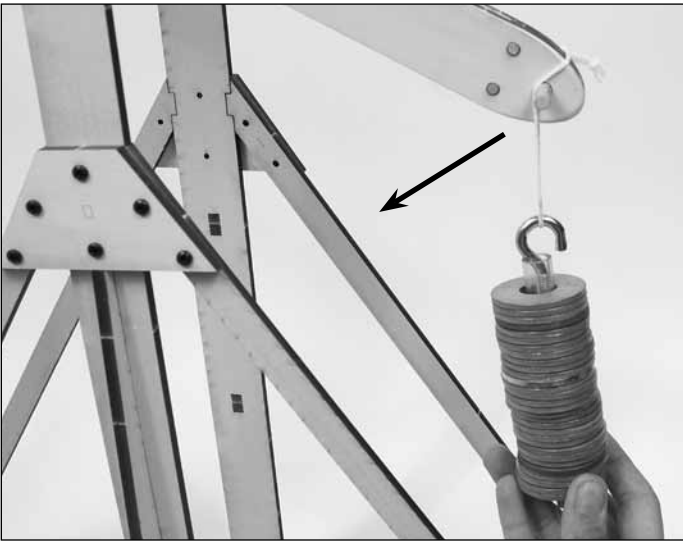


Figure 24

Making the Sling

1. Gather the sling material, template, marker, glue stick, and scissors. Cut out the template and lay it on top of the material. Using the marker, outline the template on the material. Cut out the material to the drawn shape.
2. Fold over each end approximately 3/4" and mark where the overlap ends. Apply glue stick between the mark and the end. Fold over the end and press firmly. Repeat on the other side (Figure 25). Cut a small hole in each end with scissors or another tool.

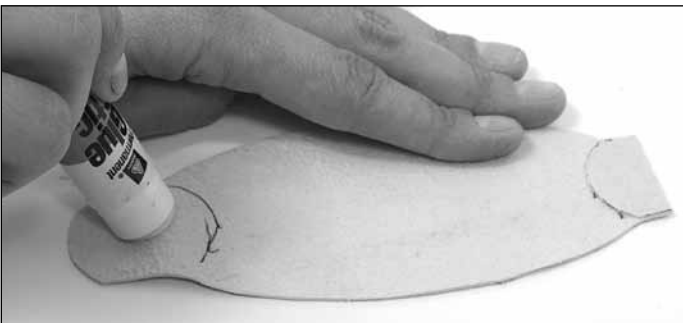


Figure 25

3. Cut two pieces 28" long from the twine. If possible, singe the ends of the twine with a small flame to keep it from raveling. Push one end through the hole on one end of the sling and tie a knot (add glue to secure the knot). Repeat with the other cord end on the other side of the sling (Figure 26).



Figure 26

4. Take the free end of one side of the twine and tie a loop 1/2" to 3/4" long. Take the other end and thread it through the small hole at the hook end of the arm. Fold the sling and twine in half and tie a knot where the sling is in the middle (Figure 27). Do not glue the knots. When folded in half, it should be 20" to 24" long.

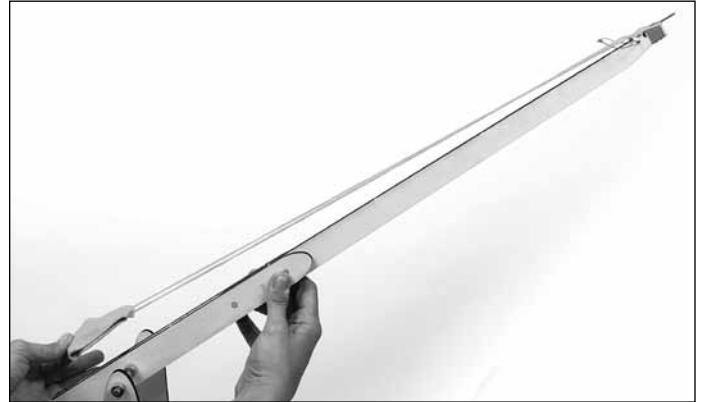


Figure 27

5. Tie a length of twine at least 2' long to the release pin and knot it (Figure 28). If desired, secure the knot with a dab of CA glue. On the other end, tie a 2" to 3" loop to use as a pull handle.

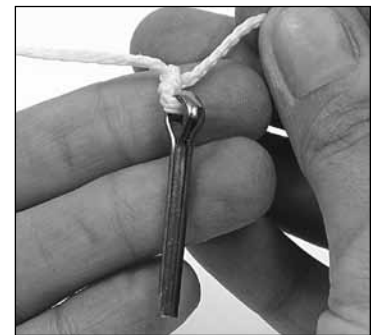


Figure 28

Attaching the Wheels

1. Collect the axles, nylon spacers, and the wheels you made earlier. With a wheel on a flat surface with Part S facing down, carefully push the axle into the axle hole (Figure 29). **Caution:** Be careful not to gouge your hand with the axle. Drop a spacer on the axle.



Figure 29

2. Slide the free end of the axle through an axle hole on one end of the trebuchet and out the opposite axle hole. Over the axle end, slide a second spacer. Then push the wheel onto the axle end (Figure 30 on next page). Carefully, push this together so the wheels are firmly on the axle but can easily spin.
3. Repeat Steps 1-2 for the second axle on the other end of the trebuchet.



Figure 30

Using the Demonstrator

Safety

- Be sure the operator and anybody close to the trebuchet during launch is wearing safety glasses.
- The wheeled base will absorb some of the energy put into the trebuchet when it launches, causing it to rock back and forth a little. Be sure it has enough room to do this without falling off a table.
- Be very careful to stay out of the travel path of the hook when preparing the trebuchet for launch. If you loose your grip on the arm while preparing for launch, the hook could scratch or cut you if you are in the travel path.
- Be sure you launch in an open area or where the projectile will hit a solid surface such as a wall.

Sling Option

1. Using the included clay, create several balls that each have a 10- to 11-gram mass (approximately 3/4" to 1" in diameter). The ideal ratio of counterweight mass to projectile mass is 100:1.
2. Place the trebuchet on a flat, solid surface such as a large sturdy desk or table or on the ground. The projectile will travel in the opposite direction from which it is launched, so keep that in mind when picking a location.
3. You will need to bend the hook (see the Tuning the Trebuchet section). Place the small twine loop of the free end of the sling over the hook and pull the hook end of the arm toward the screw eye on the trebuchet base. Hold the arm in place while pulling the sling as far from the hook as possible.

4. Holding the twine loop onto the hook and the arm down, pull the string loop so it rests behind the screw eye (Figure 31a). Push the release pin through the screw eye on top of the thread (Figure 31b). When you release the arm, the pin should hold the arm in place. Without pulling the release pin, lay out the pin's twine so you easily pull the release pin while positioning yourself on the side of the trebuchet while launching. Carefully load a ball into the sling.

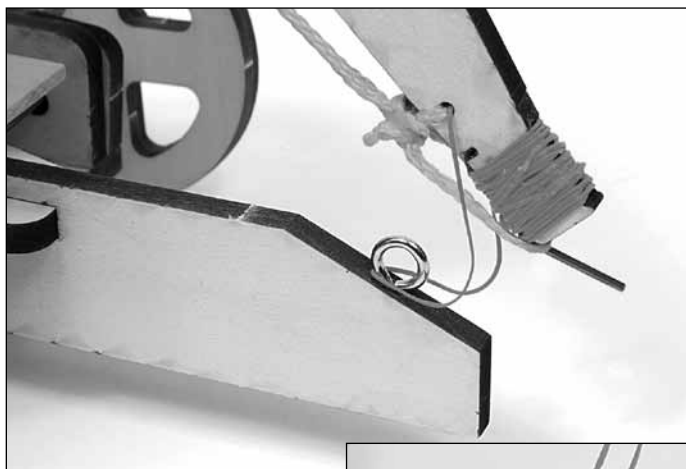


Figure 31a

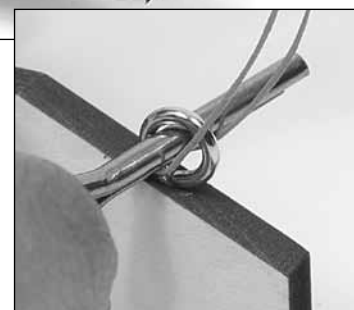


Figure 31b

5. Making sure no one is in the flight path, pull the release trigger out of the screw eye (Figure 32). The counterweight will fall down, pulling the arm up and the sling forward. The sling will follow the arm around the trebuchet with the hook letting go of the twine to release the ball in the direction the arm moved.



Figure 32

No-Sling Option

Another way to use this trebuchet is with clay balls that are molded around the end of a piece of twine. By making the twine length 20" to 24" and having a small loop on the end, you can hook this ball and twine to the trebuchet – when it launches, the ball and twine fly!

1. Measure a piece of clay that has a 10- to 11-gram mass. The ideal ratio of counterweight mass to projectile mass is 100:1. Tie a small loop – about 1/2" to 3/4" of an inch long – on the end of the leftover twine. Alternatively, tie the twine end to one of the small split rings that came with the kit (these slide off the hook easier). Starting with the loop or ring, measure and cut a piece of the twine between 18" and 20" long.
2. Mold the clay into a ball around the end of the twine. Be sure this is secure enough that the twine will not come out when used. You could test it by swinging this in a circle a few times.
3. With this option, you need to remove the sling from the trebuchet. Then, you need to bend the hook (see the Tuning the Trebuchet section).
4. Place the trebuchet on a flat, solid surface such as a large sturdy desk or table or on the ground. The projectile will travel in the opposite direction from which it is launched, so keep that in mind when picking a location.
5. Place the small loop over the hook and pull the hook end of the arm toward the screw eye on the trebuchet base. Hold the arm in place while pulling the ball as far from the hook as possible.
6. Holding the twine loop onto the hook and the arm down, pull the string loop so it rests behind the screw eye (Figure 31a, see previous page). Push the release pin into the screw eye on top of the thread (Figure 31b, see previous page). When you release the arm, the pin should hold the arm in place. Without pulling the release pin, lay out the pin's twine so you easily pull the release pin while positioning yourself on the side of the trebuchet while launching.
7. Making sure no one is in the flight path, pull the release trigger. The counterweight will fall down, pulling the arm up. The ball will follow the arm and go around the trebuchet with the hook releasing the loop so the ball is released in the direction the arm moved.

Tuning the Trebuchet

You will need to bend the hook at an angle so the hook, when prepped for launch, points up somewhat (Figure 33). How much to bend it is a matter of tuning your trebuchet.

1. Using the pliers, carefully bend the hook to about a 45-degree angle (Figure 33).
2. Using a 100:1 ratio for counterweight to projectile mass, launch the clay ball and watch how it releases.

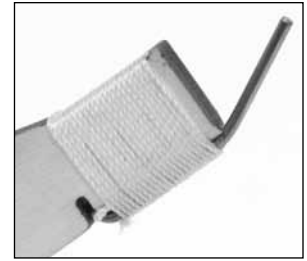


Figure 33

If it **releases too soon** and doesn't make it over the trebuchet very well, bend the hook a little more. Relaunch and observe. Keep doing this until the hook releases at the correct point in the arc.

If the trebuchet **releases too late** and the ball launches rather flat in front, then unbend the angle slightly and retest. Continue to do this until the hook releases at the correct point in the arc.

Demonstration Ideas

- Dry launch the Demonstrator, which means to launch it without the clay ball. Most of the energy goes back into the trebuchet and will shake it roughly. Then, launch it with the projectile. This will launch more smoothly. This demonstrates how the energy from the trebuchet is transmitted to the ball. Without the ball, it has to go somewhere – in the first scenario, the energy goes into the Demonstrator.
- Test the theory that a trebuchet with wheels works more efficiently than those without wheels. First, research about trebuchets and this theory. Then launch the Demonstrator several times. Record and average the results. Remove the wheels from the Demonstrator and retest using the same sling method, sling length, and clay ball mass. Record and average the results. Which way worked best?

Suggested Resources

The Art of the Catapult book by William Gurstelle (57630)
Medieval Siege video (59230)
Physical Science in Action: Simple Machines video (59182, DVD; 57648, VHS)
Siege Machines: Explore the Science, Technology, Engineering, and Math of Medieval Siege Machines book (59466)
Trebuchet Getting Started Teacher's Guide (59611)

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